Welding-Related Expenditures, Investments, and Productivity Measurement in U.S. Manufacturing, Construction, and Mining Industries

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INDUSTRY RESULTS BY SECTOR

APPENDICIES

INTRODUCTION

For those who are heavily involved in welding, there is a strong conviction that a large part of the United States' economy is dependent on welding. Continued advances in the field of welding are necessary to increase productivity and strengthen the U.S. economy. Despite this intuition, as well as anecdotes and fragmented analyses, no compelling information has been available that provides the justification for strategic actions to further develop the field of welding.

This report presents results of a comprehensive research effort commissioned by the American Welding Society and Edison Welding Institute to gather baseline information necessary to support strategic decision making concerning the field of welding. The information provided in this report focuses on welding-related expenditures and the measurement of welding productivity in specific U.S. industries where welding is a critical enabling technology. Opportunities to further improve welding productivity are also outlined.

The research leading to this report, and the results following, lay a foundation for all future economic evaluations of the welding industry. Those directly involved in the industry now have a baseline for evaluating welding-related investments and changes in productivity. Additionally, this work will facilitate efforts to provide information concerning the scope and economic impact of the welding industry to a larger audience of individuals and groups outside of the industry.

Findings presented are for industries in the Manufacturing, Construction, and Mining industries in which welding is considered a critical enabling technology. Combined revenue of these industries totaled $3.1 trillion in 2000, or approximately one-third of the total U.S. Gross Domestic Product. Industrial groups, or sectors, studied were:

- Automotive
- Aircraft & Aerospace
- Electronics & Medical
- Light Industrial Manufacturing
- Heavy Industrial Manufacturing
- Construction
- Capitalized Repair & Maintenance

MAJOR FINDINGS

1. **Welding expenditures represent a substantial contribution to the U.S. economy**. Those industries included in this study provide the backbone for our nation's defense, infrastructure, and economic well-being, and represent one-third of the total U.S. Gross Domestic Product. Welding-related expenditures by these industries were no less than $34.1 billion in the year 2000 alone. These expenditures totaled an amount equivalent to more than $325 for every household in the U.S.

2. By far, **labor represents the largest proportion of total welding expenditures**. Labor represents more than 70% percent of total welding- related expenditures in the U.S., or $22.4 billion in 2000. That total also represents 4% of the $516 billion in labor costs in those industries where welding is a critical enabling technology.

   U.S. Bureau of Labor Statistics estimates and data gathered through this research indicated that welding-related occupations provided employment for more than one-half million individuals in the U.S. in 2000. This included nearly 500,000 persons whose primary occupation was performing welding operations in establishments with two or more employees. There were also at least 65,000 individuals in management and technical roles (e.g., welding supervisors, inspectors, and engineers) whose primary responsibilities focused on welding-related operations.

   The Bureau of Labor Statistics estimates noted above are conservative as they do not include self-employed welders and people in welding-related occupations in non-production settings (welding equipment manufacturers and distributors, welding educators, consultants, and researchers, etc.). An estimate of the number of individuals in these areas could not be made based on available Bureau of Labor Statistics data and the results of this study.

3. With few exceptions, most **firms have not studied, and have only a minimal understanding of, the economics associated with the use of welding-related processes.** Over one-half (57%) of the establishments responding to the survey conducted for this study reported that they employ no measures of cost per unit of welding output. An additional 23% reported that their measures of welding economics were "minimal."

4. **Most firms do not evaluate the role and contribution of welding in the complete manufacturing process.** In the majority of firms studied, welding is viewed simply as a necessary production input for which costs must be controlled. Consequently, most companies that do evaluate welding costs do so with the objective of reducing costs rather than increasing productivity. The true value added by the use of welding processes is not known by these firms.

5. **U.S. manufacturing firms that (a) understand the role and contribution of welding in the complete manufacturing process, and (b) understand the economics associated with welding-related processes, are competing successfully,** both globally and internationally. While the vast majority of firms lack an understanding of welding process economics, there are successful firms that have, in fact, a detailed understanding of the costs associated with, and value generated by, welding processes. These firms utilize this knowledge as a competitive advantage to improve productivity and the total value of the product manufactured.

6. **There are no consistent measures of welding productivity currently being used in establishments where welding is a critical enabling technology**. Nearly one-half (47%) of the firms responding to this study's survey reported the use of no welding productivity measures. Of the 53% of establishments that did report some type of welding productivity measure, no single metric was used by more than one-half of those firms.

   Firms selected welding productivity metrics based on their specific business management objectives – typically to reduce the cost of the welding process. The nature of the production output also drove the productivity measures used.

   As issues associated with understanding the economics of welding inputs are addressed, it appears that industries will have greater incentive to move to the adoption of "standard" welding productivity measures.

7. **The shortage of qualified operators, technicians, and engineers in the field of welding is a potential threat to some U.S. industries**. Over 40% of the Heavy Industrial Manufacturing firms indicated that a shortage of qualified welders impacts productivity either "moderately" or "extensively." Approximately 30% of the firms in the Automotive and Construction industrial sectors indicated similar levels of impact. Industry experts reported that the need for qualified welders extends to all welding-related professions, including technicians and engineers.

8. **Nearly one-half of the establishments studied reported that their welding-related training needs are not being adequately met**. Many companies report difficulties locating qualified individuals with welding expertise – from apprentice welders to engineers. The nature of the work and lack of advanced welding education programs are most commonly cited as the reasons for this problem.

9. **Establishments relying on the use of welding processes are generally not actively pursuing additional automation of these processes.** Nearly 60% of all firms reported no effort to actively pursue the automation of welding processes. Because of the capital risks associated with automation, it appears that most firms allow industry leaders to take such risks and then monitor the outcome. Once industry leaders have proven a return on automation process investments, other firms will gradually follow in adopting the automated process.

10. **Tremendous opportunities exist for improving the overall productivity of U.S. firms by improving the productivity of welding-related processes**. A broad range of strategies exists for addressing these opportunities. These include:
    - Automation of welding operations.
    - Greater consideration of welding requirements during product design.
    - Refinement of automated processes that will facilitate wider adoption.
    - Improved quality control in materials and components to be joined.
    - Use of lean manufacturing approaches.
    - Improved educational opportunities in the field of welding.
    - Continued development of a national system of standards, assessment, and certification.
    - Increased knowledge sharing of productive practices between and among industries.
    - Greater support of cooperative research and development programs.

OPPORTUNITIES FOR THE WELDING INDUSTRY

The study sponsors view the findings of this study as the basis for an aggressive program of disciplined action to advance the technology of welding and the contribution it makes to the growth and strength of the U.S. economy. Components of this program might include the following:

1. **Development of procedures that will allow companies to develop a more in-depth understanding of the economics of welding.** Change and adoption of more productive welding applications will only be driven by clear economic gains. A national effort, led by the welding industry, could help manufacturers understand – in real dollars for specific manufacturing operations – how improved welding productivity can add value to the final product.

2. **Identification and pursuit of opportunities at the national, state, and local levels to improve educational opportunities in the field of welding.**

3. **Expansion of collaborative research and development efforts focusing on welding productivity improvements.** Advances in welding applications would be greatly advanced by cooperative research and development programs – both government/industry and industry/industry – that emphasize "real world" applications of semi-automated and automated processes. These programs should include research on the economics associated with the adoption of these more productive processes.

4. **Coordination of efforts to share knowledge of productive practices.** Tremendous gains in welding productivity improvement are possible if the sharing of knowledge of productive practices between and among industries can be effectively facilitated.

5. **Development of a national standard for measuring welding productivity**. Development of standard practices for measuring welding productivity will allow firms to readily adopt standards and thereby improve productivity through the monitoring of this critical process.

6. **Develop an on-going mechanism for monitoring changes in welding productivity within and across industries.** Verifying gains in welding productivity, and quantifying of the economic value of those gains, will serve as a catalyst for continued welding productivity improvements. This, in turn will continue to strengthen the economic position of those employing more productive practices.

FUTURE RESEARCH

As noted earlier, this research was designed to lay a foundation for all future economic evaluations of the welding industry. It has not only offered a basis for future comparisons, but has prompted a number of new questions for investigation as well.

While topics that might be considered as a result of this work are numerous, some are of particularly broad interest or impact. Examples of such questions that clearly merit future research include the following.

- What is the economic impact, or contribution, of welding to the U.S. economy at large, including industry sectors where welding has not been identified as a critical enabling technology?
- What is the relative total impact, or contribution, of welding to the value of products produced in industries where welding is a critical enabling technology?
- What is the value of the irreplaceable level of output resulting from the use of welding technologies?
- What is the economic impact, or contribution, of welding to the U.S. economy at large?
- What is the impact, or return on investment, for welding-related research and development expenditures?
- What is the impact, or return on investment, for welding-related training expenditures?
- How does welding productivity change over time with the application of welding technologies based on a better understanding of the economics of welding process applications?

Answers to these and other questions of vital importance to the welding industry will continue to advance the field of knowledge necessary to support effective strategic decision making in and about the field of welding.

STUDY OBJECTIVES

The objectives of this research resulting in the information presented in this report were to:

- Determine welding-related expenditures in specific U.S. industries where welding is a critical enabling technology;
- Determine the extent of welding productivity measurement in specific U.S. industries where welding is a critical enabling technology; and
- Identify where the greatest opportunities exist to further improve the productivity of welding.

APPROACH

The study began with the assembly of an Advisory Panel – a group of academicians and technical experts responsible for contributing to critical design and interpretation aspects of the study. Members of this panel included:

- **H. Lee 'Buck' Mathews, Ph.D. – Advisory Panel Director**, Professor of Marketing and Past Marketing Department Chairman, Max M. Fisher College of Business, The Ohio State University.
- **William L. Berry, Ph.D.**, Richard Ross Chair in Management and Professor of Manufacturing, Max M. Fisher College of Business, The Ohio State University. Berry also serves as the Co-director of the Center for Excellence in Manufacturing Management.
- **David T. Crary, Ph.D.**, Associate Dean and Professor of Finance, E.J. Ourso College of Business Administration, Louisiana State University.
- **John F. Dix**, Co-director of the Center for Excellence in Manufacturing Management, The Ohio State University and President, Business Development Index Limited, Inc.
- **Richard French**, Deputy Executive Director, American Welding Society.
- **James A. Richardson, Ph.D.**, John Rhea Alumni Professor of Economics and Director of the Public Administration Institute, E. J. Ourso College of Business Administration, Louisiana State University.
- **Fritz Saenger**, Director, International Business Development, Edison Welding Institute.
- **David C. Swaddling, MBA, CPA**, President of Insight·MAS, a research and consulting firm.

The Advisory Panel first conducted an assessment of industries through which welding contributes to the U.S. economy. Seven groups, or sectors, of industries were identified for targeting the research. These sectors included:

- Automotive
- Aerospace
- Electronics
- Light Industrial Manufacturing
- Heavy Industrial Manufacturing
- Construction
- Capitalized Repair & Maintenance

Table 1 provides a listing of industrial groups included in these sectors. Total value of sales for these industrial sectors is reported in Table 2.

Following the identification of key groups of industries, a Research Plan was developed to specify the study data collection and analysis process. This outline specified protocols to be followed for gathering data by both the *Top Down* and *Bottom Up* research approaches employed.

The *Top Down* data collection approach was based on a written survey of industrial establishments conducted by the U.S. Department of Commerce. The survey, specifically designed for this study, was based

on input from experts in industries included in the study. A representative sample of firms in each sector (6,353 establishment in total), were surveyed. Results obtained were extrapolated to determine total welding investments within industries. These results were subsequently compared with those derived from the *Bottom Up* field research (next described) in order to refine the accuracy of conclusions.

The *Bottom Up* data collection consisted of a series of in-depth industry representative interviews to investigate welding expenditures within industries based on the welding inputs into representative commodities. This fieldwork also investigated welding productivity evaluation approaches and the resulting levels of welding productivity. Results obtained from the investigation of specific manufacturers were extrapolated to arrive at a estimate of welding expenditures within industries which was compared to the *Top Down* results estimate.

The estimates generated by the *Top Down* and *Bottom Up* research approaches were reconciled by the researchers to arrive at a total welding-related expenditure figure for each industry studied. This reconciliation process was based on input from Industry Experts, and was reviewed and validated by the study Advisory Panel. Conclusions and appropriate supporting material are presented in this report.

Further details concerning the research methodology used, including data collection instruments and additional detail concerning the impact estimation reconciliation approach, are presented in Appendix C (pg. 89).

TABLE 1: INDUSTRIAL SECTORS AND GROUPS STUDIED

Industrial Sector	Industrial Groups Included
Automotive	All vehicle and trailer manufacturing; Automotive systems and parts manufacturing; Motorcycle & bicycle manufacturing; Automotive exhaust system repair.
Aircraft/Aerospace	Aircraft manufacturing; Aircraft parts and systems manufacturing; Missile and space vehicle manufacturing; Missile and space vehicle parts and systems manufacturing.
Electronics/Medical	Electronic components; Electronic instruments/equipment; Office and communications equipment; Medical instruments and equipment.
Light Industrial Manufacturing	Industrial/lawn/garden tractors; Materials handling equipment; Industrial tools; Heating & ventilation; Fluid, power & air transmission equipment; Valves & fittings; Light gauge building components; Pipes & tubing; Service industry machinery; Household appliances; Miscellaneous fabricated metal products.
Heavy Industrial Manufacturing	Construction & mining machinery; Farm machinery & equipment; Shipbuilding & repair; Railroad rolling stock; Military armored vehicles; Engine, turbine & power transmission equipment; Power boiler, heat exchanger, and heavy tank manufacturing; Industrial machinery; Oil & gas field machinery.
Construction	Industrial buildings; Commercial buildings; Bridge & tunnel construction; Pipeline construction; Structural steel erection; Fabricated structural metal products; Other heavy construction; Welding repair establishments.
Capitalized Repair & Maintenance	Oil & gas production and distribution; Petroleum and coal products; Primary metals industries; Metal forging & stamping; Mining operations; Electrical power generation; Paper production.

TABLE 2: FY 2000 NATIONAL GROSS DOMESTIC PRODUCT & REVENUE OF INDUSTRIAL SECTORS STUDIED

Industrial Sector	Total (millions of dollars)	Percent of Total U.S. Gross Domestic Product
U.S. Gross Domestic Product	**$ 9,224,000**	**100%**
Total Manufacturing, Construction, and Mining Industries Value of Production	**$ 5,237,000**	**57%**
Total Value of Production by Industries Targeted In This Study	**$ 3,107,721**	**34%**
Automotive Sector	$ 510,658	6%
Aircraft/Aerospace Sector	$ 141,897	2%
Electronics/Medical Sector	$ 435,400	5%
Light Industrial Manufacturing Sector	$ 227,796	2%
Heavy Industrial Manufacturing Sector	$ 147,030	2%
Construction Sector	$ 363,889	4%
Capitalized Repair & Maintenance Sector	$ 1,281,051	14%

Additional Notes:

- Industries in which welding is a critical enabling technology account for 59% of the total value of production by all Manufacturing, Construction, and Mining industries.
- Durable goods manufacturing industries in which welding is a critical enabling technology account for 90% of total U.S. durable goods value of production.

WELDING EXPENDITURES - INTRODUCTION

Information presented in this section describes the levels of welding-related expenditures in U.S. industries where welding is a critical enabling technology. Total cost of production, and welding-related costs incurred in the production process are illustrated. Areas considered are as follows:

1. Total Cost of Production

Cost of production is defined as expenditures for labor, materials, consumables (including energy) and any purchased goods and/or services required for production of a product. Production costs exclude capital expenditures. Total industrial sector production costs, and the proportion of welding-related expenditures included in those costs, are presented.

2. Labor Costs

Value added by manufacture can be defined as the total labor input costs plus profits over the total cost of production. In other words, the difference between the cost of purchased materials/consumables and the value of shipments produced. Labor input costs typically are the majority of value added by manufacture. Total industrial sector labor costs (wages, salaries and benefits), and the proportion of welding-related labor expenditures included in those costs, are presented.

3. Materials & Consumables Costs

Purchased materials and consumables typically represent more than one-half of the total cost of production for manufacturers. Materials include all purchased commodities, as well as fabricated components, subassemblies, or assemblies used in the manufacture of the final product. Consumables include those materials and resources necessary to fabricate and finish the product – including energy. Total industrial sector materials and consumables costs, and the proportion of welding-related materials and consumables included in those costs, are presented.

4. Energy Costs

While energy costs are included in total materials and consumables costs, there is an interest in breaking out these costs as an individual line item. Total energy costs in each sector, as well as energy costs to operate welding-specific equipment, tooling, and environmental control systems, are presented.

5. Other Welding-Related Production Costs

In addition to costs for labor, materials, energy, and other consumables, costs for the following purchased services were determined:

- Welding-related research & development.
- Welding process specification preparation not covered by labor costs reported above.
- Welding certification costs.
- Welding-related training not covered by labor costs reported above.
- Welding-related consulting (including purchased inspection & testing services).
- Purchased field services (by industries in the Construction and Capitalized Repair & Maintenance sectors).
- Any other welding-related expenditures not covered by labor costs reported above.

6. Capital Expenditures

Capital expenditures are defined as investments in newly built facilities and/or newly purchased equipment used to carry out manufacturing or production processes. Total capital investments, as well as capital investments for all types of

welding and welding-related equipment, tooling, inspection, and environmental control systems, are presented for each of the seven industrial sectors studied.

7. Total Expenditures

Total expenditures by industry (production costs plus capital expenditures) determined by the U.S. Department of Commerce Survey of Manufactures, is presented for the industrial sectors considered. The proportion of welding-related expenditures included in total expenditures by industrial sector is presented as well.

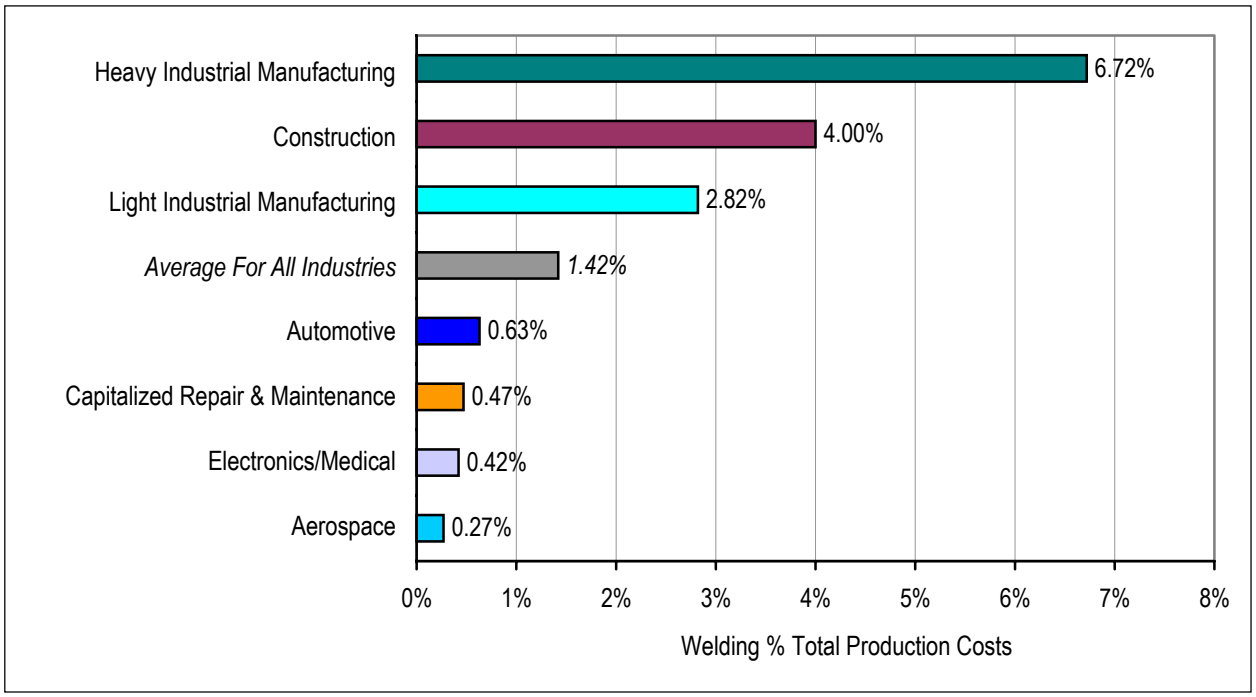
Total Cost of Production

Welding-related production costs (all non-capital expenditures) were $30.7 billion in 2000. This represented an average of 1.4% of equivalent total costs in these industries. The Heavy Industrial Manufacturing sector showed the highest percentage of welding-related costs compared to total production costs at 6.7%.

TABLE 3: FY 2000 COSTS OF PRODUCTION AND WELDING-RELATED EXPENDITURES

Industrial Sector	Cost of Production ($1,000)	Welding-Related Production Expenditures ($1,000)
Construction	$ 265,638,978	$ 10,614,690
Heavy Industrial Manufacturing	$ 109,957,550	$ 7,383,777
Light Industrial Manufacturing	$ 170,846,825	$ 4,813,018
Capitalized Repair & Maintenance	$ 819,872,896	$ 3,866,967
Automotive	$ 393,206,949	$ 2,466,641
Electronics/Medical	$ 274,301,844	$ 1,269,807
Aircraft/Aerospace	$ 99,327,922	$ 264,702
Total For All Industries:	$ ***2,133,152,965***	$ ***30,679,872***

FIGURE 1: PERCENTAGE OF TOTAL COST OF PRODUCTION REPRESENTED BY WELDING EXPENDITURES



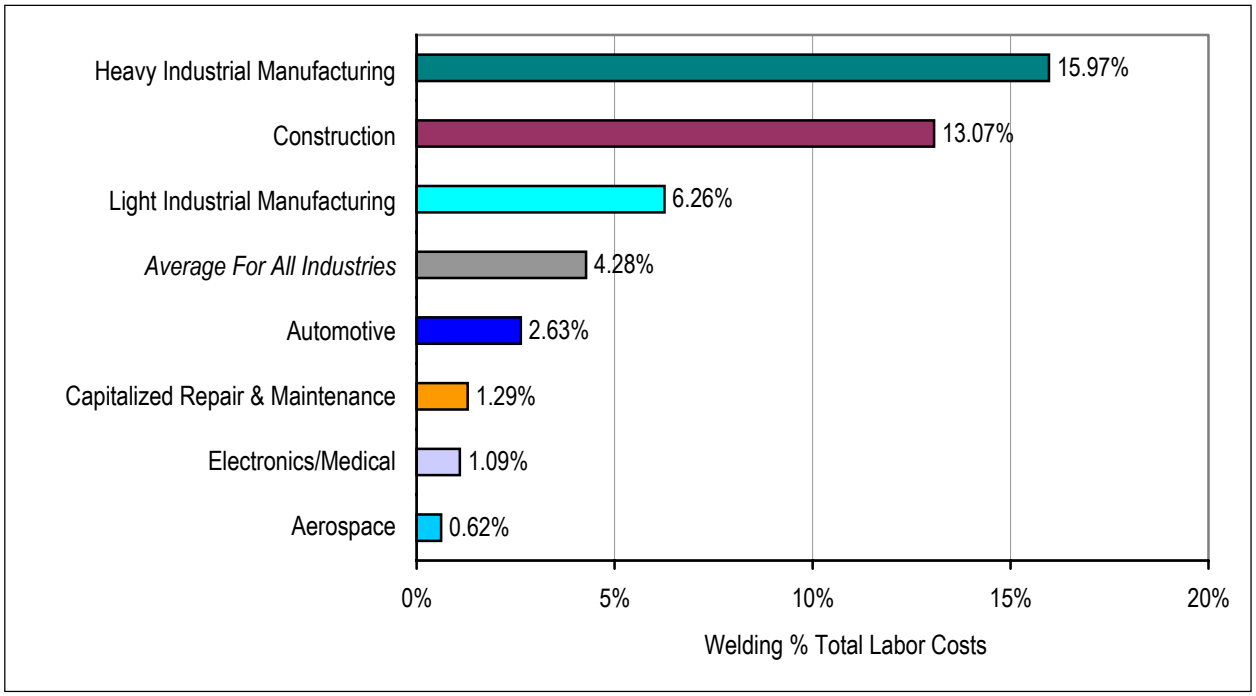
Labor Costs

Welding-related labor costs represented the largest portion of total welding-related costs in every industrial sector studied (pg. 17). Overall, welding-related labor costs totaled $22.4 billion in 2000 – an average of 4% of total labor costs in the industries studied. This proportion ranged from 0.6% in the Aircraft/Aerospace sector to 16% in the Heavy Industrial Manufacturing sector.

TABLE 4: FY 2000 INDUSTRY TOTAL AND WELDING-RELATED LABOR COSTS

Industry	Total Labor Costs ($1,000)	Welding-Related Labor Costs ($1,000)
Construction	$ 63,971,688	$ 8,358,216
Heavy Industrial Manufacturing	$ 34,081,590	$ 5,446,792
Light Industrial Manufacturing	$ 53,600,344	$ 3,355,038
Capitalized Repair & Maintenance	$ 178,706,670	$ 2,306,559
Automotive	$ 96,143,144	$ 1,816,055
Electronics/Medical	$ 83,030,733	$ 904,159
Aircraft/Aerospace	$ 33,700,545	$ 209,153
Total For All Industries:	***$ 516,234,714***	***$ 22,392,972***

FIGURE 2: WELDING-RELATED PERCENTAGE OF TOTAL LABOR COSTS



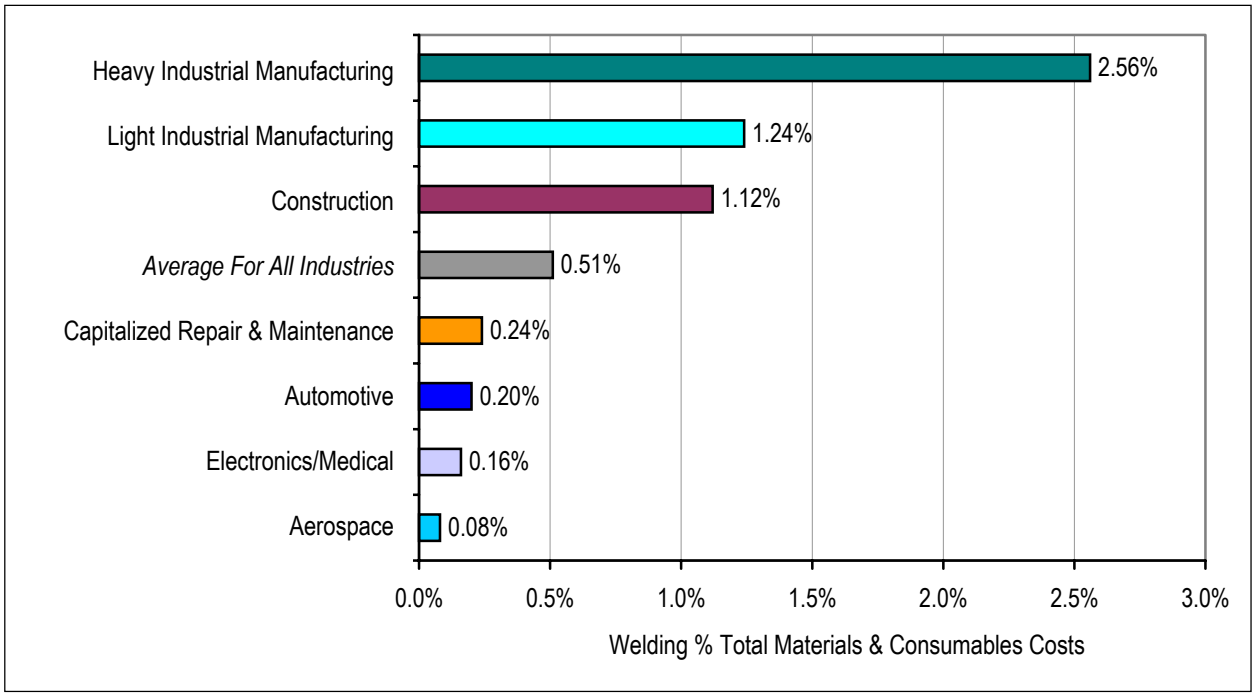
Materials & Consumables Costs

Welding-related materials & consumables costs total $8.3 billion in 2000. On average, this represented 0.5% of total materials and consumables costs in the industries studied. The Heavy Industrial Manufacturing sector had the highest percentage of welding-related costs compared to total materials and consumables costs at 2.6%.

TABLE 5: FY 2000 INDUSTRY TOTAL AND WELDING-RELATED MATERIALS & CONSUMABLES COSTS

Industry	Total Materials & Consumables Costs ($1,000)	Welding-Related Materials/Consumables ($1,000)
Construction	$ 201,667,290	$ 2,256,745
Heavy Industrial Manufacturing	$ 75,875,960	$ 1,939,986
Capitalized Repair & Maintenance	$ 641,166,225	$ 1,560,408
Light Industrial Manufacturing	$ 117,246,481	$ 1,457,980
Automotive	$ 324,063,805	$ 650,586
Electronics/Medical	$ 191,271,112	$ 365,647
Aircraft/Aerospace	$ 65,627,377	$ 55,549
Total For All Industries:	***$ 1,616,918,251***	***$ 8,286,900***

FIGURE 3: WELDING-RELATED PERCENTAGE OF TOTAL MATERIALS & CONSUMABLES COSTS



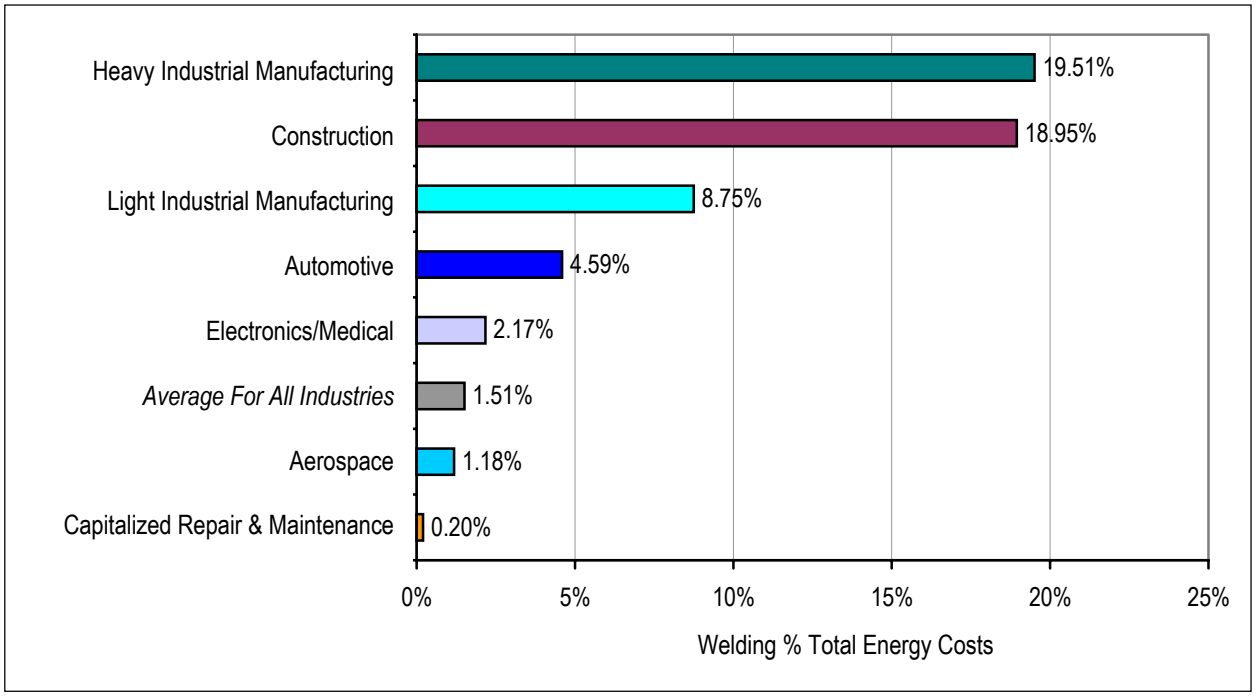
Energy Costs

Energy, while only 13.7% of the total materials & consumables costs reported on the preceding page, still represents a $74.7 billion cost to the U.S. industries studied. Welding-related energy costs represented $1.1 billion (1.5%) of this total.

TABLE 6: FY 2000 INDUSTRY TOTAL AND WELDING-RELATED ENERGY COSTS

Industry	Total Energy Costs ($1,000)	Welding-Related Energy Costs ($1,000)
Construction	$ 2,292,501	$ 434,341
Heavy Industrial Manufacturing	$ 1,132,132	$ 220,823
Light Industrial Manufacturing	$ 2,004,603	$ 175,390
Capitalized Repair & Maintenance	$ 63,688,255	$ 127,003
Automotive	$ 2,655,424	$ 122,014
Electronics/Medical	$ 2,176,999	$ 47,151
Aircraft/Aerospace	$ 794,623	$ 9,404
Total For All Industries:	***$ 74,724,536***	***$ 1,136,127***

FIGURE 4: WELDING-RELATED PERCENTAGE OF TOTAL ENERGY COSTS



Other Welding-Related Costs

Other welding-related costs included expenditures to other companies for welding–related research and development, specification preparation, certification, training, consulting, and field services. U.S. expenditures in these areas totaled $1.5 billion in 2000. Nearly 90% of that total was from purchased or subcontracted field service work by firms in the Construction and Capitalized Repair & Maintenance sectors

TABLE 7: FY 2000 OTHER WELDING-RELATED COSTS

Industrial Sector	Welding-Related Expenditures ($1,000)							Totals
	Consulting	Certification	Specification Preparation	Research & Development	Training	Other	Field Services	
Capitalized Repair & Maintenance	$108,200	$ 9,761	$ 5,794	$ 1,617	$ 13,462	$ 10,478	$562,676	$ 711,988
Construction	$ 84,246	$ 37,550	$ 15,698	$ 5,006	$ 17,621	$ 1,227	$397,470	$ 558,818
Light Industrial Manufacturing	$ 44,579	$ 4,464	$ 3,848	$ 10,317	$ 8,530	$ 851	$ 0	$ 72,589
Electronics	$ 1,950	$ 27,762	$ 14,289	$ 15,134	$ 4,472	$ 141	$ 0	$ 63,748
Heavy Industrial Manufacturing	$ 495	a	$ 27,618	$ 19,339	$ 2,140	$ 1,583	$ 0	$ 51,175
Automotive	$ 2,179	$ 2,329	$ 2,926	$ 17,516	$ 5,415	$ 31	$ 0	$ 30,396
Aircraft/Aerospace	$ 739	$ 2,051	$ 1,554	$ 1,269	$ 1,094	$ 217	$ 0	$ 6,924
Totals:	$242,388	$ 83,917	$ 71,727	$ 70,198	$ 52,734	$ 14,528	$960,146	$1,495,638

[a] Certification was not included as a line item in the Heavy Industrial Manufacturing pilot study survey. These costs are designated in the "Other" expenditures category.

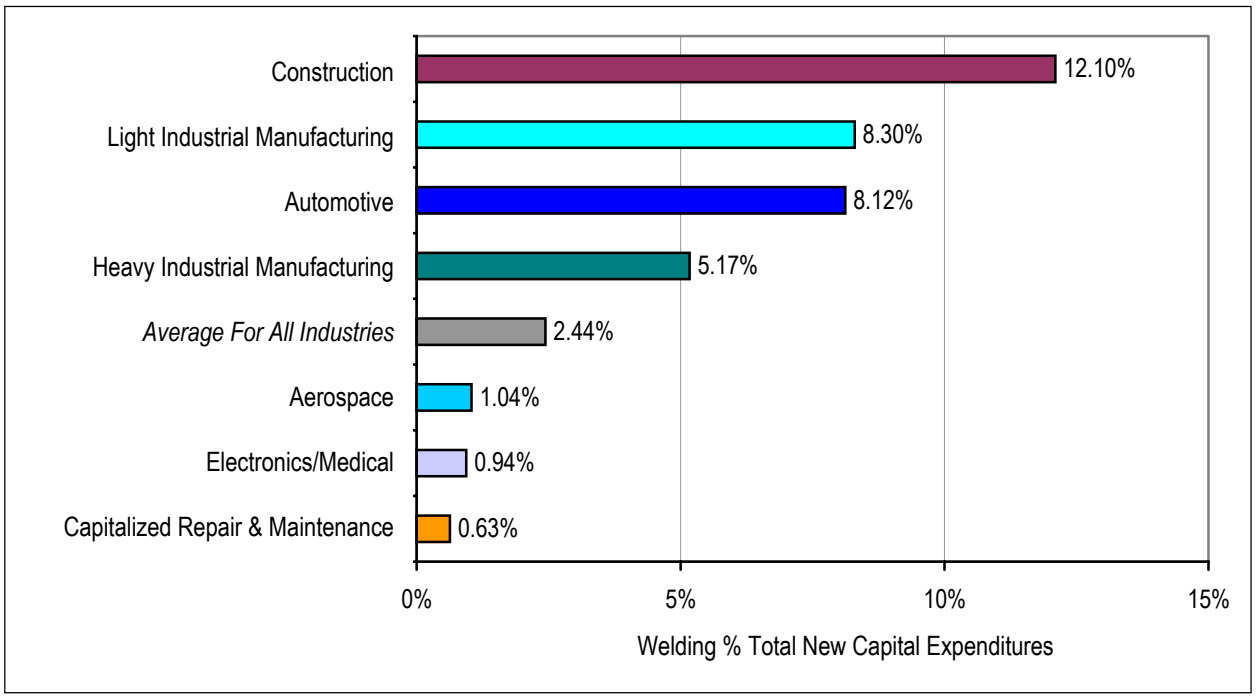
Capital Expenditures

Welding-related capital expenditures in the industries studied totaled $3.4 billion in 2000. On average, that represented 2.5% of total capital expenditures. The welding-related percentage of total capital expenditures varied tremendously among industrial sectors, from 0.6% for the Capitalized Repair & Maintenance sector to 12% for the Construction sector.

TABLE 8: FY 2000 INDUSTRY TOTAL AND WELDING-RELATED CAPITAL EXPENDITURES

Industry	Total New Capital Expenditures ($1,000)	Welding-Related Capital Expenditures ($1,000)
Automotive	$ 15,064,422	$ 1,222,415
Construction	$ 5,349,168	$ 647,240
Light Industrial Manufacturing	$ 6,811,093	$ 565,618
Capitalized Repair & Maintenance	$ 82,755,920	$ 522,729
Heavy Industrial Manufacturing	$ 4,749,074	$ 245,407
Electronics/Medical	$ 20,768,568	$ 194,871
Aircraft/Aerospace	$ 3,405,529	$ 35,331
Total For All Industries:	***$ 138,903,775***	***$ 3,434,611***

FIGURE 5: WELDING-RELATED PERCENTAGE OF TOTAL CAPITAL EXPENDITURES



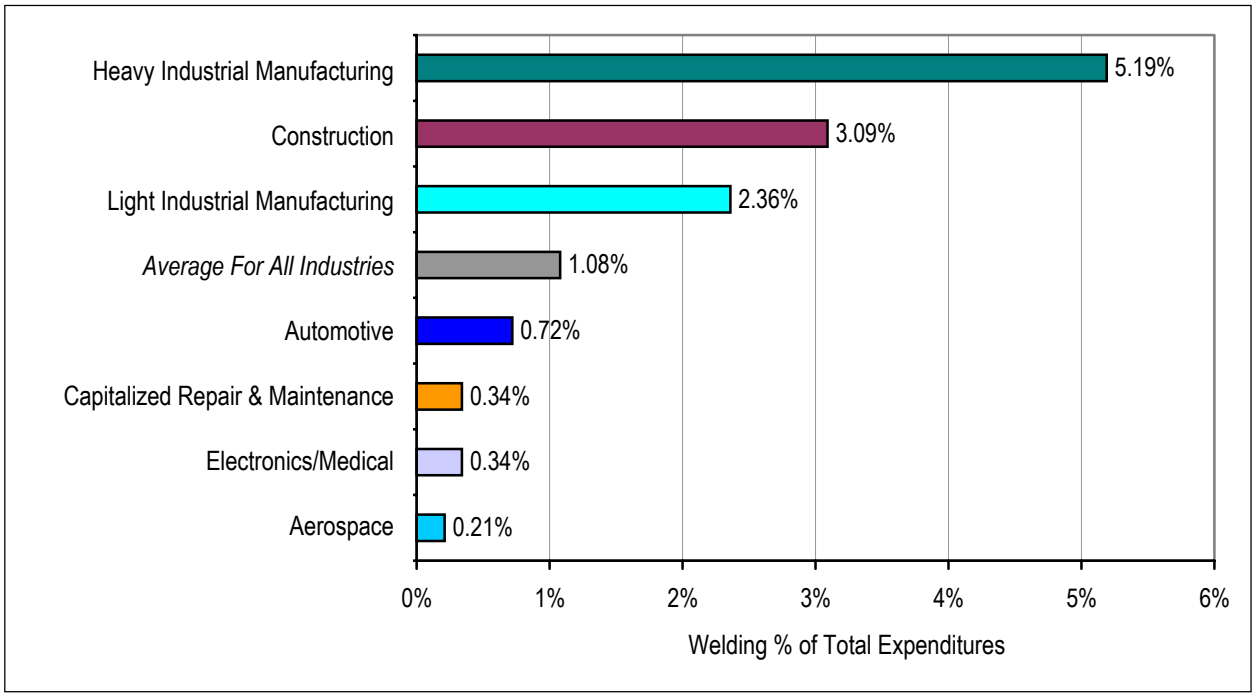
Total Expenditures

Total welding-related expenditures in the industrial sectors studied (capital purchases, materials, consumables, labor, energy, and purchased services) were $34.1 billion in 2000, or 1.1% of total expenditures for the year in these industries. The Heavy Industrial Manufacturing sector had the largest percentage of welding-related expenditures compared to total expenditures (5.2%).

TABLE 9: FY 2000 TOTAL AND WELDING-RELATED EXPENDITURES

Industry	Total Expenditures ($1,000)	Welding-Related Expenditures ($1,000)
Construction	$ 363,889,011	$ 11,262,200
Heavy Industrial Manufacturing	$ 147,030,156	$ 7,629,184
Light Industrial Manufacturing	$ 227,795,767	$ 5,378,636
Capitalized Repair & Maintenance	$ 1,281,051,399	$ 4,389,696
Automotive	$ 510,658,376	$ 3,690,056
Electronics/Medical	$ 436,399,753	$ 1,464,978
Aircraft/Aerospace	$ 141,897,032	$ 300,033
Total For All Industries:	***$ 3,107,721,494***	***$ 34,114,483***

FIGURE 6: PERCENTAGE OF TOTAL EXPENDITURES REPRESENTED BY WELDING EXPENDITURES



ALLOCATION OF WELDING EXPENDITURES - INTRODUCTION

The previous section presented data illustrating the welding-related proportion of total expenditures in the industrial sectors studied. This section focuses on how these industries allocated welding-related expenditures. This provides a benchmark for welding-related expenditure allocation for companies within these industries.

Welding-related expenditures were categorized into five areas as follows:

1. **Labor Costs**: Salaries and benefits for employees either directly involved in or supporting welding-related processes. A complete list of employee classifications considered can be found on page 4 of the survey questionnaire appended to this report.

2. **Materials & Consumables Costs**: Expenditures for welding-related materials and consumables, including expenditures for:
   - non-capitalized welding equipment purchases or rentals,
   - filler metal, flux, and solder,
   - gases used in welding processes,
   - welding-related ancillary supplies such as protective clothing and hand tools,
   - welding equipment maintenance parts, and
   - disposal of welding process byproducts.

3. **Energy Costs**: Energy costs for the operation of welding-specific equipment, tooling, and environmental control systems.

4. **Other Welding-Related Production Costs**: Expenditures for purchased services related to:
   - Welding-related research & development.
   - Welding process specification preparation not covered by labor costs reported above.
   - Welding certification costs.
   - Welding-related training not covered by labor costs reported above.
   - Welding-related consulting (including purchased inspection & testing services).
   - Purchased or subcontracted field services (by industries in the Construction and Capitalized Repair & Maintenance sectors).
   - Any other welding-related expenditures not covered by labor costs reported above.

   Note that total expenditures in this category exclude government research and development contracts with firms or agencies not directly involved in manufacturing, construction or mining (e.g., Department of Defense contracts with research institutions).

5. **Capital Expenditures**: Capital expenditures for equipment and systems used in welding-related processes, including manual, semiautomatic, and robotic welding units, welding-related tooling, and welding-related inspection and environmental control systems.

Table 10 presents welding-related production expenditures in each of the first four categories described above for industrial sectors included in the study. Table 11 indicates the percentage of total production welding-related expenditures represented by each of these categories. Table 12 presents welding-related capital investment figures and the proportion of those investment expenditures to total welding-related expenditures in each sector. Graphic presentations of this data, by type of expenditure, follow.

TABLE 10: WELDING-RELATED PRODUCTION EXPENDITURES IN U.S. INDUSTRIAL SECTORS (all figures in $1,000)

Industrial Sector	2000 Total Welding-Related Production Expenditures	Expenditures For Welding-Related:			
		Labor	Materials & consumables	Energy	Other Welding Related
Construction	$ 10,614,690	$ 8,358,216	$ 1,263,586	$ 434,341	$ 558,818
Heavy Industrial Manufacturing	$ 7,383,777	$ 5,443,792	$ 1,667,987	$ 220,823	$ 51,175
Light Industrial Manufacturing	$ 4,813,018	$ 3,355,038	$ 1,210,001	$ 175,390	$ 72,589
Capitalized Repair & Maintenance	$ 3,866,967	$ 2,306,559	$ 721,416	$ 127,003	$ 711,988
Automotive	$ 2,466,641	$ 1,816,055	$ 498,175	$ 122,014	$ 30,396
Electronics/Medical	$ 1,269,807	$ 904,159	$ 254,748	$ 47,152	$ 63,748
Aircraft/Aerospace	$ 264,702	$ 209,153	$ 39,222	$ 9,404	$ 6,923
Total For All Industries:	**$ 30,679,872**	**$ 22,392,972**	**$ 5,655,135**	**$ 1,136,127**	**$ 1,495,638**

TABLE 11: PROPORTION OF WELDING-RELATED PRODUCTION EXPENDITURES IN U.S. INDUSTRIAL SECTORS

Industrial Sector	Proportion of Expenditures For Welding-Related:			
	Labor	Materials & consumables	Energy	Other Welding-Related
Construction	78.7%	11.9%	4.1%	5.3%
Heavy Industrial Manufacturing	73.7%	22.6%	3.0%	0.7%
Light Industrial Manufacturing	69.7%	25.1%	3.6%	1.5%
Capitalized Repair & Maintenance	59.6%	18.7%	3.3%	18.4%
Automotive	73.6%	20.2%	4.9%	1.2%
Electronics/Medical	71.2%	20.1%	3.7%	5.0%
Aircraft/Aerospace	79.0%	14.8%	3.6%	2.6%
Total For All Industries:	**73.0%**	**18.4%**	**3.7%**	**4.9%**

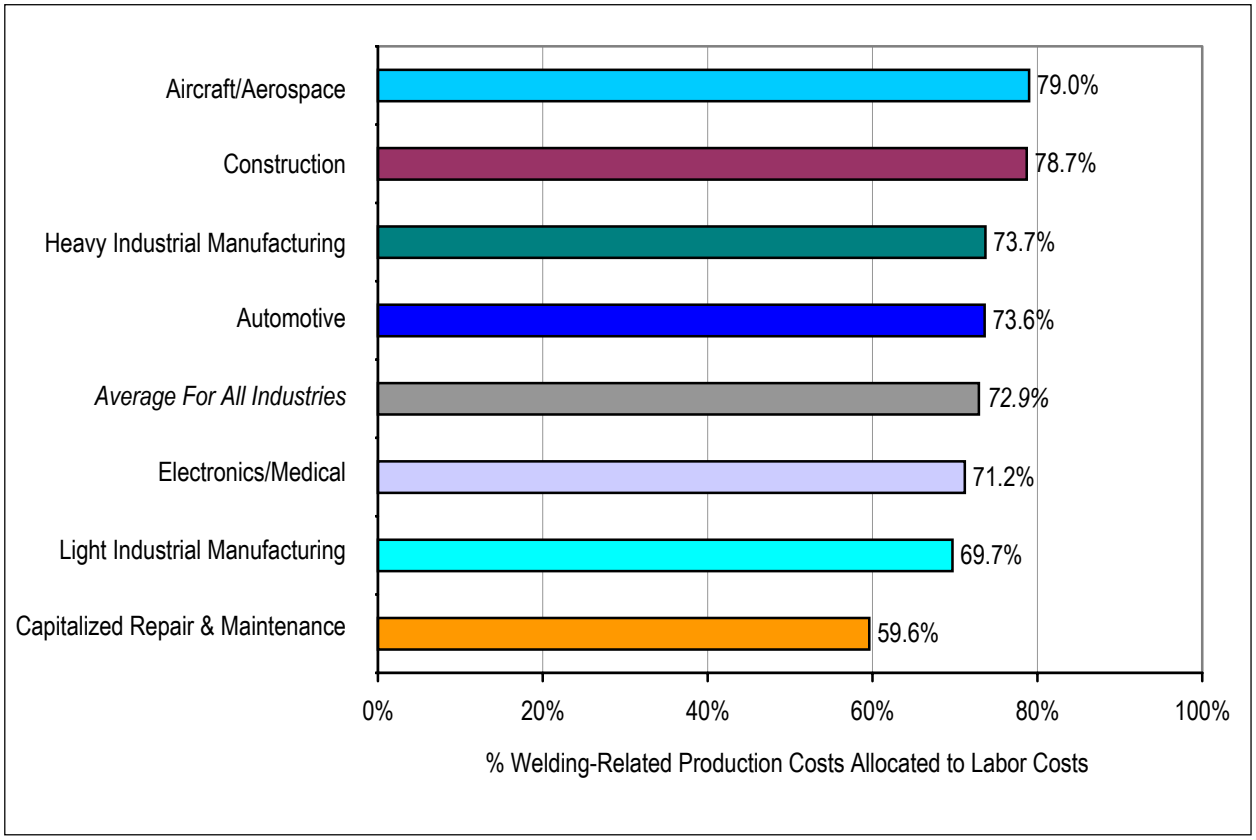
TABLE 12: PROPORTION OF WELDING-RELATED CAPITAL EXPENDITURES IN U.S. INDUSTRIAL SECTORS (figures in $1,000)

Industrial Sector	2000 Total Welding-Related Expenditures	2000 Welding-Related Capital Investment Expenditures	Proportion For Welding-Related Capital Investments
Automotive	$ 3,690,056	$ 1,223,415	33.2%
Electronics/Medical	$ 1,464,678	$ 194,871	13.3%
Capitalized Repair & Maintenance	$ 4,389,696	$ 522,729	11.9%
Aircraft/Aerospace	$ 300,033	$ 35,311	11.8%
Light Industrial Manufacturing	$ 5,378,636	$ 565,618	10.5%
Construction	$ 11,262,200	$ 647,240	5.7%
Heavy Industrial Manufacturing	$ 7,629,184	$ 245,407	3.2%
Total For All Industries:	**$ 34,114,483**	**$ 3,434,611**	**10.1%**

Labor Costs

Labor costs, including salaries and benefits for employees directly involved in supporting welding-related processes, represent the largest portion of total welding-related costs. The proportion of these costs compared to total welding-related production costs varies considerably among industrial sectors, ranging from just under 60% in the Capitalized Repair & Maintenance sector to almost 80% in the Aircraft/Aerospace sector.

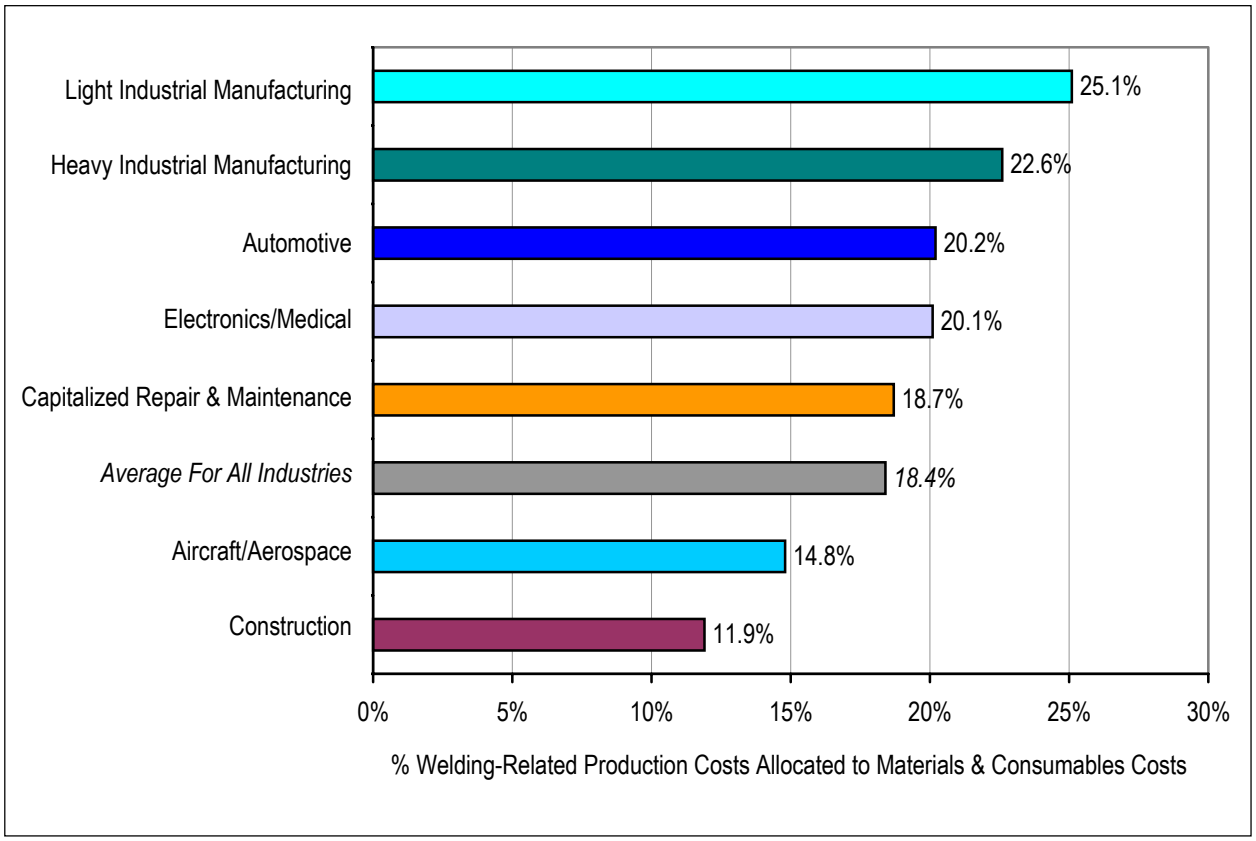
FIGURE 7: PERCENTAGE OF TOTAL WELDING PRODUCTION COSTS ALLOCATED TO LABOR COSTS



Materials & Consumables Costs

The proportion of welding-related materials & consumables costs (excluding energy costs) compared to total welding-related production costs varies considerably among industrial sectors. Average percentages ranged from a low of about 12% for the Construction sector to a high of more than 25% for the Light Industrial Manufacturing sector.

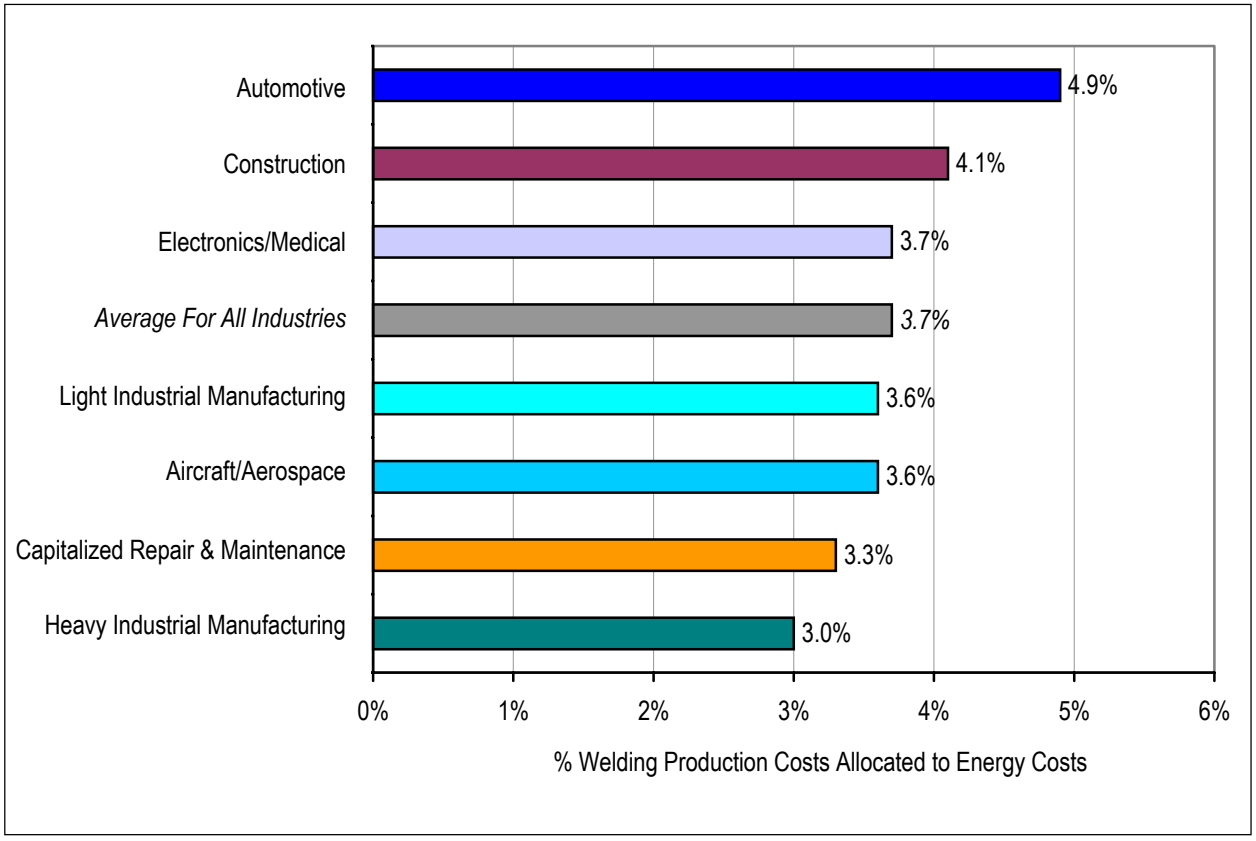
FIGURE 8: PERCENTAGE OF TOTAL WELDING PRODUCTION COSTS ALLOCATED TO WELDING-RELATED MATERIALS & CONSUMABLES COSTS



Energy Costs

Although a significant production cost ($1.1 billion), energy costs are a relatively small percentage of the total welding-related production costs in the industries studied. The average proportion of welding-related energy costs compared to total welding-related production costs ranged from 3% to 5%.

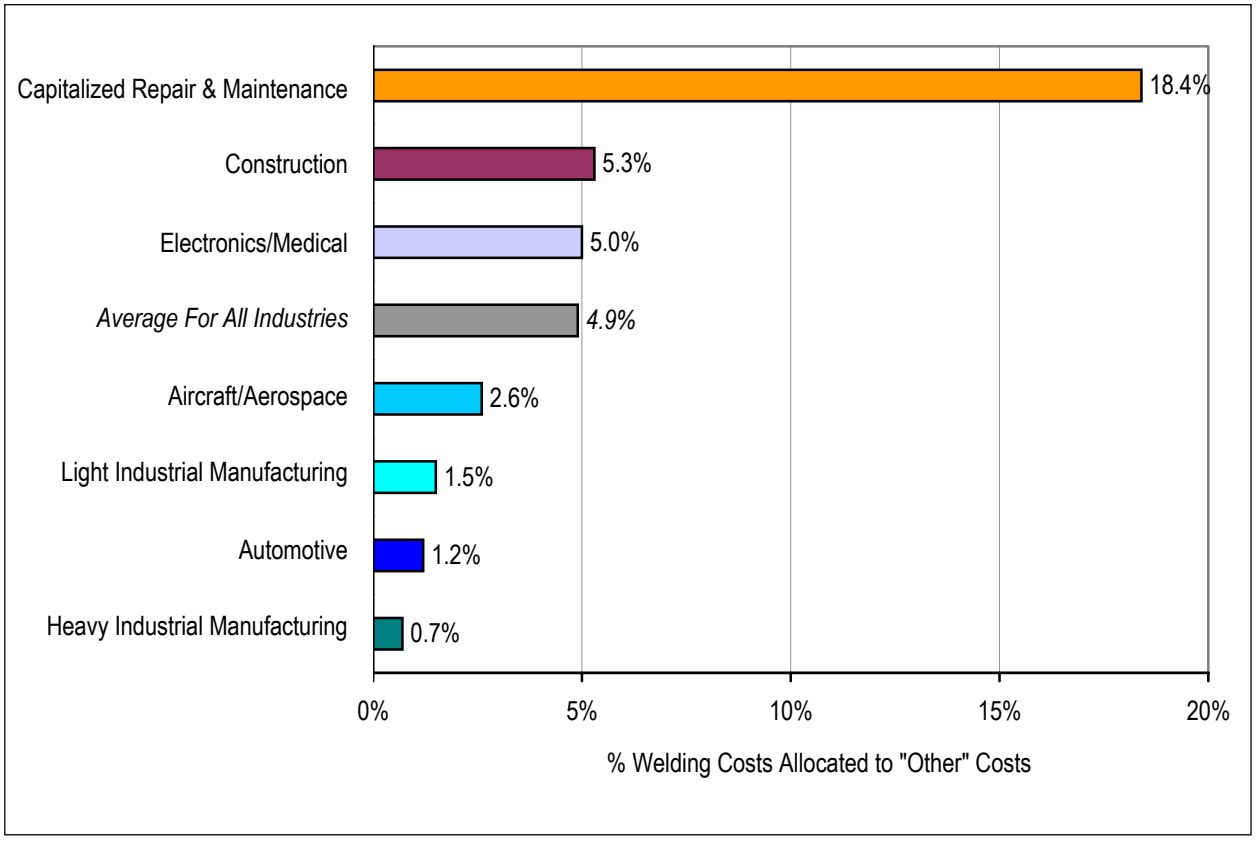
FIGURE 9: PERCENTAGE OF TOTAL WELDING PRODUCTION COSTS ALLOCATED TO ENERGY COSTS



Other Welding-Related Production Costs

Other welding-related production costs include costs for purchased welding-related research and development, process specification preparation, training, consulting, and field services. The average proportion of these costs vary dramatically among industrial sectors, ranging from less than 1% in the Heavy Industrial Manufacturing sector to more than 18% in the Capitalized Repair & Maintenance sector.

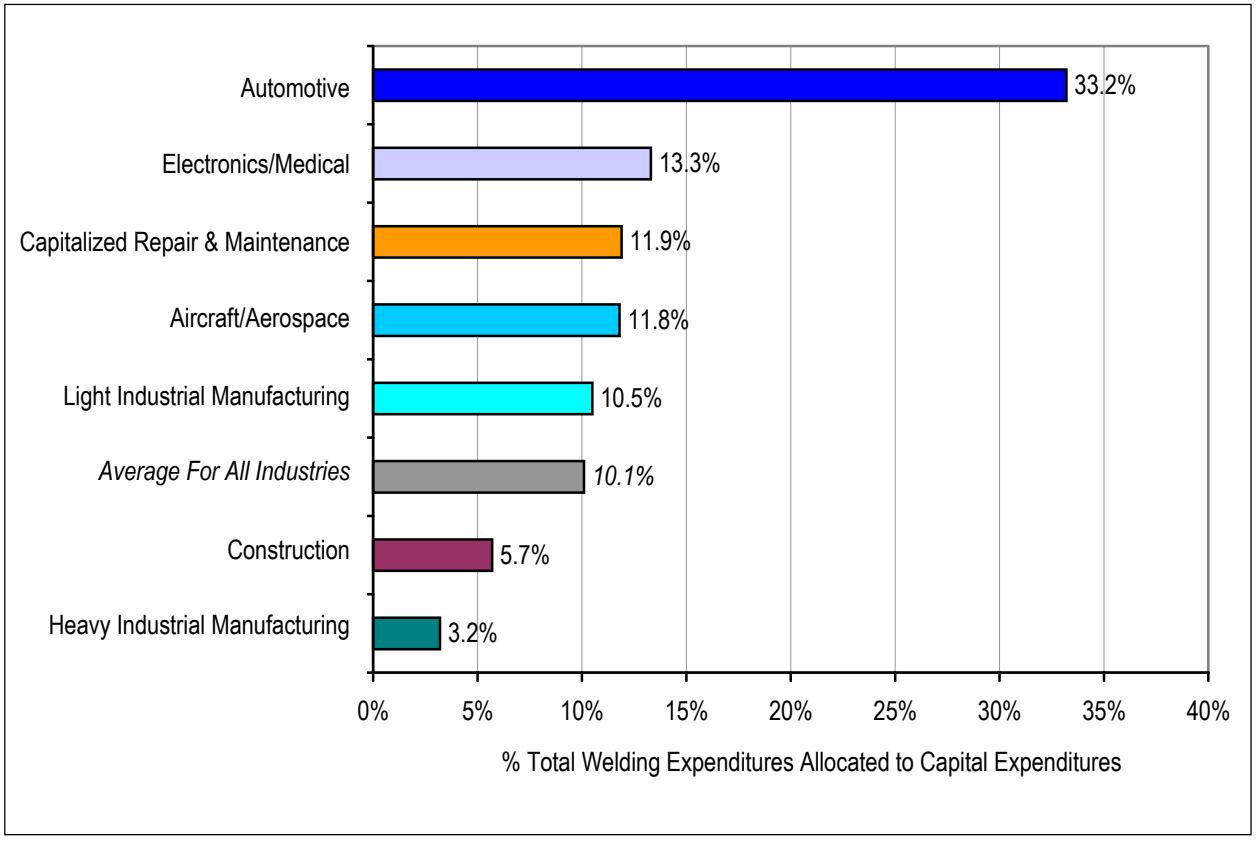
FIGURE 10: PERCENTAGE OF TOTAL WELDING PRODUCTION COSTS ALLOCATED TO ALL OTHER AREAS



Capital Expenditures

Overall, welding-related capital expenditures of $3.43 billion represent approximately 10% of total welding-related expenditures in the industries studied. The proportion of welding-related capital expenditures compared to total welding-related costs and expenditures ranges from 3.2% in the Heavy Industrial Manufacturing sector to just over 33% in the Automotive sector.

FIGURE 11: PERCENTAGE OF TOTAL WELDING COSTS & EXPENDITURES ALLOCATED TO CAPITAL EXPENDITURES



WELDING PRODUCTIVITY - INTRODUCTION

Respondents to the Department of Commerce survey were asked to report welding productivity measures used. Eight general welding productivity measures were specified as follows:

- **Welding speed** (e.g., feet welded per period of time)
- **Welding process output**: (e.g., joints completed per period of time)
- **Welding deposition rate** (e.g., pounds weld metal deposited per period of time)
- **Welding cell arc time** (percentage of time welding cell is in operation)
- **Welded product output – Standardized product** - (e.g., welded components completed per period of time)
- **Welded product output – Customized product** - (e.g., tons of steel joined per period of time)
- **Welding defect rate** (e.g., defects per 100 welds completed)
- **Performance versus time standard** (e.g., percentage of production completed within specified time standard)

Additionally, respondents were given the opportunity to indicate up to two additional welding productivity measures used other than those indicated above. A synopsis of the number and type of productivity measures used within specific industries is presented in this section.

This section also includes a summary of the extent to which establishments surveyed measure cost per unit and time efficiency of welding output. The status of other productivity-related issues – specifically welder availability, welder training, and active pursuit of automated welding process adoption is presented as well. Finally, suggestions for improving welding productivity are offered.

Use of Welding Productivity Measures

Nearly one-half (47%) of all survey respondents do not measure the productivity of their welding operations. Approximately one-third (36%) use only one welding productivity measure. The balance (17%) use multiple welding productivity measures.

FIGURE 12: WELDING PRODUCTIVITY MEASUREMENT IN U.S. ESTABLISHMENTS

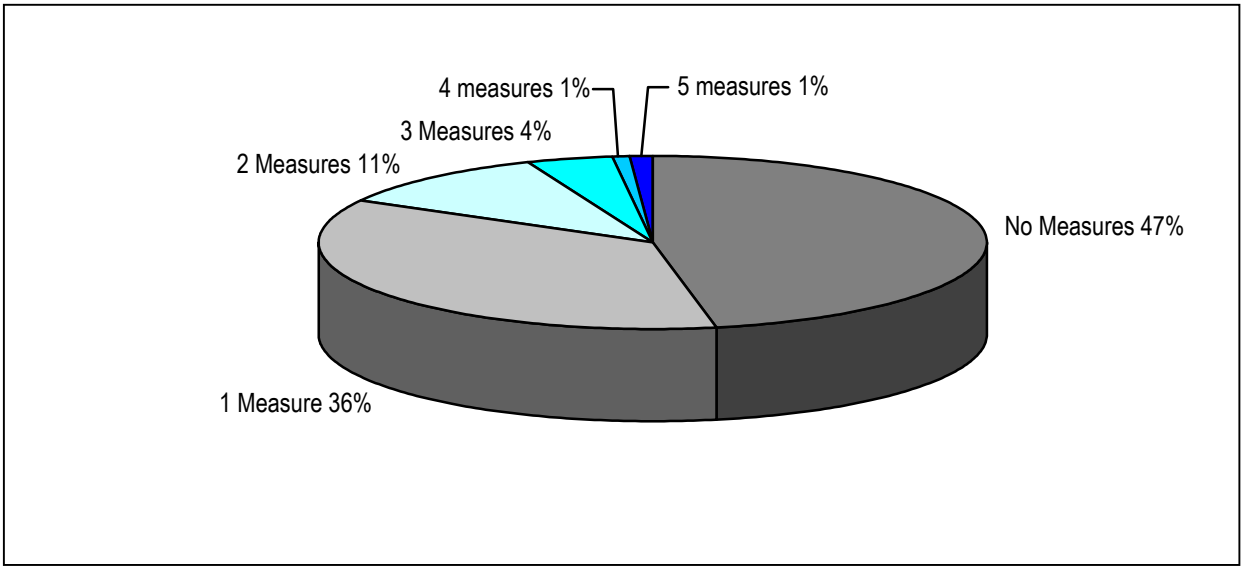


TABLE 13: WELDING PRODUCTIVITY MEASUREMENT – COMPARISON BY SECTORS

Industrial Sector	Percentage of Firms Using		
	No welding productivity measures	1 welding productivity measure	2 – 5 welding productivity measures
Electronics/Medical Sector	31%	53%	16%
Heavy Industrial Manufacturing Sector	34%	45%	21%
Light Industrial Manufacturing Sector	38%	39%	23%
Automotive Sector	44%	33%	23%
Aircraft/Aerospace Sector	54%	34%	12%
Construction Sector	56%	30%	14%
Capitalized Repair & Maintenance Sector	65%	25%	10%
All Establishments Responding:	*47%*	*36%*	*17%*

Cost Per Unit Welding Productivity Measurement

Eighty percent (80%) of the establishments responding reported minimal or no use of cost per unit measures of welding productivity. A mere 6% reported extensive use of cost per unit welding productivity measures.

FIGURE 13: COST PER UNIT OF WELDING OUTPUT MEASUREMENT BY U.S. ESTABLISHMENTS

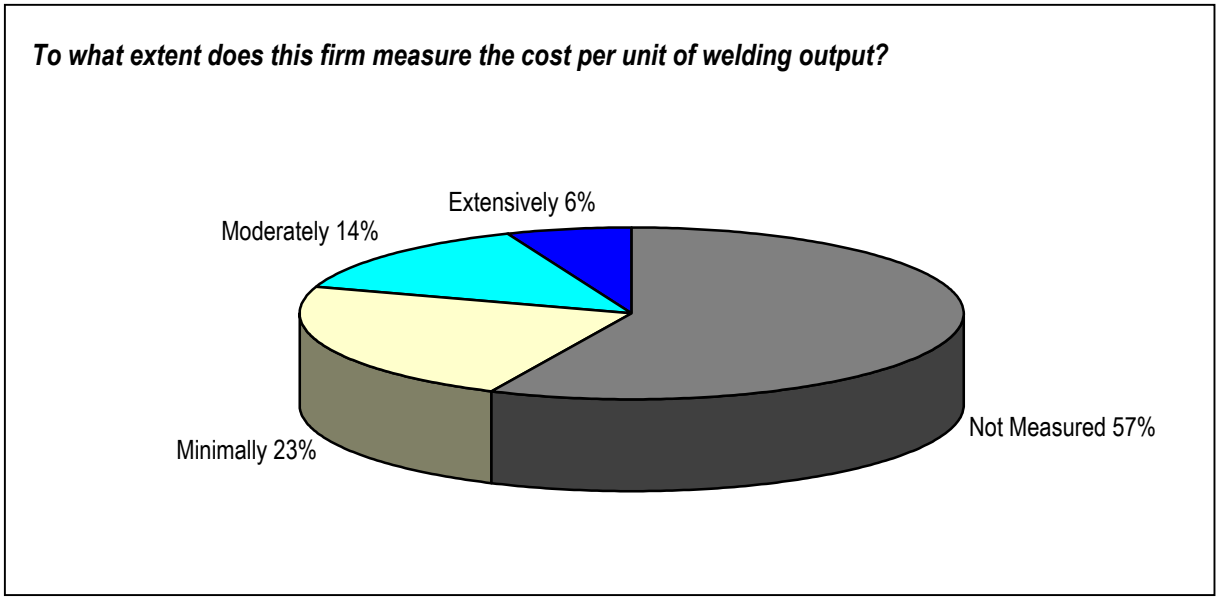


TABLE 14: COST PER UNIT OF WELDING OUTPUT MEASUREMENT – COMPARISON BY SECTOR

Industrial Sector	Percent of Establishments Measuring Cost per Unit of Welding Output:			
	Not At All	Minimally	Moderately	Extensively
Heavy Industrial Manufacturing Sector	40%	30%	21%	9%
Light Industrial Manufacturing Sector	40%	25%	24%	8%
Electronics/Medical Sector	43%	41%	16%	0%
Automotive Sector	47%	26%	16%	11%
Aircraft/Aerospace Sector	50%	29%	13%	8%
Construction Sector	58%	22%	15%	5%
Capitalized Repair & Maintenance Sector	81%	14%	4%	1%
All Establishments Responding	*57%*	*23%*	*14%*	*6%*

Factors Included in Cost Per Unit Welding Productivity Measurements

Of firms indicating the use of a cost per unit measurement, 79% reported using both materials and labor costs in that measurement. Sixteen percent (16%) consider labor only while 5% of the establishments consider materials only.

FIGURE 14: FACTORS CONSIDERED IN MEASURING COST PER UNIT OF WELDING OUTPUT

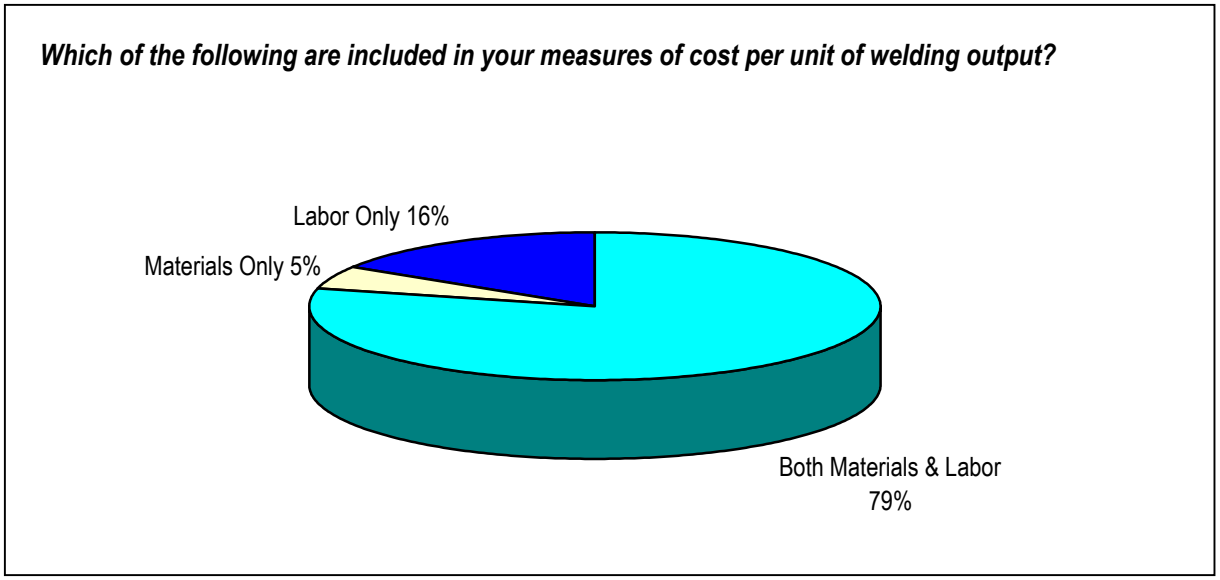


TABLE 15: FACTORS CONSIDERED IN MEASURING COST PER UNIT OF WELDING OUTPUT – COMPARISON BY SECTOR

Industrial Sector	Percent of Establishments Measuring Cost per Unit of Welding Output That Consider:		
	Both Labor & Material Costs	Labor Costs Only	Material Costs Only
Heavy Industrial Manufacturing Sector	83%	15%	2%
Light Industrial Manufacturing Sector	81%	15%	4%
Automotive Sector	81%	9%	10%
Construction Sector	80%	18%	2%
Aircraft/Aerospace Sector	79%	14%	7%
Capitalized Repair & Maintenance Sector	75%	15%	10%
Electronics/Medical Sector	66%	30%	4%
All Establishments Responding	*79%*	*16%*	*5%*

Time Efficiency Welding Productivity Measurement

Over three-fourths (78%) of the establishments responding indicated that time efficiency measures of welding productivity are used either minimally or not at all. Six percent (6%) used such measures extensively.

FIGURE 15: MEASUREMENT OF WELDING OUTPUT TIME EFFICIENCY BY U.S. ESTABLISHMENTS

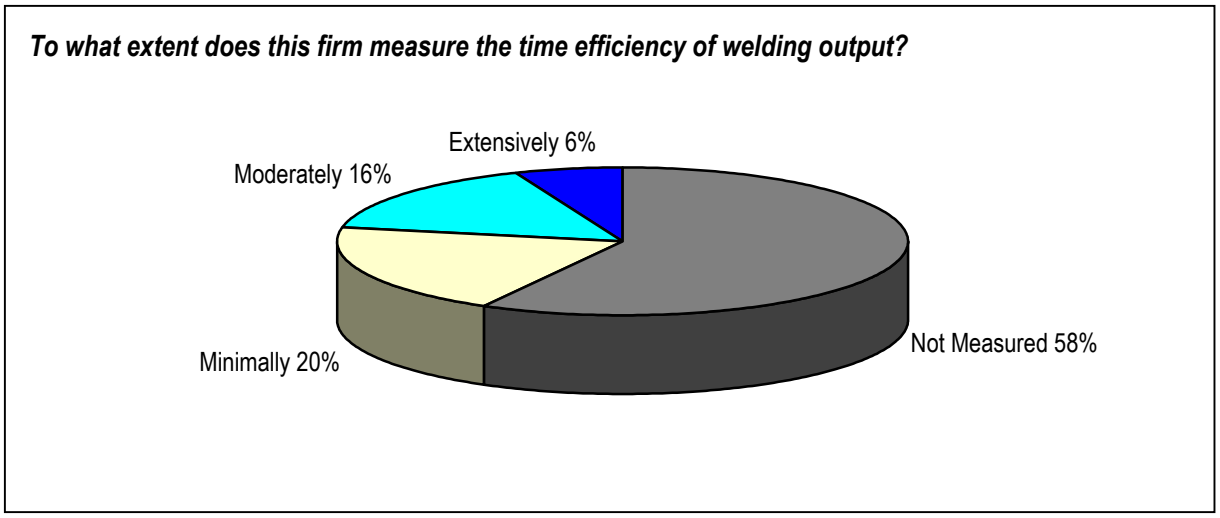


TABLE 16: MEASUREMENT OF WELDING OUTPUT TIME EFFICIENCY – COMPARISON BY SECTORS

Industrial Sector	Percent of Establishments Measuring Time Efficiency of Welding Output:			
	Not At All	Minimally	Moderately	Extensively
Heavy Industrial Manufacturing Sector	38%	25%	29%	8%
Light Industrial Manufacturing Sector	42%	21%	26%	11%
Electronics/Medical Sector	47%	36%	13%	4%
Construction Sector	50%	23%	19%	8%
Automotive Sector	53%	25%	11%	11%
Aircraft/Aerospace Sector	56%	21%	14%	9%
Capitalized Repair & Maintenance Sector	78%	17%	5%	0%
All Establishments Responding	*58%*	*20%*	*16%*	*6%*

Types of Welding Productivity Measures Used

Among the firms actually measuring welding productivity, the measures used could be categorized into the types presented below. The single most common welding productivity measure used is completion of welded components per period of time.

TABLE 17: TYPES OF WELDING PRODUCTIVITY MEASURES USED U.S. ESTABLISHMENTS

Industrial Sector	[a] Percentage of Firms Measuring:								
	Components per Period Time	Defect Rate	Performance vs. Time Standard	Joints Completed per Period Time	Feet Welded per Period Time	Metal Deposited per Period Time	Tons Metal Joined per Period Time	Welding Cell % Time on Arc	Other
Automotive Sector	62%	33%	11%	20%	6%	0%	0%	3%	16%
Aircraft/Aerospace Sector	46%	50%	12%	10%	4%	0%	0%	4%	14%
Electronics/Medical Sector	51%	35%	4%	15%	2%	0%	0%	2%	7%
Light Industrial Manufacturing Sector	53%	31%	16%	20%	8%	1%	2%	8%	12%
Heavy Industrial Manufacturing Sector [b]	--	13%	--	9%	24%	12%	10%	--	66%
Construction Sector	12%	25%	4%	29%	38%	8%	10%	2%	10%
Capitalized Repair & Maintenance Sector	5%	48%	43%	9%	0%	0%	0%	0%	16%
Averages	***43%***	***36%***	***19%***	***15%***	***10%***	***3%***	***3%***	***3%***	***22%***

[a] All percentages indicated are based on the number of establishments that actually measure welding productivity. Establishments not measuring productivity are excluded from these percentages. Rows do not total 100% as some establishments use multiple productivity measures.

[b] The Heavy Industrial Manufacturing sector served as the pilot study and had the opportunity to categorize welding productivity measures in only six areas. The majority of those Heavy Industrial Manufacturing measures classified as 'Other' were measures performance versus a specified time standard.

Impact of Welder Shortage on Productivity

One-half of the survey respondents indicated that a shortage of qualified welders has some impact on the establishment's productivity. More than 20% indicated either "moderate" or "extensive" impact on productivity because of the lack of properly qualified welders.

FIGURE 16: IMPACT OF WELDER SHORTAGE ON THE PRODUCTIVITY OF U.S. ESTABLISHMENTS

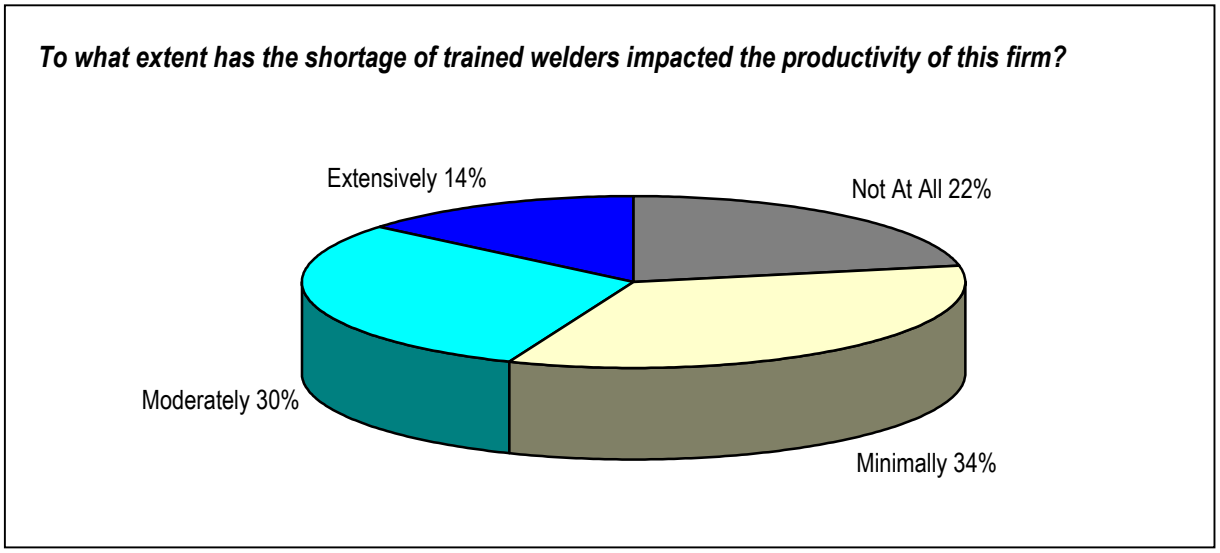


TABLE 18: IMPACT OF WELDER SHORTAGE ON PRODUCTIVITY – COMPARISON BY SECTOR

Industrial Sector	Percent of Establishments Indicating Trained Welder Shortage Has Impacted Productivity:			
	Not At All	Minimally	Moderately	Extensively
Heavy Industrial Manufacturing Sector	22%	34%	30%	14%
Construction Sector	39%	31%	20%	10%
Automotive Sector	40%	29%	21%	10%
Light Industrial Manufacturing Sector	48%	33%	15%	4%
Aircraft/Aerospace Sector	57%	24%	17%	2%
Capitalized Repair & Maintenance Sector	68%	24%	6%	1%
Electronics/Medical Sector	75%	14%	10%	1%
All Establishments Responding	*49%*	*28%*	*16%*	*6%*

Impact of Welding Training on Productivity

Nearly one-half (46%) of the establishments surveyed indicated that their welding-related training needs are being met "minimally" or "not at all." Less than 15% of the establishments reported that welding-related training needs were being met "completely." Welding-related training needs are particularly high for Construction, Heavy Industrial Manufacturing, and Automotive sector establishments.

FIGURE 17: EXTENT TO WHICH WELDING TRAINING NEEDS OF U.S. ESTABLISHMENTS ARE BEING MET

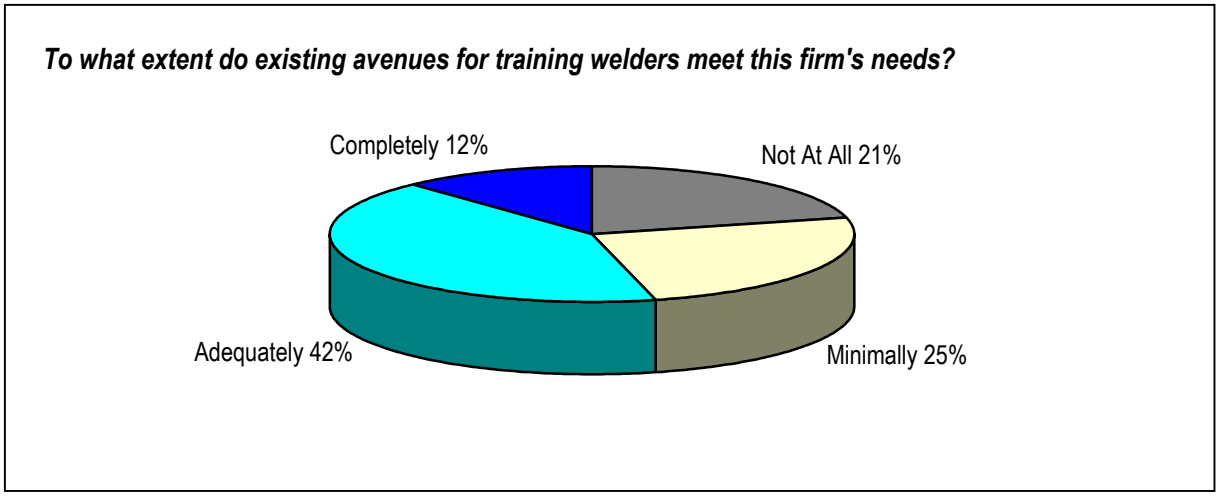


TABLE 19: EXTENT TO WHICH WELDING TRAINING NEEDS ARE BEING MET – COMPARISON BY SECTOR

Industrial Sector	Percent of Establishments Indicating Existing Welder Training Programs Meet Their Needs:			
	Not At All	Minimally	Adequately	Completely
Construction Sector	32%	28%	33%	7%
Electronics/Medical Sector	27%	16%	36%	21%
Aircraft/Aerospace Sector	23%	22%	44%	11%
Capitalized Repair & Maintenance Sector	21%	12%	48%	19%
Automotive Sector	19%	30%	38%	13%
Light Industrial Manufacturing Sector	17%	26%	47%	10%
Heavy Industrial Manufacturing Sector	14%	40%	44%	2%
All Establishments Responding	*21%*	*25%*	*42%*	*12%*

Active Pursuit of Welding Automation

U.S. establishments are generally not actively pursuing the automation of welding processes. Overall, more than three-fourths (78%) of the establishments indicated that currently their active pursuit of opportunities to automate welding processes is "minimal" or "not at all."

FIGURE 18: INTEGRATION OF AUTOMATED WELDING PROCESSES BY U.S. ESTABLISHMENTS

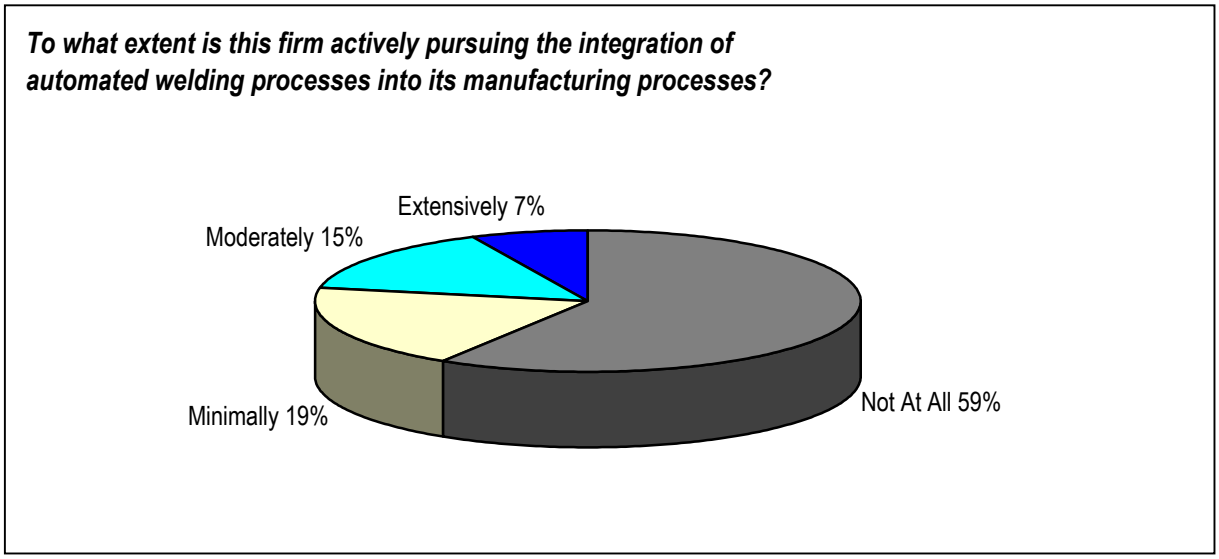


TABLE 20: INTEGRATION OF AUTOMATED WELDING PROCESSES – COMPARISONS BY SECTORS

Industry	Percent of Establishments Indicating They Are Actively Pursuing the Integration of Automated Welding Processes:			
	Not At All	Minimally	Moderately	Extensively
Heavy Industrial Manufacturing Sector	37%	31%	18%	14%
Light Industrial Manufacturing Sector	43%	23%	23%	11%
Electronics/Medical Sector	53%	14%	17%	16%
Automotive Sector	58%	18%	17%	7%
Construction Sector	58%	21%	16%	5%
Aircraft/Aerospace Sector	65%	20%	10%	5%
Capitalized Repair & Maintenance Sector	85%	9%	4%	2%
All Establishments Responding	*59%*	*19%*	*15%*	*7%*

Opportunities For Productivity Improvement

- Interviews were conducted with 55 individuals selected for their expertise in the application of welding technologies in the industries studied. These individuals were asked to identify opportunities for welding productivity improvement in their industries.
- A summary of strategies proposed for U.S. welding productivity improvement immediately follows.

ORGANIZATIONAL CONSIDERATIONS

1. **Improved educational opportunities in the field of welding**.

   The key factor limiting welding productivity in industries that rely on manual welding is the skill level of many practicing welders. Welders with limited skills are more likely to produce defective welds, which results in decreased productivity. For those companies that use more advanced welding techniques, a lack of technicians that understand the welding process hinders the optimal use of advanced processes. Finally, the lack of engineers with expertise in welding and welding process applications has resulted in the adoption of design and manufacturing practices that limit, rather than increase, the productivity of welding and the value it is able to add to the final product.

2. **Continued development of a common national system of standards, assessment, and certification**.

   As productive practices are identified, the adoption of these practices can be accelerated through their inclusion in industry standards and assessments. Certification will also help increase productivity by ensuring the skilled use of productive welding practices.

3. **Increased knowledge sharing of productive practices**.

   While sharing of knowledge concerning welding productivity improvements does take place through both formal and informal means, this sharing of knowledge is not systemic, particularly between industries. For example, many industries look to leaders in the adoption of welding automation – particularly the Automotive industry – to learn cost-effective approaches for automating repetitive welding tasks. Support for cross-industry sharing of welding productivity improvements is necessary to foster these types of improvement opportunities.

4. **Greater support of cooperative research and development programs**

   Both government/industry and industry/industry cooperative R&D programs that emphasize "real world" applications of semi-automated and automated processes would foster welding productivity improvements. These programs should include research on the economics associated with the adoption of these more productive processes.

5. **Increased understanding of the economics of welding**.

   Change and adoption of more productive welding applications will only be driven by clear economic gains. Currently, very few firms have made the effort to determine how manufacturing processes like welding can be used to optimize the value of a product. A national effort, led by the welding industry, will be necessary to help firms understand, in real dollars for specific operations, how improved welding productivity can add value to products.

TECHNICAL CONSIDERATIONS

1. **Automation of welding operations**.

   Movement from manual to automated welding processes is an obvious and thoroughly proven approach for making major improvements in welding productivity. In repetitive processes, the less human intervention there is in the process, the more productive the process becomes. Automation also contributes to improved safety and workplace environment.

2. **Greater consideration given to welding requirements in the design of the product**.

   Across all industries studied, greater attention to welding requirements during the product or process design phase would increase the productivity of the production process. Materials selection has the greatest impact on welding productivity. Often, materials are selected that cannot be optimally welded using "in-house" welding process capabilities. Additionally, lack of consideration may be given to the practical considerations of completing the welding process (e.g., clearances for welding guns, etc.). Development/Design teams with multiple disciplines represented, including welding engineers, are able to effectively address these problems.

3. **Refinement of automated processes that will allow for wider adoption and use**.

   Even in those industries that have a relatively high degree of welding automation (primarily in the Automotive and Light Industrial Manufacturing sectors) continued refinements to automated process are pursued to further reduce variability (e.g., adoption of computer process controls). Others are looking to the development of "smart" automation that will do what a manual welder instinctively does by compensating for variability in components to be joined.

   Continued development of welding processes to match the practical requirements of production environments are sought as well (e.g., laser welding equipment that can be operated by production workers; development of automated processes for welding high-strength lighter gauge steels in Automotive applications).

4. **Improved quality control in components to be joined**.

   Welding productivity can be greatly enhanced by focusing on the quality of materials to be joined. Common causes of weld defects are cleanliness of components to be joined, failure of components to be welded to meet size/fit-up specification standards, variability in metallurgical properties of stock from lot-to-lot and vendor-to-vendor, and variability in metal coatings.

5. **Adoption of lean manufacturing approaches**.

   Reduction of unnecessary steps associated with the welding process offers an opportunity for tremendous gains in productivity. With the exception of some highly-automated welding processes, much of the time required to complete a welded joint is spent in preparation of the components to be welded. Lean manufacturing evaluates the complete production process and eliminates unproductive effort in the welding preparation process.

Four groups of industries were included in the Automotive sector of this study. Those groups were defined as follows:

- **Vehicle Manufacturing** includes those firms that produce a completed vehicle (as opposed to component parts of the vehicle only). Products include automobiles, light trucks, SUVs, commercial trucks, mobile homes, campers, and all types of road-use trailers.
- **Systems & Parts** manufacturers supplying vehicle manufacturers. These manufacturers also supply the aftermarket automotive products chain. Products produced by this group of industries include engines and engine parts, electrical and electronic automotive systems/ equipment, steering and suspension components, brake systems, transmission and power train components, seating and interior trim, and air conditioner systems.
- **Cycle Manufacturing** includes firms manufacturing motorcycles and bicycles, as well as parts and accessories for motorcycles and bicycles.
- **Exhaust System Repair** includes those establishments in the automotive repair industry that are primarily focused on exhaust system repair.

Welding expenditure allocations presented for the Automotive sector are comparable to those expenditure allocations described in the presentation of the overall results (pgs. 17-23). These expenditures include:

- **Labor Costs**: Salaries and benefits for employees either directly involved in or supporting welding-related processes.
- **Materials & Consumables Costs**: Expenditures for welding-related materials and consumables.
- **Energy Costs**: Energy costs for the operation of welding-specific equipment, tooling, and environmental control systems.
- **Other Welding-Related Production Costs**: Expenditures to other companies for welding–related research and development, specification preparation, certification, training, and consulting.
- **Capital Expenditures**: Capital expenditures for equipment and systems used in welding-related processes, including manual, semiautomatic, and robotic welding units, welding-related tooling, and welding-related inspection and environmental control systems.

The total number of establishments on which welding expenditure estimates are based is as follows for this sector:

- Vehicle Manufacturing: 221 establishments
- Parts & Systems: 111 establishments
- Cycle Manufacturing: 40 establishments
- Auto Exhaust Repair: 12 establishments

The margin of error for the Automotive sector overall results is ± 2.8%. Margins of error for the industry group results increase as the number of responding establishments serving as the basis for the estimate declines. This should be kept in mind when comparing the group results.

Data concerning welding productivity in the Automotive sector are presented in the following areas:

- Number and type of welding productivity measures used.
- Measurement of cost per unit of welding output.
- Measurement of welding output time efficiency.
- The impact of welder shortage on productivity.
- The extent to which welding training needs are being met.
- The active pursuit of the integration of welding automation into manufacturing processes.

TABLE AU1: WELDING-RELATED PRODUCTION EXPENDITURES IN AUTOMOTIVE INDUSTRIES (all figures in $1,000)

Industrial Group	Expenditures For:				2000 Total Welding-Related Production Expenditures
	Labor	Materials & consumables	Energy	Other Welding Related	
Vehicle Manufacturing	$ 1,440,424	$ 261,312	$ 88,722	$ 27,650	$ 1,818,108
Automotive Parts & Systems	$ 239,120	$ 223,160	$ 31,351	$ 2,682	$ 496,313
Cycle Manufacturing	$ 28,579	$ 3,134	$ 395	$ 64	$ 32,172
Automotive Exhaust Repair	$ 107,932	$ 10,570	$ 1,546	$ 0	$ 120,048
Automotive Sector Totals	**$ 1,816,055**	**$ 498,175**	**$ 122,014**	**$ 30,396**	**$ 2,466,641**

FIGURE AU1: PROPORTION OF WELDING-RELATED PRODUCTION EXPENDITURES IN AUTOMOTIVE INDUSTRIES

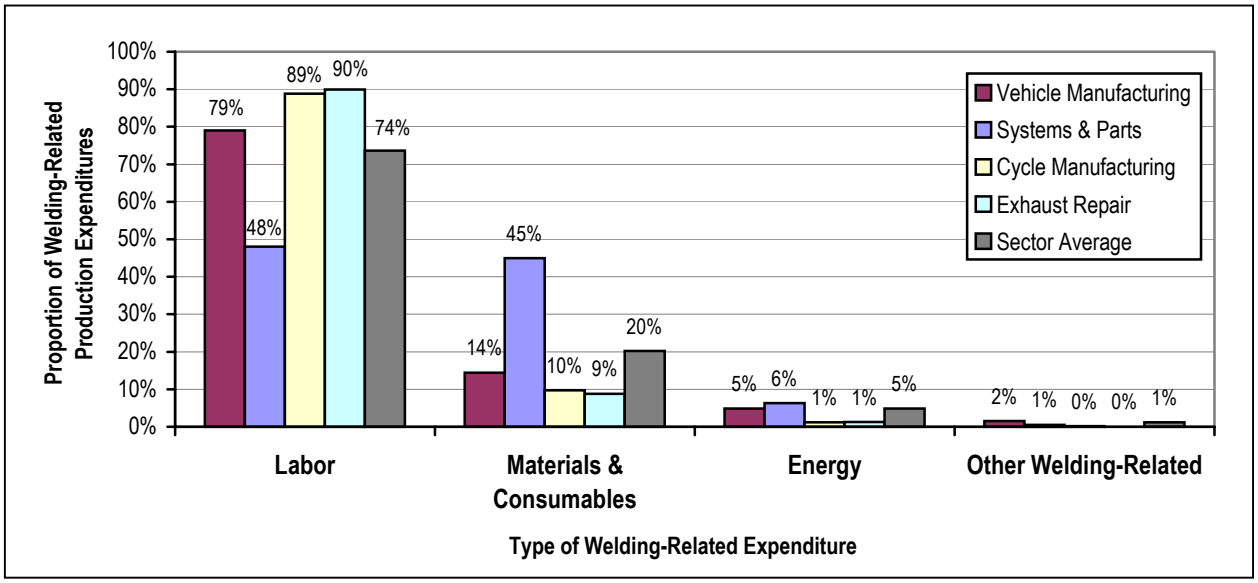


TABLE AU2: WELDING-RELATED CAPITAL EXPENDITURES IN AUTOMOTIVE INDUSTRIES (figures in $1,000)

Industrial Group	2000 Total Welding-Related Expenditures	2000 Welding-Related Capital Investment Expenditures	Proportion For Welding-Related Capital Investments
Vehicle Manufacturing	$ 2,926,146	$ 1,108,038	37.9%
Automotive Parts & Systems	$ 608,645	$ 112,332	18.5%
Cycle Manufacturing	$ 32,764	$ 592	1.8%
Automotive Exhaust Repair	$ 12,500	$ 2,452	2.0%
Automotive Sector Totals/Average	**$ 3,690,056**	**$ 1,223,415**	**33.2%**

TABLE AU3: WELDING PRODUCTIVITY MEASUREMENT – AUTOMOTIVE INDUSTRIES

Industrial Group		Number of Welding Productivity Measures Used					
		0	1	2	3	4	5-6
Vehicle Manufacturing	(n=86)	38%	42%	13%	5%	1%	1%
Automotive Systems & Parts	(n=43)	42%	23%	28%	5%	2%	0%
Cycle Manufacturing	(n=16)	75%	13%	0%	6%	6%	0%
Exhaust System Repair	(n = 5)	60%	40%	0%	0%	0%	0%
Automotive Sector Averages	(n=150)	**44%**	**33%**	**15%**	**5%**	**2%**	**1%**

TABLE AU4: TYPES OF WELDING PRODUCTIVITY MEASURES USED – AUTOMOTIVE INDUSTRIES

Industrial Sector		Percentage of Firms Measuring Productivity That Measure:								
		Components per Period Time	Defect Rate	Joints Completed per Period Time	Performance vs. Time Standard	Feet Welded per Period Time	Welding Cell % Time on Arc	Metal Deposited per Period Time	Tons Metal Joined per Period Time	Other
Vehicle Manufacturing	(n=53)	60%	33%	17%	11%	6%	4%	0%	0%	21%
Automotive Systems & Parts	(n=25)	68%	17%	24%	4%	0%	0%	0%	0%	4%
Cycle Manufacturing	(n = 4)	75%	64%	50%	0%	50%	0%	0%	0%	25%
Exhaust System Repair	(n = 2)	0%	25%	0%	0%	0%	0%	0%	0%	0%
Automotive Sector Averages	(n=84)	**62%**	**33%**	**20%**	**8%**	**6%**	**3%**	**0%**	**0%**	**16%**

FIGURE AU2: COST PER UNIT OF WELDING OUTPUT MEASUREMENT – AUTOMOTIVE INDUSTRIES

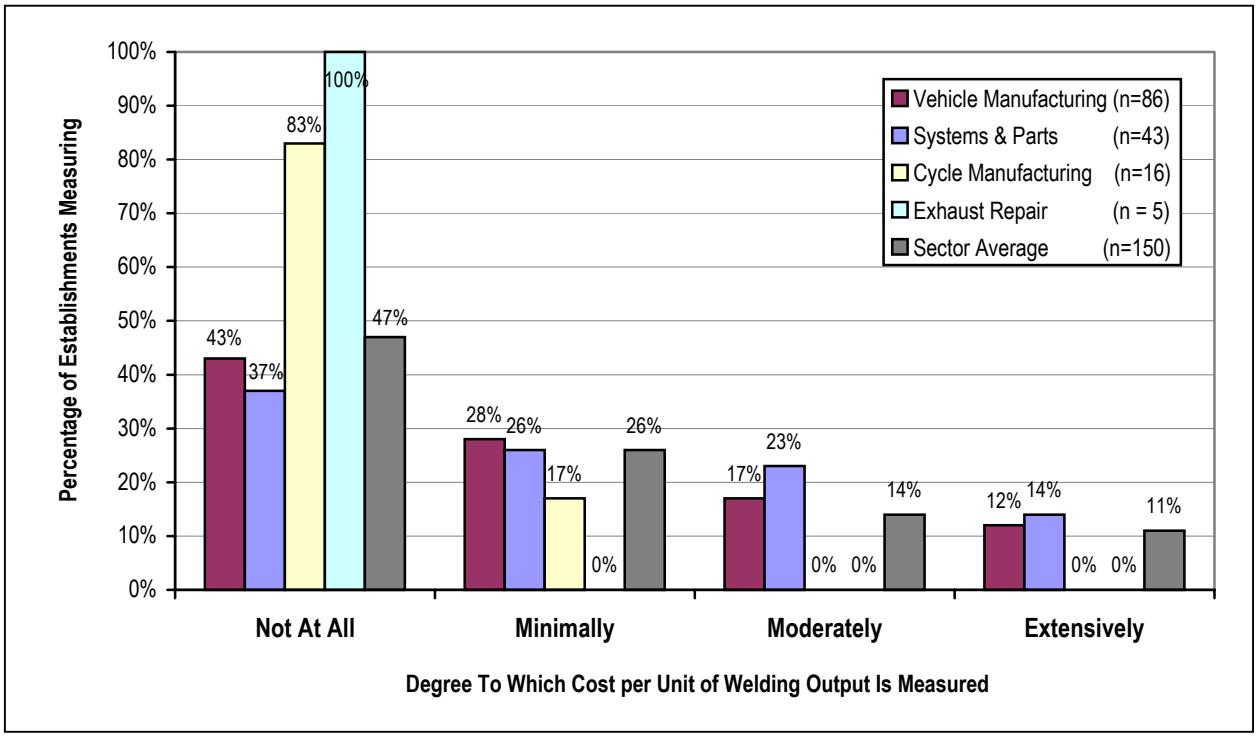


FIGURE AU3: FACTORS CONSIDERED IN MEASURING COST PER UNIT OF WELDING OUTPUT – AUTOMOTIVE INDUSTRIES

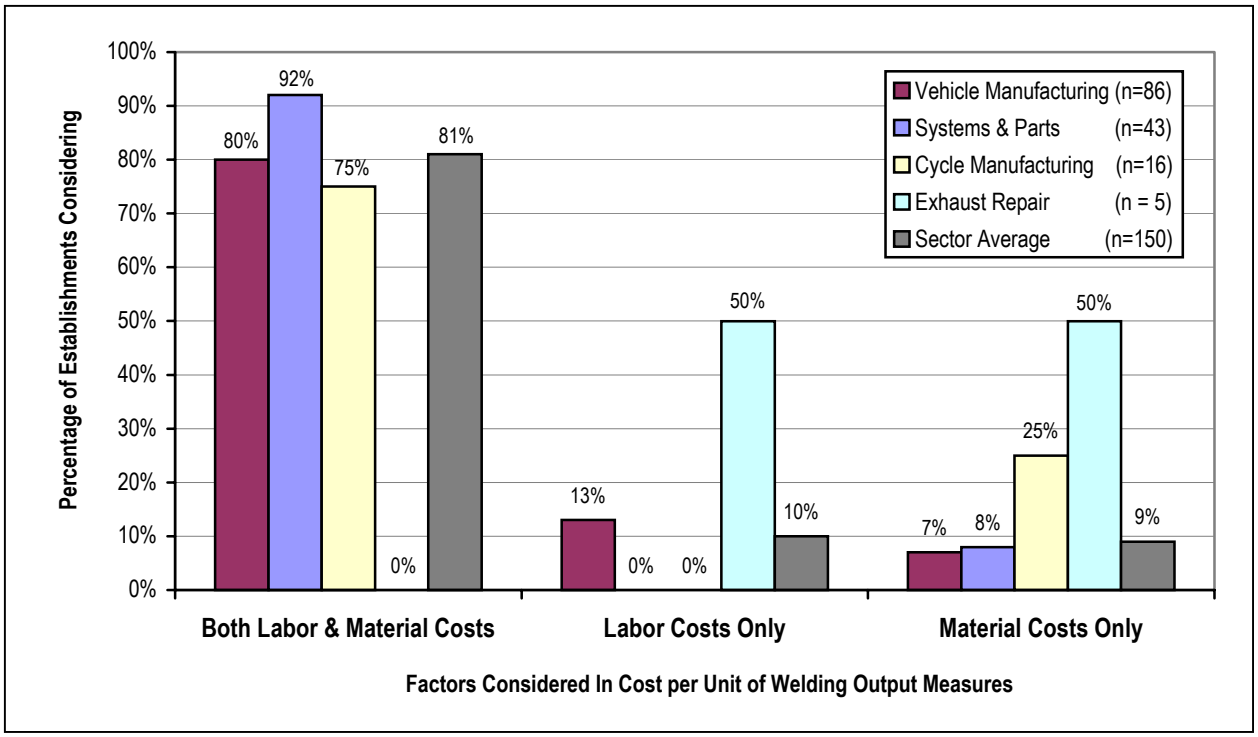


FIGURE AU4: MEASUREMENT OF WELDING OUTPUT TIME EFFICIENCY – AUTOMOTIVE INDUSTRIES

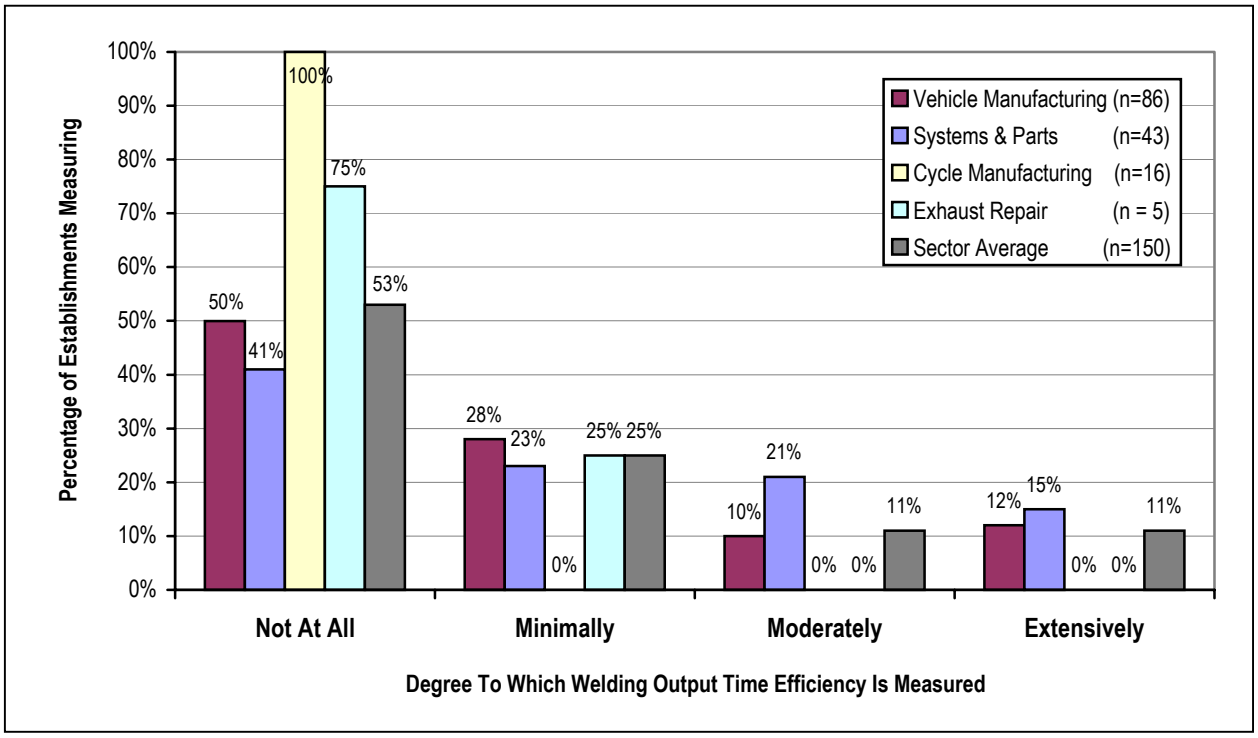


FIGURE AU5: IMPACT OF WELDER SHORTAGE ON PRODUCTIVITY – AUTOMOTIVE INDUSTRIES

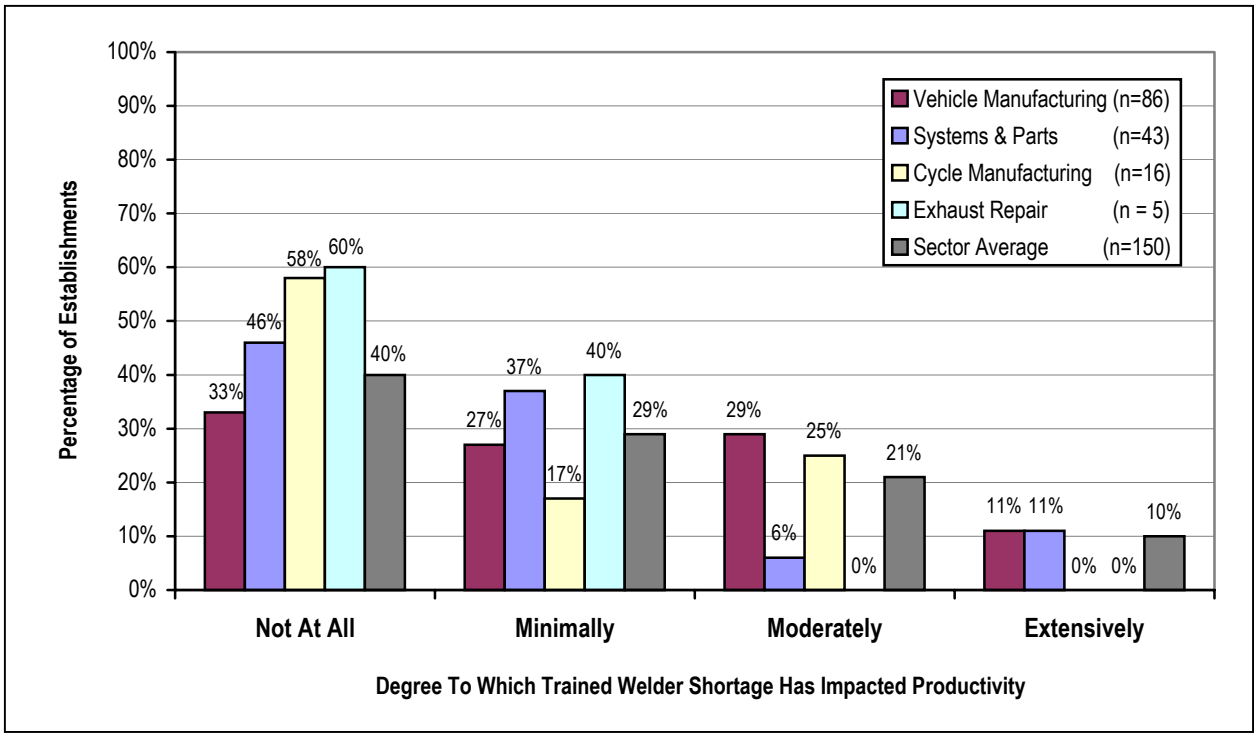


FIGURE AU6: EXTENT TO WHICH WELDING TRAINING NEEDS ARE BEING MET – AUTOMOTIVE INDUSTRIES

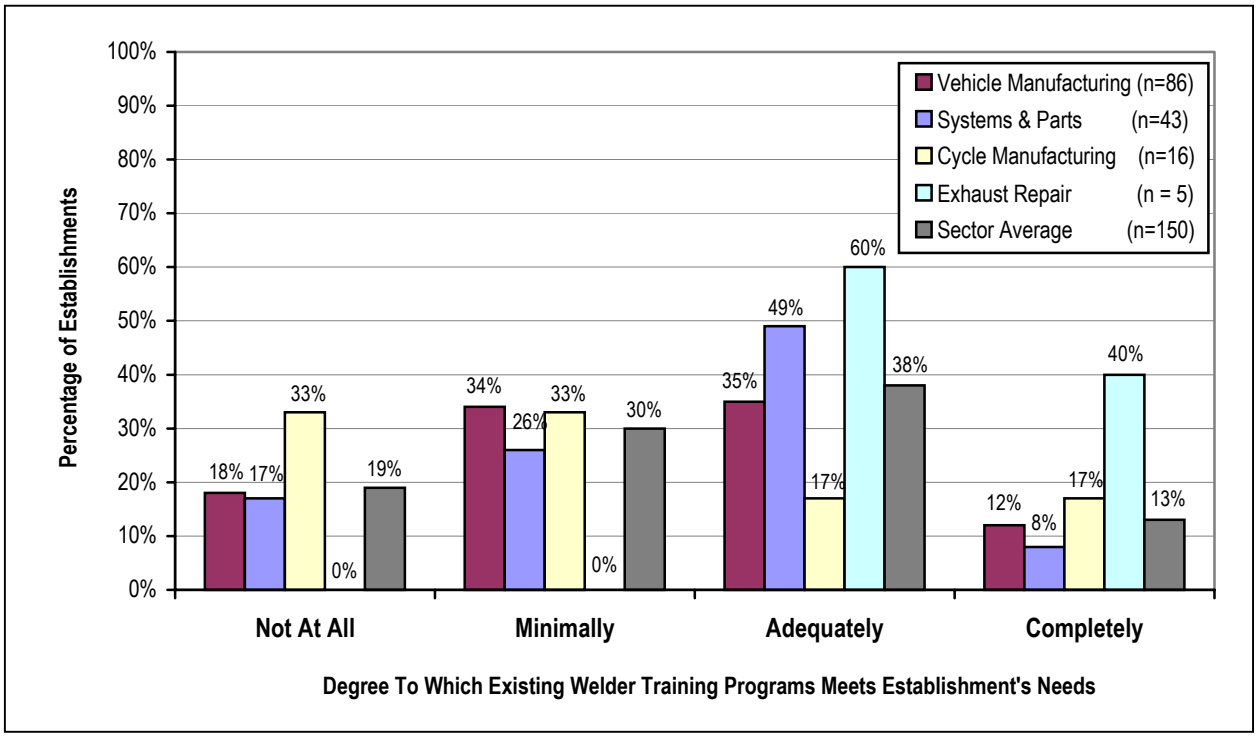
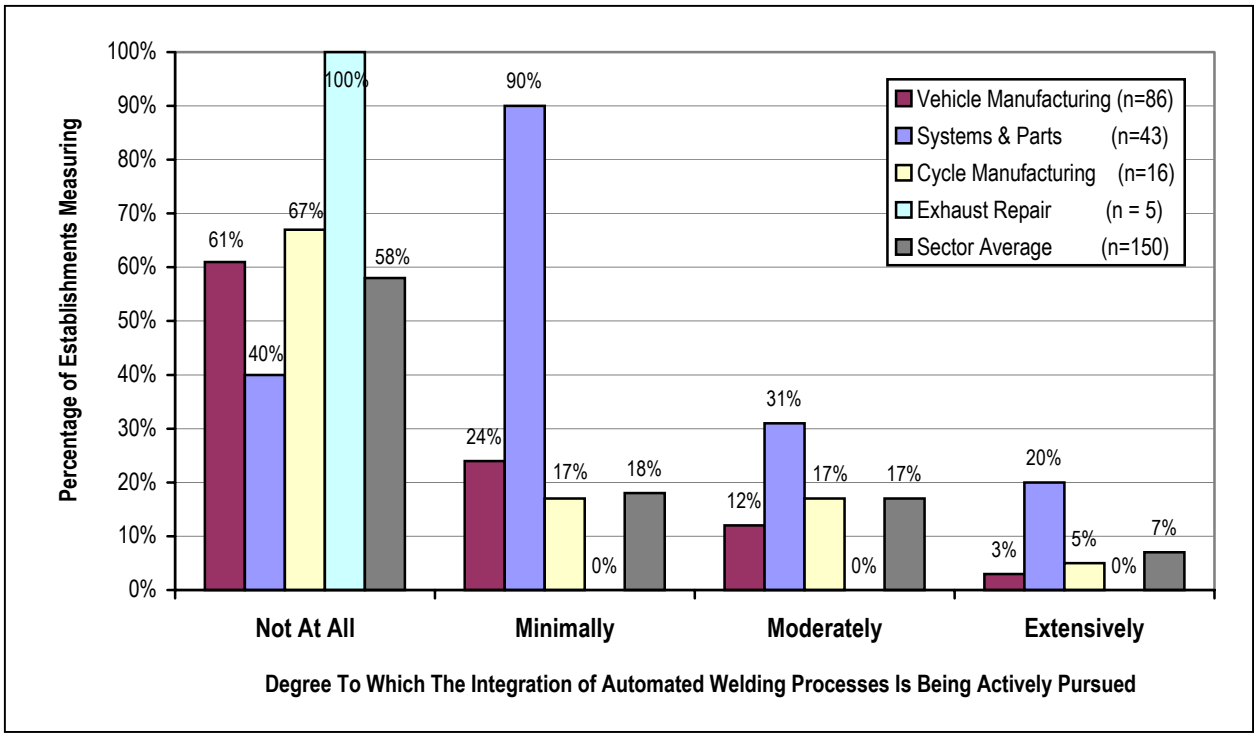


FIGURE AU7: ACTIVE PURSUIT OF WELDING PROCESS AUTOMATION – AUTOMOTIVE INDUSTRIES



Two industry groups were included in the Aircraft/Aerospace sector of this study. Those groups were defined as follows:

- **Aircraft Manufacturing** includes firms manufacturing all types of aircraft as well as aircraft engines, parts, and auxiliary equipment, and aircraft engine repair.
- **Aerospace** includes firms manufacturing guided missiles, space vehicles, as well as propulsion units, parts, and auxiliary equipment for missiles and space vehicles.

Welding expenditure allocations presented for the Aircraft/Aerospace sector are comparable to those expenditure allocations described in the presentation of the overall results (pgs. 17-23). These expenditures include:

- **Labor Costs**: Salaries and benefits for employees either directly involved in or supporting welding-related processes.
- **Materials & Consumables Costs**: Expenditures for welding-related materials and consumables.
- **Energy Costs**: Energy costs for the operation of welding-specific equipment, tooling, and environmental control systems.
- **Other Welding-Related Production Costs**: Expenditures to other companies for welding–related research and development, specification preparation, certification, training, and consulting.
- **Capital Expenditures**: Capital expenditures for equipment and systems used in welding-related processes, including manual, semiautomatic, and robotic welding units, welding-related tooling, and welding-related inspection and environmental control systems.

The total number of establishments on which welding expenditure estimates are based is as follows for this sector:

- Aircraft: 293 establishments
- Aerospace: 43 establishments

The margin of error for the Aircraft/Aerospace sector overall results is ± 2.0%. Margins of error for the industry group results increase as the number of responding establishments serving as the basis for the estimate declines. This should be kept in mind when comparing the group results.

Data concerning welding productivity in the Automotive Sector are presented in the following areas:

- Number and type of welding productivity measures used.
- Measurement of cost per unit of welding output.
- Measurement of welding output time efficiency.
- The impact of welder shortage on productivity.
- The extent to which welding training needs are being met.
- The active pursuit of the integration of welding automation into manufacturing processes.

TABLE AA1: WELDING-RELATED PRODUCTION EXPENDITURES IN AIRCRAFT & AEROSPACE INDUSTRIES (figures in $1,000)

Industrial Group	Expenditures For:				2000 Total Welding-Related Production Expenditures
	Labor	Materials & consumables	Energy	Other Welding Related	
Aircraft Manufacturing	$ 173,372	$ 28,027	$ 6,905	$ 5,341	$ 213,736
Aerospace	$ 35,781	$ 11,194	$ 2,499	$ 1,491	$ 50,965
Sector Totals	**$ 209,153**	**$ 39,222**	**$ 9,404**	**$ 6,923**	**$ 264,702**

FIGURE AA1: PROPORTION OF WELDING-RELATED PRODUCTION EXPENDITURES IN AIRCRAFT & AEROSPACE INDUSTRIES

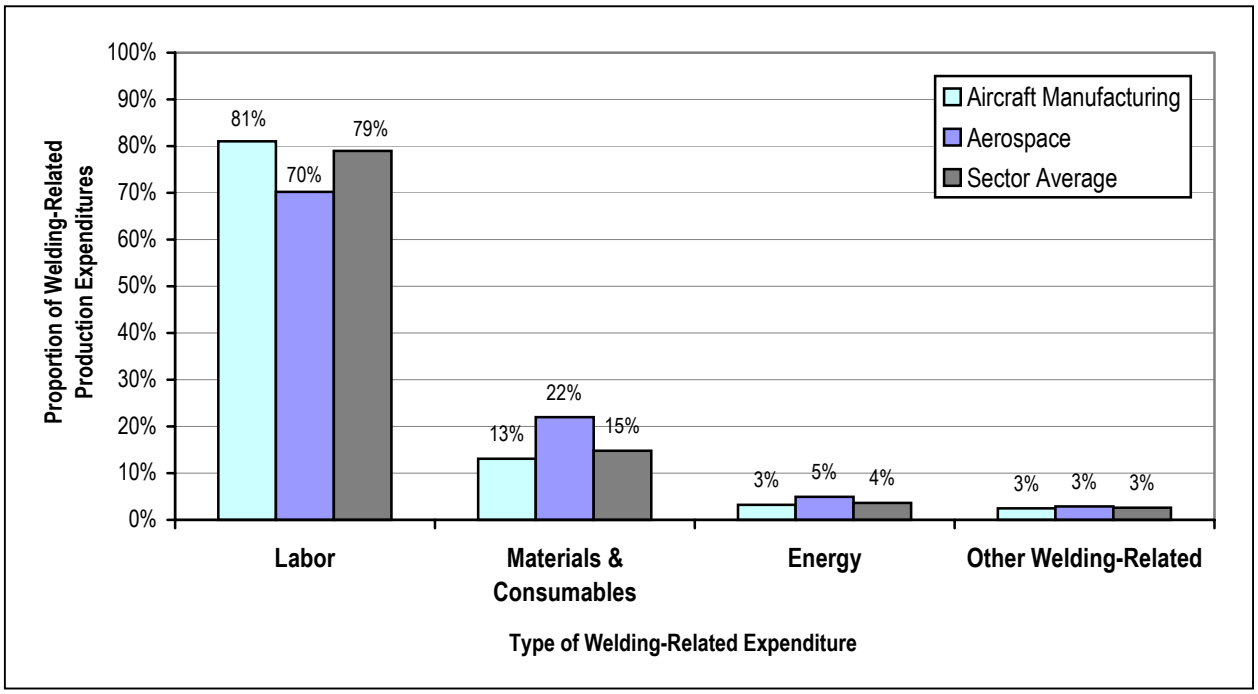


TABLE AA2: WELDING-RELATED CAPITAL EXPENDITURES IN AIRCRAFT & AEROSPACE INDUSTRIES (figures in $1,000)

Industrial Group	2000 Total Welding-Related Expenditures	2000 Welding-Related Capital Investment Expenditures	Proportion For Welding-Related Capital Investments
Aircraft Manufacturing	$ 232,522	$ 18,786	8.1%
Aerospace	$ 67,511	$ 16,546	24.5%
Sector Totals/Average	**$ 300,033**	**$ 35,331**	**11.8%**

TABLE AA3: WELDING PRODUCTIVITY MEASUREMENT – AIRCRAFT & AEROSPACE INDUSTRIES

Industrial Group		Number of Welding Productivity Measures Used					
		0	1	2	3	4	5-6
Aircraft Manufacturing	(n=94)	55%	32%	8%	3%	1%	1%
Aerospace	(n=15)	47%	47%	0%	0%	7%	0%
Sector Averages	(n=109)	**54%**	**34%**	**6%**	**3%**	**2%**	**1%**

TABLE AA4: TYPES OF WELDING PRODUCTIVITY MEASURES USED – AIRCRAFT & AEROSPACE INDUSTRIES

Industrial Sector		Percentage of Firms Measuring Productivity That Measure:								
		Defect Rate	Components per Period Time	Performance vs. Time Standard	Joints Completed per Period Time	Feet Welded per Period Time	Welding Cell % Time on Arc	Metal Deposited per Period Time	Tons Metal Joined per Period Time	Other
Aircraft Manufacturing	(n=42)	43%	50%	14%	12%	5%	5%	0%	0%	14%
Aerospace	(n = 8)	88%	25%	0%	0%	0%	0%	0%	0%	13%
Sector Averages	(n=50)	**50%**	**46%**	**12%**	**10%**	**4%**	**4%**	**0%**	**0%**	**14%**

FIGURE AA2: COST PER UNIT OF WELDING OUTPUT MEASUREMENT – AIRCRAFT & AEROSPACE INDUSTRIES

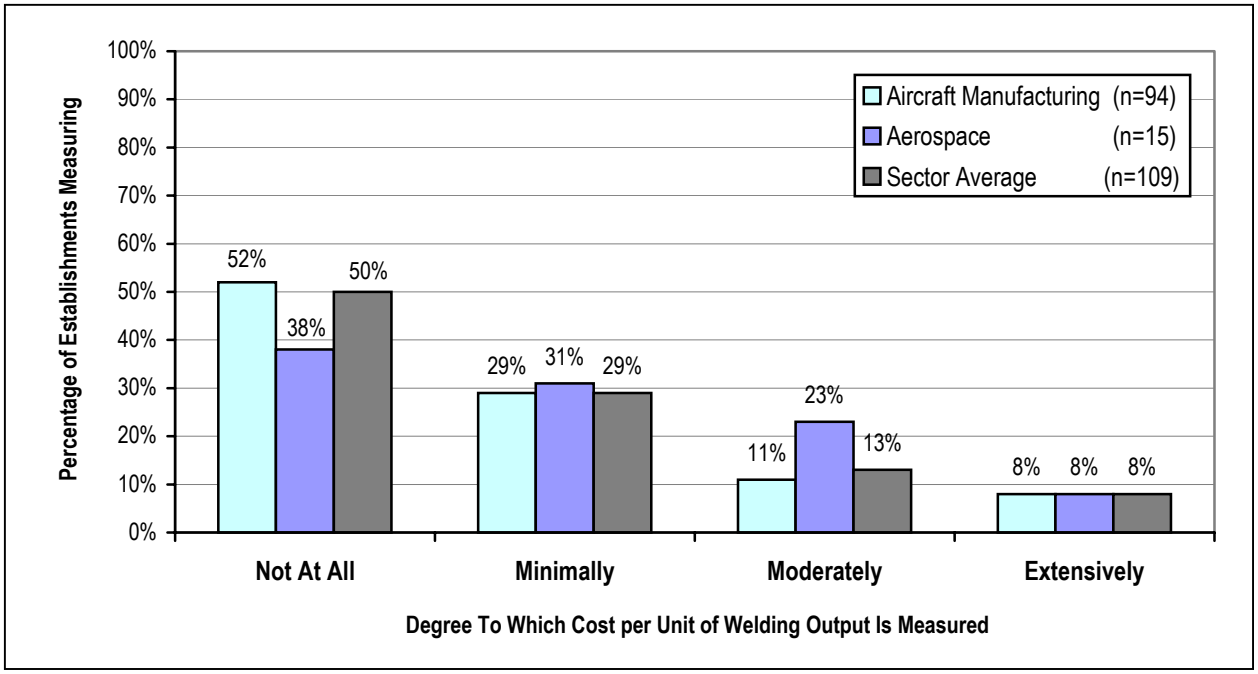


FIGURE AA3: FACTORS CONSIDERED IN MEASURING COST PER UNIT OF WELDING OUTPUT – AIRCRAFT & AEROSPACE INDUSTRIES

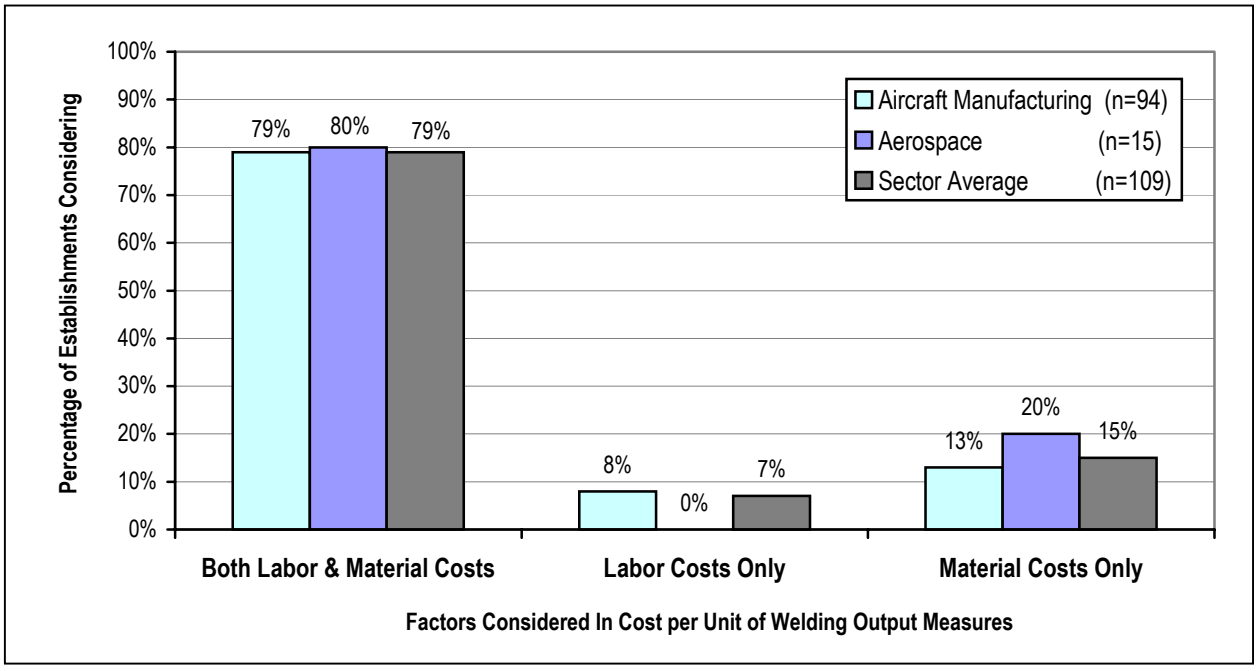


FIGURE AA4: MEASUREMENT OF WELDING OUTPUT TIME EFFICIENCY – AIRCRAFT & AEROSPACE INDUSTRIES

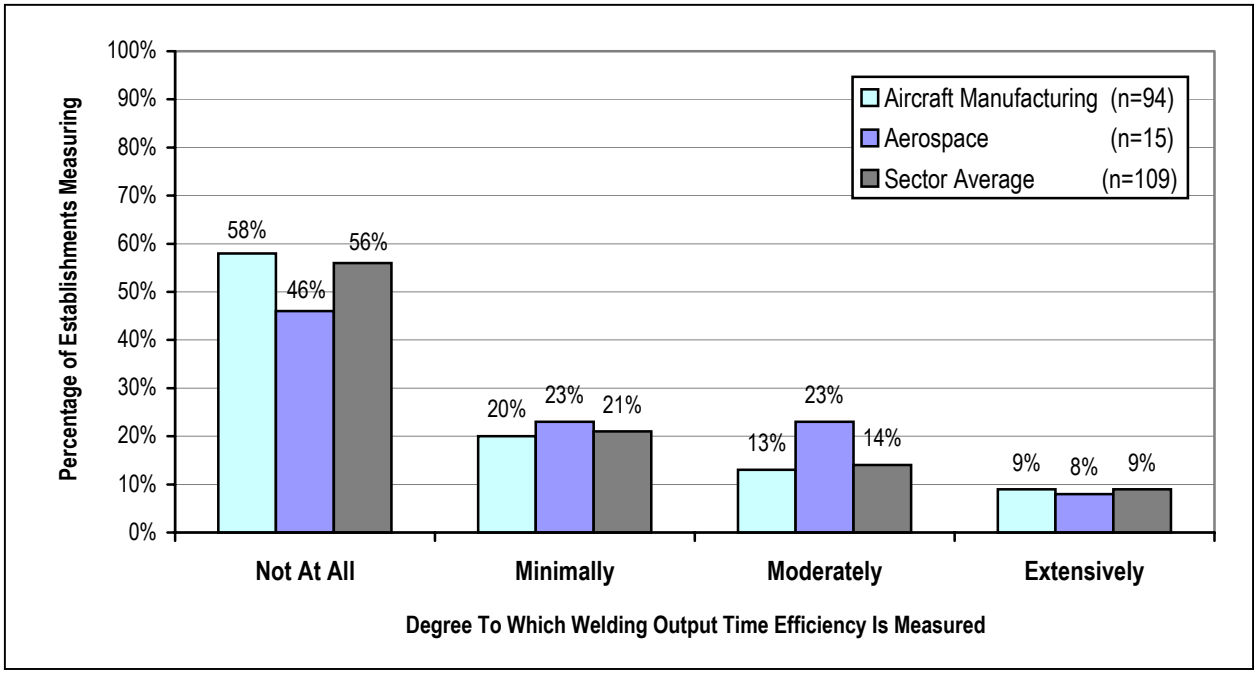


FIGURE AA5: IMPACT OF WELDER SHORTAGE ON PRODUCTIVITY – AIRCRAFT & AEROSPACE INDUSTRIES

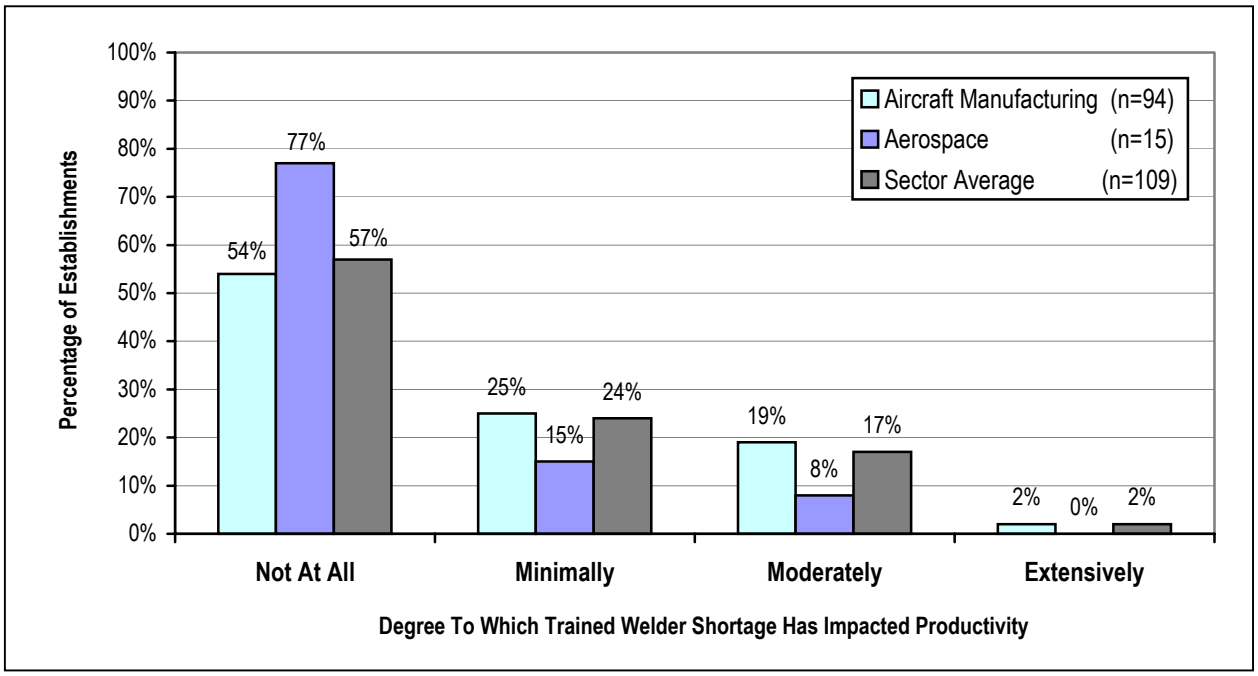


FIGURE AA6: EXTENT TO WHICH WELDING TRAINING NEEDS ARE BEING MET – AIRCRAFT & AEROSPACE INDUSTRIES

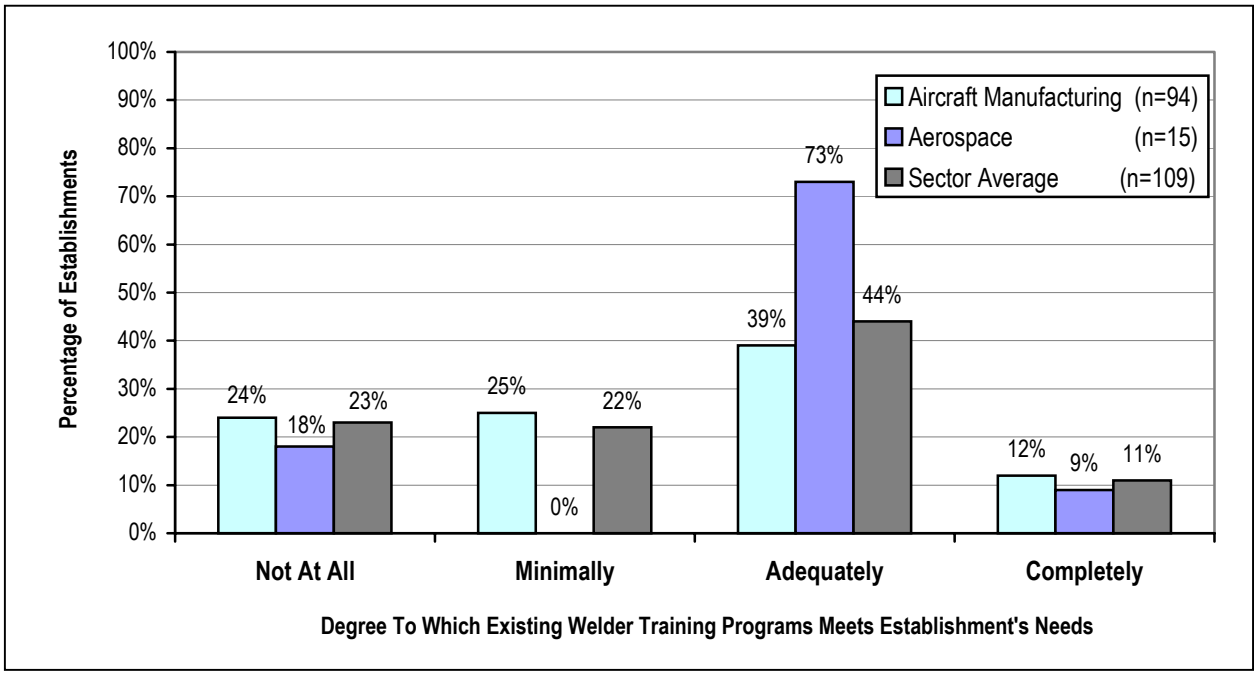
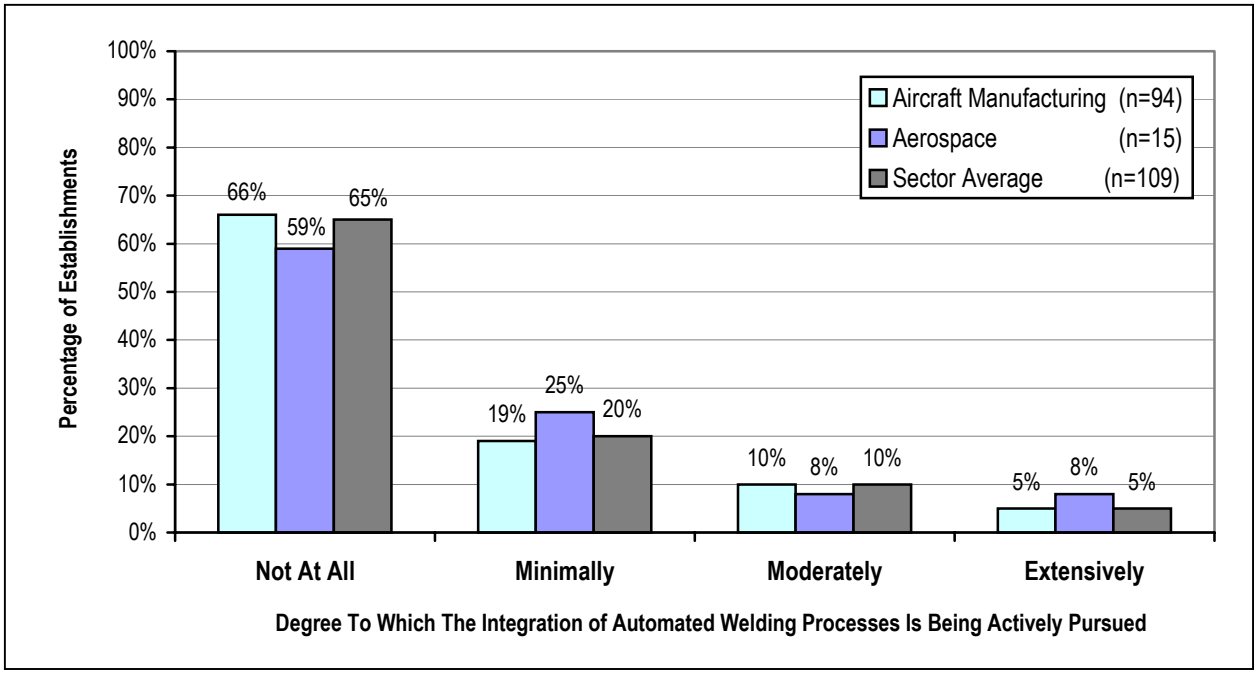


FIGURE AA7: ACTIVE PURSUIT OF WELDING PROCESS AUTOMATION – AIRCRAFT & AEROSPACE INDUSTRIES



Four groups of industries were included in the Electronics/Medical sector of this study. Those groups were defined as follows:

- **Electronic Components** includes those firms that produce printed circuit boards, semiconductors, capacitors, resistors, coils, transformers, and electrical connectors.

- **Electronic Instruments** includes firms involved in the manufacture of search and navigation equipment, laboratory equipment, environmental controls, process control instruments, fluid meters & counting devices, electrical measurement instruments, and analytical instruments.

- **Communications and Office Equipment** include firms that manufacture telephone equipment, radio and television communications equipment, computers, printers, photocopiers, accounting equipment, and other office equipment/machines.

- **Medical Devices** includes those firms that manufacture electromedical equipment, surgical instruments, surgical supplies, dental equipment and supplies, and x-ray apparatus.

Welding expenditure allocations presented for the Electronics/Medical sector are comparable to those expenditure allocations described in the presentation of the overall results (pgs. 17-23). These expenditures include:

- **Labor Costs**: Salaries and benefits for employees either directly involved in or supporting welding-related processes.
- **Materials & Consumables Costs**: Expenditures for welding-related materials and consumables.
- **Energy Costs**: Energy costs for the operation of welding-specific equipment, tooling, and environmental control systems.
- **Other Welding-Related Production Costs**: Expenditures to other companies for welding–related research and development, specification preparation, certification, training, and consulting.
- **Capital Expenditures**: Capital expenditures for equipment and systems used in welding-related processes, including manual, semiautomatic, and robotic welding units, welding-related tooling, and welding-related inspection and environmental control systems.

The total number of establishments on which welding expenditure estimates are based is as follows for this sector:

- Electronic Components: 46 establishments
- Electronic Instruments: 89 establishments
- Communications & Office Equipment: 43 establishments
- Medical Devices: 58 establishments

The margin of error for the Electronics/Medical sector overall results is ± 3.5%. Margins of error for the industry group results increase as the number of responding establishments serving as the basis for the estimate declines. This should be kept in mind when comparing the group results.

Data concerning welding productivity in the Electronics/Medical sector are presented in the following areas:

- Number and type of welding productivity measures used.
- Measurement of cost per unit of welding output.
- Measurement of welding output time efficiency.
- The impact of welder shortage on productivity.
- The extent to which welding training needs are being met.
- The active pursuit of the integration of welding automation into manufacturing processes.

TABLE EM1: WELDING-RELATED PRODUCTION EXPENDITURES IN ELECTRONICS & MEDICAL INDUSTRIES (figures in $1,000)

Industrial Group	Expenditures For:				2000 Total Welding-Related Production Expenditures
	Labor	Materials & consumables	Energy	Other Welding Related	
Electronic Components	$ 482,227	$ 165,003	$ 23,178	$ 51,584	$ 721,991
Electronic Instruments	$ 239,180	$ 54,600	$ 6,744	$ 3,053	$ 303,577
Office/Communications Equipment	$ 100,530	$ 15,389	$ 14,349	$ 2,438	$ 132,707
Medical Devices	$ 82,223	$ 19,756	$ 2,880	$ 6,674	$ 111,532
Sector Totals	**$ 904,159**	**$ 254,748**	**$ 47,151**	**$ 63,748**	**$ 1,269,807**

FIGURE EM1: PROPORTION OF WELDING-RELATED PRODUCTION EXPENDITURES – ELECTRONICS & MEDICAL INDUSTRIES

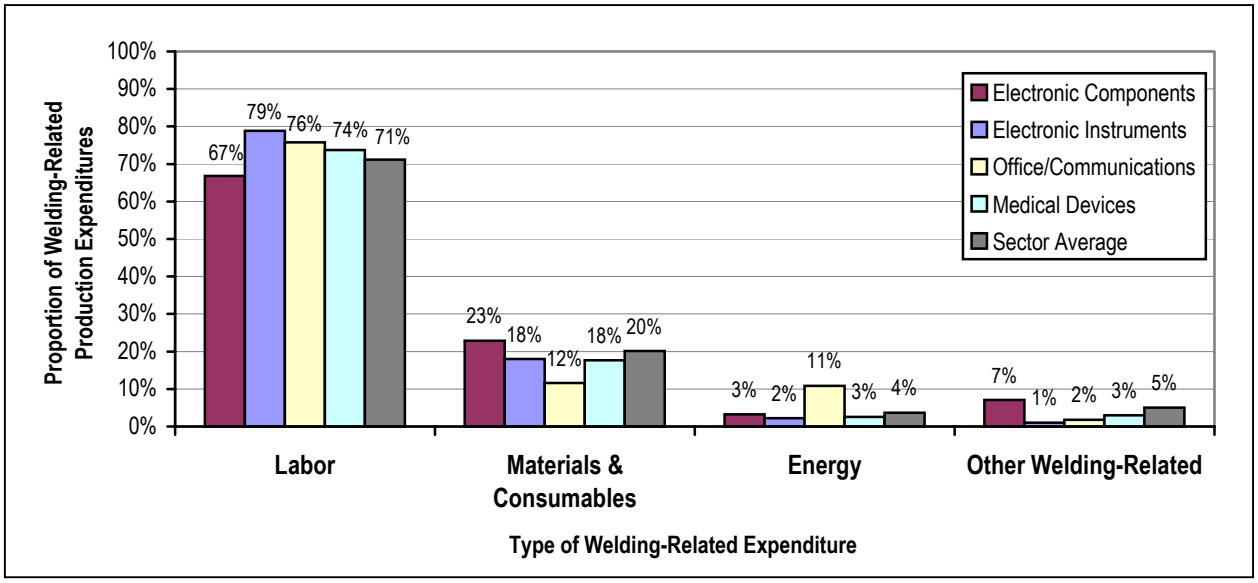


TABLE EM2: WELDING-RELATED CAPITAL EXPENDITURES IN ELECTRONICS & MEDICAL INDUSTRIES (figures in $1,000)

Industrial Group	2000 Total Welding-Related Expenditures	2000 Welding-Related Capital Investment Expenditures	Proportion For Welding-Related Capital Investments
Electronic Components	$ 849,544	$ 127,553	15.0%
Electronic Instruments	$ 331,675	$ 28,098	8.5%
Office/Communications Equipment	$ 153,550	$ 20,843	13.6%
Medical Devices	$ 129,909	$ 18,377	14.1%
Sector Totals/Average	**$ 1,464,678**	**$ 194,871**	**13.3%**

TABLE EM3: WELDING PRODUCTIVITY MEASUREMENT – ELECTRONICS & MEDICAL INDUSTRIES

Industrial Group		Number of Welding Productivity Measures Used					
		0	1	2	3	4	5-6
Electronic Components	(n=16)	13%	62%	19%	6%	0%	0%
Electronic Instruments	(n=30)	30%	63%	7%	0%	0%	0%
Office/Communications Equipment	(n=14)	43%	50%	7%	0%	0%	0%
Medical Devices	(n=20)	40%	30%	25%	5%	0%	0%
Sector Averages	(n=80)	**31%**	**53%**	**13%**	**3%**	**0%**	**0%**

TABLE EM4: TYPES OF WELDING PRODUCTIVITY MEASURES USED – ELECTRONICS & MEDICAL INDUSTRIES

Industrial Sector		Percentage of Firms Measuring Productivity That Measure:								
		Components per Period Time	Defect Rate	Joints Completed per Period Time	Performance vs. Time Standard	Feet Welded per Period Time	Welding Cell % Time on Arc	Metal Deposited per Period Time	Tons Metal Joined per Period Time	Other
Electronic Components	(n=14)	57%	21%	14%	7%	0%	0%	0%	0%	0%
Electronic Instruments	(n=21)	43%	43%	10%	0%	5%	0%	0%	0%	5%
Office/Communications Equip.	(n = 8)	50%	38%	0%	0%	0%	13%	0%	0%	13%
Medical Devices	(n=12)	58%	33%	8%	0%	0%	0%	0%	0%	17%
Sector Averages	(n=55)	**51%**	**35%**	**15%**	**4%**	**2%**	**2%**	**0%**	**0%**	**7%**

FIGURE EM2: COST PER UNIT OF WELDING OUTPUT MEASUREMENT – ELECTRONICS & MEDICAL INDUSTRIES

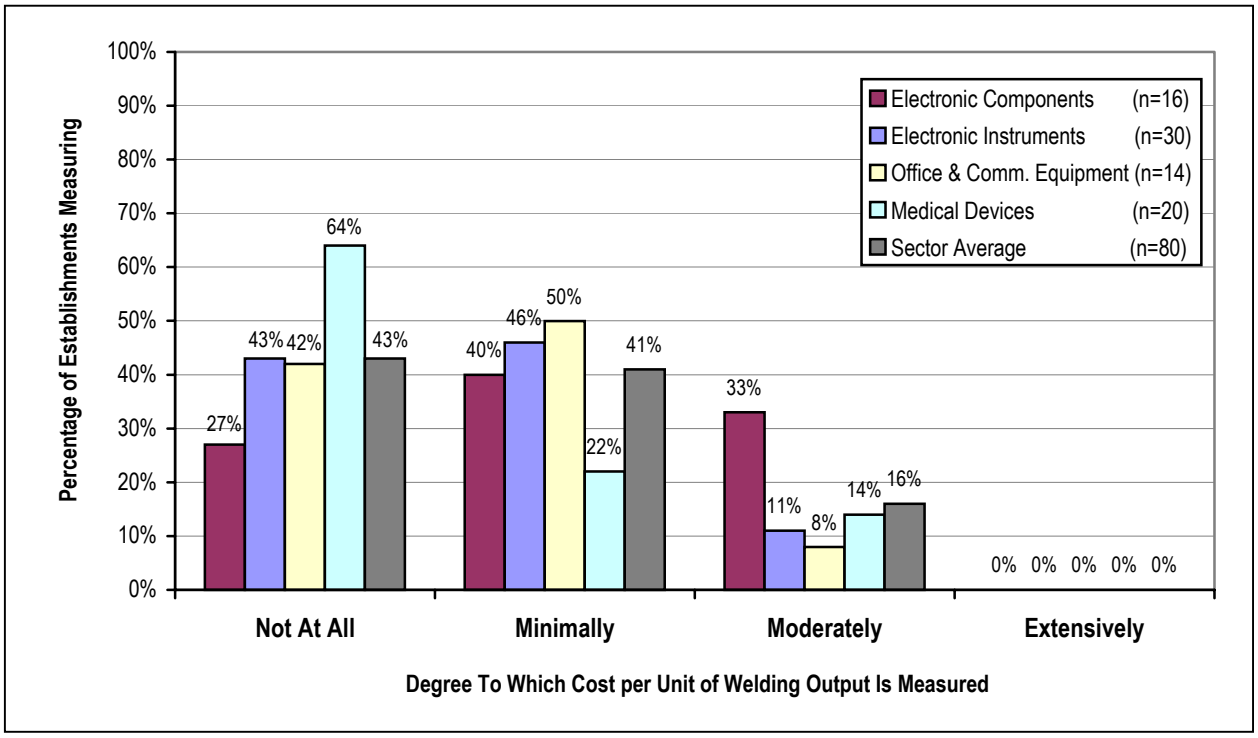


FIGURE EM3: FACTORS CONSIDERED IN MEASURING COST PER UNIT OF WELDING OUTPUT – ELECTRONICS & MEDICAL INDUSTRIES

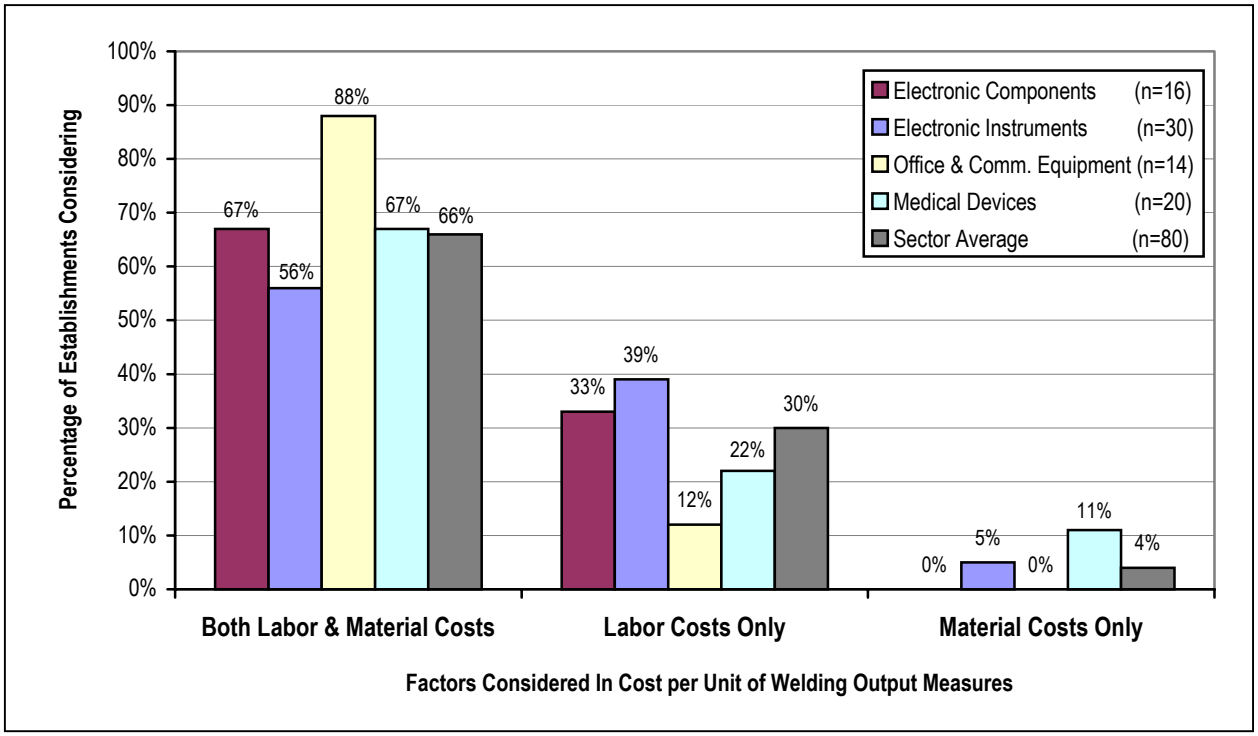


FIGURE EM4: MEASUREMENT OF WELDING OUTPUT TIME EFFICIENCY – ELECTRONICS & MEDICAL INDUSTRIES

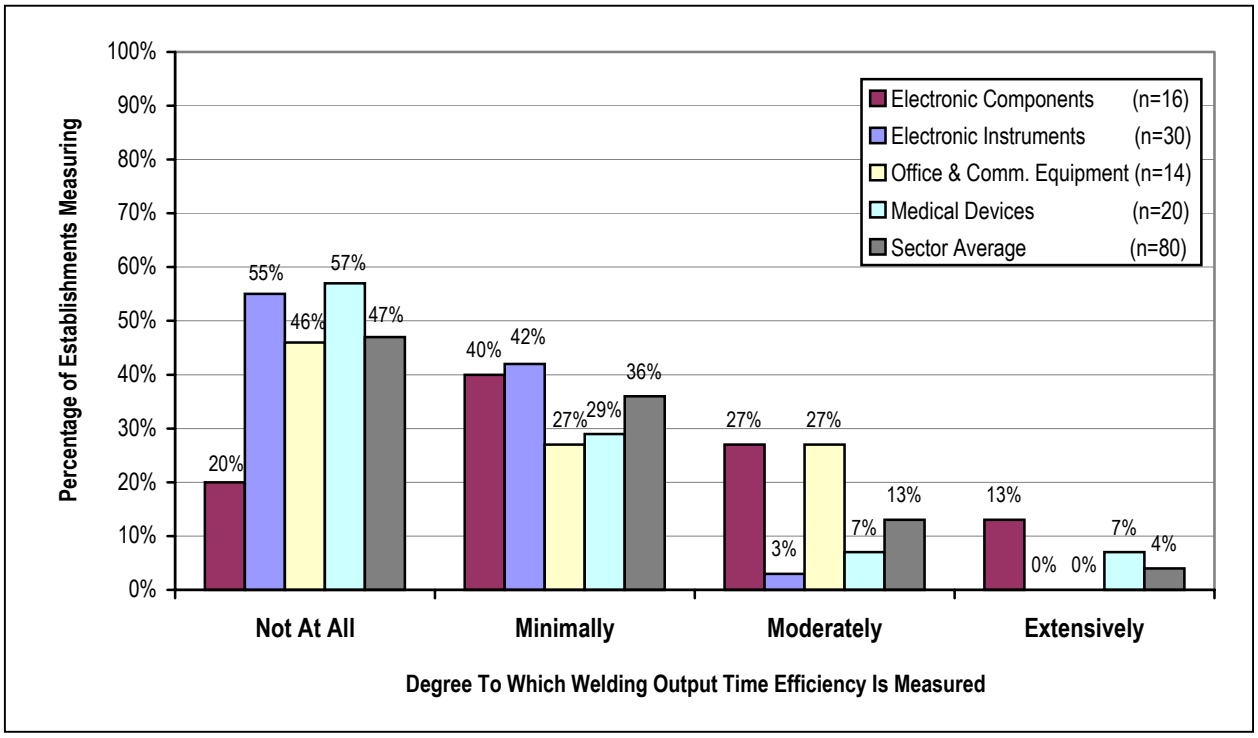


FIGURE EM5: IMPACT OF WELDER SHORTAGE ON PRODUCTIVITY – ELECTRONICS & MEDICAL INDUSTRIES

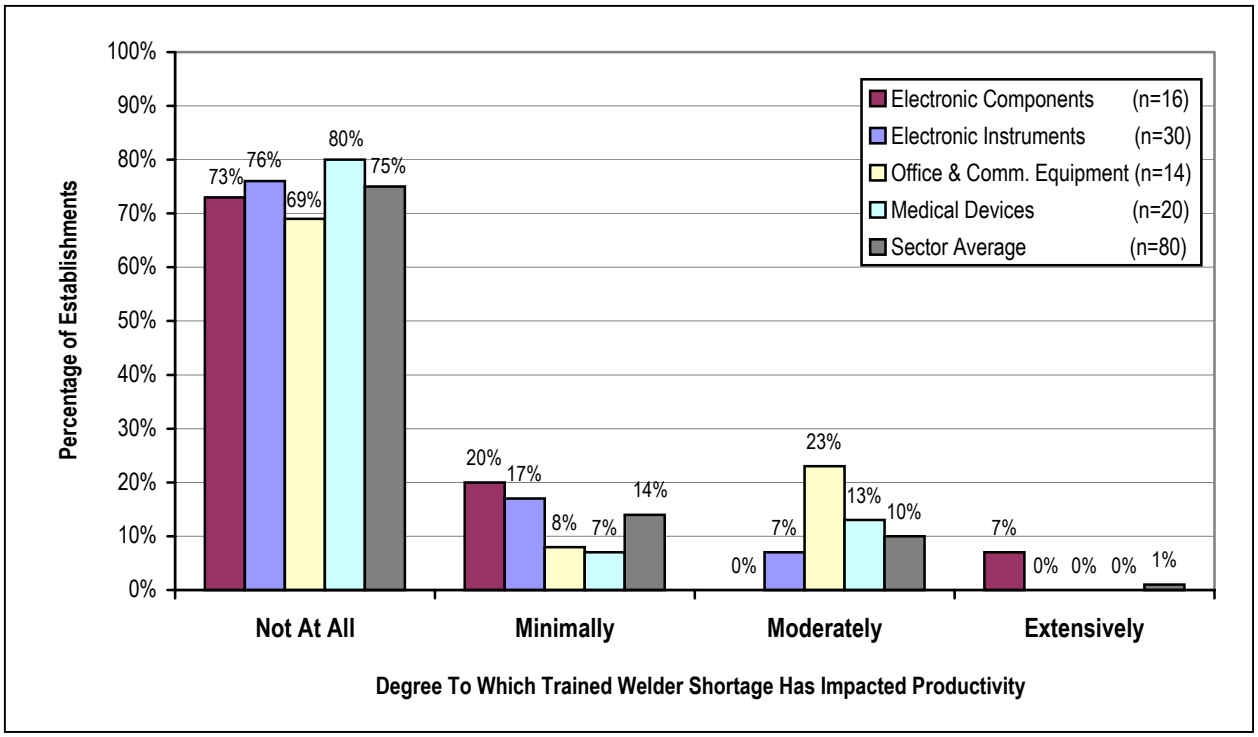


FIGURE EM6: EXTENT TO WHICH WELDING TRAINING NEEDS ARE BEING MET – ELECTRONICS & MEDICAL INDUSTRIES

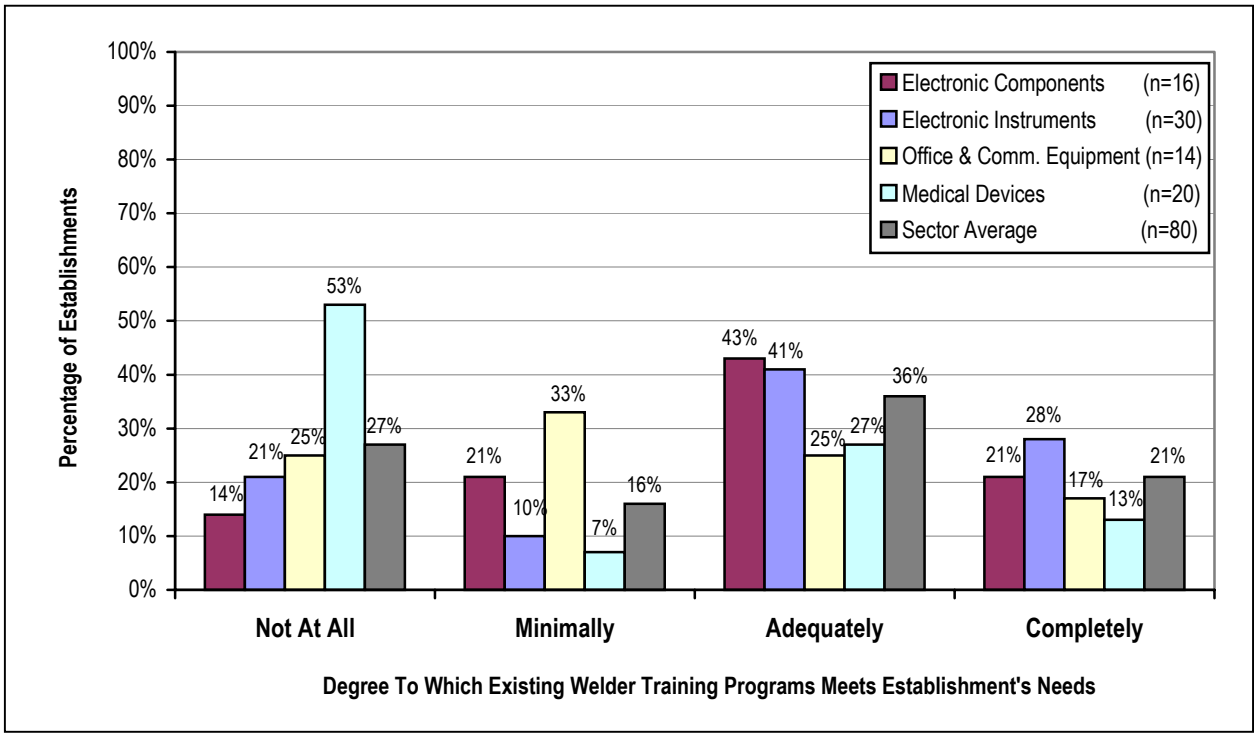
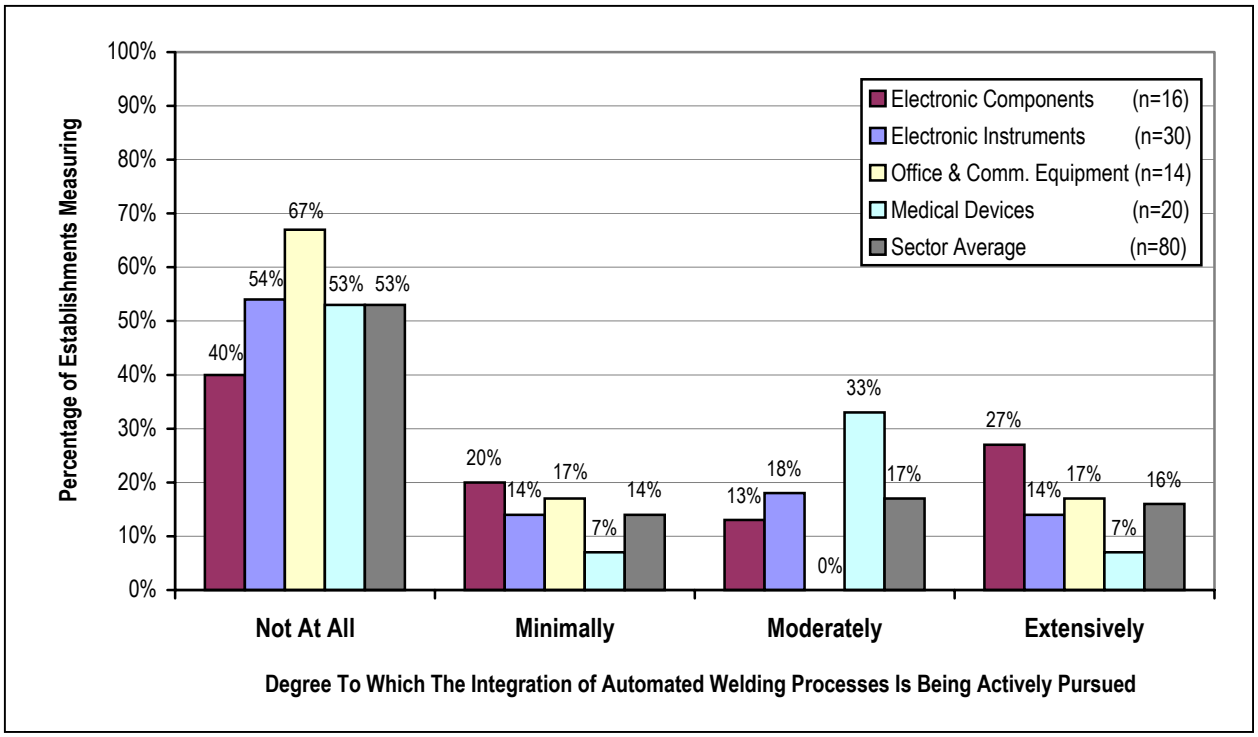


FIGURE EM7: ACTIVE PURSUIT OF WELDING PROCESS AUTOMATION – ELECTRONICS & MEDICAL INDUSTRIES



Eleven groups of industries were included in the Light Industrial Manufacturing sector of this study. Light Industrial Manufacturing industries were those characterized by the repetitive production of products containing lighter gauge metals joined by welding processes. The industry groups in this sector were defined as follows:

- **Industrial Tractor** includes those firms manufacturing industrial trucks, tractors, and trailers (e.g., for use at airports, inside manufacturing facilities, etc.) as well as lawn and garden tractors and equipment.
- **Industrial Equipment** includes firms involved in the manufacture of material handling equipment, elevators and escalators, conveyors, overhead cranes and hoists, industrial scales, and industrial patterns.
- **Industrial Tools** includes those firms manufacturing welding equipment, manual hand tools, and power-driven hand tools.
- **Heating and Ventilation** includes those firms manufacturing non-electric heating equipment, industrial blowers and fans, and industrial cooling/refrigeration equipment.
- **Fluid, Power, and Air Transmission Equipment** includes those firms manufacturing pumps and pumping equipment, air and gas compressors, and roller bearings.
- **Valves & Fittings** includes those firms manufacturing industrial valves, hydraulic valves and fittings, and plumbing fixtures/fittings.
- **Miscellaneous Fabricated Metal Products** includes those firms manufacturing hand edge tools, saw blades, hardware, small arms, ammunition, metal office furniture, miscellaneous fabricated wire products, and other miscellaneous fabricated metal products.
- **Light Gauge Building Components** include those firms manufacturing architectural metalwork, sheet metalwork, and prefabricated metal buildings.
- **Pipe & Tube** includes those firms manufacturing pipes and tubes from purchased steel as well as fabricated pipe and pipe fittings.
- **Service Industry Machinery** includes those firms manufacturing vending machines, commercial refrigeration and heating equipment, and commercial laundry equipment.
- **Household Appliances** includes those firms manufacturing household cooking equipment, freezers, refrigerators, washers, dryers, fans, vacuum cleaners, and other general household appliances.

Welding expenditure allocations presented for the Light Industrial Manufacturing sector are comparable to those expenditure allocations described in the presentation of the overall results (pgs. 17-23). These expenditures include:

- **Labor Costs**: Salaries and benefits for employees either directly involved in or supporting welding-related processes.
- **Materials & Consumables Costs**: Expenditures for welding-related materials and consumables.
- **Energy Costs**: Energy costs for the operation of welding-specific equipment, tooling, and environmental control systems.
- **Other Welding-Related Production Costs**: Expenditures to other companies for welding–related research and development, specification preparation, certification, training, and consulting.
- **Capital Expenditures**: Capital expenditures for equipment and systems used in welding-related processes, including manual, semiautomatic, and robotic welding units, welding-related tooling, and welding-related inspection and environmental control systems.

The total number of establishments on which welding expenditure estimates are based is as follows for this sector:

- Industrial Tractor:
  36 establishments
- Industrial Equipment:
  81 establishments
- Industrial Tools:
  23 establishments
- Heating and Ventilation:
  41 establishments
- Fluid, Power, and Air Transmission Equipment:
  52 establishments
- Valves & Fittings:
  34 establishments
- Miscellaneous Fabricated Metal Products:
  63 establishments
- Light Gauge Building Components:
  50 establishments
- Pipe & Tube:
  18 establishments
- Service Industry Machinery:
  45 establishments
- Household Appliances:
  36 establishments

The margin of error for the Light Industrial Manufacturing sector overall results is ± 2.9%. Margins of error for the industry group results increase as the number of responding establishments serving as the basis for the estimate declines. This should be kept in mind when comparing the group results.

Data concerning welding productivity in the Light Industrial Manufacturing sector are presented in the following areas:

- Number and type of welding productivity measures used.
- Measurement of cost per unit of welding output.
- Measurement of welding output time efficiency.
- The impact of welder shortage on productivity.
- The extent to which welding training needs are being met.
- The active pursuit of the integration of welding automation into manufacturing processes.

TABLE LIM1: WELDING-RELATED PRODUCTION EXPENDITURES – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

(all figures in $1,000)

Industrial Group	Expenditures For:				2000 Total Welding-Related Production Expenditures
	Labor	Materials & consumables	Energy	Other Welding Related	
Industrial Tractor	$ 82,505	$ 18,333	$ 12,795	$ 433	$ 114,066
Industrial Equipment	$ 92,493	$ 7,471	$ 2,793	$ 884	$ 103,640
Industrial Tools	$ 5,346	$ 2,317	$ 656	$ 14	$ 8,333
Heating & Ventilation Equipment	$ 277,414	$ 30,044	$ 10,457	$ 8,749	$ 326,664
Fluid/Air/Power Transmission Equip.	$ 48,357	$ 9,338	$ 4,783	$ 1,797	$ 64,276
Valves & Fittings	$ 130,870	$ 19,635	$ 7,840	$ 5,465	$ 163,809
Misc. Fabricated Metal Products	$ 736,772	$ 239,505	$ 49,522	$ 7,795	$ 1,033,593
Light Gauge Building Components	$ 774,438	$ 228,976	$ 32,269	$ 5,091	$ 1,040,774
Pipe & Tube Manufacturing	$ 372,008	$ 401,554	$ 21,047	$ 37,057	$ 831,666
Service Machinery	$ 785,401	$ 209,553	$ 27,448	$ 4,710	$ 1,027,111
Household Appliances	$ 49,434	$ 43,277	$ 5,780	$ 595	$ 99,087
Sector Totals	**$ 3,355,038**	**$ 1,210,001**	**$ 175,390**	**$ 72,589**	**$ 4,813,018**

TABLE LIM2: PROPORTION OF WELDING-RELATED PRODUCTION EXPENDITURES – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group	Proportion of Expenditures For:			
	Labor	Materials & consumables	Energy	Other Welding-Related
Industrial Tractor	72.3%	16.1%	11.2%	0.4%
Industrial Equipment	89.2%	7.2%	2.7%	0.9%
Industrial Tools	64.2%	27.8%	7.9%	0.2%
Heating & Ventilation Equipment	84.9%	9.2%	3.2%	2.7%
Fluid/Air/Power Transmission Equip.	75.2%	14.5%	7.4%	2.8%
Valves & Fittings	79.9%	12.0%	4.8%	3.3%
Misc. Fabricated Metal Products	71.3%	23.2%	4.8%	0.8%
Light Gauge Building Components	74.4%	22.0%	3.1%	0.5%
Pipe & Tube Manufacturing	44.7%	48.3%	2.5%	4.5%
Service Machinery	76.5%	20.4%	2.7%	0.5%
Household Appliances	49.9%	43.7%	5.8%	0.6%
Sector Averages	**69.7%**	**25.1%**	**3.6%**	**1.5%**

TABLE LIM3: WELDING-RELATED CAPITAL EXPENDITURES – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

(figures in $1,000)

Industrial Group	2000 Total Welding-Related Expenditures	2000 Welding-Related Capital Investment Expenditures	Proportion For Welding-Related Capital Investments
Industrial Tractor	$ 133,930	$ 19,684	14.8%
Industrial Equipment	$ 108,514	$ 4,874	4.5%
Industrial Tools	$ 8,455	$ 122	1.4%
Heating & Ventilation Equipment	$ 333,880	$ 7,216	2.2%
Fluid/Air/Power Transmission Equip.	$ 65,699	$ 1,423	2.2%
Valves & Fittings	$ 171,629	$ 7,820	4.6%
Misc. Fabricated Metal Products	$ 1,299,457	$ 265,864	20.5%
Light Gauge Building Components	$ 1,094,845	$ 54,071	4.9%
Pipe & Tube Manufacturing	$ 938,923	$ 107,257	11.4%
Service Machinery	$ 1,084,093	$ 56,982	5.3%
Household Appliances	$ 139,211	$ 40,125	28.8%
Sector Totals/Average	**$ 5,378,636**	**$ 565,618**	**10.5%**

TABLE LIM4: WELDING PRODUCTIVITY MEASUREMENT – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Number of Welding Productivity Measures Used					
		0	1	2	3	4	5-6
Industrial Tractor	(n=18)	17%	61%	5%	17%	0%	0%
Industrial Equipment	(n=40)	60%	30%	7%	0%	0%	3%
Industrial Tools	(n=11)	36%	55%	9%	0%	0%	0%
Heating & Ventilation Equipment	(n=19)	32%	58%	0%	5%	0%	5%
Fluid/Air/Power Transmission Equip.	(n=27)	41%	37%	11%	11%	0%	0%
Valves & Fittings	(n=16)	47%	37%	6%	13%	0%	0%
Misc. Fabricated Metal Products	(n=29)	38%	28%	28%	3%	3%	0%
Light Gauge Building Components	(n=24)	37%	46%	13%	0%	0%	4%
Pipe & Tube Manufacturing	(n = 9)	22%	22%	45%	0%	11%	0%
Service Machinery	(n=22)	23%	45%	14%	9%	5%	5%
Household Appliances	(n=17)	29%	23%	23%	6%	12%	6%
Sector Averages	(n=232)	**38%**	**39%**	**13%**	**6%**	**2%**	**2%**

TABLE LIM5: TYPES OF WELDING PRODUCTIVITY MEASURES USED – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percentage of Firms Measuring Productivity That Measure:								
		Components per Period Time	Defect Rate	Joints Completed per Period Time	Performance vs. Time Standard	Feet Welded per Period Time	Welding Cell % Time on Arc	Tons Metal Joined per Period Time	Metal Deposited per Period Time	Other
Industrial Tractor	(n=15)	60%	20%	0%	27%	0%	7%	0%	0%	27%
Industrial Equipment	(n=16)	63%	13%	6%	0%	6%	19%	0%	0%	19%
Industrial Tools	(n = 7)	29%	29%	29%	14%	0%	0%	0%	0%	14%
Heating & Ventilation Equipment	(n=13)	54%	23%	15%	39%	8%	0%	0%	0%	8%
Fluid/Air/Power Trans. Equip.	(n=16)	50%	50%	13%	13%	0%	6%	0%	0%	6%
Valves & Fittings	(n = 9)	44%	22%	56%	11%	0%	0%	0%	0%	11%
Misc. Fabricated Metal Products	(n=18)	56%	44%	22%	11%	11%	0%	0%	0%	6%
Lt. Gauge Building Components	(n=15)	53%	7%	13%	13%	7%	7%	20%	13%	13%
Pipe & Tube Manufacturing	(n = 7)	43%	14%	43%	14%	43%	29%	0%	0%	14%
Service Machinery	(n=17)	47%	41%	29%	18%	6%	18%	0%	0%	18%
Household Appliances	(n=12)	67%	67%	25%	17%	17%	8%	0%	0%	8%
Sector Averages	(n=145)	**53%**	**31%**	**20%**	**16%**	**8%**	**8%**	**2%**	**1%**	**12%**

TABLE LIM6: COST PER UNIT OF WELDING OUTPUT MEASUREMENT – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Measuring Cost per Unit of Welding Output:			
		Not At All	Minimally	Moderately	Extensively
Industrial Tractor	(n=18)	28%	28%	28%	16%
Industrial Equipment	(n=40)	58%	24%	46%	2%
Industrial Tools	(n=11)	70%	20%	0%	10%
Heating & Ventilation Equipment	(n=19)	16%	32%	47%	5%
Fluid/Air/Power Transmission Equip.	(n=27)	35%	26%	17%	22%
Valves & Fittings	(n=16)	15%	39%	31%	15%
Misc. Fabricated Metal Products	(n=29)	36%	20%	24%	20%
Light Gauge Building Components	(n=24)	59%	14%	18%	9%
Pipe & Tube Manufacturing	(n = 9)	25%	25%	25%	25%
Service Machinery	(n=22)	33%	24%	38%	5%
Household Appliances	(n=17)	37%	38%	25%	0%
Sector Averages	(n=232)	**40%**	**25%**	**24%**	**11%**

TABLE LIM7: FACTORS CONSIDERED IN MEASURING COST PER UNIT OF WELDING OUTPUT – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Measuring Cost per Unit of Welding Output That Consider:		
		Both Labor & Material Costs	Labor Costs Only	Material Costs Only
Industrial Tractor	(n=18)	71%	23%	6%
Industrial Equipment	(n=40)	82%	14%	4%
Industrial Tools	(n=11)	86%	0%	14%
Heating & Ventilation Equipment	(n=19)	100%	0%	0%
Fluid/Air/Power Transmission Equip.	(n=27)	77%	23%	0%
Valves & Fittings	(n=16)	69%	31%	0%
Misc. Fabricated Metal Products	(n=29)	72%	22%	6%
Light Gauge Building Components	(n=24)	81%	6%	13%
Pipe & Tube Manufacturing	(n = 9)	100%	0%	0%
Service Machinery	(n=22)	87%	13%	0%
Household Appliances	(n=17)	83%	17%	0%
Sector Averages	(n=232)	**81%**	**15%**	**4%**

TABLE LIM8: MEASUREMENT OF WELDING OUTPUT TIME EFFICIENCY – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Measuring Time Efficiency of Welding Output:			
		Not At All	Minimally	Moderately	Extensively
Industrial Tractor	(n=18)	45%	33%	11%	11%
Industrial Equipment	(n=40)	50%	29%	18%	3%
Industrial Tools	(n=11)	90%	0%	0%	10%
Heating & Ventilation Equipment	(n=19)	28%	17%	50%	5%
Fluid/Air/Power Transmission Equip.	(n=27)	39%	30%	9%	22%
Valves & Fittings	(n=16)	23%	31%	38%	8%
Misc. Fabricated Metal Products	(n=29)	36%	8%	32%	24%
Light Gauge Building Components	(n=24)	48%	14%	33%	5%
Pipe & Tube Manufacturing	(n = 9)	25%	0%	50%	25%
Service Machinery	(n=22)	38%	24%	33%	5%
Household Appliances	(n=17)	44%	25%	25%	6%
Sector Averages	(n=232)	**42%**	**21%**	**26%**	**11%**

TABLE LIM9: IMPACT OF WELDER SHORTAGE ON PRODUCTIVITY – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Indicating Trained Welder Shortage Has Impacted Productivity:			
		Not At All	Minimally	Moderately	Extensively
Industrial Tractor	(n=18)	47%	23%	18%	12%
Industrial Equipment	(n=40)	50%	40%	10%	0%
Industrial Tools	(n=11)	78%	11%	0%	11%
Heating & Ventilation Equipment	(n=19)	42%	42%	10%	6%
Fluid/Air/Power Transmission Equip.	(n=27)	62%	21%	13%	4%
Valves & Fittings	(n=16)	54%	23%	15%	8%
Misc. Fabricated Metal Products	(n=29)	48%	44%	4%	4%
Light Gauge Building Components	(n=24)	23%	50%	27%	0%
Pipe & Tube Manufacturing	(n = 9)	37%	38%	25%	0%
Service Machinery	(n=22)	48%	14%	33%	5%
Household Appliances	(n=17)	47%	40%	13%	0%
Sector Averages	(n=232)	**48%**	**33%**	**15%**	**4%**

TABLE LIM10: EXTENT TO WHICH WELDING TRAINING NEEDS ARE BEING MET – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Indicating Existing Welder Training Programs Meet Their Needs:			
		Not At All	Minimally	Adequately	Completely
Industrial Tractor	(n=18)	0%	41%	53%	6%
Industrial Equipment	(n=40)	19%	17%	56%	8%
Industrial Tools	(n=11)	33%	11%	33%	22%
Heating & Ventilation Equipment	(n=19)	0%	21%	68%	11%
Fluid/Air/Power Transmission Equip.	(n=27)	17%	25%	43%	12%
Valves & Fittings	(n=16)	8%	38%	46%	8%
Misc. Fabricated Metal Products	(n=29)	17%	25%	46%	12%
Light Gauge Building Components	(n=24)	32%	32%	32%	4%
Pipe & Tube Manufacturing	(n = 9)	37%	0%	50%	13%
Service Machinery	(n=22)	14%	38%	38%	10%
Household Appliances	(n=17)	20%	33%	40%	7%
Sector Averages	(n=232)	**17%**	**26%**	**47%**	**10%**

TABLE LIM11: ACTIVE PURSUIT OF WELDING PROCESS AUTOMATION – LIGHT INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Indicating They Are Actively Pursuing the Integration of Automated Welding Processes:			
		Not At All	Minimally	Moderately	Extensively
Industrial Tractor	(n=18)	22%	28%	33%	17%
Industrial Equipment	(n=40)	62%	19%	16%	3%
Industrial Tools	(n=11)	70%	30%	0%	0%
Heating & Ventilation Equipment	(n=19)	16%	32%	52%	0%
Fluid/Air/Power Transmission Equip.	(n=27)	39%	35%	17%	9%
Valves & Fittings	(n=16)	58%	8%	17%	17%
Misc. Fabricated Metal Products	(n=29)	40%	16%	20%	24%
Light Gauge Building Components	(n=24)	54%	14%	23%	9%
Pipe & Tube Manufacturing	(n = 9)	14%	43%	0%	43%
Service Machinery	(n=22)	43%	28%	19%	9%
Household Appliances	(n=17)	37%	19%	31%	13%
Sector Averages	(n=232)	**43%**	**23%**	**23%**	**11%**

Nine groups of industries were included in the Heavy Industrial Manufacturing sector of this study. Heavy Industrial Manufacturing industries were those characterized by the production of large, typically custom-built products containing heavy gauge metals joined by welding processes. Products produced in the Heavy Industrial Manufacturing sector require major investments for purchase. The industry groups in this sector were defined as follows:

- **Boiler, Heat Exchanger & Tank** includes those firms manufacturing power boilers, heat exchangers, and heavy-gauge tanks (e.g., fuel and water storage tanks).
- **Ag Machinery & Equipment** includes firms involved in the manufacture of farm tractors, combines, and all other types of farm machinery and equipment. *Does not* include lawn and garden tractor and implement manufacturing.
- **Construction & Mining Machinery** includes those firms manufacturing heavy machinery and equipment used in construction and mining operations (e.g., bulldozers, excavators, backhoes, loaders, off-road dump trucks, graders).
- **Oil & Gas Machinery** includes those firms manufacturing equipment used in oil and gas exploration and production. *Excludes* offshore oil drilling platforms and production platforms, which are accounted for in the Shipbuilding industry.
- **Industrial Machinery** includes those firms manufacturing sawmill/woodworking machinery, plastics/ rubber manufacturing machinery, paper production machinery, textile production machinery, and machine/heavy metalworking tools.
- **Engines, Turbines & Power Transmission Equipment** includes those firms manufacturing turbines and turbine generator units, industrial compressors, speed changers and industrial speed drives, and heavy mechanical power transmission equipment.
- **Ship Building & Boat Building** include those firms manufacturing military and commercial ships, barges, offshore petroleum drilling and production platforms, commercial boats, and recreational boats.
- **Railroad Rolling Stock** includes those firms manufacturing locomotive engines and all types of rail cars.
- **Armored Vehicle, Tanks, & Tank Components** includes those firms manufacturing armored vehicles (military and non-military) and military tanks.

Welding expenditure allocations presented for the Heavy Industrial Manufacturing sector are comparable to those expenditure allocations described in the presentation of the overall results (pgs. 17-23). These expenditures include:

- **Labor Costs**: Salaries and benefits for employees either directly involved in or supporting welding-related processes.
- **Materials & Consumables Costs**: Expenditures for welding-related materials and consumables.
- **Energy Costs**: Energy costs for the operation of welding-specific equipment, tooling, and environmental control systems.
- **Other Welding-Related Production Costs**: Expenditures to other companies for welding–related research and development, specification preparation, certification, training, and consulting.
- **Capital Expenditures**: Capital expenditures for equipment and systems used in welding-related processes, including manual, semiautomatic, and robotic welding units, welding-related tooling, and welding-related inspection and environmental control systems.

The total number of establishments on which welding expenditure estimates are based is as follows for this sector:

- Boiler/Heat Exchanger/Tank: 42 establishments
- Ag Machinery & Equipment: 32 establishments
- Construction & Mining Machinery: 27 establishments
- Oil & Gas Field Machinery: 9 establishments
- Industrial Machinery: 27 establishments
- Engine/Turbine/Power Equipment: 9 establishments
- Shipbuilding & Boatbuilding: 21 establishments
- Railroad Rolling Stock: 4 establishments
- Armored Vehicles & Military Tanks: 3 establishments

The margin of error for the Heavy Industrial Manufacturing sector overall results is ± 2.5%. Margins of error for the industry group results increase as the number of responding establishments serving as the basis for the estimate declines. This should be kept in mind when comparing the group results.

Data concerning welding productivity in the Heavy Industrial Manufacturing sector are presented in the following areas:

- Number and type of welding productivity measures used.
- Measurement of cost per unit of welding output.
- Measurement of welding output time efficiency.
- The impact of welder shortage on productivity.
- The extent to which welding training needs are being met.
- The active pursuit of the integration of welding automation into manufacturing processes.

TABLE HIM1: WELDING-RELATED PRODUCTION EXPENDITURES – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

(all figures in $1,000)

Industrial Group	Expenditures For:				2000 Total Welding-Related Production Expenditures
	Labor	Materials & consumables	Energy	Other Welding Related	
Boiler/Heat Exchanger/Tank Mfg.	$ 293,599	$ 248,183	$ 24,137	$ 11,400	$ 577,320
Ag. Machinery & Equipment	$ 329,551	$ 48,463	$ 17,055	$ 755	$ 395,825
Construction & Mining Machinery	$ 1,333,066	$ 615,785	$ 38,852	$ 17,844	$ 2,005,546
Oil & Gas Field Machinery	$ 144,111	$ 14,682	$ 2,320	$ 159	$ 161,273
Industrial Machinery	$ 1,549,783	$ 224,988	$ 107,237	$ 901	$ 1882,910
Engine/Turbine/Power Trans. Equip.	$ 490,646	$ 48,678	$ 10,422	$ 14,436	$ 564,182
Shipbuilding	$ 719,824	$ 376,257	$ 13,811	$ 3,078	$ 1,112,969
Railroad Rolling Stock	$ 482,039	$ 63,785	$ 3,455	$ 1,055	$ 550,334
Armored Vehicles & Tanks	$ 15,443	$ 898	$ 56	$ 741	$ 17,138
Sector Totals	**$ 5,358,063**	**$ 1,641,720**	**$ 217,346**	**$ 50,369**	**$ 7,267,497**

TABLE HIM2: PROPORTION OF WELDING-RELATED PRODUCTION EXPENDITURES – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group	Proportion of Expenditures For:			
	Labor	Materials & consumables	Energy	Other Welding-Related
Boiler/Heat Exchanger/Tank Mfg.	50.9%	43.0%	4.2%	2.0%
Ag. Machinery & Equipment	83.3%	12.2%	4.3%	0.2%
Construction & Mining Machinery	74.1%	34.2%	2.2%	1.0%
Oil & Gas Field Machinery	89.4%	9.1%	1.4%	0.1%
Industrial Machinery	82.3%	11.9%	5.7%	0.0%
Engine/Turbine/Power Trans. Equip.	87.0%	8.6%	1.8%	2.6%
Shipbuilding	71.9%	37.6%	1.4%	0.3%
Railroad Rolling Stock	87.6%	11.6%	0.6%	0.2%
Armored Vehicles & Tanks	90.1%	5.2%	0.3%	4.3%
Sector Averages	**73.7%**	**22.6%**	**3.0%**	**0.7%**

TABLE HIM3: WELDING-RELATED CAPITAL EXPENDITURES – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

(figures in $1,000)

Industrial Group	2000 Total Welding-Related Expenditures	2000 Welding-Related Capital Investment Expenditures	Proportion For Welding-Related Capital Investments
Boiler/Heat Exchanger/Tank Mfg.	$ 603,426	$ 26,106	4.3%
Ag. Machinery & Equipment	$ 418,371	$ 22,547	5.4%
Construction & Mining Machinery	$ 2,073,153	$ 67,607	3.6%
Oil & Gas Field Machinery	$ 175,247	$ 13,974	8.0%
Industrial Machinery	$ 1,907,942	$ 25,032	1.3%
Engine/Turbine/Power Trans. Equip.	$ 597,093	$ 32,911	5.5%
Shipbuilding	$ 1,129,457	$ 16,488	1.6%
Railroad Rolling Stock	$ 586,596	$ 36,262	6.2%
Armored Vehicles & Tanks	$ 17,754	$ 616	3.5%
Sector Totals/Average	**$ 7,509,039**	**$ 241,542**	**3.2%**

TABLE HIM4: WELDING PRODUCTIVITY MEASUREMENT – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Number of Welding Productivity Measures Used					
		0	1	2	3	4	5-6
Boiler/Heat Exchanger/Tank Mfg.	(n=42)	17%	51%	29%	0%	3%	0%
Ag. Machinery & Equipment	(n=32)	24%	60%	12%	4%	0%	0%
Construction & Mining Machinery	(n=27)	35%	42%	15%	4%	4%	0%
Oil & Gas Field Machinery	(n = 9)	11%	78%	0%	0%	11%	0%
Industrial Machinery	(n=27)	57%	32%	4%	4%	0%	3%
Engine/Turbine/Power Trans. Equip.	(n = 9)	45%	33%	11%	0%	11%	0%
Shipbuilding	(n=21)	21%	32%	26%	5%	5%	11%
Railroad Rolling Stock	(n = 4)	25%	50%	0%	25%	0%	0%
Armored Vehicles & Tanks	(n = 3)	33%	33%	0%	33%	0%	0%
Sector Averages	(n=174)	**34%**	**45%**	**14%**	**3%**	**3%**	**1%**

TABLE HIM5: TYPES OF WELDING PRODUCTIVITY MEASURES USED – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percentage of Firms Measuring Productivity That Measure:					
		Defect Rate	Feet Welded per Period Time	Metal Deposited per Period Time	Tons Metal Joined per Period Time	Joints Completed per Period Time	Other (a)
Boiler/Heat Exchanger/Tank Mfg.	(n=35)	12%	12%	3%	0%	9%	85%
Ag. Machinery & Equipment	(n=24)	0%	16%	0%	5%	5%	90%
Construction & Mining Machinery	(n=18)	18%	12%	35%	6%	0%	71%
Oil & Gas Field Machinery	(n = 8)	0%	13%	25%	25%	13%	63%
Industrial Machinery	(n=12)	17%	33%	8%	17%	17%	67%
Engine/Turbine/Power Trans.	(n = 5)	0%	17%	17%	0%	17%	67%
Shipbuilding	(n=17)	40%	60%	27%	27%	13%	47%
Railroad Rolling Stock	(n = 3)	33%	0%	67%	0%	0%	67%
Armored Vehicles & Tanks	(n = 2)	0%	0%	33%	0%	0%	33%
Sector Averages	(n=115)	**13%**	**24%**	**12%**	**10%**	**9%**	**66%**

(a) The Heavy Industrial Manufacturing sector served as the pilot study and had the opportunity to categorize welding productivity measures in only six areas. The majority of those Heavy Industrial Manufacturing measures classified as 'Other' were measures of performance versus a specified time standard.

TABLE HIM6: COST PER UNIT OF WELDING OUTPUT MEASUREMENT – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Measuring Cost per Unit of Welding Output:			
		Not At All	Minimally	Moderately	Extensively
Boiler/Heat Exchanger/Tank Mfg.	(n=42)	27%	34%	27%	12%
Ag. Machinery & Equipment	(n=32)	48%	12%	20%	20%
Construction & Mining Machinery	(n=27)	21%	25%	46%	8%
Oil & Gas Field Machinery	(n = 9)	22%	67%	11%	0%
Industrial Machinery	(n=27)	59%	30%	7%	4%
Engine/Turbine/Power Trans. Equip.	(n = 9)	22%	45%	11%	22%
Shipbuilding	(n=21)	47%	11%	42%	0%
Railroad Rolling Stock	(n = 4)	25%	25%	25%	25%
Armored Vehicles & Tanks	(n = 3)	0%	33%	33%	33%
Sector Averages	(n=174)	**40%**	**30%**	**21%**	**9%**

TABLE HIM7: FACTORS CONSIDERED IN MEASURING COST PER UNIT OF WELDING OUTPUT – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Measuring Cost per Unit of Welding Output That Consider:		
		Both Labor & Material Costs	Labor Costs Only	Material Costs Only
Boiler/Heat Exchanger/Tank Mfg.	(n=42)	79%	18%	3%
Ag. Machinery & Equipment	(n=32)	80%	20%	0%
Construction & Mining Machinery	(n=27)	90%	10%	0%
Oil & Gas Field Machinery	(n = 9)	100%	0%	0%
Industrial Machinery	(n=27)	78%	17%	5%
Engine/Turbine/Power Trans. Equip.	(n = 9)	86%	14%	0%
Shipbuilding	(n=21)	100%	0%	0%
Railroad Rolling Stock	(n = 4)	100%	0%	0%
Armored Vehicles & Tanks	(n = 3)	33%	67%	0%
Sector Averages	(n=174)	**83%**	**15%**	**2%**

TABLE HIM8: MEASUREMENT OF WELDING OUTPUT TIME EFFICIENCY – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Measuring Time Efficiency of Welding Output:			
		Not At All	Minimally	Moderately	Extensively
Boiler/Heat Exchanger/Tank Mfg.	(n=42)	25%	30%	33%	12%
Ag. Machinery & Equipment	(n=32)	36%	20%	28%	16%
Construction & Mining Machinery	(n=27)	21%	21%	46%	12%
Oil & Gas Field Machinery	(n = 9)	0%	11%	89%	0%
Industrial Machinery	(n=27)	63%	18%	15%	4%
Engine/Turbine/Power Trans. Equip.	(n = 9)	45%	33%	11%	11%
Shipbuilding	(n=21)	37%	5%	47%	11%
Railroad Rolling Stock	(n = 4)	25%	0%	50%	25%
Armored Vehicles & Tanks	(n = 3)	0%	67%	33%	0%
Sector Averages	(n=174)	**38%**	**25%**	**29%**	**8%**

TABLE HIM9: IMPACT OF WELDER SHORTAGE ON PRODUCTIVITY – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Indicating Trained Welder Shortage Has Impacted Productivity:			
		Not At All	Minimally	Moderately	Extensively
Boiler/Heat Exchanger/Tank Mfg.	(n=42)	20%	24%	39%	17%
Ag. Machinery & Equipment	(n=32)	12%	44%	28%	16%
Construction & Mining Machinery	(n=27)	4%	44%	32%	20%
Oil & Gas Field Machinery	(n = 9)	33%	22%	45%	0%
Industrial Machinery	(n=27)	54%	15%	23%	8%
Engine/Turbine/Power Trans. Equip.	(n = 9)	50%	12%	25%	12%
Shipbuilding	(n=21)	11%	47%	37%	5%
Railroad Rolling Stock	(n = 4)	0%	25%	25%	50%
Armored Vehicles & Tanks	(n = 3)	0%	67%	0%	33%
Sector Averages	(n=174)	**22%**	**34%**	**30%**	**14%**

TABLE HIM10: EXTENT TO WHICH WELDING TRAINING NEEDS ARE BEING MET – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Indicating Existing Welder Training Programs Meet Their Needs:			
		Not At All	Minimally	Adequately	Completely
Boiler/Heat Exchanger/Tank Mfg.	(n=42)	12%	46%	42%	0%
Ag. Machinery & Equipment	(n=32)	12%	48%	40%	0%
Construction & Mining Machinery	(n=27)	8%	40%	48%	4%
Oil & Gas Field Machinery	(n = 9)	0%	33%	67%	0%
Industrial Machinery	(n=27)	28%	20%	52%	0%
Engine/Turbine/Power Trans. Equip.	(n = 9)	12%	38%	50%	0%
Shipbuilding	(n=21)	11%	44%	39%	6%
Railroad Rolling Stock	(n = 4)	0%	0%	100%	0%
Armored Vehicles & Tanks	(n = 3)	0%	67%	33%	0%
Sector Averages	(n=174)	**14%**	**40%**	**44%**	**2%**

TABLE HIM11: ACTIVE PURSUIT OF WELDING PROCESS AUTOMATION – HEAVY INDUSTRIAL MANUFACTURING INDUSTRIES

Industrial Group		Percent of Establishments Indicating They Are Actively Pursuing the Integration of Automated Welding Processes:			
		Not At All	Minimally	Moderately	Extensively
Boiler/Heat Exchanger/Tank Mfg.	(n=42)	12%	44%	27%	17%
Ag. Machinery & Equipment	(n=32)	32%	32%	8%	28%
Construction & Mining Machinery	(n=27)	20%	48%	20%	12%
Oil & Gas Field Machinery	(n = 9)	22%	11%	45%	22%
Industrial Machinery	(n=27)	81%	8%	11%	0%
Engine/Turbine/Power Trans. Equip.	(n = 9)	12%	12%	63%	12%
Shipbuilding	(n=21)	42%	37%	0%	21%
Railroad Rolling Stock	(n = 4)	0%	25%	25%	50%
Armored Vehicles & Tanks	(n = 3)	0%	33%	33%	33%
Sector Averages	(n=174)	**37%**	**31%**	**18%**	**14%**

Seven groups of industries were included in the Construction sector of this study. The industry groups in this sector were defined as follows:

- **Industrial Buildings** includes those firms involved in the new construction, as well as reconstruction and repair, of industrial buildings, warehouses, and production facilities used primarily by manufacturers.
- **Commercial Buildings** includes those firms that construct non-residential commercial and institutional buildings such as offices, hotels, hospitals, schools, churches, etc.
- **Bridge & Tunnel** includes those firms specializing in the construction of bridges; viaducts, elevated highways; and highway, pedestrian, and railway tunnels.
- **Pipeline** includes those firms involved in the construction of pipelines, communication and power lines, and sewer and water mains.
- **Structural Steel Erection** includes establishments that are primarily engaged in the erection of structural steel, the placement of structural iron work, the installation of curtain walls, and the erection of metal storage tanks.
- **Fabricated Structural Metal Products** includes establishments primarily engaged in fabricating iron and steel or other metal for structural purposes such as bridges and buildings.
- **Miscellaneous Construction** includes those firms involved in heavy construction projects not classified in previously indicated industries. Projects include chemical complexes, dams and reservoirs, harbor and port facilities, missile facilities, oil refineries, subways, water and sewer treatment plants, power plants, industrial ovens and incinerators, athletic fields, golf courses, and irrigation projects. This industry also includes welding repair firms.

Welding expenditure allocations presented for the Construction sector are comparable to those expenditure allocations described in the presentation of the overall results (pgs. 17-23).. These expenditures include:

- **Labor Costs**: Salaries and benefits for employees either directly involved in or supporting welding-related processes.
- **Materials & Consumables Costs**: Expenditures for welding-related materials and consumables.
- **Energy Costs**: Energy costs for the operation of welding-specific equipment, tooling, and environmental control systems.
- **Other Welding-Related Production Costs**: Expenditures to other companies for welding–related research and development, specification preparation, certification, training, consulting, and field services.
- **Capital Expenditures**: Capital expenditures for equipment and systems used in welding-related processes, including manual, semiautomatic, and robotic welding units, welding-related tooling, and welding-related inspection and environmental control systems.

The total number of establishments on which welding expenditure estimates are based is as follows for this sector:

- Industrial Buildings:
  78 establishments
- Commercial Buildings:
  105 establishments
- Bridge & Tunnel Construction:
  26 establishments
- Pipeline Construction:
  48 establishments
- Structural Steel Erection:
  83 establishments
- Fabricated Structural Metal Products:
  49 establishments
- Miscellaneous Construction:
  100 establishments

The margin of error for the Construction sector overall results is ± 3.0%. Margins of error for the industry group results increase as the number of responding establishments serving as the basis for the estimate declines. This should be kept in mind when comparing the group results.

Data concerning welding productivity in the Construction sector are presented in the following areas:

- Number and type of welding productivity measures used.
- Measurement of cost per unit of welding output.
- Measurement of welding output time efficiency.
- The impact of welder shortage on productivity.
- The extent to which welding training needs are being met.
- The active pursuit of the integration of welding automation into fabrication processes.

TABLE CON1: WELDING-RELATED PRODUCTION EXPENDITURES – CONSTRUCTION INDUSTRIES (all figures in $1,000)

Industrial Group	Expenditures For:				2000 Total Welding-Related Production Expenditures
	Labor	Materials & consumables	Energy	Other Welding Related	
Industrial Buildings	$ 2,525,971	$ 201,091	$ 292,535	$ 7,485	$ 3,027,083
Commercial Buildings	$ 831,152	$ 39,941	$ 8,397	$ 39,487	$ 918,977
Bridge & Tunnel Construction	$ 16,512	$ 11,791	$ 3,586	$ 127	$ 32,015
Pipeline Construction	$ 190,597	$ 75,311	$ 27,491	$ 87,932	$ 381,331
Structural Steel Erection	$ 209,779	$ 66,333	$ 7,894	$ 2,792	$ 286,798
Fabricated Structural Metal Products	$ 2,190,643	$ 360,215	$ 65,469	$ 3,888	$ 2,620,216
Miscellaneous Construction	$ 2,393,562	$ 508,904	$ 28,968	$ 417,107	$ 3,348,541
Sector Totals	**$ 8,358,216**	**$ 1,263,586**	**$ 434,341**	**$ 558,818**	**$ 10,614,960**

TABLE CON2: PROPORTION OF WELDING-RELATED PRODUCTION EXPENDITURES – CONSTRUCTION INDUSTRIES

Industrial Group	Proportion of Expenditures For:			
	Labor	Materials & consumables	Energy	Other Welding-Related
Industrial Buildings	83.4%	6.6%	9.7%	0.2%
Commercial Buildings	90.4%	4.3%	0.9%	4.3%
Bridge & Tunnel Construction	51.6%	36.8%	11.2%	0.4%
Pipeline Construction	50.0%	19.7%	7.2%	23.1%
Structural Steel Erection	73.1%	23.1%	2.8%	1.0%
Fabricated Structural Metal Products	83.6%	13.7%	2.5%	0.1%
Miscellaneous Construction	71.5%	15.2%	0.9%	12.5%
Sector Averages	**78.7%**	**11.9%**	**4.1%**	**5.3%**

TABLE CON3: WELDING-RELATED CAPITAL EXPENDITURES – CONSTRUCTION INDUSTRIES (figures in $1,000)

Industrial Group	2000 Total Welding-Related Expenditures	2000 Welding-Related Capital Investment Expenditures	Proportion For Welding-Related Capital Investments
Industrial Buildings	$ 3,549,066	$ 521,983	14.7%
Commercial Buildings	$ 944,325	$ 25,348	2.7%
Bridge & Tunnel Construction	$ 42,362	$ 10,347	24.4%
Pipeline Construction	$ 387,733	$ 6,402	1.7%
Structural Steel Erection	$ 296,276	$ 9,478	3.2%
Fabricated Structural Metal Products	$ 2,671,519	$ 51,303	1.9%
Miscellaneous Construction	$ 3,370,920	$ 22,379	0.7%
Sector Totals/Average	**$ 11,262,200**	**$ 647,240**	**5.7%**

TABLE CON4: WELDING PRODUCTIVITY MEASUREMENT – CONSTRUCTION INDUSTRIES

Industrial Group		Number of Welding Productivity Measures Used					
		0	1	2	3	4	5-6
Industrial Buildings	(n=18)	56%	33%	6%	6%	0%	0%
Commercial Buildings	(n=29)	79%	14%	3%	0%	3%	0%
Bridge & Tunnel Construction	(n = 6)	83%	0%	17%	0%	0%	0%
Pipeline Construction	(n=13)	38%	54%	8%	0%	0%	0%
Structural Steel Erection	(n=19)	42%	37%	16%	5%	0%	0%
Fab. Structural Metal Products	(n=49)	45%	43%	8%	2%	2%	0%
Miscellaneous Construction	(n=26)	46%	35%	8%	8%	4%	0%
Sector Averages	(n=160)	**57%**	**30%**	**8%**	**4%**	**2%**	**0%**

TABLE CON5: TYPES OF WELDING PRODUCTIVITY MEASURES USED – CONSTRUCTION INDUSTRIES

Industrial Sector		Percentage of Firms Measuring Productivity That Measure: (b)								
		Feet Welded per Period Time	Joints Completed per Period Time	Defect Rate	Components per Period Time	Tons Metal Joined per Period Time	Metal Deposited per Period Time	Performance vs. Time Standard	Welding Cell % Time on Arc	Other
Industrial Buildings	(n = 8)	50%	0%	25%	0%	25%	13%	0%	0%	25%
Commercial Buildings	(n = 6)	50%	33%	33%	17%	0%	0%	0%	0%	17%
Bridge & Tunnel Construction	(n = 1)	100%	100%	0%	0%	0%	0%	0%	0%	0%
Pipeline Construction	(n = 8)	0%	50%	38%	13%	0%	0%	0%	0%	13%
Structural Steel Erection	(n=11)	55%	36%	0%	0%	18%	18%	9%	0%	0%
Fab. Structural Metal Products [a]	(n=27)	41%	11%	11%	--	19%	4%	--	--	48%
Miscellaneous Construction	(n=14)	29%	21%	36%	29%	7%	7%	7%	7%	14%
Sector Averages	(n=75)	**38%**	**29%**	**25%**	**12%**	**10%**	**8%**	**4%**	**2%**	**10%**

(a) The Fabricated Structural Metal Products industry was included in the pilot study and had the opportunity to categorize welding productivity measures in only six areas. The majority of those measures classified as 'Other' in this industry were measures of performance versus a specified time standard.

(b) All percentages indicated are based on the number of establishments that actually measure welding productivity. Establishments not measuring productivity are excluded from these percentages. Rows do not total 100% as some establishments use multiple productivity measures.

TABLE CON6: COST PER UNIT OF WELDING OUTPUT MEASUREMENT – CONSTRUCTION INDUSTRIES

Industrial Group		Percent of Establishments Measuring Cost per Unit of Welding Output:			
		Not At All	Minimally	Moderately	Extensively
Industrial Buildings	(n=18)	40%	27%	27%	6%
Commercial Buildings	(n=29)	70%	25%	0%	5%
Bridge & Tunnel Construction	(n = 6)	83%	0%	17%	0%
Pipeline Construction	(n=13)	58%	17%	17%	8%
Structural Steel Erection	(n=19)	58%	21%	21%	0%
Fabricated Structural Metal Products	(n=49)	52%	33%	13%	2%
Miscellaneous Construction	(n=26)	52%	24%	16%	8%
Sector Averages	(n=160)	**58%**	**22%**	**15%**	**5%**

TABLE CON7: FACTORS CONSIDERED IN MEASURING COST PER UNIT OF WELDING OUTPUT – CONSTRUCTION INDUSTRIES

Industrial Group		Percent of Establishments Measuring Cost per Unit of Welding Output That Consider:		
		Both Labor & Material Costs	Labor Costs Only	Material Costs Only
Industrial Buildings	(n=18)	91%	9%	0%
Commercial Buildings	(n=29)	89%	11%	0%
Bridge & Tunnel Construction	(n = 6)	50%	0%	50%
Pipeline Construction	(n=13)	86%	14%	0%
Structural Steel Erection	(n=19)	71%	29%	0%
Fabricated Structural Metal Products	(n=49)	79%	15%	6%
Miscellaneous Construction	(n=26)	75%	25%	0%
Sector Averages	(n=160)	**80%**	**18%**	**2%**

TABLE CON8: MEASUREMENT OF WELDING OUTPUT TIME EFFICIENCY – CONSTRUCTION INDUSTRIES

Industrial Group		Percent of Establishments Measuring Time Efficiency of Welding Output:			
		Not At All	Minimally	Moderately	Extensively
Industrial Buildings	(n=18)	33%	33%	27%	7%
Commercial Buildings	(n=29)	75%	20%	0%	5%
Bridge & Tunnel Construction	(n = 6)	83%	0%	17%	0%
Pipeline Construction	(n=13)	25%	25%	33%	17%
Structural Steel Erection	(n=19)	53%	16%	21%	10%
Fabricated Structural Metal Products	(n=49)	52%	38%	10%	0%
Miscellaneous Construction	(n=26)	44%	28%	20%	8%
Sector Averages	(n=160)	**50%**	**23%**	**19%**	**8%**

TABLE CON9: IMPACT OF WELDER SHORTAGE ON PRODUCTIVITY – CONSTRUCTION INDUSTRIES

Industrial Group		Percent of Establishments Indicating Trained Welder Shortage Has Impacted Productivity:			
		Not At All	Minimally	Moderately	Extensively
Industrial Buildings	(n=18)	33%	27%	27%	13%
Commercial Buildings	(n=29)	45%	40%	15%	0%
Bridge & Tunnel Construction	(n = 6)	83%	0%	17%	0%
Pipeline Construction	(n=13)	42%	33%	0%	25%
Structural Steel Erection	(n=19)	16%	63%	16%	5%
Fabricated Structural Metal Products	(n=49)	15%	38%	32%	15%
Miscellaneous Construction	(n=26)	42%	8%	33%	17%
Sector Averages	(n=160)	**39%**	**31%**	**20%**	**10%**

TABLE CON10: EXTENT TO WHICH WELDING TRAINING NEEDS ARE BEING MET – CONSTRUCTION INDUSTRIES

Industrial Group		Percent of Establishments Indicating Existing Welder Training Programs Meet Their Needs:			
		Not At All	Minimally	Adequately	Completely
Industrial Buildings	(n=18)	21%	29%	50%	0%
Commercial Buildings	(n=29)	58%	16%	21%	5%
Bridge & Tunnel Construction	(n = 6)	50%	0%	50%	0%
Pipeline Construction	(n=13)	33%	17%	25%	25%
Structural Steel Erection	(n=19)	11%	37%	47%	5%
Fabricated Structural Metal Products	(n=49)	13%	45%	38%	4%
Miscellaneous Construction	(n=26)	29%	42%	21%	8%
Sector Averages	(n=160)	**32%**	**28%**	**33%**	**7%**

TABLE CON11: ACTIVE PURSUIT OF WELDING PROCESS AUTOMATION – CONSTRUCTION INDUSTRIES

Industrial Group		Percent of Establishments Indicating They Are Actively Pursuing the Integration of Automated Welding Processes:			
		Not At All	Minimally	Moderately	Extensively
Industrial Buildings	(n=18)	33%	40%	27%	0%
Commercial Buildings	(n=29)	74%	11%	11%	5%
Bridge & Tunnel Construction	(n = 6)	100%	0%	0%	0%
Pipeline Construction	(n=13)	67%	8%	8%	17%
Structural Steel Erection	(n=19)	63%	11%	26%	0%
Fabricated Structural Metal Products	(n=49)	53%	28%	13%	6%
Miscellaneous Construction	(n=26)	42%	37%	13%	8%
Sector Averages	(n=160)	**58%**	**21%**	**16%**	**5%**

Two industry groups were included in the Capitalized Repair & Maintenance (CRM) Sector of this study. Those groups were defined as follows:

Petroleum/Chemical includes those firms involved in:

- Oil and Gas Production & Distribution.
- Chemical Manufacturing.
- Petroleum and Coal Products Manufacturing.

Other CRM firms includes those establishments involved in:

- Primary Metal Industries (manufacture of steel, aluminum, etc.).
- Metal Forging & Stamping.
- Mining Operations.
- Electrical Power Generation.
- Paper Production.

Welding expenditure allocations presented for the Capitalized Repair & Maintenance sector are comparable to those expenditure allocations described in the presentation of the overall results (pgs. 17-23). These expenditures include:

- **Labor Costs**: Salaries and benefits for employees either directly involved in or supporting welding-related processes.
- **Materials & Consumables Costs**: Expenditures for welding-related materials and consumables.
- **Energy Costs**: Energy costs for the operation of welding-specific equipment, tooling, and environmental control systems.
- **Other Welding-Related Production Costs**: Expenditures to other companies for welding–related research and development, specification preparation, certification, training, consulting, and field services. Field service expenditures represents a significant proportion of welding-related expenditures in this sector.
- **Capital Expenditures**: Capital expenditures for equipment and systems used in welding-related processes, including manual, semiautomatic, and robotic welding units, welding-related tooling, and welding-related inspection and environmental control systems.

The total number of establishments on which welding expenditure estimates are based is as follows for this sector:

- Petroleum/Chemical: 120 establishments
- Other CRM Firms: 216 establishments

The margin of error for the Capitalized Repair & Maintenance sector overall results is ± 3.2%. Margins of error for the industry group results increase as the number of responding establishments serving as the basis for the estimate declines. This should be kept in mind when comparing the group results.

Data concerning welding productivity in the Automotive Sector are presented in the following areas:

- Number and type of welding productivity measures used.
- Measurement of cost per unit of welding output.
- Measurement of welding output time efficiency.
- The impact of welder shortage on productivity.
- The extent to which welding training needs are being met.
- The active pursuit of the integration of welding automation into manufacturing processes.

TABLE CRM1: WELDING-RELATED PRODUCTION EXPENDITURES IN CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES

(all figures in $1,000)

Industrial Group	Expenditures For:				2000 Total Welding-Related Production Expenditures
	Labor	Materials & consumables	Energy	Other Welding Related	
Petroleum/Chemical	$ 589,810	$ 140,572	$ 18,273	$ 349,713	$ 1,098,368
Other CRM Industries	$ 1,716,749	$ 580,844	$ 108,730	$ 362,275	$ 2,768,599
Sector Totals	**$ 2,306,559**	**$ 721,416**	**$ 127,003**	**$ 711,988**	**$ 3,866,967**

FIGURE CRM1: PROPORTION OF WELDING-RELATED PRODUCTION EXPENDITURES IN CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES

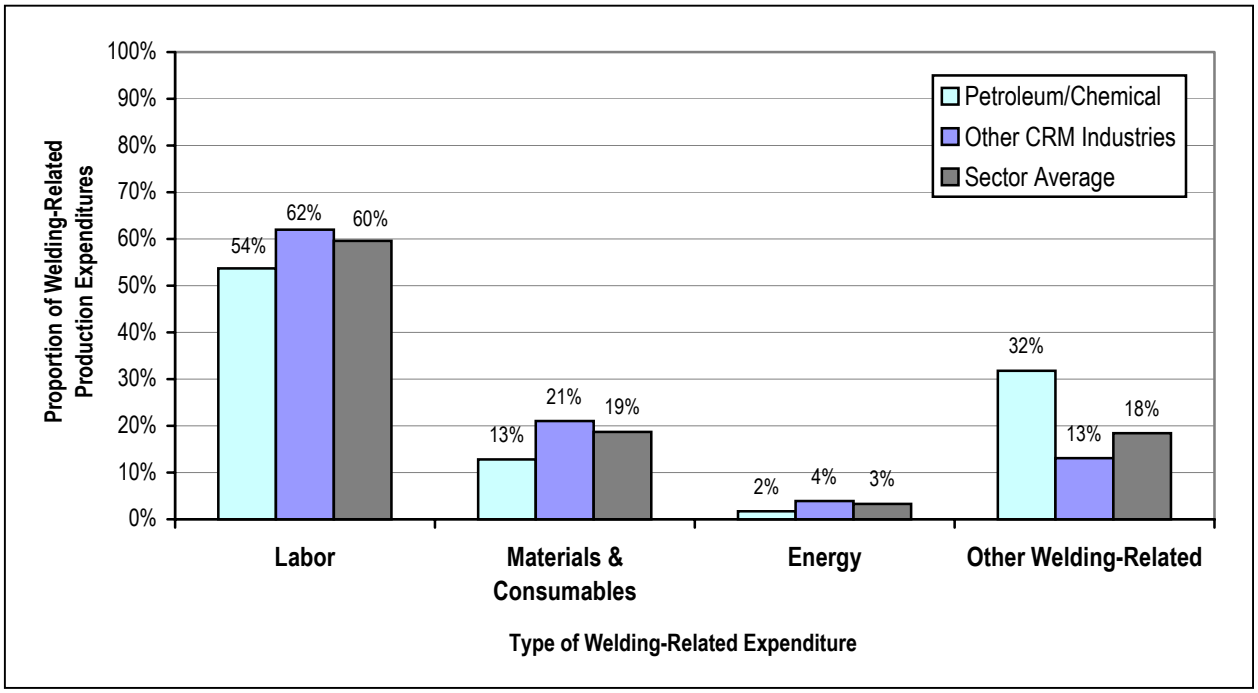


TABLE CRM2: WELDING-RELATED CAPITAL EXPENDITURES IN CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES

(all figures in $1,000)

Industrial Group	2000 Total Welding-Related Expenditures	2000 Welding-Related Capital Investment Expenditures	Proportion For Welding-Related Capital Investments
Petroleum/Chemical	$ 1,149,451	$ 51,082	4.4%
Other CRM Industries	$ 3,240,245	$ 471,647	14.6%
Sector Totals/Average	**$ 4,389,696**	**$ 522,729**	**11.9%**

TABLE CRM3: WELDING PRODUCTIVITY MEASUREMENT – CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES

Industrial Group		Number of Welding Productivity Measures Used					
		0	1	2	3	4	5-6
Petroleum/Chemicals	(n = 92)	66%	17%	10%	7%	0%	0%
Other CRM Industries	(n=157)	65%	29%	4%	1%	1%	0%
Sector Averages	(n=249)	**65%**	**25%**	**6%**	**3%**	**1%**	**0%**

TABLE CRM4: TYPES OF WELDING PRODUCTIVITY MEASURES USED – CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES

Industrial Sector		Percentage of Firms Measuring Productivity That Measure:								
		Defect Rate	Performance vs. Time Standard	Joints Completed per Period Time	Components per Period Time	Feet Welded per Period Time	Welding Cell % Time on Arc	Metal Deposited per Period Time	Tons Metal Joined per Period Time	Other
Petroleum/Chemicals	(n = 31)	68%	39%	10%	3%	0%	0%	0%	0%	10%
Other CRM Industries	(n = 55)	36%	46%	9%	6%	0%	0%	0%	0%	20%
Sector Averages	(n = 86)	**48%**	**43%**	**9%**	**5%**	**0%**	**0%**	**0%**	**0%**	**16%**

FIGURE CRM2: COST PER UNIT OF WELDING OUTPUT MEASUREMENT – CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES

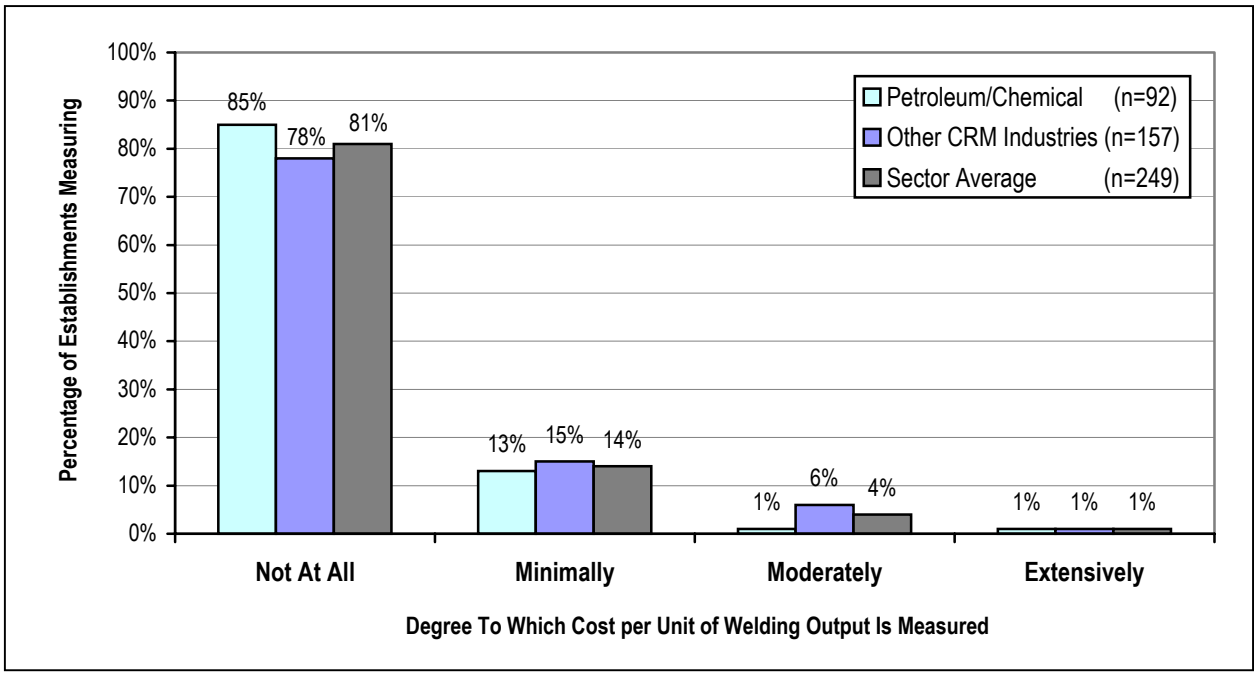


FIGURE CRM3: FACTORS CONSIDERED IN MEASURING COST PER UNIT OF WELDING OUTPUT – CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES

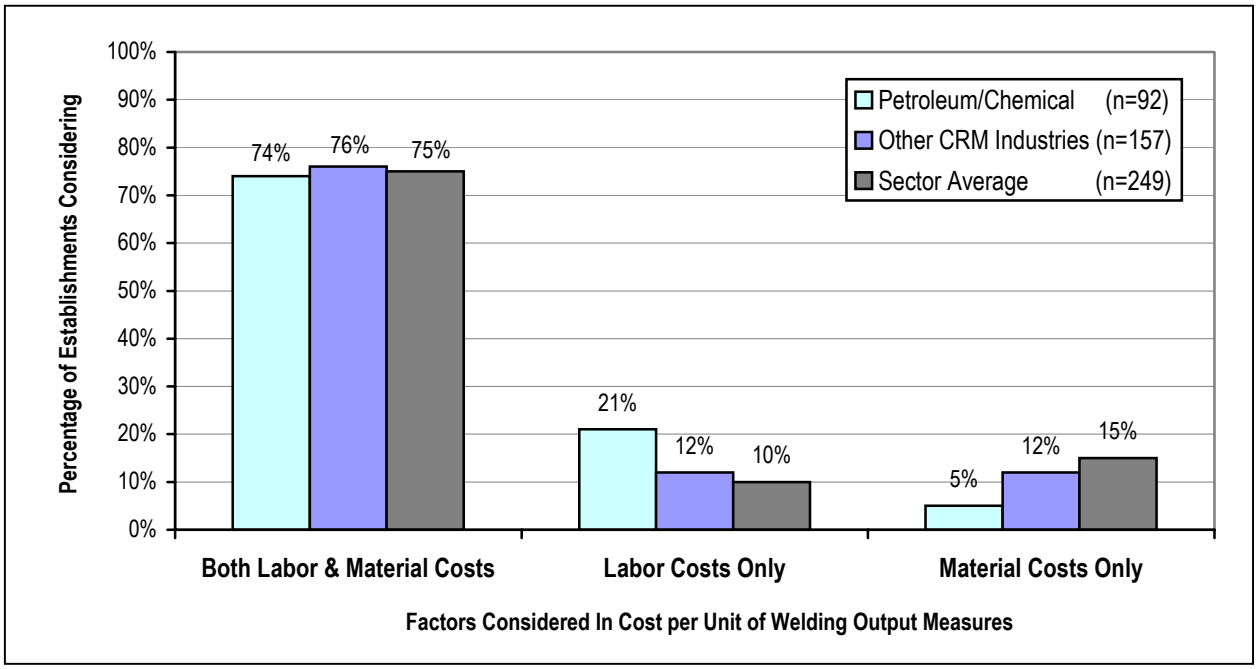


FIGURE CRM4: MEASUREMENT OF WELDING OUTPUT TIME EFFICIENCY – CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES

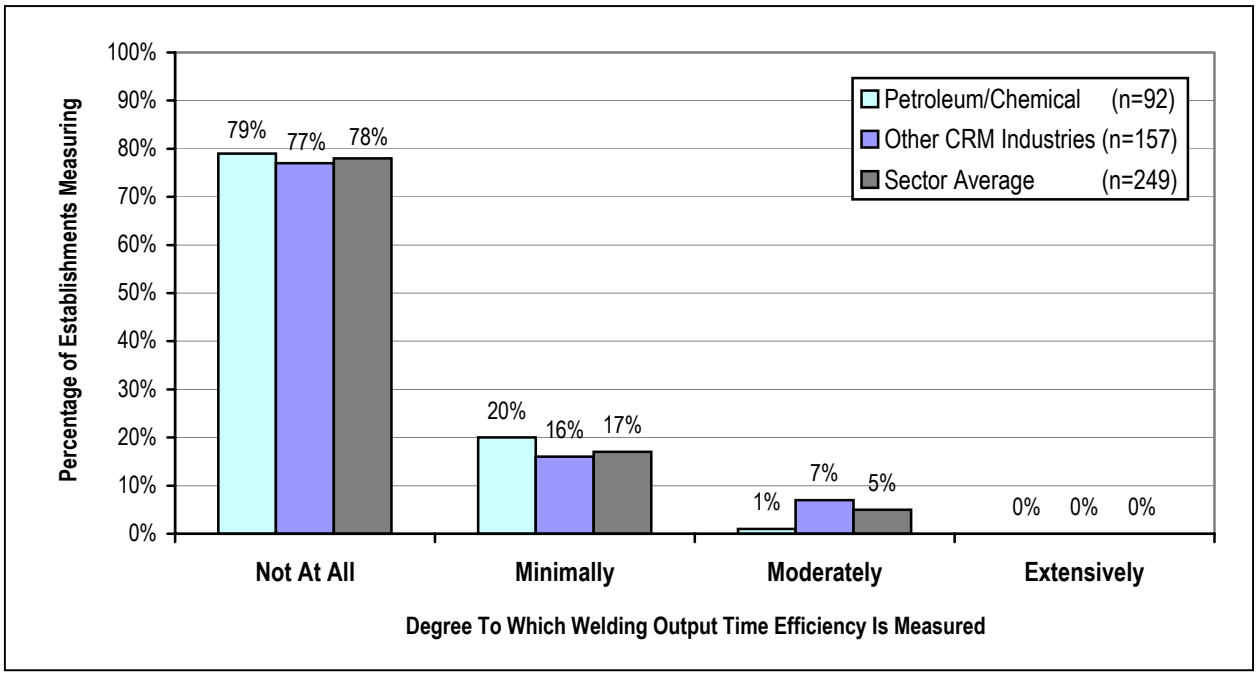


FIGURE CRM5: IMPACT OF WELDER SHORTAGE ON PRODUCTIVITY – CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES

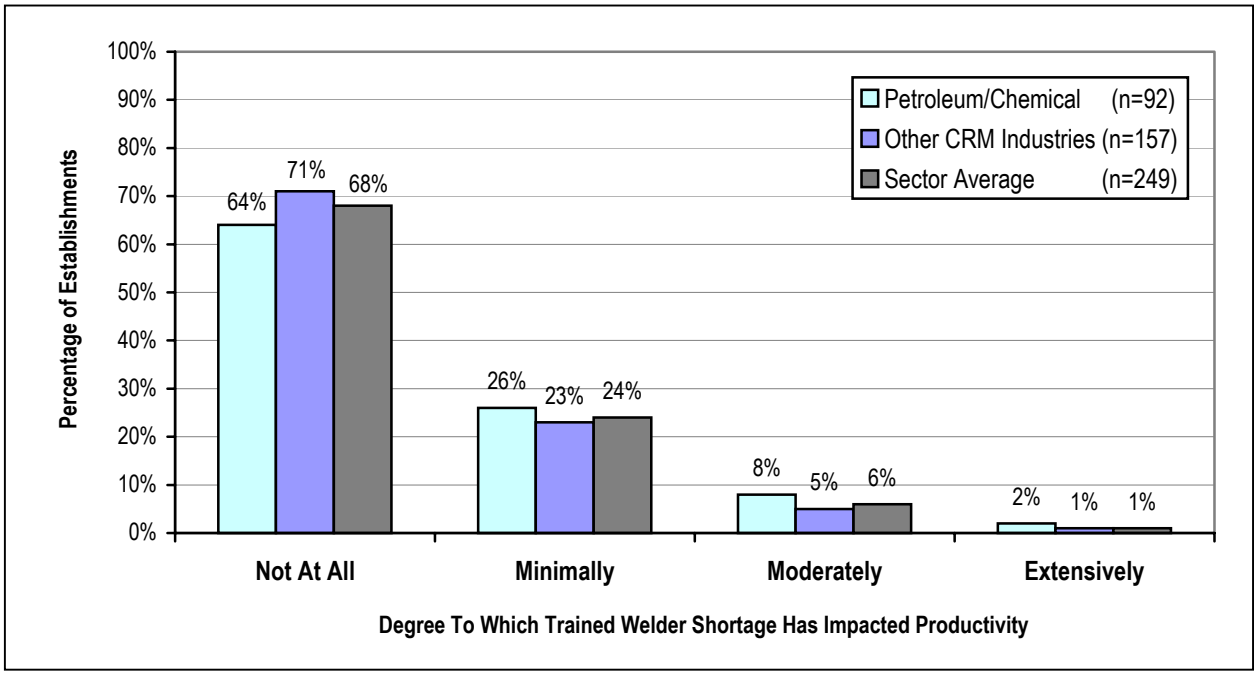


FIGURE CRM6: EXTENT TO WHICH WELDING TRAINING NEEDS ARE BEING MET – CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES

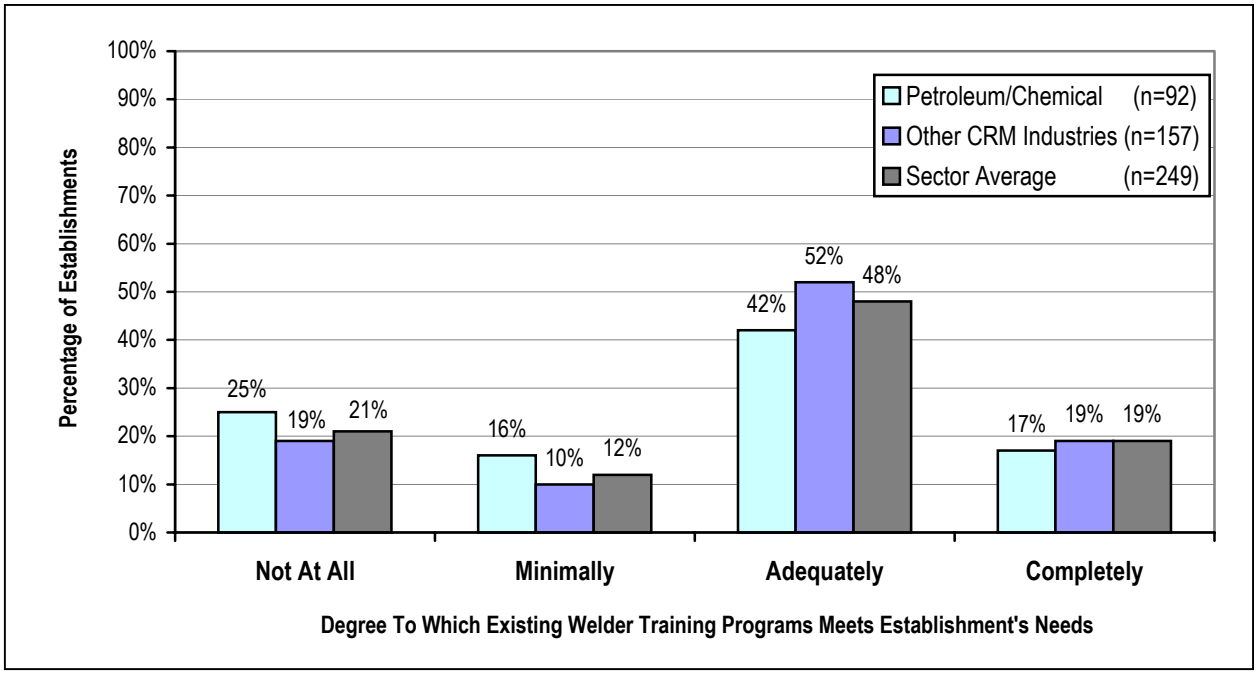
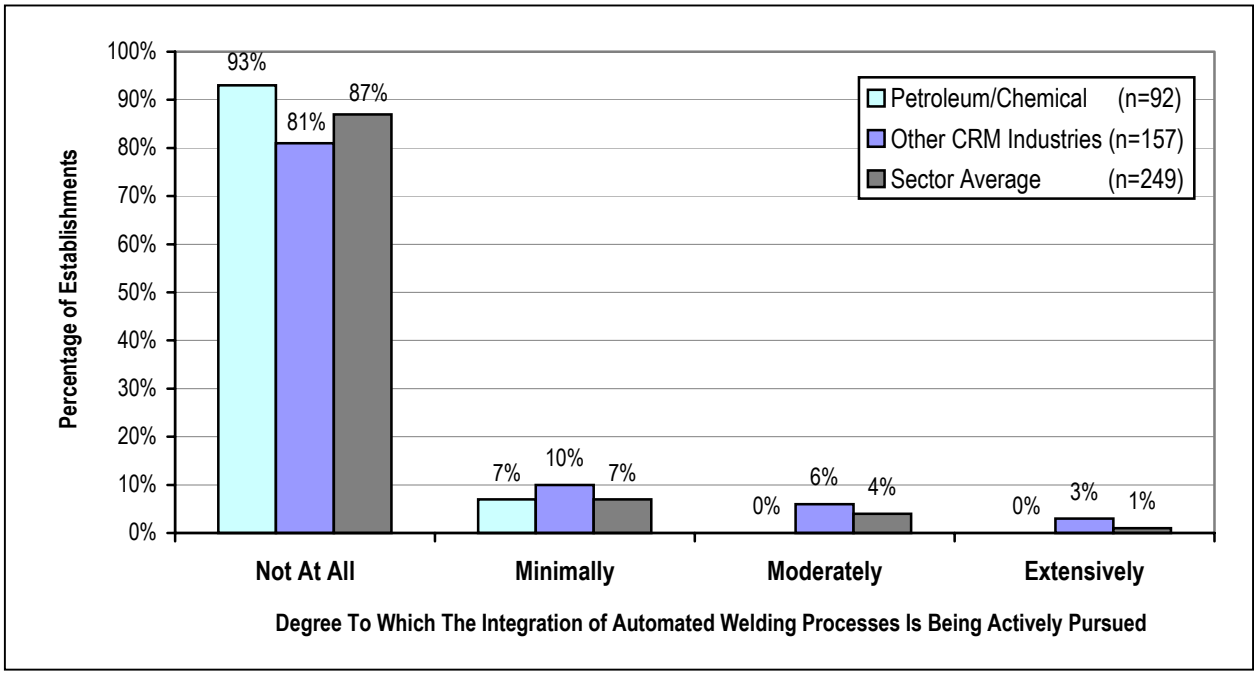


FIGURE CRM7: ACTIVE PURSUIT OF WELDING PROCESS AUTOMATION – CAPITALIZED REPAIR & MAINTENANCE INDUSTRIES



The involvement of a diverse group of experts and supporters was necessary to fully ensure the quality of the research reported in this document. Key individuals involved, their organizational affiliation, and role in this study are presented to acknowledge their contributions and demonstrate the strength of this research effort.

ADVISORY PANEL

An Advisory Panel of leading academicians, research experts, practitioners, and welding industry organization representatives was assembled at the start of this study. This panel was responsible for contributing to critical design and interpretation aspects of the research, including validation of all economic value contributions reported. Advisory Panelists, and their credentials, are as follows:

H. Lee 'Buck' Mathews, Ph.D.
Study Advisory Panel Director, Fisher College of Business, The Ohio State University.
Buck Mathews is Professor of Marketing and Past Chairman of the Marketing Faculty at both The Ohio State University and Pennsylvania State University. He teaches undergraduate, graduate, and executive education courses and has received numerous awards as a distinguished teacher. Dr. Mathews has also been an active researcher, writer, and consultant for over 25 years. His consulting interests include industrial market strategic planning, sales management, market intelligence, financial planning, and product procurement and marketing. He holds a business degree from The University of Illinois and was awarded his MBA and Ph.D. from The Ohio State University.

William L. Berry, Ph.D.
Center for Manufacturing Excellence, The Ohio State University.
William Berry holds the Richard Ross Chair in Management and is Professor of Manufacturing at The Ohio State University Max M. Fisher College of Business. He is also the Co-Director of the Center for Excellence in Manufacturing Management. His areas of expertise include manufacturing strategy and manufacturing planning and control systems. He has industrial experience with the General Electric Company in manufacturing management and is a graduate of the General Electric Manufacturing Training Program. He has served as a manufacturing strategy consultant to several firms. He is the author of over 70 papers and business cases in the areas of manufacturing strategy and manufacturing planning and control systems, and is the co-author of several books. Dr. Berry is a Past President of the Decision Science Institute and the Operations Management Association.

David T. Crary, Ph.D.
College of Business Administration, Louisiana State University.
David Crary is an Associate Dean and Professor of Finance in the E.J. Ourso College of Business Administration at Louisiana State University. Dr. Crary was designated as a Chartered Financial Analyst in 1981 and has extensive experience as an economic analyst, expert testimony witness, and consultant to business. Currently, Dr. Crary serves as Associate Dean for Executive Education and Public Outreach and is responsible for creating, marketing, and managing all post-experience non-degree programs offered by the LSU College of Business Administration. He also teaches business finance courses and serves as an undergraduate academic advisor. Prior to joining the LSU faculty in 1972, Dr. Crary was an assistant professor at the University of Southern California. He holds B.S., M.B.A., and Ph.D. degrees from The Ohio State University.

John F. Dix
Center for Manufacturing Excellence, The Ohio State University.
John Dix is Co-Director of the Center for Excellence in Manufacturing Management and the President of his own consulting firm, Business Development Index Limited, Inc. His consulting interests focus on developing strategic growth plans for manufacturers, retailers, and distributors of consumer goods. He sits on several Boards of Directors, of both business enterprises and community organizations, and teaches in the Marketing Department at the Graduate School of Business at The Ohio State University. Prior to his teaching and consulting careers, he was a Group Vice President of Borden, North American Foods. Mr. Dix holds a business degree from John Carroll University.

Richard French
Deputy Executive Director,
American Welding Society.
Richard French has served as Deputy Executive Director of the American Welding Society since 1987. He supervises the Publications Services (*Welding Journal, Inspection Trends,* and *Welding Handbook*), Technical Services (Codes and Standards), and Convention and Expositions Divisions of AWS. He is also Secretary to numerous AWS Committees, including the Welding R&D and Government Affairs Liaison committees. Mr. French also serves as Chair of the Steering Committee for the Navy Joining Center and Secretary/Treasurer of the American Council of the International Institute of Welding. He holds a B.A. degree from the University of the South.

James A. Richardson, Ph.D.
Public Administration Institute,
Louisiana State University.
James Richardson is the John Rhea Alumni Professor Economics and Director of the Public Administration Institute in the E. J. Ourso College of Business Administration at Louisiana State University. He has also served as Chairman of the Department of Economics, Acting Dean of the College of Business Administration, and Associate Vice Chancellor for Academic Affairs at LSU. Since 1987, Dr. Richardson has served as the private economist on the Louisiana Revenue Estimating Conference, the panel with the constitutional authority to provide the official revenue estimates for the state. His work in the areas of economic forecasting, economic impact, and econometrics has been published in numerous journals such as *State and Local Government, Public Finance Quarterly, Journal of Energy and Development*, and *Journal of Economic Dynamics and Control.* Dr. Richardson has provided consulting services to a broad range of governmental agencies and corporate clients. Prior to joining the LSU faculty in 1970, Dr. Richardson was a program analyst with the U.S. Bureau of the Budget. He holds an A.B. degree in economics from St. Mary's University of Texas, and A.M. and Ph.D. degrees in economics from the University of Michigan.

Fritz Saenger
Director, International Business Development,
Edison Welding Institute.
Fritz Saenger is responsible for developing EWI presence in Canada, Latin America and selected Asian countries, and serves as Team Leader, Welding Products Membership. He is also Vice Chair of the Welding Research Council Board of Directors and is active with American Welding Society. He has served as a member of the AWS Filler Metal Committee and is currently a member of the AWS Technical Papers, Marketing, Exhibition, and *Welding Journal* committees. Mr. Saenger holds eight patents in the field of gas-shielded processes and high strength filler materials and has published several technical papers on those and related subjects. He holds an engineering degree from The Ohio State University and an M.S. degree in Business Management from The New Jersey Institute of Technology.

David C. Swaddling, MBA, CPA
President, Insight·MAS.
David Swaddling is President of Insight·MAS, a research and consulting firm. His particular consulting interest is in helping companies use marketplace information to increase revenue growth and profitability. Prior to his consulting career, Mr. Swaddling practiced with KPMG Peat Marwick and was a senior executive in the computer services industry, most notably as CFO of CompuServe. He is a frequent speaker and writer on the topic of measuring and managing customer value and is co-author of *Customer Power: How to Grow Sales and Profitability in a Customer-Driven Marketplace*. He holds a business degree from Northwestern University and the M.B.A. from Ohio University. Mr. Swaddling is a Certified Public Accountant and New Product Development Professional. He is a past officer of the Product Development & Management Association and a member of the Society of Competitive Intelligence Professionals.

INDUSTRY EXPERTS

A team of Industry Experts was organized to provide industry-specific background information as well as support the collection and interpretation of data gathered in each of the industries studied. Invaluable contributions by these individuals made possible the quality and success of this research. Those professionals serving as industry experts for this study included:

- **Mr. Bruce Albrecht**, Miller Electric Manufacturing Co. — Light Industrial Manufacturing
- **Mr. Dennis Amos**, Siemens Westinghouse — Power Systems
- **Mr. Gene Bickford**, J. Ray McDermott — Shipbuilding (Offshore Oil Platforms)
- **Mr. David Bruner**, Black & Decker — Light Industrial Manufacturing
- **Mr. Glenn Campbell**, General Dynamics — Armored Vehicles
- **Mr. Jeffrey Ding**, NASA — Aerospace
- **Mr. Tom Doyle**, McDermott International — Power Systems
- **Mr. Bob Easterman**, Trinity Industries — Railroad Rolling Stock
- **Mr. David Eberwine**, Newport News — Shipbuilding
- **Mr. Joel Feldstein**, Foster Wheeler — Power Boilers/Pressure Vessels
- **Mr. William Garrison**, Boeing – Rocketdyne — Aerospace
- **Mr. Phil Grimm**, Modern Welding Company — Storage Tanks
- **Mr. Kenneth Grubb**, Wilson Greatbatch Ltd. — Electromedical Devices
- **Mr. Angelo Guinasso**, The Boeing Company — Aircraft Manufacturing
- **Mr. David Harris**, Havens Steel — Construction – Structural Fabricated Metal
- **Mr. Jim Harris**, Ashland Chemical — Capitalized Repair & Maintenance
- **Mr. Earl Helder**, GE Aircraft Engines — Aircraft Engines
- **Mr. Richard Hess**, High Steel — Construction – Structural Fabricated Metal
- **Mr. Kurt Hoffman**, RoMan Manufacturing — Automotive Component Manufacturing
- **Mr. Bruce Holliday**, Northrop Grumman Corp. — Power Systems
- **Dr. Tarsem Jutla**, Caterpillar Corporation — Construction & Mining Machinery
- **Dr. Michael Karagoulis**, GM North American Operations — Automotive Vehicle Manufacturing
- **Mr. Chris Knapp**, Guidant Cardiac Pacemakers — Electromedical Devices
- **Mr. Robert Koehl**, Ford Motor Company — Automotive Vehicle Manufacturing
- **Mr. Greg Koprowitz**, Atlantic Marine — Shipbuilding
- **Mr. Rich Kotan**, Omaha Public Power District — Capitalized Repair & Maintenance
- **Mr. Lee Kvidal**, Ingalls Shipbuilding — Shipbuilding
- **Mr. Richard LaBombard**, Xerox Corporation — Light Industrial Manufacturing

INDUSTRY EXPERTS (continued)

- **Mr. Jack Lee**, Honeywell — Aircraft Engines
- **Mr. Ernest Levert**, Lockheed-Martin Missiles and Fire Control — Aerospace
- **Mr. Howard Ludewig**, Caterpillar Corporation — Construction & Mining Machinery
- **Mr. Spencer Luke**, Dresser Rand — Industrial Machinery
- **Mr. Bill Mcgee**, Lockheed Martin Michoud Operations — Aerospace
- **Mr. Michael McGehee**, Lockheed Martin Michoud Operations — Aerospace
- **Dr. Duane Miller**, Lincoln Electric — Construction
- **Mr. William Myers**, Dresser Rand — Industrial Machinery
- **Mr. Jeff Noruk**, Tower Automotive — Automotive Vehicle Manufacturing
- **Mr. Dean Phillips**, ITW — Light Industrial Manufacturing
- **Mr. John Phillips**, Detroit Center Tool — Automotive Component Manufacturing
- **Mr. Ron Pierce**, Welding Engineering Supply Co. Inc. — Shipbuilding
- **Dr. Anatol Rabinkin**, METGLAS Solutions, Honeywell — Light Industrial Manufacturing
- **Mr. Don Rager**, Rager Consulting Inc. — Building Construction
- **Mr. Tracy Reynolds**, Micron Technology — Electronic Components
- **Mr. Bob Rivett**, Emerson — Light Industrial Manufacturing
- **Mr. Dan Rybicki**, Lockheed Martin – Houston — Aerospace
- **Mr. Jim Sawhill**, Newport News Shipbuilding — Shipbuilding
- **Mr. Ken Schmidt**, GM North American Operations — Automotive Vehicle Manufacturing
- **Mr. Joe Sloan**, Chicago Bridge & Ironworks — Storage Tanks
- **Mr. Tim Sorg**, Dana Corporation — Automotive Systems & Parts
- **Ms. Lisa Sovilla**, Atlantic Marine — Shipbuilding
- **Mr. Peter Stark**, Enron — Capitalized Repair & Maintenance
- **Mr. Phil Temple**, Detroit Edison — Capitalized Repair & Maintenance
- **Mr. Wayne Temple**, Exxon Mobil Chemical Company — Capitalized Repair & Maintenance
- **Mr. Krishna Verma**, Federal Highway Admin (DOT) — Highway & Bridge Construction
- **Mr. E.L. VonRosenberg**, Materials & Welding Technology — Pipeline Construction
- **Mr. Jerry Warren**, CNH (Case New Holland) Corporation — Agricultural Equipment
- **Mr. Tim Warren**, Ingalls Shipbuilding — Shipbuilding
- **Mr. Mike Wind**, Steelcase Corporation — Light Industrial Manufacturing

STEERING COMMITTEE

A Steering Committee, comprised of representatives from major supporting organizations, was organized to review project status against goals and assure that sponsoring organizations were fully aware of all aspects of the project. Members of the study Steering Committee included:

- **Mr. Brad Botwin**, Director, Strategic Analysis Division, U.S. Department of Commerce Bureau of Export Administration, Office of Strategic Industries and Economic Security
- **Mr. Richard French**, Deputy Executive Director, American Welding Society
- **Dr. Karl Graff**, Executive Director, Edison Welding Institute
- **Mr. Richard Sief**, President and C.E.O., Lincoln Electric Canada
- **Mr. Sam Thomas**, President and C.E.O., ESAB North America
- **Mr. Patrick R. Valente**, Deputy Director, Ohio Department of Development
- **Mr. Robert Wiseman**, Director of Engineering, Thermal Arc Division of Thermadyne

In order to frame this research effort, it was important to begin with a clear definition of a number of concepts. These concepts, and their operational definitions, are as follows:

Welding: A joining process that produces a local coalescence of materials by heating, by applying pressure, or both. The welding process fuses the surface of two distinct elements to form a single unit. Joining techniques encompassed by this definition include fusion welding, solid state welding, weldbonding, diffusion welding, brazing, and soldering. Joining by mechanical fastening (i.e., rivets, screws, bolts) is excluded by this definition.

Industry: Grouping of related businesses as defined by the North American Industrial Classification System (NAICS) which employ similar welding technologies to produce like commodities. (e.g., automobiles, buildings and bridges, construction equipment). Industries are defined, for this report, based on four digit NAICS codes.

Critical Enabling Technology: Instances where no economically feasible alternatives to the use of welding technology exist. (e.g., Automotive body manufacturing, fabricated metal products manufacturing).

Economic Contribution of Welding To An Industry: Total welding-related costs incurred in the production of the industry's output.

Welding-Related Expenditures: Welding-related expenditures equal the sum of the following four measures:

1. Welding labor costs, including direct costs (wages) and indirect costs (benefits and training).
2. Welding materials and consumables costs (e.g., electrodes, flux, industrial gases, welding accessories such as helmets, protective clothing, tools).
3. Energy costs associated executing welding processes.
4. Capital expenditures for facilities, equipment, and systems required for welding and welding-related processes (e.g., machines, robotic systems, fabricated jigs, fixtures).
5. Purchased services and other non-production costs related to welding including welding-related research and development, process specification, certification, training, consulting, and field services.

***Top Down* Approach**: An inductive reasoning approach used to determine welding-related expenditures within industries and across the U.S. economy. Computation of expenditures using the *Top Down* approach was based on data gathered by the U.S. Department of Commerce.

***Bottom Up* Approach**: A deductive reasoning approach used to determine welding-related expenditures within an industry based on welding inputs into representative commodities within that industry. Total welding-related expenditures in the industry were then extrapolated based on factors specified by industry-specific data, U.S. economic data, and industry expert estimates.

Value Reconciliation: Process of comparing and reconciling *Top Down* and *Bottom Up* estimates within specified industries in order to determine a single value which best represents the economic contribution of welding to that industry.

RESEARCH OBJECTIVES

Prior to the start of this research, the principal sponsors and the Research Team specified the primary objectives of this study. These objectives were to:

1. Determine the economic contribution of welding in specific U.S. industries where welding is a critical enabling technology.
2. Determine the productivity of welding in specific U.S. industries where welding is a critical enabling technology.
3. Determine where the greatest opportunities exist to further improve the productivity of welding in key industrial segments.

INDUSTRY PRIORITIZATION

The study began with the assembly of an Advisory Panel – a group of academicians and technical experts responsible for contributing to critical design and interpretation aspects of the study (see pgs. 83-84). The first Advisory Panel task was a thorough assessment of industries through which welding contributes to the U.S. economy. The primary purpose of this assessment was to develop a clear perspective of the importance of welding within specific industries and to properly focus data collection efforts subsequent phases of the research. Seven groups, or sectors, of industries were identified by the Advisory Panel. These were:

1. Aircraft/Aerospace
2. Automotive
3. Capitalized Repair and Maintenance
4. Construction
5. Electronics
6. Heavy Industrial Manufacturing
7. Light Industrial Manufacturing

A determination was made that this study would be conducted in two waves – the initial wave focusing exclusively on Heavy Industrial Manufacturing industries followed by the balance of the research on the six remaining sectors.

RESEARCH PLAN

Using the industry assessment results, the Research Director outlined a suggested approach for carrying out the study data collection process. This outline specified protocols to be followed in gathering data by both the *Top Down* and *Bottom Up* research approaches. The Research Plan also specified responsibilities for groups involved in the research and included a timeline for execution of the study.

INDUSTRY EXPERTS

The *Bottom Up* approach used in this study required that data be gathered from end-users in each of the industries to be targeted. An Expert Team (pgs. 86-87) was organized in each of the seven industrial sectors targeted in the study to facilitate the collection and interpretation of industry-specific data.

DATA COLLECTION INSTRUMENTS

Instruments (questionnaires and interview guides) designed to ensure the validity and reliability of data gathered through both the *Top Down* and *Bottom Up* approaches were developed through a rigorous design process. Initially, the Research Team conducted interviews with Industry Experts to understand the factors that drive firms to adopt specific welding applications and the ways in which welding productivity is measured. Based on these interview results, the Research Director drafted both *Top Down* and *Bottom Up* data collection instruments.

Each draft instrument was subjected to a validity assessment by Advisory Panel members. Feedback from the validity assessment was used to revise the instruments, which were then submitted to the Industry Experts who also reviewed and validated the questionnaires. Additional revisions were made and instruments were finalized in advance of the subsequent data collection process.

DATA COLLECTION – *TOP DOWN* APPROACH

Following the protocol specified in the Research Plan, the Office of Strategic Industries and Economic Security (SIES) of the U.S. Department of Commerce Bureau of Export Administration administered the *Top Down* data collection instrument (example appended), to 5,850 manufacturing and construction establishments in the United States. Exhibit C1 presents sample sizes, margins of error, and response rates for each of the seven industrial sectors included in the study.

The initial mailing of the Heavy Industrial Manufacturing *Top Down* survey took place in late November, 2000. Responses for the pilot study were collected through the final week of March, 2001. Mailings to establishments in the Automotive, Aircraft/Aerospace, Electronics, Light Industrial Manufacturing, Construction, and Capitalized Repair & Maintenance sectors took place in August 2001. Responses from this mailing were collected through January, 2002.

DATA COLLECTION – *BOTTOM UP* APPROACH

Following a data collection protocol, in-depth interviews and selected on-site facility tours were completed with 33 firms in industries targeted in the study. The purpose of these interviews and tours was to investigate welding expenditures within industries based on the welding inputs into representative commodities. These interviews also provided an opportunity to study factors impacting welding productivity in these industries.

DATA ANALYSIS, RECONCILIATION, & REPORTING

Using *Bottom Up* data, welding-related economic inputs were estimated for each of the firms taking part in the *Bottom Up* research. Total economic contribution of welding to the industry was then extrapolated based on multipliers gleaned from a number of sources, including (1) industry-specific findings from the 2000 U.S. Department of Commerce Survey of Manufactures, (2) annual reports and SEC filings of participating firms, and (3) Industry Expert estimates.

Welding expenditure estimates for each industry were reviewed by the expert(s) representing that industry. Adjustments to the *Bottom Up* estimates were made based on feedback from these experts. The *Bottom Up* results, along with an explanation of the rationale used in extrapolating expenditure estimates for specific industries, were then reviewed and validated by the Advisory Panel.

Following the analysis of the *Top Down* results, the Research Team reconciled these findings with those of the *Bottom Up* research. A summary of the findings from each data collection technique as well as the logic used for reconciliation of the results from the two approaches was provided to the Advisory Panel for review. Feedback from the Advisory Panelists was used in finalizing the analyses, reconciliation, and reporting of results.

All data provided by firms participating in this study were aggregated and reported as such. All industry-specific information reported was based upon input from multiple firms, protecting the confidentiality of information provided by the study participants. No industry data contained in this report can be attributed to individual firms.

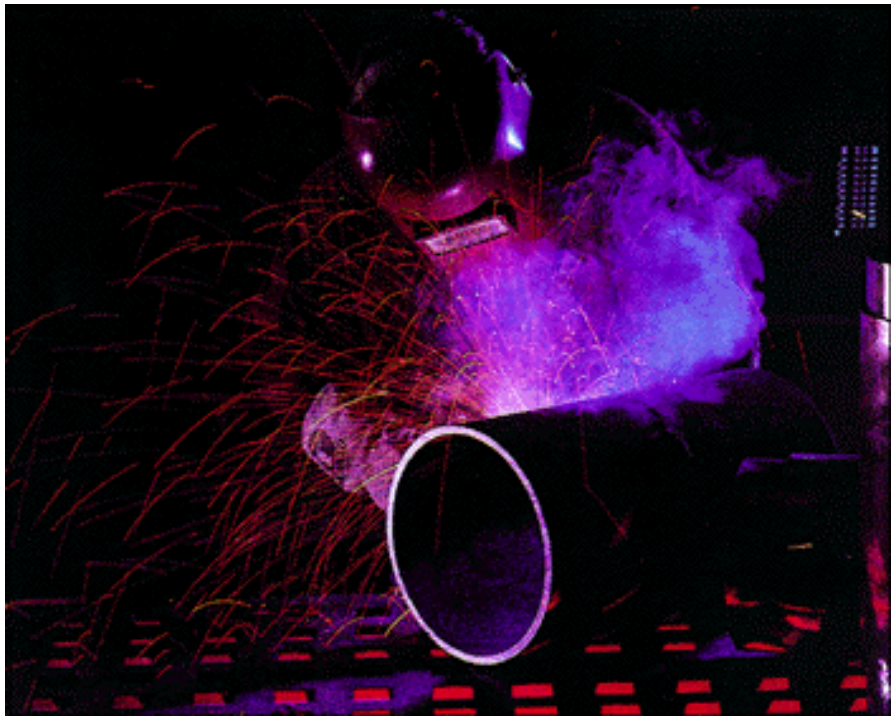
EXHIBIT C1: STUDY SAMPLING & RESPONSE

Sector	Sample	Sample Margin of Error	Total Respondents	Response Rate
Automotive	1059	± 2.8%	384	36%
Aircraft/Aerospace	986	± 2.0%	336	34%
Electronics/Medical	667	± 3.5%	231	35%
Light Industrial Manufacturing	1130	± 2.9%	480	42%
Heavy Industrial Manufacturing	500	± 3.5%	174	35%
Construction	1106	± 3.0%	439	40%
Capitalized Repair & Maintenance	900	± 3.2%	348	39%
TOTALS:	**5848**	**± 1.3%**	**2218**	**38%**

National Assessment of the Impact
of

Welding on U.S. Economic Productivity

– Survey Questions for Industry –



The Bureau of Export Administration
U.S. Department of Commerce

Office of Strategic Industries & Economic Security

National Assessment of the Impact of Welding on U.S. Economic Productivity

The U.S. Department of Commerce, Bureau of Export Administration, Office of Strategic Industries and Economic Security (BXA/SIES) is partnering with the Department of the Navy, American Welding Society, Edison Welding Institute, and welding industry supplier and user organizations to determine the economic contribution and productivity of welding in industries where welding represents a critical enabling technology. Products and services produced by these industries are central to our national security and balance of trade. Since welding represents an essential input for the generation of these products and services, improved welding productivity will increase the global competitiveness of these industries and improve the U.S. economy by improving the efficiency and profitability of companies that rely on welding.

This Report Is Required By Law

This report is required by law (50 U.S.C. App. Sec. 2155). Failure to report can result in a maximum fine of $10,000 or imprisonment up to one year, or both. **Information furnished herewith is deemed confidential and will not be published or disclosed** except in accordance with Section 705 of the Defense Production Act of 1950, as amended (50 U.S.C. App. Sec. 2155).

Burden Estimate and Request For Comment

Public reporting burden for this collection of information is estimated to average eight hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to BXA Reports Clearance Officer, Room 4513, Bureau of Export Administration, U.S. Department of Commerce, Washington, DC 20230, and to the Office of Management and Budget, Paperwork Reduction Project (0694-0076), Washington, DC 20503.

GENERAL INSTRUCTIONS

1. **WHO MUST COMPLETE THIS SURVEY:** Please complete this questionnaire if your firm requires the use of welding processes as an integral input for producing the products and/or services it sells. **Your response is due within 30 days of your receipt of this request.**

2. **WHO IS EXEMPT:** Firms that do not use welding in the manufacture of products or provision of services are exempt. Please indicate reason for your firm's exempt status (check all that apply):
   - ☐ My firm does not own or use welding or welding-related equipment.
   - ☐ My firm does not employ persons in the welding or welding-related trades.
   - ☐ My firm is a wholesaler / distributor.
   - ☐ My firm is a reseller.
   - ☐ My firm is a retailer.
   - ☐ Other (specify) _____

   Please provide your company name and address information on page 1, sign the certification on page 9, and return this document in the enclosed envelope.

GENERAL INSTRUCTIONS
(continued)

3. It is not our desire to impose any unreasonable burden on any respondent. If information requested is not available from your records in exactly the form indicated, furnish the most accurate estimates you are able to provide and designate these figures as such with the letter "e" following the estimate figure.

4. Questions related to this questionnaire should be directed to:

- Mr. Mark Crawford, Trade & Industry Analyst, (202) 482-8239, e-mail, mcrawfor@bxa.doc.gov, or
- BXA/SIES Fax (202) 482-5650.

5. Before returning your completed questionnaire, be sure to sign the certification on the last page and identify the name and phone number of the person(s) responsible for the completion and submission of this report. Return the completed questionnaire in the enclosed envelope within 30 days of receipt to:

Mr. Brad Botwin, Director
Strategic Analysis Division
BXA/SIES, Room 3876, Welding
U.S. Department of Commerce
Washington, DC 20230

DEFINITIONS

Welding: A joining process that produces a local coalescence of materials by heating, by applying pressure, or both. The welding process fuses the surface of two distinct elements to form a single unit. Joining techniques encompassed by this definition include fusion welding, solid state welding, weldbonding, diffusion welding, brazing, and soldering. Joining by mechanical fastening (i.e., rivets, screws, bolts) is excluded by this definition.

Welding Operations: Manufacturing operations involving the welding process as described above, including those material handling operations specifically associated with execution of the welding process. These operations include weld zone material cleaning processes, heat treating, stress relieving processes, beveling, and slag/spatter removal. Related **manufacturing operations excluded by this definition** include general material preparation (cleaning, marking, etc.), cutting, bending, forming, machining, and component assembly.

Establishment: A facility in which welding takes place, or where welding-related research and development takes place. Includes auxiliary facilities operated in conjunction with (whether or not physically separate from) such production facilities. Does not include wholly owned distribution facilities.

Firm: An individual proprietorship, partnership, joint venture, association, corporation (including any subsidiary corporation in which more than 50 percent of the outstanding voting stock is owned), business trust, cooperative, trustees in bankruptcy, or receivers under decree of any court, owning or controlling one or more establishments as defined above.

United States: The term "United States" include the fifty States, Puerto Rico, the District of Columbia, and the Virgin Islands.

PART I – ESTABLISHMENT INFORMATION

1. **COMPANY NAME AND ADDRESS:** Please provide the name and address of this firm or corporate division.

Company Name: _____

Street Address: _____

City: _____ State: _____ Zip: _____

2. **OWNERSHIP:** If this firm is wholly or partly owned by another firm, indicate the name and address of the parent firm and the extent of ownership.

Company Name: _____

Street Address: _____

City: _____ State: _____ Zip: _____

Country: _____

Percent Ownership: _____ %

3. **DOMESTIC vs. INTERNATIONAL SALES:** Indicate the percentage of this firm's sales during 2000, or most recently completed fiscal year, to U.S. and non-U.S. customers.

Percent sales to U.S. customers: _____ %

Percent sales to non-U.S. customers: _____ %

4. **MARKET SHARE:** Indicate the percentage of this firm's current share of the **U.S.** market for the primary products it manufactures or services it offers.

Current share of U.S. market: _____ %

5. **TOTAL CURRENT EMPLOYMENT**: Total number of employees at this establishment.

Total current employment (±5%): _____

6. **TOTAL GROSS RECEIPTS**: Indicate this establishment's total gross receipts during 2000, or most recently completed fiscal year, for all products manufactured or services provided by this establishment.

Total gross receipts for products/services: $ _____

Note: Any information submitted in response to this survey will be deemed business confidential and exempt from public disclosure in accordance with Section 705 of the Defense Production Act of 1950, as amended.

7. TOTAL MANUFACTURING EXPENDITURES (capital investments and production costs)
Indicate this establishment's total expenditures for manufacturing and production processes during 2000, or most recently completed fiscal year. Include capital investments for manufacturing process operations as well as expenditures for all materials and other consumables used in the manufacturing process.

Total Manufacturing/Production costs: $ _____

8. MANUFACTURING OR PRODUCTION CAPITAL INVESTMENTS
Indicate *either* of the following:

Total manufacturing or production capital investments made by this firm in 2000 or most recently completed fiscal year. Include investments in facilities and equipment used to carry out manufacturing or production processes:

$ _____

OR

Percentage of total manufacturing or production costs (Item 6 above) **represented by capital investments** in facilities and equipment used to carry out manufacturing or production processes during 2000 or most recently completed fiscal year:

_____ %

9. MANUFACTURING OR PRODUCTION MATERIALS & CONSUMABLES COSTS
Indicate *either* of the following:

Total manufacturing or production materials costs for this firm in 2000 or most recently completed fiscal year. Include non-capitalized investments in purchased materials and consumables used to carry out manufacturing or production processes:

$ _____

check one: ☐ figure *includes* energy costs
☐ figure *excludes* energy costs

OR

Percentage of total manufacturing or production costs (Item 7 above) **represented by purchased materials and consumables** used to carry out manufacturing or production processes during 2000 or most recently completed fiscal year:

_____ %

check one: ☐ percentage *includes* energy costs
☐ percentage *excludes* energy costs

10. MANUFACTURING OR PRODUCTION ENERGY COSTS
Indicate *either* of the following:

Total value of electrical energy consumed by manufacturing or production processes carried out by this firm in 2000 or most recently completed fiscal year:

$ _____

OR

Percentage of total manufacturing or production costs (Item 7 above) **represented by electrical energy consumed** to carry out manufacturing or production processes during 2000 or most recently completed fiscal year:

_____ %

Note: Any information submitted in response to this survey will be deemed business confidential and exempt from public disclosure in accordance with Section 705 of the Defense Production Act of 1950, as amended.

PART II – WELDING-RELATED INVESTMENTS AND OUTPUT

1. <u>WELDING-RELATED</u> CAPITAL INVESTMENTS
Indicate *either* of the following:

Total welding-related capital investments made by this firm in 2000 or most recently completed fiscal year. Include investments in welding units, welding-specific tooling costs, and welding-specific environmental control systems:

Total welding-related capital investments:

$ _____

OR

Percentage of total capital investments made by this firm in 2000, or most recently completed fiscal year, **represented by welding-specific equipment, tooling, and environmental control systems**.

Percentage of total capital investments that were welding-related:

_____ %

2. <u>WELDING-RELATED</u> MATERIALS/CONSUMABLES COSTS
Indicate *either* of the following:

Total expenditures for welding-related materials/consumables made by this firm in 2000 or most recently completed fiscal year. Include expenditures for:

- non-capitalized welding equipment purchases, leases, or rentals,
- filler metal, flux, solder, and gasses used in weld preparation and welding processes,
- ancillary supplies such as consumables, hand tools, and safety supplies used in weld preparation and welding processes
- welding equipment maintenance parts, and
- disposal of welding process byproducts.

Total welding-related materials expenditures:

$ _____

OR

Percentage of total material/consumable expenditures made by this firm in 2000, or mos recently completed fiscal year, **represented by the total cost of purchases of**:

- non-capitalized welding equipment purchases, leases, or rentals,
- filler metal, flux, solder, and gasses used in weld preparation and welding processes,
- ancillary supplies such as consumables, hand tools, and safety supplies used in weld preparation and welding processes
- welding equipment maintenance parts, and
- disposal of welding process byproducts.

Percentage of total materials expenditures that were welding-related:

_____ %

3. <u>WELDING-RELATED</u> ENERGY COSTS
Indicate *either* of the following:

Total welding-related energy costs for this firm in 2000 or most recently completed fiscal year. Include energy costs for the operation of welding-specific equipment, tooling, and environmental control systems.

Total welding-related energy costs:

$ _____

OR

Percentage of total energy costs for this firm in 2000, or most recently completed fiscal year, **represented by total energy costs to operate welding-specific equipment, tooling, and environmental control systems**.

Percentage of total energy costs that were welding-related:

_____ %

Note: Any information submitted in response to this survey will be deemed business confidential and exempt from public disclosure in accordance with Section 705 of the Defense Production Act of 1950, as amended.

4. WELDING AND WELDING SUPPORT PERSONNEL:

In Column 1: indicate the number of persons currently employed by this establishment in each of the following categories. Headcounts may be rounded to within ±5%.

In Column 2: indicate the estimated percentage of time spent by personnel in this position either directly involved in or supporting welding operations. In most cases, welding personnel spend a majority of their time (50%-100%) involved in welding operations. Support personnel typically spend a smaller percentage of time related to welding operations.

	Column 1 Headcount	**Column 2** Estimated percentage of time involved in or supporting welding operations
Welding Personnel		
▪ Welders and welding cell/unit operators		%
▪ Solderers / Brazers		%
▪ Other welding operations laborers / helpers		%
▪ Welding Engineers		%
▪ Welding Supervisors		%
▪ Welding Trainers and Technicians		%
Welding Support Personnel		
▪ Other Engineers (e.g., Mechanical, Metallurgical, Tooling)		%
▪ Other Supervisors		%
▪ Other Trainers and Technicians		%
▪ Quality Control / Quality Assurance / Inspection / Testing		%
▪ Design and Drafting Personnel		%
▪ Maintenance		%
▪ Materials Handling		%
▪ Inventory Control		%
▪ Human Resources		%

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5. **OTHER WELDING-RELATED INVESTMENTS:** Indicate additional welding-related investments made by this establishment in 2000, or most recently completed fiscal year, **that have not been accounted for** in response to Questions 1 through 4 in Part II. Include costs for materials, purchased professional services, and value of fully compensated time invested by employees of this establishment.

Type of Cost

- Welding-Related Research & Development ..... $
- Welding Process Specification Preparation ..... $
- Welding Certification Costs ..... $
- Welding-Related Training ..... $
- Welding-Related Consulting (including purchased inspection & testing services) ..... $
- Other (please indicate) _____ $

6. **PRODUCTION OUTPUT:** Indicate total production output for this establishment in 2000, or most recently completed fiscal year, **excluding any products/services with no welding inputs**. Output of each of the principal product lines produced by this establishment should be reported.

a. PRODUCT LINE A – Units Produced:

Number of units produced: .....

Description of unit: .....

b. PRODUCT LINE B – Units Produced:

Number of units produced: .....

Description of unit: .....

c. PRODUCT LINE C – Units Produced:

Number of units produced: .....

Description of unit: .....

d. Other: If this establishment commonly uses an overall output measure different from units produced, please indicate the level of output and describe the output measure.

Total output:

Definition of output measure:

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7. WELDING PRODUCTIVITY:

Column 1 – Check all welding productivity measures currently used by this firm.

Column 2 – Indicate a *representative* level of current productivity for a commonly executed welding process based on each measure checked.

Column 3 – Briefly describe the type and scope of joining operation on which each productivity measure is based (e.g., range of the production process covered by the measure, type of joints being made, type of metal joined, metal thickness).

Column 1 Measured by this firm (check all that apply)	**Welding Productivity Measure**	**Column 2** Current Level of Productivity	**Column 3** Description of Production Process(es) Measured
☐	**Defects / # of welds completed**	☐ **Defects** / 100 welds completed	
☐	**Welds or joints completed / man-hour**	☐ Welds or joints completed / man-hour	
☐	**Components completed / man-hour**	☐ Components completed / man-hour	
☐	**Feet welded / man-hour**	☐ Feet welded / man-hour	
☐	**Welding cell arc time**	☐ % weld cell arc time	
☐	**OTHER (please indicate)**	☐ Productivity Level	
☐	**OTHER (please indicate)**	☐ Productivity Level	

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8. OTHER WELDING PRODUCTIVITY MEASURES:

a. To what extent does this firm measure the cost per unit of welding output? (check one)

- ☐ NOT AT ALL
- ☐ MINIMALLY
- ☐ MODERATELY
- ☐ EXTENSIVELY

b. Which of the following are included in these cost estimates? (check one)

- ☐ BOTH MATERIALS AND LABOR
- ☐ MATERIALS ONLY
- ☐ LABOR ONLY

c. On what specific processes and/or welding outputs does this firm's <u>cost</u> analyses focus?

_____

_____

_____

d. To what extent does this firm measure the time efficiency of welding output? (check one)
[e.g., feet welded or metal deposited per period of time, joints completed per period of time]

- ☐ NOT AT ALL
- ☐ MINIMALLY
- ☐ MODERATELY
- ☐ EXTENSIVELY

e. On what specific processes and/or welding outputs does this firm's efficiency analyses focus?

_____

_____

_____

PART III – WELDING-RELATED ECONOMIC FACTORS

1. **To what extent has the shortage of trained welders impacted the productivity of this firm's U.S. operations?** (check one)

   ☐ NOT AT ALL
   ☐ MINIMALLY
   ☐ MODERATELY
   ☐ EXTENSIVELY

   Comments: _____

   _____

2. **To what extent do existing avenues for training welders meet this firm's needs?** (check one)

   ☐ NOT AT ALL
   ☐ MINIMALLY
   ☐ ADEQUATELY
   ☐ COMPLETELY

   Comments: _____

   _____

3. **To what extent is this firm actively pursuing the integration of Automotivemated welding processes into its manufacturing processes?** (check one)

   ☐ NOT AT ALL
   ☐ MINIMALLY
   ☐ MODERATELY
   ☐ EXTENSIVELY

   Comments: _____

   _____

4. **Are there other welding-related factors that are limiting the productivity of this firm?**

   _____

   _____

   _____

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CERTIFICATION

The undersigned certifies that the information herein replied in response to this questionnaire is complete and correct to the best of my knowledge. The U.S. Code, Title 18 (Crimes and Criminal Procedure), Section 1001, makes it a criminal offense to willfully make a false statement or representation to any department or agency of the Unites States as to any matter within its jurisdiction.

(Signature of Authorized Official)	(Date)
(Type or Print Name and Title of Authorized Official)	(Area Code/Phone Number)
(Type or Print Name and Title of Person to Contact Regarding This Report)	(Area Code/Phone Number)

GENERAL COMMENTS

Please use the space below to provide any additional comments or information you may wish regarding your operations, or other related issues that impact your firm.

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