WELDING IN ENGINEERING CURRICULA

By

LYNN J. CHRISTENSEN

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THESIS AND ABSTRACT APPROVED:

E. P. Chandler
Thesis Adviser

Glenn Smith
Faculty Representative

A. C. McIntosh
Dean of the Graduate School

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CHAPTER I

THE NATURE OF THE STUDY

When a new process is developed, it is quite rapidly adopted by industry. Industry is very much interested in anything new that may help speed up production, or in some other manner help put a better product on the market at a lower price. Educational institutions seem to wait until a process has been proven in industry before introducing it into the appropriate courses. This investigation is concerned with the introduction of welding into engineering curricula.

Statement and purpose of the problem. Welding is fundamentally a new technique which enables man to join metals together. The term "welding" includes the processes of cutting, shaping and joining metals in order that they may be utilized in the most effective combinations. As an industry, welding has grown very rapidly. Fifty years ago, it was only on an experimental basis that metals were being joined by welding. It would have been impossible for those early welding enthusiasts to have predicted the broad application which the welding industry knows today. From that crude art of very limited application, welding has become one of the most important tools of industry. The resulting products are not only cheaper, but superior and more durable. Welding offers four essential industrial freedoms: (1) freedom from excess weight, (2) freedom in improvement of design, (3) freedom from structural weakness, and (3) freedom to use materials where they are best suited. Fabrication by welding methods saves both time and money. Many important improvements in welding have occurred in the last few years. These improvements have extended the field of practical application of the process. They have increased the rate of weld production and enhanced the physical values of weld metal. Thus welding now obtains new and greater economies than ever before. "Design is closely allied with the application of welding. Welding allows the designer greater latitude in selection of material and its utilization."[1] Never before in history has any single industrial process played as vital a role as that now being performed by welding.

The progress made by the welding industry is due largely to the recognition, by the more progressive manufacturers, of the usefulness of welding as a tool of both repair and fabrication. Although welding has been used in industry for many years, it has only recently been introduced into engineering curricula. Engineers have studied antiquated methods of fabrication by welding methods in order to practice their profession successfully. The purpose of this investigation is to determine the manner in which the engineering schools of the United States are meeting this new demand.

Importance of the study. Education, as an institution, has been accused of being twenty or more years behind times in most fields of endeavor. Leaders in many fields feel this is a satisfactory arrangement; the students get basic ideas and the fundamentals of the field while in school, and then devote as much time as is necessary to apprentice type work where they learn about the latest developments and present practices and processes being used in their field of interest. Mr. Robert S. Green

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[1] Procedure Handbook of Arc Welding Design and Practice, p. iii.

of Ohio State University says:[2]

> Many persons regard the practice of welding as a new untested process which may come into general use sometime in the future. This point of view was out of date at least fifteen years ago, and with their many advantages and disadvantages the welding processes have taken a predominant place in industry. Welding has already replaced established forms of fasteners in many phases of fabrication, and yet many of our technical institutions are content either to ignore or to sit on the sidelines and wait to be convinced.

World War II gave a tremendous impetus to the welding industry. The developments of welding in the past ten years have indeed been great and far-reaching. The engineer who is twenty years behind the present welding processes is a lost engineer. A few institutions have a course of study leading to a degree in welding engineering or welding technology. These more progressive schools have recognized a need for such a course of study, and have recognized the truly broad scope of welding. This investigation will be concerned with the teaching of welding to students of other engineering fields who need to have some knowledge of welding. One of the reasons educational systems have failed to keep abreast of the latest developments in industry has been that they have been content to wait until someone else makes the first move. Some of the schools, recognizing the need, have made the necessary adjustments in curricula to include the teaching of welding in an adequate manner. Perhaps this investigation will encourage others to follow without further delay.

<u>Methods and procedure</u>. In order to achieve a meaningful investigation, the following procedures were used:

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[2] Robert S. Green, "A New Emphasis on Welding and Heat Treatment for Mechanical and Industrial Engineers," <u>Journal of Engineering Education</u>, (March, 1948), 496-499.

1. A series of conferences were held with the advisors of the thesis and others interested in the problem, wherein the purpose and importance of the study were discussed.
2. A search of periodical and catalog indexes was made for information of related nature and for previous studies on the subject.
3. A study was made of the college catalogs, from the various institutions, that were available at the Oklahoma Agricultural and Mechanical College Library.
4. A questionnaire was developed and sent to the accredited institutions.[3] The questionnaire was examined by several interested persons at Oklahoma Agricultural and Mechanical College, and corrections and improvements made before it was sent to the participants. The questionnaire was accompanied by a letter of introduction and explanation. A follow-up letter was sent to the institutions from which there was no response to the original letter and questionnaire. These letters and the questionnaire appear in Appendix D.
5. Arrangements were made with the American Welding Society for possible publication of a summary of results and recommendations.

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[3] Engineering education is characterized by a wide diversity of curriculums. In 1945 the Engineers' Council for Professional Development, which acts as the accrediting agency of the major professional engineering societies, recognized fifteen separate undergraduate programs, as well as a number of technical subdivisions of the major fields. In 1945 there were approximately 166 degree-conferring engineering schools and departments in the United States. Of these schools, 133 had one or more curriculums accredited by the Engineers' Council for Professional Development. See also, Harry P. Hammond, "Engineering Education," Collier's Encyclopedia, First edition, VII, 275-276. Theresa B. Wilkins, Accredited Higher Institutions, Federal Security Agency Bulletin 1949 No. 6, p. 3.

6. Tables to be used in presenting the information were outlined before the questionnaires were sent out.

Limitations. The scope of this investigation is limited to those institutions having accredited courses in some field of engineering. There are many schools teaching engineering courses that have not been accredited; however, it was felt that since the accredited schools are so well distributed geographically, the results would be representative of the trend in all engineering schools in the United States. The questionnaire was limited to three pages for the purpose of getting maximum response without over-burdening the respondents. The questions on the questionnaire were made as objective as possible; however, some misinterpretation may have occurred.

Organization of chapters. The chapters are organized in the following manner: (1) Chapter I--The Nature of the Study, (2) Chapter II--History and Review of Literature, (3) Chapter III--Presentation and Analysis of Data, and (4) Chapter IV--Conclusions, Recommendations, and Summary. The information involved lends itself quite well to an analysis through the use of tables and check sheets. The information was gathered with this in mind and most of the facts will appear in tabular form.

CHAPTER II

HISTORY AND REVIEW OF LITERATURE

In this chapter a short summary of the development of welding is presented. Literature concerning other studies of welding for engineers, including surveys of various schools which indicate the trend toward including welding in the curricula, have been reviewed.

History of the development of welding. The wide application of welding, as it is known today, has been of recent development. However, welding has had a limited application for thousands of years. Records exist which indicate forge welding was common 2,000 years before Christ and may have been known even earlier.[1]

The origin of electric arc welding is not too well known. There is evidence that the electric arc was discovered at the beginning of the nineteenth century by Vasili Dimitrievich Petrov, in the Medical Academy at St. Petersburg, Russia.[2] Toward the end of the nineteenth century, the idea of using the arc for the welding of metal and its first practical application was developed by Bernados and Slavinav, Russian scientists and technicians. "Bernados secured his earliest patent of electric arc welding in 1885, in Germany,...this method of arc welding was patented in all European countries as well as the United States."[3] Further experimentation by Bernados brought about many inventions to improve welding processes and arc characteristics of electrodes.

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[1] Boniface E. Rossi, Welding and its Application, p. 47.

[2] Vasili Dimitrievich Petrov, Information on Experiments with Galvano-Volts, pp. 163-164.

[3] Gilbert S. Schaller, A Chronicle of Arc Welding, p. 3.

Mr. Chaffee, of the Hobart Trade Schools, discusses the development of arc welding, in the United States, in the following statement:[4]

> The first really commercial application of arc welding is said to have been made about 1910, but it was the emergency conditions of the first World War that gave it real impetus in its development as an industrial process of magnitude....Early in the decade following 1920, there were introduced into this country from Europe special electrodes that produced far better results in arc welding than were possible with the bare rods. They carried a heavy coating, applied by winding and dipping, which method made them so expensive that they did not acquire a very wide commercial acceptance.

This was the beginning of the use of coated electrodes, from which have been developed the many classifications of electrodes that are available today.

It is sometimes difficult to realize that the development of the oxy-acetylene process of welding has taken place during the past fifty years. The development of the oxy-acetylene process is presented by The Linde Air Products Company as follows:[5]

> The experimental basis for the development of the oxy-acetylene process was the discovery by Le Chatelier, A French chemist, in 1895, that the combustion of acetylene with oxygen produced a flame having a temperature far higher than that of any gas flame previously known. The commercial success of the oxy-acetylene process depended upon the availability of both oxygen and acetylene in sufficient quantities. By a most interesting coincidence, work was progressing, almost simultaneously with Le Chatelier's announcement, on two other processes which were destined to insure this commercial success. In May, 1892, a method for the production of calcium carbide, the substance from which acetylene gas is produced, was discovered at Spray, N. C. In 1895 a machine for the production of liquid air was placed in operation. This machine was the forerunner of the present process for the manufacture of commercial oxygen. It is little short of amazing to note that the bringing together of the results of these two investigations--the one at the extremely high temperature of the electric furnace and the other

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[4] W. J. Chaffee, Practical Arc Welding, pp. 11-13.

[5] The Linde Air Products Company, The Oxy-Acetylene Handbook, pp. 15-16.

> at the almost unbelievably low temperature of liquid air--should yield a process which can unite or sever metals.
>
> In 1901 blowpipes of a practical type were introduced, and by 1903 the process began to be used industrially. As experience was acquired, the foundation was laid for the techniques necessary for the welding of the various metals.

Transporting acetylene gas under pressure presented a problem at first. Acetylene gas (C_2H_2) tends to break down into its components when compressed at pressures greater than fifteen pounds per square inch. By constructing a cylinder packed full of porous material--the porous material being impregnated with acetone, in which acetylene gas will dissolve--it was possible to safely transport acetylene under high pressure. With acetylene and oxygen available in convenient forms, the oxy-acetylene industry grew rapidly.

Resistance welding, which today has a particularly broad application in sheet metal industries, was discovered as discussed in the following statement by Mr. R. T. Gillette:[6]

> Resistance welding was discovered by Professor Elihu Thomson early in 1877 when he discharged a Leyden battery through the fine wire secondary of a Ruhmkorff coil with the coarse wire of the primary terminals in contact with each other.

Other welding methods have widened the application of welding until now there are over forty methods of welding the many metals in use. As new alloys are developed, the manufacturers of welding machines will make the type of welding machine needed for particular applications.

Scope of engineering curricula. Many institutions are taking steps to broaden the educational base for engineering students. There has been

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[6] R. T. Gillette, "Materials and Methods Manual 31," Materials and Methods, (November, 1947), p. 98.

considerable discussion about what should be included in engineering curricula. Some institutions have adopted a five-year curricula in engineering schools; others are attempting to meet this demand within the scope of the four-year curricula. This need for a wider educational base for engineers is causing many well established courses of technical and shop nature to be examined carefully as to their efficiency and necessity.

Ohio State University has met the portion of this problem which concerns welding in the following manner:[7]

> All of the work of the engineering shops was examined to determine whether the technical training obtained in them was of sufficient quality and quantity.
>
> We did not feel that our shops were accomplishing much in engineering training, and further, that during the short period of contact between the craftsman and the student, not a sufficient amount of skill and experience was obtained to effect any significant change in the subsequent professional status of the engineer. Consequently, the shops must be made to carry their full weight in engineering training or be discontinued in favor of other courses.
>
> Of the two possible choices, Ohio State chose to retain the work of the shops, and to present the material from the engineering standpoint. It is felt that more can be taught concerning the materials, the machines, and the processes of modern industry in the shops than in other possible courses. There are in addition certain by-products derived from the shop program. The student learns to appreciate the work of the skilled mechanic in the industrial organization; the student gains some knowledge of shop procedure and basic safety precautions; the student gains in selfconfidence; and last and in this case the least important, the student acquires some small manual skill. He is then left with a basis for future courses in safety, quality control, design, and management, and a corresponding advantage in his first positions of responsibility.
>
> The definite function of the course in Welding and Heat Treating is to illustrate the forming and treatment of metals for the tools of industry, and to provide the foundation for the use of the welding processes in production and construction fields.

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[7] Green, <u>loc</u>. <u>cit</u>., pp. 496-499.

> The specific aims of our course in Welding and Heat Treating are to develop an understanding of the heating and cooling cycle in ferrous metals, to study metals from the physical standpoint, and to integrate the knowledge of the physical and metallurgical properties of metals, as a basis for comprehension of the welding process.

The course includes two one-hour lectures each week, and two two-hour laboratory periods, and is of ten weeks duration. The students have sufficient time in the shop to become well grounded in visual inspection, and are able to distinguish readily the signs of competent welding.

Developments in welding at Rensselaer Polytechnic Institute. A welding course and laboratory have been developed at Rensselaer Polytechnic Institute which is based on research and experimentation rather than on practical experience for the engineering students. In describing the welding course for engineers, Mr. Wendell F. Hess, of that institution, states:[8]

> An open and unbiased discussion of the principal spheres of usefulness of all processes and of controversial subjects--such as electric *vs*. gas, welding *vs*. riveting as a tool of construction, welding *vs*. casting as a method of manufacture, direct current *vs*. alternating current, acetylene *vs*. other gases for cutting--has always been an aim of the course, since it is felt to be most helpful for prospective engineers. Much of their contact with welding as engineers after graduation will be through the medium of highly prejudiced individuals....The variety of the equipment is wide, the number of any one kind is very small. Our idea more nearly parallels the newer idea in the working of metals, that it is better to have a variety of useful machines such as a small rolling mill, hydraulic press, drop forging machine, etc., on which the students shall work in groups, than to have a lot of simple blacksmith forges for the students to make ornamental iron work. We feel that it is more important for our future engineers to understand the principles, than to spend any considerable amount of time merely acquiring manipulatory skill. We expect in our theory courses and in our laboratory to familiarize the student engineer with the methods

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[8] Wendell F. Hess, "Developments in Welding at Rensselaer Polytechnic Institute," *Welding Journal*, (November, 1938), pp. 14-18.

now used in welding and to make it possible for him to use his judgment in selecting the best method for his particular applications.

In addition to its use as an attribute in the training of the undergraduate engineer, the laboratories will provide opportunities for research in welding....

Rensselaer Polytechnic Institute offers a three-month summer course, to be taken after the junior year of school work, which gives the students an opportunity to get some practical "on-the-job" experience under the observation of prospective employers.[9] The objectives of the welding courses, at the various schools, may differ considerably and still serve the needs of the respective areas. The type of jobs available to the students when their school work is completed should determine what kind of welding should be stressed in a given locale.

Recent welding survey made at Oregon State College. In 1948 Mr. Asa A. Robley, Assistant Professor of Industrial Engineering at Oregon State College, made a survey of welding at that institution to show what the school was doing concerning welding for the engineering and technical students. In the report of this survey Mr. Robley states:[10]

The phenominal growth of welding as a production process during the last twenty years makes it necessary to increase the emphasis on welding in the courses offered in engineering and technical schools. Few indeed are the graduating students from these schools who will not have at least some contact with welding when they get on the job. Many of them will enter industry and be face to face with large-scale operations using all of the various types of welding. Others will enter firms where they will have the opportunity to introduce welding or to increase its use beyond the "maintenance only" niche that it has often occupied in the past.

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9 "Engineering Education at Rensselaer Polytechnic Institute," Science, (November, 1940), p. 395.

10 Asa A. Robley, "Welding in Engineering and Industrial Arts at Oregon State College," Unpublished college report, p. 1.

> The Department of Industrial Engineering and Industrial Arts at Oregon State College is therefore increasing both the facilities for and the number of courses in welding.

Four welding courses are now being taught at Oregon State College. An analysis of the number of engineering students taking these courses is presented in Table I.[11] Perhaps one of the reasons for increased interest about welding in Oregon stems from the fact that there was a great deal of welded fabrication done, during the recent war, on ships and other products in that state. Of the eight engineering curricula represented in Table I, five include welding as a required subject. Almost nine times as many students are required to take welding as are allowed to elect welding. The four courses now being offered at Oregon State College are described by Mr. Robley as follows:[12]

> IE 250--Forging and Welding--2 credits--1 lecture and 1 four-hour laboratory period per week. A beginning shop course which combines welding and flame cutting with heat-treating and forging.
>
> IE 354--Welding Processes--2 credits--2 lecture and 1 hour laboratory period per week. This course will permit a more thorough study of the various welding processes, building upon the background established in IE 250.
>
> IE 355--Welding Production--2 credits--2 lectures and 1 two-hour laboratory period per week, a study of the various welding processes and how they can be employed most profitably on a productive basis.
>
> IE 356--Welded Product Design--2 credits--1 lecture and 1 two-hour conference period per week, a study of the design of various products and structures so that they can be welded most effectively, efficiently and economically.

This may seem to be more welding than would be necessary for engineering students in many states; however, the students at Oregon State College

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[11] Ibid., p. 2.

[12] Ibid., pp. 3-6.

TABLE I

WELDING IN ENGINEERING CURRICULA AT OREGON STATE COLLEGE

CURRICULA	COURSE							
	IE 250 Forging and Welding		IE 354 Welding Processes		IE 355 Welding Production		IE 356 Welded Product Design	
	Required	Elective	Required	Elective	Required	Elective	Required	Elective
Agricultural Engineering	10		10					
Chemical and Metallurgical Engineering		10						
Civil Engineering		10		5				
Electrical Engineering	130			10				
Forest Products Engineering		10						
Industrial Administration	60		50		40			20
Industrial Engineering	50		40			20		10
Mechanical Engineering	130			10				
Total required per year	390		100		40		0	
Total elective per year		30		25		20		30
Total students per year	420		120		60		30	

will undoubtedly find it very useful.

Welding Equipment at Oregon State College. Oregon State College is taking advantage of the opportunity to get War Surplus Materials as indicated in the following statement:[13]

> Considerable new equipment for some types of welding has been obtained from the War Assets Administration which could not have otherwise been obtained. The favorable position occupied by the schools in the W. A. A. disposal program had made it possible for limited equipment budgets to be spread over several types of equipment instead of having to be spent entirely on perhaps one single item....Of course most items obtained from the W. A. A. were manufactured prior to 1944 and have been superseded by improved models but at least the school shops will not be so far behind industry for a while in the vintage of their shop equipment.

A list of the equipment that is either available now or will be during the year 1950 at Oregon State College is presented in Table II.[14]

Welding Engineering at Ohio State University. Recently, a report was given by Mr. R. S. Green to the American Welding Society at The Ohio State University on training in welding engineering.[15] Welding engineering, as described by Mr. Green, involves knowledge of three basic areas in engineering:[16]

> ...(1) the design of machines, structures and equipment as well as the design of suitable connections; (2) the materials of engineering with particular reference to metals, gases and

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[13] Ibid., p. 7.

[14] Ibid., pp. 8-9.

[15] Presented at the Thirtieth Annual Meeting, American Welding Society, Cleveland, Ohio, week of October 17, 1949, by R. S. Green, Acting Chairman, Department of Welding Engineering, The Ohio State University, Columbus, Ohio.

[16] R. S. Green, "Welding in Engineering Education," The Welding Journal, (April, 1950), p. 311.

TABLE II

WELDING EQUIPMENT AT OREGON STATE COLLEGE

Equipment	Number	Equipment	Number
Oxy-acetylene stations	16	Welding positioner	1
Portable oxy-acetylene welding outfit	1	Forging furnaces	4
Portable oxy-acetylene cutting outfit	1	Forging hammers (power)	2
Oxy-acetylene contour cutting station	1	Motor driven press	1
Oxy-acetylene cutting stations	3	Bending rolls (power)	1
Electric arc welding machines	15	Shear (power)	1
Atomic-Hydrogen Welder	1	Oven furnaces (gas)	2
Heliarc Welder	1	Pot furnace (bath)	3
Spot Welder	3	Drill presses	3
Submerged arc welder	1	Grinders	3
		Hacksaws (power)	2
		Cutoff machine	1
		Jib-crane	1

This shows only the major pieces of equipment. None of the small power or hand tools are included in this list.

> refractories; and (3) the processes and procedures of the welding industry. The practice of Welding Engineering includes such professional service as consultation, investigation, evaluation, planning, design or responsible supervision of construction or manufacturing, when such professional service requires the application of engineering principles and data.

The designing of the curriculum in welding engineering was governed by a philosophy, the major tenets of which are:[17]

> ...(1) That training shall be firmly based in mathematics and the physical sciences, (2) that the technical training or the training in the application of science shall be broad as possible, (3) that it is the job of the university to give scientific training and that it is the job of industry to provide the experience required to complete the education of an engineer, and (4) the purpose of the technical or applied science courses is to teach basic scientific principles and to show their relationship to engineering, not merely to provide a collection of unrelated data and skills.
>
> We feel that the very nature of the welding field is such as to preclude the possibility of training for a narrow area of specialization. It is concluded that a high degree of specialization would be a distinct disservice to industry and students alike. It is perhaps an oversimplification but indicative nevertheless to define our purpose to be that of training men to make things out of metal....

The duration of training is five years as adopted by the engineering college of The Ohio State University. Table III is a summary of the requirements of the welding engineering curriculum and expresses in terms of academic hours and on a percentage basis the relative weight assigned to each portion of the curriculum.[18] Table III certainly indicates a broad engineering base which when coupled with actual industrial experience should produce a well qualified welding engineer. According to Mr. Green, "The shortage of experienced welding engineers has placed graduates of the department in an enviable position with respect to employment and

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17 Ibid., p. 312.

18 Ibid., p. 313.

TABLE III

REQUIREMENTS FOR THE DEGREE BACHELOR OF WELDING ENGINEERING AT THE OHIO STATE UNIVERSITY

Course	Hours	Per cent of total
Mathematics	39	13.91
Physics	15	5.36
Chemistry	12	4.29
English	9	3.21
Engineering Drawing	15	5.36
Survey of Engineering	3	1.07
Military Science	12	4.29
Physical Education	4	1.43
Economics	6	2.14
Psychology	3	1.07
Mechanics	19	6.79
Metallurgy	12	4.29
Mechanical Engineering	20	7.14
Electrical Engineering	12	4.29
Civil Engineering	8	2.86
Industrial Engineering	16	5.71
Welding Engineering	27	9.64
Technical Elective	15	5.36
Nontechnical Elective	33	11.80
Total	280	100.00
Inspection trips	4	
Industrial Experience	12	

compensation."[19] Since The Ohio State University is the only institution to have such a curriculum, there is no opportunity to compare the curriculum with others. The curriculum can instead be judged by forthcoming students.

The gulf between welder and engineer. Unfortunately, there seems to be an ever-broadening gulf between the welder and the engineer. The increasing technicality of information published by welding periodicals written for men with engineering backgrounds tends to make this gulf a serious problem. Many engineers leave such things as the choice of joint design to the welding operator who is unqualified to make the proper choice. The need to have a better understanding between the engineer and the welding operator is discussed by Mr. Thomas J. Barry as follows:[20]

> It is astounding to continually discover the number of welders and supervisors who have no understanding whatever of so simple a subject as our A. W. S.-A. S. T. M. classification of electrodes, and any mention of arc characteristics, electrode physicals or metallurgy immediately becomes a barrage of double talk that leaves them feeling very much relieved when you go away.
>
> ...We of the AMERICAN WELDING SOCIETY have continually expanded our knowledge and understanding of various welding processes, but the men in the plants have remained at a static level, except in the case of a few companies who have the technical men and other facilities to rely upon.
>
> ...It was the war that gave welding its greatest impetus, and at the same time produced its greatest deficiency, namely, the lack of basic understanding.
>
> How can we expect a welder as a craftsman to match completeness of knowledge with the rich background possessed by the craftsmen and masters in other fields? How can we talk to

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19 Ibid., p. 315.

20 Thomas J. Barry is Welding Engineer Specialist, Harnischfeger Corporation, Chicago, Illinois. Thomas J. Barry, "Advanced Training for Welders and Supervisors," The Welding Journal, (July, 1949), pp. 639-641.

> these persons if they do not have a basic understanding of what we are trying to say?
>
> The general run of welding personnel are not people who have made an intensive study of the intricacies of welding, but are persons who know very little of many things which we take for granted, even though they are connected with welding in some capacity. This includes not only welders and supervisors, but also time study, design, engineering and other high level departments of industry....

Mr. Barry proposes to lessen the gap by an educational program for the welders and supervisors. This is of course a fine thing to increase understanding of the welder so that he might better cope with problems of the engineer. How can the engineer have an understanding of the problems of the welding operator unless he too becomes better acquainted with the actual applications of the various welding methods? Mr. W. E. Johnson, an engineer for General Electric Company, expresses his feelings concerning how engineers should become acquainted with welding when he states, "Direct observation and experience is perhaps the best method of learning...."[21] The engineer who has had some practical experience with the application of welding will better understand the the problems of the welding operator and can design the joints to be welded more efficiently.

Welding at the Case Institute of Technology. Mr. G. B. Carson, of the Case Institute of Technology, points out the importance of a good understanding of welding to the mechanical engineering student. The feeling toward welding and the type of welding course offered at that institution is discussed in the following quotation from Mr. Carson:[22]

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[21] W. E. Johnson, "Designing for Production," Mechanical Engineer, (May, 1947), 380-382.

[22] G. B. Carson, "Welding Course for Mechanical Engineering Students," Welding Journal, (August, 1940), 584-587.

Welding has become such an important method of fabrication in almost every mechanical goods industry that its omission in a mechanical engineering curriculum would be open to serious criticism.

To teach welding merely as a skill of manipulation would be grossly insufficient from the standpoint of the mechanical engineering student. It is unquestioned that operator skill must play an important part in the results obtained from any manual welding process, but beyond such skills the engineer must have a complete and thorough understanding of the processes and physical properties available to him in commercial practice. He must, in addition, understand the fundamentals of design and performance characteristics of the various types of arc, gas, electric, resistance, and atomic hydrogen welding equipments available as industrial tools.

The college makes no attempt to compete with the many excellent trade schools, and consequently does not propose to turn out qualified welding operators. It does try to turn out engineers thoroughly grounded in the fundamental theory and practice of welding.

Three hours per week are devoted to lecture-recitation, and three hours per week to laboratory practice, during one semester. The course involves: (1) gas welding, cutting, fuel gases and cutting effects; (2) electric arc welding and equipment, factors influencing welding, automatic arc welding, and electrodes; (3) weld testing, non-destructive tests; (4) electric resistance welding, spot, and automatic resistance; (5) thermit welding, atomic hydrogen welding; (6) brazing and soldering, bronze welding of cast iron; (7) welding low alloys steels, and stainless steels; (8) welding copper alloys, and aluminum alloys; (9) welding pressure vessels, welding of boilers; (10) aircraft structures; (11) welded machine structures, jigs and fixtures for welding; (12) welding design.

Welding technique is taught in the Industrial Division, and this division cooperates closely with the design division to prevent overlap and promote course coordination. The photoelastic stress analysis method is also fully covered in the design division.

Laboratory work is divided in three parts, oxy-acetylene welding and cutting, arc welding processes and field trips. Reports are written on each major laboratory assignment, and emphasis is placed on analysis of results in an attempt to create ability on the part of the student to "trouble shoot" causes of welding defects and point out remedies, since this is regarded as an important part of the mechanical engineer's duty. The college department has X-ray apparatus capable of radiographic analysis of welds...

The student engineer who completes such a course as described by Mr. Carson has an excellent welding background and should be able to cope with problems that may confront him.

Review of college catalogs. A study of engineering catalogs was made to determine the importance attached to welding by the various institutions, as indicated by the catalog summary of engineering courses which might contain welding in some form. Table IV shows the manner in which welding is presented to engineering students as indicated by the catalog study. These figures compare favorably with information gathered from the returned questionnaires, as noted in Chapter III. Welding seems to be represented reasonably accurately in the school catalogs.

Summary. In Chapter II a brief description of the development of welding has been presented. Several leading welding methods are discussed from the standpoint of dates of discovery and rapidity of growth and expansion. The wide application of welding today is of recent development; however, there has been a limited application of welding, by the forging process, for thousands of years.

TABLE IV

CATALOG STUDY OF WELDING FOR ENGINEERS

	Per cent*
Schools offering welding courses for engineers	42
Schools requiring welding courses in their engineering curricula	22
Schools not requiring any welding in engineering curricula	16
Schools offering courses such as manufacturing processes which include some welding	44
Schools not offering welding in any form	12

* The summation of the per cent column is over 100 per cent because of overlapping of many schools under the various headings.

Few studies of a related nature have been made. A review of the literature, concerning welding for engineering students, from Oregon State College, Ohio State University, Rensselaer Polytechnic Institute, and The Case Institute of Technology has been presented. The importance of having the engineer and the welding operator understand each other's problems has been discussed. The manner in which welding is presented in the college catalogs is also discussed.

CHAPTER III

PRESENTATION AND ANALYSIS OF DATA

This chapter will present information gathered from the returned questionnaires. Lists of the schools to which questionnaires were sent, and those schools from which returns were received will be found in Appendix B. The questionnaire and related letters appear in Appendix D.

Respondents. Of the 134 questionnaires which were sent, 117, or eighty-eight per cent, were either returned or a letter was written explaining the situation concerning welding at the respective institutions. The questionnaires and the letters of introduction were addressed to the Deans of the schools of engineering of the 134 institutions. The questionnaires were completed by the Deans or were referred to the various engineering departments as indicated in Table V. A total of fourteen departments are represented in the replies. The greatest number of answers received were completed by the following two groups. The deans of the various institutions answered a total of sixty questionnaires or fifty-one per cent of the total number returned. The mechanical engineering department faculty returned thirty-four questionnaires or twenty-nine per cent.

Representation of states. All of the states in the Union have at least one engineering curricula which has been accredited by the Engineers' Council for Professional Development; therefore, at least one questionnaire was sent to an institution in each state. Since the most heavily populated states have the largest number of accredited engineering institutions, a greater number of questionnaires were sent to institutions in

TABLE V

ANALYSIS OF RESPONDENTS BY DEPARTMENTS

Respondent	Number	Per cent
Deans	60	51.
Architectural	1	.85
Chemical	1	.85
General	2	1.7
Industrial	4	3.4
Mechanical	34	29.
Metallurgy	3	2.55
Metal processes	1	.85
Engineering shop	5	4.45
Manufacturing Processes	2	1.7
Industrial Arts	1	.85
Welding Engineering	1	.85
Machine Design	1	.85
Administrative Engineering	1	.85
Totals	117	100.00

those states. Forty-six states and the District of Columbia were represented in the returns. No returns were received from New Hampshire and Virginia. The industrial development in these states has been comparatively slight and thus welding may not seem important.

Departments that offer welding. A total of fourteen different titles were given by respondents as the official title of the department in which welding was being offered or taught to engineering students at the various institutions. The mechanical engineering department, as indicated in Table VI, is the department responsible for welding in the greatest number of institutions. Forty-five, or approximately sixty per cent, who answered this part of the questionnaire, indicated that welding was taught by the mechanical engineering department. The metallurgical engineering department was second highest with seven institutions, or approximately nine per cent, reporting this department as the one teaching welding. Only one institution reported having a welding engineering department--this was at The Ohio State University. Utah State Agricultural College has a welding unit in the metalwork department which offers a four-year curriculum in welding for the engineering students at that institution.

Welding required or elected. Of the sixteen engineering curricula listed in Table VII which are accredited by the Engineers' Council for Professional Development,[1] the students in mechanical engineering are required to take welding at the greatest number of institutions. This is to be expected since it is the mechanical engineering department that offers welding at most of the institutions as indicated in Table VI. A total of

[1] Wilkins, op. cit., pp. 92-103.

TABLE VI

DEPARTMENTS THAT TEACH WELDING TO ENGINEERING STUDENTS

Department	Number	Per cent
1. Administrative engineering	1	1.33
2. Agricultural and mechanical	1	1.33
3. Civil engineering	2	2.66
4. Economics of engineering	1	1.33
5. Engineering shops	3	3.99
6. General engineering	4	5.44
7. Industrial Arts department	1	1.33
8. Industrial engineering	3	3.99
9. Industrial Education department	3	3.99
10. Manufacturing processes department	1	1.33
11. Mechanical engineering	45	60.00
12. Metallurgical engineering	7	9.35
13. Metal processing department	1	1.33
14. Metalwork department, welding unit	1	1.33
15. Welding engineering	1	1.33
Totals	75	100.00

TABLE VII

WELDING FOR SIXTEEN ENGINEERING CURRICULA

Curriculum	Number of accredited institutions*	Number of respondents from accredited institutions	Total number of respondents for Question Four**	Welding required	Per cent	Welding elective	Per cent
1	2	3	4	5	6	7	8
1. Aeronautical	41	34	28	22	79	6	21
2. Agricultural	4	3	16	11	69	5	31
3. Architectural	17	13	8	4	50	4	50
4. Ceramic	11	9	4	1	25	3	75
5. Chemical	55	46	27	16	60	11	40
6. Civil	120	98	30	12	40	18	60
7. Electrical	126	104	42	28	67	16	33
8. Fuel technology	2	2	2			2	100
9. General	8	7	14	6	43	8	57
10. Industrial	29	24	33	26	79	7	21
11. Mechanical	107	87	63	58	92	5	8
12. Metallurgical	37	27	20	10	50	10	50
13. Mining	32	26	11	4	36	7	64
14. Naval architecture	4	3	2			2	100
15. Petroleum	19	18	10	4	40	6	60
16. Sanitary	29	27	8	1	12	7	88
Totals				203		107	

Column (2) of this table gives the total number of institutions that have either had the above curricula accredited or have them as options of other accredited curricula. Not all of the respondents answered each question. This necessitated having two columns, (3) and (4), in place of just one. The per cent columns are based only on those respondents who answered the question on this particular subject.

* Wilkins, op. cit., pp. 92-103.

** See Appendix D.

fifty-eight respondents indicated that welding was a required subject for mechanical engineering students at the respective institutions. Table VII lists the sixteen accredited engineering curricula and indicates those in which welding is either required or an elective. This table shows only the fact that some kind of welding program is required or may be elected--the particular type of welding courses offered will be discussed later in this chapter. It is significant that there are over eleven times as many institutions which require mechanical engineering students to take welding as there are institutions that offer welding as an elective for these students. This tendency, although not so pronounced, is noticeable in the totals where, as the summation of all the curricula, there is a ratio of approximately two required to each one elected.

The number of institutions wherein the students may elect welding exceeds those where welding is required in only seven curricula. These seven curricula include fields in which the application of welding would be limited, or in which the importance of welding is at least minor. Only four institutions have an accredited curriculum in agricultural engineering. Respondents from eleven institutions indicate welding is required in agricultural engineering. Welding may be elected as part of agricultural engineering in five additional institutions. This indicates that many institutions, where the agricultural engineering curricula are not yet accredited, require students to take some welding when studying in that field. This is significant since it indicates that welding is not just an after-thought, but is being considered as an important subject in the development of curricula, which may soon become accredited, in those institutions.

Other curricula. In addition to the sixteen accredited curricula listed in Table VII, the respondents named five others, in which welding was required, that might be considered as non-accredited engineering curricula. These curricula are listed in Table VIII. Just as the welding

TABLE VIII

NON-ACCREDITED CURRICULA SUGGESTED BY RESPONDENTS

Curriculum	Required	Elective
1. Engineering physics	1	
2. Textile engineering	1	
3. Forestry engineering	1	
4. Automotive engineering	1	
5. Welding engineering	1	

industry is growing, so might these other courses grow and become standard accredited curricula at some time in the future. The last of the suggested courses, welding engineering, has been developed at Ohio State University during the past few years and is the basis for a degree in welding engineering.[2]

Per cent of students that elect welding. Of the respondents who indicated in Table VII that welding may be taken as an elective, a subsequent question was asked to determine the percentage of students actually taking welding as an elective. Table IX gives the results of the forty-eight respondents to this question. One of the respondents reported that the

[2] Although this course has not as yet been accredited by the Engineers' Council for Professional Development, the course is one which is preparing men to be welding engineers. This is an indication of a need for such a course in that area.

TABLE IX

PER CENT OF STUDENTS THAT TAKE WELDING WHEN IT IS NOT REQUIRED

Number of respondents reporting this percentage	Per cent	Number of respondents reporting this percentage	Per cent
1	12	1	4
0	11	2	3
9	10	6	2
1	9	3	1
0	8	12	0
1	7	2	Few or small percentage
0	6		
10	5		

per cent varied with the different curriculums and that at that institution there was a large percentage of the agricultural engineering students that elected welding, but relatively small percentages of the other curriculums did so. This is undoubtedly the case in most of the institutions and the figures presented in Table IX can be considered to be the estimated averages of all the curricula at the institutions. The greatest estimated percentage was that twelve per cent of those students not required to take welding did so, the average of the estimates being six per cent.

Special courses for engineers. Many institutions have developed welding courses especially for engineering students. Fifty of the 117 respondents reported that a welding course designed especially for engineering students had been adopted. The nature of the course varied a great deal, depending upon the needs of the locale. Table X is a list of the schools, listed alphabetically by states, that reported a special course in welding for engineering students. It will be noted that fifty per cent of the respondents that answered this portion of the questionnaire reported that a special course designed for engineering students was being offered. Only two of the fifty respondents indicated that the special course involved lecture only; all of the others included some form of laboratory work. Respondents of six institutions reported that the engineers received only work in the laboratory in the special course. An average of one and four-tenths hours per week are spent in lecture with three schools giving three hours of lecture on welding per week. The average time spent in the laboratory is over three hours per week. The content of the welding course for engineers varies considerably; the amount of time devoted to "design for welding" for example varied from zero to twenty hours with an average of four and one-tenth hours. The time devoted to "procedures, speeds, and costs" follows somewhat the same pattern with a spread from zero to fifty hours and has an average of over nine hours. This can be accounted for to some extent since certain phases of welding may be covered in other courses. Mr. C. Higbie Young of the Cooper Union for the Advancement of Science and Art states on his questionnaire return that:

> ...We have no courses or subjects dealing entirely with welding. The mechanical engineers have a course in Mechanical Processes in the first semester of the third year,...approximately eight hours of this is given to all types of welding.... In the senior year, the subject of Machine Design is given. We devote approximately four hours to the design characteristics of welded joints...the main purpose of this is to acquaint the machine designer with the approach to the problem of welded construction.

Similar statements were made on returns from several of the other institutions, indicating that many engineering curriculums provide for study of "design for welding" in addition to those listed in Table X.

TABLE X

INSTITUTIONS OFFERING SPECIAL COURSES IN WELDING FOR ENGINEERS

Institutions	Semester credits	Quarter credits	Lecture hours	Laboratory hours	Hours devoted to design	Hours devoted to procedures, speeds and costs
1. Alabama Polytechnic Institute, Auburn		1	1	2		
2. University of Arizona, Tucson	2		1	3		
3. Stanford University, Palo Alto		2	1	4	5	10
4. Colorado Agricultural and Mechanical College, Fort Collins		3	1	6		
5. University of Delaware, Newark	2		1	3	0	0
6. University of Florida, Gainesville	3		2	3	4	4
7. Georgia Institute of Technology, Atlanta		1	1	2	4	2
8. University of Idaho, Moscow	2		1	3	10	15
9. Illinois Institute of Technology, Chicago	2		2			
10. Northwestern University, Evanston, Illinois		1	1	2	0	some
11. University of Illinois, Urbana	3		2	3	10	2
12. Purdue University, Lafayette	2		2	4	0	16
13. Rose Polytechnic Institute, Terre Haute	2		1	3		
14. Iowa State College of Agriculture and Mechanical Arts, Ames		2	1	6	some	some
15. State University of Iowa, Iowa City	2		2	4	1	23
16. Louisiana Polytechnic Institute, Ruston	1			3		30
17. Louisiana State University, Batan Rouge	1			3	0	0
18. University of Maine, Orono	1/2		1	4	0	
19. Massachusetts Institute of Technology, Cambridge					1	2
20. Tufts College, Medford		1	1	3	unk.	unk.
21. Michigan College of Mining and Technology, Houghton		1+	1	2		2
22. University of Michigan, Ann Arbor	2		1	3	3	5
23. Wayne University, Detroit, Michigan	2		1	3	2	2
24. University of Minnesota, Minneapolis	3		2	3	2	1

TABLE X (Continued)

Institution	Semester credits	Quarter credits	Lecture hours	Laboratory hours	Hours devoted to design	Hours devoted to procedures, speeds and costs
25. Mines and Metallurgy, Rolla	1			3	1	0
26. Washington University, St. Louis	2		1	3	10	10
27. Montana State College, Bozeman		2		4	0	0
28. University of Nevada, Reno	1		1	2	6	6
29. Stevens Institute of Technology, Hoboken			1	3	0	8
30. New Mexico College of Agricultural and Mechanic Arts, State College	2			6	0	some
31. Cornell University, Ithaca						
32. Rensselaer Polytechnic Institute, Troy	4		3	2+		
33. Syracuse University, Syracuse				3		12
34. State College of Agriculture and Engineering, Raleigh	1			2	0	2
35. North Dakota Agricultural College, State College		2	3		9	30
36. Ohio State University, Columbus		3	2	4	4	4
37. University of Toledo, Toledo	2		1	2.5	9	9
38. University of Oklahoma, Norman	1		3			
39. Oregon State College, Corvallis		6	2	2	20	20
40. Pennsylvania State College, State College	1		1	2		6
41. Agricultural and Mechanical College of Texas, College Station		2	1	6	12	18
42. Rice Institute, Houston	2			6		
43. Texas Technological College, Lubbock	1		1	2	0	
44. University of Texas, Austin	3		1	6	0	
45. University of Utah, Salt Lake City		1	1	2	10	6
46. Utah State Agricultural College, Logan		2	2	4		
47. State College of Washington, Pulman	4		2	6	0	0
48. West Virginia University, Morgantown	2			6		
49. University of Wisconsin, Madison	2		1	3	14	50
50. University of Wyoming, Laramie		2	1	3	0	0
Averages	2	2	1.46	3.4	4.1	9.2

When welding is offered. The respondents were asked to report the year in which the engineering students are scheduled to take the welding course. Table XI shows that only ten institutions have welding scheduled for the freshman year; although, in an additional eleven schools welding may be taken any year. In eighty-five per cent of the reporting institutions, welding is taken after the freshman year. This may indicate that

TABLE XI

THE YEAR IN WHICH WELDING IS TO BE TAKEN

	Freshman year	Sophomore year	Junior year	Senior year	Any year
Number of institutions *	10	39	29	21	11

* These figures do not represent separate and individual institutions, since several of the respondents reported that welding may be taken during more than one year.

the course is of greatest value when the student has had a year or more of other subjects. Mr. H. M. Black of the Iowa State College, recognizing the importance of teaching welding in connection with some metallurgy, made the statement on the returned questionnaire that, "Welding should be taught in parallel with a good course in engineering metallurgy. If it follows such a course, you can really teach welding fundamentals." The engineering faculty at the Rice Institute in Houston, Texas, feels that it is an advantage to teach welding during the fourth year. The questionnaire return of Mr. James Woodburn of that institution has the following statement:

> ...I cannot put our shop courses in the first or second year, and the third year being so crowded, we have placed the shop courses in the fourth year, and feel that it is a decided advantage because the student is more mature and can understand the ideas being presented much more thoroughly.

Comments from the returns of other schools indicate that welding can be better understood and is more valuable to the student if taken after various other engineering subjects.

Welding course content. The respondents were asked to indicate, (1) which welding methods or processes were being taught, (2) whether the methods or processes were taught as a part of a general course or as a special course in welding for engineering students, and (3) whether the course was a lecture or laboratory course. This information is presented in Table XII. The processes that involve oxy-acetylene welding or cutting and those that involve an electric arc welding machine are the ones with the greatest number of respondents reporting. Only in the cases of metallic arc welding and oxy-acetylene welding did the number of respondents who present welding in the laboratory exceed the number of those presenting any type of welding through use of lectures. These two popular processes are apparently being presented in some cases without the benefit of an accompanying lecture. The advantages and disadvantages of this procedure will be discussed later in Chapter IV. The totals show there is a tendency in the entire group to present the various processes by the lecture method and in some cases without an accompanying presentation in the laboratory. Approximately one and three-fourths as many welding processes are offered to engineering students in courses especially designed for engineering students as in courses open to all students. It was rather unexpected to the writer to find a good representation of the comparatively recent welding developments such as the inert gas-arc, metal spray, spot

TABLE XII

WELDING PROCESSES AND MANNER OF PRESENTATION

Process	General course	Special course for engineers	Presented in lecture	Presented in laboratory
1. Forge welding	13	15	31	15
2. Resistance welding	12	25	37	27
3. Metallic arc welding	17	28	39	42
4. Carbon arc welding	14	22	39	23
5. Atomic hydrogen welding	7	16	32	16
6. Inert gas-arc welding	6	17	36	16
7. Air-acetylene welding	3	13	18	10
8. Oxy-acetylene welding	22	31	39	53
9. Oxy-other fuel welding	3	9	19	1
10. Thermit welding	6	15	33	3
11. Gas brazing	19	27	26	37
12. Electric brazing	7	17	26	13
13. Dip brazing	3	12	24	2
14. Furnace brazing	4	11	25	3
15. Oxy-acetylene cutting, manual	27	40	53	47
16. Machine cutting	13	26	33	33
17. Contour machine cutting	4	13	22	9
18. Arc cutting	10	14	25	18
19. Metal spray		3	3	1
20. Spot projection		1	1	
21. Hardfacing	1	1	1	1
22. Automatic arc		1	1	1
23. Soft soldering		1	1	1
24. Silver brazing		1	2	
25. Induction welding			1	
Totals	201	359	567	390

projection, automatic arc, and induction welding processes. Schools possessing equipment for the teaching of these processes include them in the welding course for engineers. These schools certainly are not twenty years behind times.

Materials being welded. There seems to be considerable difference of opinion as to just how much welding practice an engineering student should have. Mr. Robert A. Wyant of Rensselaer Polytechnic Institute summarizes the feelings of many of the respondents concerning the extent of welding practice the engineering students should have when he states, "...we make no pretense of training welding operators so we confine our work to the flat position only." Other such statements include the fact that the opportunity for welding practice was limited to the welding of more common metals. Table XIII is a list of common metals included in welding courses for engineering students and indicates the positions in which those metals are welded by students. The tendency to concentrate on welding in the flat position only is evident in the totals, although a large number do teach welding in all positions.

Bronze and extruded shapes are materials added to the questionnaire list by the respondents--this accounts for the low numbers in these materials. In addition to the information in Table XIII, some of the respondents reported that other materials were welded during demonstrations but were not included in later laboratory practice by the students. Others included such practical welding experience as the repair and fabrication of locally manufactured items.

Welding equipment. Respondents were requested to indicate the type of equipment being used in their laboratories. They listed twelve types

TABLE XIII

COMMON METALS INCLUDED IN WELDING COURSES FOR ENGINEERS AND THE POSITIONS IN WHICH THEY ARE WELDED

Metals	Position in which the metals are welded				
	Flat	Vertical	Overhead	Horizontal	All
Cast iron	32	3	1	3	8
Cast steel	9	3	1	2	5
Low carbon steel	42	14	6	16	17
High carbon steel	13	3	1	5	4
Stainless steel	15	3	2	3	3
Aluminum	23	3	1	3	3
Copper	8	3	1	1	2
Brass	10	3	1	2	5
Sheet metal	21	7	1	4	12
Plate	20	9	3	7	15
Tubing	13	3	3	3	12
Pipe	13	5	5	3	12
Bronze	1				
Extruded shapes					1
Totals	220	59	26	52	99

of equipment in addition to the twelve which were included in the questionnaire. Only fifty-eight per cent of the total number of respondents indicated that welding equipment was available in the school for instructional purposes. The extent to which the various types of equipment are used is indicated in Table XIV. The last twelve items would probably have had higher representation had the items been included in the questionnaire. Some institutions have indicated the joint use, by two or more departments, of such equipment as X-ray machines, magnaflux machines, fatigue and impact machines, and other types of testing and analyzing machines. This is indeed a cooperative and economical plan as it allows better use of the equipment without the added expense of the equipment for each department. Arc welding and oxy-acetylene welding are strong favorites in institutions where engineering students get some actual welding practice with averages of approximately nine work stations for each process in the institutions. Oxy-acetylene cutting and resistance welding equipment is reported by a large number of respondents. The number of units reported is low because the equipment is used by all the students. Such equipment as the photo-elastic, photo-micrographic, and heat treating equipment in schools as shown in Table XIV indicates those institutions feel that welding can be most valuable when taught in conjunction with other courses which use this type of equipment or when the welding course itself includes the use of this equipment.

The feelings of many of the respondents are expressed by Mr. L. A. Moore of the University of Wyoming in the statement, "...we do not have enough modern welding equipment for our engineers." Many institutions were able to get War Surplus Equipment, as indicated in Chapter II, to improve this condition.

TABLE XIV

WELDING EQUIPMENT AVAILABLE FOR TEACHING WELDING TO ENGINEERING STUDENTS

Type of Equipment	Number of respondents reporting	Maximum number of units in any one institution	Average number of units per institution	Number of respondents reporting this type of equipment but not specifying number
1. Arc welding stations	58	28	8.6	5
2. Oxy-acetylene stations	55	49	8.8	5
3. Manual oxy-acetylene cutting	35	9	2.6	4
4. Machine oxy-acetylene cutting	37	2	1	2
5. Contour oxy-acetylene cutting	16	3	1.1	2
6. Resistance welding	44	9	1.6	3
7. Inert gas-arc welding	19	2	1.2	2
8. Automatic welding machines	8	3	1.4	0
9. Equipment for photo-micrographic studies	37			37
10. Equipment for photo-elastic studies	24			24
11. Equipment for tension and bending tests	49	6	2	26
12. Equipment for heat treating welded specimens or projects	47	20	4.3	29
13. Atomic hydrogen welding machine	3	1	1	0
14. Thermit welding equipment	1	1	1	0
15. Magnaflux machine	3	1	1	0
16. Fatigue testing machine	1	1	1	0
17. Impact testing machine	1	1	1	0
18. X-ray machine	3	1	1	0
19. Power shear	2	1	1	0
20. Micro-hardness testing machine	2	1	1	0
21. Lathe	1	1	1	0
22. Drill press	12	2	2	8
23. Grinders	2	4	4	0
24. Induction heating equipment	1	1	1	0

Courses involving some welding. Many institutions provide welding for the engineering students as a part of a general course which may present many common fabrication processes. A total of forty-one of the 117 respondents present welding in this manner. Table XV lists the various course titles in which welding is included and some general information about these courses.

Mr. H. W. Bibber of Union College in New York comments on the manner in which that institution teaches welding to the engineering students as follows:

> At our institution we give civil engineering and electrical engineering only. We have always been light on shop work, scheduling no courses and having no equipment. We depend on frequent inspection trips to the General Electric Company works here, and summer employment in the plant to give our students the familiarity. Welding is discussed in a course in the Jr. year called "Mechanics of Materials" where methods of fabrication are discussed, and where students are taken on inspection trips to Schenectady Works of the General Electric Company where all types of welding are seen. Weldments in structures are presented again to our civil engineers in our courses in Structures and Structural Design. No student ever holds an electrode under our auspices though many have summer jobs where they learn.

In some of the general courses for the engineering students no provision is made for welding practice. However, valuable information can be secured by taking advantage of the opportunity to make local field trips to companies where many types of welding are done. Several respondents indicated that field trips were used to supplement other training in welding. The general courses vary somewhat with twenty-two different course titles reported; and the credits for the courses vary from non-credit courses to others offering up to nine credits. The important point is that even though many institutions cannot schedule welding courses as such, due to a number of limiting factors, welding is included in a general course along

TABLE XV

COURSES INVOLVING SOME WELDING

Title of course	Number reporting	Average credit hours/week	Average number of lecture hours/week	Average number of laboratory hours	Per cent of time spent in welding
1. Introduction to metal-working processes	1	1	1	3	20
2. Manufacturing processes	16	2.5	1.4	3.5	25
3. Production processing	1	2.5	2	0	20
4. Metal processing	2	5	2	2.5	22
5. Machine shop methods	1	2	1	3	50
6. Mechanics of materials	1	1	1	2	60
7. Casting, working, and welding of metals	1	2	1	2	33
8. Metallurgy of and welding of metals	1	3	2	2	100
9. Machine tool laboratory	1	5	2	6	15
10. Processing of engineering materials	1	2	1	3	15
11. Engineering production processes	1	1	1	2	5
12. Shop processes	1	1	0	3	5
13. Shop work	4	1.75	.5	2.3	14
14. Methods of manufacturing, casting, welding, and heat treating metals	1	2	1	2	50
15. Welding engineering	1	3	2	3	60
16. Engineering materials and processes	1	5	2	3	15
17. Mechanical technology	1	0		6	
18. Shop welding	1	2	1	2.5	75
19. Production engineering	2	4	2.5	4.5	58
20. Metal casting, forming and welding	1		3	2	35
21. Mechanical processes	1	3	2	3	
22. Material processes					
Averages		2.3	3.2	2.9	34.6

with other shop processes. The average amount of time devoted to welding is approximately thirty-five per cent.

Welding libraries. The respondents were asked to report on the size of the welding library at their respective institutions by indicating the number of books and periodicals, which were primarily concerned with welding, available in the institutions' libraries. The reports indicated great variation in the welding libraries, with a minimum of none and a maximum of 2,000 books and 100 periodicals. Table XVI gives some statistics on the library results.

TABLE XVI

BOOKS AND PERIODICALS ABOUT WELDING IN THE LIBRARIES OF ENGINEERING SCHOOLS

	Number of schools	Maximum number per institution	Average number per institution
Books	60	2,000	70
Periodicals	53	100	7.5

Seven institutions reported having what is called a Lincoln Library. Mr. A. F. Davis, secretary of the James F. Lincoln Arc Welding Foundation, describes the Lincoln Library as follows:

> The trustees of our Foundation authorized the establishing of welding libraries or collections of welding books in a good number of the engineering schools throughout the United States. This is quite a good sized collection of books, codes, reprints, etc. It is kept up regularly as new technical books, codes or articles appear; the latest to this collection having been the Handbook of the American Welding Society. The purpose of the libraries being to encourage and stimulate scientific interest in, and scientific study, research and education in respect of, the development of the arc welding industry through advance in the knowledge of design and practical application of the arc welding process.

These schools are indeed fortunate to have this fine collection of books and this service extended to them for a nominal fee. A few respondents mentioned that they were able to obtain valuable literature for welding libraries from many of the large companies who are interested in welding.

Film libraries. Film strips, motion pictures, and slides are being collected to form film libraries at a few institutions. Several of the respondents indicated they felt films were excellent teaching aids that can be used in the instruction of welding because the film can show the broad scope of welding as well as details of instruction at a relatively low cost. Many schools have projection equipment which is available to all fields of endeavor. Such a situation lends itself nicely to the problem of presenting welding to engineering students. Films may be obtained from many welding firms without charge. Table XVII is a list of training films available that can be obtained by ordering well in advance of showing time.

Welding as an engineering option. The respondents were asked to indicate if any provisions had been made for engineering students at the various institutions to elect welding as an engineering option. Sixty-three respondents stated that it was not possible to elect welding as an engineering option. Welding can be an engineering option in seven institutions under varied conditions. Mr. P. E. Kyle, assistant director of the School of Metallurgical Engineering at Cornell University, states that "a welding problem may be elected as a senior project." Students at Ohio State University who are interested in welding, may major in welding but no provision is made for students of other engineering fields to elect welding as an option. The general feeling toward welding as an option

TABLE XVII

WELDING MOVIES AVAILABLE FOR ENGINEERING EDUCATION

Title of Movie Film	Color, Sound, Size	Showing Time
The Inside of Arc Welding	Color, sound, 16 mm.	6 reels, 10 min. each
The Inside of Atomic-Hydrogen Welding	Color, sound, 16 mm.	2 reels, 10 min. each
This is Resistance Welding	Color, sound, 16 mm.	25 min.
The Story of A.-C. Welding		
Welding of Aluminum (describing all types of welding)	Black and white sound, 16 mm.	20 min.
New Horizons in Welding	Black and white sound, 16 mm.	20 min.
The Prevention and Control of Distortion in Arc Welding	Color, sound	20 min.
The Magic Wand of Industry--Arc Welding	Color, sound	25 min.
Manufacture by Arc Welding	Black and white silent, 16 mm.	45 min.
Structural Steel Welding	Kodachrome silent, 16 mm.	(400 ft.)
Oxy-acetylene Welding of Red Brass Pipe	Kodachrome silent, 16 mm.	(350 ft.)
The Construction of The Airlines Terminal	Kodachrome silent, 16 mm.	(400 ft.)
Earthmoving Takes Wings		
Introduction to Oxy-acetylene Welding	Black and white sound, 16 mm.	20 min.
Installation of Continuously Welded Rail in Moffat Tunnel	Color, sound, 16 mm.	(400 ft.)
Fabrication of Stern Frames	Color, sound, 16 mm.	(750 ft.)
Fabrication of Heavy Parts by Thermit Welding	Color, sound, 16 mm.	(1,000 ft.)
Oxy-acetylene Welding Light Metal	Black and white sound, 16 mm.	21 min.
Manual Cutting to a Line-Freehand	Black and White sound, 16 mm.	21 min.
The Guided Bend Test	Black and white sound, 16 mm.	17 min.
Preheating Welding and Stress Relieving	Black and white silent, 16 mm.	15 min.
Profits of Progress	Black and white sound, 16 mm.	10 min.
Prosperity Process	Black and white sound, 16 mm.	20 min.
Story of Arc Welding	Color, sound, 16 mm.	25 min.
Welding	Black and white sound, 16 mm.	25 min.
Unionmelt Welding--An Electric Welding Process, U-4	Black and white silent, 16 mm.	15 min.

TABLE XVII (Continued)

Title of Movie Film	Color, Sound, Size	Showing Time
Unionmelt Welding in Industry, U-5	Black and white silent, 16 mm.	15 min.
Unionmelt Welding in General Applications, U-7	Black and white silent, 16 mm.	15 min.
Flame-Priming the Drum Gates of Grand Coulee Dam, B-8	16 mm.	15 min.
Flame-Cutting of Billets and Bars, B-9	16 mm.	15 min.
Flame-Hardening by the Oxy-acetylene Process, K-2	16 mm.	30 min.

seems to be expressed by Mr. W. C. Truckenmiller of the University of Michigan as follows: "I believe that welding is of a sufficiently specialized nature that it has no position as an engineering option in undergraduate curricula. It occupies a position similar to machine shop practice in this respect." Not all of the respondents had this attitude and the feeling may change as industry makes a greater demand for engineers having a background in welding engineering.

Is sufficient welding being offered to engineers? Respondents from forty-six institutions were of the opinion that sufficient welding was being offered in their respective institutions. Twenty-two respondents felt that the welding courses should be added, revised, or improved. The types of welding courses being offered by the various institutions were discussed earlier in this chapter.[3] Mr. J. W. Field, of the New Mexico Agricultural and Mechanic Arts College, stated concerning the adequacy of welding at that institution, "It depends a lot of course in which line of work the student intends to follow." This is of course true and is emphasized by the following statement by Mr. H. B. Hashall of the University of Maryland, "...adequate for options given; a production option in mechanical engineering would require more welding." Mechanical engineering students get the greatest amount of welding at the present time, as previously noted.[4] The engineering courses at some schools are now being reviewed for the purpose of providing adequate welding. Finding sufficient time is a problem for many as indicated by Mr. Otis Benedict, Jr. of the

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[3] See pages 30-35.

[4] See page 27.

Pratt Institute, "We in the Manufacturing Processes Department would like to have more time for instruction in welding, but at present see no way of getting more time." As mentioned earlier, this problem has resulted in the adoption of a five-year program in some institutions. Mr. Ralph Scorah, Chairman of the College of Engineering at the University of Missouri, who reported inadequate welding for engineering students, asks the following question: "Considering the whole engineering curriculum and the place of the engineering graduate in the profession, what is the fair and equitable time allowance for welding and how should that time be used?" The types of courses offered, the types of equipment in use, which are discussed earlier, give an over-all picture of what the average institution has to offer in the way of welding for engineers. An attempt to answer the question of Mr. Scorah more completely is made in the conclusions of Chapter IV.

Comments and suggestions of respondents concerning welding for engineering students. The respondents were asked to make constructive comments and suggestions about present or proposed welding courses for engineering students. The response to this request was particularly good with about thirty respondents making some type of comment. These comments are compiled in the Appendix and will be analyzed as a group in the conclusions in Chapter IV. This analysis will aid in answering Mr. Scorah's question.

Summary. In this chapter, information gathered from the returned questionnaires was presented and analyzed. The questionnaire consisted of fifteen questions, each designed to obtain pertinent information, and the information from each question was presented and analyzed individually. The comments and suggestions of respondents concerning welding for engineering students are compiled in the Appendix and, when analyzed as a group, give an indication of what type of welding course should be had for engineering students.

CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In this chapter, a brief summary of the preceding chapters will be presented. A list of conclusions and recommendations, drawn from a study of the information on returned questionnaires including the comments of the respondents, are also presented.

Summary of study. Fifty years ago, welding was practiced on an experimental basis only. Industrially, welding has improved and expanded rapidly. Industry is very much interested in anything new that may help speed up production, or in some other manner help put a better product on the market at a lower price. This investigation is concerned with the introduction of welding into engineering curricula of colleges and universities. Although welding has been used in industry for many years, it has only recently been introduced into engineering curricula. The purpose of this investigation is to determine the manner in which the engineering schools of the United States are meeting this new demand.

Education, as an institution, has been accused of being twenty or more years behind times in most fields of endeavor. The welding industry has progressed at such a tremendous rate during the last few years that it would be a serious situation to have engineering students graduating who were twenty years behind in their understanding of present day methods and procedures.

A college catalog study and an investigation by questionnaire of all institutions having accredited undergraduate engineering curricula was made to determine how welding was being taught in the institutions. Questionnaires were sent to the Deans of the Schools of Engineering of 134 institutions.

In Chapter II a brief description of the development of welding was presented. The study revealed that some experimental work had been done on certain welding processes as early as 1885, but the major portion of the development of the processes has occurred during the past fifty years. There has been a limited application of welding, by the forging method, for thousands of years. Few studies of a related nature have been made. Studies made at Oregon State College, Ohio State University, Rensselaer Polytechnic Institute, and The Case Institute of Technology were reviewed. The manner in which welding is presented in the college catalogs was discussed. The importance of having the engineer and the welding operator understand each other's problems was discussed by Mr. Thomas J. Barry, welding specialist for the Harnischfeger Corporation in Chicago, Illinois.

In Chapter III, information gathered from the returned questionnaires was presented and analyzed. On the questionnaire, answers to fifteen questions were requested, each designed to obtain pertinent information. The information from each question was individually presented and analyzed. Of the 134 questionnaires which were sent, 117, or eighty-eight per cent, were returned or a letter of explanation was written regarding the welding situation at the respective institutions. All except two states were represented in the returns. Fourteen different titles were given by respondents as the official title of the department in which welding was being offered or taught to engineering students. Respondents indicated that sixty per cent of all welding for engineers is offered by the mechanical engineering departments. Only one institution -- Ohio State University -- reported having a welding engineering department.

The Engineers' Council for Professional Development has accredited sixteen undergraduate engineering curricula. Of the sixteen curricula, students in mechanical engineering are required to take welding in the greatest number of institutions. Respondents suggested five curricula in which welding is important in addition to the sixteen accredited curricula. In one institution, as high as twelve per cent of the students who are not required to take welding do so as an elective.

Fifty institutions have developed welding courses especially for engineering students. The nature of the course varies a great deal, depending upon the needs of the locale. An average of approximately one and one-half hours are spent in lecture each week and about three hours are devoted to laboratory work. There is a tendency to schedule welding courses during the sophomore year in the majority of the institutions, however, some respondents stated that they thought there was a big advantage in having welding taught just before the advanced engineering courses in design. A total of twenty-five welding processes were reported by respondents. Emphasis is being placed on electric arc welding, electric resistance welding, oxy-acetylene welding and cutting, and inert gas-arc processes.

Although many of the respondents indicated that the development of manual skill was not a major objective in an engineer's course in welding, a large number of courses for engineers teach welding in all positions and include many materials as indicated in Table XIII. Modern welding equipment is available in many institutions for teaching welding to engineering students, but, most of the respondents indicated they would like to have more and better equipment.

Some respondents indicated it was extremely hard to find enough time in a four-year engineering curricula to include shop courses. The adoption of five-year curricula has solved this problem for some institutions; others have developed courses of a general nature which include several types of shop subjects in one course.

Libraries containing books, periodicals, and films pertinent to welding are being developed at many institutions. Interested companies sometimes offer assistance in providing literature or films to be shown to engineering students.

What constitutes the right kind of welding course for engineering students? This question is partially answered in the figures presented in Chapter III. The conclusions of the entire study aid in further answering this question. Several respondents indicated that courses at their respective institutions were being reviewed to see if welding was being presented in an adequate manner.

Conclusions and recommendations. This investigation has determined the manner in which welding is being taught to engineering students. The study has also raised questions concerning (1) the amount of time which should be devoted to welding, (2) the manner in which this time should be spent, (3) the type of course in welding which is desirable for engineers, (4) the course content, and other pertinent problems. Information has been gathered from the returned questionnaires, from comments and suggestions by the respondents, and from quotations from several leaders in the engineering and welding fields. Many of the respondents expressed a desire to be informed of the results of this investigation. Arrangements were made with the American Welding Society for possible publication of a summary of the results of the investigation. From a study of the questionnaires and a careful review of other information, the following conclusions and recommendations have been drawn which should help answer the above questions:

1. The importance of welding in an engineering curriculum is determined to a great extent by the immediate need of such knowledge in any given field. Almost without exception, the respondents were agreed that mechanical engineering students should be required to take some welding. Local industrial conditions will influence the amount of welding required in other engineering curricula. It would be well to examine the present means of presenting welding to engineering students to see if it is being done in the most efficient manner. Steps should be taken to insure the inclusion of welding in other courses where it is applicable. All engineering courses should emphasize welding as one of the most popular and versatile fabrication and repair processes.

2. Welding courses should be closely coordinated with other courses. Welding can be most valuable to engineering students when taken at the same time or immediately after courses in metallurgy, metallography, and other similar courses. Engineering courses in machine design and structural design should follow welding. These courses should be taught in terms of welded design where welding is applicable. Students can become familiar with welding if in drawing courses, the students are required to use welding symbols and standard methods of indicating welds on items being drawn.

3. There is a great need for better text material for teaching welding to engineering students. Handbooks and books for teaching manual skills are plentiful but apparently there are no texts suitable for teaching welding to the engineer. A book, written especially for this purpose, is needed.

4. Many of the respondents recognize a need for more welding for engineering students but, due to crowded time schedules, find it very difficult or impossible to add any more courses. This crowded time schedule

problem has led to the adoption of five-year curricula at a few institutions. Many older courses are being examined to see if they are making the best use of the time allotted to them.

5. Where crowded time schedules appear, many institutions have developed a general shop course which includes several manufacturing processes. This type of course is better than not having any course at all in which welding can be presented.

6. Lectures, demonstrations by qualified men (in addition to regular staff), movies, slides, chalk talks, and seminar discussions are excellent methods of presenting welding to engineering students where regular courses cannot be scheduled.

7. Students should be encouraged to obtain summer employment in locations and in types of work where they can become familiar with the application of many industrial processes. School credit is sometimes given for this type of work.

8. Engineering students are not expected to become proficient welding operators; manual skill is not important. Instead, the objective of a welding course for engineers should be to give the students an understanding of all the welding methods and the application of these methods in the engineering field. Students should have enough actual welding practice so they can appreciate the problems of the welding operator and perhaps eliminate some of these problems in future design.

9. Laboratory work should include simple shop experiments designed to acquaint the student with common welding problems in industry.

10. Valuable help may be obtained from companies interested in welding in the form of lectures, free literature, movies, etc.

11. Institutions should take advantage of opportunities to conduct students on frequent field trips into industrial plants.

12. Institutions should also take advantage of opportunities to secure equipment from war surplus supplies where possible.

13. The success of the Welding Engineering curriculum at Ohio State University and the interest expressed by several respondents in similar curricula indicates that this field is becoming more important and will probably become an accredited curriculum sometime in the future.

14. Where possible, a special course designed for engineers is the best way to present welding to engineering students.

15. Welding for engineers should not be scheduled during the freshman year. The students understand it better when they are more mature and it is most valuable to them if taken later.

16. The course content should include a discussion of the various types of metals and the processes by which they can be welded. Machine design and structural design are affected by welding and should be included in any welding course for engineers. "Procedures, speeds, and costs" of welding are also important to the engineer.

17. A library of books, periodicals, and other literature pertinent to welding should be made available to engineering students by every institution.

18. A few institutions are engaged in experimental research work concerning various phases of welding. This type of work should be encouraged in more institutions.

19. Future studies concerning welding for engineering students might well be devoted to developing welding courses, instructional material, and other material that can be used to present welding to engineers.

APPENDIX A

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Books

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APPENDIX B

LIST OF INSTITUTIONS HAVING ACCREDITED UNDERGRADUATE ENGINEERING CURRICULA

* Respondents

1. Alabama	*Alabama Polytechnic Institute Auburn, Alabama
	*University of Alabama Tuscaloosa, Alabama
2. Arizona	*University of Arizona Tucson, Arizona
3. Arkansas	*University of Arkansas Fayetteville, Arkansas
4. California	*California Institute of Technology Pasadena, California
	*Stanford University Palo Alto, California
	*University of California Berkeley, California
	*University of Santa Clara Santa Clara, California
	*University of Southern California Los Angeles, California
5. Colorado	*Colorado Agricultural and Mechanical College Fort Collins, Colorado
	*Colorado School of Mines Golden, Colorado
	*University of Colorado Boulder, Colorado
	*University of Denver Denver, Colorado
6. Connecticut	*United States Coast Guard Academy New London, Connecticut
	*University of Connecticut Storrs, Connecticut

APPENDIX B (Continued)

	Yale University New Haven, Connecticut
7. <u>Delaware</u>	*University of Delaware Newark, Delaware
8. <u>District of Columbia</u>	*Catholic University of America Washington, D. C.
	*George Washington University Washington, D. C.
	*Howard University Washington, D. C.
9. <u>Florida</u>	*University of Florida Gainesville, Florida
10. <u>Georgia</u>	*Georgia Institute of Technology Atlanta, Georgia
11. <u>Idaho</u>	*University of Idaho Moscow, Idaho
12. <u>Illinois</u>	*Illinois Institute of Technology Chicago, Illinois
	*University of Illinois Urbana, Illinois
	*Northwestern University Evanston, Illinois
13. <u>Indiana</u>	*Purdue University Lafayette, Indiana
	*Rose Polytechnic Terre Haute, Indiana
	*University of Notre Dame Notre Dame, Indiana
14. <u>Iowa</u>	*Iowa State College of Agriculture and Mechanic Arts Ames, Iowa
	*State University of Iowa Iowa City, Iowa

APPENDIX B (Continued)

15. Kansas	Kansas State College of Agriculture and Applied Science Manhattan, Kansas
	*University of Kansas Lawrence, Kansas
16. Kentucky	*University of Kentucky Lexington, Kentucky
	*University of Louisville Louisville, Kentucky
17. Louisiana	*Louisiana Polytechnic Institute Ruston, Louisiana
	*Louisiana State University Baton Rouge, Louisiana
	*Tulane University New Orleans, Louisiana
18. Maine	*University of Maine Orono, Maine
19. Maryland	*Johns Hopkins University Baltimore, Maryland
	*University of Maryland College Park, Maryland
20. Massachusetts	*Harvard University Cambridge, Massachusetts
	*Massachusetts Institute of Technology Cambridge, Massachusetts
	*Northeastern University Boston, Massachusetts
	*Tufts College Medford, Massachusetts
	*Worcester Polytechnic Institute Worcester, Massachusetts
21. Michigan	*Michigan College of Mining and Technology Houghton, Michigan
	*Michigan State College East Lansing, Michigan

APPENDIX B (Continued)

	*University of Detroit Detroit, Michigan
	*University of Michigan Ann Arbor, Michigan
	*Wayne University Detroit, Michigan
22. Minnesota	*University of Minnesota Minneapolis, Minnesota
23. Mississippi	*Mississippi State College State College, Mississippi
24. Missouri	*University of Missouri Columbia, Missouri
	*Mines and Metallurgy Rolla, Missouri
	*Washington University St. Louis, Missouri
25. Montana	*Montana School of Mines Butte, Montana
	*Montana State College Bozeman, Montana
26. Nebraska	*University of Nebraska Lincoln, Nebraska
27. Nevada	*University of Nevada Reno, Nevada
28. New Hampshire	Dartmouth College Hanover, New Hampshire
	University of New Hampshire Durham, New Hampshire
29. New Jersey	Newark College of Engineering Newark, New Jersey
	*Princeton University Princeton, New Jersey
	*Rutgers University New Brunswick, New Jersey

APPENDIX B (Continued)

*Stephens Institute of Technology
Hoboken, New Jersey

30. New Mexico

*New Mexico College of Agriculture and Mechanic Arts
State College, New Mexico

*New Mexico School of Mines
Socorro, New Mexico

University of New Mexico
Albuquerque, New Mexico

31. New York

*Alfred University
Alfred, New York

*City College of the City of New York
New York, New York

*Clarkson College of Technology
Potsdam, New York

*Columbia University
New York, New York

*Cooper Union
New York, New York

*Cornell University
Ithica, New York

*Manhattan College
New York, New York

*New York University
New York, New York

*Polytechnic Institution of Brooklyn
Brooklyn, New York

*Pratt Institute
Brooklyn, New York

*Rensselaer Polytechnic Institute
Troy, New York

*Syracuse University
Syracuse, New York

*Union College and University
Schenectady, New York

APPENDIX B (Continued)

*University of Rochester
Rochester, New York

Webb Institute of Naval Architecture
New York, New York

32. North Carolina

*Duke University
Durham, North Carolina

*State College of Agriculture and Engineering
Raleigh, North Carolina

33. North Dakota

*North Dakota Agricultural College
State College, North Dakota

*University of North Dakota
Grand Forks, North Dakota

34. Ohio

Case Institute of Technology
Cleveland, Ohio

*Fenn College
Cleveland, Ohio

*Ohio State University
Columbus, Ohio

*University of Akron
Akron, Ohio

*University of Cincinnati
Cincinnati, Ohio

*University of Toledo
Toledo, Ohio

35. Oklahoma

*Oklahoma Agricultural and Mechanical College
Stillwater, Oklahoma

*University of Oklahoma
Norman, Oklahoma

*University of Tulsa
Tulsa, Oklahoma

36. Oregon

*Oregon State College
Corvallis, Oregon

37. Pennsylvania

*Bucknell University
Lewisburg, Pennsylvania

APPENDIX B (Continued)

*Carnegie Institute of Technology
Pittsburgh, Pennsylvania

*Lehigh University
Bethlehem, Pennsylvania

*Pennsylvania State College
State College, Pennsylvania

*Swarthmore College
Swarthmore, Pennsylvania

University of Pennsylvania
Philadelphia, Pennsylvania

University of Pittsburgh
Pittsburgh, Pennsylvania

*Villanova College
Villanova, Pennsylvania

38. Rhode Island

*Brown University
Providence, Rhode Island

*Rhode Island State College
Kingston, Rhode Island

39. South Carolina

*Clemson Agricultural College
Clemson, South Carolina

The Citadel
Charleston, South Carolina

University of South Carolina
Columbia, South Carolina

40. South Dakota

*South Dakota State College of Agriculture and Mechanic Arts
Brookings, South Dakota

41. Tennessee

*University of Tennessee
Knoxville, Tennessee

*Vanderbilt University
Nashville, Tennessee

42. Texas

*Agricultural and Mechanical College of Texas
College Station, Texas

*College of Mines and Metallurgy
El Paso, Texas

APPENDIX B (Continued)

	*Rice Institute Houston, Texas
	Southern Methodist University Dallas, Texas
	*Texas Technological College Lubbock, Texas
	*University of Texas Austin, Texas
43. <u>Utah</u>	*University of Utah Salt Lake City, Utah
	*Utah State Agricultural College Logan, Utah
44. <u>Vermont</u>	*Norwich University Northfield, Vermont
	*University of Vermont Burlington, Vermont
45. <u>Virginia</u>	University of Virginia Charlottesville, Virginia
	Virginia Military Institute Lexington, Virginia
	Virginia Polytechnic Institute Blacksburg, Virginia
46. <u>Washington</u>	*State College of Washington Pulman, Washington
	University of Washington Seattle, Washington
47. <u>West Virginia</u>	*West Virginia University Morgantown, West Virginia
48. <u>Wisconsin</u>	Marquette University Milwaukee, Wisconsin
	*University of Wisconsin Madison, Wisconsin
49. <u>Wyoming</u>	*University of Wyoming Laramie, Wyoming

APPENDIX C

Appendix C consists of comments and suggestions of the questionnaire respondents concerning welding for engineering students.

1. Mr. Wm. E. Heuer, Associate Professor of Mechanical Engineering, University of Toledo, Toledo, Ohio.

   I would recommend that a welding course to be a must for all College of Mechanical Engineering Students. The University of Toledo College of Engineering has this in mind.

2. Mr. G. C. Williams, Professor of Chemical Engineering, University of Louisville, Louisville, Kentucky.

   This subject is discussed in about 6-8 lectures and one metallographic laboratory period in a pair of courses on metallography. This amount is quite adequate.

3. Mr. Robert A. Wyant, Associate Professor of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, New York.

   I am very much interested in your project, not only as a teacher in the welding field but also as chairman of the Education Committee of the American Welding Society. It is needless to say that the committee will be very much interested in your results. I feel our program is adequate, however, there is room for improvement. The greatest need is for better text material.

4. Dr. J. Woodburn, Chairman of the Mechanical Engineering Department, Rice Institute, Houston, Texas.

   I feel that this field is extremely important to mechanical engineers and we try to give them as much of it as possible. The student takes six hours of laboratory work per week throughout the year, that is, the mechanical engineers and electrical engineers. This course is an elective for other departments. In addition to our regular staff, we have at various times throughout the year qualified men to give talks and/or demonstrations to the engineering students in welding....which I think is much better than having the same old lecture courses that are usually found in many engineering schools. Liberal use is made of educational films put out by the various industrial firms dealing with welding equipment or machine shop equipment. These films are excellent and particularly those which are colored and have a sound track, and I believe that it is much easier for a student to grasp ideas in this manner rather than trying to tell him or teach him in the class room.

   The way our courses are set up in these various shops is that immediately after completing this work follow it up with machine design, such work then being fresh in their memory and can be used to the best possible maximum advantage.

   We have a small enrollment...and, therefore, can spend considerable time with the individual students in their shop courses which I believe is a decided advantage....

APPENDIX C (Continued)

5. Mr. Henry Silha, Professor of Mechanical Engineering Department, University of Idaho, Moscow, Idaho.

In the Mechanical Engineering Department we offer a course in welding designed for engineers. We take up design considerations, welding techniques, metallurgy of welding and allied problems....

6. Mr. C. Higbie Young, The Cooper Union for the Advancement of Science and Art, Cooper Square, New York 3, New York.

...we have no courses or subjects dealing entirely with welding. The mechanical engineers have a course in Mechanical Processes in the first semester of the third year....Approximately eight hours of this is given to all types of welding, including forge welding, drop forge welding, electric arc welding, electric resistance welding, and flame cutting and welding. Largely, this is to acquaint the boys with the processes and limitations, primarily designed to give them a background necessary to a machine designer.

In the senior year, the subject of Machine Design is given. We devote approximately four hours to the design characteristics of welded joints. Again, the main purpose of this is to acquaint the machine designer with the approach to the problem of welded construction.

All of this material is supplemented with lantern slides and blackboard chalk talks. We feel that since we are making our boys engineers and not welders what we are giving them is sufficient until they get into industry and find the need for it when they will be able to supplement their present knowledge with further study.

7. Mr. Webster N. Jones, Carnegie Institute of Technology, Schenley Park, Pittsburgh 13, Pennsylvania.

All shop courses in the College of Engineering and Science at the Carnegie Institute of Technology were discontinued some years ago, and no welding courses or welding shop practice is included in the engineering curricula.

8. Mr. C. A. H. Joerzen, Dean of the College of Engineering, University of Cincinnati, Cincinnati, Ohio.

No courses in welding are offered. Boys interested in welding get it in their cooperative work. Welding demonstrations are held.

9. Mr. C. S. Crouse, Head, Department of Mines and Metallurgical Engineering, University of Kentucky, Lexington 29, Kentucky.

We do not offer welding courses as such, but do include some instructions in our summer course for metallurgical engineers.

10. Mr. N. H. Barnard, Chairman of Department of Mechanical Engineering, University of Nebraska, Lincoln 8, Nebraska.

Our welding material and practice is for engineering students to use in a career. They are not expected to become welders. More time could be used profitably but a tight curriculum does not permit.

11. Mr. G. T. Murati, LCDR, in charge of Engineering Laboratory, U. S. Coast Guard Academy, New London, Connecticut.

Welding consists of a short sound movie--about half an hour, a short lecture--about half an hour and a practical welding period of two hours with three students under one instructor. This is all the formal coverage in this subject, however, there is a practical work program which runs 3 hours a week for 8 semesters for all students, and some do get extra instruction in welding during this program. However this is a hit and miss proposition and only a small percentage would get extra welding instruction.

12. Mr. A. C. Good, Professor of Engineering Shop Department, Wayne University, Detroit, Michigan.

There is a great need for a text book on welding written especially for students in Engineering Colleges and Universities.

13. Mr. Walter D. Emerson, Head, Mechanical Engineering Department, Norwich University, Northfield, Vermont.

Simple shop experiments would be helpful.

14. Mr. W. B. Kouwenhoven, Dean of Engineering, The Johns Hopkins University, Baltimore 18, Maryland.

We do not offer a course in welding at the Johns Hopkins University. We do however offer advanced work on the properties of electric arcs and on the physics of the arc. In addition, we carry on considerable fundamental research in the field of welding.

15. Mr. Conrad dek Bliss, Professor of Industrial Engineering, North Carolina State College of Agriculture and Engineering, Raleigh, North Carolina.

We feel that adequate training in welding is important in about the same relation as other production processes. Coverage of the basic fundamentals of welding are about all that can be accomplished in the regular engineering training. We can hardly hope to train men as real specialists in welding as it is not the purpose of an engineering education to create specialists in any one field. An attempt to do so would cut too deep into the common core of basic engineering training, the basic engineering subjects common to any group who are graduated as engineering graduates in any branch of engineering. We believe that industry wants men well grounded in these fundamentals, rather than specialists.

16. Mr. George L. Sullivan, Dean of the College of Engineering, University of Santa Clara, Santa Clara, California.

We require all of our engineering students to take shop instruction one afternoon a week during the freshman year. As part of this shop instruction they receive some instruction on both electric and gas welding. This is all the direct instruction they get, but the strength of welded joints is treated in design courses for the Civil Engineers and Mechanical Engineers in their junior year.

17. Mr. R. G. Paddock, Professor of Mechanical Engineering, University of Arkansas, Fayetteville, Arkansas.

We do not give any separate courses in welding. In our Elementary Forge and Machine Shop course one three hour period is devoted each to electric arc welding and gas torch welding.

18. Mr. John C. Reed, Chairman of Department of Mechanical Engineering, Bucknell University, Lewisburg, Pennsylvania.

...Our instruction in welding is given in connection with (or as a part of) a required course entitled Process Engineering. In this course different types of welding are covered in lecture and some practical work is given in the laboratory portion of the course.

The work is covered in approximately four or five 1-hour lectures and about three 3-hour periods in the laboratory. We realize that this is not enough time for such an important subject, but we do not know where to obtain more time in an already crowded mechanical engineering curricula.

It is only occasionally that one of our students expresses any particular interest in welding. No doubt this accounts for our lack of development of welding courses.

19. Mr. H. M. Black, Head of Department of Mechanical Engineering, Iowa State College, Ames, Iowa.

...Teach it in parallel with a good course in engineering metallurgy. If it follows such a course, you can really teach welding fundamentals.

20. Mr. Harry Udin, Professor of Metallurgy, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.

Metal Processing 3.12, consists of ten clock hours of lecture and ten clock hours of lab in each of the fields of Foundry, Metal Working and Welding. Some 300 students take this course. For students who have completed 3.12, we offer a course in Welding Engineering, 3.15, consisting of two lectures per week for 15 weeks--no lab. This course covers materials (50%), processes (25%), costs (5%), and design (20%). M.I.T. has no formal shop program.

21. Mr. F. M. Feiker, Dean of Engineering, George Washington University, Washington, D. C.

We recognize welding as an important method of manufacture, but we do not have time to give technical instruction in it. ...like many other important and strategic methods of engineering practice, the time now necessary to teach basic and fundamental courses, makes it impossible to do more than to "work in" welding theory and practice in courses in manufacturing methods, machine design and engineering materials, and in the form of seminar discussion.

22. Mr. L. J. Lassalle, Dean of Engineering, Louisiana University, Baton Rouge, Louisiana.

We find it impossible to put all the subjects that are desirable in a 4 year curriculum.

23. Mr. Fred J. Lewis, Dean of School of Engineering, Vanderbilt University, Nashville, Tennessee.

We have received considerable help and literature from the Linde Air Products Company.

24. Mr. A. M. Hill, Head, Mechanical Engineering Department, Tulane University, New Orleans, Louisiana.

We use movies on welding technique. A steel barrel manufacturer is visited (Rheem Manufacturing Company) and class sees large resistance welders in operation.

25. Mr. Myron G. Mochel, Associate Professor of Mechanical Engineering, Clarkson College of Technology, Potsdam, New York.

At Clarkson we do not teach welding as it is our present belief that the skill and ability to weld is not the function of an engineer, but the work of a tradesman. We further believe that if an engineer becomes directly associated with welding practice, he can readily obtain the necessary welding training.

Our Mechanical Engineering Curriculum includes some very intensive work dealing with Engineering Materials and Manufacturing, including some work in our Materials Laboratory and on our Manufacturing Laboratory. Our objective is to cover thoroughly the subject of materials and manufacturing with the thought of giving our mechanical engineering students an excellent background for mechanical design or manufacturing. Accordingly, we discuss welding, but do not have the students weld.

26. Mr. C. J. Freund, Dean of the College of Engineering, University of Detroit, Detroit 21, Michigan.

There are no formal courses in welding in the College of Engineering of the University of Detroit. However, instruction in welding technology is an integral part of the subject matter in the aeronautical, chemical, metallurgical, electrical and mechanical divisions of instruction. Emphasis is placed on welding particularly in the machine design courses, and I believe that there is a corresponding attention paid to welding in structural courses.

APPENDIX D

Appendix D consists of a letter of introduction to the questionnaire, the questionnaire, and a follow-up letter.

OKLAHOMA AGRICULTURAL AND MECHANICAL COLLEGE
School of Trade and Industrial Education

Stillwater

March 24, 1950

Dear Sir:

Welding, as an industry, has grown at a tremendous rate and has won its place as one of the foremost methods of fabrication today. Engineering schools are faced with the ever present problem of keeping their various curricula in tune with the needs of industry. In recognition of this fact, I am making a survey of the offerings in welding in the colleges in this country whose engineering curricula have been accredited by the Engineers' Council for Professional Development. This survey will include a careful study of the catalogs of the respective schools together with information which I hope to secure through questionnaires addressed to deans of engineering schools. The results of the survey will be the basis for a thesis under the title, Welding in the Engineering Curricula, and a summary of the findings will be sent to the editor of the Welding Journal for publication.

I am asking for your cooperation in this study. Enclosed is a questionnaire which I kindly ask you to complete and return to me in the self-addressed and stamped envelope at your convenience. An effort has been made to arrange the questionnaire in a form that will require the least amount of your time. Your cooperation will be greatly appreciated.

Very sincerely yours,

Lynn J. Christensen

Lynn J. Christensen, Instructor
Engineering Shopwork

LJC/hd

WELDING IN THE ENGINEERING CURRICULA

Lynn J. Christensen, Instructor
Engineering Shopwork
Oklahoma Agricultural and Mechanical College
Stillwater, Oklahoma
Spring, 1950

Directions: Please fill in the blanks below as they apply to your institution.

---

1. Reported by ______________________ Position ______________________

   Name of Institution ____

   City ______________________ State ______________________

2. The official title of the department that offers welding courses for engineering students is ______________________________________.

3. Number of full time and equivalent of part time teachers in department ____.

4. If welding is included in your shop program, please indicate below if it is offered as a required or as an elective subject in the engineering curricula.

Curriculum	Required	Elective	Curriculum	Required	Elective
Aeronautical	____	____	Industrial	____	____
Agricultural	____	____	Mechanical	____	____
Architectural	____	____	Metallurgical	____	____
Ceramic	____	____	Mining	____	____
Chemical	____	____	Naval Architecture	____	____
Civil	____	____	Petroleum	____	____
Electrical	____	____	Sanitary	____	____
Fuel Technology	____	____	Other	____	____
General	____	____			

5. Approximately what percent of the students elect to take welding in departments in which it is not a requirement? _____%

6. Does your school offer a welding course that is designed especially for engineering students? (Yes (No) If the answer is "Yes":

   A. How many hour credits are given? ______ Semester Hrs. ______ Quarter Hrs.

   B. Give number of clock hours per week. _____ Lecture _____ Laboratory

   C. Give number of hours of the course devoted to machine and structural design for welded fabrication. ______ Hours

   D. Give number of hours devoted to procedures, speeds, and costs. ______

7. If welding is offered as a part of your shop program, during what year may it be taken? Fresh. _____ Soph. _____ Jr. _____ Sr. _____ Any year _____

8. Following is a list of processes common in welding. Please check the ones which are included in your welding course.

Process treated	General course	Special course for engineers	Presented during lecture period	Presented during laboratory period
Forge welding	____	____	____	____
Resistance welding	____	____	____	____
Metallic arc welding	____	____	____	____
Carbon arc welding	____	____	____	____
Atomic hydrogen welding	____	____	____	____
Inert gas-arc welding	____	____	____	____
Air-acetylene welding	____	____	____	____
Oxy-acetylene welding	____	____	____	____
Oxy-other fuel welding	____	____	____	____
Thermit welding	____	____	____	____
Gas brazing	____	____	____	____
Electric brazing	____	____	____	____
Dip brazing	____	____	____	____
Furnace brazing	____	____	____	____
Oxy-acetylene cutting				
Manual	____	____	____	____
Machine	____	____	____	____
Contour machine	____	____	____	____
Arc cutting	____	____	____	____
Other processes				
____________	____	____	____	____
____________	____	____	____	____
____________	____	____	____	____

9. Laboratory work for the above courses includes welding of the following materials in the positions indicated.

	Material	Flat	Vert.	O. H.	Horiz.	All
____	Cast iron	____	____	____	____	____
____	Cast steel	____	____	____	____	____
____	Low carbon steel	____	____	____	____	____
____	High carbon steel	____	____	____	____	____
____	Stainless steels	____	____	____	____	____
____	Aluminum	____	____	____	____	____
____	Copper	____	____	____	____	____
____	Brass	____	____	____	____	____
____	Sheet metal	____	____	____	____	____
____	Plate	____	____	____	____	____
____	Tubing	____	____	____	____	____
____	Pipe	____	____	____	____	____
	Others					
____	____________	____	____	____	____	____
____	____________	____	____	____	____	____
____	____________	____	____	____	____	____

10. Equipment available for teaching welding to engineering students. Give number.

Arc welding machines and booths (work stations) .... ______
Oxy-acetylene torches and tables (work stations) .... ______
Manually operated oxy-acetylene cutting machines and tables .... ______
Oxy-acetylene cutting machines and tables (automatic) .... ______
Oxy-acetylene cutting machines and tables (contour machines) .... ______
Resistance welding machines .... ______
Inert gas-arc welding machines .... ______
Automatic welding machines .... ______
Equipment for photomicrographic studies .... ______
Equipment for photoelastic studies .... ______
Equipment for tension and bending tests .... ______
Equipment for heat treating welded specimens or projects .... ______
Other

______________________________ .... ______
______________________________ .... ______
______________________________ .... ______

11. Is welding offered to engineering students as a part of a course in manufacturing processes? (Yes) (No) If yes, please give official title of the course. ____________________ Credit hours ______. Number of hours in lecture ______. Hours in laboratory ______. Percent of the time devoted to welding ______.

12. The welding library consists of approximately ______ books and ______ periodicals that pertain to welding for engineers. Give number.

13. Have any provisions been made for engineering students at your institution to elect welding as an engineering option? (Yes) (No)

14. In your own opinion, do you feel that the opportunity for your engineering students to learn about welding is adequate. (Yes) (No)

15. I would appreciate any comments or suggestions you may have concerning the improvement of welding courses for engineering students.

Thank you very kindly for your cooperation.

Lynn J. Christensen

Lynn J. Christensen

OKLAHOMA AGRICULTURAL AND MECHANICAL COLLEGE
School of Trade and Industrial Education

Stillwater

April 13, 1950

Dear Sir:

Recently, I sent you a questionnaire concerning Welding in the Engineering Curricula. I hope you will find time to complete the questionnaire and return it so the results will be representative of all the engineering schools concerned with this problem.

Thank you for your cooperation.

Sincerely yours,

Lynn J. Christensen, Instructor
Engineering Shopwork

LJC/hd

Typist:

Harold A. Coonrad