THE ENGINEERING FOUNDATION

Welding Research Council

Sponsored by the American Welding Society and American Institute of Electrical Engineers

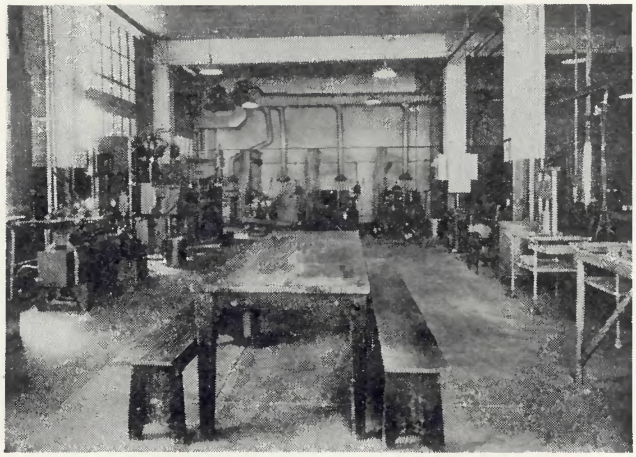
Supplement to the Journal of the American Welding Society, March 1943

Our University Research Workers and Their Laboratories

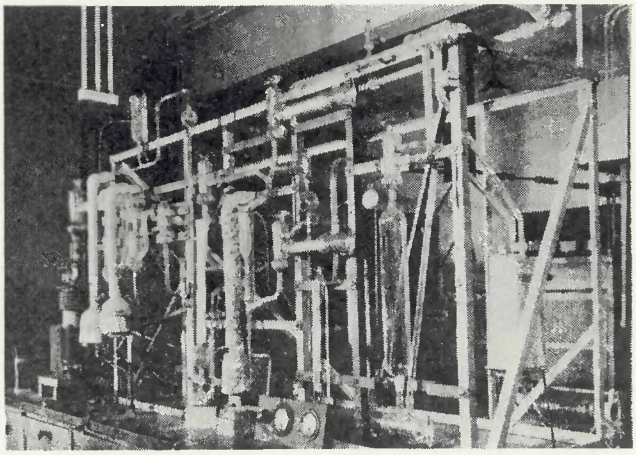
[EDITORIAL NOTE: *In order to familiarize our readers and industry with the talent and facilities available in the universities, the Welding Research Council proposes each month to publish in so far as it is able, a review of the welding research work at some particular university.*]

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Mass.

SEVERAL years ago Dr. John Norton of Massachusetts Institute of Technology presented a brief talk at one of the Annual Conferences of the University Research Committee (then known as the Fundamental Research Division). Dr. Norton pointed out that a few preliminary experiments had indicated the usefulness of the X-ray diffraction method in the measurement of residual stresses at the surface of piece of metal. The Council was quick to recognize the opportunities of the use of this tool and a program was quickly developed. Other departments of the University were brought in. Parallel investigations on residual stresses were started under Professor MacGregor using rotating flywheels. These and other investigations are mentioned below. The reader is invited to study the outline of the work under way and to meet some of the scientists responsible for the work.



General View of One Section of Welding Laboratory, Dept. of Mech. Eng., M. I. T.



Apparatus for Analysis of Oxygen and Nitrogen in Steel by Vacuum Fusion Method. Steel Making Laboratory, Dept. of Metallurgy, M.I.T.

Outline of Welding Research

Facilities Available:

Divided between Departments of Mechanical Engineers and Metallurgy. In M. E. Department, the facilities are under general direction of Prof. C. W. MacGregor and include:

1. Welding Laboratory (Profs. Kyle, Kiley).
2. Testing Materials Laboratory (Prof. Cowdrey).
3. Research Laboratory of Mechanics of Materials (Prof. MacGregor).

Also in M. E. Department and under direction of Prof. A. V. de Forest:

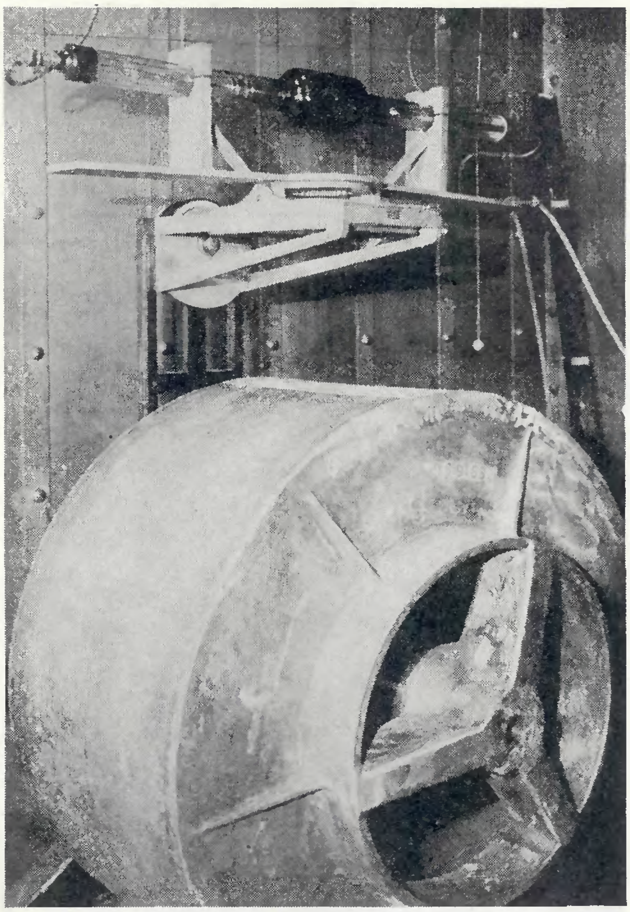
4. Dynamic Strength of Materials Laboratory.

In Metallurgy Department, under supervision of Prof. R. S. Williams, there are three laboratories:

5. Metallography Laboratory (Profs. Homerberg and Cohen).
6. X-ray Metallography Laboratory (Profs. Norton and Rosenthal).
7. Steelmaking Laboratory (Prof. Chipman).

The detailed facilities of these laboratories are as follows:

1. Apparatus for fatigue testing spot welds, resistance spot and butt welders, oxyacetylene welding and



Typical Set-up for Radiographic Inspection of a Welded Seam. Radiographic Laboratory, Dept. of Metallurgy, M.I.T.

cutting apparatus, direct- and alternating-current arc welders, and machines for performing all of the physical tests commonly used on welds.

2. A general testing laboratory for all sorts of mechanical testing.

3. A special research laboratory for problems of mechanics of materials. Included is equipment for photoelastic investigations.

4. Equipment for making stress-strain diagrams at high rates of loading up to approximately 8000 inches per inch per second at the maximum load. A complete description of the method is not yet available but the equipment is available for research work. These high rates of loading can be applied to the change in the yield point, in maximum, and breaking loads as the speed of loading is increased.

For fatigue work, a Rayflex Fatigue machine which may be used for studying the fatigue properties of butt-welded joints in sections up to $^1/_2$ in. thick by 4 in. wide. This machine was used by Dr. Rosenthal on his work on internal stresses.

The Stresscoat method of investigating strain distribution. NOTE: The laboratory has determined that in the presence of high internal stress it is easily possible to show the results of these stresses in causing extremely local yield-point phenomena under the first application of load. In other words, wherever locked-up stresses are present in steel which shows yield-point phenomena, this local yielding may be very readily indicated. After the first application of the load, the areas which have yielded locally will respond elastically on the next load application.

Resistance wire strain gages and equipment for the accurate determination of static and dynamic strain distribution. Wire gages of this type are very suitable for the measurement of internal stress by the relaxation system of cutting the metal in suitable places to relieve the internal stress after the wire gages have been installed.

Facilities for the magnetic powder inspection of welds; also fluorescent penetrating oil method of locating surface cracks and porosity in non-ferrous materials.

5. A general laboratory for metallography with complete facilities for microscopic examination and magnetic and dilatometric studies.

6. X-ray equipment for radiographic inspection up to 275 kv. (Special cooperation with Department of Physics permits radiographic work up to 2000 kv.) Also complete X-ray diffraction equipment for studies of metals including measurement of residual stresses.

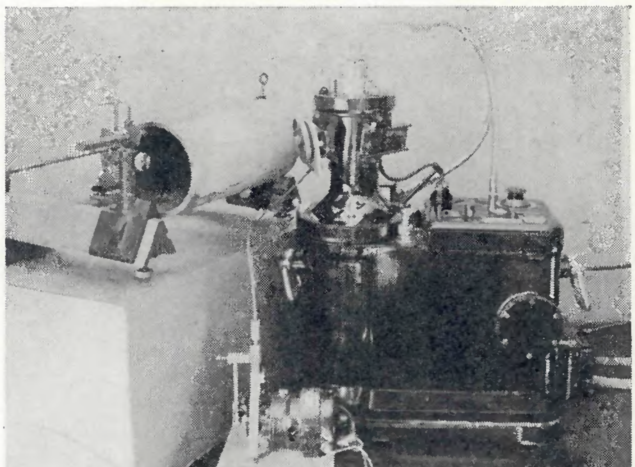
7. Equipment for melting special alloys in heats up to 150 lb. Also vacuum melting. Facilities for chemical analyses, determination of oxygen and nitrogen by vaccum fusion and determination of solubility of gases in metals.

NOTE: While all of the facilities listed are not being used at the moment for welding research, excellent cooperation exists between the different groups so that the special equipment of one laboratory can be made available to others working on a particular problem. The advantage of this situation as well as the many other contingent facilities available at M. I. T. is of enormous value.

Welding Research Projects Under Way:

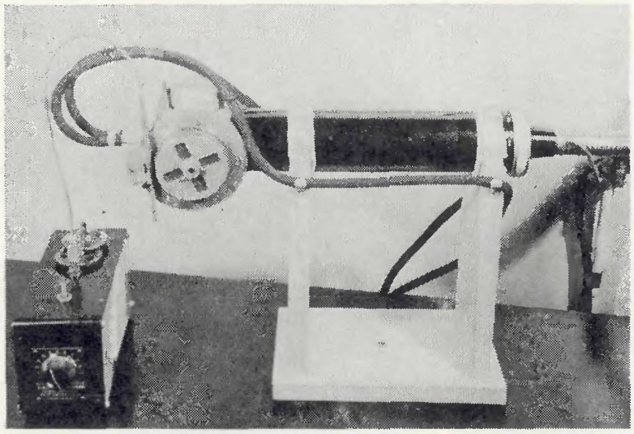
1. Fatigue Strength of Spot Welds—H. E. Kiley. This investigation is concerned with the fatigue testing of single spot welds in low carbon steel. In the testing, the laboratory has tried to produce reversing shear stresses in the welds by placing them in the chords of a vibrating cantilever beam. At the outset of the work, they used a magnetic device for forcing a vibration in the beam, but now they are using a testing machine in which the beam's vibrations are produced directly. This apparatus will largely eliminate bending stresses which have complicated the stress picture in previous tests. In this connection, the laboratory is making use of plotoelastic analysis in measuring the nature and magnitude of the stresses producing fatigue failure at the welds.

As data are obtained, they will be reported in the form of a ratio of endurance limit to ultimate static strength



Set-up for Measuring Residual Stresses in Welded Tubing by X-Ray Diffraction Method. X-Ray Metallography Lab., Dept. of Metallurgy, M.I.T.

for a spot weld in a given metal. Such information would be of value in connection with the design of spot-welded structures. This investigation is being continued, and as soon as a sufficient number of tests have been completed, the results will be reported.



Simplified and Portable X-Ray Unit for Stress Measurement with Cameras Mounted Directly on Shockproof X-Ray Tube. X-ray Metallography Laboratory, Dept. of Metallurgy, M.I.T.

2. High Speed Rotating Disk—C. W. MacGregor. There is underway at M. I. T. at the present time an investigation on High Speed Rotating Disks under the sponsorship of the Weld Stress Committee. One of the major problems is to investigate the effect of the residual stresses produced by welding small disks inside larger ones on the strength and ductility of such disks when subjected to high speeds of rotation. Due to the large restraint present in such welds and the consequent development of excessive residual stresses, this type of weld has always been difficult to fabricate in practice. The rotating disk has the advantage of being able to superimpose on the residual stresses due to welding a two-dimensional stress system with both radial and tangential stresses of nearly equal magnitude over a considerable portion of the disk. In addition, certain known residual stress systems will be introduced in solid disks and superimposed on those due to rotation. It is hoped that this study will throw new light on the effect of combined stresses on the strength and ductility of welds.

Most of the equipment has been designed and some of it already has been received from the manufacturers. The Lukenweld Company, Incorporated, through Mr. Everett Chapman, Chairman of the Sub-Committee on Weld Stresses, has fabricated a testing tank for these experiments. The Watertown Arsenal at the suggestion of Colonel Jenks will assist in some of the final machining operations on this tank which will be shipped to M. I. T. for final assemly. It is hoped that conditions will permit us to make some of the initial tests within a few months.

3. Influence of Residual Stresses on Behavior of Structure Subjected to Working Loads. This Welding Research Committee project under the direction of Profs. Norton and Rosenthal has been under way for the past year and has been confined to simple unwelded structures. Its purpose was to show the influence of working stresses upon existing systems of residual stress and to demonstrate the influence of these residual stresses on the mechanical behavior of the structure. In this work, the X-ray technique of measuring residual stresses in a non-destructive manner has been invaluable. The results of this work have been presented in a recent issue of The Welding Journal.

The project is now continuing for more complex structures in which the simple conditions for plastic flow and consequent relief of residual stresses are complicated by the presence of notches, inhomogeneities and three-dimensional states of stress.

4. Weldability Research—Prof. D. Rosenthal. A direct method of testing hardenability associated with welding in arc included steels.

The principal object of the proposed investigation is to devise a direct and simple method by means of which is welding technique can be predicted that will keep the hardness of steels sensitive to quenching below a specified value.

It is proposed to achieve the above object, first, by determining a specific factor that will characterize the hardenability of steel in arc welding irrespective of the conditions of heat flow of the particular process used and, second, by determining another specific factor that will take into account these conditions. When continuing this information a suitable welding technique may be found that will limit the hardness of steel to the desired value.

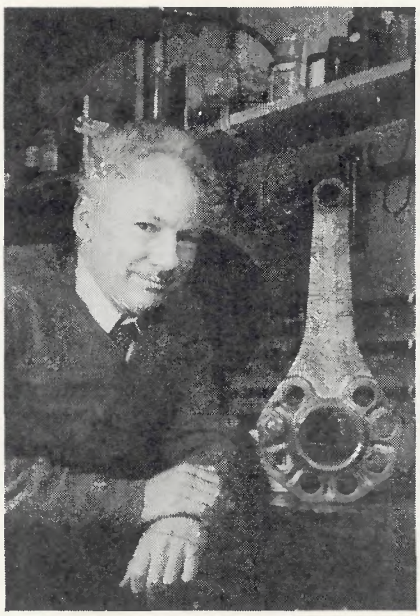
In addition, the method will provide a convenient means, first, to relate the hardenability in welding to the hardenability in quenching and, second, to compare different types of electrodes in so far as their influence on hardenability is concerned.

Publications of Research Projects (from X-ray Metallography Laboratory):

1. J. T. Norton, "The Examination of Welds by the X-ray Diffraction Method," American Welding Society Journal, **9**, 9, 11 (1930).
2. J. T. Norton, "X-ray Methods of Studying Stress Relief in Welds," The Welding Journal, **16**, 10, Research Suppl., 19–22 (1937).
3. J. T. Norton and B. Loring, "Stress Measurement in Weldments by X-ray," The Welding Journal, **20** (6), Research Suppl., 284-s to 287-s (1941).
4. J. T. Norton and D. Rosenthal, "An Investigation of the Behavior of Residual Stresses under External Load and Their Effect on Safety," The Welding Journal, **22** (2), Research Suppl., 63-s to 79-s (1943).

BIOGRAPHY

Alfred Victor de Forrest



Born April 7, 1888, New York, N.Y.; son of Lockwood and Meta (Kemble) de Forest; married Izette Taber of Philadelphia in Bar Harbor, Me., 1912; children, s. Taber, 1913, dau. Judith, 1915; Middlesex School, 1907; Grad. M. I. T., 1911, S.B.; Delta Psi; draftsman, New London Ship & Engine Co., 1912–13; instructor, Princeton Univ., 1913–15; Asst. Research Engineer, Rem-

C. W. MacGregor

John T. Norton

Daniel Rosenthal

ington Arms Co., 1915–18; Research Engineer, American Chain Co., 1918–30; consulting engineer on strength and fatigue of metals and methods of inspection, 1928 to date; President, Magnaflux Corp., 1930 to date; Associate Prof. M. I. T., 1934–37; Prof. M. I. T., 1937 to date. Member of A.S.M., A.S.T.M., A.I.M.M.E., Fellow of I. A.S.; Newcomen Society, Century Association, Amer. Acad. Arts and Sciences. Dudley Medal A.S.T.M., 1928; Longstreth Medal, Franklin Institute, 1936; Sylvanus Albert Reed Award, I.A.S., 1938; Modern Pioneer, Nat. Assoc. of Mfgs., 1940; Henry Marion Howe Lecturer, A.I.M.M.E., 1941. Author of many articles.

Professor C. W. MacGregor

Born May 25, 1908, in Dayton, Ohio. Elementary and high-school training in Dayton public schools. In 1929 awarded the degrees of B.S. in Electrical Engineering and B.S. in Engineering Mathematics from the University of Michigan. Studied under Professor S. Timoshenko during this time. Accepted position as research engineer in October 1929 with the Westinghouse Electric and Manufacturing Company. Attended night school during this period at the University of Pittsburgh and was awarded the degrees of M.S. in Mechanical Engineering in 1932 and Ph.D. in Mathematics and Mechanical Engineering in 1934 with highest honors. Leaving Westinghouse in the spring of 1934 and after short periods with the Gulf Research and Development Corporation in Pittsburgh and the U. S. Bureau of Reclamation in Denver, Col., accepted instructorship at M. I. T. in the fall of 1934. Promoted to Assistant Professor in 1937, to Associate Professor in 1938 and to Professor in 1942.

Both before and since coming to M. I. T., most of his work has been in the fields of elasticity, plasticity, the testing of materials, and stress analysis in design. In 1937 organized the Laboratory for Mechanics of Materials at M. I. T. In 1942 was placed in charge of the Materials Division of the Mechanical Engineering Department comprising the Testing of Materials, Welding, Foundry, and Metal Processing Laboratories. Besides teaching applied mechanics, advanced testing of materials, plasticity, etc., carrying on extensive research work in various fields such as rolling of metals, high-speed rotating disks, cold working problems, strength of materials under combined stresses, impact, etc.

Awarded the Louis E. Levy medal by the Franklin Institute May 1941 and the Charles B. Dudley medal by the A.S.T.M. in June 1941.

Secretary of Special Research Committee on Rolling of Steel of the A.S.M.E. and member of Sub-Committee on Weld Stresses.

John Torrey Norton

Norton, Prof. John T(orrey). Massachusetts Institute of Technology, Cambridge, Mass. Metallurgy, Medford, Mass., Nov. 13, 1898. Nashua, N. H., High School. B.S., M.I.T., 1918. Sc.D., M.I.T., 1933. Instructor, Physics, M.I.T., 1920–26. Asst. Prof. Physics, 1926–29. Associate Prof., Metallurgy, 1930–41. Prof., Metallurgy, 1942— .

Member of: Am. Inst. Min. and Met. Eng.; Am. Phys. Soc.; Am. Soc. for Metals; British Institute of Metals; Am. Soc. Testing Materials; Field Artillery Association; Army Ordnance Assn.; Fellow of the American-Scandanavian Foundation.

Field of Research: Physical Metallurgy; X-ray Metallography; Physics of Metals; spent one term at University of Stockholm studying in this field. In charge of laboratories of Radiography and X-ray Metallography in Dept. of Metallurgy, M. I. T.

Daniel Rosenthal

Born in Lodz (Poland), March 19, 1900.

Degrees received: University of Brussels, Belgium: Civil Engineer, 1924; Aeronautical Engineer, 1925; Sp. Dr. of Engineering, 1932.

Position held: (*a*) With the University of Brussels, Belgium: Assistant, 1924–28; Instructor, 1928–38; Agregé (Assistant Professor), 1938–40. (*b*) With Massachusetts Institute of Technology, Cambridge, Mass.: Research Associate, 1941–42; Assistant Professor of Metallurgy since 1942; Consulting Engineer to the Belgian Arcos Co. (Electrodes Mfg. Co.).

Membership: International Society for Testing Materials, Belgian Engineering Society, American Welding Society, Society of Sigma Xi, Fellow of the Belgian-American Educational Foundation.

Field of Research: Metallurgy and Physics of Welding.

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Supplement to the Journal of the American Welding Society, April 1943

Our Research Laboratories

Rensselaer Polytechnic Institute

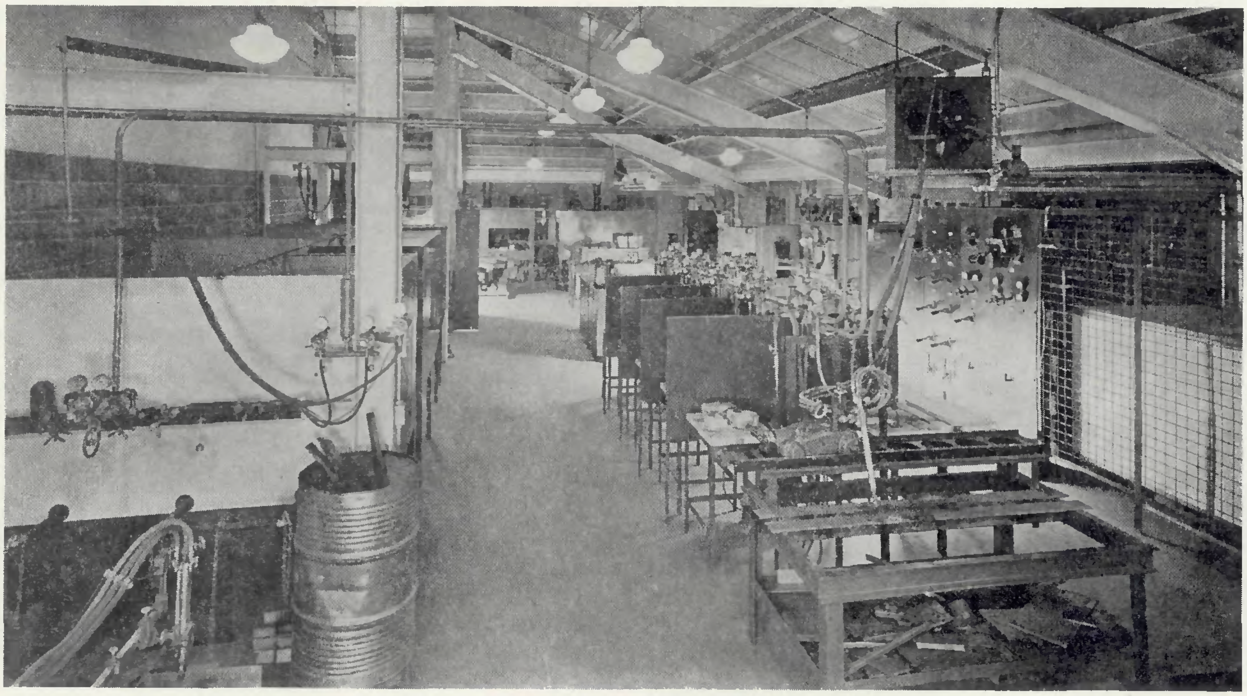
WHEN one thinks of welding research at R.P.I. one automatically associates the name of Dr. Wendell F. Hess with this work. The activities of the research group at R.P.I. have been varied, covering arc, gas and resistance welding. In the last mentioned field, it ranks as the major research laboratory of this country.

A Description of Research Facilities at the University

The welding laboratory of the Rensselaer Polytechnic Institute includes equipment for all of the most important processes. Electric arc welding may be performed either manually or automatically, with alternating or direct current. Three d.-c. equipments provide low, medium and high ranges of current, from 25 to 600 amp. The a.-c. equipment comprises transformers for medium and for high ranges of current from 100 to 750 amp. The automatic metallic arc-welding equipment may be used on either alternating or direct current and with bare or covered electrode or single-electrode feed. Automatic carbon-arc equipment is also available with provision for the addition of filler metal and the use of a powdered flux.

Atomic-hydrogen welding equipment is also available with 30- and 60-amp. torches. Gas-welding equipment includes a group of torches for manual welding and cutting. Cutting equipment also includes a straight-line cutting machine which has been very useful in the preparation of plates for welding, and a shape-cutting machine capable of cutting on curves in accordance with templates or circles by means of radius rods. Resistance-welding equipment includes a large and small spot welder, a seam-welding machine and a flash-welding machine. The resistance-welding equipment is supplied by a large motor generator set in order to absorb the large single-phase load which may be drawn by the resistance-welding equipment which would normally create too heavy a demand on the Institute power system.

Electronic control equipment provides a maximum flexibility for research in the field of spot and seam weld-



General View of Laboratory

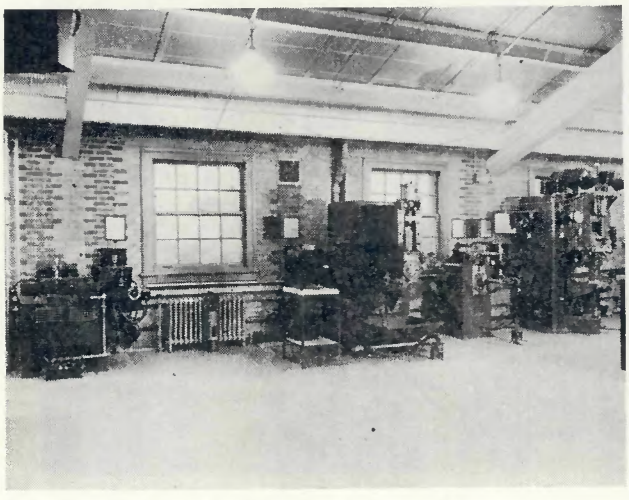
ing. The control is equipped for automatic postheating and for a wide variety of special welding sequences to permit the spot welding of heavy plate.

The purpose which has governed the selection of equipment from the very beginning was to provide equipment suitable for research and not simply for instruction or demonstration. Features were incorporated to permit fundamental research by providing flexibility of arrangement and accuracy of control of the welding variables. The variety of the equipment is wide and the number of units of any one kind is small. The laboratory is thus an engineering laboratory in the department of metallurgical engineering and is not used to supplement the usual shop courses. The laboratory is used by the various student groups studying welding to supplement the theory with just sufficient laboratory experience to better grasp the underlying principles. Time is not available for acquiring manipulatory skill.

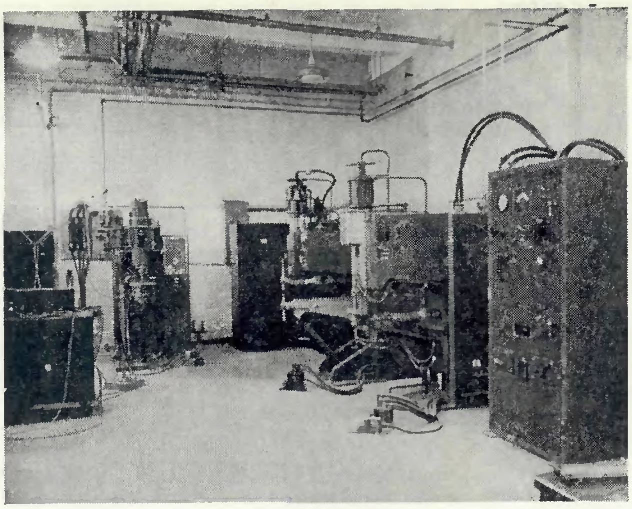
In addition to the regular equipment which is the property of the welding laboratory, there have been for the past two years from one to three machines in the laboratory on loan from various companies for the purpose of spot welding aluminum alloys for aircraft. These machines have been changed from time to time to keep abreast of the very latest developments in the field of stored energy spot-welding equipment. A special control equipment providing unusual flexibility for research in this field has been purchased on loan to the laboratory for work under its contracts by the Army Air Forces.

The welding laboratory is unusually well situated in a new and well-equipped group of metallurgical engineering laboratories which provide the necessary facilities for evaluating the results of experimental welds. These laboratories include metallographic, both visual and photographic, radiographic, spectrographic and testing laboratories. Electrochemical electroplating equipment has also been used in connection with a number of welding researches. The testing laboratory equipment includes an automatic stress-strain recorder and special extensometers for the testing of welds. It also includes a Vickers hardness testing equipment and Izod, Charpy and tensile attachments for a Riehle impact machine, as well as the usual Rockwell hardness measuring equipment.

Special equipment has been built up in the laboratory for the measurement of spot-welding current, spot-welding electrode pressure during welding and flash-welding energy input and distribution of energy during flash welding. This laboratory has pioneered in the de-



Resistance Welding Machines



Aircraft Research Laboratory

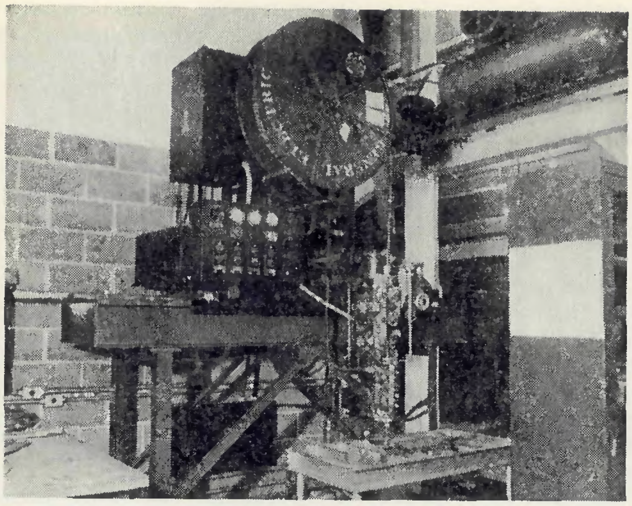
velopment of electrical-measuring equipment for both spot and flash welding. The special equipment has made possible the extension of research in many important fields, particularly that of spot welding.

Unusually fine equipment has been obtained for the automatic recording of temperatures at high speed. This equipment has been found particularly useful in the correlation of weld-cooling curves with welding conditions. The measurement of weld-cooling curves provides an essential link between fundamental metallurgical principles and welding practice. The automatic-temperature-measuring equipment has also proved to be a necessary tool for establishing the fundamental principles of the spot welding of heavy plate and particularly the heat treatment of spot welds within the welding machine. New and further fundamental advances in the field of arc welding will be made possible by virtue of spectrographic analysis equipment which has recently been acquired by the laboratory through the generosity of the Chicago Bridge and Iron Co.

Some of the Historical Background of the Welding Research Activities of the University

Activities in the field of welding began at the Rensselaer Polytechnic Institute in 1929 as a result of a request from the Navy Department that a course in welding be given to Naval Officers who were being sent to the Institute for a special three-year training period from the Bureau of Yards and Docks of the Navy Department. Dr. Hess had become interested in arc welding about two years before this time as a result of a loan to the Rensselaer Polytechnic Institute of an arc-welding motor-generator set by the Lincoln Electric Co. This experience led to the assignment to teach the Navy course.

The major developments in the welding laboratory at Rensselaer Polytechnic Institute dated from a suggestion of Captain G. A. Duncan of the Bureau of Yards and Docks in the Navy Department, and a member of the Class of 1912 at the Institute. He felt that ignorance of the possibilities of welding was breeding a prejudice against its adoption. He suggested that younger engineers should be educated in the science of welding and made more familiar with its opportunities and limitations. A further specific suggestion was that the Rensselaer Polytechnic Institute should equip itself with an adequate welding laboratory. During the summer following Captain Duncan's suggestion, Dr. Hess made three trips covering different geographical sections for



Automatic Arc Welding Setup

the purpose of studying at first hand various phases of the application of welding. During these visits, an opportunity was provided to discuss with many of the leaders in the field of welding the purposes, value and equipment which should be provided in a university welding laboratory.

As a result of visiting many of the manufacturers of welding equipment, the availability and cost of such equipment as was necessary to equip a welding laboratory of the type desired were determined and a budget prepared. The University was unusually fortunate in having financial assistance for setting up such a laboratory through the generosity of Mr. George T. Horton, President of the Chicago Bridge and Iron Co., a strong advocate of welding. The new laboratory, established in 1937, occupies a little more than 3000 sq. ft. of the top floor of the Ricketts Laboratory. The third and fourth floors of this building are occupied by the department of metallurgical engineering which was new and very well equipped during the years just prior to the establishment of the welding laboratory.

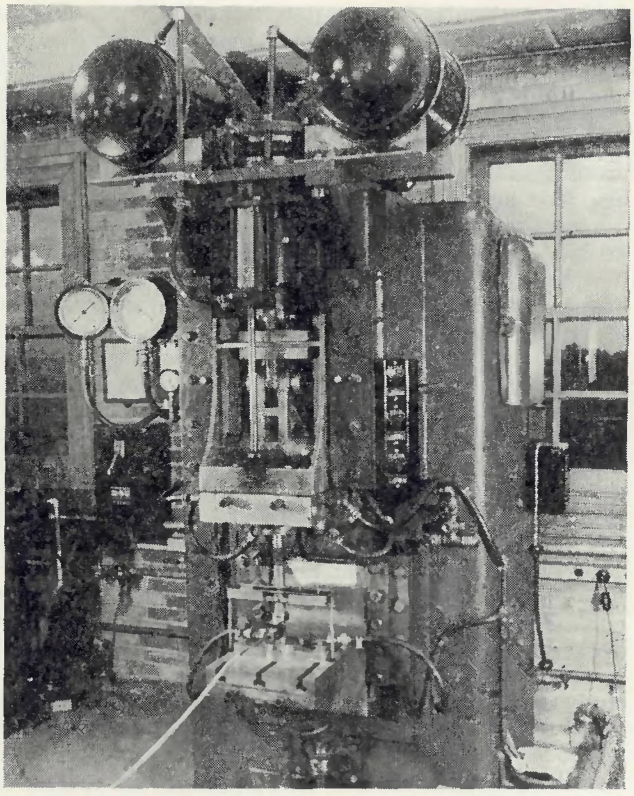
From the standpoint of fundamental research the welding laboratory is very fortunate in being affiliated with the department of metallurgical engineering whose facilities for heat treatment, microscopic examination and photography, radiographic examination and diffraction studies and physical testing equipment are admirably fitted for a wide variety of welding research.

In 1938 the Welding Research Committee extended its first resistance-welding fellowship to the Rensselaer Polytechnic Institute for the purpose of studying some fundamental principles in the spot welding of low carbon and stainless steels. This fellowship has been continued until the present time and Reports Nos. 2, 3, 4, 5, 7, 8, 15 and 22 have been published as a result of this work. In January 1939 Mr. Robert A. Wyant was added to the research staff of the welding laboratory in connection with the spot-welding research programs. In August of 1939 the International Nickel Co. established its first fellowship in the study of the resistance welding of nickel and high-nickel alloys. Mr. Albert Muller was added to the research staff at this time to take care of the nickel programs which have been continued until the present time. Report No. 13 has been published as a result of the International Nickel Co. fellowships. The published report combines a large number of reports which have been submitted to the company during the course of the investigations. In October 1940 the National Advisory Committee for Aeronautics, the Army Air Forces and the Navy Bureau of Aeronautics established their first research program in connection with the spot welding of aluminum alloys for aircraft. In support of the aircraft program, the Aluminum Co. of America has contributed annually for the purchase of special equipment used in these investigations. The Oakite Co. has also made a contribution to the equipment fund. The Taylor-Winfield Corp., the Federal Machine and Welder Co. and the Sciaky Corp. have contributed to the aircraft spot-welding program through the loan of welding machines comprising a variety of stored energy equipment not possessed by the welding laboratory. The Army Air Forces also contributed the loan of a special control cabinet for studying a variety of wave forms of stored energy discharges in the effort to determine whether more suitable wave forms might be found than those provided by commercially available equipment. In all this work the University, of course, had the guidance and advice of appropriate project committees of the Welding Research Council.

A Brief Statement of the Current Investigations Under Way

The following investigations are under way at the present time:

1. Resistance Welding Fellowship. This program is continuing the study of the spot welding of hardenable steels. The program has completed during the past year a study of the proper methods of obtaining tough spot welds in X-4130 aircraft steel in the 0.040-in. thickness. Work has also been practically completed but not yet reported on the same gage of three plain carbon steels: SAE 1020, SAE 1035 and SAE 1045. The work during the coming year will complete a study of these four materials in the 0.125-in. thickness. This program has opened up a new field of spot welding in which it has been shown to be possible to produce remarkable tough-



Large Spot Welding Machine

ness of welds made in hardenable steels by means of a postheat treatment in the welding machine. The program is a continuation of work undertaken during the early part of last year under the sponsorship of the Great Lakes Steel Corp. on their low-alloy steel NAX 9115.

2. A program sponsored by the International Nickel Co. on the resistance welding of nickel and high nickel alloys is now studying the flash welding of these alloys in both rod and sheet form, together with a number of other special problems. An important fundamental angle of the investigation has been the development of methods of measuring the energy used in flash welding and the distribution of that energy during and subsequent to the flashing process. Recent work has involved the study of the spot welding of these alloys using stored-energy welding equipment.

3. Aircraft spot-welding research on aluminum alloys is engaged in developing methods for the surface preparation of aluminum prior to spot welding and is studying the fundamental effects of wave shape and the use of variable pressure cycles during the welding operation. Adaptation of the A.S.T.M. statistical methods is being made for the purpose of evaluating the quality of welding produced by a welding machine or a group of machines under the same supervision. The value of this type of work is important to the design and use of spot welding in the more highly stressed parts of aircraft structures. Specimens are being prepared under carefully controlled conditions for fatigue and corrosion studies.

4. Under the support of the Office of Scientific Research and Development, a program of research is being carried out to develop the necessary technical information for the spot welding of low-alloy steels in the range of thickness from $^1/_4$ to $^1/_2$ in.

5. Under the Office of Scientific Research and Development a study is being made for the purpose of correlating weld-cooling curves with welding conditions. This will make possible a great forward step in the application of fundamental metallurgical information to the arc welding of various steels. It will be readily possible for any particular steel to determine the welding conditions which should be used to obtain satisfactory ductility. For any given steel it will be possible to determine the maximum thickness in which it may be considered weldable under various assumed limitations as to welding technique. In other words, a given steel will be weldable up to a certain thickness without preheat and up to still heavier thicknesses for different degrees of preheat. It is gratifying that present arc-welding research is able to provide an important link in the technical information necessary to place this process upon a more scientific basis. The experimental work is being widely extended by means of mathematical solutions to permit the determination of a much larger body of information than would otherwise be possible with a limited amount of experimental investigation. The experimental work is being utilized to bring the mathematical solutions into their proper relation with regard to factors which cannot be absolutely determined by mathematical solutions alone. In turn, the mathematical solutions, once properly established, widely extend the amount of available data over that which was determined experimentally.

6. Parallel to the last mentioned OSRD program, work is going forward under the support of the Welding Research Council to provide other necessary links in the scientific application of arc welding. These include a study of the physical properties of arc-welded joints made under controlled conditions and the study of the methods of determining the necessary fundamental metallurgical information to complete the weldability picture. This program includes the testing of welds in ship steel made under controlled conditions as to plate temperature, arc voltage, arc current and travel speed. The welds are being made in $^1/_4$-, $^1/_2$-, 1- and $1^1/_2$-in. plate, using ship steel for the first major group of welds.

A Biographical Reference to Some of the Leading Professors Interested in Welding Research

The generous encouragement of welding research by the Institute authorities, and in particular by President W. O. Hotchkiss and members of the Board of Trustees, has contributed in large measure to the ability of the welding laboratory to be of service to the nation in the present war effort. Dr. Matthew A. Hunter, head of the Department of Metallurgical Engineering, has assisted in guiding the conduct of the programs by his mature good judgment and has been of inestimable assistance during the present critical man-power situation in making available every possible hour of staff and student time for the effective conduct of the war research programs.

Mr. Robert A. Wyant, who joined the staff of the welding laboratory in 1939 after a period of industrial experience with the International Harvester Co. and the Bell Telephone Laboratories, was made a regular member of the faculty early in 1942 with the rank of Assistant Professor in the Department of Metallurgical Engineering. He has made an excellent record in the development of special measurement techniques and in the guidance of the aircraft spot-welding research programs.

Dr. Lynn L. Merrill of the Institute's Department of Mathematics is making a signal contribution to the extension of information experimentally determined in the weldability program. Professor E. H. Van Winkle of the Department of Business Administration is assisting in the application of statistical methods to the evaluation of welding quality in the spot welding of aluminum alloys for aircraft. Professor L. W. Clark of the Department of Mechanics has made available additional testing equipment and time of members of his staff for supplementing the testing facilities in the Department of Metallurgical Engineering and expediting important welding research. Professor G. Howard Carragan of the Department of Physics has loaned optical apparatus and given valuable advice on optical problems associated with welding research. Dr. A. W. Davison, until recently head of the Department of Chemistry and Chemical Engineering, has loaned valuable additional floor space in the chemical engineering laboratories for war-welding research and has obtained special materials needed in the research. Numerous other members of the faculty have contributed to the welding research programs.

Brief Biography of Wendell F. Hess

Attended Rensselaer Polytechnic Institute at Troy, N. Y., for four years, graduating in 1925 with the degree E.E. (Electrical Engineer). Graduate study at theRensselaer Polytechnic Institute for three years ending 1928 with the degree D.Eng. (Doctor of Engineering). Instructor in Electrical Engineering and Physics, Rensselaer Polytechnic Institute, 1928 to 1930.

In 1929 began teaching course in welding to United States Navy Annapolis graduates sent to Rensselaer Polytechnic Institute by the Bureau of Yards and Docks for special training. Continued since that date.

Assistant Professor of Electrical Engineering and Physics, 1930 to 1937. Assistant Professor in Metallurgical Engineering, 1937 to 1938. Associate Professor in Metallurgical Engineering and Head of Welding Laboratory, 1938 until the present time.

Wendell F. Hess

Offices Held: Chairman, Northern New York Section of AMERICAN WELDING SOCIETY; Past District Vice-President of the AMERICAN WELDING SOCIETY New York and New England district; Present Chairman of Committee on awards, AMERICAN WELDING SOCIETY. Member of A.W.S., A.I.E.E. and S.P.E.E.

Publications

1. "Development in Welding at Rensselaer Polytechnic Institute," by Wendell F. Hess, WELDING RESEARCH SUPPLEMENT, March 1938.
2. "Studies of Spot Welding of Low Carbon and Stainless Steels," jointly with R. L. Ringer, Jr., WELDING RESEARCH SUPPLEMENT, October 1938.
3. "The Spot Welding of Low Carbon Steels," jointly with R. L. Ringer, Jr., WELDING RESEARCH SUPPLEMENT, April 1939.
4. "Further Studies of the Spot Welding of Low Carbon and Stainless Steels," jointly with R. A. Wyant, THE WELDING JOURNAL, AMERICAN WELDING SOCIETY, October 1939.
5. "An Investigation of the Spot Welding of Automobile-Grade Mild Steel," jointly with R. A. Wyant, THE WELDING JOURNAL, AMERICAN WELDING SOCIETY, October 1939.
6. "The Measurement of Spot-Welding Current," jointly with R. A. Wyant and A. Muller, presented at the A.I.E.E. Mid-Winter Meeting, published in the *Transactions of the American Institute of Electrical Engineers*, Vol. 59, June 1940.
7. "Changes in the Shape of Spherical Spot-Welding Electrodes," jointly with R. A. Wyant, WELDING RESEARCH SUPPLEMENT, October 1940.
8. "A Method of Studying the Effects of Friction and Inertia in the Resistance Welding Machines," jointly with R. A. Wyant, WELDING RESEARCH SUPPLEMENT, October 1940.
9. "Spot Welding of 0.040 In. Alclad 24S-T with Alternating-Current Equipment," jointly with R. A. Wyant and B. L. Averbach, distributed by N.A.C.A., May 1941, as Report No. 1, Aircraft Spot-Welding Research and published in the WELDING RESEARCH SUPPLEMENT, September 1941, pages 402-s to 409-s.
10. "Report on Investigation of Spot-Weld Test Specimens—Part I—Comparison of Specimen Types and Dimensions—Alclad 24S-T 0.020 In., 0.040 In., 0.064 In. in Thickness," jointly with R. A. Wyant and B. L. Averbach, Report No. 2, Aircraft Spot-Welding Research, N.A.C.A., September 1941. Published also in the WELDING RESEARCH SUPPLEMENT, March 1942, pages 113-s to 119-s.
11. "An Investigation of the Surface Treatment of Alclad 24S-T in Preparation for Spot Welding," jointly with R. A. Wyant and B. L. Averbach, Report No. 3, Aircraft Spot-Welding Research, N.A.C.A., September 1941. Published also in the WELDING RESEARCH SUPPLEMENT, June, 1942 pages 258-s to 265-s.
12. "An Investigation of Spot-Weld Test Specimens—Part II—Comparison of Specimen Types and Dimensions—52S-$^1/_2$H 0.040 In. in Thickness," jointly with R. A. Wyant and B. L. Averbach, Report No. 4, Aircraft Spot-Welding Research, N.A.C.A., October 1941. Published also in the Welding Research Supplement to THE WELDING JOURNAL, March 1942, pages 119-s to 122-s.
13. "The Spot Welding of Nickel, Monel and Inconel," jointly with Albert Muller, WELDING RESEARCH SUPPLEMENT, October 1941, pages 417-s to 427-s.
14. "Evaluating Welded Joints," by W. F. Hess, WELDING RESEARCH SUPPLEMENT, October 1941, pages 453-s to 459-s.
15. "Electrical Measurement of Electrode Pressure During Spot Welding," jointly with L. D. Runkle, WELDING RESEARCH SUPPLEMENT, October 1941, pages 491-s to 499-s.
16. "An Investigation of the Spot Welding of Aluminum Alloys Using Condenser-Discharge Equipment Provided by the Taylor-Winfield Corporation," jointly with R. A. Wyant and B. L. Averbach, Report No. 5, Aircraft Spot-Welding Research, N.A.C.A., March 1942.
17. "Examination of Spot Welds in Alclad 24S-T," jointly with R. A. Wyant and B. L. Averbach, Report No. 6, Aircraft Spot-Welding Research, N.A.C.A., March 1942.
18. "An Investigation of the Spot Welding of Aluminum Alloys Using Magnetic Energy Storage Equipment Provided by the Sciaky Brothers," jointly with R. A. Wyant and B. L. Averbach, Report No. 7, Aircraft Spot-Welding Research, N.A.C.A., May 1942.
19. "The Spot Welding of Dissimilar Thickness of Alclad 24S-T," jointly with R. A. Wyant and B. L. Averbach, Report No. 8, Aircraft Spot-Welding Research, N.A.C.A., June, 1942.
20. "An Investigation of Current Wave Form for Spot Welding Alclad 24S-T, 0.020 In. in Thickness," jointly with R. A. Wyant and B. L. Averbach, Report No. 9, Aircraft Spot-Welding Research, N.A.C.A., July 1942.
21. "The Surface Treatment of Alclad 24S-T Prior to Spot Welding," jointly with R. A. Wyant and B. L. Averbach, Report No. 10, Aircraft Spot-Welding Research, N.A.C.A., September 1942.
22. "The Spot Welding of 0.040 In. S.A.E. X-4130 Steel," by W. F. Hess and D. C. Herrschaft, WELDING RESEARCH SUPPLEMENT, October 1942, pages 441-s to 447-s.
23. "The Effects of Cooling Rate on the Properties of Arc-Welded Joints in Carbon Moly 0.50 Plate," by W. F. Hess, published in WELDING RESEARCH SUPPLEMENT, December 1942, pages 608-s to 619-s.

Swiss Acetylene Society

THE following notes are extracted from the annual report of the Swiss Acetylene Society for 1941, which was published in June 1942. The year 1941 was the thirty-first year of the Society's existence and was characterized by unusually heavy demand for carbide, oxygen, acetylene and welding equipment. The demand was met in 1941, but with limited supply of material and requirements of the army for manpower, it is difficult to state for how much longer the demand can be supplied. The usual services provided by the Society, such as publications, courses of instruction, and inspection, have been maintained, two developments in particular being outstanding: the right-hand welding of thin sheet, and oxyacetylene pressure welding. A new and growing use for acetylene is for automobiles and trucks, 4000 of which were equipped for operation with acetylene instead of gasoline in 1941 in Switzerland. The Society had 870 members at the end of 1941.

Correction

On page 93-s of the February Supplement, in the "Requirements for First Class Welds in Switzerland," item (6), the formula was given as $k = (T/R)$. This should read $k = (50\ T/R)$.

THE ENGINEERING FOUNDATION

Welding Research Council

Sponsored by the American Welding Society and American Institute of Electrical Engineers

Supplement to the Journal of the American Welding Society, May 1943

Research in Our Universities

LEHIGH UNIVERSITY
Bethlehem, Pa.

PROBABLY no other university has a longer or more sustained record of cooperation in welding research than does Lehigh University. The research work has been a two-pronged affair carried on in two different departments, Metallurgical and Civil Engineering, and in widely different fields. In both instances the contributions have been notable and have added materially to our basic knowledge.

The brief description of the work at Lehigh is divided into main branches, (1) Metallurgical and (2) Structural.

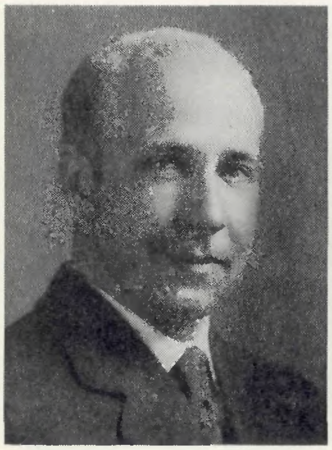
METALLURGICAL RESEARCH

The welding research being done at present under the direction of the Metallurgical Department involves the evolution of a system for predicting the ductility in the zone adjacent to an arc weld, whatever the joint design may be and whatever plate thickness, atmospheric temperature and rate of heat input per inch may be followed. The purpose of this system is to extend the field of arc welding to those low-alloy and high carbon steels which are not now welded because of fear of the embrittling effect of the arc heat on the steel and rapid cooling in this zone from the high temperature. It appears that this system will permit the choice of correct welding procedure for each heat of steel without making any welding tests but simply by the preparation of a Jominy end quench bar and a few simple notch bend specimens.

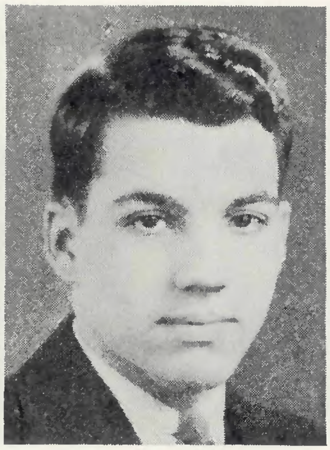
General Laboratory (East End)

This work was begun in 1940 with the assistance of Dr. E. M. Mahla of the Du Pont Company. The work has received financial support from the Welding Research Committee and from the Office for Scientific Research and Development. It has been carried out in coordination with a similar study made at Rensselaer Polytechnic Institute under the same auspices. A report of the results will be released in the near future by N.D.R.C. for publication in THE WELDING JOURNAL.

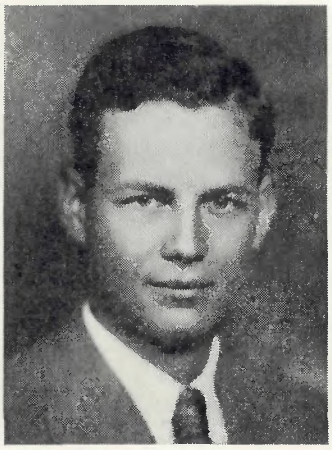
The Metallurgical Group



G. E. Doan

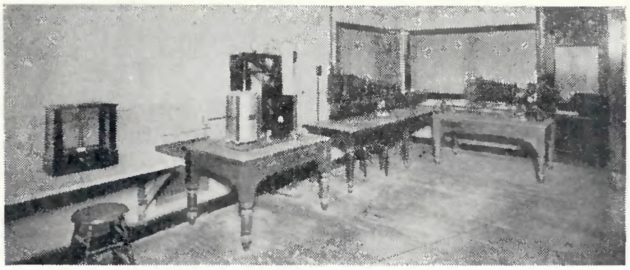


R. D. Stout



J. H. Frye, Jr.

S. S. Tör



Microscope Room

The Men Doing the Work

Gilbert E. Doan graduated from Lehigh University as Chemical Engineer in the Class of 1919. He spent a year as metallographist at the U. S. Naval Engineering Experiment Station at Annapolis under the supervision of Dr. D. J. McAdam and in 1920 joined the Una Welding Co. of Cleveland, Ohio, as Director of the Research Laboratory. He visited all of the larger street railway systems in North America, teaching arc welding to a large number of track repairmen and construction crews. In 1922 he was sent to Germany by his firm to investigate current progress in arc welding in that country. From 1924 to 1926 he spent as a graduate student in metallurgy at the University of Berlin and received the Ph.D. degree in 1927. In 1929 he spent five months at the U. S. Naval Research Laboratory at Anacostia in collaboration with Dr. Robert F. Mehl in development of the Gamma Ray Method of Radiography. In 1930, Engineering Foundation established a welding research fellowship at Lehigh University which continued under Professor Doan's direction until 1938. He has served as consultant to many industrial corporations, especially on problems involving radiography of steel castings and in the development of welding processes. He is now Head of the Department of Metallurgy.

Robert D. Stout was born in Reading, Pa., and educated in the public schools there. He received a B.S. from Penn State in 1935 and an M.S. from Lehigh University in 1941. From 1935 to 1939 he was connected with the research laboratories of the Carpenter Steel Co. Since 1939, he has been instructor in metallurgy at Lehigh University. His doctorate work is on the subject of weldability.

Sadun S. Tör was born on March 2, 1916, in Istanbul, Turkey. After finishing his primary education in a Turkish school he entered Robert College, Istanbul, Turkey. In 1936, after finishing his junior year in the Mechanical Engineering Department of Robert College he came to the United States of America on a Turkish Government Scholarship and entered the Colorado School of Mines, Golden, Colo., to study mining engineering. He received his Engineer of Mines diploma from this institution in June 1939, and then stayed on to get his Master's degree in Mining Engineering in 1940. In the fall of 1940 he entered Lehigh University, Bethlehem, Pa., and received his Master's degree in Metallurgy in 1941. During this period he became interested in the problems of heat flow in arc welding and in the summer of 1941 he started to work on this problem together with Robert D. Stout. At present he is still working on this arc welding project at Lehigh.

Bibliography of Research Reports

G. E. Doan, "Inspection of Welds with Gamma Rays," presented at the Thirteenth Annual Convention of the American Society for Steel Treating, Boston, Sept. 21 to 25, 1931.

G. E. Doan, "Arcs in Inert Gases, II," *Physical Review*, May 1934.

G. E. Doan, "Concerning Crater Formation," AMERICAN WELDING SOCIETY JOURNAL, July 1932.

G. E. Doan and J. L., Myer, "Arc Discharge Not Obtained in Pure Argon Gas," *Physical Review*, **40**, (1), 36–39 (April 1, 1932).

G. E. Doan and J. M. Weed, "Metal Deposition in Electric Arc Welding," AMERICAN WELDING SOCIETY JOURNAL, Sept. 1932.

G. E. Doan, "Arcs in Inert Gases, III," *Physical Review*, May 15, 1935.

G. E. Doan, "Arc Welding in Argon Gas," *Electrical Engineering*, July 25, 1935.

G. E. Doan, "Annual Progress Report on the Welding Industry for 1935," *Steel*, Jan. 6, 1936.

G. E. Doan, "The Metallurgy of 'Pure' Iron Welds," *Metals Technology and Transactions, A.I.M.E.*, Feb. 1936.

G. E. Doan, "Metal Deposition in Arc Welding," THE WELDING JOURNAL, **17** (1), 15–19 (1938).

G. E. Doan and A. M. Bounds, "Arc Welding Atmospheres," *Ibid.*, **17** (6), 1–4 (1938).

G. E. Doan and S. S. Young, "Crater Formation in Arc Welding," *Ibid.*, **17** (10) 61–67 (1938).

G. E. Doan and M. C. Smith, "Studies in Arc Welding," *Ibid.* (preprinted in November 1939), **18** (10), 62–68 (1939).

G. E. Doan, "Annual Review of Progress in Welding," *Steel*, **104**, 183 (Jan. 2, 1939).

G. E. Doan and R. E. Lorentz, Jr., "Crater Formation and the Force of the Electric Welding Arc in Various Atmospheres," presented at Annual Meeting, A.W.S., Cleveland, Ohio, October 21–25, 1940.

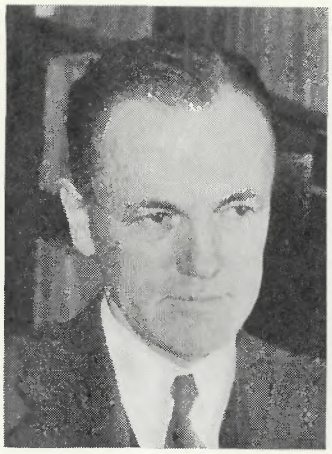
G. E. Doan, "Annual Review of Progress in Welding," *Steel*, **106** (1), 210 (Jan. 1, 1940).

E. M. Mahla, M. C. Rowland, C. A. Shook, and G. E. Doan, "Heat Flow in Arc Welding," THE WELDING JOURNAL, **20** (10), Research Suppl., 459-s to 468-s (1941)

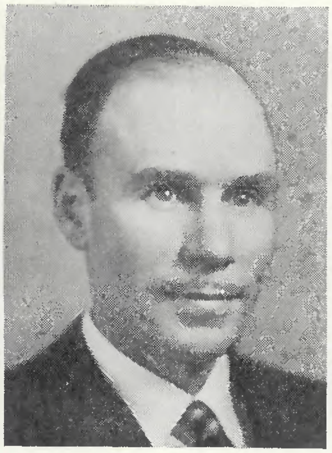
STRUCTURAL WELDING

Welding activities began at Lehigh University in the winter of 1926–27 with a Welding Symposium under the direction of Professors R. J. Fogg, F. V. Larkin and Bradley Stoughton. These Symposiums were held annually until the depression and did much to stimulate welding in the Lehigh Valley and neighboring districts. The Symposiums consisted of demonstrations of the various kinds of welding by representatives from industry, physical tests of welded joints and the presentation of papers on selected subjects. One year the theme was "Welding Versus Riveting," and another year "In-

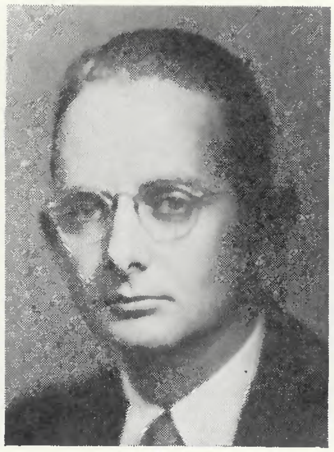
Welding Laboratory



H. Sutherland



C. Jensen



Bruce Johnston

R. M. Mains

spection of Welding." In 1929, Mr. Hagglund of the Merritt, Chapman, Scott Corp., demonstrated his carbon arc torch for cutting steel under water. The latter demonstration took place in the swimming pool.

Research on welded connections in structural building frames was commenced at Lehigh in 1936, under the direction of Professor Inge Lyse, then in charge of the Fritz Laboratory. A research fellowship was established in cooperation with what was then the Structural Steel Welding Committee of the American Bureau of Welding, under the chairmanship of Leon S. Moisseiff. A series of related test projects was carried out under three successive research fellowships, maintained from 1933 to 1939. During this time six papers were published in the JOURNAL OF THE AMERICAN WELDING SOCIETY on different aspects of welded building frame research, principally on beam to column connections (References 1 to 6 below). Plans for a new committee were formulated by the AMERICAN WELDING SOCIETY at this time. In the interim (1939–40), the welding research at Fritz Laboratory continued without interruption under a Lehigh University Fellowship. In the fall of 1940 the Lehigh Welding Research Fellowship was renewed under the newly formed Committee G, on Structural Steel, of the AMERICAN WELDING SOCIETY. A program of tests on miscellaneous welded building connections currently used in design practice was completed by the summer of 1941 (Reference 9), at which time the research fellow was called to duty in the U. S. Naval Reserve.

A list of papers resulting from this work is as follows:

1. Inge Lyse and Norman G. Schreiner, "An Investigation of Welded Seat Angle Connections," AMERICAN WELDING SOCIETY JOURNAL, **14** (2), 1–15 (1935).
2. Inge Lyse and Douglas Stewart, "A Photoelastic Study of Bending in Welded Seat Angle Connections," *Ibid.*, **14** (2), 16–20 (1935).
3. Inge Lyse and Glenn J. Gibson, "Welded Beam-Column Connections," *Ibid.*, **15** (1), 28–38 (1936).
4. Inge Lyse and Glenn J. Gibson, "Effect of Welded Top Angles on Beam-Column Connections, THE WELDING JOURNAL, **16** (10), 2–9 (1937).
5. Inge Lyse and E. H. Mount, "Effect of Rigid Beam-Column Connections on Column Stresses," *Ibid.*, **17** (10), 25–31 (1938).
6. Bruce Johnston and E. H. Mount, "Designing Welded Frames for Continuity," *Ibid.*, **18** (10), Research Suppl., 355-s to 374-s (1939).
7. H. J. Godfrey and E. H. Mount, "Pilot Tests on Covered Electrode Welds," *Ibid.*, **19** (4), Research Suppl., 133-s to 136-s (1940).
8. Bruce Johnston and Lloyd Green, "Flexible Welded Angle Connections," *Ibid.*, **19** (10), Research Suppl., 402-s to 408-s (1940).
9. Bruce Johnston and Gordon R. Deits, "Tests of Miscellaneous Welded Building Connections," *Ibid.*, **21** (1), Research Suppl., 5-s to 27-s (1942).

The Men in Charge

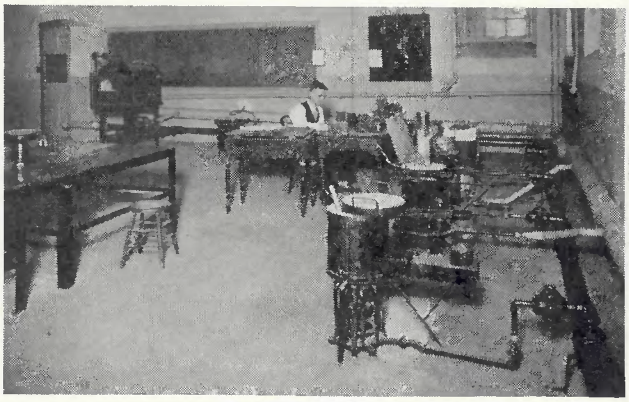
Hale Sutherland, Education: Harvard, University A.B., 1906; Massachusetts Institute of Technology, S.B., 1911.

On the staff of the Department of Civil Engineering at Massachusetts Institute of Technology, 1913–30, except for two years in the U. S. Army (1917–19); absent on leave at Robert College, Istanbul, Turkey (1926–27).

Professor of Civil Engineering and Head of the Department, Lehigh University since 1930.

Author: with W. W. Clifford, *Introduction to Reinforced Concrete Design*, 1926. With R. C. Reese, second edition of same in press. With H. L. Bowman, *Structural Theory*, 3rd edition, 1942; *Structural Design*, 1938.

Bruce Johnston, Born, Oct. 13, 1905. C. E., Univ. of Illinois, 1930; M.S., Lehigh, 1934; Ph.D., Columbia, 1938.



Furnace Room (Looking West)

Awarded James J. R. Croes Medal, 1937, by A.S.C.E., for co-authorship of paper, "Structural Beams in Torsion."

Prior to graduation from Illinois was testing inspector of materials during construction of Coolidge Dam, Ariz., 1927–29. Structural Designer for Roberts and Schaefer Co., Chicago, 1930–31. Research Fellow, Lehigh University, 1932–34. Instructor in Civil Engineering, Columbia University, 1934–38. Assistant Professor, Lehigh University, and Assistant Director of Fritz Laboratory, 1938–41. Associate Professor and Associate Director, same, 1941–42. Author or co-author of various papers on materials and structural research and analysis. Since June 1942, on leave from Lehigh Univ. as Engineer (Civil Service) with Bureau of Yards and Docks, U. S. Navy Dept., Washington, D. C.

Chairman, A.S.C.E. Committee on Design of Structural Members. Member of the Structural Steel Committee and Fundamental Research Committees of the A.W.S. Member, Tau Beta Pi, Sigma Xi, Chi Epsilon. Registered Professional Engineer, State of New York.

Cyril Jensen's work in welding dates back to 1927 when he took a short course in arc welding given by the Lincoln Electric Co., at Cleveland. The first research work he did was carried on without benefit of skilled operators. His accomplishments are most tersely given in the list of my research papers at the end of this sketch. For the past half dozen years short courses in welding engineering were offered to seniors in the civil, mechanical and industrial engineering curricula; and in the year 1941 a graduate course was given in structural welding.

At present Professor Jensen is on leave of absence doing research work at the U. S. Naval Engineering Experiment Station, Annapolis, Md.

Publications of Cyril D. Jensen

"Inspection of Structural Steel Welding," AMERICAN WELDING SOCIETY JOURNAL, January 1929.

"Investigation of Welded Connections Between Beams and Columns," *Ibid.*, April 1930.

"Effect of Current on Strength and Ductility of Arc Welds," *Ibid.*, January 1931.

"Electric Arc Welding Under Water," *Ibid.*, October 1933.

"Combined Stresses in Fillet Welds," *Ibid.*, February 1934.

"Discussion of an Investigation of Seat Angle Connections," *Ibid.*, February 1935.

"Welded Structural Brackets," *Ibid.*, October 1936.

"Designs Involving Fillet Welds," THE WELDING JOURNAL, January 1937.

"Welded Girders with Inclined Stiffeners," Co-author with Wm. Lotz, *Ibid.*, October 1937.

"Stress Distribution in Welds Subject to Bending," Co-author with R. E. Crispen, *Ibid.*, October 1938.

"Welded Girders with Inclined Stiffeners," co-author with Charles Antoni, and Prof. J. Reynolds, *Ibid.*, April 1941.

R. M. Mains, Born, January 18, 1918, Denver, Colorado. Graduated in Civil Engineering with special honors, University of Colorado, 1938. Research Graduate Assistant, University of Illinois, Engineering Experiment Station, 1938–40, degree, M.S. in C.E., 1940.

Instructor of Mechanics, Missouri School of Mines, with testing work on materials for Fort Leonard Wood and instructor of National Defense Training Courses, 1940–41. Engineer of Tests at Fritz Engineering Laboratory, Lehigh University, 1941–42, with work on Ph.D. degree concurrently. Assistant Director of Fritz Engineering Laboratory, since July 1942.

Member: American Society of Civil Engineers, and Committee on Design of Structural Members; Tau Beta Pi; Associate Member of Sigma Xi. Recipient of M. S. Ketchum award at University of Colorado.

Present Work:

A. W. S. Program of Tests of Welded Top-Plate and Seat-Angle Connections now in progress with J. L. Brandes as Research Fellow; report to be submitted in June.

A.I.S.C. Program of Tests of Stability of Stiffened Plates now in progress with A. G. Brodsky as Research Fellow; report to be submitted in June.

A.I.S.C. Program of Tests of Columns as Parts of Frames about to commence actual tests with George Packer as Research Fellow; report to be submitted in Sept.

THE ENGINEERING FOUNDATION

Welding Research Council

Sponsored by the American Welding Society and American Institute of Electrical Engineers

Supplement to the Journal of the American Welding Society, July 1943

Research Work in Welding at the University of Illinois

ONE of the great Engineering Schools of the Country is the University of Illinois at Urbana. It would be impossible in a few pages to high spot the research facilities of this Institution with particular reference to welding. At this time therefore, we will merely refer to some of the outstanding contributions and contributors in the welding field as reported in various issues of the JOURNAL and *Research Supplement.* There are several other departments not mentioned which have become interested in welding but it is hoped to give an account of these activities at a later date. The particular order in which the departments are mentioned has no particular significance.

Department of Civil Engineering

Tests of Welds

The first research work on welds conducted by the Civil Engineering Department of the University of Illinois consisted of tests to determine the static strength of welds connecting carbon-steel plates. All welds were made with a manually operated metallic arc, the operator being a regular welder employed by a commercial structural fabricator. The object of the tests was to determine the static strength of the welds and to determine the physical properties of the deposited metal. Tests were made on both butt welds and fillet-welded lap joints. The specimens were welded with electrodes furnished by a number of manufacturing companies. Some electrodes were coated and others were bare. The results of this investigation were described in University of Illinois, Engineering Experiment Station Circular No. 21 published in 1930. With very few exceptions the butt-weld specimens broke outside of the weld. The tests of the deposited metal showed that the coated rods gave a much more ductile weld than the uncoated rods, a fact that is now universally recognized.

Tests of Welded Joints Connecting Structural Members

The second investigation was made to determine the feasibility of welding the steel frames of buildings for complete continuity. Both static and fatigue tests were included in the investigation. The static tests comprised two series:

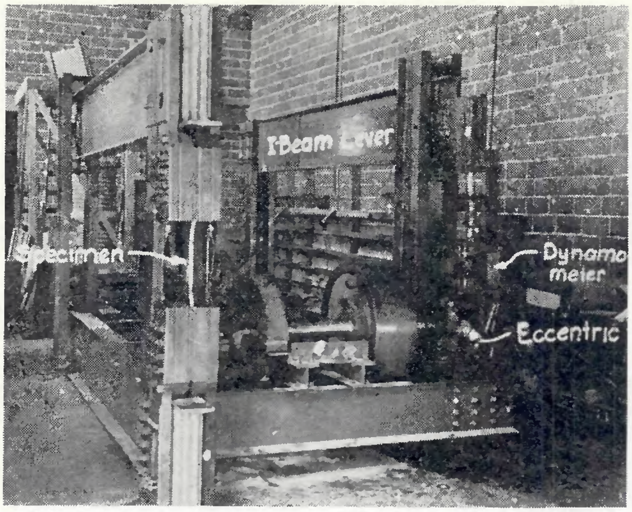
1. Tests of joints similar to connections that might be used where two steel I-beams are framed into a transverse girder in such a way as to make the I-beams continuous in their action. Tests were made on a number of types of joints to determine: (*a*) the strength of the joints to resist both moment and shear, and (*b*) the rigidity of the connections.
2. Tests of joints similar to moment-resisting connections that might be used to attach a girder to a column. Tests were made on a number of types of connections to determine: (*a*) the moment-resisting capacity of the joint, and (*b*) the rigidity of the joint,

The specimens for the fatigue tests, which were moment-resisting joints connecting girders to columns, such as might be used for the wind bracing of a steel frame building, were subjected to a stress cycle in which the moment on the joint was varied from a moment in one direction to a moment in the opposite direction. These connections were quite similar to the moment-resisting connections tested statically. The object of the tests was to determine the number of cycles required to break the connection when the stress resulting from the moment had certain predetermined values.

These tests are reported in the JOURNAL OF THE AMERICAN WELDING SOCIETY, 15 (1), 28 (1936).

The Effect of Residual Longitudinal Stresses Upon the Load-Carrying Capacity of Columns

The Nickel Plate Railroad had a number of viaducts with high steel towers which were overloaded due to an increase in the weight of the rolling stock. The railroad reinforced the columns of these viaducts by attaching plates with longitudinal fillet welds. At the request of the railroad the Civil Engineering Department of the University made tests to determine the thermal stresses set up in these columns due to welding and, finding that the thermal stresses were quite large, made additional tests



Fatigue Machine for Testing Specimens in Fatigue at Loads Varying from 200,000 Lb. Tension to 2,000,000 Lb. Compression

to determine the effect of these thermal stresses upon the load-carrying capacity of columns. The latter part of this work, which consisted of laboratory test, was done in the following manner. Six columns 20 ft. long, identical with the original viaduct columns, were fabricated by riveting. Two of these columns were reinforced by one of the methods used in reinforcing the viaducts and two others were reinforced by another method used in reinforcing the viaducts. The remaining two specimens were used as controls. Strain readings were taken before and after welding the reinforcement onto the columns to determine the thermal stresses produced by welding. These readings showed that residual stresses as high as 30,000 psi. existed in the reinforced columns before they were subjected to any load. All specimens were subjected to a static test and the ultimate load-carrying capacity of each was determined. These tests indicated that, although there were residual stresses in the columns of 30,000 psi. before the columns were loaded, the addition of the reinforcing plates increased the load-carrying capacity in direct proportion to the increase in the section. That is, the reinforcing plates were 100% effective in increasing the load-carrying capacity of the columns even though residual stresses of 30,000 psi. were induced by the welding processes.

These tests are reported in University of Illinois, Engineering Experiment Station Bulletin No. 280.

Fatigue Tests of Butt Welds in Structural Steel Plates

Three investigations have been made by the Civil Engineering Department at the University of Illinois to determine the fatigue strength of butt welds in structural steel plates. The specimens for all tests were subjected to either a pulsating or a reversed axial load. The plates were approximately 5 in. wide at mid-length where the weld was located. Some were $^3/_4$ in., others were $^7/_8$ in. thick.

The specimens for the first investigation were subjected to a stress which varied from 0 to a tension and the fatigue strength was determined for failure at 2,000,000 cycles. Two kinds of plates were used, carbon structural steel and silicon structural steel. Some of the carbon plates were welded with an automatic carbon arc, the others were hand welded with a shielded-arc metallic-arc electrode. Some specimens welded with the automatic carbon arc were tested in the as-welded condition, others were stress relieved by heat treatment prior to the tests.

Of the hand-welded specimens, some were tested in the as-welded condition, others were peened, others were stress relieved by heat treatment and for still others the weld was planed flush with the base plate on both sides. There was one series of purposely poor welds made by the hand-welding process.

Of the silicon-steel specimens, some were tested in the as-welded condition and others were tested after the weld had been planed flush with the base plate on both sides. The results of the tests of the first investigation are presented in University of Illinois, Engineering Experiment Station Bulletin No. 310.

The second investigation to determine the fatigue strength of butt welds was made under the supervision of the Fatigue (Structural) Committee, Industrial Research Division, Welding Research Council of the Engineering Foundation. It consisted of a very extensive series of fatigue tests of butt welds in $^7/_8$-in. carbon-steel plates welded under the most favorable conditions of intelligence of supervision and of welding operator skill.

All the specimens were hand welded with a shielded-arc metallic-arc electrode. Tests were made on cycles with three ratios of minimum to maximum stress as follows: tension to an equal compression; zero to tension; and tension to a tension one-half as great. The tests were planned so that one group of tests would give the fatigue strength corresponding to failure at 100,000 cycles and another series was planned to give the fatigue strength corresponding to failure at 2,000,000 cycles. The specimens used in these tests were supposed to represent the optimum of what might be expected from a first-class fabricating shop experienced in structural welding.

The results of the tests are presented in University of Illinois, Engineering Experiment Station Bulletin No. 327.

The third investigation of the fatigue strength of butt welds differed from the second in that the specimens contained butt welds of the quality which may be expected from a first-class fabricator welding under commercial conditions. Six series of specimens were obtained by contract, two series each from two fabricators and one series each from two other fabricators. The physical and chemical properties of the plates and position of welding were approximately the same for these specimens as they were for the specimens of the second investigation. The results obtained from these tests were compared with the results obtained from the tests of the second investigation, using the latter as basic values. In addition to the above, the third series of tests included specimens that were welded in various positions and with various electrodes. It also included specimens that were welded in the field and specimens that were welded by the automatic carbon arc and the Unionmelt processes.

The results are presented in University of Illinois, Engineering Experiment Station Bulletin No. 344, which will be ready for distribution about July 1, 1943.

Fatigue Tests of Fillet and Plug Welds

Tests were made to determine the fatigue strength of fillet welds connecting plates and channels. Tests were also made to determine the fatigue strength of plates connected with plug welds. Because so little is known of the fatigue strength of joints of this type, the first series of tests was planned primarily to determine what types of fillet-weld and plug-weld joints have the greatest fatigue strength. These preliminary tests have been completed and will appear as a University of Illinois, Engineering Experiment Station Bulletin, probably some time about January 1, 1944.

Tests are underway for a systematic study of the types of fillet-weld, plug-weld and slot-weld joints which proved to have the highest fatigue strength.

High-Speed Tension Tests of Welded Joints

Plates containing joints were subjected to high-speed tension tests. The specimens were loaded by dropping a steel block weighing 2300 lb., a distance of 10 ft. and allowing it to impinge upon a nut on the lower end of a steel rod suspended from the lower end of the specimen. Comparative tests were made on a 3- x $^3/_8$-in. plate without any joint and on a similar plate containing a butt weld. All of the specimens containing a butt weld with the reinforcement on broke outside the weld. Some of the specimens containing a butt weld with the reinforcement planed flush with the base plate failed outside the weld, others failed in the weld. The elongation in 8 in. was as great for the welded specimens subjected to a drop test as it was for similar specimens subjected to a static test, but it was not quite so great for specimens with welds as it was for plates without welds.

The results of these tests will be presented in the JOURNAL OF THE AMERICAN WELDING SOCIETY.

Department of Theoretical and Applied Mechanics

Early Investigation of Welding Processes

The first systematic study of welding carried on in the Department of Theoretical and Applied Mechanics was done by Mr. H. L. Whittemore, now Chief of the Engineering Mechanics Section of the National Bureau of Standards. His work was a study of the strength of oxyacetylene welds in steel and resulted in the publication of Bulletin No. 45 of the Engineering Experiment Station, published in 1910. The outstanding conclusion of Mr. Whittemore's tests was that the great source of weakness in welds is incompleteness of fusion across the section of the weld. That conclusion is still a fairly sound one. From Mr. Whittemore's time up to 1937 a number of miscellaneous amounts of testing in welding was done in this department, mainly under the direction of Prof. H. F. Moore.

Strength of cast-iron welds was studied and relative strength of forged welds and fusion welds of rods was also studied. Some work was done, mainly as commercial testing, on the fatigue strength of welds and a fatigue strength of welds of 90% or more of the strength of the base metal was demonstrated by some of the users of mechanically controlled welding processes for steel.

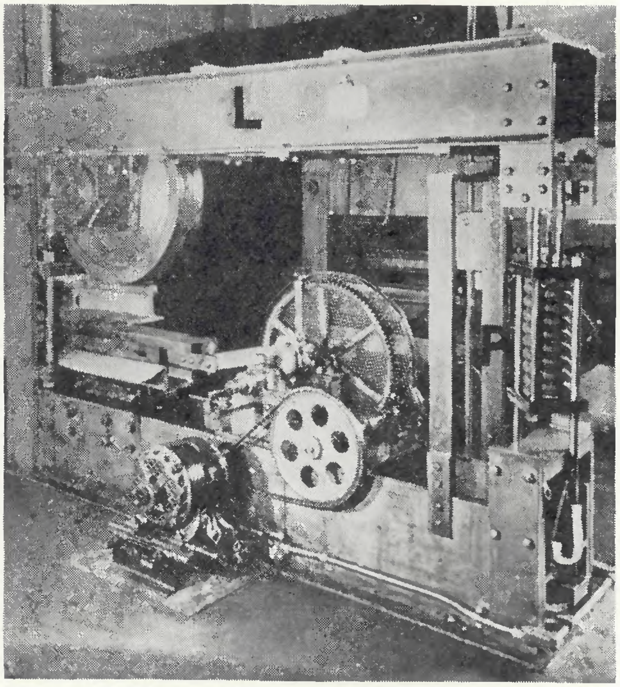


Fig. 1—Rolling-Load Machine for Fatigue Tests of Welded Rail

Investigation of Welded Rails

In 1937 a systematic study of the strength of continuous welded rail was undertaken in the Talbot Laboratory in cooperation with the Association of American Railroads. Various static and metallographic studies were made of welds made by gas fusion, by the Thermit process, by the Sperry electric process and by the Oxweld gas-heated pressure process.* The main tests under repeated stress caused by the repeated passage of a short section of rails under a loaded wheel.

The special rolling-load testing machine used is shown in Fig. 1. The welded joint specimen *S* is pulled backward and forward under a wheel *W*, the load on which can be varied from zero to 75,000 lb. The load is applied through the lever *L* by means of a screw jack *J*, and is measured by the compression of the spring *P*. The maximum bending moment on the weld is equal to the load on the wheel times the distance from the vertical center line of the weld to the point of contact of the wheel when the specimen is in its extreme right-hand position, and the minimum moment is zero, when the wheel is over the support. A revolution counter is attached to the crankshaft of the machine, and an automatic cut-off switch is operated by the drop of the lever *L* when a specimen breaks. The stroke of the machine is 12 in. and its speed is 60 strokes per minute.

A number of specimens of different types of welded joint (not less than three) were tested for each of two weights of rail, 112 and 131 lb. The first specimen of each group was tested under a load of 75,000 lb. If the specimen broke before it had withstood 2,000,000 cycles of load a second specimen was put in under a lower load. If this specimen broke, a third specimen was put in at a still smaller load and was tested to fracture, or until it had withstood 2,000,000 cycles of load. Tests were made of rail welded by an ordinary oxyacetylene torch, of welds made by Thermit process, of welds made by the Oxweld gas-heated process using pressure on the rails joined and by the Sperry electric flash-welded joint using pressure.

The selection of 2,000,000 cycles of stress was based on measurements of some half a million strains in rails

* No arc-welded joints were submitted to the investigation for test.

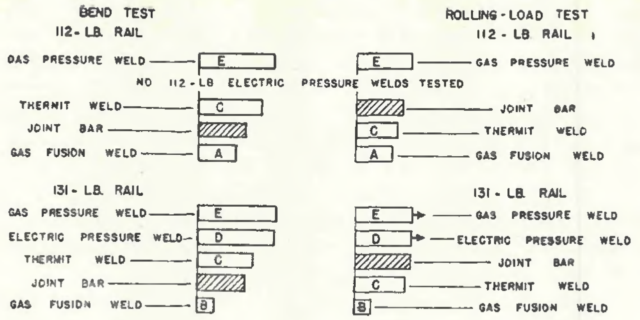


Fig. 2—Relative Strength of Rail Joints as Shown by Static Bend Test and Rolling-Load Test

in service and the frequency (about one in 600) of loads about double the average wheel load.

The failures produced included failures by an internal fissure in the head of the rail, failures by fissures starting near the fusion of web and head and failures starting from the surface near the corner of the tread of the rail. Tests were also made of rails with rail joints made with the ordinary joint bars. Drop tests and static bending tests of welded rail, rail without weld and rails joined by joint bars were also made and in general the results of the bend tests and the rolling-load tests are shown in Fig. 2. These tests showed that with the Sperry process or the Oxweld pressure process welded rail tested seemed to be about $^3/_4$ as strong as the rail without weld, while the bend tests showed about the same strength as those of rails without welds. The Thermit welded rail tested showed about the same strength as joint-bar joints.

Department of Mining and Metallurgy

The list of the equipment in the Department of Mining and Metallurgical Engineering, of which Professor H. L. Walker is the head, is as follows:

1. Melting furnaces, both arc and high-frequency induction types of 50-lb. capacity.
2. Furnaces for heat treating at temperatures up to 3000° F. with various hearth capacities, some of which can be supplied with gas atmosphere or vacuum for heat treatment without oxidation.
3. Equipment for grinding, polishing, etching and microexamination of metals.
4. Fully equipped machine shop facilities for preparation of test specimens and construction of experimental apparatus.
5. Full equipment for tests of tensile, impact and fatigue properties. Jigs are also available for standard bend tests, for tee bends of $^1/_2$-in. thick plate and the Haigh notch bend test on $^1/_2$-in. thick plate.
6. Furnaces and equipment are available for making the Jominy-bar hardenability test. Hardness testing machines include the Rockwell, Brinell and Vickers-Brinell. Equipment is also available for time-dilation studies in obtaining "S" curves.
7. Welding equipment consists of a 300-amp. d.-c. machine and a 1-kva. spot welder. The department has also constructed a table to move specimens under a stationary, manually controlled electrode at various controlled speeds. A high-speed recorder is available for time-temperature studies in the base metal adjacent to the weld during welding. The reaction rate of this temperature-recorder is 3000° F. per second.

The department also expects soon to have X-ray diffraction equipment in the department for the study of welding stresses, crystallography and microradiographs. Such equipment is now available through Dr. G. L. Clark in the X-ray division of the Chemistry Department but with the advent of their machine a great deal more work in the metallurgical field can be done than on the already overcrowded facilities in the Chemistry Department.

A research program on welded armor plate has recently been completed in the department which is now engaged almost entirely in cooperating with Professor W. M. Wilson in his study of fatigue of welded joints. A comprehensive program of studies is under way to determine the effects of rolling and thermal stresses on fatigue. The combined effects of metallurgical change and thermal stresses are also being correlated with fatigue behavior. The above research in correlating metallurgy with fatigue behavior is under the jurisdiction of Committee F's subcommittee on Metallurgical Damage of which Dr. A. B. Kinzel is chairman.

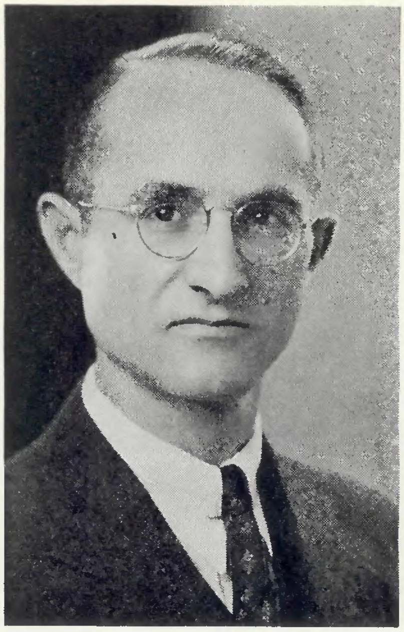
There will soon be under way another program of tests to correlate fatigue behavior with metallurgical effects produced under various conditions of metallic arc welding which are of interest to Committee F.

Some of the publications by Dr. W. H. Bruckner in the welding field resulting from the research conducted in this laboratory in addition to those of which he is coauthor with Professor Wilson which are not listed below are: "The Weldability of Steels," THE WELDING JOURNAL, Jan. 1942; "Weld Quench Gradient Tests," THE WELDING JOURNAL, Oct. 1942. One contribution has been made to the literature surveys in the paper on "The Heat Effect in Welding," THE WELDING JOURNAL, Oct. 1937. Another contribution is in the A.S.T.M. paper, "The Use of the Charpy Test as a Method of Evaluating Toughness Adjacent to Welds."

Some of the Members of the Staff Interested in Welding Research

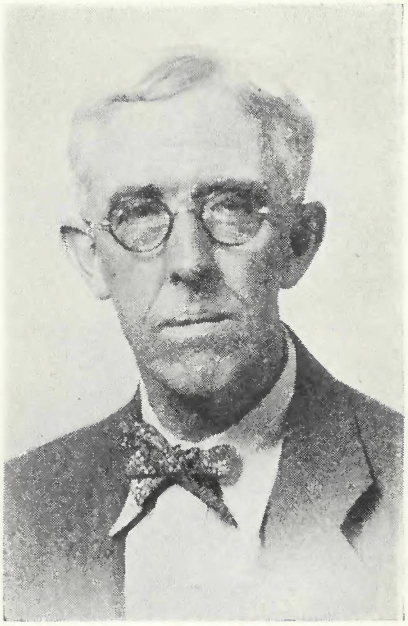
W. H. Bruckner, Research Assistant Professor of Metallurgical Engineering. Graduated as Chemical Engineer from Columbia University; was Research Engineer with Crucible Steel Company at Harrison, N. J.; Physical Metallurgist at American Smelting and Refining Company at Maurer, N. J., and at the Naval Research Laboratory at Anacostia, D. C., before coming to Illinois in 1938 as Research Metallurgist. Society memberships include A.I.M.E., A.S.M., A.S.N.E. (Naval), A.W.S., Electro-Chemical Society, Epsilon Chi, Sigma Xi.

G. H. Fett, Associate, Department of Electrical Engineering. Born in Chicago, Ill., June 19, 1909. Educated at Univ. of Ill., B.S. in E.E., with high honors, 1931; Iowa State College, M.S., 1932; Univ. of Ill., Ph.D. (Engrg.), 1940. Married; two daughters. Grad. Asst. in E.E., Iowa State College, 1931–32; Research Engineer, Littelfuse Inc., Chicago, 1933–35; Jr. Eng.,



W. H. Bruckner

G. H. Fett



H. F. Moore

W. M. Wilson

Federal Power Commission, 1936; Asst., Instr., Associate in E.E., Univ. of Ill., 1935 to date.

Co-author of textbook, *Introduction to Circuit Analysis*, 1939, 1943. Author of papers in the field of arc discharges and welding electrodes.

Member, AMERICAN WELDING SOCIETY, A.I.E.E., Am. Physical Soc., Sigma Xi, Tau Beta Pi, Eta Kappa Nu; Past-Chairman, Urbana Section, A.I.E.E.

H. F. Moore, Research Professor of Engineering Materials. Graduated from the New Hampshire College of Agriculture and the Mechanic Arts (now the University of New Hampshire) in 1898, B.S. in Mechanical Engineering. Received from Cornell University the degree of Mechanical Engineer in 1899, and the degree of Master of Mechanical Engineering in 1903. Served as an instructor in Machine Design at Cornell, designing engineer for the Riehle Bros. Testing Machine Company., Instructor and Assistant Professor of Engineering Mechanics in charge of the Materials Testing Laboratory at the University of Wisconsin, and in 1907 came to the staff of the Engineering Experiment Station of the University of Illinois.

He has designed a number of testing machines and instruments for measuring strain. He has been especially active in the study of the fracture of metals under repeated stress and has published a number of articles, bulletins and (with Prof. J. B. Kommers) a book on that subject. In connection with his studies in this field he has been in charge of an extensive investigation of railroad rails and their failures since 1931, and together with his associates, Professors H. R. Thomas, R. E. Cramer, N. J. Alleman and Mr. S. W. Lyon he carried out the investigation of continuous welded rail mentioned above.

Wilbur M. Wilson, Research Professor of Structural Engrg., 118 Arthur Newell Talbot Lab., Univ. of Ill., Urbana, Ill.; res. 807 S. Busey Ave.; Engineering Research. Born at West Liberty, Iowa, July 6, 1881; son of Mathias and Ruth (Mosher) Wilson. Educated at Iowa State Coll., B.M.E., 1900; Cornell Univ., M.M.E., 1904; Iowa State Coll., C.E., 1914. Married June 28, 1905, Teresa Stewart; two children, Grace, Matt. Instr., Mech. Eng., Iowa State Coll., 1901–03; Grad. Fellow, Sibley College, Cornell Univ., 1903–04; Asst. Prof. in Mech. Eng., Iowa State Coll., 1904–07; practiced Eng. (Structural) 1907–13; Asst. Prof. in Struc. Eng., Univ. of Ill., 1913–17; Capt. & Major of Engrs., U.S.R., U. S. Army, 1917–19; Assoc. Prof. of Struc. Eng., Univ. of Ill., 1919–22; Research Prof. of Struc. Eng., Univ. of Ill., 1922 to date. Awarded Chanute Medal by Western Soc. of Engrs., 1916, for paper entitled "Wind Stresses in the Steel Frames of Office Buildings"; awarded James J. R. Croes Medal by the Am. Soc. of Civil Engrs., 1936, for paper entitled "Laboratory Tests of Multiple-Span Reinforced Concrete Arch Bridges"; awarded Chanute Medal by Western Soc. of Engrs., 1937, for paper entitled "Present Status of Structural Welding"; awarded Wason Medal by Am. Con. Inst., 1938, for paper entitled "Tests of Rigid Frame Bridges."

Member, Examining Com. for Registering Structural Engrs. (Ill). Author of numerous articles in scientific and technical Journals and of bulletins of the Univ. of Ill. Eng. Expt. Sta. Mem.: Am. Soc. C. E., A.S.T.M., A.R.E.A., A.A.A.S., W.S.E., S.P.E.E., A.W.S., I.A.B.S.-E., I.S.E. and A.C.I.

Professor Wilson received the honorary degree of Dr. of Eng. from Iowa State College in 1942. His hobbies are farming, floriculture and cabinetmaking.

THE ENGINEERING FOUNDATION

Welding Research Council

Sponsored by the American Welding Society and American Institute of Electrical Engineers

Supplement to the Journal of the American Welding Society, December 1943

Our Research Laboratories

Polytechnic Institute of Brooklyn

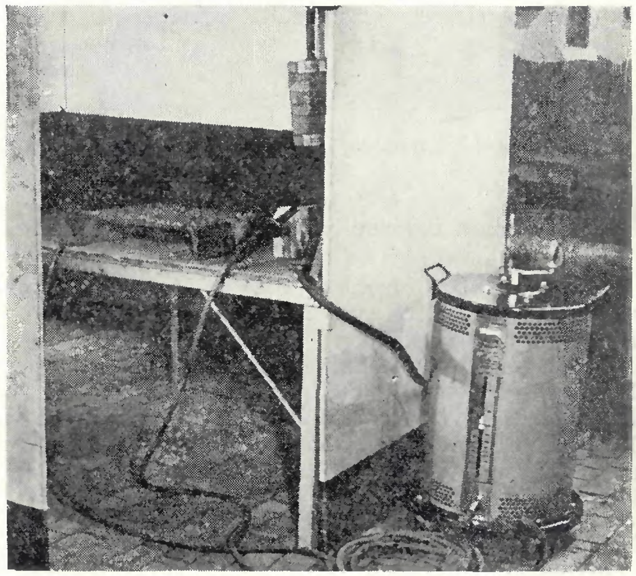
WELDING Research at Polytechnic Institute of Brooklyn is closely associated with the name of Professor Otto H. Henry. The limited welding facilities at the Institute do not offer the possibility for research on problems where special welding equipment is requisite; therefore, the welding research activities have been confined solely to the mechanical testing of welds under various conditions. In this respect, the research group has made valuable contributions.

Description of Research Facilities at Polytechnic Institute of Brooklyn

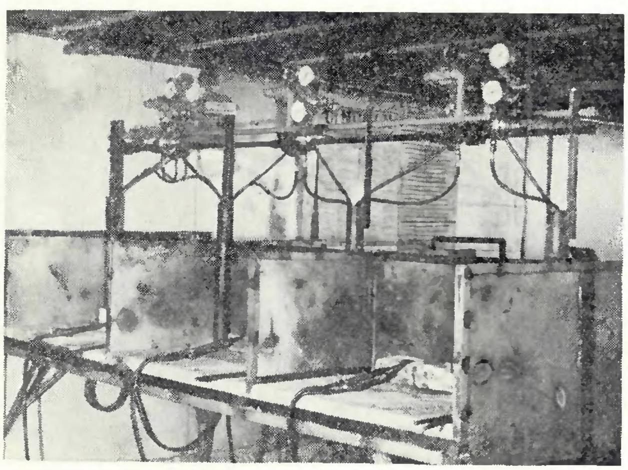
The Welding Laboratory at the Institute was initiated for the purpose of familiarizing the young engineers with the possibilities and limitations of welding since it was felt that this science was to play a major role in the progress of the mechanical world.

The oxyacetylene welding equipment comprises a permanent welding unit with six stations, each equipped with individual gas regulators. Gases are piped to the stations from central cylinders fitted with master regulators to control and maintain line pressure. Torches are of the light type having a capacity up to $1^1/_2$-in. plate. Two cutting attachments for light cutting are available and can be connected to any of the six welding torches. Four portable welding and cutting outfits also are available.

Arc-welding equipment consists of two 200-amp. d.-c. motor-generator sets, one 250-amp. portable d.-c. motor-generator set and one 250-amp. a.-c. transformer type welder.



Welding Laboratory—Arc-Welding Equipment



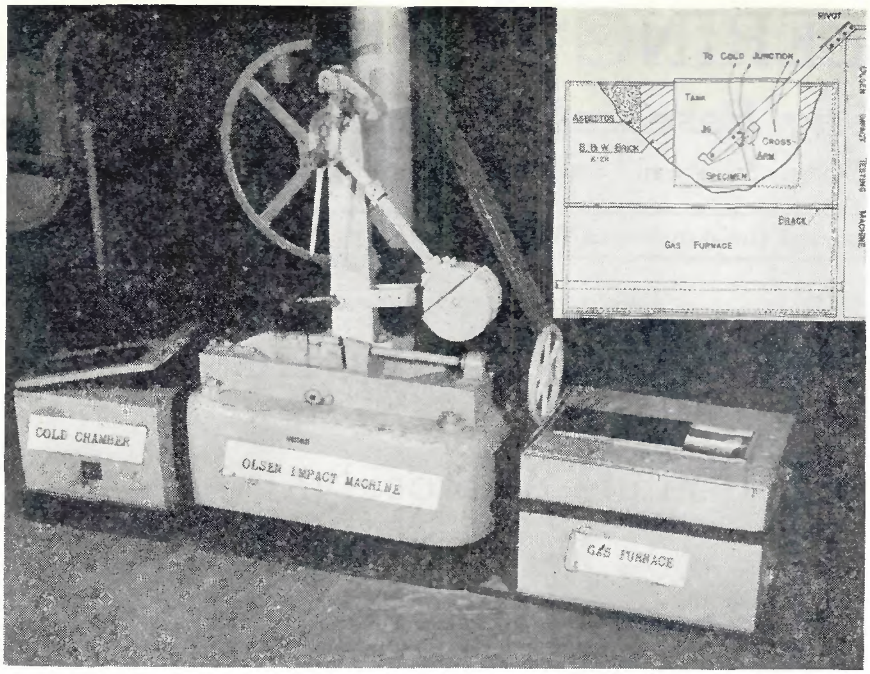
Welding Laboratory—Gas-Welding Equipment

In contrast with the picture presented by the Welding Laboratory, the Materials Testing Laboratory is unusually well equipped and comprises:

1. A 100,000-lb. and a 30,000-lb. capacity Riehle Universal testing machine.
2. A Tinius Olsen pendulum type impact machine (125 ft.-lb. capacity) which may be easily converted into a tensile-impact machine.
3. A 600-ft.-lb. capacity Charpy type impact machine.
4. Several types of fatigue testing machines.
5. Equipment for determining the damping characteristics of welds.
6. Hardness testing equipment.
7. Several types of torsion testing machines.

The materials testing laboratory is affiliated with the Metallurgy Division of the Mechanical Engineering Department whose modern facilities for microscopic, magnaflux and X-ray examination as well as for photography and heat treatment, are well fitted for a great variety of fundamental welding research.

At present, the research activities at the Polytechnic Institute are focused on two problems: effect of peening and mechanical testing of plate obtained from all-welded ships that have recently failed in service.



Arrangement of Apparatus for Conducting Tensile-Impact Tests at Different Temperatures

Short Biography of Otto H. Henry

West Virginia University, B.S. in Mechanical Engineering, 1919, M.E., 1923; Polytechnic Institute of Brooklyn, M.M.E. 1936.

Instructor Mech. Drawing for Sheet Metal Workers, 1918; Instr. Steam and Experimental Engg., 1918–19; Instr. of Mech. Engg., Polytechnic Inst. of Brooklyn, 1919–25, Assistant Prof. Mech. Engg., 1925–39; Associate Prof. of Metallurgical Engg., 1939 to date.

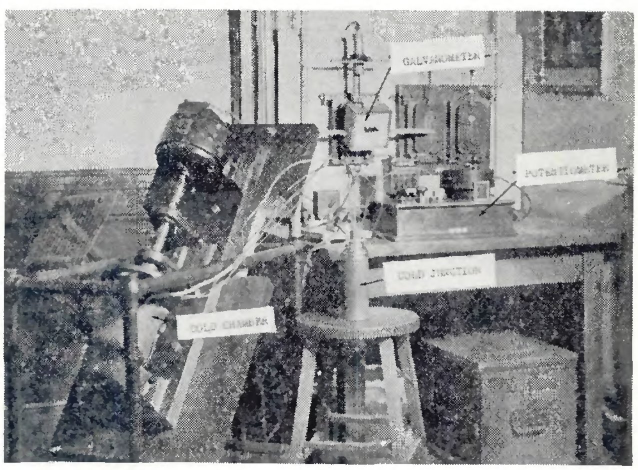
Societies and Honors

Member: A.S.M.E., A.S.M. and A.I.M.E., Fund. Research Committee of American Welding Society, Tau Beta Pi, Phi Lambda Upsilon, Sigma Xi.

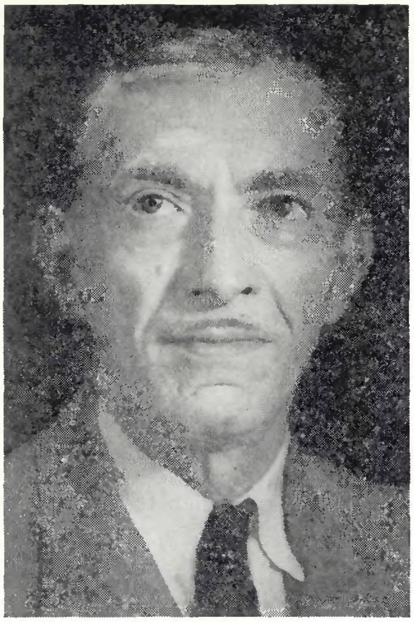
Prof. Henry has delivered more than 20 lectures on Welding Metallurgy before the N. Y. Chapter of A.W.S. and A.W.S.-A.S.M.E.

Publications

1. "Static and Impact Tensile Properties of Some Welds at Ordinary and Low Temperatures," presented at Atlantic City, October 1937. The Welding Journal, Research Suppl., February 1938.
2. "Impact Tests of Welds," *Ibid.*, February 1938.
3. "The Metallography of Welds," presented before New York Chapter, American Welding Society. Lecture Course. Published in The Welding Journal, April 1938.
4. "Fatigue Tests of Welds at Elevated Temperatures." Co-author with A. Amatulli. Published in The Welding Journal, Research Suppl., June 1938.
5. "Tensile Impact Tests on Welds at Low Temperatures." Published in The Welding Journal, Research Suppl., August 1938.
6. "Testing the Physical Properties of Welds." Co-author with G. E. Claussen, presented Jan. 24, 1938, before New York Section Evening Lecture Course. Published in The Welding Journal, May 1939.
7. "Tensile and Tensile Impact Tests of Stainless Steel Welds at Low Temperatures," *Welding Research Supplement*, 326-s to 328-s (September 1939).
8. "Tensile Tests of Arc Welded Monel Metal at Low Temperatures." Co-author with J. Babakian. *Ibid.*, 112-s (February 1941).
9. "High Temperature Tensile Tests of Welded 18–8," *Ibid.*, 135-s to 137-s (March 1941).
10. *Welding Metallurgy*, book. Co-author with G. E. Claussen. Published November 1941 by A.W.S.
11. "The Effect on the Endurance Limit of Submerging Fatigue Specimens in a Cold Chamber." Co-author with T. D. Coyne. *Welding Research Supplement*, 249-s to 254-s (May 1942).
12. "A Study of the Embrittling Effect of Zinc Upon Stainless Steel," *Ibid.*, Vol. VII (June 1942).
13. "The Effect on the Endurance Limit of Submerging Resistance Welded Fatigue Specimens in a Cold Chamber," *Ibid.*, Vol. VII, No. 6 (June 1942).
14. "Tensile Tests of Stainless Steel Welds at Low Temperatures," *Ibid.*, 384-s to 386-s (August 1942).
15. "The Effect on the Endurance Limit of Submerging Welded Fatigue Specimens in a Cold Chamber," *Ibid.*, 387-s to 388-s (August 1942).
16. "The Tensile Impact Resistance of Carbon-Molybdenum Welds at Elevated Temperatures." Co-author with Marcel A. Cordovi. *Ibid.*, 416-s to 420-s (September 1942).
17. "An Investigation of the Static Notched Bar Behavior of Steel with Reference to Tri-Axial Stress and the Technical Cohesive Strength." Co-author with James G. Farmer. *Ibid.*, Vol. VIII, No. 4, 150-s to 162-s (April 1943).
18. "Tensile Tests of Arc-Welded Nickel and Monel Metal at Low Temperatures." Co-author with J. Martinez, *Ibid.*, Vol. VIII, No. 6, 270-s to 271-s (June 1943).

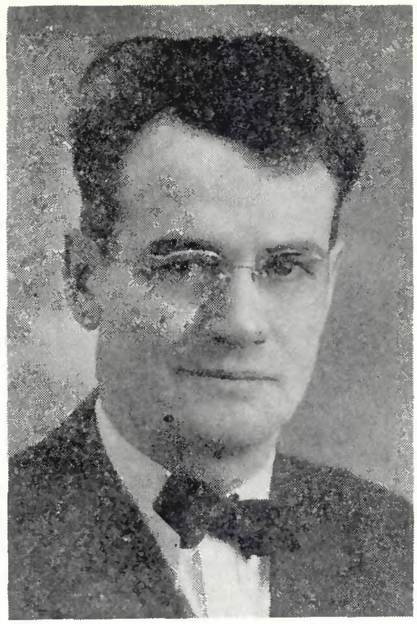


Arrangement of Apparatus for Conducting Low-Temperature Fatigue Tests



Otto H. Henry

F. C. Saacke



W. H. Ruten

19. "The Determination of the Effect of Various Types of Weld Metal on the Internal Damping Characteristics of Steel Specimens." Co-author with R. R. Feitl and J. A. Falcon. *Ibid.*, Vol. VIII, No. 6, 266-s to 269-s (June 1943).
20. "The Effect on the Endurance Limit of Submerging Fatigue Specimens in a Cold Chamber." Co-author with A. Stirba, Jr., *Ibid.*, Vol. VIII, No. 8, 372-s to 373-s (August 1943).

Some of the Members of the Staff Interested in Welding Research

W. H. Ruten, University of Michigan, B.Sc., M.A.; Instructor in Industrial Trades, Public Schools, Dearborn, Mich.; and Indianapolis, Ind.; Asst. Prof. Pract. Mechanics—University of Nebraska; Asst. Prof. in charge of Industr. Labs., Polytechnic Inst. of Brooklyn, 1941 to date.

F. C. Saacke, Cornell University, M.E., 1931; Instructor in Department of Machine Design, 1930–31. Research Engineer in welding materials and procedures. Apparatus Research and Development Department, Air Reduction Sales Co., 1931 to date. Instructor in Welding Theory, Delehanty Welding Institute, 1941–43. Instructor in Welding and Design, Department of Metallurgy, Polytechnic Institute of Brooklyn, 1938 to date. Society Memberships—A.W.S., A.S.M., Phi Kappa Phi.

Reviews of Recent Foreign Welding Literature

EDITORIAL NOTE—*The Welding Research Council is unable to obtain current foreign welding Literature and these abstracts are taken from the Welding Literature Review published by the Institute of Welding.*

INVESTIGATIONS ON THE INFLUENCE OF WELDING CONDITIONS ON THE DISTRIBUTION OF THE STRENGTH OF ELECTRICALLY SPOT-WELDED SHEETS OF VARIOUS ALUMINIUM ALLOYS. *Zeitschrift für Metallkunde*, vol. 34, 1942, Aug., pp. 187–193.

The authors have examined about 10,000 spot welds in various aluminum alloys made by different factories; the variations observed were great irrespective of the type of machine used, the prior surface treatment or the manufacturer. In general, however, an increase in cold work increases the mean strength of spot welds, but such welds generally show a low shear strength. (*Abstracted in J. of Inst. of Metals, 1943, April, pp. 129–130.*)

HARD SOLDERING UNDER PROTECTIVE GAS. *Metall und Erz*, vol. 38, 1941, pp. 326–329; *Chemical Abstracts*, vol. 36, 1942, 6129.

Two basic types of hard soldering are distinguished: (1) hard soldering with copper, and (2) hard soldering with zinc-bearing, relatively low-melting solders. By the use of protective gases in electrically heated furnaces it is possible to carry out soldering without a flux. By omission of flux and prevention of oxidation of the parts to be soldered, significant failures in hard soldering are avoided. Preparation of the work is so simple that it can be conducted by unskilled workers. Iron and steel parts are advantageously soldered with copper. As protective gas, incompletely burned illuminating gas is suitable. The lower-melting brasses, however, are soldered with silver solder. In the application of zinc-bearing alloys care should be taken in the suitable disposal of the solder in the solder joint to prevent the melting point of the solder from being raised unfavorably high by zinc vaporization. In many cases incompletely burned illuminating gas is sufficient protection if it has been subjected to thorough drying by silica gel or by intense cooling. In special cases cracked ammonia or incompletely burned and thoroughly dried ammonia are used. (*Abstracted in J. of Inst. of Metals, 1943, p. 129.*)

THE CORROSION-RESISTANCE OF HARD-SOLDERED JOINTS IN PURE ALUMINUM. *Autogene Metalbearbeitung*, vol. 35, 1942, no. 5, pp. 69-72.

Strips of pure aluminum sheet were soldered with aluminum-silicon alloy and immersed for periods up to

(*Continued on page 640-s*)