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TESTS OF WELDED COPPER JOINTS

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A Summary Report of An Investigation

Conducted by

The University of Illinois Engineering Experiment Station

in Cooperation with

The Copper and Brass Research Association

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TESTS OF WELDED COPPER JOINTS

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SYNOPSIS

This bulletin presents a summary and brief analysis of the results of an extensive series of tests of welded copper joints prepared by the carbon-arc, shielded-arc, inert-gas-shielded-arc, and oxy-acetylene processes. The joints were made in three base materials: (a) electrolytic tough-pitch, (b) deoxidized high-phosphorus, and (c) oxygen-free high conductivity copper. In addition to the mechanical properties and details of the welding procedures, the results from hardness studies and extensive metallurgical studies are presented for each of the joints.

TESTS OF WELDED COPPER JOINTS

I. INTRODUCTION

During recent years, a great many new procedures and processes have been developed in the art of copper welding. The processes and procedures have not always been well suited to all coppers and, at times, have not been applied properly. Consequently, commercial welds in copper have shown a great variety in quality and properties.

One of the factors which is of paramount importance in the welding of copper is the personal factor. The techniques and abilities of the operators vary considerably and may account for a large part of the variation obtained in the properties of welded copper joints prepared by different individuals.

1. Object and Scope of Investigation

The investigation reported herein was suggested by the Copper and Brass Research Association as a means of obtaining fundamental design data for the various types of welded copper joints in use in the copper industry. Four welding processes have been included in the program: (a) carbon-arc, (b) shielded-arc, (c) inert-gas-shielded-arc, and (d) oxy-acetylene. These four processes, using a variety of filler metals, have been applied to three coppers: electrolytic tough-pitch, deoxidized high-phosphorous, and oxygen-free high conductivity (OFHC).

In the original planning for this investigation, it was considered desirable to test joints prepared by a number of fabricators from the copper industry. These joints are referred to herein as Series I. Each of the fabricators was asked to indicate the types of welded copper joints normally prepared in their shops. The fabrication of the test specimens was then assigned to these various concerns so that each would fabricate joints by a process which he generally employed. In a few cases, however, fabricators were requested to prepare specimens by a procedure with which they were not thoroughly acquainted.

A second series of joints was prepared by one fabricator who was chosen as one of the best qualified in the industry to produce good quality welded copper joints. Although highly qualified, the fabricator of the Series II specimens was not completely familiar with all of the welding procedures included in the program.

It is realized that the welds used in this study were not necessarily prepared with the most desirable welding procedures. However, the results of the laboratory studies and the weld procedure data furnished by the fabricators provide information concerning the expected strength of joints prepared by these procedures. Although the tests reported herein do not include all of the latest developments in the field of copper welding, they do indicate the characteristics of the welds produced by the procedures reported. It is hoped that the tests will help to stimulate improvements in the existing procedures and the development of new procedures for the welding of copper structures in order that the base materials may be used more efficiently and effectively.

2. Acknowledgments

The tests reported in this bulletin are part of an investigation resulting from a cooperative agreement between the Engineering Experiment Station of the University of Illinois and the Copper and Brass Research Association and have been a part of the Structural Research program of the Civil Engineering Department under the general direction of N. M. Newmark, Research Professor of Structural Engineering. The project has been under the general direction of W. H. Munse, Research Associate Professor of Civil Engineering and R. J. Mosborg, Research Assistant Professor of Civil Engineering. Messrs. N. A. Weil, Tung Au, and F. L. Howland, Research Assistants in Civil Engineering, conducted the tests and were assisted by Messrs. R. Smith and W. McKenzie, laboratory mechanics of the Civil Engineering Department. The metallurgical studies were made under the direction of R. W. Bohl, Assistant Professor of Metallurgical Engineering.

The assistance and encouragement of an Advisory Committee representing the copper industry has been most helpful in this investigation. The authors would like to acknowledge, in particular, the assistance received from Mr. A. I. Heim, Engineer for the Copper and Brass Research Association and Secretary of the Advisory Committee.

II. DESCRIPTION OF MATERIALS AND TESTS

3. Description of Materials

Three types of copper have been included in this investigation: electrolytic tough-pitch copper, deoxidized high-phosphorus copper and OFHC copper. The three coppers, in 1/8-in. and 1/4-in. thicknesses, were obtained from one copper producer. This was done so that all of the joints produced by the various fabricators would be from the same base materials.

The first series of joints was prepared by ten copper fabricators. Although the procedures used for the preparation of these specimens were the same as those generally used by the fabricators, there were a few instances in which a fabricator was asked to prepare a joint by a procedure with which he was not too well acquainted. The second series of joints was prepared by a single fabricator who was considered to have a great deal of background and experience in the fabrication of welded copper joints.

Each of the fabricators was requested to record the details of the procedure used by his concern in the fabrication of the test material. Although a standard form had been prepared for the weld procedure data, the completeness of this data was found to vary considerably from one fabricator to the next. The details of these procedures will be presented later in order that the reader may correlate the results of the tests with the detailed welding procedures.

The welding procedures reported for the Series II tests are somewhat more consistent than those presented for the Series I tests. Even in this case, however, the information supplied is not complete. In addition to the weld procedure data, the fabricator of the Series II specimens provided radiographs of the welds.

4. Description of Specimens

A total of 42 welded joints was prepared in duplicate from 12 in. by 60 in. copper sheets. These sheets were welded along the 60-in. length, thereby making joints which were 24 in. wide by 60 in. long.

A summary of the type of joint, filler metal, type of copper, and joint number as originally proposed for this program is presented in Table 1. The odd numbers in this table designate joints fabricated from 1/8-in. material, whereas the even numbers represent joints produced from 1/4-in. copper sheet. However, during the fabrication of the test joints, a number of changes were made in the welding processes and filler metals. As a result, it was necessary to reclassify all of the joints in accordance with the weld fabrication data. This latter classification and description of joints are presented in Table 2.

Tensile test specimens comparable to ASTM Designation E8-49 for flat sheet specimens were prepared with a gage length 2 in. long and a reduced section 1-1/2 in. wide. These specimens were cut from the center of each of the welded joints with the weld transverse to the axis of the specimen. One of the specimens assembled in the special pullheads developed for this program is shown in Fig. 1.

In the preparation of the tensile test specimens, all backing strips and weld reinforcements were removed to provide a uniform basis of comparison for all of the joints. Such a procedure was necessary because of the great variety of welds included in the program. In any application of the data presented herein, it must be borne in mind that the strengths represent a joint for which the weld reinforcement has been removed, and that a joint with reinforcement may be somewhat stronger.

5. Description of Tests

The tensile tests of the welded joints were conducted in a 30,000-lb Riehle Universal testing machine. A mechanical extensometer was used to obtain the elongation over a 2-in. gage length centered on the joints. These measurements combined with the indicated load have been used to obtain what has been called a yield index for the welded joints. The term "yield index", rather than yield strength, has been chosen to indicate the yielding of these joints because yielding may have occurred in the base metal and/or weld metal, and consequently, may not be too significant. However, the value of yield index provides a convenient basis for comparison of the behavior of the welded joints tested. A similar designation, "elongation index", has been used to indicate the total per cent elongation in the specimen.

The tensile tests of welded joints were conducted primarily at room temperature (approximately 80°F). In addition, those joints which exhibited the greater strengths were tested also at temperatures of +400°F and -321°F. These latter studies were conducted to determine the effect of high and low temperatures on the behavior of the joints.

In conjunction with the tensile tests, extensive studies were made to determine the metallurgical characteristics of the joints. The specimens for these metallurgical studies consisted of small strips which were cut normal to the joint and contained a section of the weld. One of the specimen faces containing the weld section was ground with successively finer grit emery papers through 3/0 grit. The surface was then metallographically polished by an electrolytic method; it was considered inadvisable to polish the surface of this soft material mechanically.

After a suitable metallographic surface had been obtained, a micro-hardness survey was made along a straight-line traverse parallel to the surface of the plate and included the weld metal, heat-affected zone, and the base metal. The indentations were made with a Tukon Hardness Tester, using a 136 deg. Vickers Diamond Pyramid Indentor under a load of 1,000 gm.

The specimens were then etched and photographed at magnifications of from 2X to 4X to obtain a record of the macrostructure of each joint. In some cases, it was extremely difficult to obtain pictures which would reveal both the base metal and weld metal structures because of the difference in their reflectivity.

The specimens were next examined under a microscope and the microstructure of the various parts of the joints noted. Photo-micrographs were made of the significant regions of many of the joints.

III. PRESENTATION AND DISCUSSION OF TEST RESULTS

On the basis of the welding processes, the results of the tests have been divided into four general classifications: carbon-arc, shielded-arc, inert-gas-shielded-arc, and oxy-acetylene. These results are summarized as follows:

	Process			
	Carbon-Arc	Shielded-Arc	Inert-Gas-Shielded-Arc	Oxy-Acetylene
Weld Fabrication Data	Table 3	Table 6	Table 9	Table 12
Hardness Survey	Fig. 2	Fig. 5	Fig. 8	Fig. 11
Mechanical Properties	Table 4	Table 7	Table 10	Table 13
Macrostructures	Fig. 3	Fig. 6	Fig. 9	Fig. 12
Metallurgical Examination	Table 5	Table 8	Table 11	Table 14
Radiographic Examination	Fig. 4	Fig. 7	Fig. 10	Fig. 13

6. Carbon-Arc Welding Process

Summaries of the weld fabrication data for the joints prepared by the carbon-arc process are given in Table 3. In general, the joints listed in the first part of this table were made using a copper silicon rod, while those in the second part of the table were made with a phosphor-bronze rod. Differences will be noted in some of the procedures and occasionally part of the important information is missing. However, except for joints No. 50A and 50B, the basic information is available.

The mechanical properties determined from room temperature tests of the specimens welded by the carbon-arc process are summarized in Table 4. In the first part of this table, it can be seen that welds prepared with the deoxidized copper base metal gave the greatest strengths while the specimens of electrolytic tough-pitch copper and OFHC copper, in individual cases, gave low strengths. The weld strengths presented in the second part of the table are generally somewhat greater than those in the first part of the table. The lower strengths in the second group seem to have occurred when a phosphor-copper rather than a phosphor-bronze rod was used as the filler metal. The welds prepared with the phosphor-bronze filler metal generally provided a considerable amount of ductility in the joints also.

Macrostructures of each of the welds prepared by the carbon-arc process are presented in Fig. 3. An indication of the magnification of each of these weld sections may be obtained readily since the odd-numbered joints were made of 1/8-in. plate while the even-numbered joints were made of 1/4-in. plate.

The summaries of the metallurgical examinations of each of the joints are given in Table 5. In these tables, it can be seen that all of the joints except 50A showed relatively good continuity. Joint 50A, however, appeared to be lacking in bonding action and as a result exhibited an extremely low tensile strength. The heat-affected zone of the carbon-arc welded joints was large in most cases. This is evident in the macrostructures and in the hardness surveys of the welds.

A majority of the welded joints of Series II exhibited moderate to heavy porosity in the weld metal. The radiographs in Fig. 4 also show the porosity noted in the metallurgical summary of Table 5. Another feature noted in the metallurgical examination was the presence of copper oxide in the grain boundaries of the heat-affected base metal of those joints prepared with tough-pitch copper. This structure resulted from migration of the Cu_2O initially present in the copper.

7. Shielded-Arc Welding Process

The weld fabrication data for the joints prepared by the shielded-arc process are summarized in Table 6. For the most part, the welds summarized in the first part of Table 6 were prepared with a copper-silicon rod while those in the latter part of the table were prepared with a phosphor-bronze rod. In general, these joints were prepared in the flat position, using a backing strip, clamping, and preheating.

The mechanical properties of the joints are listed in Table 7. Most of the specimens made with the shielded-arc process fractured in the heat-affected zone or base metal except for the tough-pitch copper joints made with a copper-silicon rod. In general, the deoxidized copper specimens gave the greatest strengths. With few exceptions, the joints in the 1/4-in. material were consistently weaker than those in the 1/8-in. material.

The macrostructures and metallurgical examinations of the shielded-arc welded joints revealed porosity in many of the joints. This is shown also in the radiographs of Fig. 7.

8. Inert-Gas-Shielded-Arc Welding Process

The weld fabrication data for the inert-gas-shielded-arc welded joints are listed in Table 9. All of these joints were welded in the flat position and, in most cases, with a backing strip and clamping. The shield for all of the joints was argon gas, with a DC current.

The mechanical properties of the inert-gas-shielded-arc welded joints are summarized in Table 10. In all cases, the strength and ductility of these joints approached those of the base metal. Except for joint No. 10, the average strength obtained in these tests ranged from 26,000 to 31,000 psi.

The metallurgical examination indicated that these joints were, in general, quite sound and possessed excellent continuity. Some of the joints exhibited poor alignment; however, this did not seem to have any detrimental effect on their properties. The radiographs of Fig. 10 also show the excellent continuity and soundness of the inert-gas-shielded-arc welded joints.

9. Oxy-Acetylene Welding Process

Table 12 summarizes the weld fabrication information for the joints prepared by the oxy-acetylene welding process. In general, the joints in the first part of this table were fabricated with a bronze rod whereas those in the second part of the table were prepared using a copper rod. Because numerous techniques were used in this process, the detailed weld procedures vary considerably from one joint to the next.

Table 13 presents a summary of the mechanical properties of the specimens fabricated by the oxy-acetylene process. In every case, the specimens exhibited strengths which were less than those of the base metal; a strength of approximately 29,000 psi appeared to be the maximum obtainable. In addition to a relatively low ultimate strength, the joints failed with a small amount of ductility. Several other observations based on the data in Table 13 are as follows: (1) of the two types of rod used, the brass rod produced joints which had the better mechanical properties, (2) the deoxidized copper joints appeared to be the strongest, and (3) many of the specimens failed through the weld.

The metallurgical studies (Fig. 12 and Table 14) indicate that, except in the case of deoxidized copper joints, all of the welds made with a brass rod contained moderate porosity and oxide penetration. A heavy porosity was noted in the joints prepared with a copper rod. In addition, these latter joints did not have good bond or continuity and the base metal contained large heat-affected zones.

10. Effect of Temperature on Mechanical Properties

The joints of Series II which developed the higher strengths were tested at temperatures of -321°F and +400°F. Results of these tests are summarized in Tables 15 and 16 respectively.

The welded joints tested at -321°F developed ultimate strengths which were considerably above that obtained at room temperature and ranged from 38,000 to 50,000 psi. However, the lower strengths occurred only in the case of the electrolytic tough-pitch copper; the ultimate strength of the other joints (at -321°F) was generally in the neighborhood of 46,000 psi. At this same temperature, the base metals had an ultimate strength of approximately 52,000 psi*.

The joints tested at +400°F exhibited ultimate strengths between 14,000 and 22,000 psi. The average strength of these joints was approximately 17,000 psi. The base metal strength at +400°F was about 23,000 psi*.

IV. ANALYSIS AND INTERPRETATION OF TEST RESULTS

11. General Discussion

A study has been made of the structural state of the joints and the subsequent changes in the structures resulting from welding. The observations based on this study, in turn, have been used to understand more fully the results of the tensile tests.

Microstructures wholly typical of a particular type of welded joint are difficult to obtain since the technique and skill of the welder are as important as the methods and materials used. This is emphasized by the large variations in the metallurgical structure and mechanical properties exhibited by the joints of supposedly duplicate plates. A great many valid observations, however, can be made on the basis of the metallurgical data from the various joints.

The low physical properties of the joints can generally be attributed to one or more of the following: (1) oxides in the metal,

* "Mechanical Properties of Coppers at Various Temperatures", by W. H. Munse and N. A. Weil, Proceedings ASTM, Vol. 51, 1951, p. 996.

(2) weld metal porosity, (3) extreme grain growth in the base metal, (4) poor penetration and flow of the weld metal, (5) lack of structural continuity across the bonding interface, or (6) poor alignment.

Oxides are introduced readily during welding either from oxygen in the atmosphere or some other source, a notable exception being the inert-gas-shielded-arc method. In tough-pitch copper, the oxides are already present in the base metal and, with the addition of heat, may be redistributed into deleterious concentrations at the grain boundaries. The formation of copper oxide during welding or the redistribution of copper oxide which is already present in the base metal can seriously affect the quality of bond in a joint. Its presence also has a serious effect on the ductility of the metal, particularly when it is located in continuous masses.

Porosity in the weld metal is a common defect which is extremely difficult to control. It may be caused by: (a) the presence of gases which dissolve when the metal is molten and rapidly evolve when the melt solidifies, (b) reaction within the melt of oxygen or oxides and dissolved reducing agents, and (c) an entrapment of the surrounding atmosphere in the melt. An excellent correlation was generally found between the mechanical properties of the welded joints and the extent of porosity in the weld metal. In these tests there was no evidence that the type of base metal influenced the extent of weld metal porosity. However, there did appear to be a greater prevalence of shrinkage type porosity in the welds made with copper or brass rods than in the welds made with copper-silicon or bronze rods. The welds made with copper and brass rods solidify through a narrow range of temperature. Hence there is little time for the dendritic cavities, formed during solidification, to be filled by the molten metal. In addition, the base metal is an excellent conductor of heat and produces a rapid rate of solidification of the melt which also tends to increase the degree of porosity. The rate of cooling, however, can be retarded by preheating the plate, thus decreasing the capacity of the plate to conduct heat away from the weld. The voids formed by shrinkage are small and uniformly distributed. Therefore, they are much less important than the porosity voids resulting from gas evolution.

Many of the welds contained gas (CO) porosity; this was particularly true of the carbon-arc welds, and to a lesser degree, for the oxy-acetylene and shielded-arc welds. It is believed that this porosity has been caused by either faulty technique or unfamiliarity with the welding process. Of the procedures used, only the inert-gas-shielded-arc process produced sound weld metal structures consistently.

One of the more important effects of the large amount of heat introduced during welding is the grain growth of the base metal structure in the vicinity of the joint. These coarse grains have a lower strength and hardness, and more important, have less ductility than the finer-grained structure of the base metal. The carbon-arc method of welding, because of its high rate of heat input, does not cause much grain growth. The other methods of welding all have a greater tendency to cause grain coarsening, especially the oxy-acetylene method.

Another defect revealed by the metallurgical examination was the incomplete bonding at many butt interfaces. In order to develop the full strength of the joint, structural continuity must exist across the interface. If this continuity is not obtained, a crack which propagates readily under load is present. This type of structure is illustrated in Fig. 14.

12. Carbon-Arc Joints

In general, the lower mechanical properties of the joints of the carbon-arc group were a direct result of excessive porosity or oxide formation. Gas porosity often occurs when this method of welding is used if precautions are not taken to prevent the highly soluble CO from becoming entrapped in the solidifying melt. An example of such a condition is shown clearly in Fig. 15.

Another factor which may be of considerable importance in this development of gas porosity is the humidity of the surrounding atmosphere at the time of welding. Welds prepared on a humid day may absorb and entrap moisture from the air and thus contain an unusually large degree of porosity. This may account for the lower strengths obtained in some of the joints in this group. Joints No. B1, B49, and B2 (See Fig. 3) are examples of joints which contained large amounts of porosity and had relatively low strengths.

Joint 50A is another example of a very poor welded joint. This may be attributed to faulty welding technique since carbon-arc welds which were sound and had a strength approaching that of the three base metals were produced.

13. Shielded-Arc Joints

The shielded-arc process, in general, gave better joints with tough-pitch copper than did the carbon-arc process. Nevertheless, this process also provided a number of joints which were relatively weak.

The joints prepared using a phosphor-bronze rod appeared to be superior to those produced with a copper silicon rod. Sounder welds were duced when filler rods containing a deoxidizing element such as phosphorus were used. Welds prepared with these two rods may be compared in Figs. 16a and 16b.

Another defect noted in the examinations of the shielded-arc joints was the incomplete bonding at the butt interfaces in a number of joints. If welding does not produce structural continuity across the interface, the junction is, in effect, a crack which propagates readily under load. Figure 16a illustrates incomplete bonding of this type.

Evidence that severe thermal stresses existed in the weld metal is shown in Fig. 17a and 17b. In the former figure, deformation bands in the form of dark parallel lines can be seen in the weld metal. Similar markings are visible in the latter figure around the large gas cavity which appears to provide a stress concentration.

The metallurgical survey indicated that the low strength obtained in joint No. 6 (Series I) may have been the result of incomplete continuity across the butt interface of the joint. This same condition may be noted in the case of joints No. 54A, B22 and B54. The joints of the shielded-arc group exhibited relatively good strengths except where full penetration was not obtained. The porosity in these joints, although quite heavy in some cases, did not reduce the strength of the joints to less than 75 percent of the base metal strength.

14. Inert-Gas-Shielded-Arc Joints

Of the processes considered in this program, the inert-gas-shielded-arc procedure produced the best joints regardless of the base metal. In a number of the cases, it was found that the heat-affected zone of the joints was relatively large. However, the joints exhibited excellent continuity and little micro-porosity (See Fig. 18a), and, although some oxide penetration did exist, it was found to only a limited degree (See Fig. 18b).

15. Oxy-Acetylene Joints

A defect introduced in the oxy-acetylene method of welding is the absorption of oxygen by the metal at high temperatures and the subsequent precipitation of this oxygen at the grain boundaries as Cu_2O. These particles can seriously reduce the strength and ductility of the joint as their number and continuity increase. If, in addition, the plate is heated in a reducing atmosphere, a reaction occurs between the oxide and the reducing gas to form water vapor. This results in the formation of high internal pressures, which may disrupt the grain boundaries and set up a harmful internal stress system.

The formation of oxides also may prevent bonding at the weld metal-base metal interface. Incomplete bonding of this type is clearly shown in Fig. 19a. Figure 19b shows a narrow penetration of oxide which prohibited grain growth near the weld metal interface. A more serious formation of grain boundary oxides may be seen in Fig. 19c.

An unusual distribution of oxide was noted in joint No. 59A (Fig. 20). The metallurgical specimen showed two types of oxide penetration: in one area, (Fig. 20a), the oxides precipitated at the grain boundary, while in another area, (Fig. 20b), the oxide particles outline a grain structure other than that revealed by the etchant. Apparently, after the oxide precipitation occurred in the grain boundaries, deformation and recrystallization established a new grain structure. When the mechanical test specimens were cut from this plate, cracks such as that pictured in Fig. 20c were noted. A metallographic specimen, cut to include this crack and polished in a direction perpendicular to the crack, revealed several additional fine fissures as shown by Fig. 20d. In Fig. 20e (magnification of 200X) it can be seen that a heavy precipitation of Cu_2O at the grain boundaries destroyed the intergranular cohesion of the material.

The structure of the joints prepared with an oxy-acetylene flame and a brass filler rod were quite similar for deoxidized and OFHC copper. However, the tough-pitch copper was characterized by a very slight degree of coarsening of the base metal structure and the precipitation of copper oxide in the grain boundaries of the base metal in the vicinity of the joint. When a brass filler rod was used, the penetration and structural continuity were not as good as expected. Since the melting point of the filler metal is lower than that of the base metal, the filler metal flows freely at a temperature below that at which good penetration of the base metal can occur. This may be seen in Fig. 21.

The weld data and macrostructures of the joints prepared by the oxy-acetylene process reveal the great variety of procedures and joint details used by the different fabricators. The Series I specimens included beveled (single and double), scarfed and butt type joints. The Series II specimens were prepared by one fabricator and consequently are more consistent. Nevertheless, the 1/8-in. thick joints of Series II exhibited a great deal of misalignment.

Thus, the greatest variation in procedure, strength, and general properties was found in the joints prepared by the oxy-acetylene process. This process probably requires the greatest skill on the part of the operator.

TABLE 1

WELDED COPPER JOINT DESCRIPTIONS AS PROPOSED IN THE INITIAL PROGRAM

WELDING PROCESS	FILLER METAL	JOINT NUMBER (EACH INCLUDES A AND B PLATES)		
		ELECTROLYTIC TOUGH PITCH	PHOSPHOROUS DEOXIDIZED	OXYGEN-FREE HIGH CONDUCTIVITY
CARBON-ARC	COPPER-SILICON ROD	1, 2	17, 18	49, 50
CARBON-ARC	PHOSPHOR-COPPER ROD	3, 4	19, 20	51, 52
SHIELDED-ARC	COPPER-SILICON ROD	5, 6	21, 22	53, 54
SHIELDED-ARC	PHOSPHOR-BRONZE ROD	7, 8	23, 24	55, 56
METAL-ARC	DEOXIDIZED COPPER ROD	9, 10	25, 26	57, 58
OXY-ACETYLENE	BRASS ROD	11, 12	27, 28	59, 60
OXY-ACETYLENE	COPPER ROD	13, 14	29, 30	61, 62

Welding Process	Filler Metal	Joint Numbers: Electrolytic Tough Pitch	Joint Numbers: Phosphorus Deoxidized	Joint Numbers: Oxygen Free High Conductivity
Carbon-Arc	Copper-Silicon Alloy (3 o/o)	1A,1B,2A,2B	17A,17B,18A,18B	49A,49B
Carbon-Arc	Phosphor-Bronze (Cu-Sn, Grade D)	4A,4B		
Carbon-Arc	Copper-Phosphorus Alloy (93-7)		19A,19B	
Carbon-Arc	Phosphor-Bronze (Cu-Sn, Grade Not Known		20A,20B	52A,52B
Carbon-Arc	Deoxidized-Copper (Type Not Stated)	3A,3B		
Inert-Gas-Shielded-Arc (Tungsten Electrode)	Silicon Deoxidized Copper	9A,9B,10A,10B	25A,25B,26A,26B	57A,57B,58A,58B
Shielded-Arc	Copper-Silicon Alloy (3 o/o) (Covered Electrode: AWS-ASTM ECuSi)	5A,5B,6A,6B	21A,21B,22A,22B	54A,53A,53B
Shielded-Arc	Phosphor-Bronze (A) (Covered Electrode; AWS-ASTM ECuSn-A)	7A,7B,8A,8B	24A,24B	55A,55B,56A,56B
Oxy-Acetylene	Silicon Deoxidized Copper	14A,14B		62A,62B
Oxy-Acetylene	Phosphor Deoxidized Copper (Silver-Bearing)			61A,61B
Oxy-Acetylene	Phosphor and Manganese Deoxidized Copper (Silver-Bearing)		30A,30B	
Oxy-Acetylene	Low-Fuming Manganese Bronze (Melting Range 1590-1630°F)		28A,28B	60A,60B
Oxy-Acetylene	Naval Brass (Melting Range 1630-1650°F)	11A,11B	27A,27B	
Oxy-Propane	Spelter (Melting Range 1570-1610°F)	12A,12B		59A,59B

[illegible]

(AS REPORTED BY [illegible])

	ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
	SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.	1A 1B	2A 2B	B1	B2	17A 17B	18A 18B	B17	B18	49A 49B	50A 50B	B49	B50
FILLER METAL	EVERDUR	HERCULOY	OLYMPIC BRONZE	OLYMPIC BRONZE	EVERDUR	OLYMPIC BRONZE W	OLYMPIC BRONZE	OLYMPIC BRONZE	EVERDUR 1010	NO DATA AVAILABLE	OLYMPIC BRONZE	OLYMPIC BRONZE
SOURCE	AMERICAN BRASS CO.	REVERE CO.	CHASE CO.	CHASE CO.	AMERICAN BRASS CO.	CHASE CO.	CHASE CO.	CHASE CO.	AMERICAN BRASS CO.		CHASE CO.	CHASE CO.
ROD SIZE, IN.	5/32	3/16	1/4	5/32-1/4	5/32	3/16	5/32-3/16	5/32-1/4	5/32		1/4	5/32-1/4
FLUX												
TYPE	EVERFLUX SHAKER	H AND H LIQ. PAINT	EVERFLUX PASTE	EVERFLUX PASTE	EVERFLUX SHAKER	NONE	EVERFLUX PASTE	EVERFLUX PASTE	EVERFLUX SHAKER		EVERFLUX PASTE	EVERFLUX PASTE
JOINT DESIGN												
EDGE PREP.	SQUARE	30° BEVEL	40° BEVEL	40° BEVEL	SQUARE		40° BEVEL	40° BEVEL	SQUARE		40° BEVEL	40° BEVEL
ROOT SPACE, IN.	1/16	1/16	1/16	1/16	1/16	1/8	1/16	1/16	NONE		1/16	1/16
POSITION	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT		FLAT	FLAT
BACKING	COPPER	STEEL	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER		COPPER	COPPER
CLAMPING	YES	YES	YES	YES	YES	YES	YES	YES	YES		YES	YES
ARC METHOD												
ELECTRODE SIZE, IN.	3/8	3/8	3/8	5/16-3/8	3/8		5/16	5/16-3/8	3/8		3/8	5/16-3/8
CURRENT		D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.		D.C.	D.C.
POLARITY	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT		STRAIGHT	STRAIGHT
VOLTAGE		38-40	28	28-30		37	25-26	28-27			28	25-27
AMPERAGE	150,200	A 375-400 B 450-500	210	180-240	150,200	260	160-150	200-270	125-150		210	190-260
PREHEAT TEMP. °F	300	1100	600	600			600	600	300		600	600
PROCEDURE												
PASSES	2	2			2	1			2			
SPEED, IN/MIN												
PEENING	NONE	YES	NONE	NONE	NONE	NONE	NONE	NONE	NONE		NONE	NONE

	ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				[illegible]		
	SERIES I		SERIES II		SERIES I		SERIES II		SERIES I	SERIES II	
	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.	3A 3B	4A 4B	B3	B4	19A 19B	20A 20B	B19	B20	52A 52B	B51	B52
FILLER METAL	DEOX COPPER	PHOSPHOR BRONZE 310	PHOSPHOR BRONZE	PHOSPHOR BRONZE	PHOSPHOR COPPER	PHOSPHOR BRONZE	PHOSPHOR BRONZE	PHOSPHOR BRONZE	PHOSPHOR BRONZE	PHOSPHOR BRONZE	PHOSPHOR BRONZE
SOURCE	REVERE CO.	AMERICAN BRASS CO.	AMERICAN BRASS CO.	AMERICAN BRASS CO.	WESTINGHOUSE	MORRIS WHEELER	AMERICAN BRASS CO.	AMERICAN BRASS CO.	MORRIS WHEELER	AMERICAN BRASS CO.	AMERICAN BRASS CO.
ROD SIZE, IN.	1/8	3/16	1/4	1/4	1/8	1/4	1/4	1/4	1/4	1/4	1/4
FLUX TYPE	NONE	NONE	EVERFLUX PASTE	EVERFLUX PASTE	H AND H LIQ. PAINT	EVERFLUX SHAKER	EVERFLUX PASTE	EVERFLUX PASTE	EVERFLUX SHAKER	EVERFLUX PASTE	EVERFLUX PASTE
JOINT DESIGN											
EDGE PREP.		45° BEVEL	40° BEVEL	40° BEVEL	SQUARE	60° BEVEL	40° BEVEL	40° BEVEL	60° BEVEL	40° BEVEL	40° BEVEL
ROOT SPACE, IN.	1/32	NONE	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
POSITION	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT
BACKING	NONE	STEEL	COPPER	COPPER	STEEL	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER
CLAMPING	NONE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
ARC METHOD											
ELECTRODE SIZE, IN.	1/8	3/8	3/8	1/2	3/16	1/2, 3/8	3/8	1/2	1/2, 3/8	3/8	1/2
CURRENT	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.
POLARITY	REVERSE	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT	STRAIGHT
VOLTAGE	31	45	40	36	30-35		38	40		38	39
AMPERAGE	215	300, 350	200	320	150-175	325, 425	190	370	325-425	190	290
PREHEAT TEMP. °F	NONE	NONE	600	600	400	300	600	600	300	600	600
PROCEDURE											
PASSES	1	2			2	2			2		
SPEED, IN/MIN		15			12						
PEENING	NONE	NONE	NONE	NONE	YES	NONE	NONE	NONE	NONE	NONE	NONE

[illegible]

SUMMARY OF MECHANICAL PORPERTIES AT ROOM-TEMPERATURE OF JOINTS [illegible]

		ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				[illegible]			
		SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES III	
		1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.		1A 1B	2A 2B	B1	B2	17A 17B	18A 18B	B17	B18	49A 49B	50A 50B	B49	B50
	SPEC. NO												
MAXIMUM STRENGTH (P.S.I.)	1	28,340	26,590	14,600	16,460	31,070	27,000	31,590	25,970	28,840	11,070	12,540	28,380
	2	31,650	23,040	13,820	26,630	30,530	30,240	31,030	26,160	32,080	8,840	17,940	29,370
	3	20,230	25,290			30,440	17,810			29,900	8,170		
	4	25,690	22,730			31,900	26,700			23,860	6,990		
AV.		26,480	24,410	14,210	21,540	30,980	25,440	31,310	26,060	28,670	8,770	15,240	28,870
YIELD INDEX (P.S.I.)	1	12,920	13,380		10,950	14,940	10,420	12,330	10,760	12,400	7,560	8,480	10,060
	2	14,200	11,670	10,300	12,750	14,190	10,410	12,060	11,480	12,990	6,470	13,150	10,620
	3	12,840	10,570			13,760	12,010			16,100	5,890		
	4	13,930	9,720			14,710	11,560			14,150	5,270		
AV.		13,470	11,330	10,300	11,850	14,400	11,100	12,190	11,120	13,910	6,300	10,810	10,340
ELONGATION INDEX (o/o)	1	21.5	18.8	3.1	6.5	47.7	23.8	29.0	21.5	19.7	4.3	5.1	28.5
	2	27.5	14.7	4.8	16.0	40.8	42.7	38.0	19.5	31.8	5.0	4.8	35.5
	3	7.0	17.8			28.5	12.7			28.7	4.4		
	4	12.8	16.3			30.7	33.7			25.3	3.2		
AV.		17.2	16.9	3.95	11.2	36.9	28.2	33.5	20.5	26.4	4.2	4.9	32.0
REDUCTION OF AREA (o/o)	1	59.0	28.0	8.0	17.0	88.0	48.0	52.0	40.0	64.0	13.0	15.0	51.0
	2	49.0	27.0	14.0	14.0	84.0	77.0	67.0	43.0	69.0	10.0	5.0	56.0
	3	21.0	28.0			83.0	29.0			70.0			
	4	17.0	19.0			83.0	64.0			51.0	1.0		
AV.		36.5	25.5	11.0	15.5	84.5	54.5	59.5	41.5	63.5	8.0	10.0	53.5
LOCATION OF FRACTURE*	1	E.W.	E.W.	M.W.	M.W.	B.M.	M.W.	B.M.	B.M.	H.Z.	M.W.	M.W.	B.M.
	2	E.W.	H.Z.	M.W.	B.M.	H.Z.	H.Z.	B.M.	B.M.	H.Z.	M.W.	E.W.	B.M.
	3	E.W.	E.W.			B.M.	M.W.			H.Z.	M.W.		
	4	E.W.	E.W.			H.Z.	E.W.			E.W.	M.W.		

* FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE
B.M. = BASE METAL

TABLE V (CONT'D) [illegible]

SUMMARY OF MECHANICAL PROPERTIES AT ROOM TEMPERATURE OF JOINTS [illegible]

		ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
		SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
		1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.		3A 3B	4A 4B	B3	B4	19A 19B	20A 20B	B19	B20		52A 52B	B51	B52
	SPEC. NO.												
MAXIMUM STRENGTH (P.S.I.)	1	23,020	30,330	31,790	18,480	20,990	30,690	31,150	27,540		30,220	26,830	30,870
	2	24,150	28,530	22,020	20,620	18,180	31,180	17,800	19,510		29,850	19,640	26,250
	3	17,710	30,360			32,620	30,620				30,650		
	4	16,790	20,630			16,435	30,580				30,490		
	AV.	20,420	27,460	26,900	19,550	22,060	30,770	24,470	23,520		30,300	23,230	28,560
YIELD INDEX (P.S.I.)	1	13,420	13,710	10,700	10,570	16,210	12,280	11,050	8,670		11,380	11,460	9,480
	2	13,270	12,180	10,690	10,690	15,160	11,410	10,850	8,780		14,710	11,170	9,370
	3	12,260	13,540			16,490	11,380				10,070		
	4	12,960	14,290			13,840	11,450				10,650		
	AV.	12,980	13,420	10,690	10,630	15,420	11,630	10,950	8,720		11,700	11,310	9,420
ELONGATION INDEX (o/o)	1	8.0	30.5	32.3	7.5	3.7	36.5	30.6	22.0		35.0	16.6	40.5
	2	8.9	5.7	9.6	9.5	3.5	37.7	8.1	8.0		30.2	8.0	18.0
	3	4.5	10.8			17.8	34.1				28.7		
	4	3.5	11.7			7.3	28.3				38.2		
	AV.	6.2	14.7	20.9	8.5	8.1	34.1	19.3	15.0		33.0	12.3	29.2
REDUCTION OF AREA (o/o)	1	15.0	60.0	56.0	15.0	3.0	83.0	85.0	30.0		83.0	26.0	83.0
	2	14.0	60.0	21.0	10.0	35.0	83.0	12.0	15.0		33.0	23.0	25.0
	3	11.0	56.0			83.0	83.0				75.0		
	4	8.0	21.0			31.0	83.0				85.0		
		12.0	49.2	38.5	12.5	38.0	83.0	48.5	22.5		69.0	24.5	54.0
LOCATION OF FRACTURE*	1	E.W.	B.M.	B.M.	E.W.	M.W.	B.M.	B.M.	M.W.		H.Z.	M.W.	B.M.
	2	E.W.	H.Z.	M.W.	E.W.	E.W.	B.M.	M.W.	M.W.		M.W.	M.W.	M.W.
	3	E.W.	H.Z.			E.W.	B.M.				B.M.		
	4	E.W.	E.W.			E.W.	B.M.				B.M.		

* FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE

[illegible]

		SERIES I			[illegible]		
WELD NO. (1)	BASE METAL (2)	APPEARANCE OF JOINT (3)	MICROSTRUCTURE OF BASE METAL (4)	MICROSTRUCTURE OF WELD METAL (5)	APPEARANCE OF JOINT (6)	MICROSTRUCTURE OF BASE METAL (7)	[illegible] (8)
1	ELECT	STEEP STRUCTURAL GRADIENT AT JOINT, SOME CONTINUITY.	NARROW HAZ. (HEAT-AFFECTED ZONE)	SEGREGATION IN CONCENTRIC RINGS IN WM. (WELD METAL)	STRUCTURAL CONTINUITY AND PENETRATION GOOD.	SOME OXIDE PENETRATION IN GRAIN BOUNDARY NEAR JOINT.	VERY HEAVY POROSITY.
2	ELECT	EXCELLENT CONTINUITY ACROSS INTERFACE.	NARROW HAZ.	SOUND WM.	POOR CONTINUITY AT ROOT OF WELD.	HEAVY OXIDE PENETRATION NEAR JOINT.	HEAVY POROSITY.
17	DEOX	GOOD BOND.	LARGE HAZ. SOME OXIDE PENETRATION AT EDGE OF PLATE.	MODERATE EXTENT OF MICRO-POROSITY.	FAIR PENETRATION, GOOD CONTINUITY.	NO OXIDE PENETRATION NEAR JOINT.	SOUND WM.
18	DEOX	CRACKED AT JUNCTION.	MODERATE HAZ.	STRONG COLUMNAR GROWTH. MICRO-SHRINKAGE POROSITY.	GOOD CONTINUITY AND FAIR PENETRATION.	SMALL OXIDE PENETRATION AT EDGE OF PLATE.	HEAVY POROSITY.
49	OFHC	GOOD CONTINUITY.	MODERATE HAZ. GRAIN GROWTH INHIBITED NEAR JOINT.	MODERATE MICRO-POROSITY IN WM.	GOOD PENETRATION AND CONTINUITY.	SOME OXIDE PENETRATION AT EDGE OF PLATE.	VERY HEAVY POROSITY.
50	OFHC	JOINT SHOWS GOOD PENETRATION AND CONTINUITY. BUTT JOINT IS ENTIRELY LACKING IN ANY BONDING ACTION.	MODERATE HAZ.	HIGHLY CORED. SOME MACRO-POROSITY.	GOOD PENETRATION AND CONTINUITY.	NO OXIDE PENETRATION.	MODERATE POROSITY.

		SERIES II			SERIES III		
WELD NO. (1)	BASE METAL (2)	APPEARANCE OF JOINT (3)	MICROSTRUCTURE OF BASE METAL (4)	MICROSTRUCTURE OF WELD METAL (5)	APPEARANCE OF JOINT (6)	MICROSTRUCTURE OF BASE METAL (7)	MICROSTRUCTURE OF WELD METAL (8)
3	ELECT	GOOD BOND.	NARROW HAZ.	VERY POROUS WM.	SHARP GRADIENT, LITTLE PENETRATION.	SOME OXIDE, PENETRATION NEAR JOINT.	VERY SOUND WM
4	ELECT	GOOD BOND.	NARROW HAZ. SOME GRAIN GROWTH INHIBITED ALONG EDGE AT PLATE.	HEAVILY CORED BUT SOUND.	POOR CONTINUITY ACROSS INTERFACE.	HEAVY OXIDE PENETRATION NEAR JOINT.	HEAVY POROSITY.
19	DEOX	SHARP BOUNDARY AT JUNCTION.	MODERATE HAZ.	HIGHLY CORED, EXTENSIVE POROSITY.	GOOD PENETRATION AND CONTINUITY.	NO OXIDE PENETRATION	MODERATE POROSITY.
20	DEOX	SHARP GRADIENT, LITTLE PENETRATION.	MODERATE HAZ.	CORED WM. LARGE AMOUNT OF MICRO-POROSITY.	GOOD PENETRATION AND CONTINUITY.	NO OXIDE PENETRATION.	HEAVY POROSITY.
51	OFHC				FAIR PENETRATION AND CONTINUITY.	SOME OXIDE PENETRATION AT EDGE OF PLATE.	MODERATE POROSITY.
52	OFHC	LITTLE PENETRATION. SHARP BREAK.	LARGE HAZ.	HEAVY CORING AND POROSITY.	FAIR PENETRATION, GOOD CONTINUITY.	SOME OXIDE PENETRATION AT EDGE OF PLATE.	SOUND. FEW PITS.

SUMMARY OF WELD FABRICATION DATA FOR SHIELDED-ARC PROCESS

(AS REPORTED BY FABRICATORS)

	ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
	SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.	5A 5B	6A 6B	B5	B6	21A 21B	22A 22B	B21	B22	53A 53B	54A	B53	B54
FILLER METAL	SIL-TRODE	KOP-R-ARC	COPPER SILICON	COPPER SILICON	SIL-TRODE	BRONZEND E	COPPER SILICON	COPPER SILICON	SIL-TRODE	BRONZEND E	COPPER SILICON	COPPER SILICON
SOURCE	AMPCO METAL	KREMBS AND CO.	ARCOS CORP.	ARCOS CORP.	AMPCO METAL	ARCOS CORP.	ARCOS CORP.	ARCOS CORP.	AMPCO METAL	ARCOS CORP.	ARCOS CORP.	ARCOS CORP.
ROD SIZE, IN.	5/32	3/16	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32
FLUX												
TYPE		FLUXINE PAINT										
JOINT DESIGN												
EDGE PREP.	SQUARE	DOUBLE U	40° BEVEL	40° BEVEL	SQUARE	30° BEVEL	40° BEVEL	40° BEVEL	SQUARE	BEVEL 3/32	40° BEVEL	40° BEVEL
ROOT SPACE, IN.	1/8	1/16	1/16	1/16	3/32	TIGHT	1/16	1/16	1/8	1/8	1/16	1/16
POSITION		FLAT	FLAT	FLAT		15° ANGLE	FLAT	FLAT		FLAT	FLAT	FLAT
BACKING		STEEL	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER	STEEL	COPPER	COPPER
CLAMPING	NONE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
ARC METHOD												
ELECTRODE SIZE, IN.	5/32	3/16	5/32	[illegible]	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32
CURRENT	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.
POLARITY	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE
VOLTAGE	26	30-40	35-37	32	26	29	32	32-40	26	60	32-30	35-38
AMPERAGE	200	175-250	160-150	170-200	200	140	140	190-170	200	225-250	140-160	190-170
PREHEAT TEMP. °F	1000	900-1100	800		1000	1000	800		750-800	CHERRY RED	800	
PROCEDURE												
PASSES		2			1				1	2		
SPEED, IN/MIN												
PEENING	NONE	YES	NONE	NONE	NONE	[illegible]	NONE	NONE	NONE	NONE	NONE	NONE

[illegible]

(AS REPORTED BY FABRICATOR)

	ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS			O.F.H.C.			
	SERIES I		SERIES II		SERIES I	SERIES II		SERIES I		SERIES II	
	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.	7A 7B	8A 8B	B7	B8	24A 24B	B23	B24	55A 55B	56A 56B	B55	B56
FILLER METAL	BRONZEND P	PHOS-TRODE	PHOSPHOR BRONZE	PHOSPHOR BRONZE	PHOS-TRODE	PHOSPHOR BRONZE	PHOSPHOR BRONZE	BRONZEND P 5060	PHOS-TRODE	PHOSPHOR BRONZE	PHOSPHOR BRONZE
SOURCE	ARCOS CORP.	AMPCO METAL	ARCOS CORP.	ARCOS CORP.	AMPCO METAL	ARCOS CORP.	ARCOS CORP.	ARCOS CORP.	AMPCO METAL	ARCOS CORP.	ARCOS CORP.
ROD SIZE, IN.	1/8	1/4	5/32	3/16	1/4	5/32	3/16	3/16	1/4	5/32	3/16
FLUX											
TYPE								NONE			
JOINT DESIGN											
EDGE PREP.	30° BEVEL		45° BEVEL	45° BEVEL		45° BEVEL	45° BEVEL	BUTT		45° BEVEL	45° BEVEL
ROOT SPACE, IN.	TIGHT	5/32	3/32	3/32	5/32	3/32	3/32	1/32	5/32	3/32	3/32
POSITION	FLAT		FLAT	FLAT		FLAT	FLAT	FLAT		FLAT	FLAT
BACKING	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER	COPPER
CLAMPING	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
ARC METHOD											
ELECTRODE SIZE, IN.	1/8	1/4		3/16	1/4	5/32	3/16	3/16	1/4	5/32	3/16
CURRENT	D.C.		D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.
POLARITY	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE	REVERSE
VOLTAGE	29	27	32	40-38	27	30-28	35-32	37	28	30	37
AMPERAGE	135	350-375	140	280-260	350-375	150-160	280-260	240	350-475	150	230
PREHEAT TEMP.° F	1000	800			800			NONE	800		
PROCEDURE											
PASSES		2			2			2			
SPEED, IN/MIN.											
PEENING		NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE

[illegible]

		ELECTROYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
		SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
		1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.		5A 5B	6A 6B	B5	B6	21A 21B	22A 22B	B21	B22	53A 53B	54A	B53	B54
	SPEC. NO.												
MAXIMUM STRENGTH (P.S.I.)	1	21,680	10,740	25,720	25,140	30,890	24,620	25,110	14,990	26,520	9,500	27,950	18,200
	2	20,070	11,280	22,560	31,430	31,480	28,780	28,850	29,750	31,470	9,790	29,980	30,580
	3	19,420	17,980			31,020	22,450			30,170			
	4	19,320	18,050			32,280	24,250			29,990			
	AV.	20,120	14,510	24,140	28,280	31,420	25,020	26,980	22,370	29,540	9,640	28,960	24,390
YIELD INDEX (P.S.I.)	1	13,860	8,660	11,620	11,430	13,830	10,760	11,690	10,670	11,620	9,380	12,410	9,830
	2	13,250	10,120	10,580	10,030	13,550	10,590	11,770	11,110	11,860	9,610	11,070	8,350
	3	14,120	12,570			14,420	10,220			12,360			
	4	15,580	12,610			13,760	10,700			12,710			
	AV.	14,200	10,990	11,100	10,730	13,890	10,570	11,730	10,890	12,140	9,940	11,740	9,090
ELONGATION INDEX (o/o)	1	7.2	4.5	16.7	13.5	18.3	21.3	16.8	6.5	21.3	2.5	17.2	8.5
	2	5.8	4.5	11.6	28.5	11.7	35.9	31.8	35.5	30.2	2.0	24.2	38.0
	3	3.0	7.8			16.7	19.7			28.5			
	4	3.5	8.7			28.4	20.7			28.5			
	AV.	4.9	6.4	14.1	21.0	18.8	24.4	24.3	21.0	25.9	2.2	20.7	23.2
REDUCTION OF AREA (o/o)	1	14.0	18.0	29.0	22.0	87.0	31.0	26.0	12.0	28.0	6.0	26.0	18.0
	2	22.0	14.0	32.0	30.0	45.0	56.0	79.0	7.0	65.0	4.0	53.0	37.0
	3	2.0	25.0			90.0	52.0			69.0			
	4	10.0	19.0			87.0	36.0			38.0			
	AV.	12.0	19.0	30.5	26.0	77.2	43.7	52.5	9.5	50.0	5.0	39.5	27.5
LOCATION OF FRACTURE*	1	E.W.	M.W.	E.W.	E.W.	H.Z.	M.W.	M.W.	M.W.	E.W.	M.W.	M.W.	M.W.
	2	E.W.	M.W.	B.M.	B.M.	H.Z.	H.Z.	B.M.	B.M.	H.Z.	M.W.	B.M.	B.M.
	3	E.W.	E.W.			H.Z.	M.W.			H.Z			
	4	E.W.	E.W.			H.Z.	E.W.			H.Z.			

* FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE
B.M. = BASE METAL

TABLE 7 (CONT'D)

SUMMARY OF MECHANICAL PROPERTIES AT ROOM TEMPERATURE OF JOINTS WELDED BY THE SHIELDED-ARC PROCESS

		ELECTROYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
		SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
		1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.		7A 7B	8A 8B	B7	B8		24A 24B	B23	B24	55A 55B	56A 56B	B55	B56
	SPEC. NO.												
MAXIMUM STRENGTH (P.S.I.)	1	30,810	27,320	27,540	20,840		29,790	31,130	24,270	31,160	25,070	22,120	16,890
	2	24,380	30,940	27,320	27,080		28,760	31,210	20,870	32,870	30,150	30,860	23,730
	3	29,800	30,200				30,750			27,480	28,490		
	4	31,270	31,350				30,600			30,820	30,630		
	AV.	28,940	29,950	27,430	23,960		29,970	31,170	22,570	30,580	28,580	26,490	20,310
YIELD INDEX (P.S.I.)	1	14,750	12,550	10,410	9,340		11,900	11,520	9,780	13,980	12,250	12,460	8,270
	2	13,830	13,930	10,480	9,800		11,890	12,010	9,850	15,410	14,250	12,430	8,740
	3	17,150	13,260				11,460			13,190	16,770		
	4	15,490	13,390				11,190			13,450	13,170		
	AV.	15,160	13,280	10,440	9,570		11,610	11,760	9,810	14,010	14,110	12,440	8,500
ELONGATION INDEX (o/o)	1	17.1	18.8	21.2	11.8		32.0	36.9	14.5	26.5	24.0	13.9	10.5
	2	11.1	31.0	16.3	19.5		39.2	31.2	11.0	22.8	32.0	23.2	17.0
	3	14.8	27.7				40.3			22.0	21.4		
	4	17.5	33.8				37.0			29.1	41.4		
	AV.	15.1	27.8	18.7	15.6		37.1	34.0	12.7	25.1	29.7	18.5	13.7
REDUCTION OF AREA o/o	1	13.0	31.0	37.0	18.0		52.0	85.0	14.0	87.0	43.0	46.0	16.0
	2	19.0	61.0	18.0	22.0		57.0	79.0	19.0	83.0	80.0	60.0	13.0
	3	6.0	28.0				84.0			66.0	80.0		
	4	16.0	55.0				83.0			78.0	76.0		
	AV.	13.5	43.7	27.5	20.0		69.0	82.0	16.5	77.0	69.7	53.0	14.5
LOCATION OF FRACTURE*	1	H.Z.	E.W.	B.M.	M.W.		H.Z.	B.M.	B.M.	H.Z.	E.W.	M.W.	M.W.
	2	M.W.	B.M.	B.M.	B.M.		H.Z.	B.M.	M.W.	H.Z.	H.Z.	B.M.	B.M.
	3	H.Z.	H.Z.				B.M.			H.Z.	H.Z.		
	4	H.Z.	B.M.				B.M.			B.M.	B.M.		

* FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE
B.M. = BASE METAL

[illegible]

WELD NO. (1)	BASE METAL (2)	SERIES I: APPEARANCE OF JOINT (3)	SERIES I: MICROSTRUCTURE OF BASE METAL (4)	SERIES I: MICROSTRUCTURE OF WELD METAL (5)	SERIES II: APPEARANCE OF JOINT (6)	SERIES II: MICROSTRUCTURE OF BASE METAL (7)	SERIES II: MICROSTRUCTURE OF WELD METAL (8)
5	ELECT	STEEP GRADIENT.	VERY NARROW HAZ	EXTENSIVE MICRO-POROSITY.	MICRO-POROSITY AT INTERFACE.	INTER-DENDRITIC AT JOINT.	MODERATE POROSITY.
6	ELECT	NO CONTINUITY ACROSS INTERFACE.	NO CONTINUITY ACROSS BUTT. SOME OXIDE PENETRATION.	HEAVY POROSITY.	LITTLE PENETRATION, GOOD CONTINUITY ACROSS INTERFACE.	SOME OXIDE PENETRATION NEAR JOINT.	MODERATE POROSITY.
21	DEOX	GOOD BOND.	VERY LARGE HAZ.	21-A SOUND 21-B HEAVY POROSITY.	EXCELLENT PENETRATION AND CONTINUITY.	OXIDE PENETRATION ALONG EDGE OF PLATE.	MODERATE POROSITY.
22	DEOX	STEEP GRADIENT BUT GOOD CONTINUITY.	VERY LARGE HAZ.	SOUND WM.	POOR PENETRATION, POROSITY IN WM OUTLINES JOINT.	NO OXIDES PRESENT.	HEAVY POROSITY.
53	OFHC	GOOD CONTINUITY ACROSS WM-BM JUNCTION.	LARGE HAZ.	HEAVY MACRO- AND MICRO-POROSITY.	FAIR PENETRATION AND GOOD CONTINUITY.	NO OXIDES PRESENT.	MODERATE POROSITY.
54	OFHC	NO BONDING ACROSS BUTT INTERFACE.	MODERATELY LARGE HAZ.	EXTENSIVE MICRO-POROSITY.	FAIR PENETRATION, GOOD CONTINUITY.	NO OXIDE PRESENT.	HEAVY POROSITY.

		SERIES I			SERIES III		
WELD NO. (1)	BASE METAL (2)	APPEARANCE OF JOINT (3)	MICROSTRUCTURE OF BASE METAL (4)	MICROSTRUCTURE OF WELD METAL (5)	APPEARANCE OF JOINT (6)	MICROSTRUCTURE OF BASE METAL (7)	MICROSTRUCTURE OF WELD METAL (8)
7	ELECT	GOOD BOND	LARGE HAZ.	SOUND WM.	GOOD CONTINUITY.	HEAVY OXIDE PENETRATION NEAR JOINT.	SOUND WM.
8	ELECT	SHARP INTERFACE WITH LITTLE CONTINUITY.	SOME INCLUSIONS AT GRAIN BOUNDARY.	DENSE, LITTLE CORING EVIDENT.	FAIR CONTINUITY, POROSITY AT INTERFACE.	SOME OXIDE PENETRATION AT JOINT AND EDGE OF BM.	HEAVY POROSITY.
23	DEOX				GOOD PENETRATION AND FLOW.	SOME OXIDE PENETRATION AT EDGE OF PLATE.	SOUND
24	DEOX	POOR DIFFUSION AT INTERFACE. CRACK NEAR EDGE.	NARROW HAZ.	HEAVY POROSITY.	FAIR PENETRATION, GOOD CONTINUITY IN GENERAL.	NO OXIDES PRESENT.	HEAVY POROSITY.
55	OFHC	FAIR CONTINUITY ACROSS JOINT.	LARGE HAZ.	VERY SOUND WM.	EXCELLENT CONTINUITY AND PENETRATION.	NO OXIDES PRESENT.	VERY SOUND.
56	OFHC	VERY SHARP GRADIENT	LARGE HAZ	EXTENSIVE CORING AND MICROPOROSITY.	FAIR CONTINUITY AND PENETRATION.	SOME OXIDE PENETRATION AT JOINT AND PLATE FACE.	HEAVY POROSITY.

(AS REPORTED BY FABRICATOR)

	ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
	SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.	9A 9B	10A 10B	B9	B10	25A 25B	26A 26B	B25	B26	57A 57B	58A 58B	B57	B58
FILLER METAL	ANACONDA 372	ANACONDA 372	ANACONDA 372	ANACONDA 372	ANACONDA 372	ANACONDA 372	ANACONDA 372	ANACONDA 372	ANACONDA 372	ANACONDA 372	ANACONDA 372	ANACOND 372
SOURCE	AIR REDUCTION	REVERE CO.	AMERICAN BRASS CO.	AMERICAN BRASS CO.	AIR REDUCTION	REVERE CO.	AMERICAN BRASS CO.	AMERICAN BRASS CO.	AIR REDUCTION	REVERE CO.	AMERICAN BRASS CO.	AMERICAI BRASS C
ROD SIZE, IN.	1/8	3/16	1/16	1/16	1/8	3/16	1/16	1/16	1/8	3/16	1/16	1/16
FLUX TYPE	NONE	MARVEL BRAZE PAINT			NONE	MARVEL BRAZE PAINT			NONE	MARVEL BRAZE PAINT		
JOINT DESIGN												
EDGE PREP.	SQUARE BUTT	NO BEVEL	SQUARE BUTT	30° BEVEL	SQUARE BUTT	NO BEVEL	SQUARE BUTT	30° BEVEL	SQUARE BUTT	45° BEVEL	SQUARE BUTT	30° BEVI
ROOT SPACE, IN.	TIGHT	1/32	1/16	NONE	TIGHT	1/32	1/16	NONE	TIGHT	1/32-1/16	1/16	NONE
POSITION	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT	FLAT
BACKING	STEEL	NONE	COPPER	COPPER	STEEL	NONE	COPPER	COPPER	STEEL	NONE	COPPER	COPPER
CLAMPING	YES	NONE	YES	YES	YES	YES	YES	YES	YES	NONE	YES	YES
GAS METHOD												
TORCH MAKE		LINDE 500 AMPS	AIRCOMATIC GUN 2S	AIRCOMATIC GUN 2S		LINDE 500 AMPS	AIRCOMATIC GUN 2S	AIRCOMATIC GUN 2S		LINDE 500 AMPS	AIRCOMATIC GUN 2S	AIRCOMAT GUN 2S
GAS SHIELD	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON	ARGON
GAS AMOUNT		15 LITERS	35 CFH	35 CFH		15 LITERS	35 CFH	35 CFH		15 LITERS	35 CFH	35 CFH
ARC METHOD												
ELECTRODE SIZE, IN.			1/16	1/16			1/16	1/16			1/16	1/16
CURRENT	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.	D.C.
POLARITY	STRAIGHT	STRAIGHT	REVERSE	REVERSE	STRAIGHT	STRAIGHT	REVERSE	REVERSE	STRAIGHT	STRAIGHT	REVERSE	REVERSE
VOLTAGE	70	40			70	40			70	40		
AMPERAGE	250	250	330	370	300	250	330	350	300	250	300	370
PREHEAT TEMP. °F	UNKNOWN	600		250	UNKNOWN	600		250	UNKNOWN	600		250
PROCEDURE												
PASSES		3				3				A-3, B-2		
SPEED, IN/MIN			21	13			22	13			23	12
PEENING	NONE	NONE			NONE	NONE			NONE	NONE		

TABLE 10

SUMMARY OF MECHANICAL PROPERTIES AT ROOM TEMPERATURE OF JOINTS WELDED BY THE INERT-GAS-SHIELDED-ARC PROCESS

		ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
		SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
		1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.		9A 9B	10A 10B	B9	B10	25A 25B	26A 26B	B25	B26	57A 57B	58A 58B	B57	B58
	SPEC. NO.												
MAXIMUM STRENGTH (P.S.I.)	1	28,380	24,310	30,680	31,020	31,230	29,690	30,850	31,320	28,940	28,660	27,640	29,990
	2	27,000	24,070	30,160	30,810	30,560	29,700	30,340	30,660	28,670	29,600	30,740	30,920
	3	33,780	25,960			30,410	29,400			25,160	29,440		
	4	22,130	25,170			23,270	28,730			22,760	29,770		
AV.		27,820	24,880	30,420	30,910	28,870	29,380	30,590	30,990	26,380	29,370	29,190	30,450
YIELD INDEX (P.S.I.)	1	12,620	9,350	11,330	11,660	14,830	9,680	12,180	12,150	12,790	9,860	10,780	10,420
	2	12,260	9,060	10,930	10,950	12,680	10,010	10,410	9,370	13,260	9,520	10,660	10,870
	3	13,580	9,590			12,220	7,970			12,860	9,290		
	4	12,160	11,120			12,750	8,600			13,050	8,530		
AV.		12,650	9,780	11,130	11,300	13,120	9,060	11,290	10,760	12,990	9,300	10,720	10,640
ELONGATION INDEX (o/o)	1	24.0	19.2	32.4	36.0	31.6	58.8	25.5	34.0	25.0	32.5	22.4	49.0
	2	15.8	18.0	28.6	32.0	36.4	47.7	30.5	50.0	18.3	42.7	33.0	47.0
	3	21.5	18.8			38.9	58.5			16.3	46.5		
	4	16.7	17.3			16.0	52.1			9.5	46.7		
AV.		19.5	18.3	30.5	34.0	30.7	54.3	28.0	44.0	17.3	42.1	27.7	48.0
REDUCTION OF AREA (o/o)	1	61.0	28.0	41.0	32.0	85.0	86.0	77.0	66.0	79.0	70.0	74.0	76.0
	2	57.0	26.0	33.0	32.0	84.0	83.0	62.0	83.0	39.0	73.0	61.0	84.0
	3	44.0	19.0			84.0	84.0			39.0	78.0		
	4	36.0	22.0			56.0	83.0			28.0	83.0		
AV.		49.5	23.7	37.0	32.0	77.2	84.0	69.5	74.5	46.2	76.0	67.5	80.0
LOCATION OF FRACTURE*	1	E.W.	E.W.	B.M.	B.M.	H.Z.	B.M.	B.M.	B.M.	E.W.	H.Z.	M.W.	B.M.
	2	E.W.	E.W.	B.M.	B.M.	H.Z.	B.M.	M.W.	B.M.	M.W.	H.Z.	M.W.	B.M.
	3	E.W.	E.W.			H.Z.	B.M.			M.W.	H.Z.		
	4	M.W.	E.W.			M.W.	B.M.			M.W.	H.Z.		

* FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE
B.M. = BASE METAL

SUMMARY OF METALLURGICAL EXAMINATIONS OF JOINTS WELDED BY THE INERT-GAS-SHIELDED-ARC PROCESS

		SERIES I			SERIES II		
WELD NO. (1)	BASE METAL (2)	APPEARANCE OF JOINT (3)	MICROSTRUCTURE OF BASE METAL (4)	MICROSTRUCTURE OF WELD METAL (5)	APPEARANCE OF JOINT (6)	MICROSTRUCTURE OF BASE METAL (7)	MICROSTRUCTURE OF WELD METAL (8)
9	ELECT	LITTLE CONTINUITY ACROSS BUTT JOINT.	LARGE HAZ. GOOD PENETRATION.	SOUND WM.	EXCELLENT CONTINUITY. GOOD PENETRATION	AREAS OF EUTECTIC AT JUNCTION.	VERY SOUND.
10	ELECT	SHARP GRADIENT, LITTLE CONTINUITY.	NARROW HAZ. SOME INCLUSIONS AT GRAIN BOUNDARY NEAR JUNCTION.	MICROPOROSITY DUE TO SHRINKAGE, SOME CRACKS IN GRAIN BOUNDARY.	EXCELLENT CONTINUITY.	SLIGHT OXIDE PENETRATION AT PLATE FACE.	VERY SOUND.
25	DEOX	GOOD CONTINUITY.	MODERATE HAZ.	SOUND WM	EXCELLENT CONTINUITY.	SLIGHT OXIDE PENETRATION AT PLATE FACE.	VERY SOUND.
26	DEOX	EXCELLENT BOND. GOOD CONTINUITY.	MODERATE HAZ.	VERY SOUND.	EXCELLENT CONTINUITY.	SLIGHT OXIDE PENETRATION AT PLATE FACE.	VERY SOUND.
57	OFHC	EXCELLENT CONTINUITY.	VERY LARGE HAZ.	VERY SOUND WM.	EXCELLENT CONTINUITY. IRREGULAR FLOW OF WM. REGIONS OF INCOMPLETE PENETRATION.	NO OXIDES PRESENT.	VERY SOUND.
58	OFHC	EXCELLENT CONTINUITY.	LARGE HAZ.	SOME MICRO-POROSITY.	EXCELLENT CONTINUITY	NO OXIDES PRESENT.	VERY SOUND

TABLE 12

SUMMARY OF WELD FABRICATION DATA FOR OXY-ACETYLENE PROCESS

(AS REPORTED BY FABRICATOR)

	ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
	SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.	11A 11B	12A 12B	B11	B12	27A 27B	28A 28B	B27	B28	59A 59B	60A 60B	B59	B60
FILLER METAL	TOBIN BRONZE	SPELTER SOLDER	25 M BRONZE	25 M BRONZE	TOBIN BRONZE	25 M BRONZE	25 M BRONZE	25 M BRONZE	SPELTER SOLDER	NO. 25 BRAZO	25 M BRONZE	25 M BRONZE
SOURCE	VULCAN COPPER CO.	CHASE CO.	OXWELD	OXWELD	VULCAN COPPER CO.	LINDE	OXWELD	OXWELD	CHASE CO.	OXWELD	OXWELD	OXWELD
ROD SIZE, IN	3/16		3/16	1/4	3/16	3/16	3/16	1/4		1/4	3/16	1/4
FLUX	OXWELD BRAZO	BORAX	OXWELD BRAZO	OXWELD BRAZO	OXWELD BRAZO	OXWELD BRAZO	OXWELD BRAZO	OXWELD BRAZO	BORAX	OXWELD BRAZO	OXWELD BRAZO	OXWELD BRAZO
TYPE	PASTE	LIQUID	PASTE	PASTE	PASTE	PASTE	PASTE	PASTE	LIQUID	PASTE	PASTE	PASTE
JOINT DESIGN												
EDGE PREP.	45° BEVEL	BEVELED	45° BEVEL	45° BEVEL	45° BEVEL	30° BEVEL	45° BEVEL	45° BEVEL	BEVELED	45° BEVEL	45° BEVEL	45° BEV
ROOT SPACE, IN.	1/32		3/32-1/4	3/32-1/4	1/32	3/16-5/8	3/32-1/4	3/32-1/4		1/8	3/32-1/4	3/32-1/
POSITION	FLAT	FLAT	20° ANGLE	20° ANGLE	FLAT	15° ANGLE	20° ANGLE	20° ANGLE	FLAT		20° ANGLE	20° ANG
BACKING	NONE		COPPER	COPPER	NONE	COPPER	COPPER	COPPER		NONE	COPPER	COPPER
CLAMPING	YES	NONE	NONE	NONE	YES	YES	NONE	NONE	NONE	NONE	NONE	NONE
GAS METHOD												
TORCH MAKE	AIR RED. 9803		OXWELD W17 AIRCO 800	OXWELD W17 AIRCO 800	AIR RED. 9803	OXWELD W17	OXWELD W17 AIRCO 800	OXWELD W17 AIRCO 800	HARRIS	OXWELD W17	OXWELD W17 AIRCO 800	OXWELD AIRCO 8
TIP SIZE	NO. 188	NO. 20	NOS., 40, 7	NO. 40, 7	NO. 188	NO. 40	NOS. 40, 7	NOS. 40, 7	NO. 20	NO. 60	NOS. 40, 7	NOS. 40
GAS	OXY-ACET. (NEUT.)	OXYPROPANE (NEUT.)	OXY-ACET. (SL. OX.)	OXY-ACET. (SL. OX.)	OXY-ACET. (NEUT.)	OXY-ACET. (NEUT.)	OXY-ACET. (SL. OX.)	OXY-ACET. (SL. OX.)	OXYPROPANE (NEUT.)	OXY-ACET. (CARB.)	OXY-ACET. (SL. OX.)	OXY-ACE (SL. OX
GAS AMOUNT	48 CF		50 CF	64 CF	44 CF		43 CF	68 CF			45 CF	60 CF
PREHEAT TEMP. °F.	1200				1200							
PROCEDURE												
PASSES	1		1	1	1	1	1	1			1	1
SPEED, IN/MIN.												
PEENING	NONE		NONE	NONE	NONE			NONE		NONE	NONE	NONE

TABLE 12 (CONT'D)

SUMMARY OF WELD FABRICATION DATA FOR OXY-ACETYLENE PROCESS

(AS REPORTED BY FABRICATORS)

	ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
	SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.	13A 13B	14A 14B	B13	B14	29A 29B	30A 30B	B29	B30	61A 61B	62A 62B	B61	B62
FILLER METAL	NO DATA AVAILABLE	American Brass 372	Si Deox Copper	Si Deox Copper	NO DATA AVAILABLE	Ag Bearing Copper	Si Deox Copper	Si Deox Copper	Pesco	Si Deox Copper	Si Deox Copper	Si Deox Copper
Source		American Brass Co.	American Brass Co.	American Brass Co.		American Brass Co.	American Brass Co.	American Brass Co.	Not Given	Revere Co.	American Brass Co.	American Brass Co.
Rod Size		3/16	1/4	1/4		3/16, 1/8	1/8	1/4	3/16	3/16	1/4	1/4
FLUX Type		Oxweld Braze-Borax Paste	Oxweld Brazo Paste	Oxweld Brazo Paste		None	Oxweld Brazo Paste	Oxweld Brazo Paste	Pesco Flux Paint	Pesco Flux Paint	Oxweld Brazo Paste	Oxweld Brazo Paste
JOINT DESIGN Edge Prep.		30° Bevel	45° Bevel	45° Bevel		30° Bevel	90° Incl Angle	90° Incl Angle	Square Butt	90° Incl Angle	90° Incl Angle	90° Incl Angle
Root Space		3/16-5/8	3/32-1/4	3/32-1/4		1/8-7/8	3/32-1/4	3/32-1/4	1/8	1/32	3/32-1/4	3/32-1/4
Position		15° Angle	20° Angle	20° Angle		Vertical	20° Angle	20° Angle		Flat	20° Angle	20° Angle
Backing		Copper	Copper	Copper		None	Copper	Copper	None	None	Copper	Copper
Clamping		Yes	None	None		Yes	None	None	None	None	None	None
GAS METHOD Torch Make		Oxweld W17	Oxweld W17 Airco 800	Oxweld 17 Airco 800		Oxweld W17	Oxweld W17 Airco 800	Oxweld W17 Airco 800	Oxweld W17		Oxweld W17 Airco 800	Oxweld W17 Airco 800
Tip Size		No. 30	Nos. 40, 7	Nos. 40, 7		No. 40	Nos. 40, 7	Nos. 40, 7	No. 60		Nos. 40, 7	Nos. 40, 7
Gas		Oxy-Acet (Neut.)	Oxy-Acet (Sl. Ox.)	Oxy-Acet (Sl. Ox.)		Oxy-Acet (Neut.)	Oxy-Acet (Sl. Ox.)	Oxy-Acet (Sl. Ox.)	Oxy-Acet (Carb.)	Oxy-Acet (Carb.)	Oxy-Acet (Sl. Ox.)	Oxy-Acet (Sl. Ox.)
GAS AMOUNT			26 cf	45 cf			25 cf	40 cf	200 cf		26 cf	40 cf
PREHEAT TEMP. ° F										600		
PROCEDURE Passes		2	1	1		2	1	1		2	1	1
Speed												
Peening			None	None		Yes	None	None	None	None	None	None

TABLE 13

SUMMARY OF MECHANICAL PROPERTIES AT ROOM TEMPERATURE OF JOINTS WELDED BY THE OXY-ACETYLENE PROCESS

		ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
		SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
		1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.		11A 11B	12A 12B	B11	B12	27A 27B	28A 28B	B27	B28	59A 59B	60A 60B	B59	B60
	SPEC. NO.												
MAXIMUM STRENGTH (P.S.I.)	1	17,850	25,950	26,430	21,270	33,630	16,050	29,430	29,640	28,810	21,040	29,450	28,490
	2	18,900	27,100	28,510	18,370	18,880	7,850	30,230	29,980	25,250	22,650	30,070	29,990
	3	16,080	28,520			32,860	14,440			28,340	16,860		
	4	16,600	24,280			31,130	14,800			26,400	14,510		
	AV.	17,360	26,460	27,470	19,820	29,120	13,270	29,830	29,810	27,200	18,760	29,760	29,460
YIELD INDEX (P.S.I.)	1	14,090	16,830	10,460	7,550	20,880	10,980	8,240	7,970	16,710	11,350	9,010	7,020
	2	13,700	14,600	11,240	8,320	11,960		8,740	9,160	16,170	14,010	9,350	6,260
	3	11,760	11,020			10,620	10,230			14,910	11,990		
	4	10,160	10,820			9,960	12,590			14,970	10,840		
	AV.	12,430	13,320	10,850	7,930	13,360	11,270	8,490	8,570	15,690	12,050	9,180	6,640
ELONGATION INDEX (o/o)	1	4.0	14.5	14.2	8.4	12.8	5.7	34.9	42.0	12.1	14.7	20.2	39.5
	2	4.0	17.1	19.0	6.2	8.4	0	33.8	25.0	7.1	18.0	32.6	40.0
	3	3.7	24.0			24.1	3.4			12.8	7.4		
	4	3.5	16.0			36.0	1.5			19.3	6.0		
	AV.	3.8	17.9	16.6	7.3	20.3	2.6	34.3	33.5	12.8	11.5	26.4	39.7
REDUCTION OF AREA (o/o)	1	12.0	6.0	12.0	1.0	44.0		83.0	78.0	83.0	11.0	57.0	83.0
	2	2.0	31.0	43.0	4.0	21.0		78.0	78.0	42.0	25.0	76.0	85.0
	3	27.0	13.0			77.0				81.0	4.0		
	4	4.0	11.0			81.0				56.0	6.0		
	AV.	11.2	15.2	27.5	2.5	55.7		80.5	78.0	65.5	11.5	66.5	84.0
LOCATION OF FRACTURE*	1	E.W.	E.W.	B.M.	E.W.	H.Z.	E.W.	B.M.	B.M.	B.M.	E.W.	B.M.	B.M.
	2	E.W.	B.M.	B.M.	E.W.	M.W.	E.W.	B.M.	B.M.	B.M.	E.W.	B.M.	B.M.
	3	E.W.	E.W.			H.Z.	E.W.			B.M.	E.W.		
	4	E.W.	E.W.			H.Z.	E.W.			B.M.	E.W.		

* FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE
B.M. = BASE METAL

SUMMARY OF MECHANICAL PROPERTIES AT ROOM TEMPERATURE OF JOINTS WELDED BY OXY-ACETYLENE PROCESS

		ELECTROLYTIC TOUGH PITCH				DEOX HIGH PHOS				OFHC			
		SERIES I		SERIES II		SERIES I		SERIES II		SERIES I		SERIES II	
		1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.	1/8 IN.	1/4 IN.
WELD NO.		13A 13B	14A 14B	B13	B14	29A 29B	30A 30B	B29	B30	61A 61B	62A 62B	B61	B62
	SPEC. NO.												
MAXIMUM STRENGTH (P.S.I.)	1	14,800	18,200	19,960	17,080	30,990	28,490	26,850	23,050	16,560	19,630	18,110	23,300
	2	14,800	16,680	16,410	13,040	14,820	28,670	26,270	21,880	12,590	13,160	16,950	21,630
	3	15,350	10,530			26,000	28,260			17,760	22,660		
	4	22,850	18,360			30,560	28,660			14,070	21,080		
	AV.	16,950	15,940	18,180	15,060	25,590	28,520	26,560	22,460	15,240	19,130	17,530	22,460
YIELD INDEX (P.S.I.)	1	11,540	8,970	9,190	6,930	9,470	17,570	8,000	6,760	11,460	8,280	8,530	6,320
	2	11,110	8,770	8,480	7,150	8,800	17,350	8,530	6,550	11,980	8,800	8,060	7,390
	3	9,910	10,330			9,950	17,050			13,900	7,830		
	4	10,230	10,980			8,460	19,380			13,180	7,960		
	AV.	10,700	9,760	8,830	7,040	9,170	17,840	8,260	6,650	12,630	8,220	8,290	6,850
ELONGATION INDEX (o/o)	1	2.5	10.3	10.6	11.6	33.8	39.5	32.6	22.0	6.5	19.5	9.0	20.5
	2	2.5	9.1	9.6	7.6	3.4	35.7	30.0	18.0	3.1	13.5	9.2	19.5
	3	6.0	2.5			17.4	25.7			5.5	26.2		
	4	13.8	8.1			23.2	26.2			5.5	21.5		
	AV.	6.2	7.5	10.1	9.6	19.4	31.8	31.3	20.0	5.1	20.2	9.1	20.0
REDUCTION OF AREA (o/o)	1	31.0	46.0	14.0	21.0	51.0	75.0	69.0	41.0	23.0	38.0	16.0	36.0
	2	42.0	22.0	18.0	20.0	2.0	69.0	76.0	30.0	19.0	18.0	15.0	18.0
	3	22.0	4.0			17.0	50.0			11.0	27.0		
	4	25.0	21.0			8.0	61.0			22.0	33.0		
	AV.	30.0	23.2	16.0	20.5	19.5	63.7	72.5	35.5	18.7	29.0	15.5	27.0
LOCATION OF FRACTURE*	1	E.W.	E.W.	E.W.	M.W.	H.Z.	B.M.	M.W.	M.W.	M.W.	E.W.	M.W.	M.W.
	2	E.W.	E.W.	E.W.	M.W.	M.W.	H.Z.	M.W.	M.W.	M.W.	E.W.	M.W.	M.W.
	3	M.W.	E.W.			M.W.	E.W.			E.W.	H.Z.		
	4	M.W.	E.W.			M.W.	E.W.			E.W.	H.Z.		

* FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE
B.M. = BASE METAL

TABLE 14

SUMMARY OF METALLURGICAL EXAMINATIONS OF JOINTS
WELDED BY THE OXY-ACETYLENE PROCESS

		SERIES I			SERIES II		
WELD NO. (1)	BASE METAL (2)	APPEARANCE OF JOINT (3)	MICROSTRUCTURE OF BASE METAL (4)	MICROSTRUCTURE OF WELD METAL (5)	APPEARANCE OF JOINT (6)	MICROSTRUCTURE OF BASE METAL (7)	MICROSTRUCTURE OF WELD METAL (8)
11	ELECT	LITTLE DIFFUSION ACROSS JOINT. SHARP GRADIENT.	MODERATE HAZ. OXIDES IN GRAIN BOUNDARY NEAR JUNCTION.	CONSIDERABLE POROSITY.	LITTLE PENETRATION. POOR PLATE ALIGNMENT.	VERY HEAVY OXIDE PENETRATION.	MODERATE POROSITY.
12	ELECT	SHARP GRADIENT, LITTLE PENETRATION.	LARGE HAZ. OXIDES AT GRAIN BOUNDARY, FORMING SOME CRACKS.	MACRO- AND MICRO-POROSITY.	LITTLE PENETRATION.	VERY HEAVY OXIDE PENETRATION AT JOINT AND PLATE FACE.	MODERATE POROSITY.
27	DEOX	SHARP GRADIENT, LITTLE PENETRATION.	LARGE HAZ. SOME OXIDES AT GRAIN BOUNDARY NEAR JOINT.	SOUND WM	VERY LITTLE PENETRATION.	SMALL OXIDE PENETRATION AT JOINT.	SOUND
28	DEOX	CRACKS ALONG INTERFACE. POOR CONTINUITY.	OXIDE PENETRATION IN BM. EXTREMELY LARGE HAZ.	SOUND WM	GOOD CONTINUITY, NO PENETRATION.	NARROW OXIDE REGION AT JOINT.	SOUND
59	OFHC	POOR BOND	DEEP OXIDE PENETRATION WITH INTERGRANULAR CRACKS. LARGE HAZ, HIGHLY DEFORMED.	CONSIDERABLE POROSITY.	NO PENETRATION, POOR CONTINUITY.	HEAVY OXIDE PENETRATION AT JOINT.	MODERATE POROSITY.
60	OFHC	POOR BOND	VERY LARGE HAZ. OXIDES NEAR WELD.	CONSIDERABLE POROSITY. POOR FLOW AND WETTING ACTION.	NO PENETRATION, GOOD CONTINUITY.	SLIGHT OXIDE PENETRATION AT JOINT.	MODERATE POROSITY.

TABLE 14 (CONT'D)

SUMMARY OF METALLURGICAL EXAMINATIONS OF JOINTS WELDED BY THE OXY-ACETYLENE PROCESS

WELD NO.	BASE METAL	SERIES I APPEARANCE OF JOINT	SERIES I MICROSTRUCTURE OF BASE METAL	SERIES I MICROSTRUCTURE OF WELD METAL	SERIES II APPEARANCE OF JOINT	SERIES II MICROSTRUCTURE OF BASE METAL	SERIES II MICROSTRUCTURE OF WELD METAL
13	ELECT	GOOD BOND	LARGE GRAINS IN AREAS REMOVED FROM JOINTS. (RECRYSTALLIZATION)	SOME RECRYSTALLIZATION OF WM. VERY HEAVY POROSITY.	VERY LITTLE PENETRATION. EXCESSIVE WM DEPOSIT.	HEAVY OXIDE PENETRATION AT JOINT AND EDGE OF BM.	VERY HEAVY POROSITY.
14	ELECT	MARKED BY OXIDE PENETRATION.	DEEP PENETRATION OF OXIDES NEAR JUNCTION. NARROW HAZ.	LARGE DEPOSIT OF WM. SOUND WM.	WM-BM JUNCTION OUTLINED BY OXIDES EXCESSIVE WM DEPOSIT.	VERY HEAVY OXIDE PENETRATION OVER LARGE AREA.	VERY HEAVY POROSITY.
29	DEOX	NO PENETRATION AT GAP. EXTREMELY WEAK BOND.	NO EVIDENCE OF GRAIN GROWTH.	APPLIED FROM ONE SIDE ONLY. VERY POOR FLOW.	EXCELLENT PENETRATION AND CONTINUITY.	SMALL OXIDE PENETRATION AT JOINT.	SOUND
30	DEOX	GOOD BOND	LARGE HAZ. SOME RECRYSTALLIZATION IN BM AND WM. HIGHLY COLDWORKED NEAR SIDE OF WELD.	SOME RECRYSTALLIZATION. SLIGHT POROSITY.	OXIDES AND POROSITY OUTLINE JOINT, POOR PENETRATION.	HEAVY OXIDE PENETRATION AT EDGE AND JOINT.	VERY HEAVY POROSITY.
61	OFHC	POOR CONTINUITY	VERY LARGE HAZ. INTERGRANULAR CRACKS IN BM NEAR JUNCTION.	HEAVY POROSITY. LARGE DEPOSIT OF WM.	POOR PENETRATION, FAIR CONTINUITY.	SOME OXIDATION AT EDGE NEAR REINFORCEMENT.	VERY HEAVY POROSITY.
62	OFHC	POOR BOND OUTLINED BY OXYGENATED AREAS.	DEEP OXIDE PENETRATION AT GRAIN BOUNDARY. VERY LARGE HAZ, BUT INHIBITED NEAR JUNCTION.	SOME MICRO-POROSITY. LARGE AMOUNT OF METAL DEPOSITED.	FAIR PENETRATION, GOOD CONTINUITY.	SOME OXIDATION AT JOINT.	VERY HEAVY POROSITY.

TABLE 15

SUMMARY OF MECHANICAL PROPERTIES OF JOINTS TESTED AT -321 °F

WELD NO.	SPEC. NO.	CARBON-ARC PROCESS B17	B18	B50	B3	B52	SHIELDED-ARC PROCESS B5	B6	B53	B7	B23
MAXIMUM STRENGTH (P.S.I.)	1	47,140	42,670	40,500	35,720	47,140	39,300	42,470	37,600	39,710	48,470
	2	46,020	48,480	44,530	25,950	47,590	31,630	41,290	46,110	46,030	48,200
	3	49,670	40,850	43,640	41,780	48,880	41,280	44,120	44,180	48,180	49,080
	4	47,950	38,380	43,380	50,510	48,740	38,990	48,550	47,800	45,570	50,340
AV.		47,690	42,590	43,010	38,490	48,090	37,800	44,110	43,920	43,620	49,020
YIELD INDEX (P.S.I.)	1	14,700	13,030	13,420	17,570	--	15,520	18,820	15,760	17,400	14,280
	2	16,690	13,660	13,120	16,380	14,600	16,310	17,140	12,260	18,020	--
	3	15,590	13,620	16,100	17,970	--	17,450	14,110	19,280	16,750	16,950
	4	17,080	13,230	12,320	18,580	12,140	17,920	16,100	20,730	15,020	16,270
AV.		16,010	13,380	13,740	17,620	13,370	16,800	16,410	17,010	16,800	15,830
ELONGATION INDEX (o/o)	1	47.4	33.1	26.0	13.6	38.4	22.4	22.8	14.6	18.4	41.8
	2	36.4	50.4	36.5	8.2	35.6	10.3	22.0	29.1	23.8	37.5
	3	49.5	30.8	35.6	18.5	53.5	19.3	31.3	19.6	24.2	44.3
	4	32.3	26.9	33.1	38.5	49.0	19.8	41.5	18.3	28.6	46.1
AV.		41.4	35.3	32.8	19.7	44.1	17.9	29.4	20.4	23.7	42.4
REDUCTION OF AREA (o/o)	1	70.0	53.0	42.0	4.0	49.0	27.0	22.0	30.0	27.0	80.0
	2	48.0	66.0	55.0	11.0	51.0	17.0	25.0	48.0	23.0	67.0
	3	78.0	51.0	56.0	20.0	77.0	21.0	32.0	21.0	29.0	71.0
	4	61.0	41.0	51.0	56.0	71.0	29.0	34.0	41.0	51.0	72.0
AV.		64.2	52.7	51.0	22.7	62.0	23.5	28.2	35.0	32.5	72.5
LOCATION OF FRACTURE*	1	H.Z.	H.Z.	E.W.-H.Z.	M.W.	H.Z.	E.W.-H.Z.	E.W.-H.Z.	E.W.-H.Z.	E.W.-H.Z.	H.Z.
	2	E.W.-H.Z.	H.Z.	H.Z.	M.W.	H.Z.	E.W.-H.Z.	E.W.-H.Z.	H.Z.	E.W.-H.Z.	H.Z.
	3	H.Z.	H.Z.	E.W.-H.Z.	M.W.	B.M.	E.W.-H.Z.	H.Z.	E.W.-H.Z.	E.W.-H.Z.	H.Z.
	4	H.Z.	E.W.-H.Z.	E.W.-H.Z.	H.Z.	H.Z.	E.W.-H.Z.	E.W.-H.Z.	E.W.-H.Z.	H.Z.	H.Z.

*FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE
B.M. = BASE METAL

TABLE 15 (CONT'D)

SUMMARY OF MECHANICAL PROPERTIES OF JOINTS TESTED AT -321° F

INERT-GAS-SHIELDED-ARC PROCESS

WELD NO.	SPEC. NO.	B9	B10	B25	B26	B57	B58
MAXIMUM STRENGTH (P.S.I.)	1	46,960	47,630	44,780	46,560	50,000	50,080
	2	43,450	45,510	48,570	48,250	48,990	47,990
	3	43,450	49,340	48,010	48,880	49,050	49,240
	4	46,330	47,950	46,530	48,410	47,510	49,920
AV.		45,020	47,610	46,970	48,020	48,890	49,310
YIELD INDEX (P.S.I.)	1	16,650	11,820	15,150	14,510	14,600	14,560
	2	16,580	13,430	12,650	11,820	--	16,100
	3	15,540	13,240	14,010	12,490	15,030	13,550
	4	15,200	12,570	--	10,640	14,310	16,100
AV.		15,990	12,760	13,940	12,380	14,650	15,080
ELONGATION INDEX (o/o)	1	38.0	35.0	36.0	48.6	46.0	54.9
	2	26.8	34.4	46.5	52.2	42.6	51.5
	3	30.6	44.0	44.5	54.0	47.3	51.9
	4	30.5	33.5	41.3	51.8	41.3	56.1
AV.		31.5	36.7	42.1	51.6	44.3	53.6
REDUCTION OF AREA (o/o)	1	55.0	35.0	66.0	74.0	71.0	77.0
	2	37.0	34.0	76.0	74.0	56.0	67.0
	3	50.0	36.0	77.0	77.0	57.0	61.0
	4	54.0	34.0	56.0	69.0	70.0	75.0
AV.		49.0	34.7	68.7	73.5	63.5	70.0
LOCATION OF FRACTURE *	1	M.W.	H.Z.	E.W.	H.Z.	H.Z.	H.Z.
	2	E.W.	H.Z.	H.Z.	H.Z.	M.W.	H.Z.
	3	M.W.	E.W.	H.Z.	H.Z.	E.W.	H.Z.
	4	H.Z.	E.W.	M.W.	H.Z.	M.W.	H.Z.

OXY-ACETYLENE PROCESS

WELD NO.	SPEC. NO.	B11	B12	B27	B28	B59	B60
MAXIMUM STRENGTH (P.S.I.)	1	42,930	37,690	43,130	47,790	47,390	46,750
	2	51,140	44,910	47,900	47,840	39,650	47,670
	3	46,970	35,780	48,460	47,070	48,010	47,850
	4	38,690	36,790	47,610	47,910	49,410	45,670
AV.		44,930	38,790	46,770	47,650	46,110	46,980
YIELD INDEX (P.S.I.)	1	5,430	11,980	--	18,000	--	12,120
	2	--	12,920	13,710	10,710	14,890	10,530
	3	--	--	13,640	10,590	14,900	12,010
	4	12,650	12,260	13,880	10,220	15,440	11,250
AV.		9,040	12,390	13,740	12,380	15,080	11,480
ELONGATION INDEX (o/o)	1	18.5	17.0	27.4	50.1	22.0	43.4
	2	29.1	26.8	38.1	50.8	16.0	46.3
	3	27.0	16.1	36.6	46.5	33.5	47.6
	4	16.4	15.8	39.5	48.6	35.0	45.9
AV.		22.7	18.9	35.4	49.0	26.6	45.8
REDUCTION OF AREA (o/o)	1	--	6.0	57.0	78.0	16.0	85.0
	2	4.0	17.0	78.0	78.0	23.0	66.0
	3	10.0	6.0	73.0	76.0	44.0	82.0
	4	8.0	2.0	73.0	75.0	45.0	70.0
AV.		7.3	7.7	70.2	76.7	32.0	75.7
LOCATION OF FRACTURE *	1	E.W.	E.W.	E.W.	H.Z.	M.W.	H.Z.
	2	E.W.	E.W.	B.M.	B.M.	M.W.	H.Z.
	3	E.W.	E.W.	B.M.	B.M.	H.Z.	H.Z.
	4	E.W.	E.W.	B.M.	B.M.	H.Z.	H.Z.

* FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE
B.M. = BASE METAL

TABLE 16

SUMMARY OF MECHANICAL PROPERTIES OF JOINTS TESTED AT +400° F

		CARBON-ARC PROCESS					SHIELDED-ARC PROCESS				
WELD NO.	SPEC. NO.	B17	B18	B50	B3	B52	B5	B6	B53	B7	B28
MAXIMUM STRENGTH (P.S.I.)	1	21,890	18,280	18,400	17,510	17,550	15,970	18,140	16,100	19,160	21,390
	2	22,450	17,560	18,200	19,990	16,830	12,280	17,190	17,270	17,770	21,330
	3										
	4										
	AV.	22,170	17,920	18,300	18,750	17,190	14,120	17,660	16,680	18,460	21,360
YIELD INDEX (P.S.I.)	1	9,300	9,240	8,500	8,800	7,790	10,800	9,950	10,510	9,190	8,900
	2	10,020	9,140	9,050	9,750	7,350	11,160	8,940	10,040	8,830	9,420
	3										
	4										
	AV.	9,660	9,190	8,770	9,270	7,570	10,980	9,440	10,270	9,010	9,160
ELONGATION INDEX (o/o)	1	32.6	13.5	18.6	10.6	14.5	10.2	10.3	7.8	16.4	32.8
	2	32.3	14.6	16.5	16.2	14.3	4.0	11.2	10.4	12.2	30.2
	3										
	4										
	AV.	32.4	14.0	17.5	13.4	14.4	7.1	10.7	9.1	14.3	31.5
REDUCTION OF AREA (o/o)	1	54.0	7.0	32.0	17.0	28.0	9.0	2.0	20.0	8.0	65.0
	2	62.0	10.0	12.0	31.0	30.0		10.0	24.0	1.0	60.0
	3										
	4										
	AV.	58.0	8.5	22.0	24.0	29.0	9.0	6.0	22.0	4.5	62.5
LOCATION OF FRACTURE*	1	H.Z.	E.W.-H.Z.	H.Z	M.W.	H.Z.	E.W.-H.Z.	E.W.-H.Z.	E.W.-H.Z.	E.W.-H.Z.	H.Z.
	2	H.Z.	E.W.-H.Z.	E.W.-H.Z.	E.W.-H.Z.	H.Z.	E.W.-H.Z.	E.W.-H.Z.	E.W.-H.Z.	E.W.-H.Z.	H.Z.
	3										
	4										

* FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE
B.M. = BASE METAL

SUMMARY OF MECHANICAL PROPERTIES OF JOINTS TESTED AT +400° F

		INERT-GAS-SHIELDED-ARC PROCESS						OXY-ACETYLENE PROCESS					
WELD NO.		B9	B10	B25	B26	B57	B58	B11	B12	B27	B28	B59	B60
	SPEC. NO.												
MAXIMUM STRENGTH (P.S.I.)	1	19,780	19,660	21,960	22,570	15,340	18,040	17,120	16,490	20,500	20,610	14,360	20,590
	2	18,430	18,900	21,790	21,390	16,990	16,730	16,500	12,290	22,050	20,680	16,760	19,420
	3												
	4												
	AV.	19,100	19,280	21,870	21,980	16,160	17,380	16,810	14,390	21,270	20,640	15,560	20,000
YIELD INDEX (P.S.I.)	1	9,350	10,220	10,090	10,050	9,410	9,090	9,770	7,050	8,090	6,990	7,760	6,700
	2	8,980	9,810	9,330	8,550	8,620	9,830	8,200	6,750	9,370	6,510	8,620	6,100
	3												
	4												
	AV.	9,160	10,010	9,710	9,300	9,010	9,460	8,980	6,900	8,730	6,750	8,190	6,400
ELONGATION INDEX (o/o)	1	18.9	19.8	31.0	34.5	8.2	15.8	8.5	10.6	35.6	41.4	9.8	34.6
	2	14.2	16.4	34.2	48.8	10.9	14.0	10.5	5.1	23.3	39.5	12.9	26.6
	3												
	4												
	AV.	16.5	18.1	32.6	41.6	9.5	14.9	9.5	7.8	29.4	40.4	11.3	30.6
REDUCTION OF AREA (o/o)	1	25.0	25.0	73.0	62.0	6.0	15.0		6.0	62.0	68.0	20.0	67.0
	2	17.0	18.0	74.0	72.0	8.0	18.0	9.0	3.0	69.0	74.0	20.0	35.0
	3												
	4												
	AV.	21.0	21.5	73.5	67.0	7.0	16.5	9.0	4.5	65.5	71.0	20.0	51.0
LOCATION OF FRACTURE	1	E.W.	E.W.	H.Z.	H.Z.	E.W.	E.W.	E.W.	E.W.	B.M.	E.W.	E.W.	B.M.
	2	E.W.	E.W.	H.Z.	B.M.	E.W.	E.W.	E.W.	E.W.	B.M.	H.Z.	H.Z.	E.W.
	3												
	4												

* FRACTURE LOCATION

M.W. = MIDDLE OF WELD
E.W. = EDGE OF WELD
H.Z. = HEAT AFFECTED ZONE
B.M. = BASE METAL

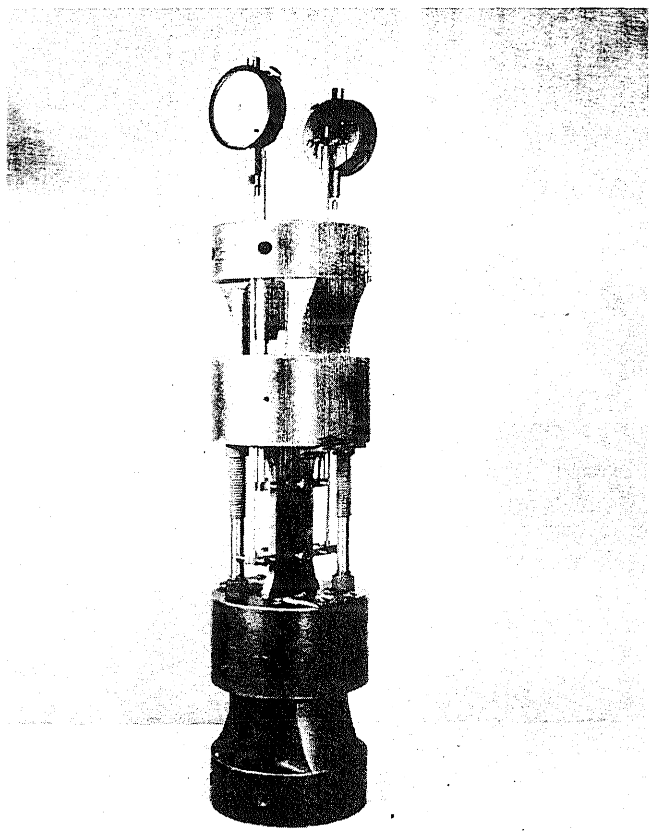


FIG. I ASSEMBLY FOR TESTS OF WELDED COPPER JOINTS

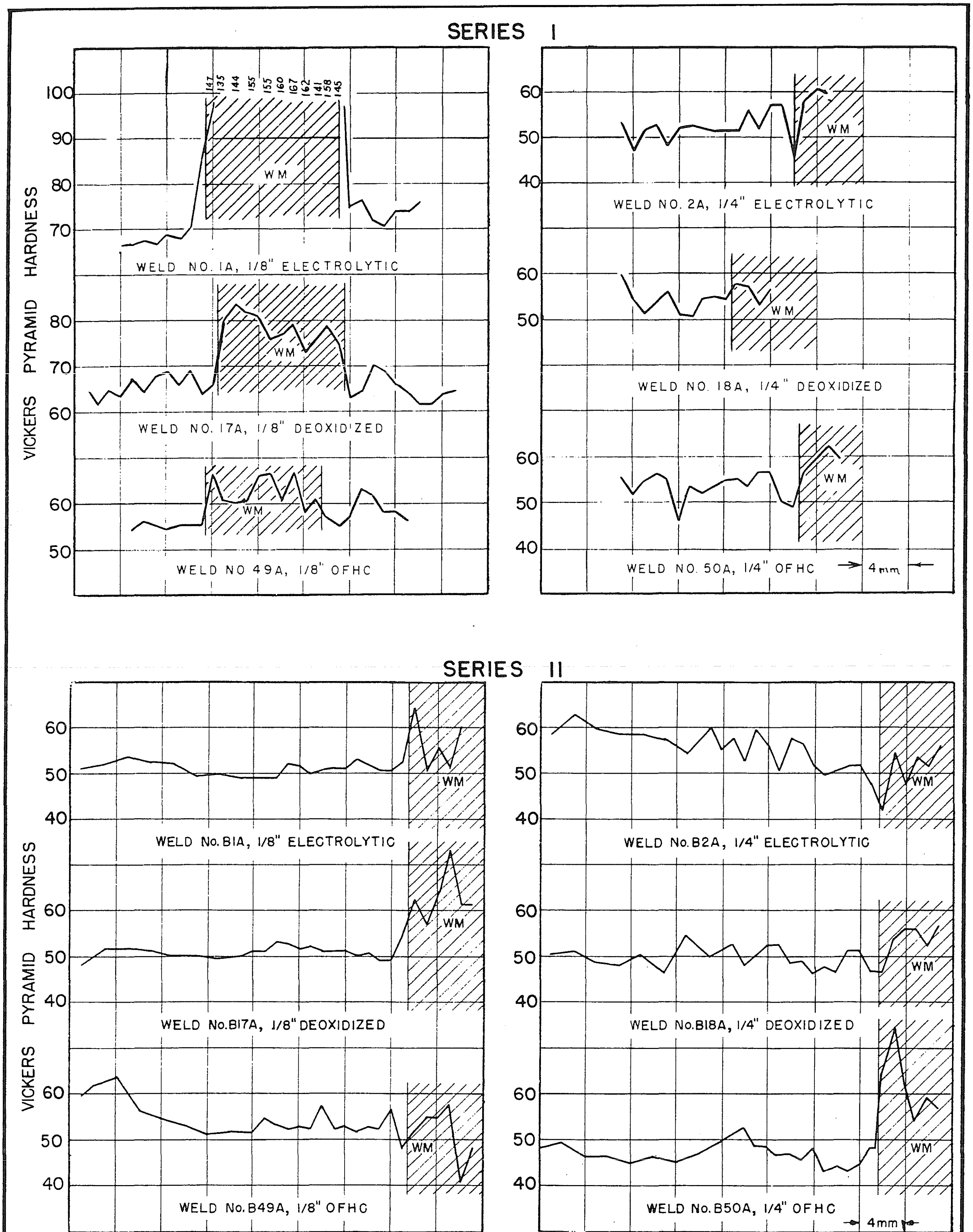


FIG. 2a HARDNESS SURVEYS ON COPPER JOINTS WELDED BY THE CARBON-ARC PROCESS

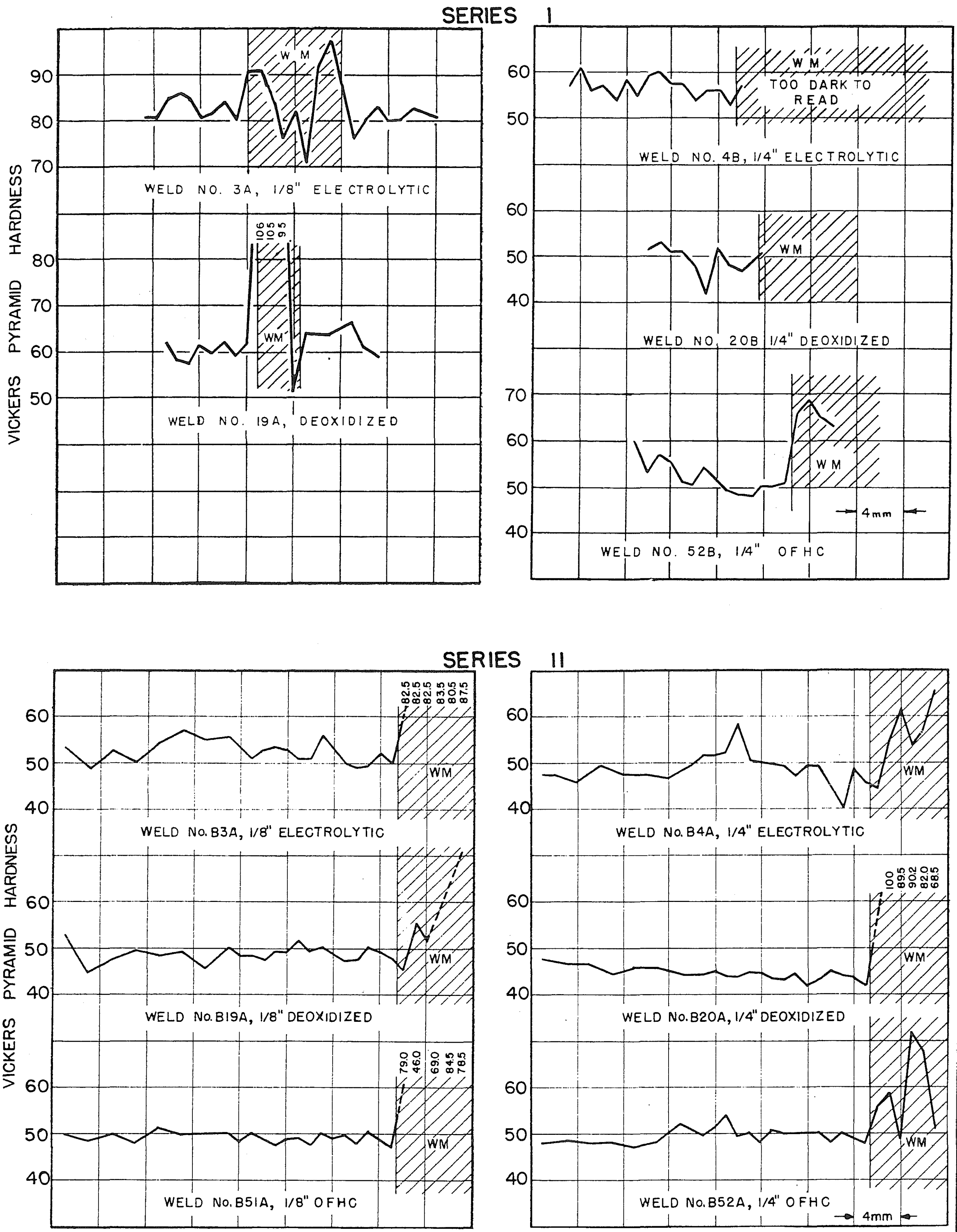


FIG. 2 b HARDNESS SURVEYS ON COPPER JOINTS WELDED BY THE CARBON—ARC PROCESS

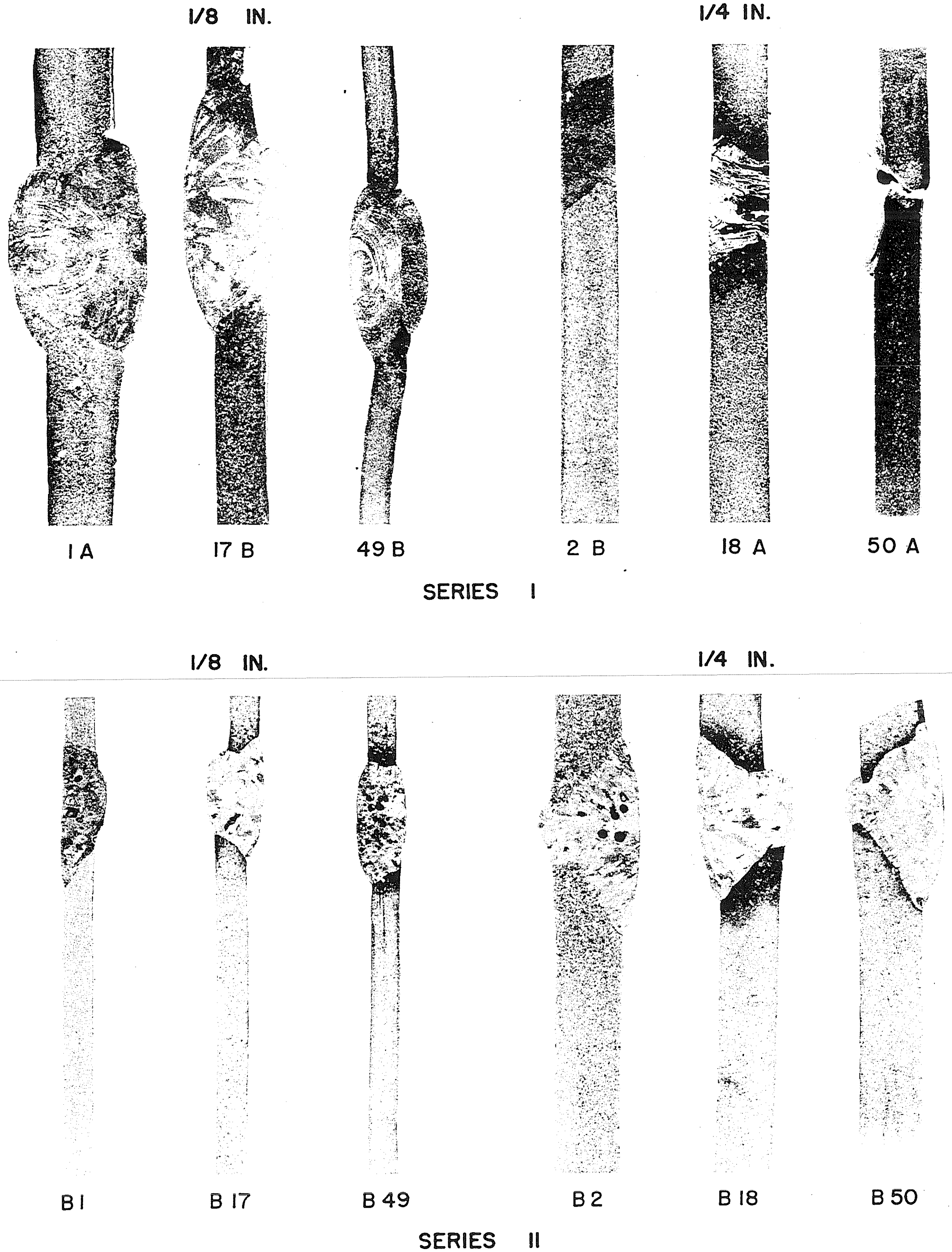


FIG. 3a MACROSTRUCTURES OF COPPER JOINTS WELDED BY THE CARBON-ARC PROCESS

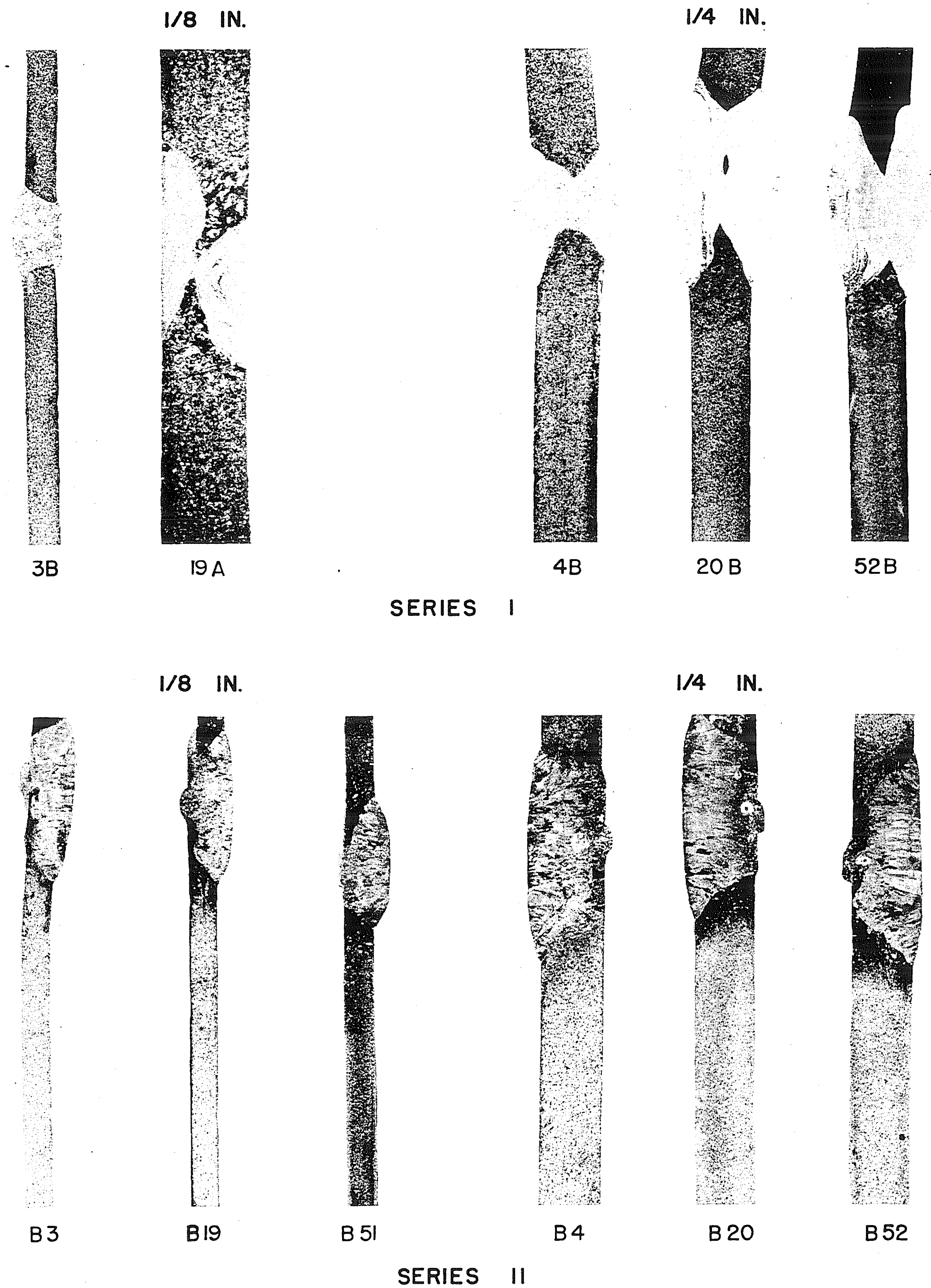


FIG. 3b MACROSTRUCTURES OF COPPER JOINTS WELDED BY THE CARBON-ARC PROCESS

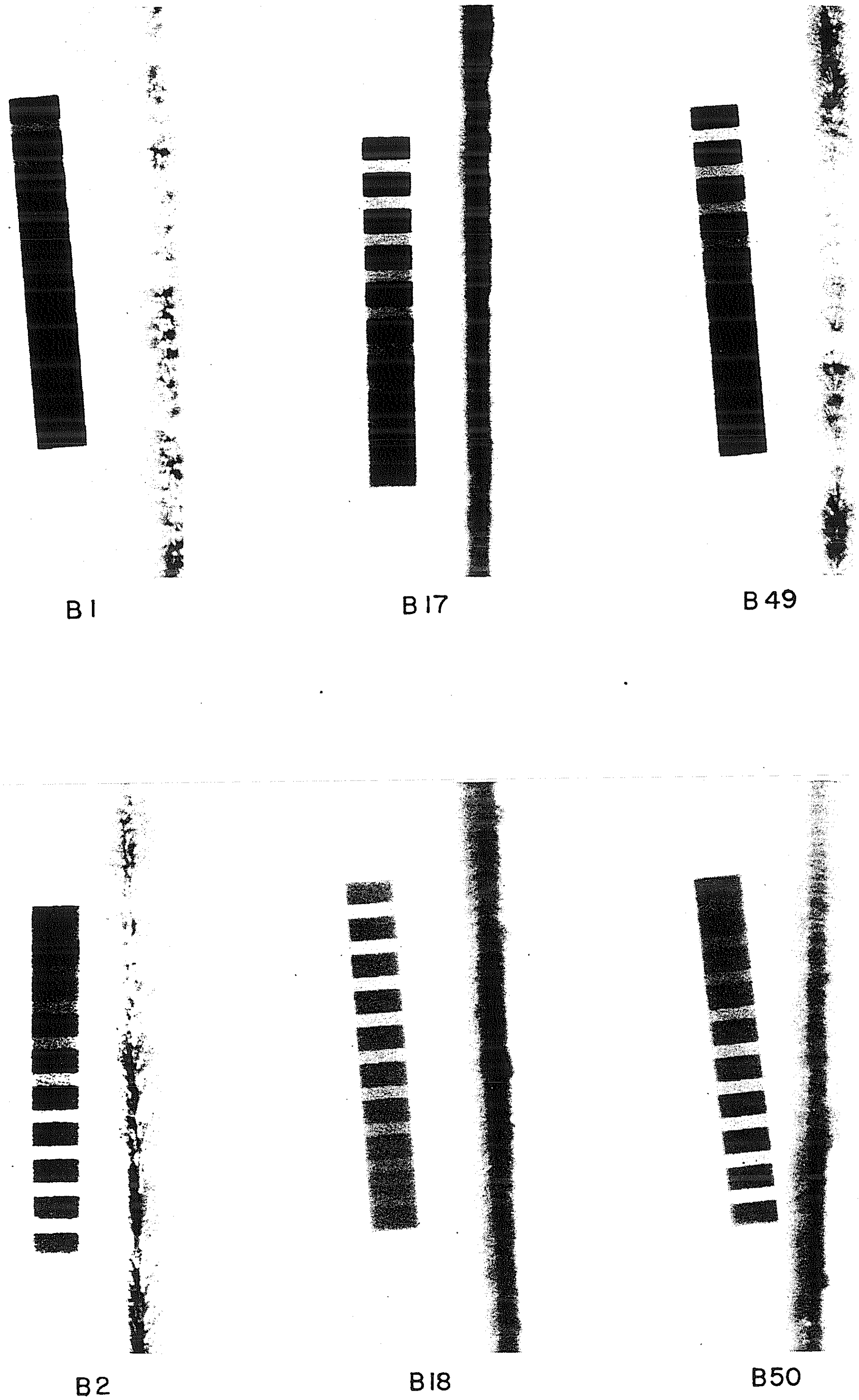


FIG. 4a RADIOGRAPHS OF COPPER JOINTS WELDED BY THE CARBON-ARC PROCESS, SERIES II

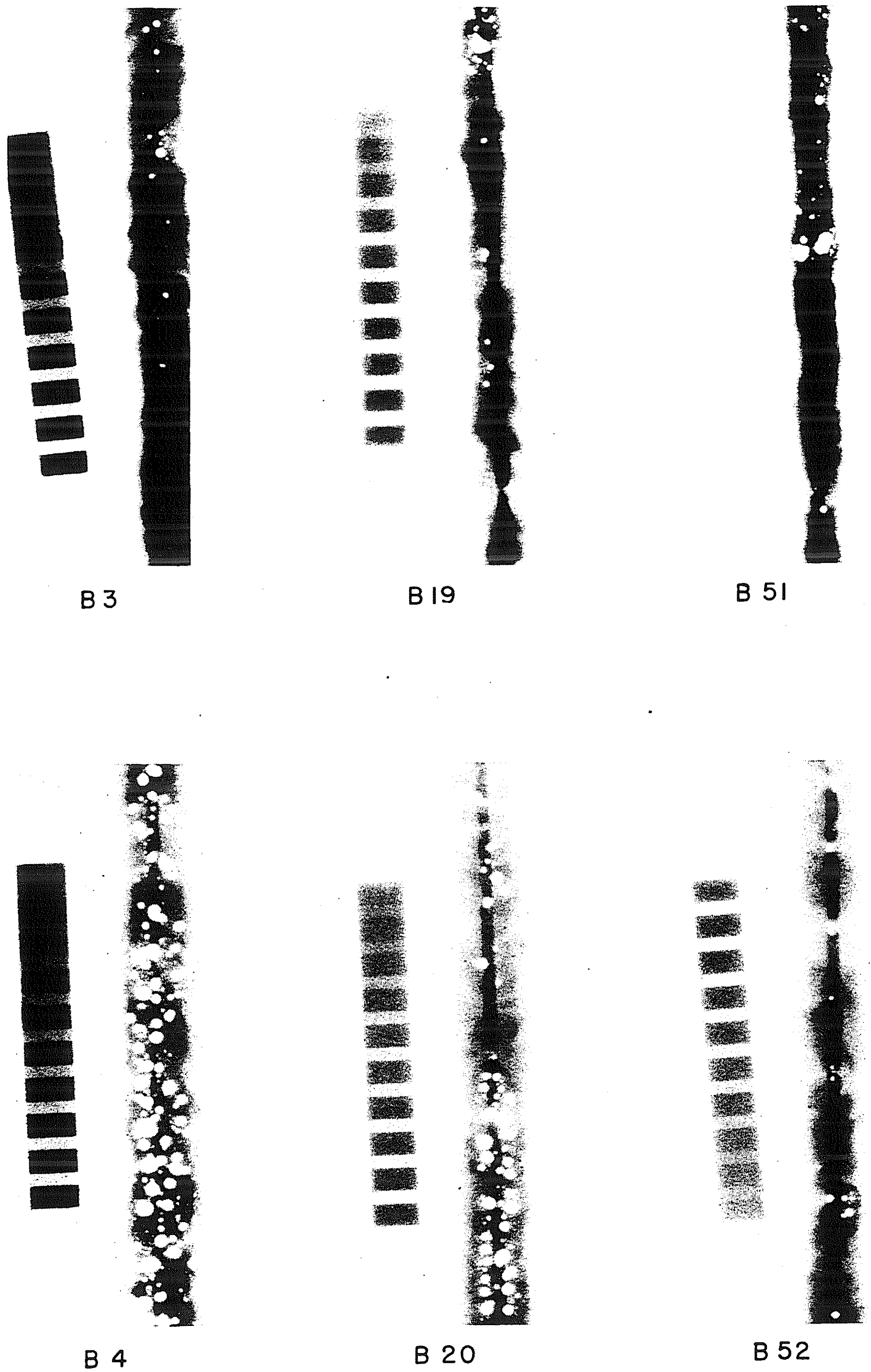


FIG. 4b RADIOGRAPHS OF COPPER JOINTS WELDED BY THE CARBON-ARC PROCESS, SERIES II

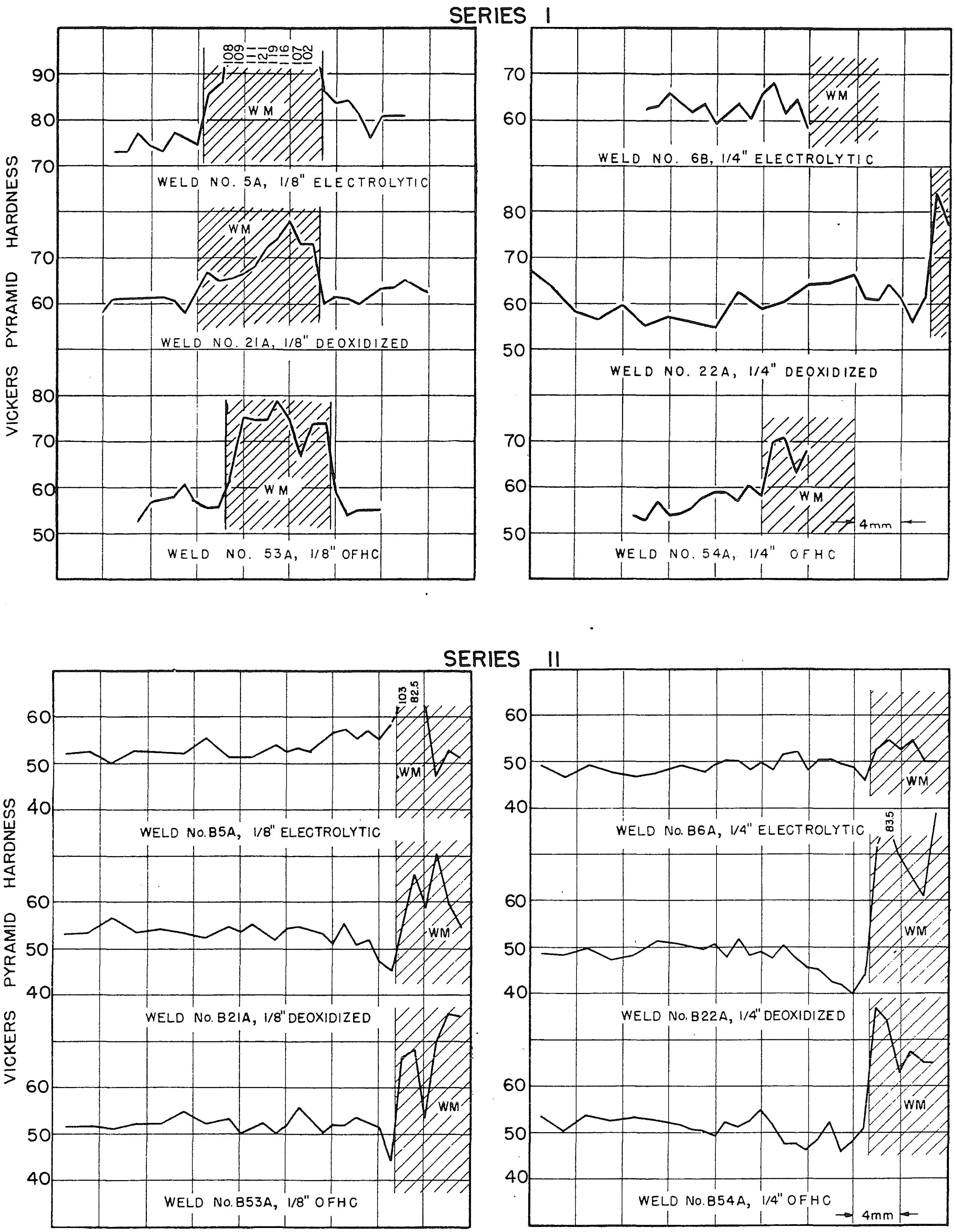


FIG. 5a HARDNESS SURVEYS ON COPPER JOINTS WELDED BY THE SHIELDED-ARC PROCESS

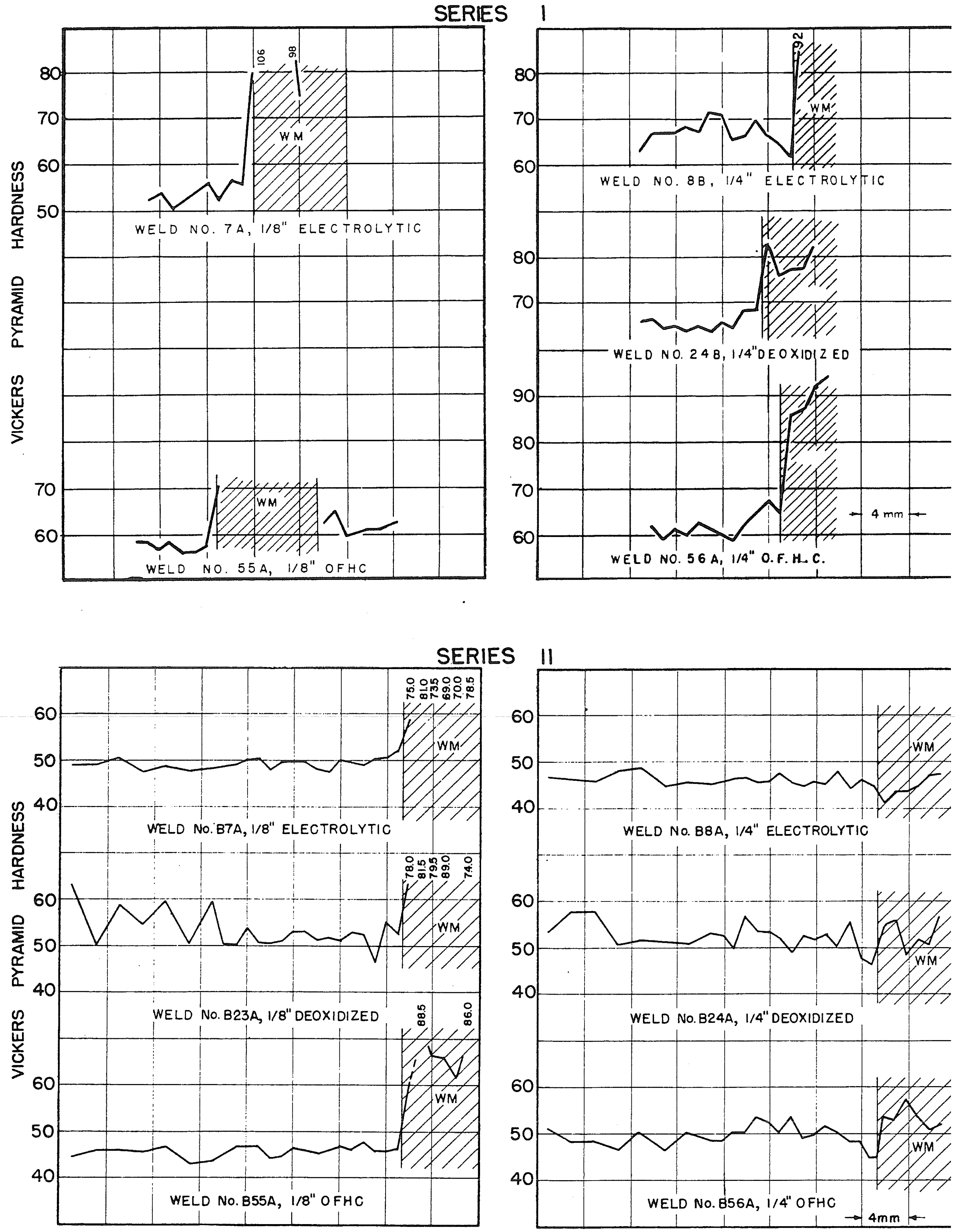


FIG. 5 b HARDNESS SURVEYS ON COPPER JOINTS WELDED BY THE SHIELDED — ARC PROCESS

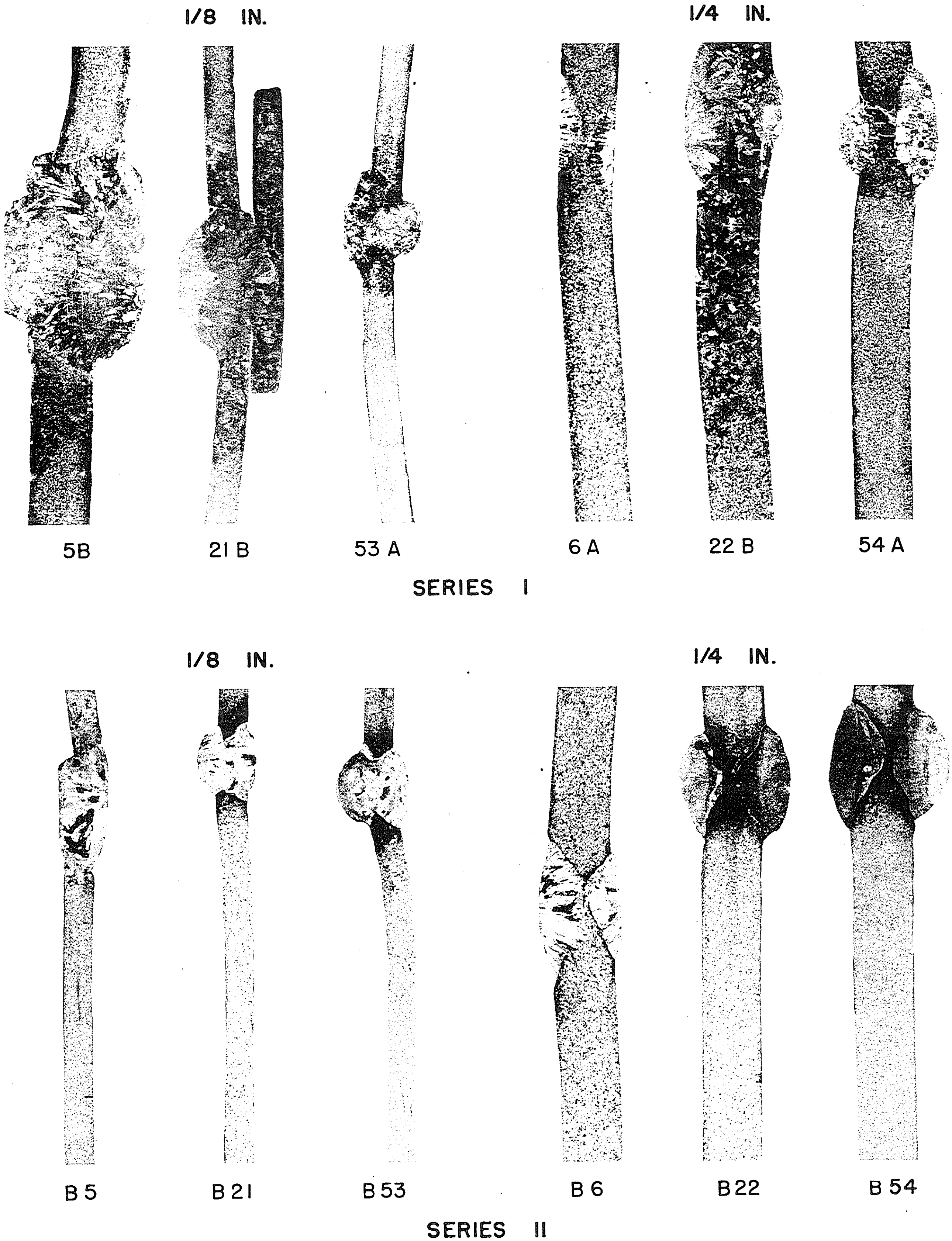


FIG. 6a MACROSTRUCTURES OF COPPER JOINTS WELDED BY THE SHIELDED-ARC PROCESS

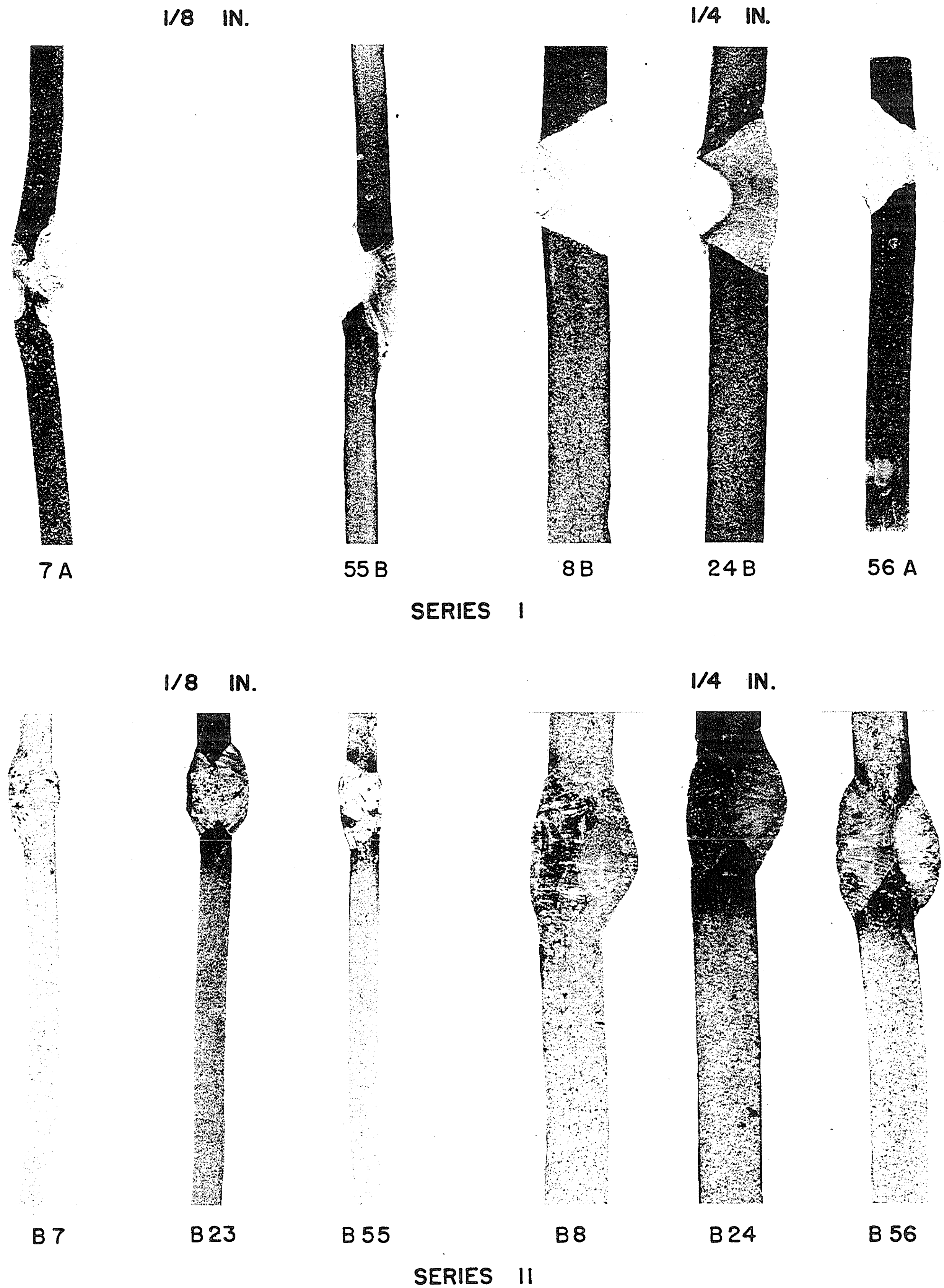


FIG. 6 b MACROSTRUCTURES OF COPPER JOINTS WELDED BY THE SHIELDED - ARC PROCESS

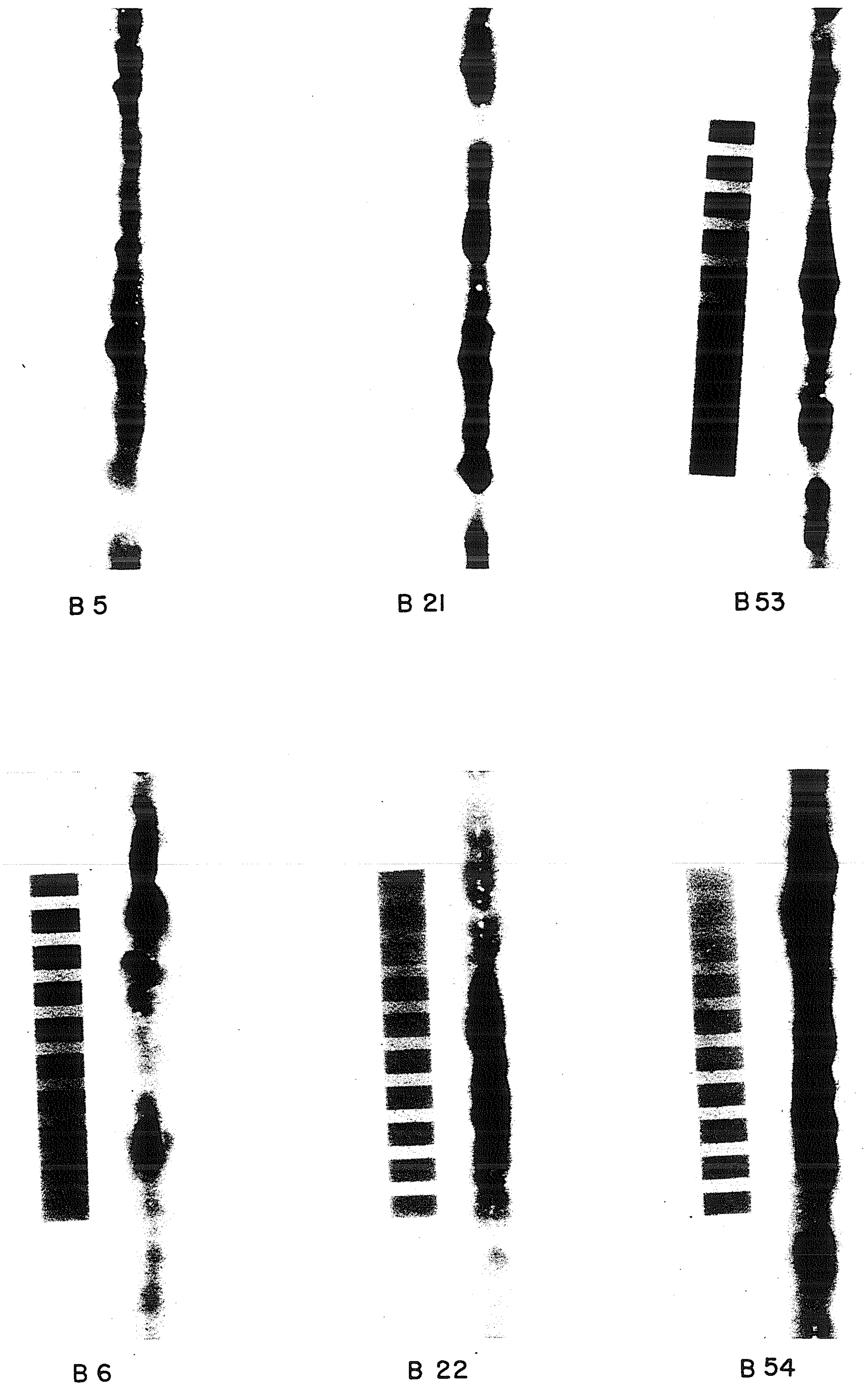


FIG. 7a RADIOGRAPHS OF COPPER JOINTS WELDED BY THE SHIELDED-ARC PROCESS, SERIES II

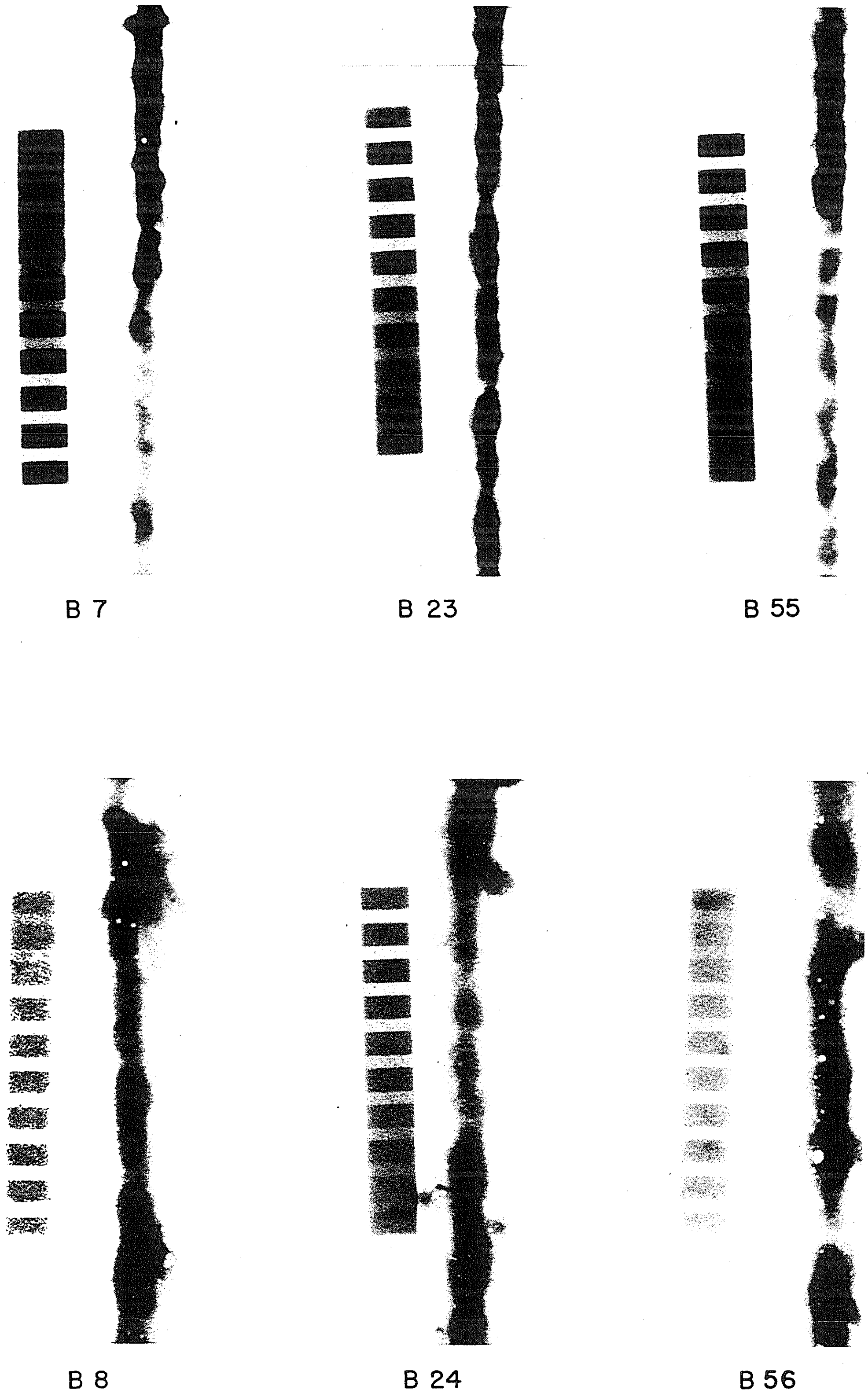


FIG. 7b RADIOGRAPHS OF COPPER JOINTS WELDED BY THE SHIELDED-ARC PROCESS, SERIES II

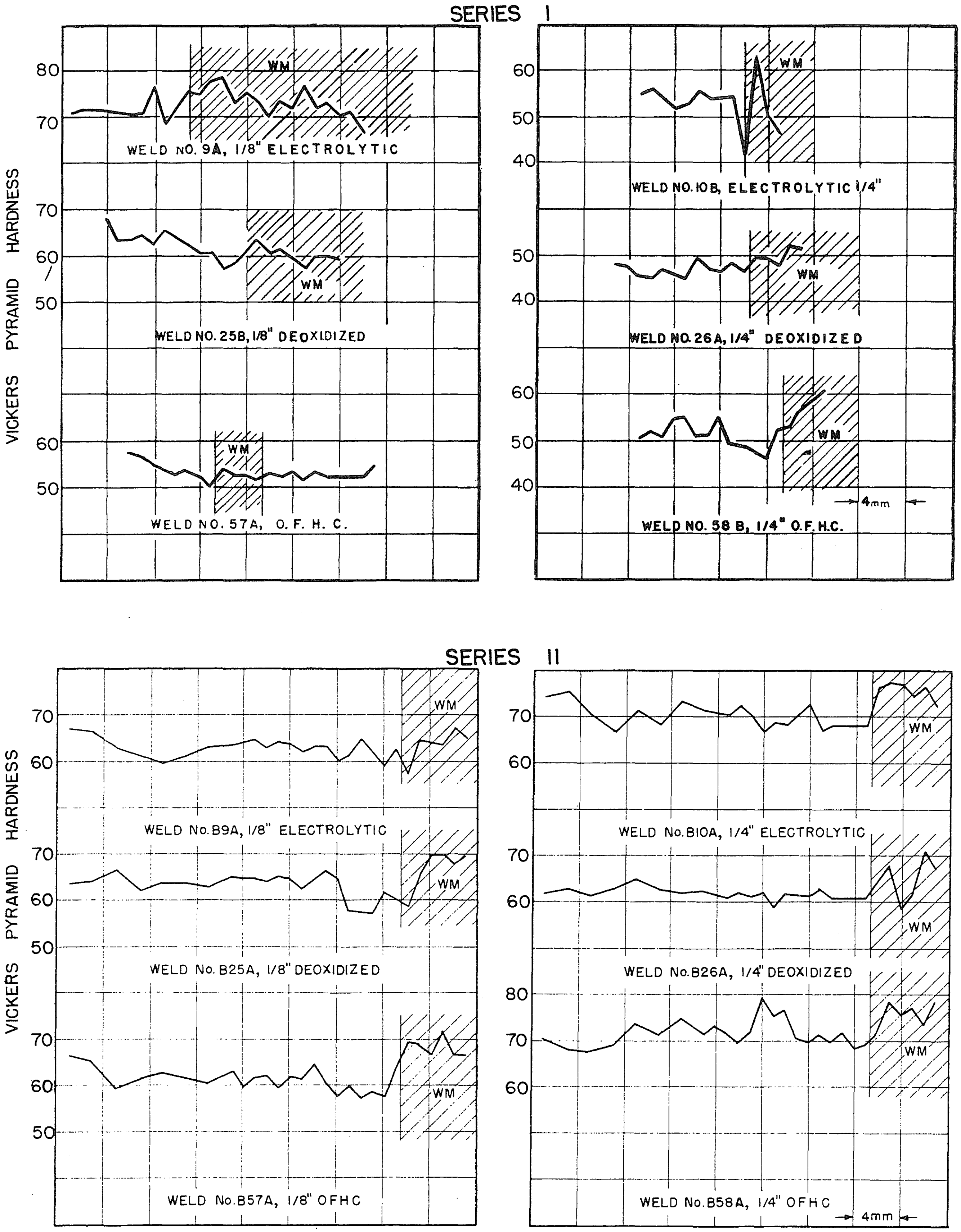


FIG. 8 HARDNESS SURVEYS ON COPPER JOINTS WELDED BY THE INERT-GAS-SHIELDED-ARC PROCESS

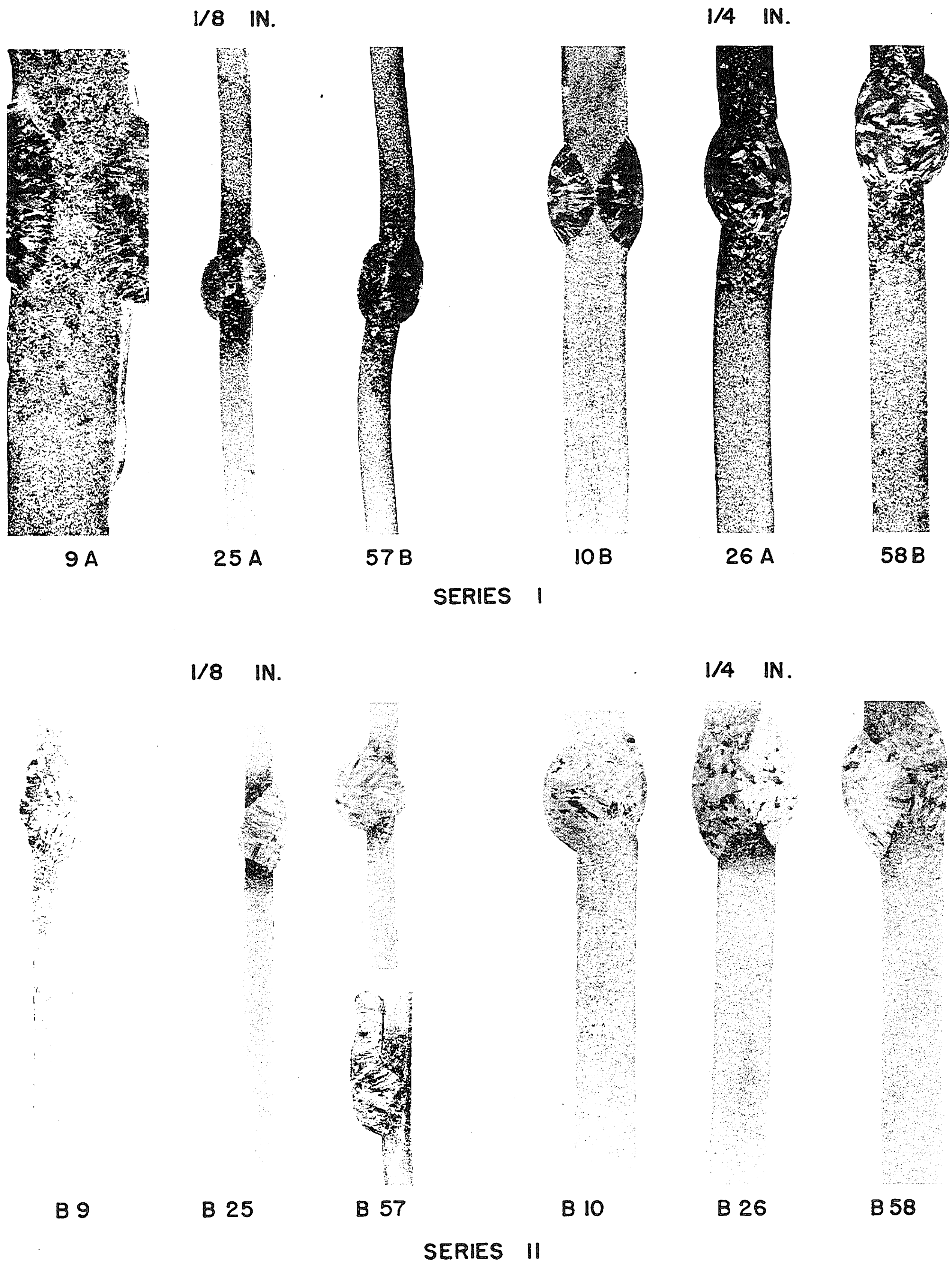


FIG. 9 MACROSTRUCTURES OF COPPER JOINTS WELDED BY THE INERT-GAS-SHIELDED-ARC PROCESS

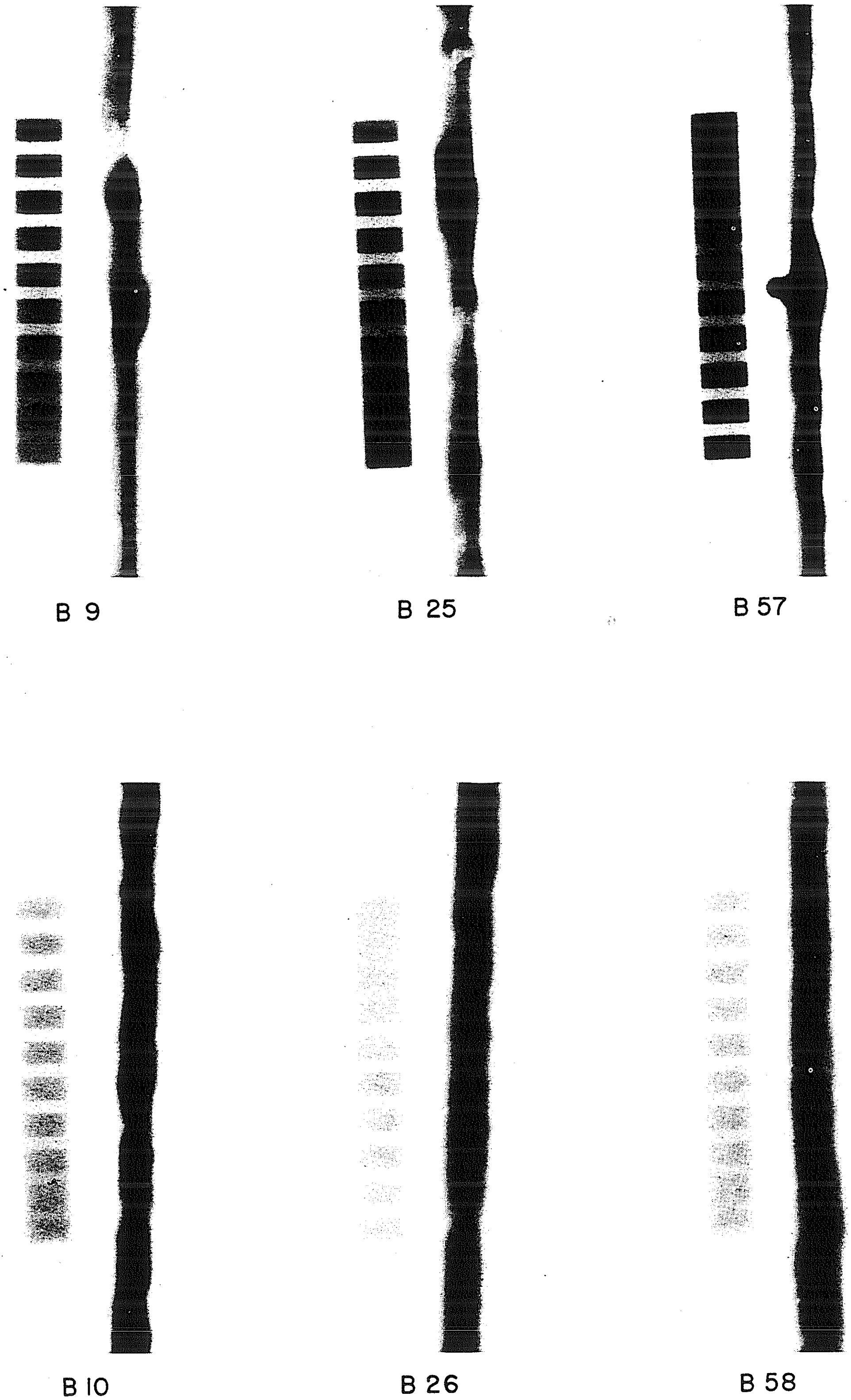


FIG. 10 RADIOGRAPHS OF COPPER JOINTS WELDED BY THE INERT-GAS-SHIELDED-ARC PROCESS, SERIES II

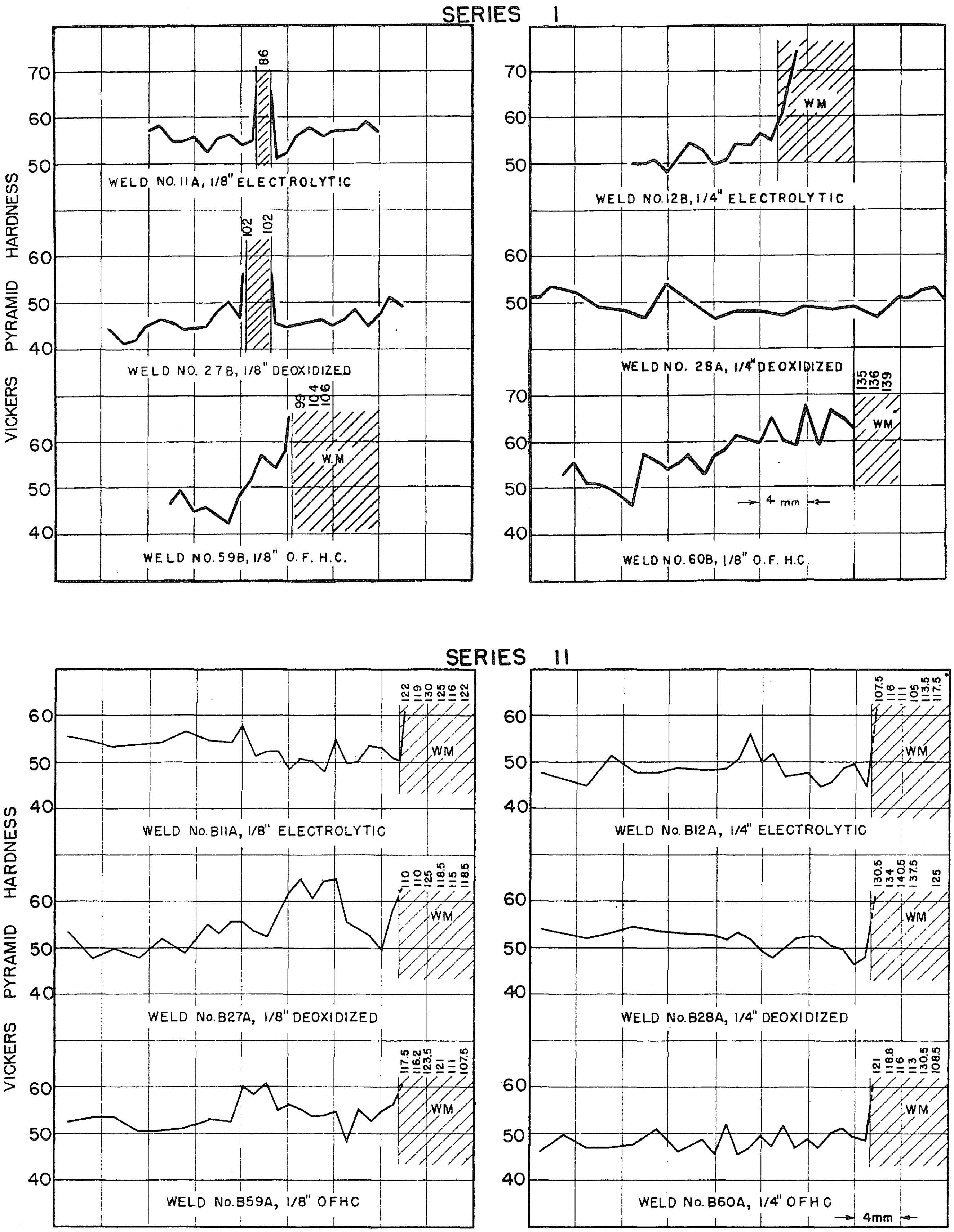


FIG. 11a HARDNESS SURVEYS ON COPPER JOINTS WELDED BY THE OXYACETYLENE PROCESS

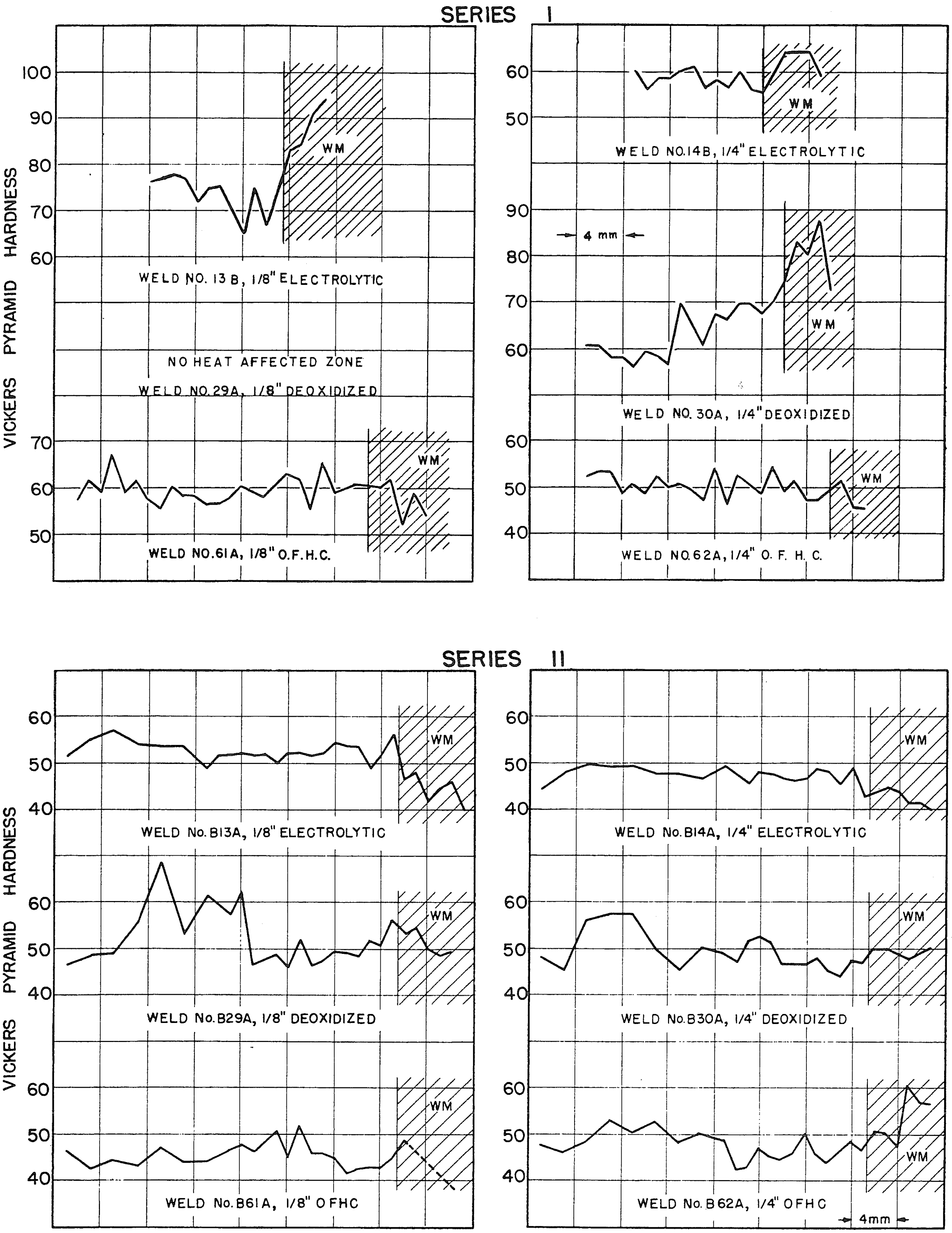


FIG. 11b HARDNESS SURVEYS ON COPPER JOINTS WELDED BY THE OXYACETYLENE PROCESS

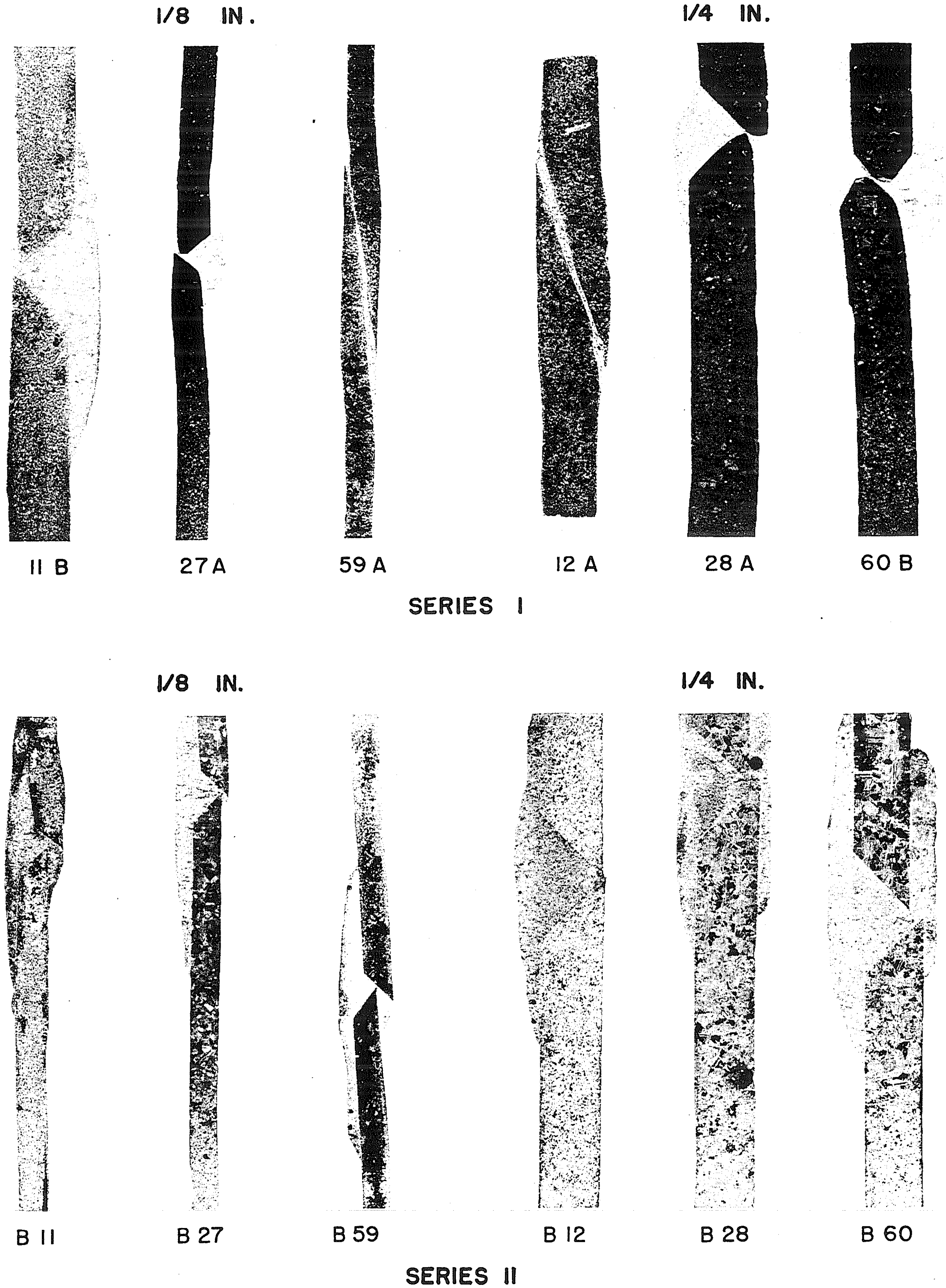


FIG. 12a MACROSTRUCTURES OF COPPER JOINTS WELDED BY THE OXYACETYLENE PROCESS

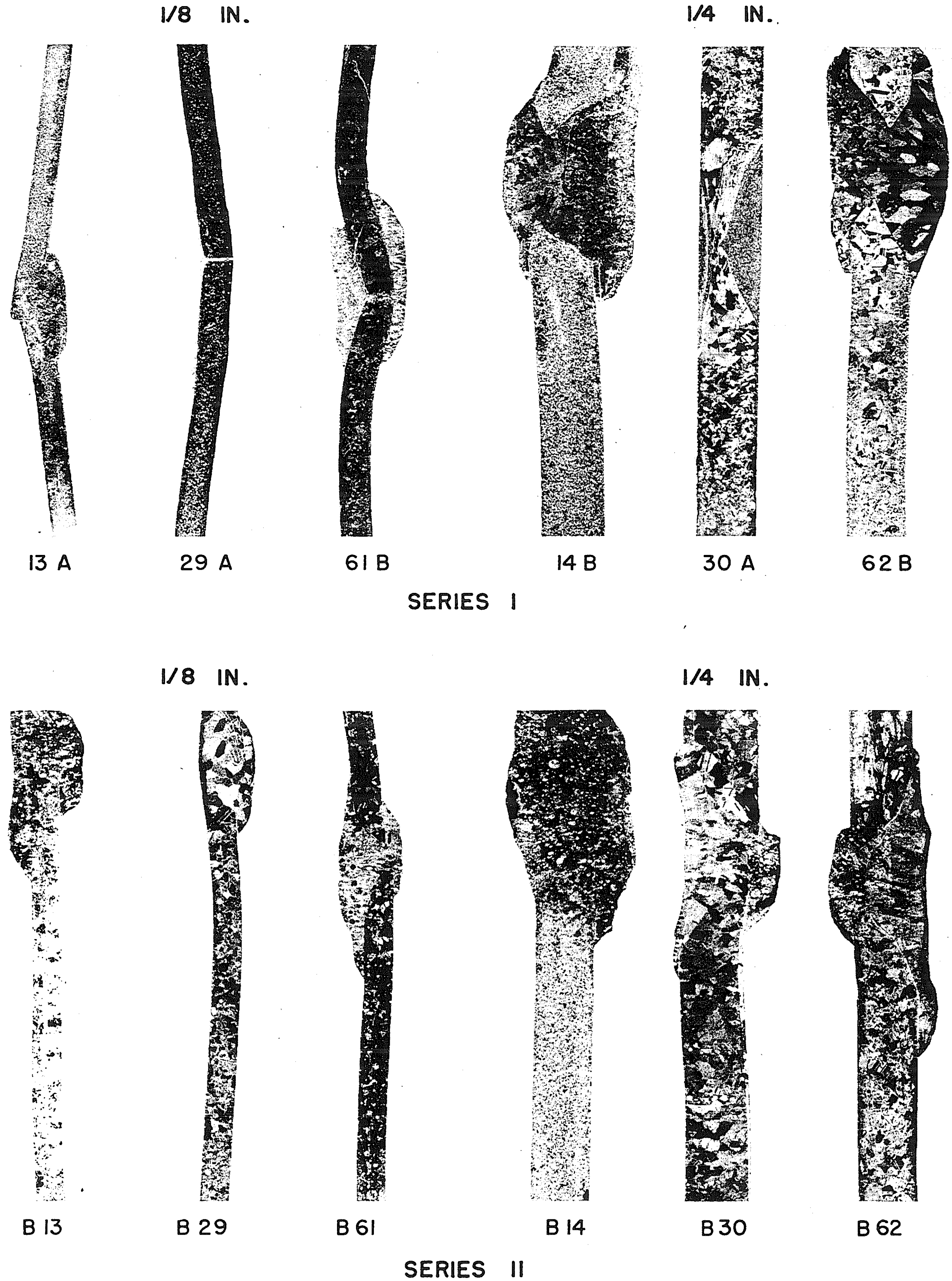
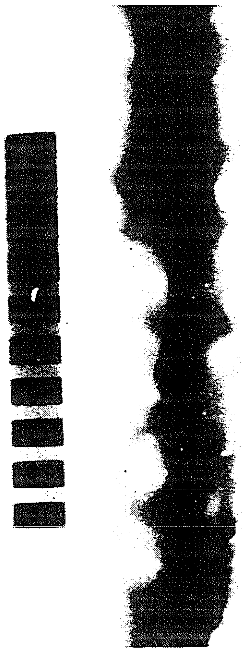


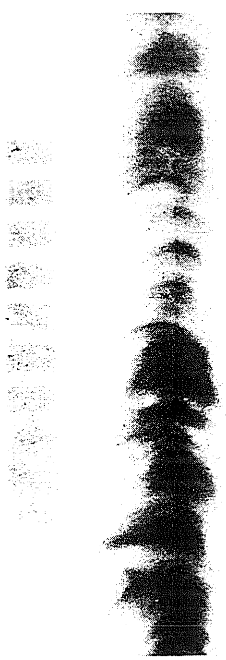
FIG. 12 b MACROSTRUCTURES OF COPPER JOINTS WELDED BY THE OXYACETYLENE PROCESS



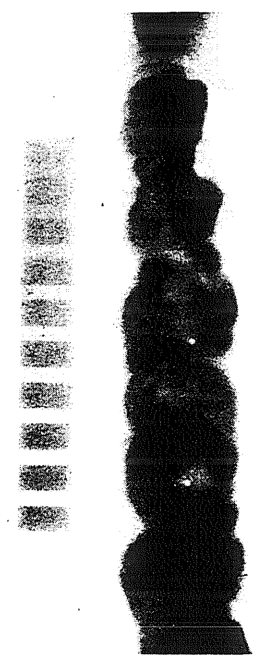
B 11

B 27

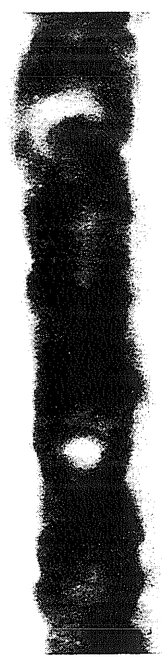
B 59



B 12



B 28



B 60

FIG. 13a RADIOGRAPHS OF COPPER JOINTS WELDED BY THE OXYACETYLENE PROCESS, SERIES II

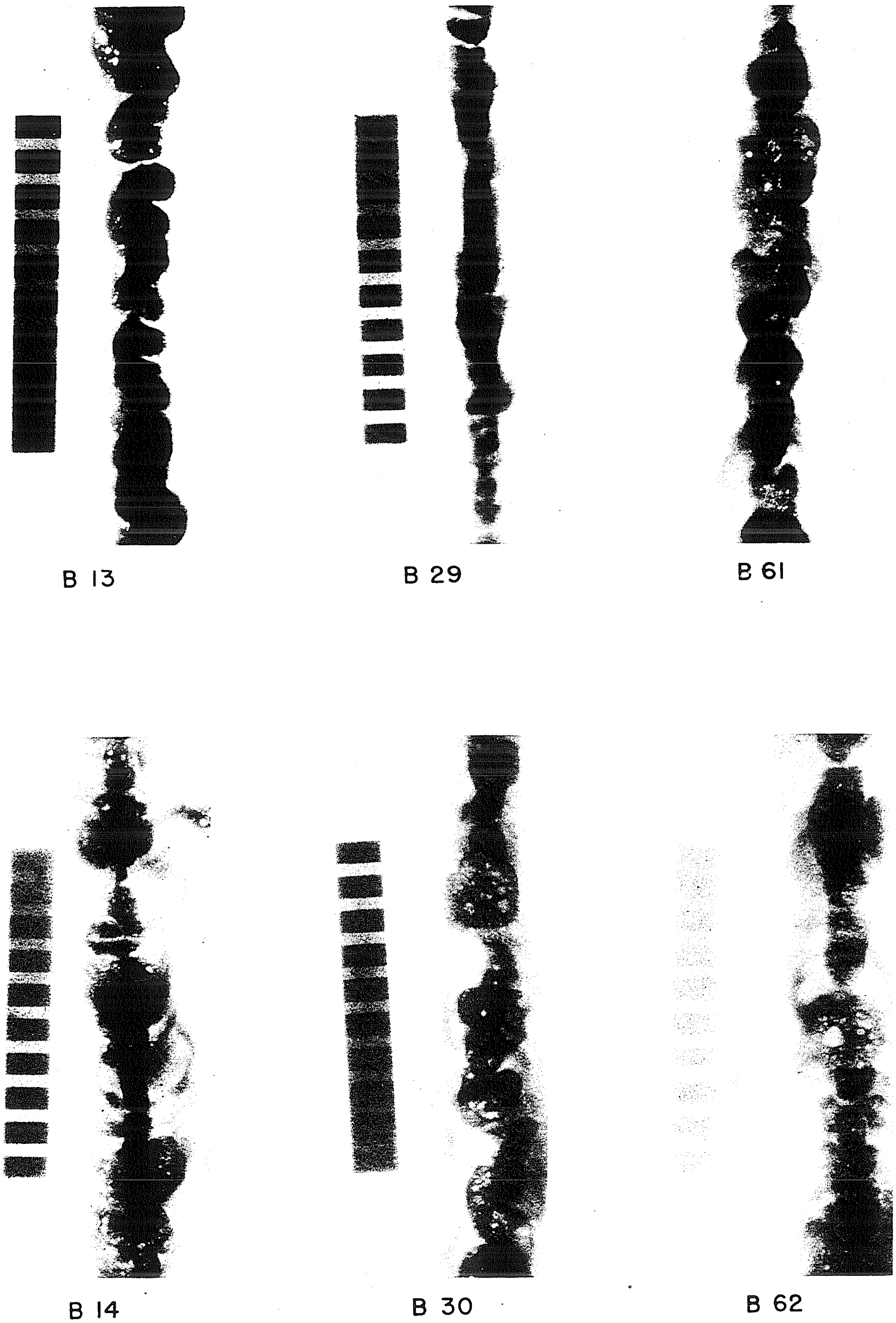


FIG. 13b RADIOGRAPHS OF COPPER JOINTS WELDED BY THE OXYACETYLENE PROCESS, SERIES II

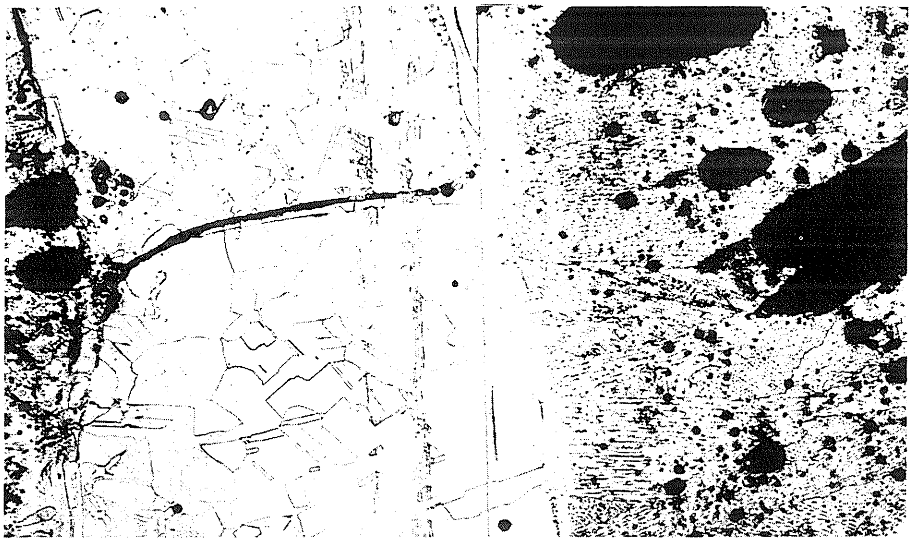


FIG. 14 LACK OF BONDING AT BUTT INTERFACE IN JOINT 54 A. COPPER SILICON ROD, SHIELDED — ARC PROCESS. 25X

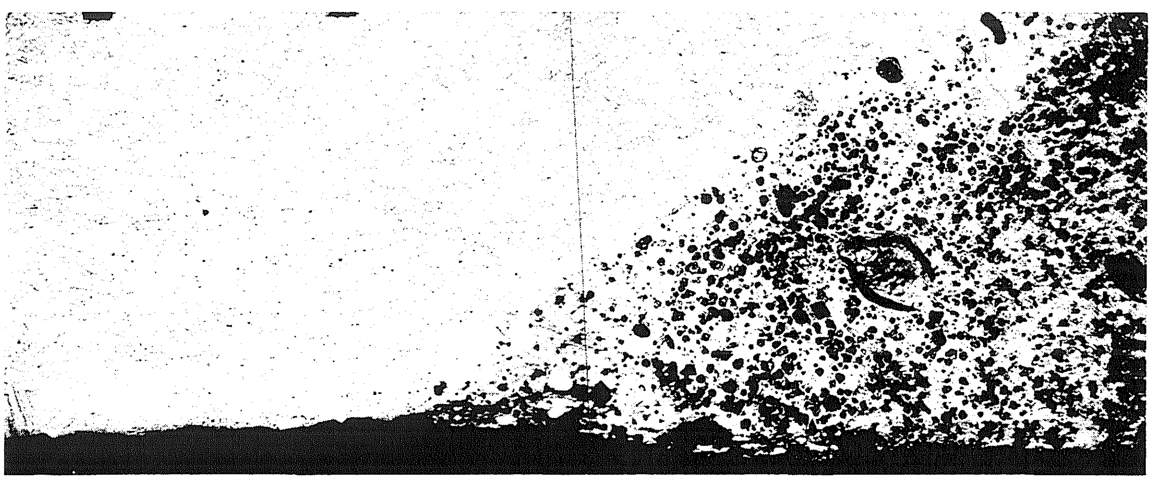
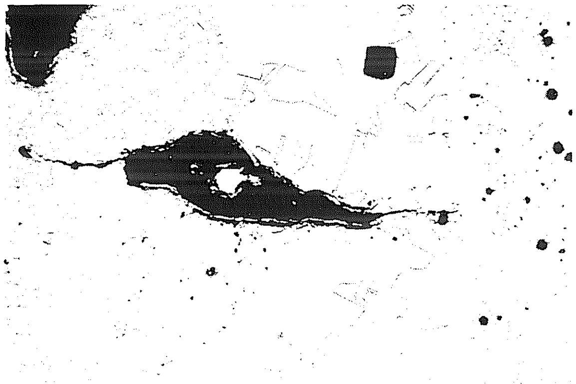


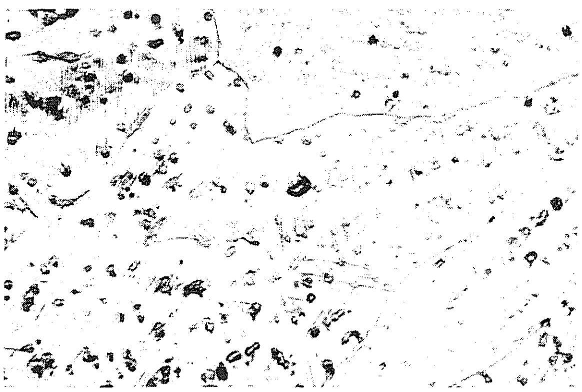
FIG. 15 HEAVY GAS POROSITY AND NARROW HEAT-AFFECTED ZONE IN JOINT B1. COPPER SILICON ROD, CARBON—ARC PROCESS. 30 X



(a) JOINT B54. COPPER SILICON ROD. 30X

(b) JOINT 56A PHOSPHOR BRONZE ROD. 25X

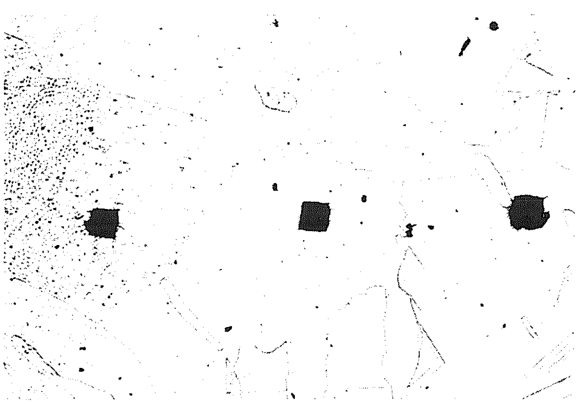
FIG. 16 COMPARISON OF JOINTS PRODUCED BY SHIELDED-ARC METHOD USING DIFFERENT FILLER METALS



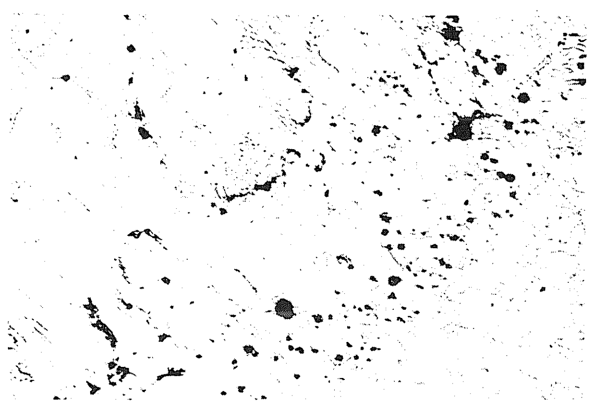
(a) JOINT 7A. 300X

(b) JOINT 21B. 25X

FIG. 17 EVIDENCE OF DEFORMATION IN WELD METAL DUE TO THERMAL DISTORTION. SHIELDED-ARC PROCESS

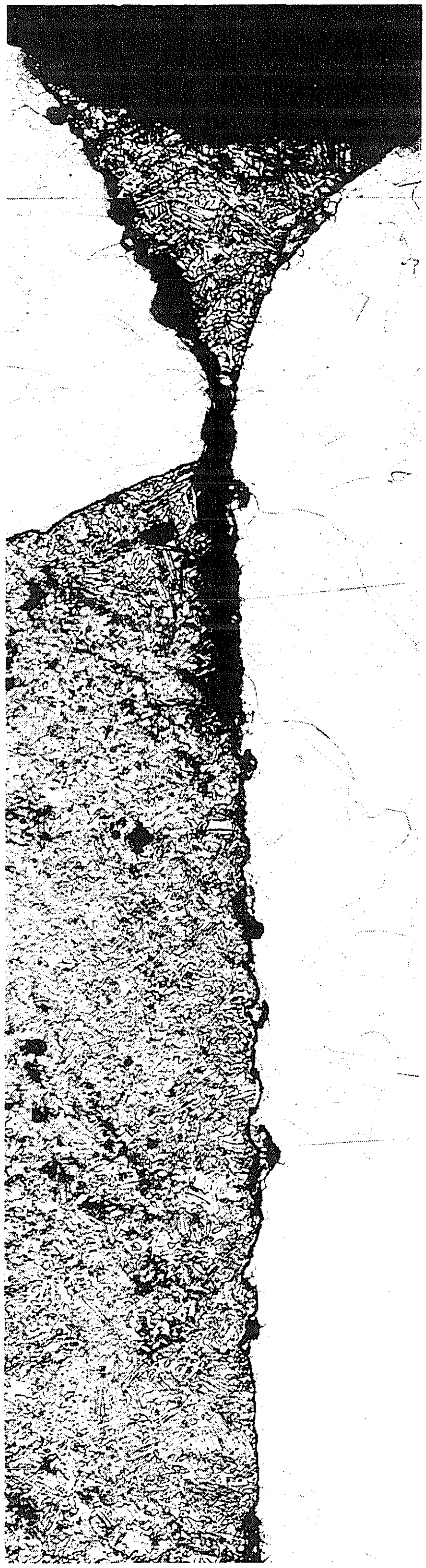


(a) JOINT 58B. 25X

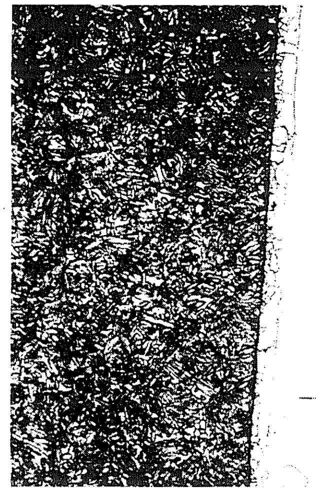


(b) JOINT 10A. 25X

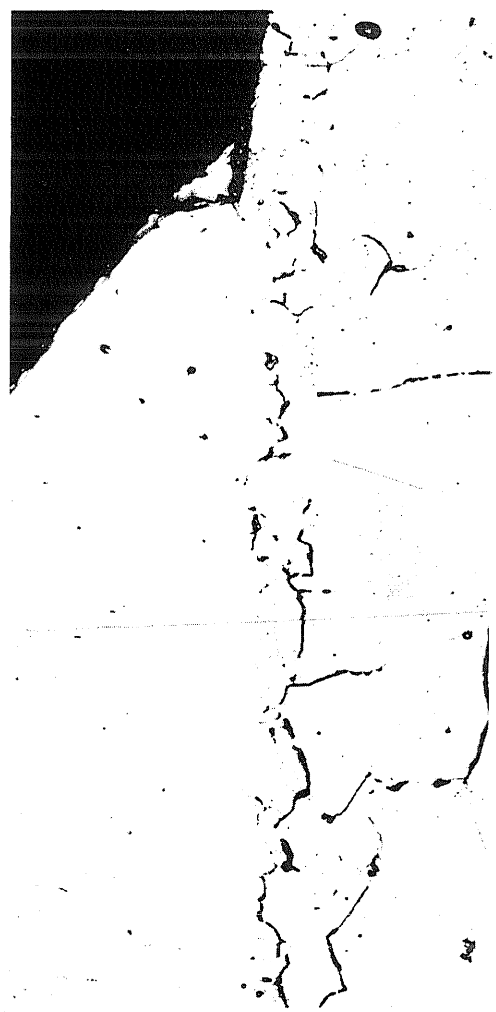
FIG. 18 STRUCTURES PRODUCED BY INERT-GAS-SHIELDED-ARC PROCESS, DEOXIDIZED COPPER ROD



(a) JOINT 28 A- 25X



(b) JOINT 60 B - 25X



(c) JOINT 62 B - 25X

FIG. 19 EFFECT OF Cu_2O ON STRUCTURE OF JOINTS PRODUCED BY OXYACETYLENE PROCESS

(a) GRAIN BOUNDARY PRECIPITATION. 25X

(b) PHANTOM PRECIPITATIO OF OXIDE. 200X

(e) SAME AREA AS (c). 200X

(c) CRACK NEAR WELD. 1.5X

(d) SAME AREA AS (c). 25X

FIG. 20 COPPER OXIDE FORMATIONS IN JOINT 59A. BRASS ROD, OXYACETYLENE PROCESS

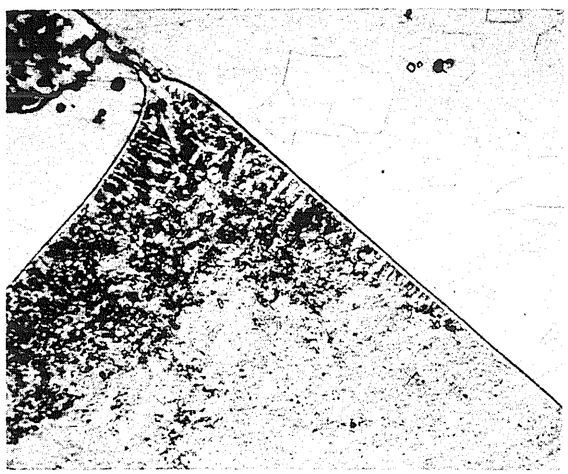


FIG. 21 SHALLOW PENETRATION IN JOINT B 27.

BRASS ROD, OXYACETYLENE PROCESS. 25 X