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SOME EFFECTS OF WELDING ON THE RESISTANCE TO REPEATED LOADING

by

Jan Marcel Ruzek

A THESIS

Presented to the Graduate Faculty
of Lehigh University
in Candidacy for the Degree of
Master of Science

Lehigh University
1951

Approved and recommended for acceptance as a thesis in partial fulfillment of the requirements for the degree of Master of Science.

Date ____________________

Dr. Robert D. Stout
Professor of Metallurgy

Dr. Gilbert E. Doan
HEAD, Department of
Metallurgy

ACKNOWLEDGMENT

The thesis presents a part of the studies made during the course of the last year research program on pressure vessel steels carried out at Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pennsylvania.

The author is greatly indebted to Dr. Robert D. Stout, Professor of Metallurgy at Lehigh University, who supervised the research program and was professor in charge for the present thesis. His advice and invaluable suggestions are most sincerely appreciated.

The Fabrication Division of the Pressure Vessel Research Committee of the Welding Research Council is the sponsor of the research program.

The execution of work was made possible by the cooperation of Mr. Kenneth R. Harpel, laboratory foreman, and Mr. Pierce Schmid. The typing of the thesis was done by Mrs. Jean E. Bond, Jr. Their cooperation is gratefully appreciated.

TABLE OF CONTENTS

ABSTRACT

The origin and the progress of cracking in specimens manufactured from ASTM - A201 steel and welded with electrode AWS - E6020 were investigated. The study revealed that the weld deposit is the area most susceptible to the cracking. It was established that the slip bands, developed by loading beyond the yield point, initiate the cracking. The slip bands are oriented at 45° angles to the direction of bending. The forked ends are specific for propagation of cracking. The fusion line acts as a barrier and delays the progress of cracking which is fairly uniform otherwise.

The repeated load testing of welded ASTM - A201 steel was used to determine the influence of low temperature cooling rates following the welding. The heat treatment provided low cooling rates, which proved to be beneficial. The post heating appears to preserve higher ductility than the preheating. The presence of hydrogen in the weld may be responsible for its decrease in ductility.

INTRODUCTION

The study of the effect of various fabrication operations such as welding, cold forming and heat treatment on the mechanical properties of pressure vessel steels is under study in the Fritz Engineering Laboratory at Lehigh University at the present time. This project is sponsored by the Fabrication Division of the Pressure Vessel Research Committee.

Since welding is now widely used in the fabrication of pressure vessels, considerable attention is being directed to the behavior of the welded pressure vessel steels.

It is a well known fact that many pressure vessels are subject to cyclic loading either due to filling and emptying or due to alternating high and low pressures during the service. The factor of high and low temperatures during operation acts in a similar way. It was decided therefore to conduct a series of tests, which would simulate the cyclic loading which occurs during the use of the vessels. A special testing machine was built for this purpose in Fritz Engineering Laboratory.

In these tests, the emphasis was put on the investigation of the behavior of these steels under repeated loading and stressing beyond the yield point.

In other words, the portion of the plastic range of the steel, adjacent to the yield point was of interest. The reason for this decision was that vessel structures during service are often temporarily stressed in such a manner that certain parts of the vessel may enter the plastic range and become over-stressed. It is natural of course that such parts are the weakest parts of the structure and, therefore, their behavior is of paramount importance.

The survey of the origin and the propagation of cracking was conducted in order to show which part of the weld deposit and its adjacent areas are most susceptible to cracking and further, to show in what manner the cracking starts and how it is propagated.

This main program of investigation was supplemented by parallel investigation of the influence of the low temperature cooling rates on the ductility of welded pressure vessel steels tested under repeated load.

The recent work of Professor A. E. Flanigan 1) and his co-workers in the University of California at Los Angeles, California shows the importance of the rate at which the cooling weld traverses temperatures below 400° F. The investigations of the California group revealed that rapid cooling of welds of E6010 electrode promotes low ductility of weld deposit. Since low ductility of welds on vessels partly stressed into the plastic range could cause severe damage, it was suggested therefore to investigate the influence of different cooling rates on ductility of welded vessel steels tested under repeated load and stressed beyond the yield point.

The results obtained at Lehigh University in this investigation are generally consistent with those of Professor Flanigan. They show that the weld ductility is definitely affected by the rate of cooling even at temperatures as low as 200° F. The influence of hydrogen in the weld is also indicated.

The test program included two levels of preheat or post heat, namely 200° F. and 400° F. were used. Two different heat inputs were chosen and provided by two different lengths of weld beads. In order to obtain a basis for the comparison of results a series of specimens without any heat treatment was provided. To check the influence of hydrogen content, two separate series of specimens were welded with low-hydrogen electrodes.

TEST PROGRAM

Steel

The steel used for these tests was the pedigreed steel, described fully in the previous reports to the Pressure Vessel Research Committee 2). It was ASTM grade A-201. The chemical analysis of the steel is shown in Table I.

	C	Mn	P	S	Si	Cr	Ni	Cu
A-201	0.15	0.53	0.20	0.022	0.20	0.04	0.03	0.07

TABLE I - CHEMICAL ANALYSIS OF PLATES

The steel used for the manufacture of the specimens was in plates 5/8 inch thick in as-delivered condition.

Specimen Preparation

The design of the specimen is identical with the design used in the Repeated Load Tests which is a part of an extensive investigation sponsored by the Pressure Vessel Research Committee at Lehigh University and is shown in Fig. 1. The as-delivered large plates were flame cut into smaller size plates of dimensions 18" x 18" to enable easier handling. These were subsequently machine-saw cut to that exact size of test specimens desired.

Welding

The positions of welding beads were then layed out on each specimen in such a manner that the center point of the weld coincided with the narrowest part of the throat which was machined later. The welding of the specimens was done automatically in order to secure a high degree of reproducibility. No mill scale was removed prior to welding. All welds of the Series I and II, as shown in Table II, were deposited with a popular brand of 3/16 inch AWS E6020 electrodes. The welding conditions were 30 volts with the current of 175 amperes and a travel speed of 10 inches per minute.

The welding of Series III was done with a common brand of 3/16 inch AWS E6016 electrodes. This electrode required conditions of 26 volts and 200 amperes, the arc speed being again 10 inches per minute.

The heat treatment before or after welding was performed in an electric furnace and the time of heating was in all cases 1 hour.

The preheated specimens were transported quickly from the furnace to the welding table and the welding operation was started no later than 15 seconds after the removal of the specimen from the furnace. Generally, the same period of time was required for the transfer of the specimens from the welding table into the furnace for post heating. The post heated specimens were removed from the furnace and allowed to cool at room temperature. In a similar manner, the welding operation of preheated or non-heat treated specimens was followed by air cooling to room temperature.

Machining

The reinforcement of the weld-beads on both sides of each specimen was then removed by machining, in order to prevent stress concentration at the ripples of the weld bead. During this operation, a thin layer of the base metal was removed together with the reinforcement of the weld deposit in order to provide smooth surfaces on the parallel planes of the throat, free of any kind of notch, which would cause stress concentration and thus could influence the life of the specimen.

Subsequently, the specimens were provided with machined throats as in Fig. 1. The sharp corners of the throat were filed off to 1/16 inch radius. The throat of the specimen ensured that the particular part of the specimen would be stressed in the desired fashion.

The Testing Machine

As pointed out above, a special repeated load testing machine was designed and built for the testing of the pressure vessel steels. It is shown in Fig. 2. The design permits the use of this machine either as a constant load or a constant deflection machine merely be replacing the coil spring between the horizontal swing bars with a rigid link. Constant deflection was used in this particular investigation. The power is supplied by a 1 1/2 HP three-phase motor at 1750 RPM. The speed for this investigation was reduced to about 200 RPM at the loading crank; however, any choice of speed is available by the proper combination of pulleys. The machine was provided with a microswitch and a relay which are turned off automatically by the broken specimen which falls on the microswitch at the end of the test.

Testing Procedure

The testing machine was calibrated to establish the relation between the chosen deflection and the strain in the outermost fibres of the throated part of the specimen by means of SR-4 strain gages. 0.5% strain in the outermost fibres was chosen as the maximum loading limit in this particular investigation; 0.5% strain corresponds to 5,000 microinches per inch, which strain provides yielding in an appreciable part of the specimen throat, the yield point limit being considered at approximately 1310 microinches per inch. A suitable cycle counter was attached to the testing machine.

Great care was taken to adjust each specimen properly in the machine so that tensile and compressive stresses in each cycle were of identical magnitude; in other words, positive and negative deflections were identical.

Each specimen was adjusted securely in the fixed fixture at one end and the driving fixture connected with the upper set of the swing bars at the other end of the specimen. The position of the throated part of the specimen was always adjusted in such a way that the distance between the center point of the throat and the center point of the driving fixture was constant and equal to the proper length of the moment arm.

The design, the construction and the calibration of the repeated-load testing machine is fully described in other reports to the Pressure Vessel Research Committee 3).

Crack Detection

The specimens chosen for the investigation of the origin and progress of the cracking were polished on the upper of the two parallel surfaces. No effort was made to reach perfect microscopic polish, but care was taken not to introduce any scratches across the throat which would ultimately influence the life of the specimen. Part of the polished specimens was tested in the unetched condition. On the other specimens the polished area was lightly etched with 2% Nital solution in order to distinguish clearly the weld deposits from adjacent areas of heat affected zone and unaffected base metal.

A microscope was located above the specimen to permit examination of the polished throat during testing. The magnification used was 50x or 40x, which allowed a reasonably large area to be watched. A set of pictures of the area most susceptible to cracking, the narrowest part of the throat, was taken before each test was started. The entire throat of the specimen was under constant survey by microscope after the test was started. The test was interrupted at regular intervals to enable a thorough search of the surface. When the first sign of cracking appeared, the test was interrupted and the area photographed. A great deal of effort was spent in recording the progress and typical mode of the process of cracking. Special attention was paid to the progress of cracking across the fusion line and the boundaries of the heat-affected zones.

The number of cycles before appearance of the first crack and the total number of cycles to the fracture were the data of interest in this study. The proper recording of the first crack required a constant observation of the throated part of the specimen after the test was started.

Endpoint of Testing

Originally the machine was designed to shut off when the specimen broke into two and so fell on a microswitch feeding into the power relay switch. It was found that frequently the specimen would fail except for a paper-thin section which would hold together sometimes for a dozen, sometimes for several hundred cycles. This action contributed needless scatter to the results.

It was decided to define the endpoint of the test as that at which the load carrying capacity of the specimen dropped to virtually zero. A magnifying lever was rested on the end of the throat section nearest the stationary clamp. A small elastic movement in the specimen at this point actuated a flag between a light source and a photo cell. The light reaching the cell varied directly as the amount of movement of the flag, and the voltage output of the cell was fed to a DC amplifier, the output of which was recorded on an Esterline-Angus voltmeter. When the throat of the specimen was cracked sufficiently, it no longer communicated load to the fixed end and the flag movement became small, as did the output voltage to the recorder. By this method, the end point of the test could be recorded without constant attendance of an operator.

DISCUSSION OF RESULTS

Part I. The Survey of Origin and Progress of Cracking

The microscopic observation of the polished surfaces of specimens at frequent intervals during the testing revealed several points of interest. In Fig. 3. is shown a polished surface of the specimen before the test was started. Similarly, Fig. 4. shows a typical appearance of the polished and etched surface in which can be distinguished the weld deposit, heat-affected zone, and unaffected base metal before the start of the test. As soon as the test was started, during the first cycle, the outer surfaces of the specimens were stressed beyond the yield point causing immediate yielding of the metal. This yielding is most extensive in the coarse grain, cast-like structure of the weld deposit. The slip planes propagated almost instantly to the surface of the specimen and formed a net of slip lines. The general direction of the slip bands follows the familiar pattern of yield lines on tensile loading, at roughly a 45° angle to the direction of bending. The examination of the heat-affected zone and unaffected base metal did not reveal any change in appearance after the first few cycles. The additional cycles cause at first a thickening of the net of slip lines in the weld deposit and gradually force a similar yield pattern in the unaffected zone. The heat-affected zone being composed of fine grain structure does not reveal any pronounced change in appearance almost until the end of the life of the specimen.

In Fig. 5. and 6. are shown micrographs of polished and polished+etched surfaces respectively after several hundreds of cycles. Examination reveals a difference in slip patterns between weld and base metal. The long and very pronounced slip lines of the weld deposit are easily distinguishable from the short slip lines of the unaffected metal. The heat-affected zone shows scarcely any change in appearance.

The extent of the yielding of the metal in different parts of the weld is finally so well pronounced that under proper lighting the appearance of the polished surface resembles an etched surface.

As the testing continued some of the slip bands in the weld metal, having most favorable conditions of the maximal stresses, lengthened and broadened gradually. Shortly before the first crack developed, the slip bands in a particular area broadened in a peculiar double V-shape, (Fig. 8. and 16.). The metal within each triangle of the mentioned double-V seemed to commence "breathing". Finally both halves of the double-V joined into an X-shape and the first crack opened. The ends of the crack retained the fork-like appearance throughout the process of cracking, following the 45° orientation of the slip bands. The speed of progress of cracking through the weld metal was fairly uniform.

The record of the progress of cracking is shown in a series of photographs, Fig. 7. to 14. for the polished specimen. In Figs. 14. to 21 is recorded a similar series of photographs on an etched specimen. As the crack progressed toward the fusion line of the weld, the speed of propagation slowed down and momentarily stopped. The forked pattern temporarily disappeared, (Fig. 14. and 23.). The fusion line seemed to act as a barrier preventing otherwise continuous progress of the crack. The propagation of the crack at this point appeared in some cases as a merging of simultaneously formed numerous small cracks. The load is relieved by the opening of the main crack and the secondary small cracks are arrested.

An attempt was made to record the progress of the cracking across the fusion line and across the boundary of the heat affected zone and into the base metal. This appears in Fig. 22. to 27. Suitable points of reference were selected in order to enable to observe that the progress of one particular crack was followed and further to enable easier observation with respect to the important lines, in particular, the fusion line and the boundary of heat-affected zone.

The study of cracking has shown that in the welded specimens the cracks originate consistently in favorably oriented slip bands in the coarse grain columnar structure of the weld deposit. It was observed furthermore, that the center of the weld bead is the most susceptible area of cracking. In no case was the crack observed to originate in the heat-affected zone or in the base metal.

The start of the cracking appeared to happen in all cases in identical fashion and obeyed the principle of maximal shear.

The fusion line acts as an obstacle and delays considerably the progress of cracking. This interesting phenomenon should be investigated more thoroughly in order to understand its mechanics.

Part II. The Repeated Load Testing

The results of this particular investigation are presented in Table III and Fig. 28. Table III presents the individual test results of the investigation. Fig. 28. employs the average values of each set of specimens arranged in a bar graph for easier examination.

The examination of the Fig. 28. reveals several points of interest.

First of all attention should be paid to sets No. 1 and No. 6. These two sets being without any heat treatment whatsoever, are the basis for the comparison of behavior of the welded steel under different treatments. The specimens of set No. 1 and set No. 6 were provided respectively with bead 3 inches or 6 inches long on each side of the specimen. Two different lengths of welds were chosen in effort to learn if the higher heat input of the set No. 6 improves the ductility of the weld deposits and thus lengthens the life of the specimens. As shown in Fig. 28., no appreciable difference was observed due to the greater heat input of set No. 6.

The beneficial influence of preheating and post-heating is apparent especially in the Series I., the results of Series II being somewhat scattered.

The heat treatment even at slightly elevated temperatures, as were used in these investigations, definitely improves the resistance to cracking. Closer examination of Fig. 28. shows the improvement due to the heat treatment. The preheating raises not only the total number of cycles to the fracture, but seems also to delay the appearance of the first crack. The comparison of the preheating and the post heating at the identical temperatures speaks much in favor of post heating. The number of cycles to fracture was raised by preheating about 20%. The post heating raised the level of cycles approximately 50%.

The hydrogen content of the weld deposits is held at least partly responsible for the reduced ductility of the weldments. An attempt was made to learn if the low-hydrogen deposits will exhibit appreciably higher resistance to the cracking under severe conditions of repeated load testing. Series III was welded with low-hydrogen electrodes of class AWS - E6016, other conditions being kept identical.

The examination of Fig. 28. shows a pronounced effect of the electrode type. The cracking tendency was appreciably delayed. The ductility of the deposits is higher, and correspondingly high is the number of cycles to fracture which was raised in average about 100%.

As indicated by the work of Professor Flanigan the rate of cooling at low temperatures after welding with high-hydrogen electrodes may influence the final properties of the weldment. The mechanics of this process is dependent primarily on hydrogen content introduced into the weld. If the cooling rate is rapid, the retained hydrogen tends to cause numerous microfissures in the weld deposit. These microfissures acting as notches appreciable lower the

the mechanical properties of the metal. The slow low temperature cooling rates seem to enable the escape of parts of hydrogen by diffusion. This naturally would result in decreased tendency to microcracking. Considerably higher number of cycles to fracture obtained with the specimens welded with the low hydrogen electrodes seems to support the importance of the presence or absence of hydrogen in the weldment.

From the presented results it appears that there is a note worthy effect of the low temperatures cooling rates when the welding is performed with high hydrogen electrodes.

SUMMARY AND CONCLUSIONS

Part I. The Survey of Origin and Progress of Cracking

The microscopic survey of the origin and the progress of cracking was performed on specimens manufactured from steel ASTM - A201 and welded with electrode AWS - E6020. Polished and polished+etched surfaces were examined. A series of photo micrographs recorded the origin of cracking and its progress across the fusion line and boundary of heat-affected zone.

Summarizing the results it may be stated:

1) The coarse-grain, as-cast structure of the weld deposit is the origin of cracking.

2) Initially during testing slip bands develop at a 45° angle to the direction of bending, in the direction of maximum shear.

3) The slip bands located in the most favorable position seem to initiate the start of cracking.

4) The fusion line acts as an obstacle, stops temporarily and delays the progress of cracking.

5) The forked ends of the crack are typical for the propagation of the crack and are initiated by favorably located slip bands.

6) The appearance of slip bands is specific for each area of the weld. The slip bands in the weld deposit are long and well pronounced due to the coarse-grained structure. The slip lines of the

heat-affected zone are very short and barely visible at 50 diameters, because of the fine grain structure. The slip bands of the unaffected base metal are appreciably shorter than that of weld deposits.

Part II. Repeated Load Testing

The repeated load testing of welded pressure vessel steels was used to determine the influence of low-temperature cooling rates following the welding. The ductility was measured by means of the number of cycles to fracture of the bead-on-plate repeated load test specimens, used in other investigations sponsored by the Pressure Vessel Research Committee. Several different cooling rates were introduced either by means of different heat input or by preheating or post-heating.

The results may be summarized as follows:

1) Lower ductility is introduced in E6020 weldments by the rapid cooling.

2) Low temperature heat treatment improves the ductility. Post-heating seems to be more beneficial than preheating.

3) The results indicate, that fast cooling rates are important at temperatures as low as 200° F.

4) The presence of hydrogen in the weld deposits decreases its ductility, probably due to formation of microfissures.

5) The specimens welded with low-hydrogen electrode exhibit considerable improvement in ductility of the weld deposits.

Tables II and III

Figures 1 to 28

(pages 24 -46)

TABLE II - Heat treatment, weld lengths, and electrode.

SERIES I

	Set 1	Set 2	Set 3	Set 4	Set 5
Heat treatment	None	Preheat 200°F	Postheat 200°F	Preheat 400°F	Postheat 400°F
Weld length	3 inch weld on each side of specimen				
Electrode	AWS - E6020				

SERIES II

	Set 6	Set 7	Set 8	Set 9	Set 10
Heat treatment	None	Preheat 200°F	Postheat 200°F	Preheat 400°F	Postheat 400°F
Weld length	6 inch weld on each side of specimen				
Electrode	AWS - E6020				

SERIES III

	Set 11	Set 12
Heat treatment	None	None
Weld length	3 in.	6 in.
Electrode	AWS - E6016	

TABLE III - Individual test results

Series I.

Set No.	Spec. No.	Cycles to first crack	Average	Cycles to fracture	Average
1	1	1100	768	3730	3900
	2	750		3500	
	3	720		4930	
	4	500		4140	
	5	770		3200	
	6 *	2500		5800	
2	1	1050	1200	4800	5048
	2	1900		4722	
	3	800		4752	
	4	1500		7796	
	5 *	520		2872	
	6	750		3173	
3	1	1200	2142	4164	6041
	2	2700		5459	
	3	1600		4380	
	4	2350		6202	
	5	2600		7700	
	6	2400		8340	
4	1	2800	2127	4735	5070
	2	1150		3774	
	3	1050		3405	
	4	2580		4904	
	5	2760		7402	
	6	2420		6202	
5	1 *	4929	2494	10682	6407
	2	3500		6327	
	3	2100		6870	
	4	2100		6420	
	5	2500		6320	
	6	2270		6100	

* Specimen not included in average values.

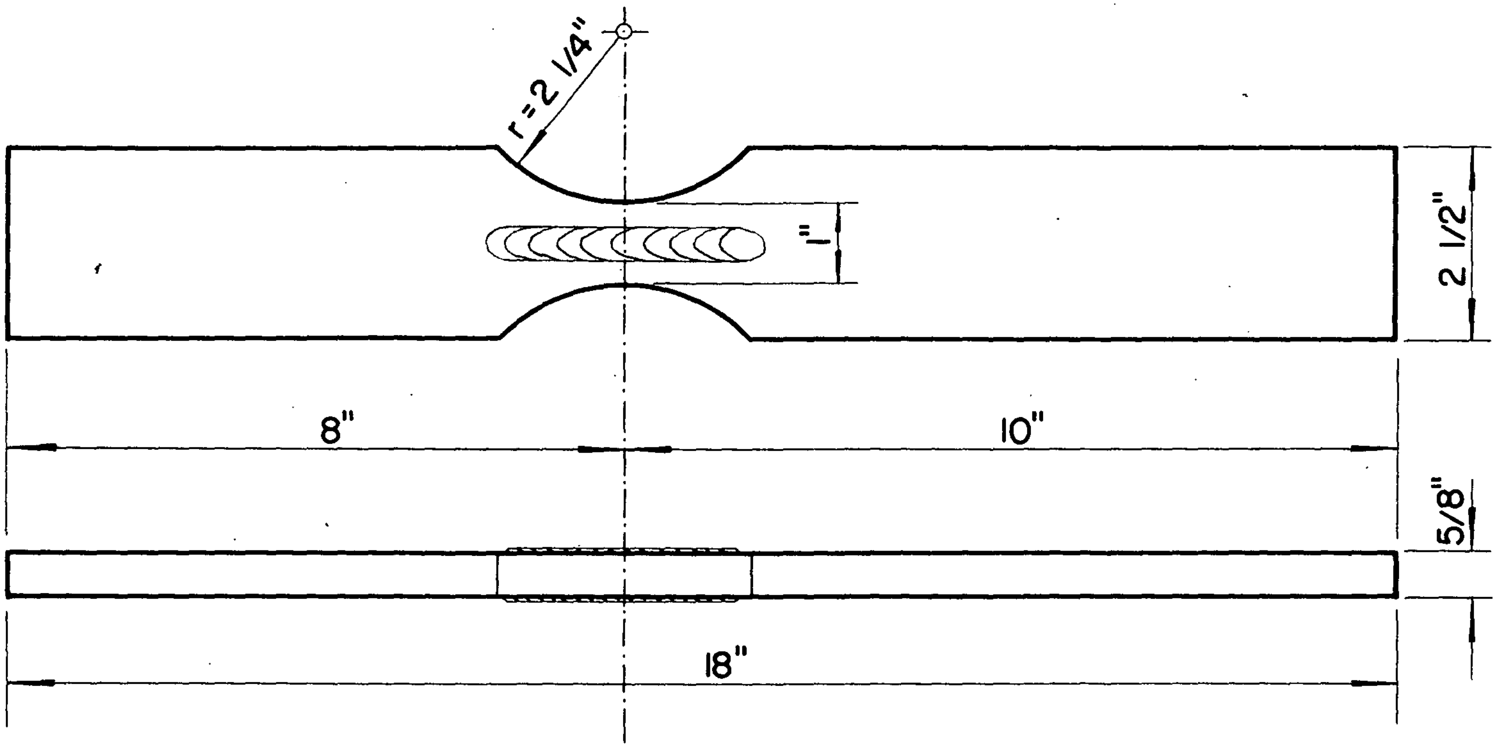
Series II.

Set No.	Spec. No.	Cycles to first crack	Average	Cycles to fracture	Average
6	1 *	1400	1154	4827	4545
	2	800		5536	
	3	1150		4055	
	4	1200		4402	
	5	1020		4820	
	6	1600		3913	
7	1	620	1000	3510	4077
	2	540		4244	
	3	1900		4195	
	4	770		4323	
	5	565		4121	
	6	1600		4067	
8	1 *	2090	1254	4821	5694
	2	790		4798	
	3	1280		5291	
	4	1620		6450	
	5	1200		6150	
	6	1380		5784	
9	1	2300	1141	5217	5149
	2	1520		5401	
	3	620		3837	
	4	920		6487	
	5	840		5020	
	6	650		4933	
10	1 *	1530	1506	7214	5462
	2	1530		5202	
	3	980		4712	
	4	1150		4736	
	5	1950		6372	
	6	1920		6290	

* Specimen not included in average value.

Series III.

Set No.	Spec. No.	Cycles to first crack	Average	Cycles to fracture	Average
11	1 2 3	2600 2200 2660	2487	7864 8200 7543	7869
12	1 2 3	2500 2600 3110	2737	8368 8600 9124	8697



Note : Weld - beads were milled flush with the specimen surface before testing.

FIG. 1. REPEATED LOAD TEST SPECIMEN.

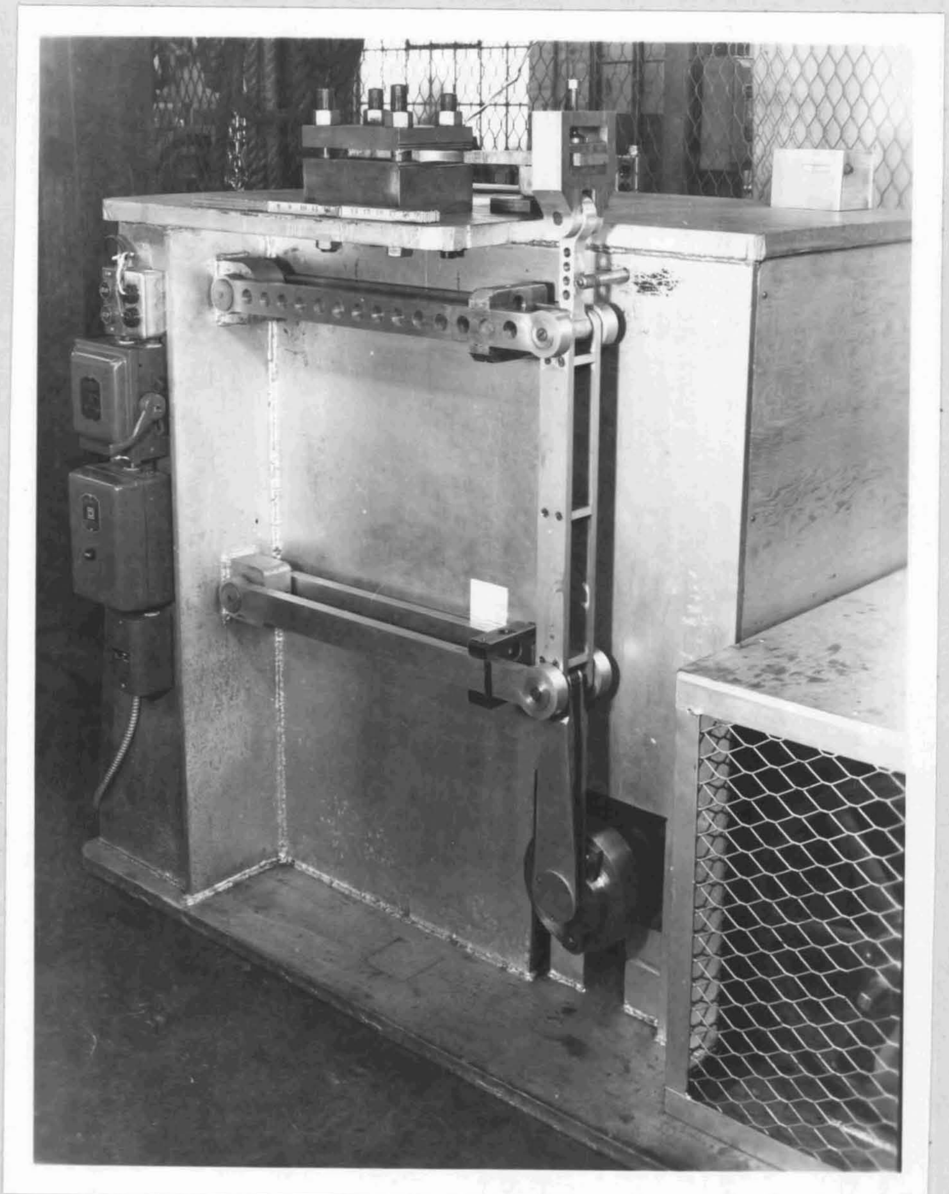
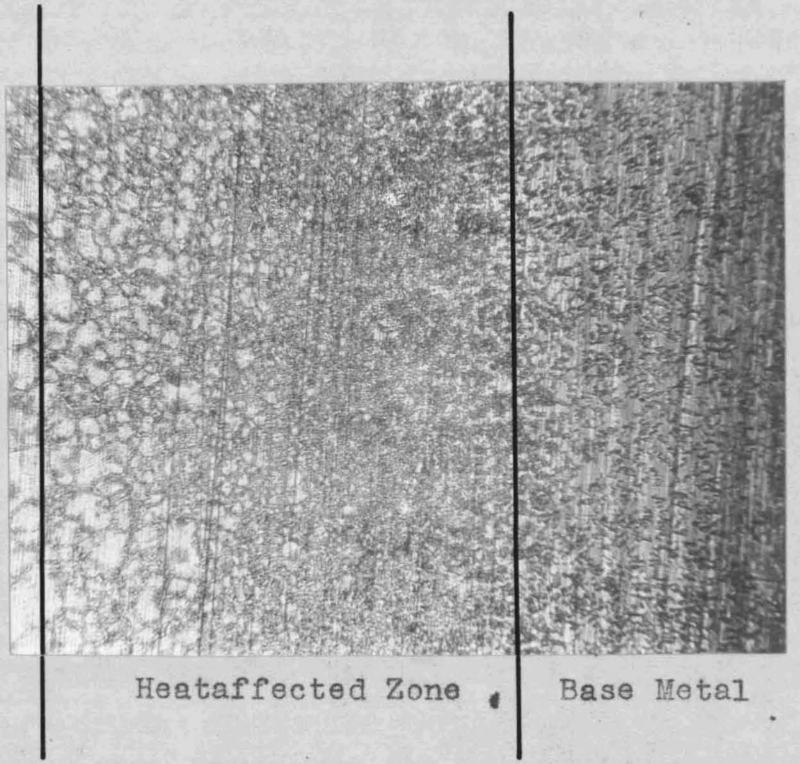


Fig. 2. Repeated Load Testing Machine

Fig. 3.

Fig. 4.

50x


Weld Metal
Heataffected Zone
Base Metal
Fusion Line
Boundary of Heat affected Zone

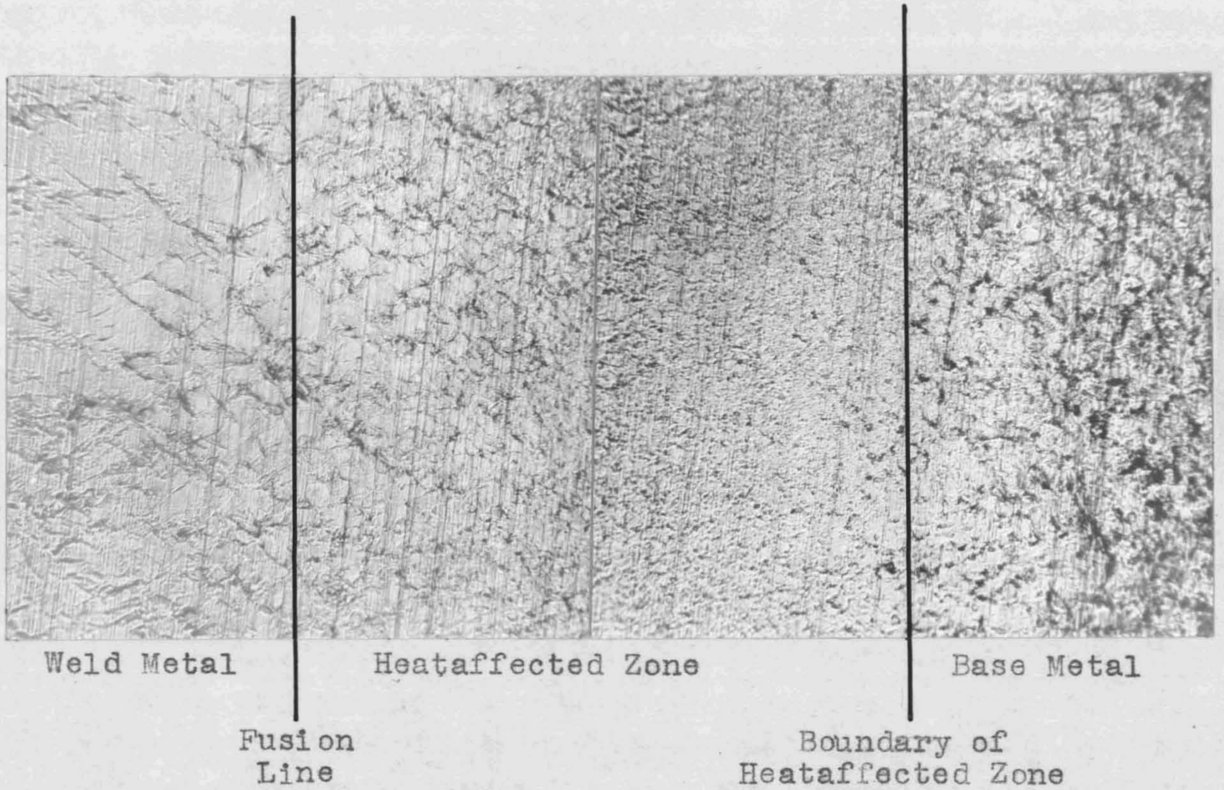

Weld Metal
Heataffected Zone
Base Metal
Fusion Line
Boundary of Heataffected Zone

Fig. 5.

50x

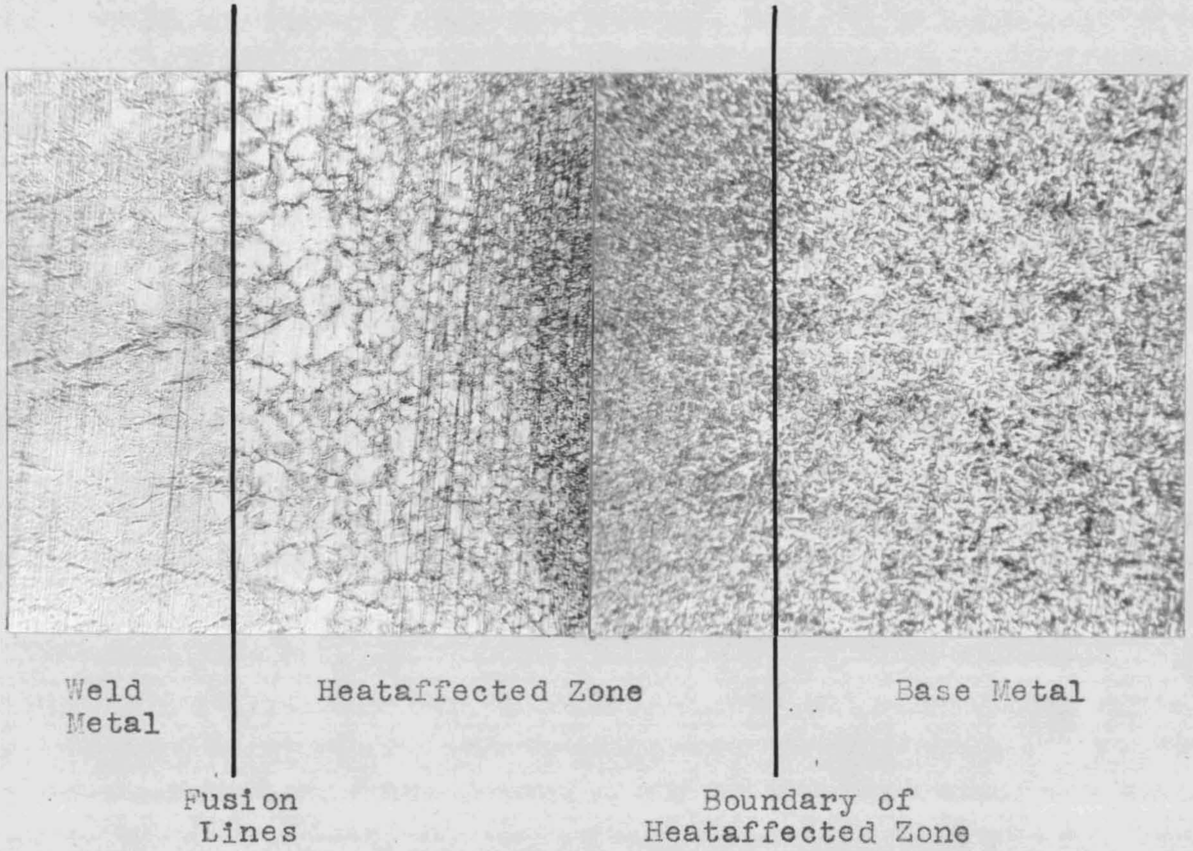
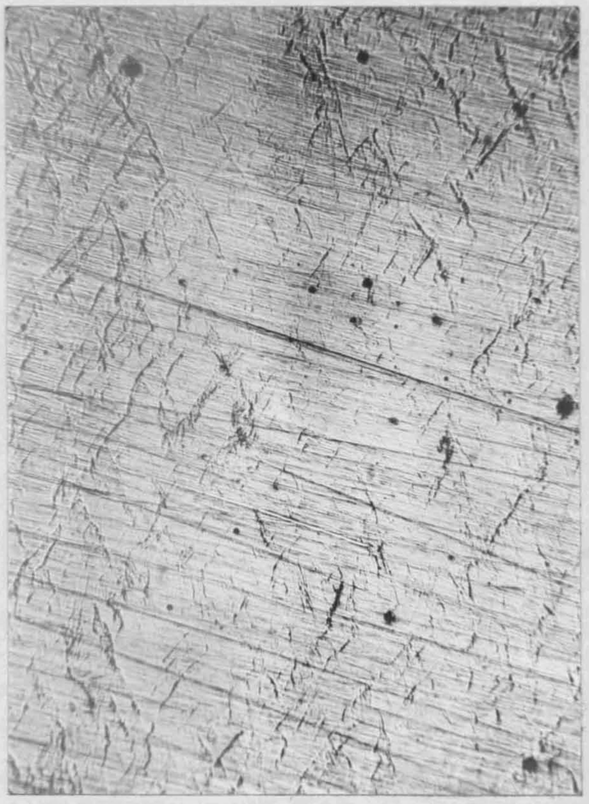

Weld Metal
Heataffected Zone
Base Metal
Fusion Lines
Boundary of Heataffected Zone

Fig. 6.

50x



1355 cycles 50x

Fig. 7.

1400 cycles 50x

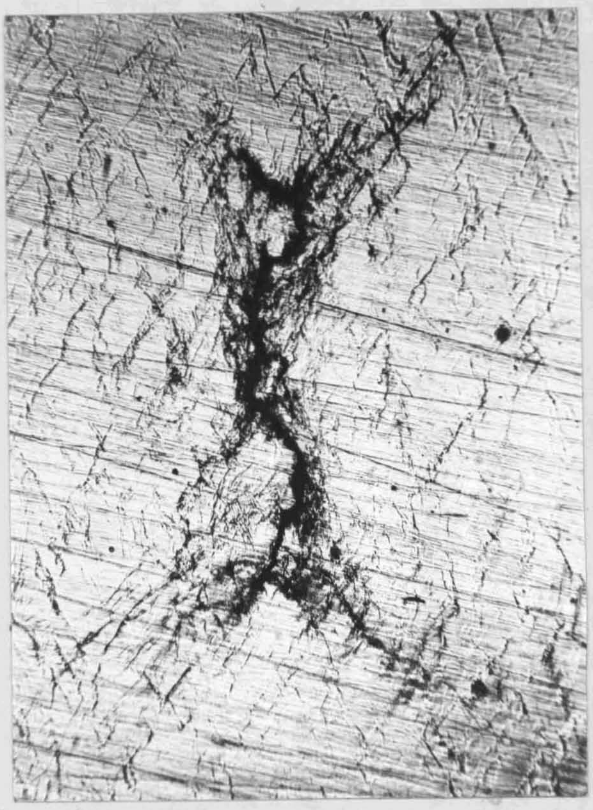
Fig. 8.

1447 cycles 50x

Fig. 9.

1502 cycles 50x

Fig. 10.



1600 cycles 50x

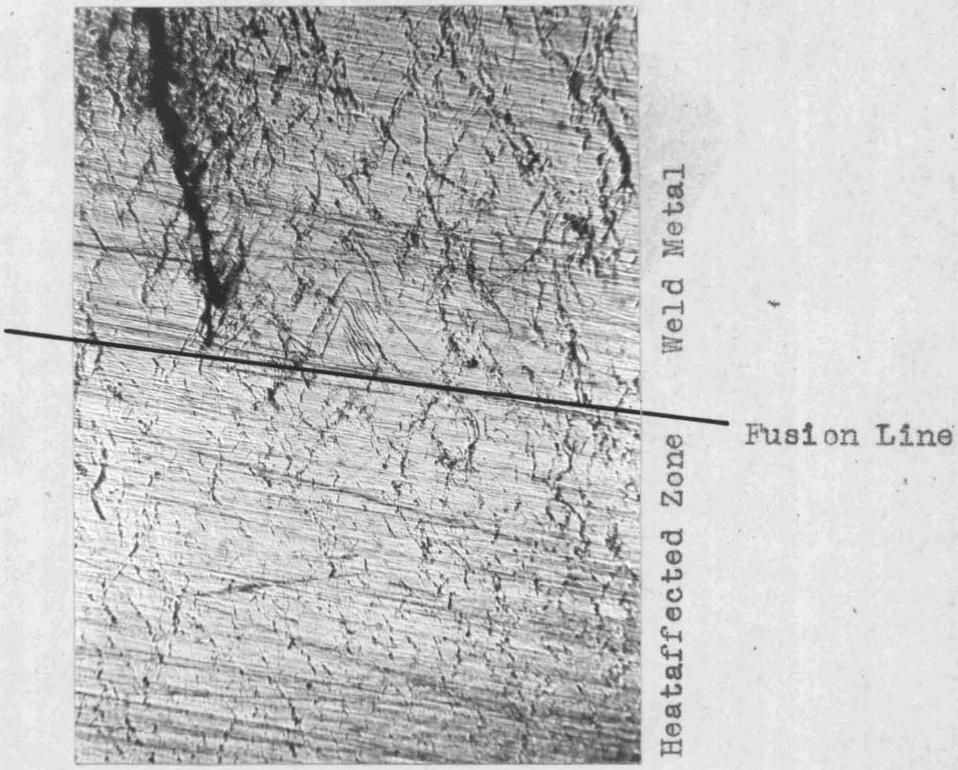
Fig. 11.

1700 cycles 50x

Fig. 12.

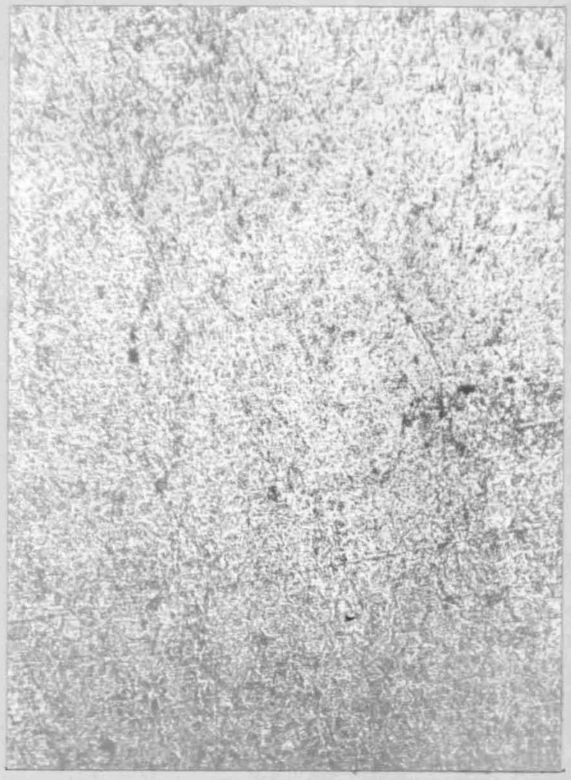
1812 cycles 50x

Fig. 13.



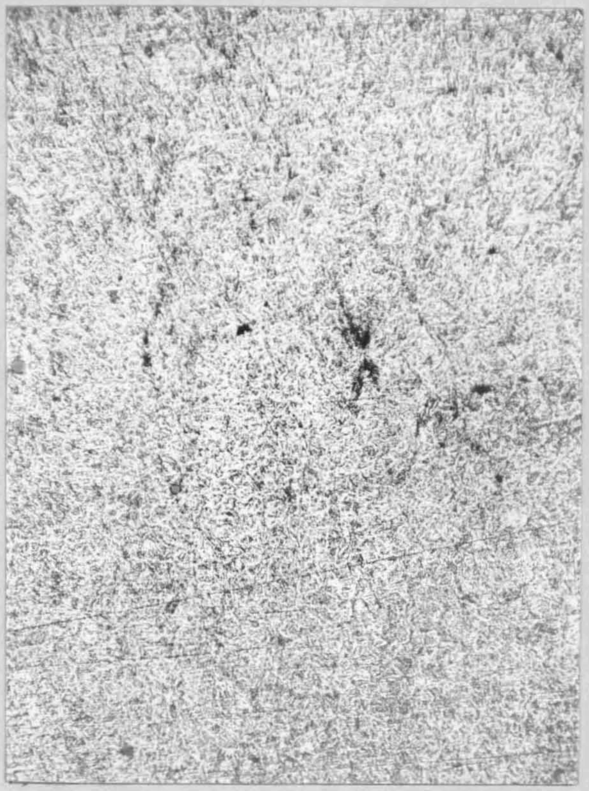
2620 cycles 50x

Fig. 14.



1530 cycles 40x

Fig. 15.



1544 cycles 40x

Fig. 16.

1556 cycles 40x

Fig. 17.

1602 cycles 40x

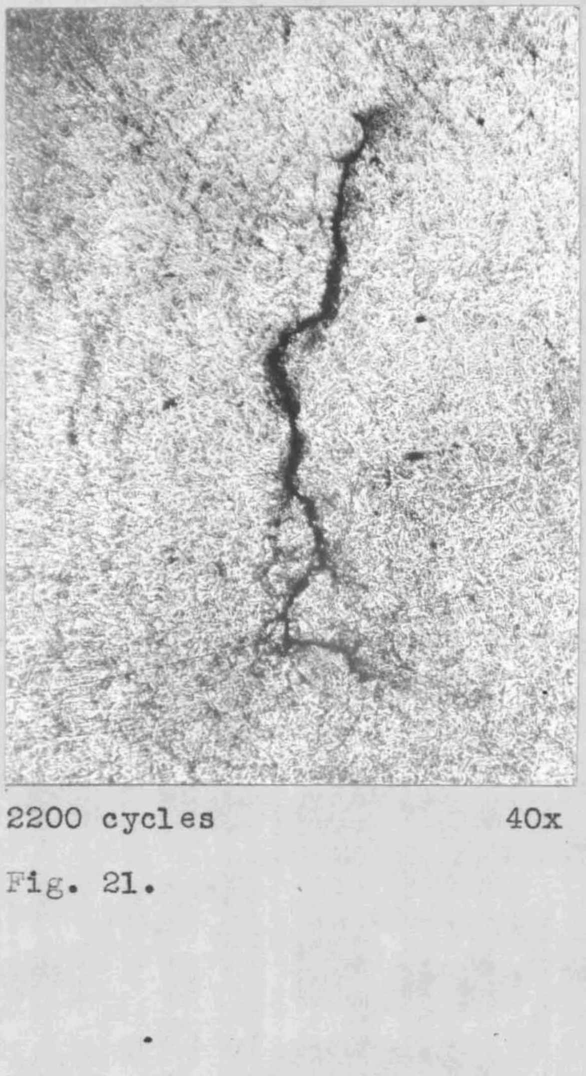
Fig. 18.

1727 cycles 40x

Fig. 19.

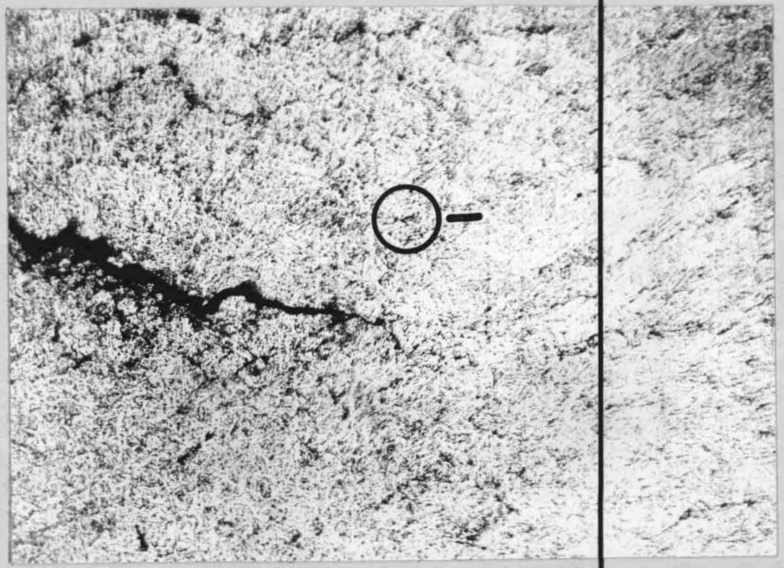
1957 cycles 40x

Fig. 20.



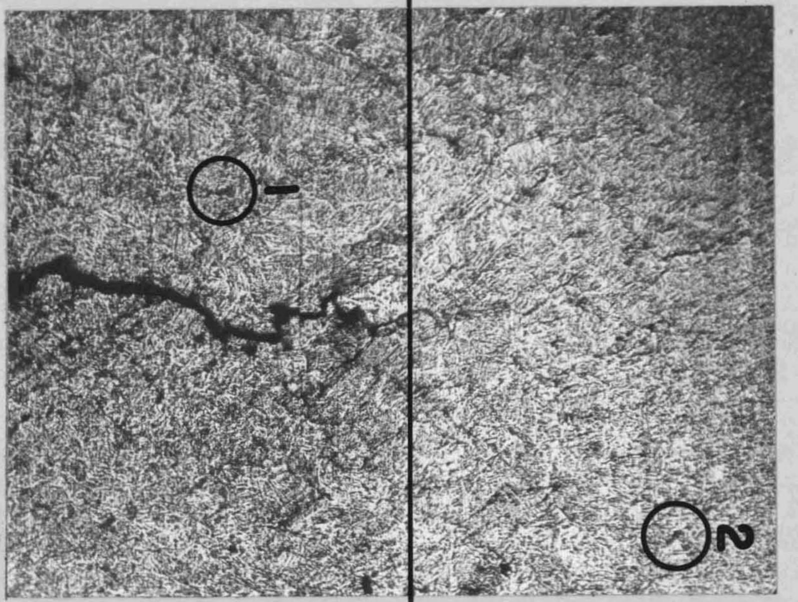
2200 cycles 40x

Fig. 21.



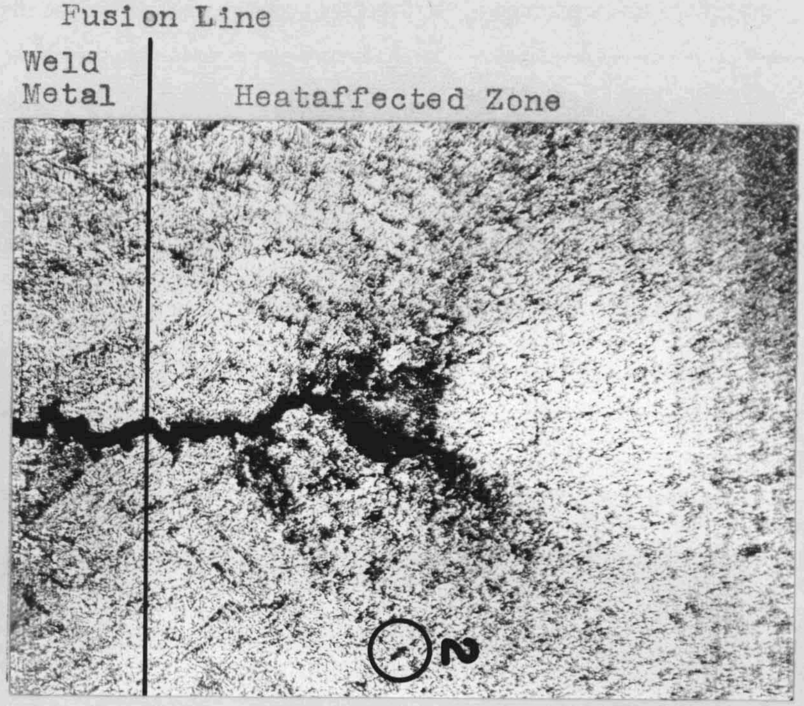
4788 cycles 40x

Fig. 22.



4970 cycles 40x

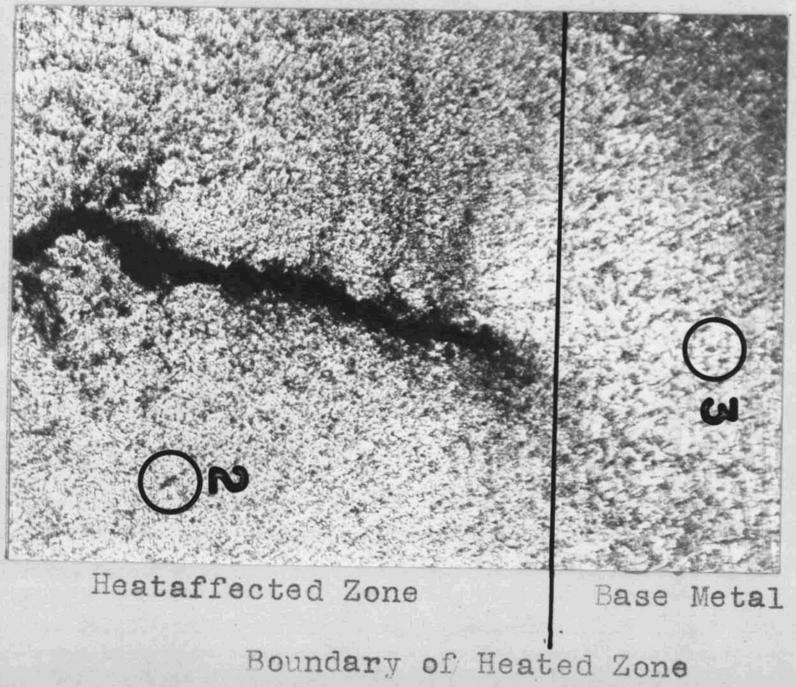
Fig. 23.



5661 cycles

Fig. 24.

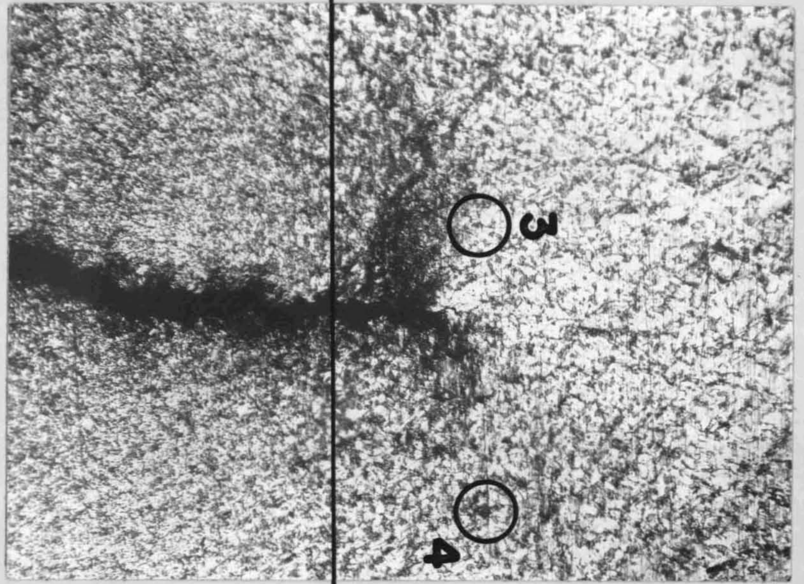
40x



5978 cycles

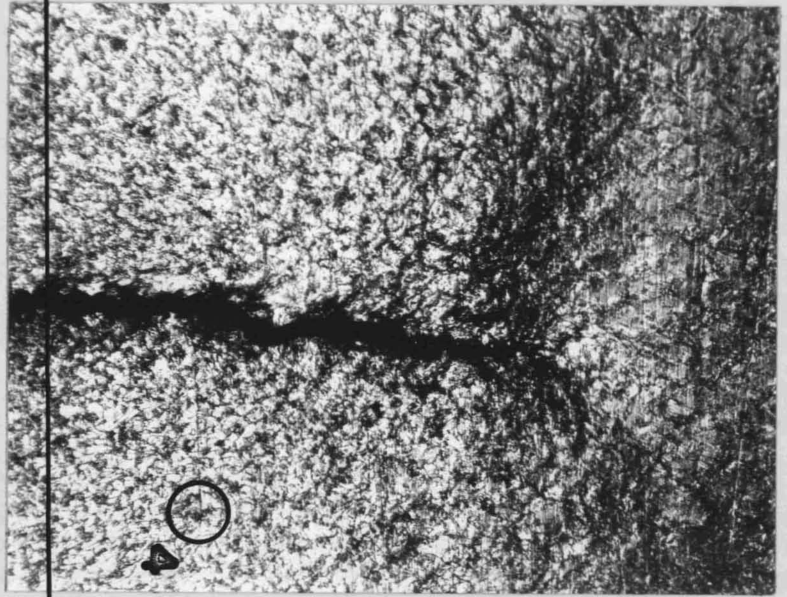
Fig. 25.

40x



6212 cycles 40x

Fig. 26.



6491 cycles 40x

Fig. 27

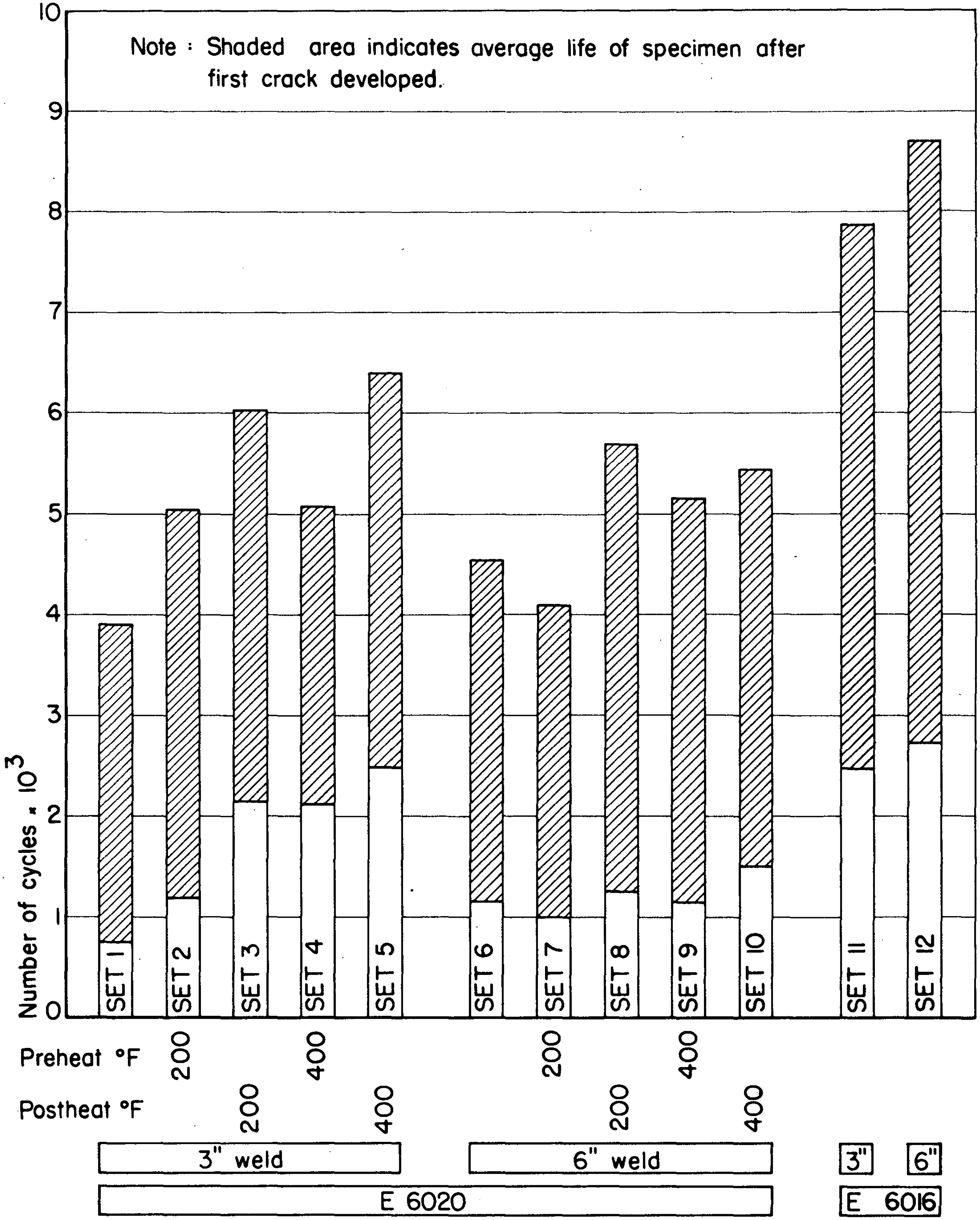


FIG. 28. SUMMARY OF REPEATED LOAD TESTS.

List of References

Vita

(pages 48 - 49)

LIST OF REFERENCES

(1) Flanigan, A. E.
Bocarsky, S. I.
McGuire, G. B.
"Effect of Low-Temperature Cooling Rate on the Ductility of Arc Welds in Mild Steel"

(2) Osborn, C. J.
Scotchbrook, A. F.
Stout, R. D.
Johnston, B. G.
"Composition and Property Variation of Two Steels"

(3) Tör, S. S.
Ruzek, J. M.
Stout, R. D.
"Repeated Load Tests on Welded and Prestrained Steels"

VITA

The author was born as the second child of Jan and Frantiska Ruzek on March 30, 1915 in Pisek, Bohemia, Czechoslovakia. He entered the Czech Technical University in Prague, Czechoslovakia in September 1933, and graduated in June 1939 with a diploma in civil engineering.

During 1938 - 1942 he worked as a research assistant in the Research Institute of the Technical University in Prague under Professor Dr. F. Klokner. From 1942 to 1946 he worked at the SKODA - Works in Pilsen in the Central Welding Department, at first as a welding engineer and later as chief welding engineer. In the year 1943 he took a leave of absence and entered the Technical University of Vienna. He graduated in welding engineering. In the year 1943 he was awarded professional degree in civil engineering.

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