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METALLURGICAL EXAMINATION OF A "CHASE"-TYPE LITHOGRAPHIC FRAME FROM THE CANADIAN GOVERNMENT PRINTING BUREAU

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

The frame was manufactured by butting and flash welding or upset resistance welding at each of the four corners. The cross piece at the middle of the frame was dovetailed at each end and fusion welded at the joints in the plane of each surface of the plate.

The different sections, consisting of semi-killed steel, containing approximately 0.18% C and 0.04% Si, were similar but not identical.

High tensile and yield strengths indicated that the material had been cold rolled.

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INTRODUCTION

On January 20, 1970, a memorandum was received from Mr. V. A. Haw, Chief, Mineral Sciences Division, Mines Branch, Department of Energy, Mines and Resources, requesting the assistance of the Physical Metallurgy Division concerning a "Chase" that had been submitted by Mr. E. H. Wise of the Canadian Government Printing Bureau, to the Mineral Sciences Division. Chemical analyses, material identification, and a determination of the methods of fabricating the "Chase" were requested.

VISUAL EXAMINATION

The "Chase" is shown in Figure 1. The holes had been drilled in the frame to obtain the material required for a chemical analysis.

CHEMICAL COMPOSITION

The chemical composition of the frame was determined and reported in Mineral Sciences Division Test Report MS-AC-70-41. The results listed in the following Table represent material from two sections of the frame which were assumed to be parts of one plate at the time of drilling. It was subsequently shown that they were not identical.

CHEMICAL COMPOSITION (PER CENT)

Element	"Chase"	SAE 1018
Carbon	0.17	0.15-0.20
Manganese	0.78	0.60-0.90
Silicon	0.04	-
Phosphorus	0.014	0.040 max
Sulphur	0.049	0.050 max
Copper	0.06	-
Nickel	<0.02	-

The chemical composition conforms to an SAE 1018 grade of semi-killed steel. The composition represents a blend of two melts of a similar grade of steel.

SPECTROGRAPHIC ANALYSIS

Spectrographic analysis was carried out on pieces from members AB and BC. The results reported in Mineral Sciences Division Internal Report MS-AC-70-47 are listed below:

Composition, Per Cent

Element	AB	BC
Sulphur	0.025	0.021
Phosphorus	0.012	0.007
Silicon	<0.03	<0.03
Manganese	0.76	0.78
Nickel	0.018	0.028
Chromium	0.035	0.028
Molybdenum	0.013	0.016
Vanadium	ND	ND
Niobium	ND	ND
Tin	0.013	0.020
Copper	0.018	0.125

The elements shown by these analyses, when considered with the 0.17% C shown under "Chemical Composition", are consistent with a steel similar to a semi-killed SAE 1018 grade. However, they show also, that sections of the frame, AB and BC, are slightly different in composition and therefore do not come from the same original plate or melt of steel.

RADIOGRAPHIC EXAMINATION

X-ray radiographs were taken at the six corner locations A to F inclusive, indicated on the sketch in Figure 2. No evidence of porosity or slag inclusions was found at corner locations A, B, D or E. A small crack indication, as shown in Figure 3, was found at the inside corner of each of these locations.

The radiographs taken at C and F show that the middle member of the frame had been dovetailed to fit into members AE and BD. The radiograph at C, shown in Figure 4, is similar to that at F.

The presence of the light outline around the dovetail indicated lower-density regions. This observation, as well as the presence of porosity at the dovetail, indicated that the middle members were thinner at the dovetail ends, and that metal-arc welding had been used to fuse the members together, and to permit obtaining flush surfaces after grinding.

MAGNETIC PARTICLE INSPECTION

Magnetic-particle inspection confirmed the presence of the discontinuities or cracks that were located by the radiographic examination.

HARDNESS TESTS

Readings obtained, using the Rockwell tester, showed a hardness on the Rockwell "B" scale of 92 on a cross section through member BC remote from any corners.

A hardness survey of the fusion weld at the dovetail joint in member FC, shown in Figure 8, gave the following Rockwell B hardness values.

Weld Metal	94
Fusion Line	96
Heat-Affected Zone	85-92
Base Metal	92

These hardness values showed that the weld metal could have approximately the same hardness as the cold-worked base metal and that there had been a slight softening in the heat-affected zone due to annealing of the cold-worked material.

MECHANICAL TESTING

Tensile tests were conducted on one specimen from AB and two from BC, one as received, and one after a normalizing heat treatment. The results are tabulated below:

Tensile Properties

Specimen	UTS, kpsi	Yield, 0.2% Offset	% El.	% RA	Hardness Rockwell B
AB	81.6	77.6	17	60	87.5
BC	101.0	97.4	13	46	94.5
BC (normalized)	73.6	42.0	31	61	84.5

A normalizing treatment altered the properties to resemble those of an SAE 1018 composition in a similar condition and, together with the hardness evaluation, confirmed that the high mechanical properties were obtained by cold rolling.

METALLOGRAPHIC EXAMINATION

Each of the corners A, B, D and E was polished with grit #2 emery paper and etched with a 2% nital solution. The appearance of the etched surface revealed the orientation of the different members of the frame as well as supplying further evidence that they had been flash or upset resistance welded. A photograph of location B is shown in Figure 5. To explore this evidence further, a micro-specimen was cut at corner A, Figure 2, and polished. This is shown in Figures 6(a) and 6(b). The appearances and the dimensions of the inclusions show that they are longitudinal in part of the specimen and transverse in the other. This indicates that two pieces of material were joined at right angles to one another.

A micro-specimen from corner B was polished and etched to permit viewing the apparent crack as oriented in Figure 3. This revealed that the crack actually resulted from a lack of fusion of the plates at the inner corner for a distance of 0.25 in.

Beyond that point the metal had fused properly. This is illustrated in Figure 7.

A micro-specimen, from location C, Figure 2, was prepared and etched in nital to show the fusion weld joining members DB and FC at the dovetail joint. This section of the joint is illustrated in Figure 8.

A transverse specimen from member BC was polished and etched in 2% nital. This procedure showed that the micro-structure Figure 9, was composed of ferrite and pearlite, and was consistent with an SAE 1018 grade of steel. Although cold work was not evident in the micro-structure, the degree of cold work required to provide those tensile properties obtained might not be visually detectable.

SUMMARY AND CONCLUSIONS

The steel conformed to SAE 1018 semi-killed plain carbon steel. The plate sections that were analyzed consisted of semi-killed steel containing approximately 0.18% C, 0.8% Mn and 0.04% Si. They consisted of similar but not identical material, which indicated that they originated from different melts of steel. The plates had been cold rolled to provide the yield- and tensile-strength levels obtained in the tensile tests.

The "Chase" type frame was manufactured by butting and flash welding or upset resistance welding at each of the locations A, B, D and E shown in Figures 1 and 2.

Due to the rapid cycle of heating and cooling in flash welding or upset resistance welding, it is expected that loss of the strength of the steel imparted by cold working would be minimal. It is suggested that, if attempts are made to fabricate frames employing cold-worked steel and arc-welding processes, care must be taken to minimize heating of the cold-worked steels. This implies making small, low-energy input, welds, and letting the joint areas cool down to room temperature between each individual weld pass.

If replacement frames must be made employing arc welding rather than flash or upset resistance welding and if it is found that too much reduction of strength occurs in cold-worked steels, then consideration might be given to manufacturing frames from quenched and tempered steels and compatible high-strength electrodes. Material costs would be higher than for cold-worked materials.

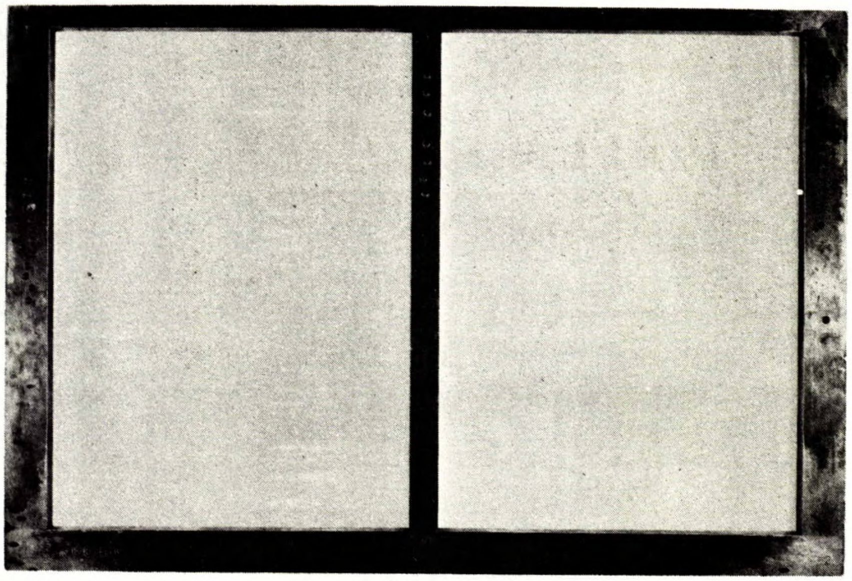
The cross piece at the middle of the frame was joined by means of a dovetail joint at each end and fusion welding, as shown in Figures 4 and 8. The fusion was made at the joints in the planes of the plate.

The dovetail joint, although evidently satisfactory, could be strengthened somewhat by having a greater depth of weld deposit at the line of interface of the dovetail.

ACKNOWLEDGEMENT

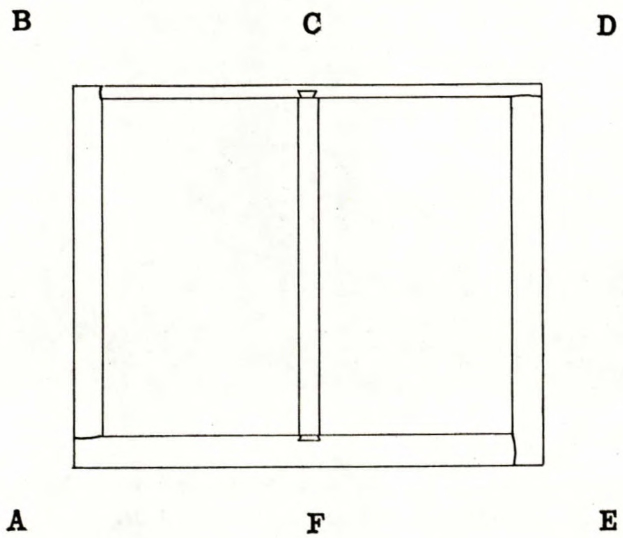
The assistance is acknowledged of Mr. W. P. Campbell, Welding Section, concerning welding aspects of this investigation.

RDMcD/GDA/sg



As received Approx. X1/8

Figure 1. "Chase" as received



Approx. X1/10

Figure 2. Sketch of "Chase" illustrating the locations of flash welds at corners and fusion welds at dovetail joints on the cross member.

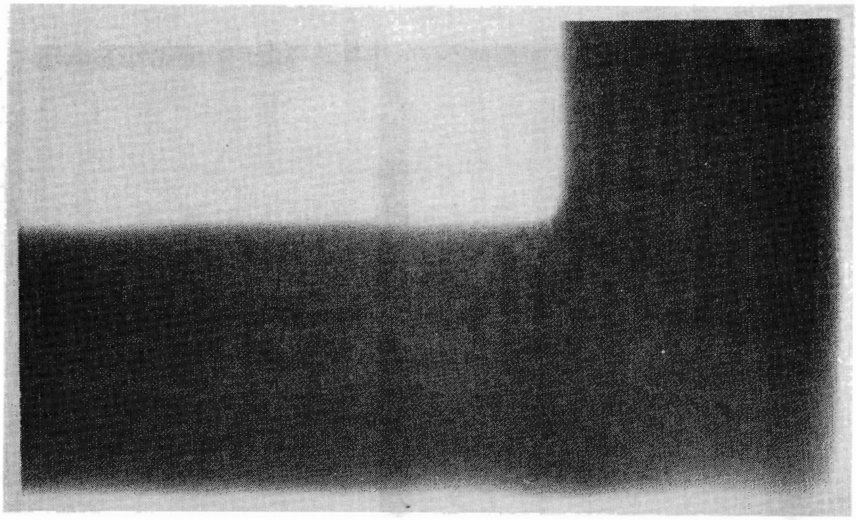


Figure 3. Radiograph of area around location A, showing evidence of crack.

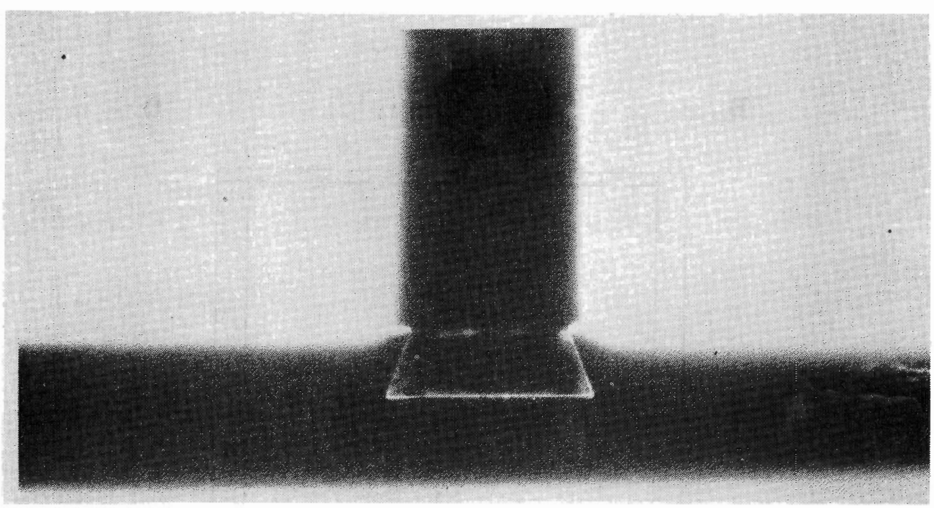


Figure 4. Radiograph of area around location C, showing dovetail construction.

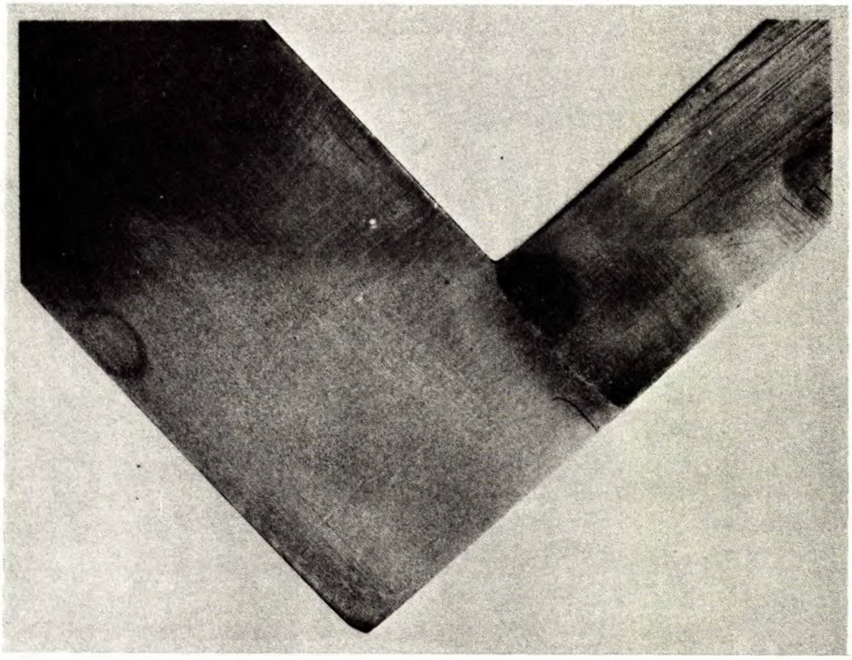
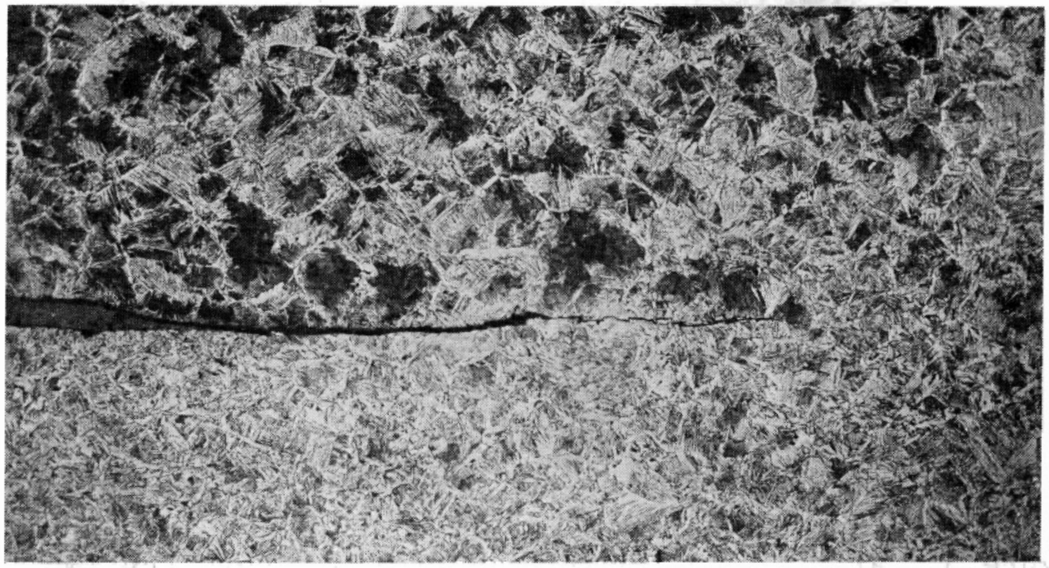


Figure 5. Area around location B showing where the two pieces were butted and flash welded. The surface was ground and etched 15 sec in 2% nital.

Figure 6(a). X100

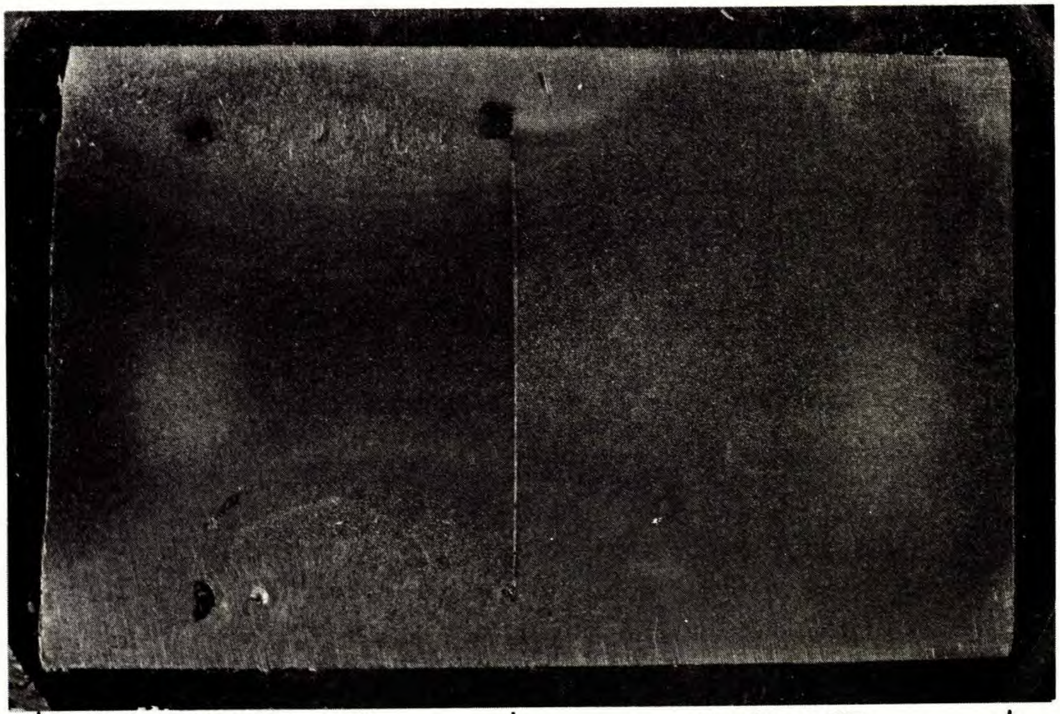
Figure 6(b). X100

Photomicrographs taken on the same surface of a specimen from the area around location A. The orientation of the inclusions shows that there were two pieces of material welded together at right angles.



Etched 15 sec in 2% nital. X50

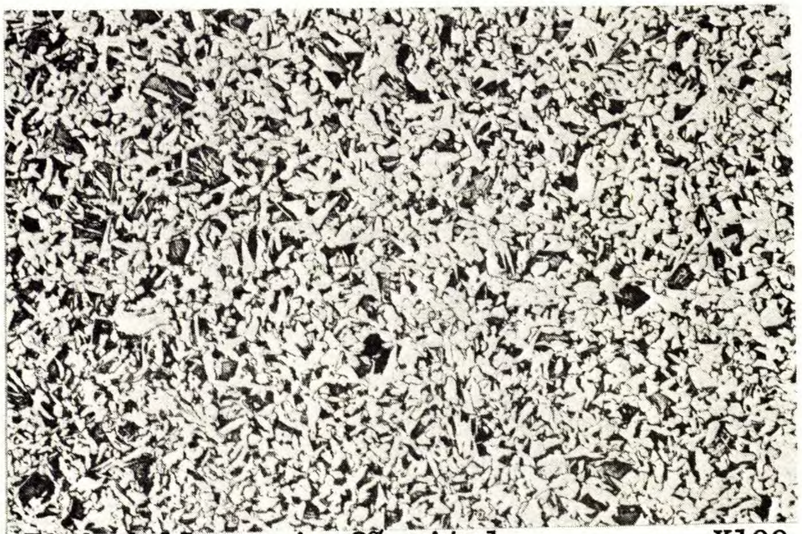
Figure 7. Partial lack of fusion in weld area of corner B.



Member FC | Member DB

Etched 20 sec in 2% nital.

Figure 8. Section through plate thickness cut in the FC direction, showing the fusion weld at the dovetail joint of members FC and DB.



Etched 15 sec in 2% nital. X100

Figure 9. Microstructure of base metal consisting of dark pearlite and light ferrite grains.