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NATIONAL BUREAU OF STANDARDS REPORT

9829

EXAMINATION OF STOCK POD SECURITY CHAIN

To

Bureau of Research and Engineering
U. S. Post Office Department
Washington, D. C.



U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

Examination of Stock POD Security Chain

Reference: (a) Post Office Department, Bureau of Research and Engineering, letter dated February 15, 1968, RE-17-68(R).

Introduction: A 2 ft (approx.) length of zinc-coated stock POD security chain was submitted under Reference (a). It was requested that an investigation be initiated to establish the reason for the low impact resistance of this type of chain.

Specific requirements for this chain are that it be in accordance with Federal Specification RR-C-271a for a Type I, Grade C, Class 4, welded steel proof coil chain. Other requirements are that it shall be zinc coated, case hardened to a depth of no less than 0.005 inch and shall be file hard. The nominal (trade) size shall be 3/8" and shall conform to the dimensions and physical requirements shown in Table VII of Federal Specification RR-C-271a.

Mechanical Properties: A one foot length of chain was loaded in tension to a proof load of 3720 pounds. The load was removed and the links were examined for indications of failure as outlined in paragraph 4.4.1.4 of Federal Specification RR-C-271a; there were no failures. The load was reapplied and increased until failure of the chain had occurred. This load (breaking load) was 8,240 pounds. The specification requirement for 3/8 inch nominal (trade) size of chain is 7,440 pounds minimum. Fracture occurred at two areas on the fifth link of the ten link segment. All of the links except one contained secondary cracks at the ends of the links. There were no cracks at the weld areas on any of the links.

An additional tensile test, not required for specification purposes, was performed on a single link in order to determine the ductility of the weld. The link was cut through on the side opposite the weld. A tensile load was applied to the link and was increased until fracture occurred at a load of 2210 pounds. A sudden decrease in load was noted when the applied load reached 1700 pounds. This was believed to be the yield load or the load required to produce initial cracking. There were no failures in the weld area, but secondary cracks were observed at areas on each side of the weld approximately 1/4 inch from the weld. Fracture occurred at an area approximately 1/2 inch from the weld.

The fracture surfaces on all of the broken links had a granular (cleavage) appearance and there was no indication of a reduction in area at the fracture. This indicates that the links failed in a brittle manner.

A compression (or crushing) test was performed on a single link. The link was placed on one edge between two rams and a compressive load was applied. This load was increased until fracture occurred. A sudden decrease of load at 5580 pounds indicated that cracking had initiated or that the yield load had been reached. Fracture occurred at 8,380 pounds at both ends of the link; secondary cracks and partial fractures were noted at the weld area and at the opposite edge. Examination of the areas where complete fracture was noted, revealed that they were also of a brittle nature.

Chemical Analyses: Sections were cut from two different chain links for chemical analysis of the carbon content in the core areas of the steel. The results of these analyses, based on the average of duplicate determinations, showed that the carbon content of the steel was 0.05%. Federal Specification RR-C-271a requires that the chemical composition of the steel be no greater than 0.35%. There is no minimum requirement.

Metallographic Examination and Hardness Tests: One link was sectioned and prepared for metallographic examination. The depth of the carburized case was found to be approximately 0.04 inch. Figure 1 shows the gradation of the carbon penetration from the outer edge, where it is at a maximum, to the core where it approaches the carbon content of the carbon steel used in the fabrication of the chain. Examination of the microstructure at a higher magnification (figure 2) revealed the following microstructural conditions:

- a. Tempered martensite plates (dark needlelike structures).
- b. Untempered martensite (light gray areas).
- c. Nodular pearlite (dark gray areas).
- d. Cementite at the grain boundaries.
- e. Large prior austenitic grain size as indicated by the size of the tempered martensite plates and the boundaries outlined by cementite.

This structure, because of conditions b, d, and e above, would tend to be brittle. We believe it was produced by quenching the chain directly from the carburizing temperature without a subsequent tempering treatment. The long length of time or high temperature required to carburize to a 0.04 inch depth would have produced the large austenite grains. A delay in quenching or cooling at a rate less than the critical cooling rate could produce cementite boundaries and pearlite. The darkened martensite plates indicate that the initial martensite was formed at high temperatures and was tempered during the cool down, rather than during a subsequent tempering treatment. The fact that the smaller martensitic areas appear untempered indicates that no adequate tempering treatment was applied after cool down.

Microhardness determinations (KHN (500 gr.)) were obtained at several areas across the approximate center of the cross section. These determinations converted to approximately equivalent Rockwell hardness values revealed: (1) the hardness of the outer case area was R_C 63-64; (2) the hardness of the intermediate zone between the outer case and the core was R_C 50 at the extreme outside to R_C 33 adjacent to the core; and (3) the hardness of the core was R_B 78-79. Specifications require only that the chain be file hard. In this respect the carburized case was resistant to abrasion by a file.

Reheating, Hardening and Tempering: Since the results obtained from the above tests and examinations showed that the carburized case was excessively brittle, an experiment was conducted to determine if additional heat treatment would improve the ductility of the case without significant decrease in hardness. Specimens were stripped of the zinc coating by immersion in a 1:1 hydrochloric acid solution, rinsed and dried. They were then heated to 1425°F for 20 minutes, quenched in water, tempered for 1 1/2 hours at 350°F and air cooled.

Metallographic examination of the case in a section cut from one of the specimens (figures 3 and 4) revealed that the grain had been refined considerably, with the result that all martensite present had fine plate size. There was no evidence of cementite at grain boundaries; instead it was dispersed as fine spheroids. Nor was there any trace of pearlite. All of the martensite appeared uniformly tempered. A comparison of figures 2 and 4, both at the same magnification, strikingly reveals the improvement brought about in the structure by this heat treatment. Microhardness determinations were obtained for comparison with those obtained for the stock POD security chain. The hardness at the surface was R_C 63-64. This is sufficiently hard to resist the abrasive action of a file.

A compression test was performed on a half link which had been given the additional heat treatment. In contrast to the behavior of the stock POD security chain, this specimen showed a significant amount of ductility as indicated by the slow decrease in load from the time cracks were initiated until complete fracture occurred. There was no evidence of a granular appearance on the fracture surface.

Conclusions: The results obtained from an examination of stock POD security chain revealed that it met the requirements as set forth in Federal Specification RR-C-271a for a Type I, Grade C, Class 4, welded steel proof coil chain and the additional requirements as specified by the Post Office Department.

However, it was determined that the stock chain was susceptible to failure due to the extreme brittleness of the carburized case. In order to improve the ductility without decreasing the hardness, it is recommended that the chain be given an additional heat treatment after carburization. This should consist of reheating to a temperature of 1425°F, holding at this temperature for one-half hour and then quenching immediately in water. Care should be taken to prevent surface decarburization. Hardening should be followed by tempering at 350°F for 1 1/2 hours.

It should also be possible to improve toughness by decreasing the thickness of the case. Since a minimum case thickness of 0.005 inch is required, it seems unnecessary to have a case thickness of 0.04 inch. It is the purpose of the case to supply sufficient hardness so as to resist cutting by a saw. The core, on the other hand is designed to support the case and provide toughness. Even though the suggested heat treatment improves the toughness of the case considerably, the core is still the principal toughness contributor and therefore reducing its area by increasing the amount of case would normally be detrimental in a situation where brittleness is a problem. A thinner case would resist sawing equally as well but for not as long.

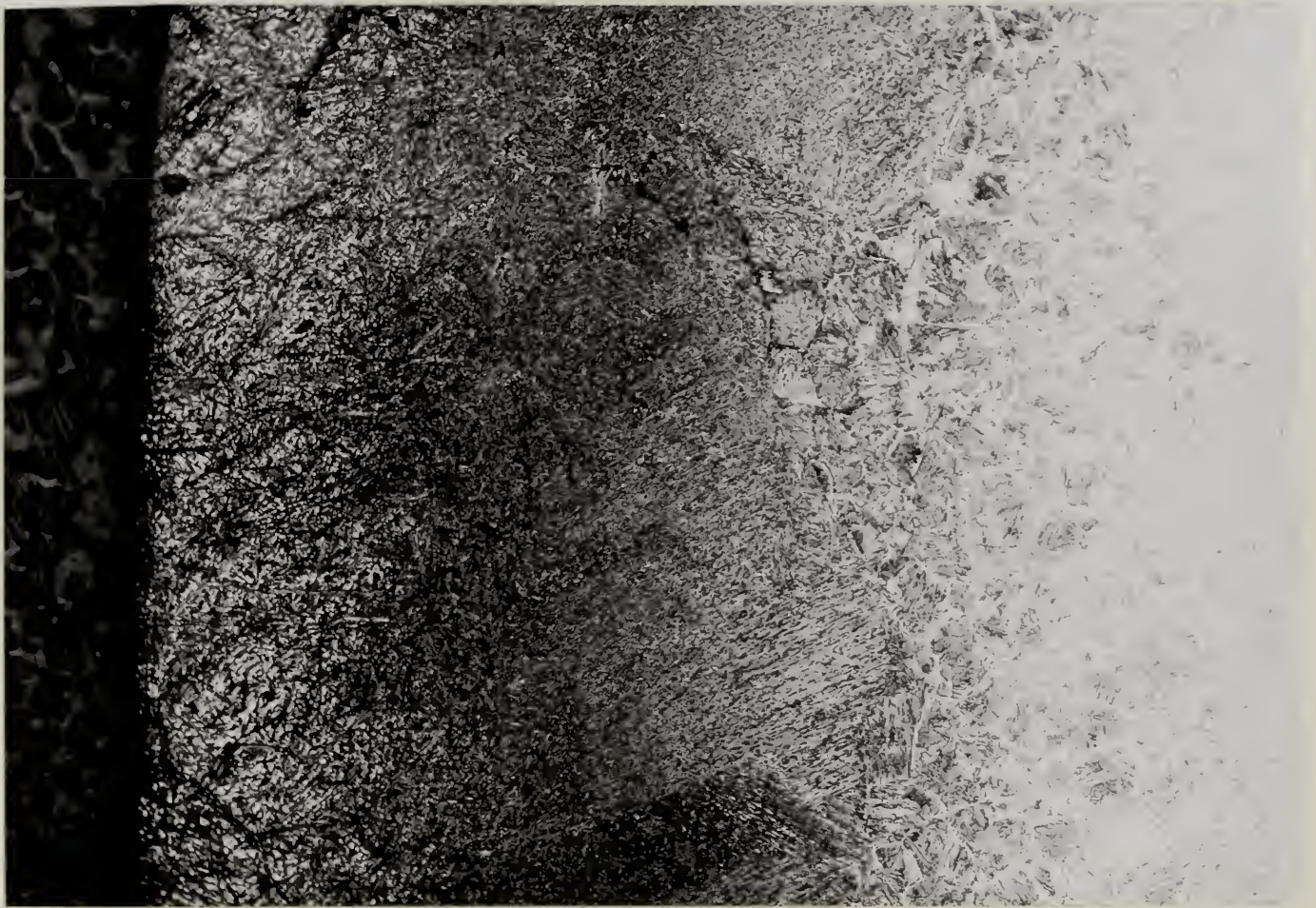


Figure 1. Microstructure of a section from a stock POD security chain link. Carburized case is approximately 0.04 inch thick. Photomicrograph shows the gradation of the carbon penetration from the outer edge (darker area) where it is at a maximum to the lighter etching core area where it is at a minimum approaching the carbon content of the core. Etched with nital. X 100.

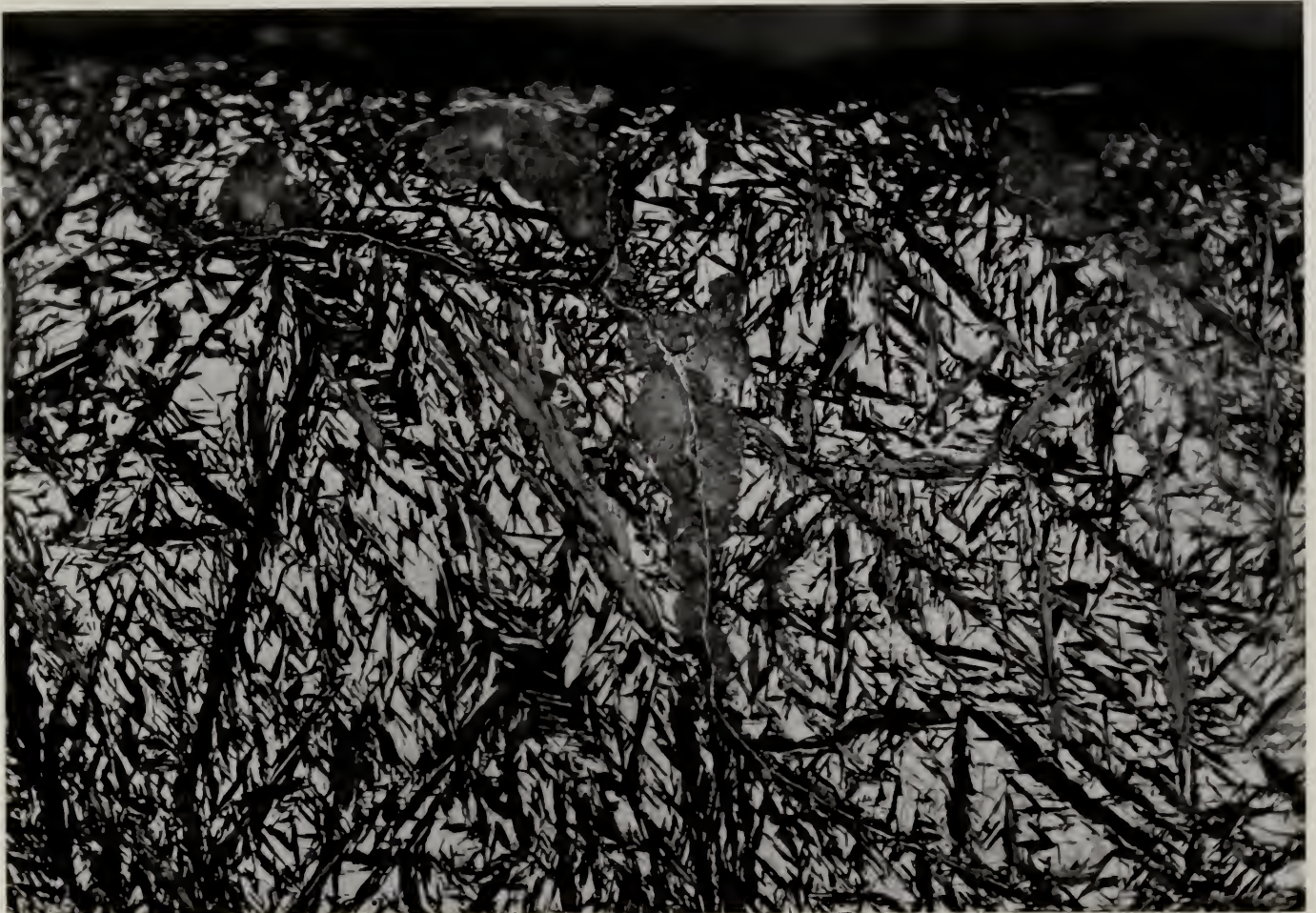


Figure 2. A portion of the area shown in Figure 1 showing the following conditions: (a) tempered martensite plates (dark needlelike structures), (b) untempered martensite (light gray areas), (c) nodular pearlite (dark gray areas), (d) cementite at the grain boundaries and (e) large prior austenitic grain size as indicated by the size of the tempered martensite plates and the boundaries outlined by cementite. Etched with nital. X 500.

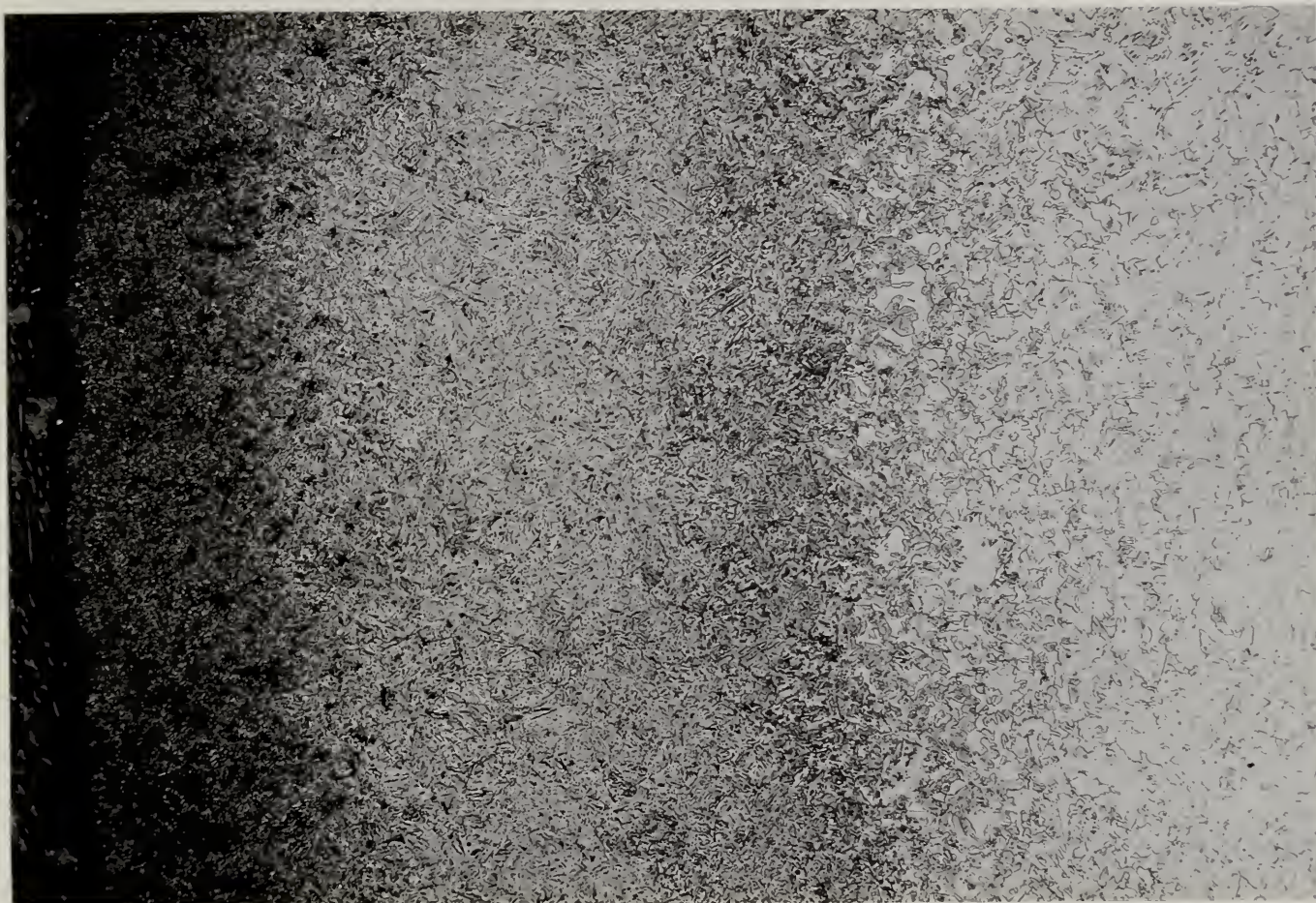


Figure 3. Microstructure of stock POD security chain after (1) reheating to 1425°F for 20 minutes and water quench and (2) tempering for 1 1/2 hours at 350°F and air cool. Matrix of carburized case is tempered martensite with some small particles (not visible at this magnification) of Fe₃C. Core matrix is ferrite with some pearlite. Etched with nital. X 100.



Figure 4. Portion of carburized case area of stock POD security chain after additional heat treatments noted in Figure 3. Grain size is very fine. Spherodized particles of Fe_3C are scattered throughout the martensite matrix. Etched with nital. X 500.

