NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT 3120546 | JUN 10 1970 | NBS REPORT 9981

METALLURGICAL EXAMINATION AND MECHANICAL TESTS OF MATERIAL FROM THE POINT PLEASANT, W. VA. BRIDGE

Part 5

By

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To

Bureau of Public Roads
Federal Highway Administration
Department of Transportation

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

Metallurgical Examination and Mechanical Tests of
Material from the Point Pleasant, W. Va. Bridge

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Four reports have been prepared previously in this series on the results of investigations at NBS on material from the Point Pleasant, West Virginia Bridge. Each of the four reports has been concerned with the examination of selected items salvaged from the bridge. The submitting agency requested an examination involving chemical analysis and tensile and notch impact tests on one of five hanger fragments shipped to NBS. The fragments numbered 12C, 12U, 14U, 14C, and 16U, respectively, contained a fracture surface on one end and were flame-cut on the other. All five fragments showed evidence of twisting or bending. Fragment 12C was selected for the aforementioned tests because it was least deformed. Paint was observed on what appeared to be the fracture origin in 12C. The submitting agency, thereupon, requested additional work on the fragment. The additional work included an analysis of the paint at the fracture origin, analysis of the fracture, and metallographic examination of the 12C material. The paint analysis was performed by the FBI laboratory because of the capability of that Laboratory for conducting the unique type of analysis required.

Material: Fragment No. 12C (Bridge Member C_{17}-$U_{17}N$), shown in Figure 1, was approximately 1 1/4 in. X 6 in. X 24 in., as received. It was quite rusted on all surfaces. There were, however, vestiges of an orange colored paint and of an aluminum paint on the sides of the piece. All specimens for mechanical tests were removed from the fragment in a section extending from about three inches from the fracture surface to about four inches from the flame-cut end. A section was cut from 12C that contained the fracture surface. It is shown in Figures 2a and 2b.

Chemical Analysis: The results of a chemical analysis conducted by the NBS Analytical Chemistry Division on a sample from 12C are given in Table 1.

Table 1. Chemical Analysis of 12C

	%
Carbon	0.26
Manganese	0.74
Sulfur	0.035
Phosphorus	0.038
Silicon	< 0.08
Nickel	< 0.08
Chromium	< 0.08
Molybdenum	< 0.08
Iron	Balance

The composition of the sample complies with that specified for structural steel, ASTM A7-24.

Tension Tests: Tension tests were conducted on hanger 12C specimens whose principal axes were aligned parallel to the rolling direction of the hanger and at right angles to the rolling direction. Due to material limitations it was not feasible to prepare specimens for tests in the larger size specified in ASTM A7-24. Accordingly, tension tests were conducted on sub-sized specimens with a 0.252 inch diameter and one inch gage length in the reduced section. Tensile test results are given in Table 2.

Charpy Impact Tests: Charpy V-notch impact tests were conducted on both longitudinal and transverse specimens cut from the 12C section. The impact tests were conducted at temperatures ranging from 0 to 250 F. Test results are given in Table 3.

Fracture Examination: Various features in the fracture surface and adjoining areas of the 12C fragment are shown in Figures 2a, 2b, 3a, and 3b. Figure 2a is a head-on view of the fracture surface. The fracture origin is within the boxed area. Orange colored paint was visible on the fracture surface in this area. Arrow, A, points to the battered south-west corner of 12C adjacent to the fracture origin. Arrow, B, points to a secondary crack observed in the fracture surface. This crack was about one-half inch long on the surface and it penetrated the examination section. Figure 2b contains an oblique view of the fracture surface. Vestiges of lead and aluminum bridge paint adjacent to the fracture are visible as grey and white indications, respectively, to the left of the inscription.

The fracture surface at the origin was a relatively flat area about the size of a thumb nail. The remainder of the fracture surface was hackly. The plane of the fracture was oriented at approximately 76 degrees from the longitudinal axis of the hanger, Figure 3a. Appreciable necking of the hanger occurred prior to fracture (see Figure 3b).

Metallographic Examination: The microstructure of the 12C hanger material was examined at several points along the fracture profile and in areas adjacent to the fracture surface. Decarburization and deformation were observed at the fracture origin, Figure 4a. Continuous cleavage of grains predominated in the section of the fracture profile containing lead, and beyond, (see Figure 4b). Secondary cracks were observed adjacent to the fracture surface approximately one inch from the origin, Figures 5a and 5b. In examination of the structure at mid-section the following were observed:

a. Discontinuous cleavage, Figure 6a.

b. Additional secondary cracks, Figure 6b.

c. Propagation of the secondary crack of Figure 2a through a ferrite band, Figure 7.

Analysis of Paint on Fracture Surface: The FBI Laboratory report covering the analysis of the paint at the fracture origin in hanger 12C is contained as Addendum 1 to this report. The FBI Laboratory examination was nondestructive.

Discussion and Conclusions: ASTM A7-24 lists only sulfur and phosphorus requirements. The contents of these elements in hanger 12C are less than the maxima permitted in that standard. Accordingly, the chemical composition of 12C complies with composition requirements specified in ASTM A7-24.

The tensile properties: yield strength, tensile strength, percent elongation and reduction of area comply essentially with ASTM A7-24 requirements. Longitudinal yield strength and tensile strength were substantially greater than transverse yield strength and tensile strength, respectively. The 12C hanger fragment was received in a twisted condition and evidently had been subjected to plastic deformation. The 12C hanger was designed to carry tensile loads. If direct tensile loads at some time contributed to extension and plastic deformation of the member, the disparity between longitudinal and transverse values may be attributed to the Bauschinger effect. The Bauschinger effect is the phenomenon by which plastic deformation of a polycrystalline metal, caused by stress applied in one direction, reduces the yield strength where the stress is applied in the opposite direction.

The hanger material exhibited very low notch toughness at 30 F, the approximate temperature at the time of the bridge collapse. The low notch toughness is attributed primarily to the coarse grain size found in the material.

Several detrimental structural conditions which could weaken the hanger were observed in metallurgical examination of the 12C material. These included the following:

a. Decarburization on the side where the fracture originated.

b. Non-uniform microstructure. A medium-sized grain structure consisting of pearlite in a ferrite matrix in outer areas of the hanger section gave way to coarse grains in a ferrite network in the interior of the section.

c. A ferrite band extended longitudinally through the middle of the hanger.

It is believed that a crack was formed at what was later to become the fracture origin during fabrication of the hanger. The crack could have resulted from hot shortness of the material. The existence of a pre-existent crack at the fracture origin may be inferred from the FBI report. In this report lead paint found at the fracture origin was considered to have been deposited wet. This would indicate the presence of a pre-existent crack.

The presence of continuous cleavage throughout a great part of the fracture surface and the presence of secondary cracks adjacent to the main fracture path would seem to indicate that a high energy type of fracture occurred. Torsional or bending stresses were evidently involved. This is indicated by the twisted nature of the fragment. The pre-existing, lead-containing crack, in the 12C hanger was a stress raiser that contributed to initiation of the fracture.

Table 2. Results of Tension Tests on 12C Hanger Material

Item	Specimen No.	Specimen Orientation	Yield Point ksi	Yield Strength 0.2% Offset, ksi	Tensile Strength ksi	Elongation in 1 inch %	Reduction of Area, %
12C Hanger	L1	longitudinal		46.4	71.0	32	61
	L2	"		40.6	70.6	33	62
	L3	"		43.5	69.6	33	62
	Average	"		43.5	70.4	33	62
	T1	transverse		37.2	67.3	28	56
	T2	"		35.3	66.5	30	50
	T3	"		36.9	67.3	32	52
	Average	"		36.5	67.0	30	53
Specified, Structural Steel, ASTM A7-24	-	longitudinal	30.0 min.	-	55-65[a]	22 min. in 2 inch	-

a Minimum depending on range of specimens tested. Specimen range not to exceed 14.0 ksi maximum and individual specimen maximum in range not to exceed 74.0 ksi.

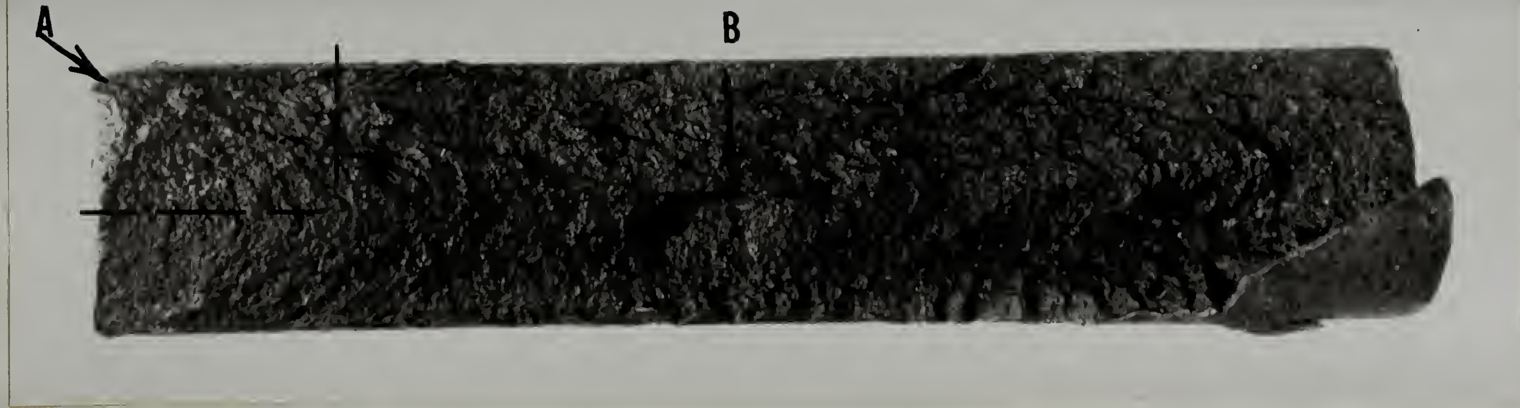
Table 3. Charpy V-notch Impact Test Results

	Test Temperature, F										
	0	32	75	100	125	145	165	190	212	230	250
	Longitudinal Specimens										
1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
2	2	3	7.5	13	37.5	47	54	59.5	71.5	75.5	82.5
3	0	0	5	15	40	60	75	80	95	95	100
4	1	3	10	23	41	46	48	61	70	71	74
	Transverse Specimens										
1	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
2	2.0	4.5	8	17	21.5	24.5	29	31	34.5	32	36
3	0	0	10	15	45	50	65	85	90	100	100
4	1	6	12	22	28	33	38	44	46	47	47

Code

1. Specimen no.
2. Impact Energy, ft lb
3. Percent Shear
4. Lateral Expansion, 10^{-3} in.

Figure 1. Hanger fragment 12C (Bridge Member C_{17}-$U_{17}N$) as-received. Approx. 1/3 X



a

b

Figure 2. Features observed on fracture surface and adjacent areas of fragment from hanger 12C. Approx. 1 X

a. Fracture origin is shown within boxed area. Arrow, A, points to battered south-west corner of 12C adjacent to fracture origin. Arrow, B, points to secondary crack.

b. Oblique view of fracture surface. Vestiges of bridge paint are shown to left of inscription; lead paint appearing grey, aluminum paint, white.

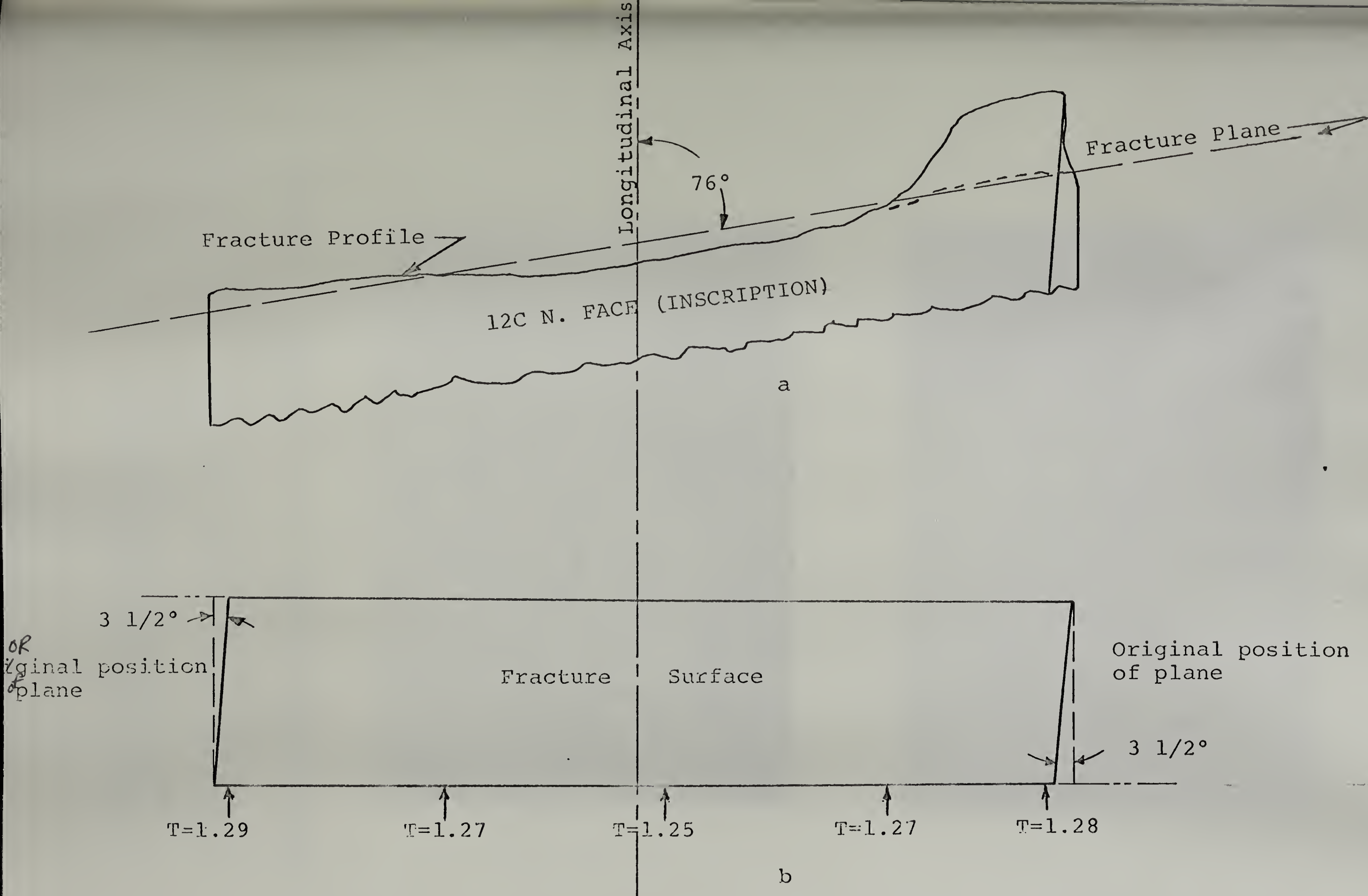
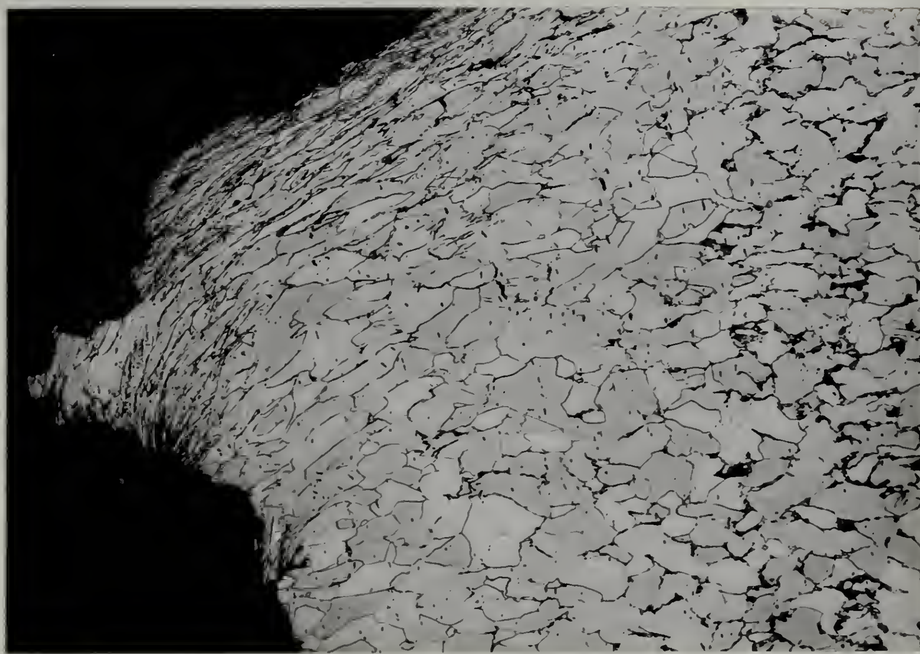
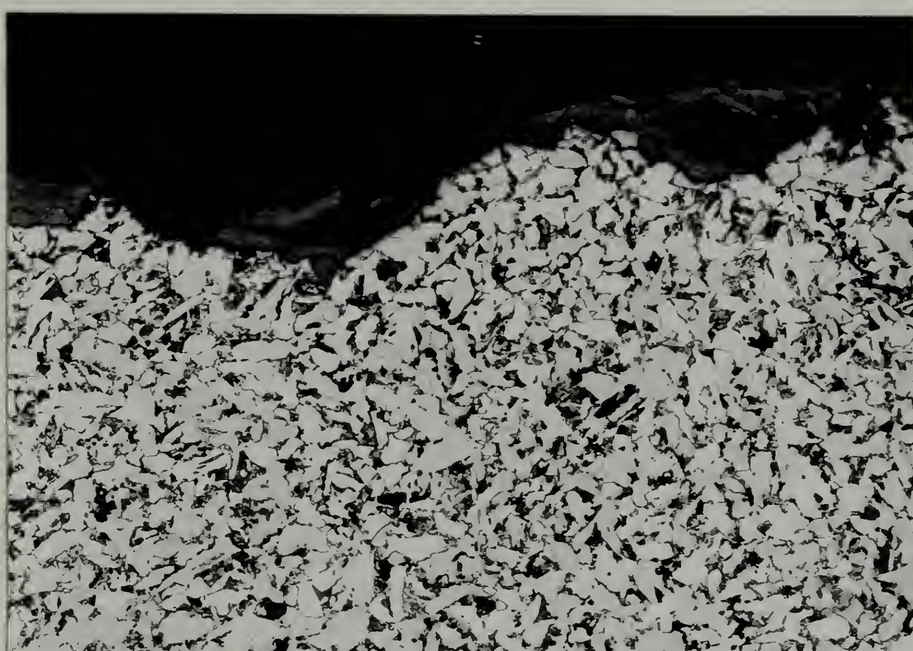


Figure 3. Fractures of 12C hanger section containing fracture surface.
a. Fracture plane oriented at angle of 76 degrees to longitudinal axis of hanger.
b. Planes of end surfaces rotated 3 1/2 degrees from original positions. T-values are thickness in inches of section at stations shown.



a



b

Figure 4. Microstructures observed along fracture profile. Etched with 1% Nital. X 100

a. Deformation and decarburization at fracture origin. Note large grain size.
b. Continuous cleavage predominated in the section of the fracture profile where lead was deposited.

a

b

Figure 5. Secondary cracks approximately one inch from fracture origin. X 100

a. Unetched.

b. Etched with 1% Nital. Note transcrystalline nature of secondary cracks.

a

b

Figure 6a. Discontinuous cleavage in fracture profile at mid-section. Etched with 1% Nital. X 80

Figure 6b. Secondary cracks observed at mid-section. Unetched. X 80

Figure 7. Secondary crack of Figure 2a is shown propagating through a ferrite band. Note large grain size and ferrite grain boundary network (white). Etched with 1% Nital. X 100

Addendum 1

7-1 (Rev. 4-17-67)

REPORT
of the
FBI
LABORATORY

FEDERAL BUREAU OF INVESTIGATION
WASHINGTON, D. C. 20535

To: Mr. C. F. Scheffey, Chief
Structures and Applied Mechanics Division
Bureau of Public Roads
U. S. Department of Commerce
Washington, D. C. 20591

April 30, 1970

Re: ANALYSES OF PAINT FROM
POINT PLEASANT, WEST VIRGINIA,
BRIDGE

J. Edgar Hoover

John Edgar Hoover, Director

YOUR NO.
FBI FILE NO. 95-160247
LAB. NO. PC-C5871 KL

Examination requested by: Mr. Glenn W. Geil
Washington, D. C.

Reference: Letter 3/20/70

Examination requested: Instrumental

Specimen: Evidence personally delivered by Mr. I. J. Feinberg on 3/20/70

K1 Sample of bridge steel

Results of examination:

Specimen K1 is a piece of irregular-shaped metal approximately 6 1/8" in length. A residual odor of oil

1 - Mr. Glenn W. Geil
Acting Chief
Engineering Metallurgy Section
National Bureau of Standards
Washington, D. C. 20234

 (continued on next page)

clings to K1. The possible source of this odor might be the oil used by the cutting tool at the time K1 was cut. The notation "12C N. FACE" is inscribed on one side of K1. Various paint layers are clearly visible to the left of this inscription. The lower left hand corner has the following layer structure of paint:

A. (1) Aluminum (top layer)
   (2) Dirty light gray
   (3) Orange (bottom layer)

To the right of the above paint layers is a large painted surface having the following layer structure:

B. (1) Aluminum (top layer)
   (2) Orange (very thin)
   (3) Aluminum
   (4) Dirty light gray
   (5) Orange (bottom layer)

Variegated paint deposits are present on the top of K1. These deposits were deposited while wet and consist of the colors, orange, aluminum and light gray. Some of the valleys formed by the irregularity of the top surface of K1 show accumulations of all three paints, other valleys have accumulations of two paints and other valleys have accumulations of only one paint.

According to information forwarded to the FBI Laboratory on April 21, 1970, a copy of the original specifications for painting of the Point Pleasant Bridge called for the following:

Par. 73. Titled - Shop Painting.

"One coat of pure red lead mixed in the proportion of 20 pounds dry red lead, 5 pints of raw linseed oil, 2 gills turpentine, and 2 gills liquid dryer, or such other paint of equal grade as may be selected by the consulting engineer."

(continued on next page)

Par. 37 - Titled - Field Painting.

"This paragraph calls for 2 coats of different color of THE VERY BEST QUALITY OF PAINT of such manufacture and color as may be selected by the engineer"

Microscopic and instrumental comparison examinations of the bottom layer of orange paint from layer structure B and a sample of orange paint from the top of K1 disclosed no distinguishable differences between them with regard to the color and type of paint. Similar examinations of the top layer of aluminum paint from layer structure A and a sample of aluminum paint on top of K1 also showed no distinguishable differences between them with regard to the type of paint. Minor differences were noted between the top layer of aluminum paint from layer structure B and the aluminum paint on top of K1. The light gray paint on top of K1 could not be associated with the dirty gray paint on the side of K1 due to differences in color and type of paint.

Specimen K1 is being retained in the FBI Laboratory until called for by a representative of the National Bureau of Standards, Washington, D. C.