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CONTRACTOR REPORT ARLCD-CR-81017

HIGH FRAGMENTATION STEEL PRODUCTION PROCESS

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**US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY**

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ERRATA

P. 18	Fig. 2	Add: Magnification = 500x
P. 19	Fig. 3	Add: Magnification = 500x
P. 20	Fig. 4	Add: Magnification = 500x
P. 23	Para. 3	Change: "old inclusion" to "odd inclusion"
P. 208	Fig. H3	Change: "Billet 20" to "Billet 2C"

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number) HF-1 Steel Metallurgical Evaluation MMT-Process improvement		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Two heats of BOF HF-1 steel were purchased, one from Republic Steel and one from Bethlehem Steel. Essential steel manufacturing information was obtained for future reference. Both heats were metallurgically characterized with respect to microstructure, macrostructure, cleanliness, segregation, hardness, and obtainable tensile properties.		

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INTRODUCTION

The production of high fragmentation steel to date has been problematic and uneconomical. The purpose of this project is to investigate and report on the refinement of production processes and techniques in order to reduce costs and yield a quality product for use in the production of projectile metal parts.

Problems encountered with HF-1 include excessive machining requirements in trepanning the boattail areas of projectiles, high energy requirements in the spheroidize anneal of forgings, two-hit nosing operations requiring intermediate stress relief, inability of heat treatments to impart both mechanical properties and the toughness needed to meet drop test requirements, and steel anomalies. It is the purpose of this project to investigate and correct these problem areas in three phases, the first of which is the subject of this report.

This first phase consists of two tasks: the purchase of HF-1 steel (Task A); and its metallurgical evaluation (Task B); as described below.

Task A. Purchase of HF-1 Steel, MIL-S-50783

Contractor shall purchase one heat of HF-1 Steel of approximately 150 tons from each of two separate suppliers. Steel shall be manufactured by the basic oxygen furnace (BOF) method, and shall be in suitable round corner squared (RCS) size for fabrication into 155-mm M549 projectiles by contractor processes. All bars shall have been marked as to heat, ingot, and location within that ingot. Note that this identification shall be kept on all steel throughout its processing cycle.

At a minimum, each supplier shall have a steel bar from three ingots per heat slow-cooled from under the lower critical --by methods not using a furnace. Material shall be comprised of the first and last usable ingots and an ingot approximately from the middle of the melt. Cooling method envisioned is one that the steel industry would have to institute should an over-capacity situation exist for alloy steel, i.e., where cooling facilities would be inadequate for quantity of steel being rolled (such as mobilization).

Task B. Characterization of Steel Supplied

The three ingots from each heat, along with material from the three ingots adjacent to them, and cooled by conventional furnace method, shall receive metallurgical evaluation by the contractor. As a minimum, these evaluations shall include chemistry, cleanliness (as per ASTM-E-45, Microscopical Methods, Method C), segregation, and macro and micro quality. Surface quality of all incoming material shall also receive character-

ization with regard to laps, seams, etc. Comparisons shall be made between heats, cooling techniques, and location within the heat.

Material from all six ingots, previously mentioned from each heat, shall have a minimum of three Jominy End Quench specimens machined and tested as per ASTM-A-255 to determine the ability of steel to harden. Then using the information obtained a minimum of five longitudinal and transverse coupons each shall be subjected to an austenitize, quench and temper heat treatment designed to result in material with a minimum yield strength of 120,000 psi and a minimum elongation of 12%. Longitudinal coupons shall have a minimum thickness of base. Tensile specimens shall be machined from these coupons and mechanical property results shall be obtained and correlated with Jominy data.

Contractor shall retain remaining steel in anticipation of second year optimization efforts.

It should be noted here that the steel from Republic does not fully comply with SOW MFX-001. Republic uses only slow-cooling in the production of HF-1. This situation was brought to the attention of the government by Chamberlain Manufacturing Corporation's letter of 28 August 1979, and the purchase of Republic's HF-1 was subsequently approved. Since one of the objects of this project was to obtain data on alternate slow cooling processes, Republic's method satisfies the intent of the SOW.

TASK A: PURCHASE OF STEEL*

Republic

Heat 8068860 of HF-1 steel was produced in Masland, Ohio on 12/17/79, in accordance with MIL-S-50783. The heat consisted of 161553 kg (356,163 lbs.) of HF-1 at a cost of \$95,902.81. Colin MacCrindle, Chamberlain Manufacturing Corporation Metallurgical Engineer, was present during processing.

Tap (fig. B1): 200 tons of 100% scrap are melted in an electric furnace and finished as BOF quality steel.

Pour (fig. B2): Forty (40) hot top ingots (25 x 27 inches) are poured at 1515°C (2750°F) along with a cast jominy bar.

* All figures referred to in this section are found in Appendix B.

Soak (fig. B3): The ingots are then soaked at 1120°C (2050°F) for eight hours and a shrinkage of approximately six inches is cropped from the top.

Reduce (fig. B4-5): The ingots are then reduced through a series of thirteen passes at a rate of 7% to 15% per pass on a 35 inch blooming mill, to 10 x 8 3/4 inches.

Crop Ends: Both ends are cropped square.

Cool: Pit cool.

Segregation: A two inch cross section is cut and etched with 50% sulfuric acid. The segregation is then evaluated in accordance with ASTM-E-381. For this heat, the macro etch was taken from the top, middle, and bottom of each first, middle and last ingot.

Anneal and Cool: The blooms are pit-annealed at 1120°C (2050°F) and pit-cooled.

Grind (fig. B6): The blooms are then surface ground on all four sides to remove surface defects.

Re-heat (fig. B7): Re-heating to 1090°C (2000°F) is accomplished in a pusher-type furnace at the 18 inch mill.

Reduce (fig. B8): This operation is done on a seven pass reversing mill in which reduction proceeds from 10 x 8 3/4 to 9 x 8 to 8 x 8 to 8 x 7 to 7 x 6 to 6 x 6 to 6 x 5 1/4 inches.

Final Size (fig. B9): A final size of approximately 5 1/4 x 5 1/4 inches is accomplished on a single pass finishing stand.

Crop: A six inch crop is taken from the leading edge of each billet.

Saw: The billets are hot sawn to equal mult size of 47.8 kg. (105.5 lbs.).

Stamp Identification: Each end of each billet is stamped with aircraft quality steel identification in accordance with the Scope of Work (Table 1).

Preliminary Cooling (fig. B10): The billets are run out on a preliminary cooling bed before the next operation.

Pit Cool (fig. B11): Final cooling is accomplished by placement of the billets in a pit to slow cool from approximately 650°C (1200°F) for seventy-two hours.

Steel made by this process is termed to be double converted.

1000
0000

NUMERALS INDICATE
LETTERS "

INBOOTS
CUTS

ROTATION POURED NOT TO BE USED FOR ANY OTHER STAMPING
FROM TOP TO BOTTOM - " " " " " " " " " " " "

ALL STAMPING MUST BE ON TOP END OF ALL CUTS

THIS APPLIES TO BLOOMING HILLS

BAR Mills

HEAT TREAT (WHEN COLD SAWING MATERIAL TO LENGTH)

FOUR INGOTS CAST ON A HEAT - EACH INGOT ROLLED TO TWO CUTS
STAMPING WILL BE AS FOLLOWS:

<i>T</i> ₃ = End Or Incar	1A		1B		<i>S</i> ₁ = End Or Incar
	2A		2B		
	3A		3B		
	4A		4B		

800M
T3-EMC-2B

ASSUME EACH BLOOM ROLLED AND CUT IN FOUR
* TAKE BLOOM 28 FOR EXAMPLE:

28A [redacted] 285 [redacted] 280 [redacted] 280 [redacted]

THERE MAYBE ANOTHER CASE WHERE A FURTHER SUB-DIVISION IS NECESSARY;
(THIS HOWEVER WILL BE VERY RARE AS WHERE MATERIAL GRES TO COLD SAWS IT IS GENERALLY
NOT CUT TO LENGTH AT LANBERTON AND THE COLD SAWS SIMPLY STAMP THE LANBERTON
CUT NUMBERS.)

WHENEVER IT OCCURS ANOTHER SERIES OF CUN-LETTERS MUST BE ADDED MAKING ONE NUMERAL AND THREE LETTERS IN THE IDENTIFICATION MARK.

FOR EXAMPLE ASSUME THE CUT 2BC ABOVE IS COLD SAWED INTO FOUR PIECES:

TOP END C/F 2 BC

250A [] 250B [] 250C [] 250D []

5961-26

REPUBLIC STEEL CORP.
CENTRAL ALLOY DISTRICT

Bethlehem

Heat 17K4209 was produced by Bethlehem Steel at Lackawanna, New York on 1/25/80. D. Covey, Quality Control Manager of Chamberlain Manufacturing Corporation, and W. Sharpe of ARRADCOM were present. 185973 kg (410,000 lbs.) of steel were produced at a cost of \$81,658.52.

Tap (fig. B12): a 200 ton BOF heat of 30% scrap and 70% hot metal was poured into a BOF and tapped at 1590°C (2900°F).

Pour (fig. B13): 20 ingots, 30 x 35 inches, weighing 9299 kg (20,500 lbs.) each are teemed from a bottom pour ladle.

Cool and Strip (fig. B14): After cooling the hot topped ingots are stripped from the molds.

Equalize: Billets are heated to 910°C (1675°F) and homogenized for 18 hours.

Soak (fig. B15): The equalized billets are now heated to 1200°C (2200°F) to prepare for rolling.

Roll (fig. B16): Seventeen passes with 11.5% reduction are required to reduce the steel on a 44 inch blooming mill. There is 11% top and 5% bottom discard.

Scarf (fig. B17): All blooms are hot scarfed.

Roll (fig. B18): Intermediate size is achieved on the 30 inch billet mill.

Reheat (fig. B19): Due to excess cooling the billets are soaked at 1200°C (2200°F) for one hour.

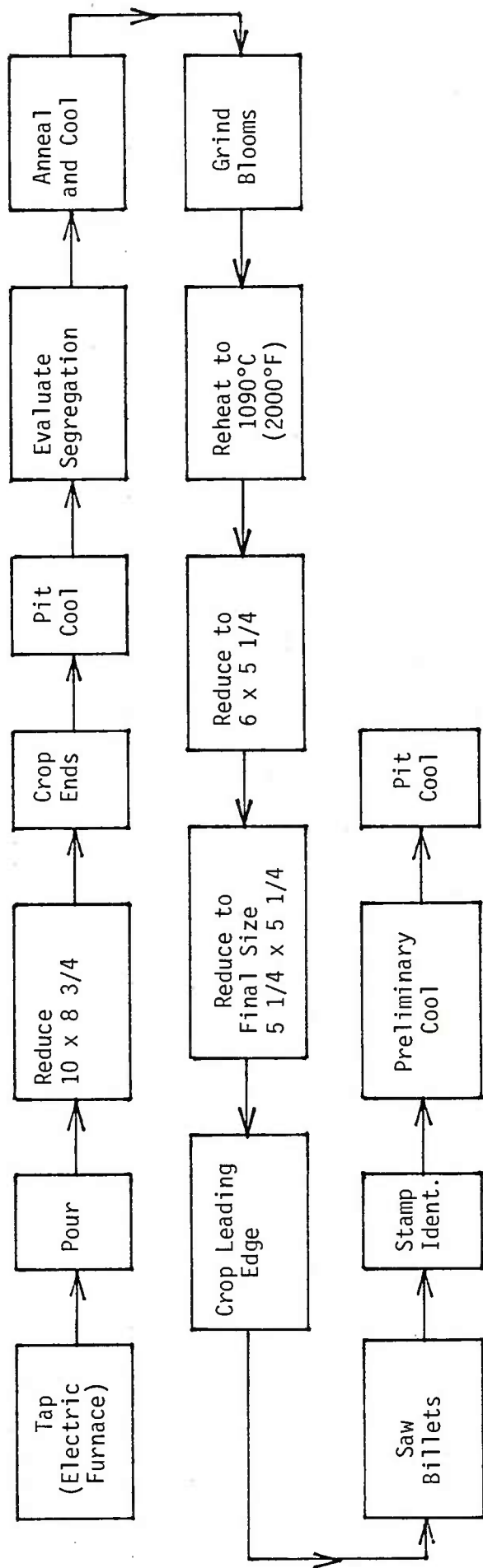
Finish Size (fig. B20): The billets are now reduced to the finished size of approximately 5 1/4 x 5 1/4 inches on the 21 inch billet mill, producing 10 billets per bloom, including 12 shorts.

Transfer to hot bed and identify (fig. B21): Identification of all full length product is accomplished with each ingot bearing a sequential numerical marker and each billet bottom end identified as X (bottom), I, (I), H, (H), (C), C (middle), (B), B, and T (top). Shorts were identified as T and represent the top billet per ingot number.

Bung Cool (fig. B22): Billets from ingots 2 thru 9, and 11 thru 19 were bung furnace cooled from 700°C (1300°F).

Alternate (Slow) Cool (fig. B23): Billets from ingots 1, 10, and 20 were charged into a cooling box as an alternate slow cooling process.

REPUBLIC



BETHLEHEM

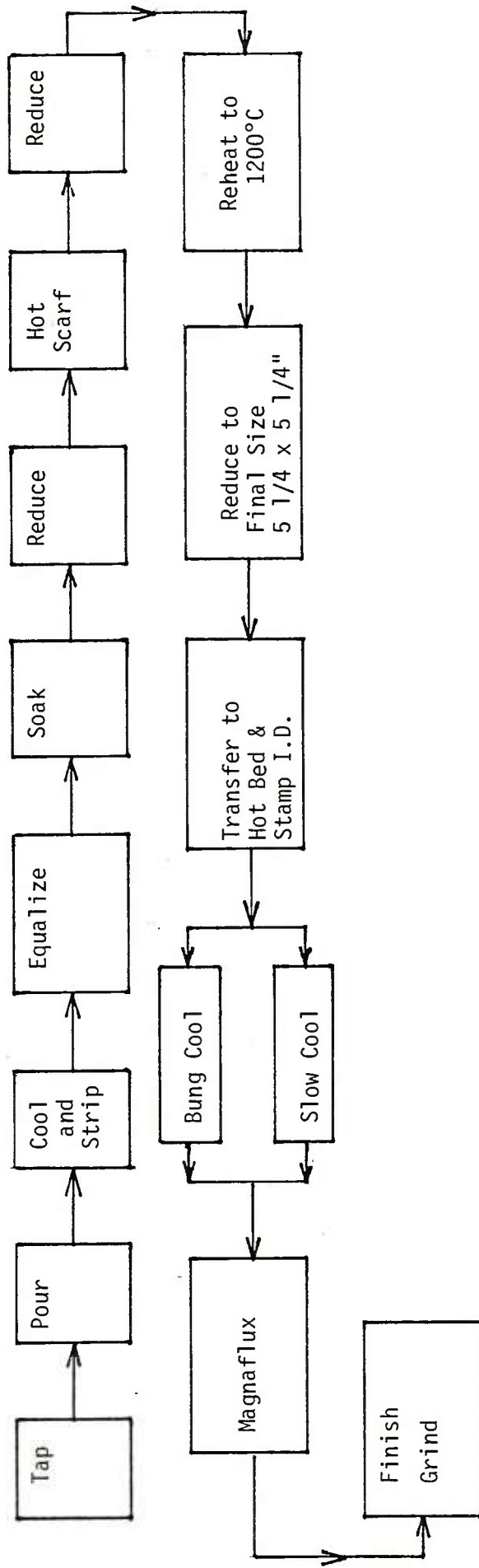


Figure 1 : Republic Steel Production Process versus Bethlehem Steel Production Process (single converted)

Inspect (fig. B24): After cooling, all billets are Magnafluxed for surface defect detection.

Grind (fig. B25): Surface defects detected in the previous operation are eliminated with a surface grinder.

Identifications:

Comparison of Process

A flow-charted comparison of the Republic and Bethlehem processes may be seen in figure 1.

TASK B. CHARACTERIZATION OF HF-1

Surface Quality

A representative photograph of Republic's HF-1 is included as figure B26. It can be seen from this photograph that the billets are straight and show little surface grinding. Bethlehem's HF-1, as seen in figures B27 and B28, exhibits evidence of considerable surface grinding to condition the billet. It appears that Republic's conditioning in the mill, before subsequent reduction, accounts for the significant difference in final conditioning.

Republic's hot sawed ends are shown in figures B29 and B30. Hot sawing produces a relatively smooth face which is square, whereas Bethlehem's hot-sheared ends (figures B31 and B32) are rough and out-of-square.

A possible consequence of the hot shear method involves entry into the die pot or cavity. Problems could arise here, because of the out-of-square ends.

Dimensions

The specifications of HF-1 issued by Chamberlain Manufacturing Corporation called for a diagonal measure of $6.8 + 0.090 - 0.060$ inches. Figures C1 through C6 illustrate the actual measurements, all of which meet the specifications and are included in appendix C.

No problems are expected because of billet size or shape, save the previously mentioned hot-sheared end configuration.

Metallurgical Evaluation

Heat Chemistry

Each of the suppliers of HF-1 submitted a chemical analysis of their product.

The ordering specifications are shown in table 2. They are given as percentages of total composition.

TABLE 2. Chemical specifications for HF-1 steel

	C	Mn	P	S	Si	Ni	Cr
Min	1.00	1.60	---	---	0.70	---	---
Max	1.15	1.90	0.035	0.040	1.00	0.25	0.20
	Mo	Cu	Al				
Min	---	---	---				
Max	0.60	0.35	0.020				

Both heats were delivered within specifications as shown in tables 3 and 4, below.

TABLE 3. Ladle analysis of heat 8068860 (Republic)

C	Mn	P	S	Si	Ni	Cr	Mo	Cu	Al
1.05	1.74	.010	.016	.81	.12	.17	.03	.21	.004

TABLE 4. Ladle analysis of heat 517K4209 (Bethlehem)

C	Mn	P	S	Si	Ni	Cr	Mo	Cu	Al
1.11	1.74	.028	.013	.82	.02	.06	.011	.020	.005

Billet Chemistry

For ease of reference, tables 5 and 6 are a composite of each supplier's billet chemistry analysis compared with U.S. Testing Company's analysis of that heat.

Both vendors derived their chemistry ratings from mid-radius samples; whereas U.S. testing analyzed edge samples taken from 1/8 inch below the surface of the billet. Republic is higher in sulfur, nickel, chromium, molybdenum, and copper contents; whereas Bethlehem has more carbon, phosphorous, and silicon. The relevance of the lower levels of chromium and nickel in the Bethlehem HF-1 are discussed elsewhere, in conjunction with hardenability.

U.S. Testing was sent edge samples for chemical analysis so that the edge chemistry 0.25 inches beneath the surface could be compared with the chemistry analysis of the steel mill which is taken at mid-radius.

U. S. Testing Company reported higher levels of chromium and copper than Bethlehem, for the subject heat (Table 6). Both laboratories were instructed to perform check analysis on their data and both replicated their original results. The Bethlehem values appear to be correct in the light of hardenability values (see below).

Edge versus Mid-radius

TABLE 5. Chemistry, heat 8068860, Republic (mid-radius) versus U. S. testing (edge)

		C		Mn		P		S		Si	
		Rep	UST	Rep	UST	Rep	UST	Rep	UST	Rep	UST
1	TOP	1.04	1.09	1.70	1.63	0.009	.016	0.019	0.012	0.82	0.83
	MID	1.04	0.96	1.72	1.63	0.008	.004	0.018	0.009	0.80	0.81
	BOT	1.04	1.09	1.71	1.62	0.016	.006	0.017	0.016	0.83	0.86
20	TOP	1.04	1.02	1.73	1.63	0.010	.013	0.016	0.013	0.81	0.82
	MID	1.03	0.93	1.72	1.62	0.008	.013	0.017	0.019	0.82	0.82
	BOT	1.04	1.10	1.73	1.68	0.009	.009	0.018	0.019	0.80	0.84
40	TOP	1.03	1.12	1.78	1.68	0.011	.008	0.016	0.007	0.80	0.75
	MID	1.04	1.08	1.76	1.67	0.008	.010	0.017	0.012	0.80	0.80
	BOT	1.05	0.95	1.76	1.64	0.011	.010	0.017	0.026	0.81	0.84
Mean		1.04	1.04	1.74	1.64	0.010	.010	0.017	0.015	0.81	0.82

		Ni		Cr		Mo		Cu		Al	
		Rep	UST	Rep	UST	Rep	UST	Rep	UST	Rep	UST
1	TOP	0.12	0.14	0.17	0.16	0.03	.03	0.21	0.18	0.005	<.005
	MID	0.12	0.12	0.17	0.17	0.03	.01	0.20	0.12	0.006	.005
	BOT	0.12	0.11	0.17	0.16	0.03	.03	0.20	0.14	0.005	.005
20	TOP	0.12	0.11	0.17	0.15	0.03	.02	0.20	0.17	0.004	.005
	MID	0.12	0.12	0.17	0.15	0.03	.01	0.20	0.17	0.005	.005
	BOT	0.12	0.14	0.17	0.15	0.03	.03	0.20	0.18	0.003	.005
40	TOP	0.12	0.13	0.17	0.16	0.03	.04	0.21	0.17	0.003	.005
	MID	0.12	0.12	0.17	0.15	0.03	.03	0.20	0.18	0.006	.005
	BOT	0.12	0.14	0.17	0.16	0.03	.03	0.20	0.17	0.005	.005
Mean		0.12	0.125	0.17	0.156	0.03	.025	0.20	0.164	0.005	.005

TABLE 6. Chemistry, heat #517K4209, Bethlehem (mid-radius)
versus U.S. testing (edge)

		C		Mn		P		S		Si	
		Beth	UST	Beth	UST	Beth	UST	Beth	UST	Beth	UST
1	TOP	1.12	1.08	1.74	1.63	0.027	0.021	0.012	0.015	0.77	0.78
	MID	1.14	1.10	1.77	1.68	0.028	0.023	0.014	0.017	0.88	0.88
	BOT	1.11	1.14	1.74	1.69	0.026	0.022	0.013	0.012	0.75	0.80
2	TOP	1.11	1.02	1.72	1.61	0.028	0.017	0.012	0.015	0.81	0.86
	MID	1.08	1.18	1.72	1.68	0.029	0.023	0.010	0.010	0.86	0.87
	BOT	1.09	1.25	1.73	1.69	0.025	0.026	0.012	0.012	0.83	0.80
10	TOP	1.13	1.15	1.74	1.69	0.024	0.019	0.012	0.005	0.79	0.76
	MID	1.13	1.01	1.78	1.69	0.029	0.024	0.014	0.012	0.84	0.78
	BOT	1.09	0.99	1.73	1.65	0.025	0.023	0.013	0.016	0.79	0.81
11	TOP	1.13	0.94	1.73	1.64	0.031	0.027	0.016	0.014	0.84	0.74
	MID	1.13	1.29	1.76	1.63	0.027	0.020	0.012	0.007	0.87	0.75
	BOT	1.10	1.15	1.72	1.64	0.027	0.018	0.013	0.007	0.82	0.80
19	TOP	1.13	0.92	1.72	1.71	0.030	0.007	0.013	0.003	0.82	0.86
	MID	1.11	1.15	1.71	1.68	0.029	0.022	0.012	0.003	0.87	0.86
	BOT	1.08	1.05	1.74	1.68	0.029	0.025	0.011	0.014	0.81	0.80
20	TOP	1.14	0.92	1.72	1.60	0.025	0.025	0.014	0.010	0.83	0.86
	MID	1.12	1.13	1.76	1.70	0.028	0.023	0.013	0.028	0.84	0.81
	BOT	1.09	1.10	1.78	1.65	0.025	0.018	0.013	0.017	0.78	0.84
Mean		1.12	1.08	1.74	1.589	0.0273	0.213	0.0127	0.0114	0.819	0.814
		Ni		Cr		Mo		Cu		Al	
Beth		0.02		0.06		0.011		0.020		0.005	
UST		0.01-0.03		0.10-0.14		0.01		0.05-0.12		0.005	

Note, that only manganese seems to be segregated. It has higher values toward the center. This is consistent for both heats of steel.

Segregation

In order to determine the segregation of HF-1, billet sections from both heats were compared to macrographs in MIL-STD-1459A. Both heats were classified as acceptably sound steel. The macrographs are contained in Appendix D for comparison.

The segregation ratings for the subject steel are shown in tables 7 and 8. The rating system consists of an alpha character and a numeral. A - designates center defects; B - subsurface; C - ring; and D - miscellaneous defects. The numerical designation indicates the severity of the defect, progressing from one to seven, seven being the most severe. Any defect in the D series can be grounds for the rejection of the steel.

The steel was etched in a solution of 50% hydrochloric acid and 50% water after sections were sawed. Upon comparison with the macrograph standards of MIL-STD-1459A, all steel from both heats was rated as clean and sound.

TABLE 7. Segregation evaluation: Republic

Billet			
1TOP	B1	C1	A2
1MID	B1	C1	A2
1BOT	B1	C1	A2
20TOP	B1	C1	A2
20MID	B1	C1	A2
20BOT	B2	C2	A2
40TOP	B2	C1	A2
40MID	B1	C2	A1
40BOT	B2	C2	A1

TABLE 8. Segregation evaluation: Bethlehem

Billet			
1TOP	B2	C2	A2
1MID	B2	C1	A2
1BOT	B1	C1	A1
2TOP	B1	C1	A1
2MID	B1	C2	A2
2BOT	B1	C1	A1
10TOP	B1	C1	A1
10MID	B1	C1	A2
10BOT	B1	C1	A1
11TOP	B2	C1	A2
11MID	B1	C1	A3
11BOT	B1	C1	A1
19TOP	B1	C1	A3
19MID	B1	C2	A2
19BOT	B1	C1	A1
20TOP	B1	C1	A2
20MID	B1	C1	A1
20BOT	B1	C1	A1

Hardenability

The hardenability for each heat was determined by its manufacturer through the end-quench, or Jominy test, which consists of water quenching a 1" test specimen and measuring to what extent it hardens at varying distances, measured in 1/16" increments from the quenched end.

Republic Steel performed Jominy tests on forged Jominy bars. Austenitization temperature was 843°C (1550°F) and quench was performed as specified in ASTM-255, End Quench Hardenability of Steel. Table 9 gives the hardenability assigned to the heat and figures E1 through E10 show the hardenability curves for Republic's HF-1.

Bethlehem ran Jominy Tests on forged billet samples which were normalized at 870°C (1600°F) prior to machining. All samples were 1 3/8 inches round and austenitized at 843°C (1550°F), soaked for one hour and quenched in the manner prescribed by ASTM-255. Table 10 is the hardenability assigned to the heat by Bethlehem and figures E11 through E29 indicate the Jominy curves. They are included as Appendix E.

TABLE 9. Hardenability values

REPUBLIC STEEL CORPORATION
CLEVELAND, OHIO

CUSTOMER ORDER NUMBER AND DATE: 5-53004-303

INVOICE NUMBER: 303-284

CHAMBERLAIN MFG CORP

SHIP TO: SAME AS SOLD TO UNLESS OTHERWISE INDICATED

END QUENCH HARD RC IN 16THS

	END QUENCH HARD RC 1N 16THS																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	26	28	30	32		
B1	62	62	62	62	62	62	62	61	60	58	54	48	46	44	43	42	41	40	39	38	37	36	36	35	34	
M1	62	62	62	62	62	62	61	61	59	56	50	46	44	43	42	41	40	39	38	38	37	36	35	34	32	
T1	62	62	62	62	62	61	61	60	57	52	48	46	44	42	41	40	39	38	38	37	36	36	36	35	34	
B20	62	62	62	62	62	62	62	60	57	52	48	44	43	42	41	40	39	38	37	36	35	35	34	33		
M20	62	62	62	62	62	62	60	60	57	52	47	44	43	41	41	40	39	38	37	37	36	35	35	34		
T20	62	62	62	62	62	62	61	59	56	51	47	44	42	41	41	40	38	37	37	36	35	35	34	34		
B40	62	62	62	62	62	61	61	60	59	55	50	47	44	44	42	41	39	39	38	36	36	36	35	35		
M40	62	62	62	62	62	62	61	60	58	53	48	46	44	42	41	41	39	38	37	36	36	36	34	34		
T40	62	62	62	62	62	62	62	60	59	55	51	46	44	42	42	40	39	38	37	36	36	35	34	34		
HEAT	62	62	62	62	62	62	61	60	58	52	48	45	44	42	41	40	39	38	37	36	36	35	34	34		

Bethlehem Steel

Jominy Hardenability

Hardness results on some tests varied erratically from 57 Rc to 59 Rc at J1 through J6. We do not know the cause of this variation.

Test location (top, middle, or bottom of the ingot) had no noticeable influence on hardenability results.

Assigned hardenability of the heat is:

<u>J1</u>	<u>J2</u>	<u>J3</u>	<u>J4</u>	<u>J5</u>	<u>J6</u>	<u>J7</u>	<u>J8</u>	<u>J9</u>	<u>J10</u>	<u>J12</u>	<u>J14</u>	<u>J16</u>	<u>J18</u>	<u>J20</u>
58	58	58	58	58	57	55	51	48	47	45	44	42	41	40
<u>J24</u>	<u>J28</u>	<u>J32</u>												
38	35	34												

Forged billet samples normalized at 1600°F prior to machining to 1 3/8" round were used for all Jominy tests.

All tests were austenitized at 1550°F. Furnace temperature was stabilized at 1550°F prior to austenitizing the tests. Tests were kept in the furnace for 1 hour and immediately quenched. All tests were quenched for 20 minutes.

Probe results are shown in Table 10.

TABLE 10. Hardenability values

	<u>J1</u>	<u>J2</u>	<u>J3</u>	<u>J4</u>	<u>J5</u>	<u>J6</u>	<u>J7</u>	<u>J8</u>	<u>J9</u>	<u>J10</u>	<u>J12</u>	<u>J14</u>	<u>J16</u>	<u>J18</u>	<u>J20</u>	<u>J24</u>	<u>J28</u>	<u>J32</u>
1 Top	57	58	57	57	58	57	55	51	48	46	45	44	42	41	40	40	37	37
2 Top	58	57	57	57	58	57	54	50	47	46	44	43	42	41	40	38	34	34
10 Top	59	58	58	57	57	57	54	50	47	46	44	43	42	41	40	38	38	37
11 Top	58	58	58	58	58	58	55	51	49	48	45	43	42	41	40	38	34	34
19 Top	58	57	57	57	58	56	55	52	48	47	44	44	42	41	40	38	34	35
20 Top	58	59	57	58	58	58	55	50	49	46	45	44	43	42	41	36	35	34
1 Middle	57	59	58	58	58	58	55	52	49	48	45	45	43	41	40	37	37	35
2 Middle	58	58	58	58	59	57	55	50	48	47	45	44	43	41	39	38	36	34
10 Middle	57	56	56	56	57	56	53	49	48	47	45	43	42	42	41	36	35	34
11 Middle	59	58	58	59	59	57	56	52	48	47	46	44	43	41	40	39	36	35
19 Middle	58	58	58	57	58	56	53	50	48	47	46	43	43	42	39	37	35	35
20 Middle	59	57	58	59	58	57	54	49	48	46	45	43	43	41	41	38	37	32
1 Bottom	59	58	58	59	59	58	56	52	49	47	45	44	42	41	40	40	35	33
2 Bottom	58	58	59	59	59	57	54	51	49	47	46	44	43	42	41	38	34	34
10 Bottom	58	57	57	57	57	56	53	50	47	47	45	43	41	41	40	36	35	33
11 Bottom	58	59	58	58	59	58	55	51	48	47	44	43	42	42	40	39	34	32
19 Bottom	59	59	59	58	57	58	56	50	48	48	44	43	42	41	40	38	34	34
20 Bottom	59	57	58	59	59	58	58	56	54	49	46	45	43	42	41	40	37	35

Comparison

The Jominy values for Republic's HF-1 are consistent and regular. The steel hardened to Rc 60 and above from J1 through J8 and maintained uniformity throughout.

The values for Bethlehem are erratic from J1 through J6, ranging from Rc 57 to Rc 59 and are consistently less hardenable than the Republic Steel.

Within each heat, there are no significant differences because of location in the heat, nor are there any significant differences between Bethlehem's Bung and Box Cooled samples.

The previously mentioned low chemistry values for Nickel and Chromium for Bethlehem's HF-1 are supported by the significantly lower hardenability values indicated here.

Billet Cross Section Hardness Patterns

A 10 x 10 grid of 1/2 inch blocks was incised on the face of sections from each billet. One hundred hardness readings were then taken from each section. Tables 11 and 12 below represent the arithmetic mean of the Rc hardness of each section and its Brinell Hardness Number. Actual hardness readings are included in Appendix F.

TABLE 11. Hardness pattern - Republic

	<u>Rc (Mean)</u>	<u>BHN</u>
1 TOP	32.409	298
1 MID	32.805	300
1 BOT	38.800	300
20 TOP	33.575	307
20 MID	32.554	299
20 BOT	37.892	348
40 TOP	35.692	327
40 MID	29.696	279
40 BOT	35.728	327

Heat: Mean Rc = 34.35

Billet, Mean Rc:

Location, Mean Rc:

1 = 34.671
20 = 34.673
40 = 33.705

TOP = 33.892
MID = 31.685
BOT = 37.473

TABLE 12. Hardness pattern - Bethlehem

	<u>Cooling Method</u>	<u>Rc (Mean)</u>	<u>BHN</u>
1 TOP	Box	32.888	300
1 MID		30.366	284
1 BOT		29.302	278
2 TOP	Bung	30.802	287
2 MID		25.974	260
2 BOT		24.231	250
10 TOP	Box	30.514	285
10 MID		27.758	268
10 BOT		30.016	283
11 TOP	Bung	29.195	277
11 MID		29.282	278
11 BOT		30.103	283
19 TOP	Bung	29.893	281
19 MID		29.779	280
19 BOT		24.748	252
20 TOP	Box	30.952	288
20 MID		30.429	285
20 BOT		30.174	283

Heat: Mean Rc = 29.245 BHN = 278

Billet Mean:

1 = 30.852	11 = 29.526
2 = 27.002	19 = 28.140
10 = 29.429	20 = 30.518

Method Mean:

Box	=	30.298
Bung	=	28.223

Location Mean:

	<u>Box</u>	<u>Bung</u>	<u>Both</u>
TOP	31.451	29.963	30.707
MID	29.517	28.343	28.931
BOT	29.830	26.360	28.095

The overall hardness of the Republic Steel is Rc 34.35, more than Rc 5, higher than the Bethlehem overall of Rc 29.245. Republic's HF-1 is slightly harder on the bottom of all billets.

The mean hardness for Bethlehem's Box Cooled material is Rc 30.298 and that for Bung Furnace Cooled is Rc 28.223.

The box cooled material is slightly more consistent in hardness from top to bottom within a billet with the highest consisting in Billets 20T, C and X.

Elevated Temperature Tests (Burning Tests)

In order to determine the effect of elevated temperatures on the structure of as-received HF-1 steel, samples were heated to 1120°C (2050°F), 1148°C (2100°F), and 1205°C (2200°F), air cooled, polished, and deeply etched with Wesley-Austin Solution (see Appendix K). Under close examination, no melting was encountered at the triple points of austenite grain boundaries, as illustrated in figures 2 thru 4.

A sample was heated to 2400°F, air cooled, polished, and deeply etched as before. This sample clearly shows the effect of intergranular melting (figure 5). It was noticed that if a sample was not overheated the grain boundaries were white on initial etching while in an over heated sample the grain boundaries immediately turned black and polishing delineates the grain boundaries.

HF-1
Burning - Experimental



Figure 2. Photomicrograph of Austenitic grain triple point after heating to 1120°C (2050°F).

HF-1
Burning - Experimental

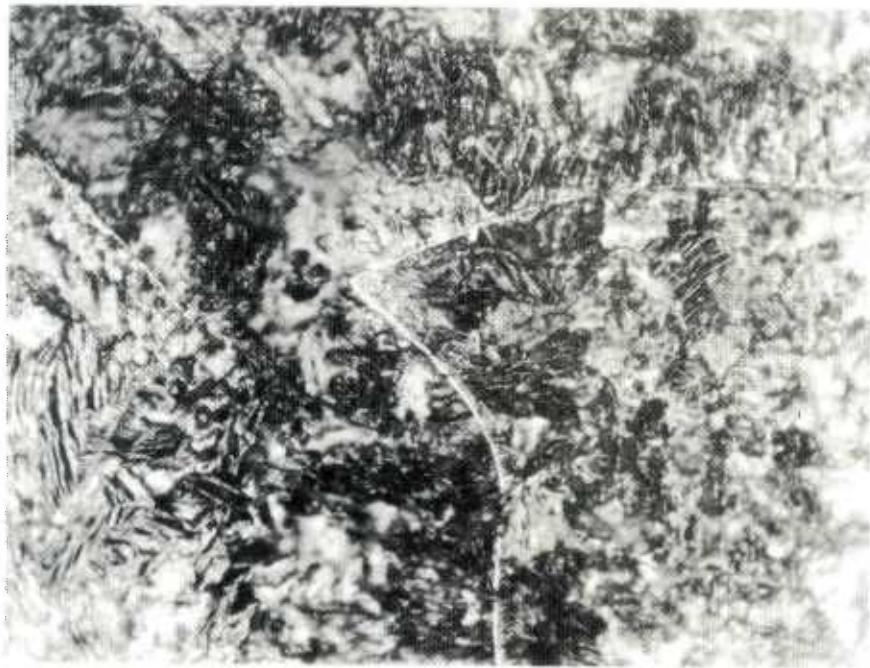


Figure 3. Photomicrograph of Austenitic grain triple point after heating to 1148°C (2100°F)

HF-1
Burning - Experimental



Figure 4. Photomicrograph of austenitic grain triple point after heating to 1205°C (2200°F)

HF-1

Burning - Experimental

A.



B.

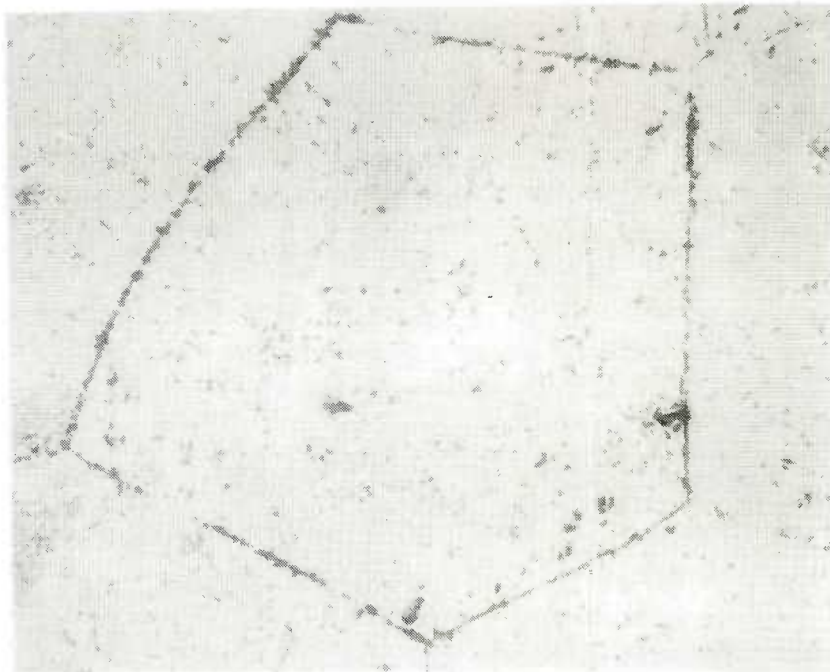


Figure 5. Photomicrograms of Austenitic Grain triple point after heating to 2400°F

- a. 63 x etched and polished
- b. 125 x etched and polished

Metallography - as received

Republic Steel Corporation

Each billet was sectioned metallographically. All billets showed a fine pearlite rim varying from 0.025 to 0.055, progressing towards a fine to coarse pearlitic core. These structures are illustrated in figures G1 thru G9. Figure 5 is a magnified composite of the bottom billet of the twentieth ingot.

The rim is four points harder on the Rockwell C scale than the core. This is not a significant variation in a hot forging operation since the structure would be homogenized at forging temperature.

Bethlehem Steel Corporation

Each billet was sectioned and examined. The billets from the ingots that were box cooled (ingots 1, 10, and 20) revealed the same rim-core structure as billets from Republic Steel. Some of the billets that were bung furnace cooled had a broken-up pearlitic structure. This can be expected as the bung furnace produces a slower, more controlled cooling.

These structures are illustrated in figures G10 thru G27. Figures 6 and 7 illustrate the magnified composite of a bung and furnace cooled structure of an ingot.

Inclusions

Republic Steel

On first analysis, optical microscopy was unable to reveal the exact nature of some of the inclusions. All samples exhibited a grey elongated type of inclusion. This is typical of Manganese sulfide; but in this instance black areas were associated with the grey inclusions.

A good example of this is illustrated by figures 8 and 9. In order to ascertain the exact nature of the inclusion, it was examined by a Scanning Electron Microscope (SEM) with an Electron Defraction X-ray Analyzer attachment (EDAX). Analysis of the grey mass proved that it was a Manganese sulfide as illustrated in figure 10. The black area was then analyzed and revealed the following elements: Aluminum, Silicon, Sulfur, Calcium, Manganese, Titanium and Iron. This is illustrated in figure 11.

Figure 12 is an analysis of the area away from the inclusion showing only manganese and iron.

Bethlehem Steel

Inclusions from Bethlehem Steel are illustrated in figure 13 and were evaluated in the same manner as those from Republic Steel. The grey areas in figure 13 were analyzed and showed Manganese Sulfide again as shown in figure 14.

The black areas associated with the grey inclusions were analyzed and revealed the following elements: Aluminum, Calcium Sulfur, Manganese and Iron. Notice in Bethlehem's material that there is no Titanium or Silicon. This is illustrated in figure 15. The stringer inclusions are silicates.

An old inclusion was detected in this material. It was square and angular with a black spot in it as illustrated in figure 16. An EDAX evaluation (figure 17) of the grey square revealed the following elements: Aluminum Silicon, Calcium Titanium and Iron. The base compound has been identified as Titanium Nitrite. The black spot (figure 18) contains only Titanium and Iron. Figure 19 is an EDAX evaluation of background. The analyses of both heats contained variations in the levels of the individual elements of their contents.

All inclusions were rated according to the ASTM E-45 standard method. Some difficulty was experienced during the final polishing of the specimen. Normal practice of polishing suggests an aqueous suspension of Alumina. This practice smeared the sulfide inclusions and sometimes spotted the specimen. It was found that an alcohol suspension of Alumina must be used to produce clearly defined inclusions.

The inclusion ratings are as follows:

Micro-Cleanliness (Inclusion Rating)

The micro-cleanliness of the two heats of steel was rated according to ASTM E45-76 method D, as previously stated these two major inclusions present, sulfide and silicates.

TABLE 13. Inclusion Rating - Republic

	Manganese Sulfide	Calcium Silicate
1AA	A 1½ thin	C 2-2½ heavy
1BA	A 2 thin	C 1 thin
1BD	A 2½ thin	C 1 thin
20AA	A 1½ thin	C 1 thin
20BA	A 1½ thin	C 1 thin
20BD	A 1½ thin	C ½ thin
40AA	A 1½ thin	C 1½ heavy
40BA	A 1½-2 thin	C 2 heavy
40BD	A 1½ thin	C 1 thin

TABLE 14. Inclusion Rating - Bethlehem

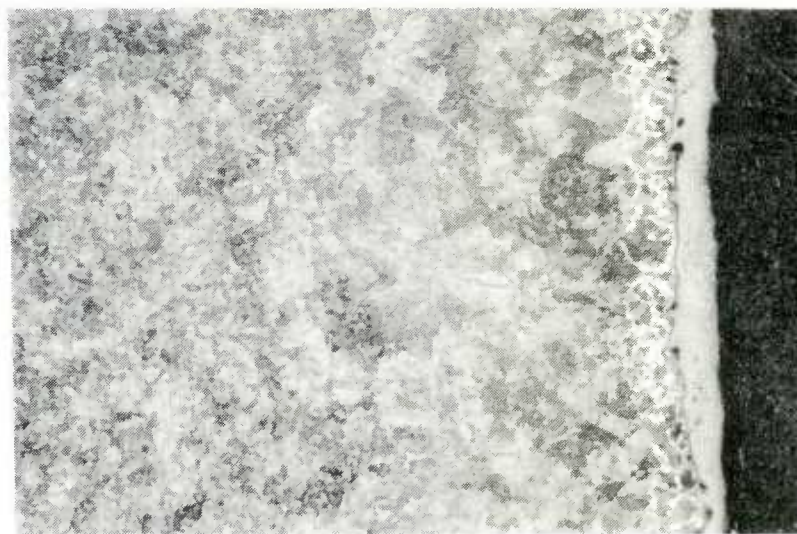
	Manganese Sulfide	Calcium Silicates
1T	A 2 thin	C $2\frac{1}{2}$ heavy
1C	A 1 thin	C $1\frac{1}{2}$ thin
1X	A 2 thin	C 2 thin
2T	A $1\frac{1}{2}$ thin	C 2 thin
2C	A $1\frac{1}{2}$ thin	C 1 thin
2X	A $1\frac{1}{2}$ thin	C 1 thin
10T	A 2 thin	C $1\frac{1}{2}$ thin
10C	A $1\frac{1}{2}$ thin	C 1 thin
10X	A 1 thin	C 2 thin
11T	A 2 thin	C 1 thin
11C	A 2 thin	C 1 thin
11X	A 2 thin	C 2 thin
19T	A $2\frac{1}{2}$ thin	C $1\frac{1}{2}$ heavy
19C	A $1\frac{1}{2}$ thin	C 1 thin
19X	A 2 thin	C $1\frac{1}{2}$ thin
20T	A 2 heavy	C 2 thin
20C	A 2 thin	C $2-2\frac{1}{2}$ thin
20X	A 2 thin	C $1\frac{1}{2}$ thin

From the inclusion rating tables, it can be seen that Republic Steel is somewhat cleaner than the heat from Bethlehem Steel. This was expected and is due to Electric furnaces versus Basic Oxygen furnaces practices.

Figure 20 is an example of a typical inclusion of Republic Steel.

Figure 21 is an example of a typical inclusion of Bethlehem Steel.

Republic Steel Billet 20BD



63x Cross
Section

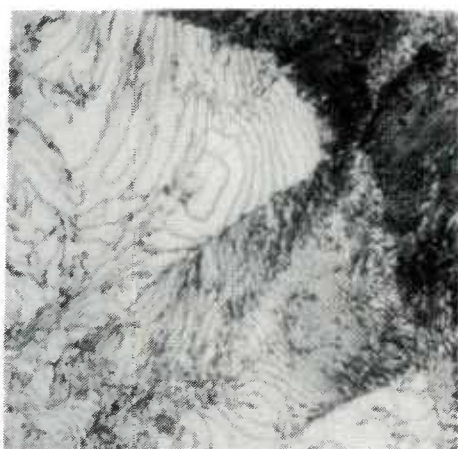


500x
Cross
Section

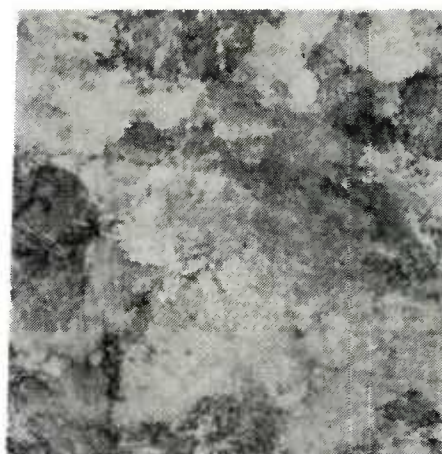
Core

Rim
width 0.051 inches

Edge
Scale 0.004 inches



Core

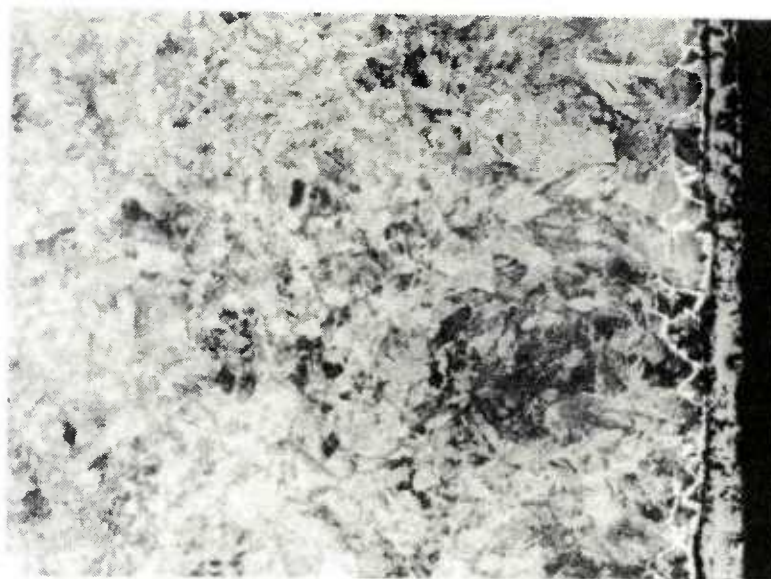


Rim

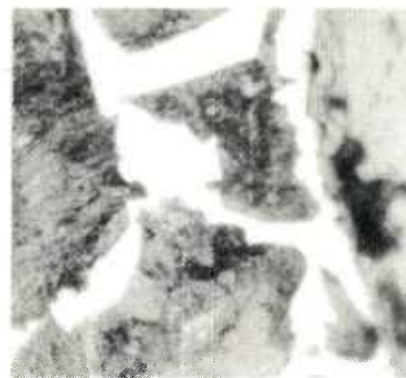
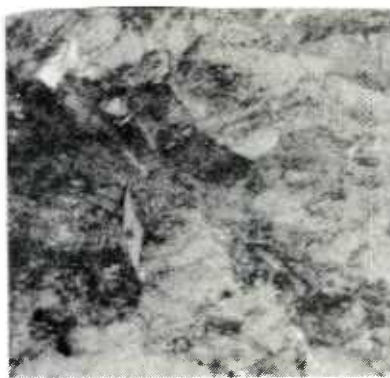
1000x
Cross Section

Figure 6. Composite Structure. Picral Etchant.

Bethlehem Steel
20C



63x Cross
Section

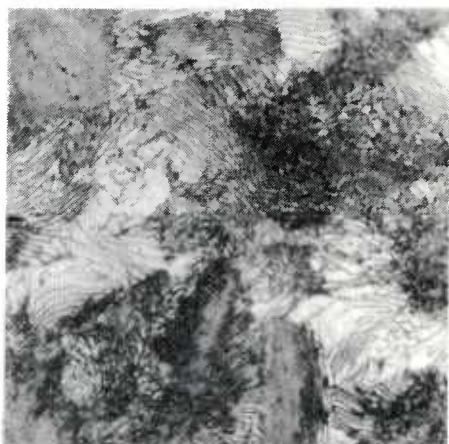


500x
Cross
Section

Core

Rim
width .025 inches

Edge
Scale 0.004 inches



Core

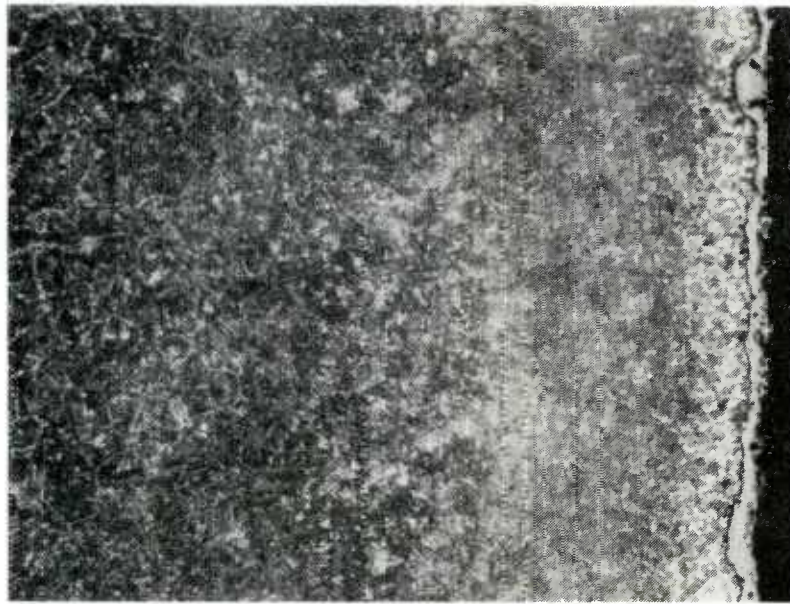


Rim

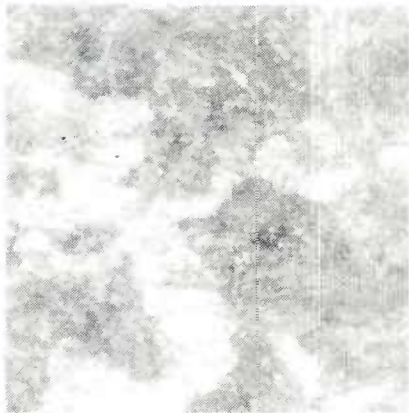
1000x
Cross Section

Figure 7. Composite Structure. Picral Etchant

Bethlehem Steel
2T



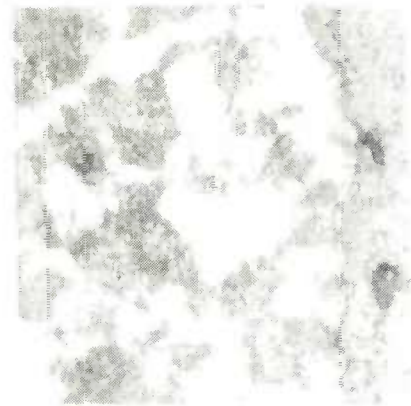
63x Cross
Section



Core



Rim
width 0.024 inches



Edge
Scale 0.001 inches

500x
Cross
Section



Core



Rim

1000x
Cross Section

Figure 8. Composite Structure. Picral Etchant.

REPUBLIC STEEL
SEM
Inclusion Analysis

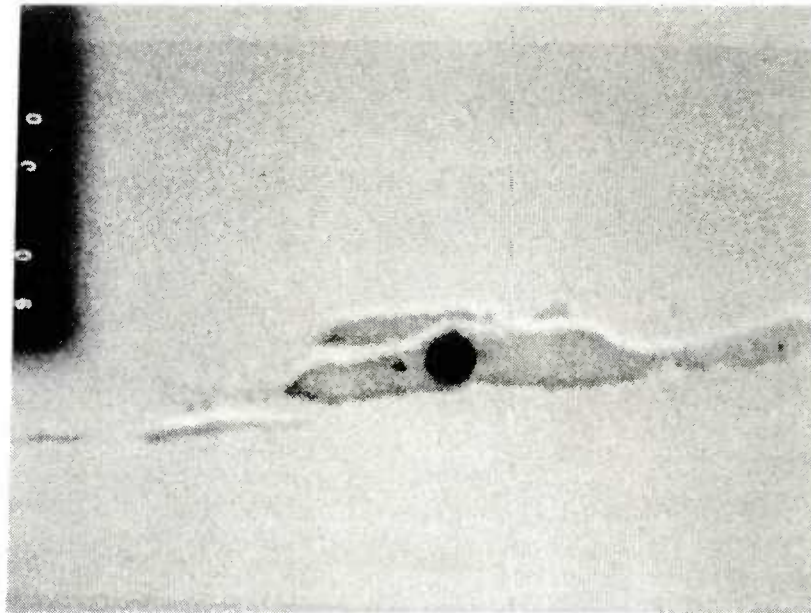
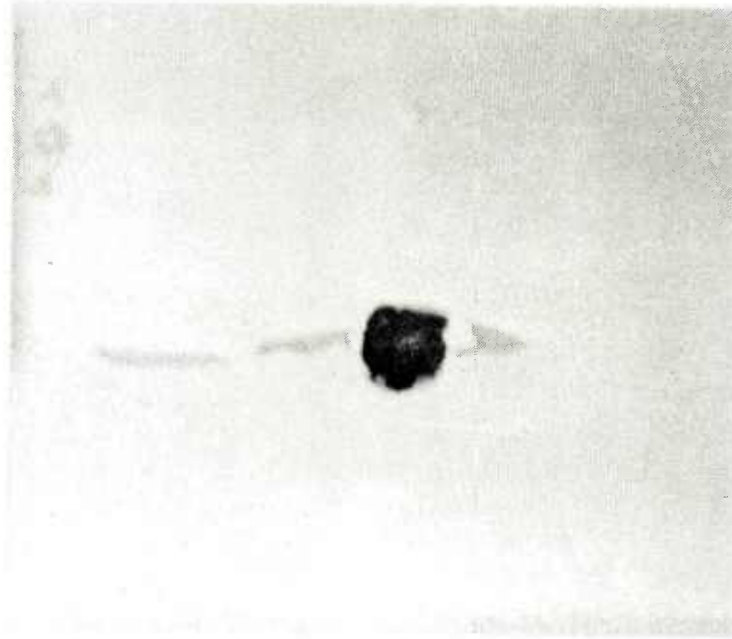


Figure 9. Two illustrations of inclusion from Republic 20BD. 1000x

REPUBLIC STEEL

SEM

EDAX Evaluation of Inclusion

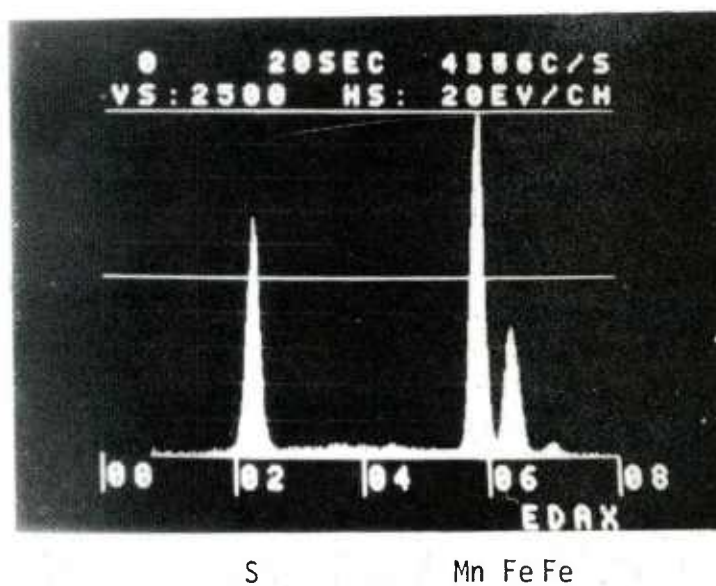


Figure 10. EDAX Evaluation of grey area of inclusion indicating Manganese sulfide.

REPUBLIC STEEL

SEM

EDAX Evaluation of Inclusion

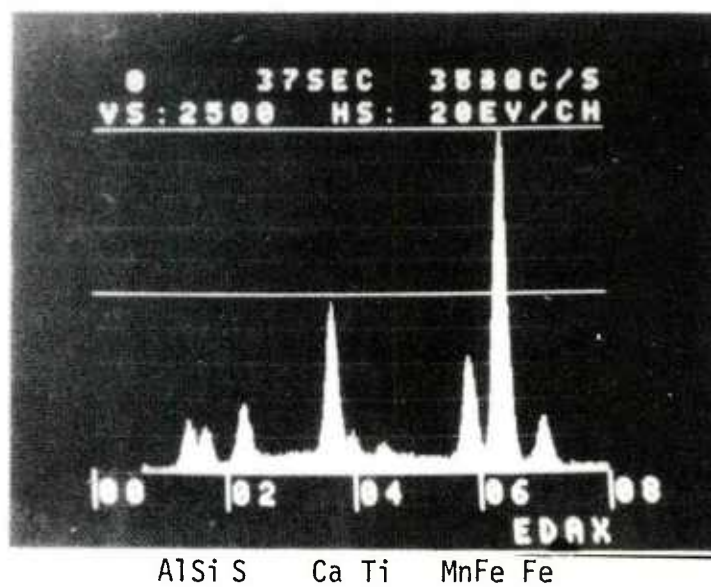


Figure 11. EDAX Evaluation of black area of inclusion indicating a complex calcium silicate.

REPUBLIC STEEL

SEM

EDAX Analysis of Inclusion

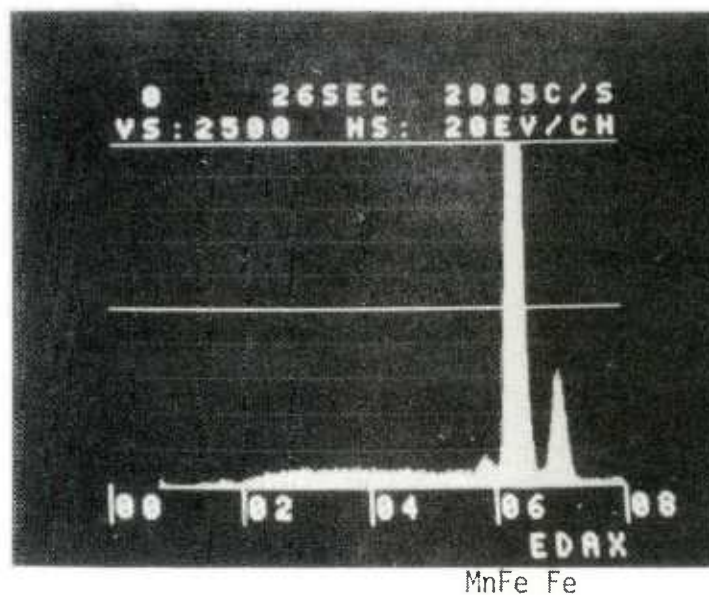


Figure 12. EDAX Evaluation of area away from inclusion. (background)

BETHLEHEM STEEL
SEM
Inclusion Analysis

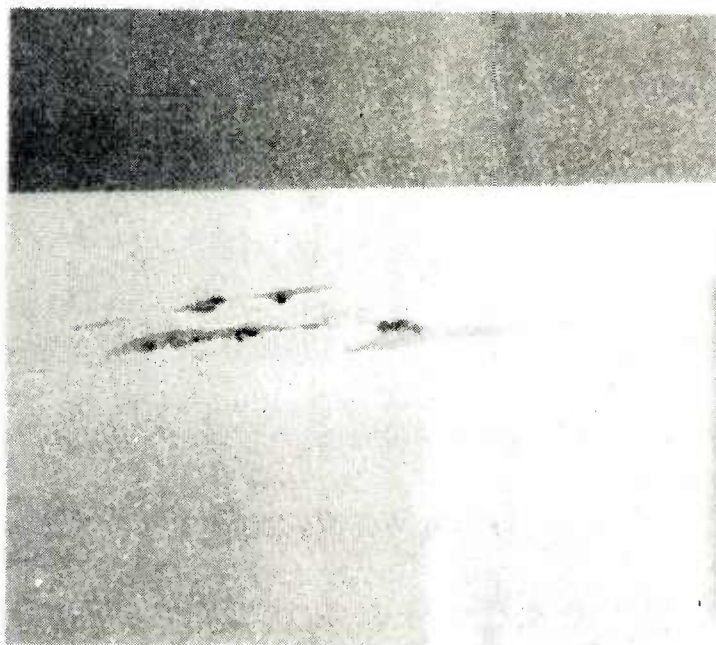


Figure 13. Illustration of stringer inclusion with black area. 500x

BETHLEHEM STEEL

SEM

EDAX Evaluation of Inclusion

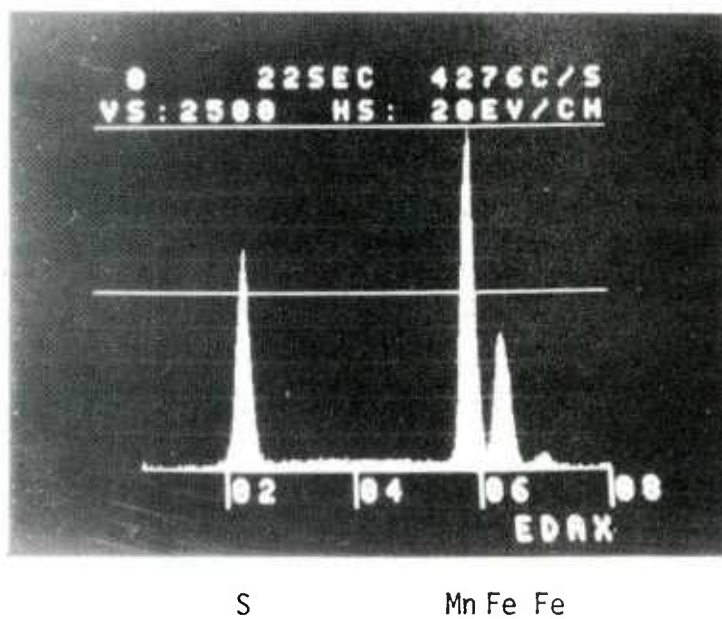


Figure 14. EDAX Evaluation of grey area indicating manganese sulfide.

BETHLEHEM STEEL
SEM
EDAX Evaluation of Inclusion

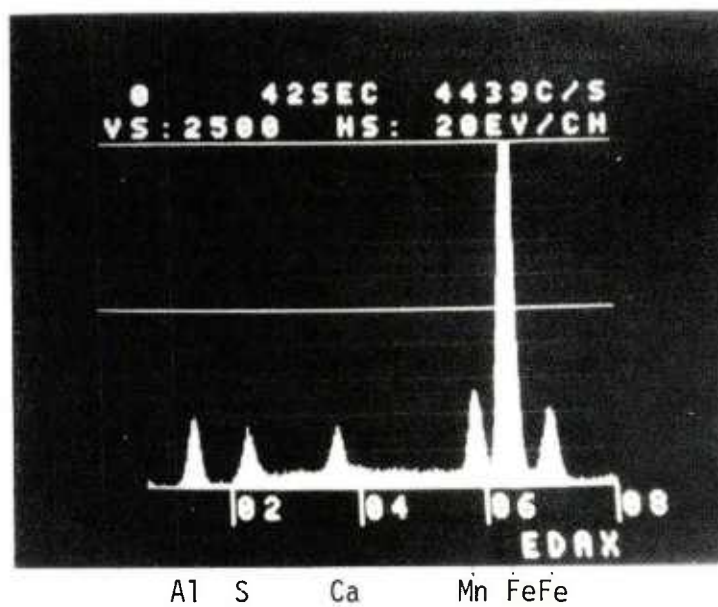


Figure 15. EDAX Evaluation of grey area in figure revealing a complex sulfide.

BETHLEHEM STEEL
SEM
EDAX Evaluation of Inclusion

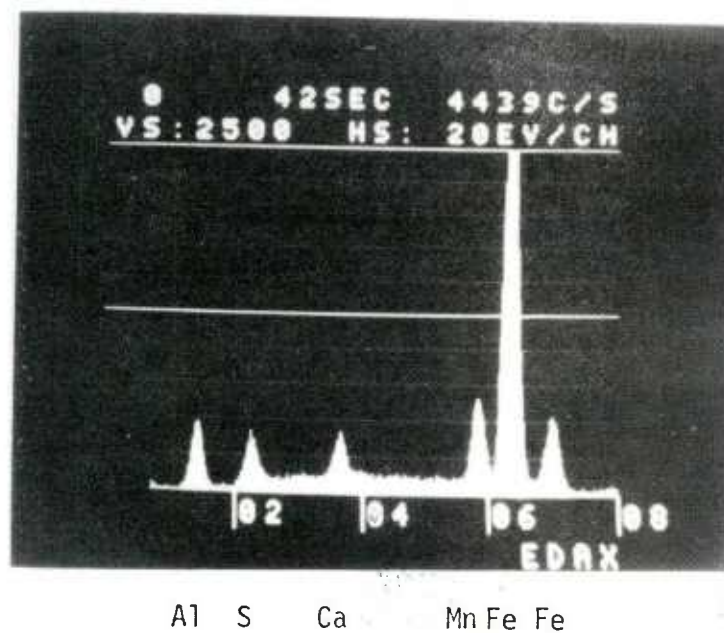


Figure 16. EDAX Evaluation of black area indicating a complex calcium alumina sulfide.

BETHLEHEM STEEL

SEM

EDAX Evaluation of Inclusion

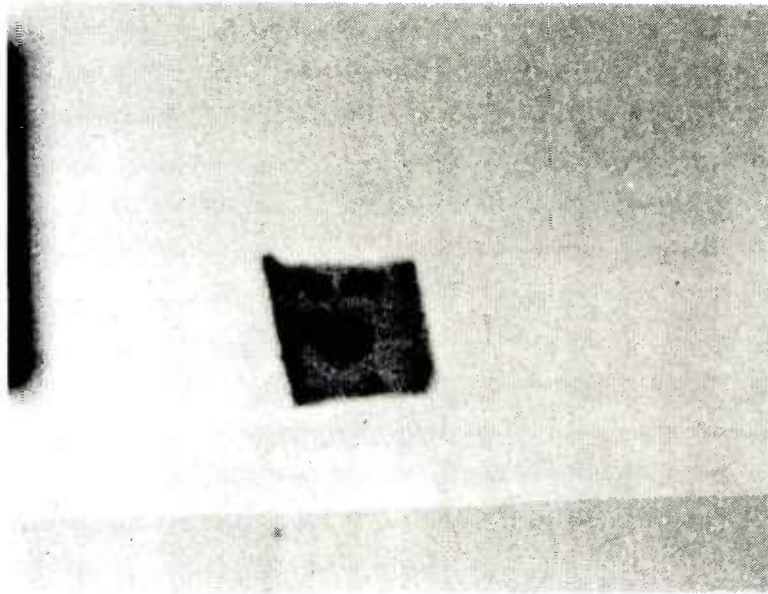


Figure 17. Illustration of odd inclusion. 2000x

BETHLEHEM STEEL

SEM

EDAX Evaluation of Inclusion

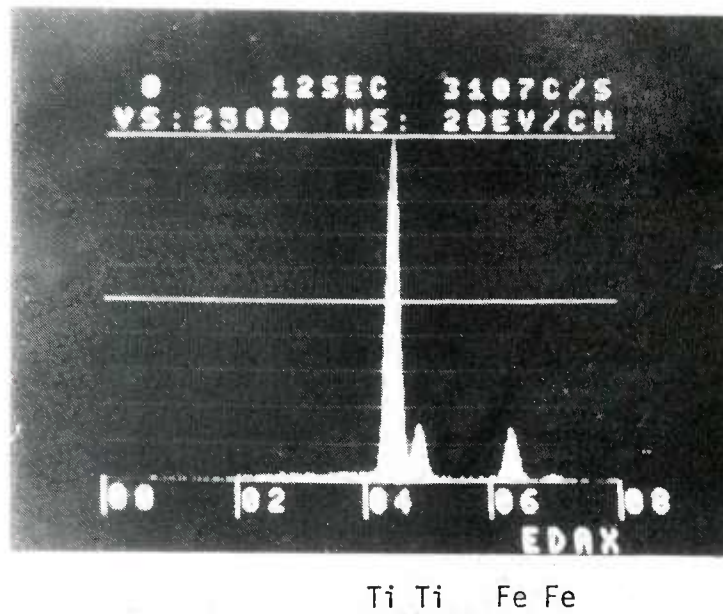


Figure 18. EDAX evaluation of black area in center of square inclusion revealing high purity titanium and iron.

BETHLEHEM STEEL

SEM

EDAX Evaluation of Inclusion

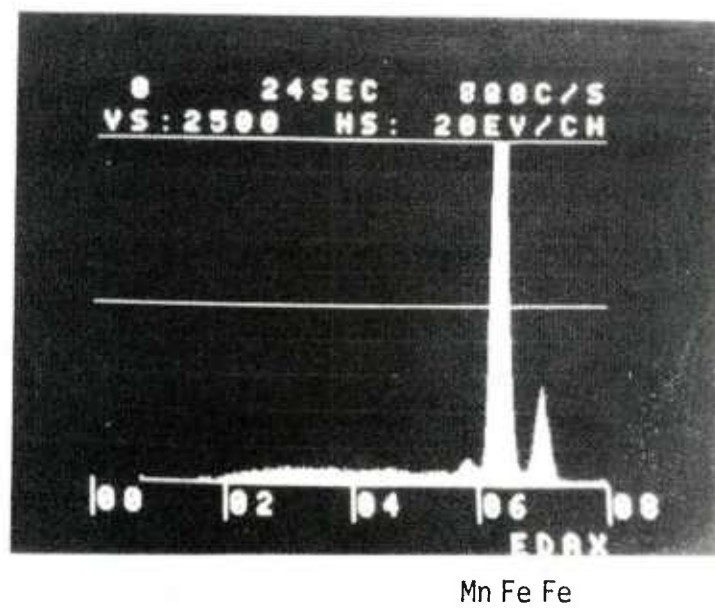


Figure 19. EDAX Evaluation of area away from inclusion.

Republic Steel

Inclusions

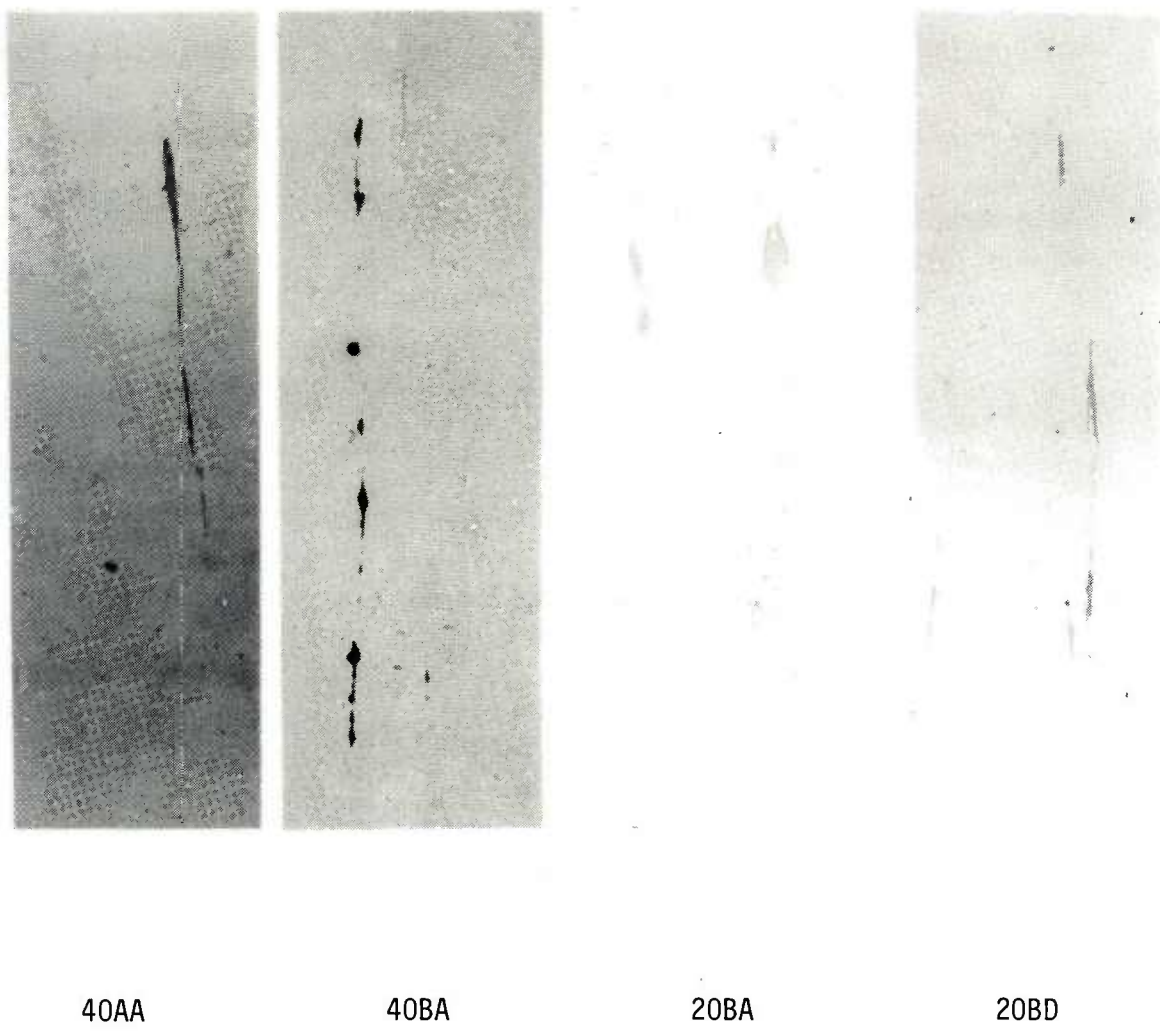
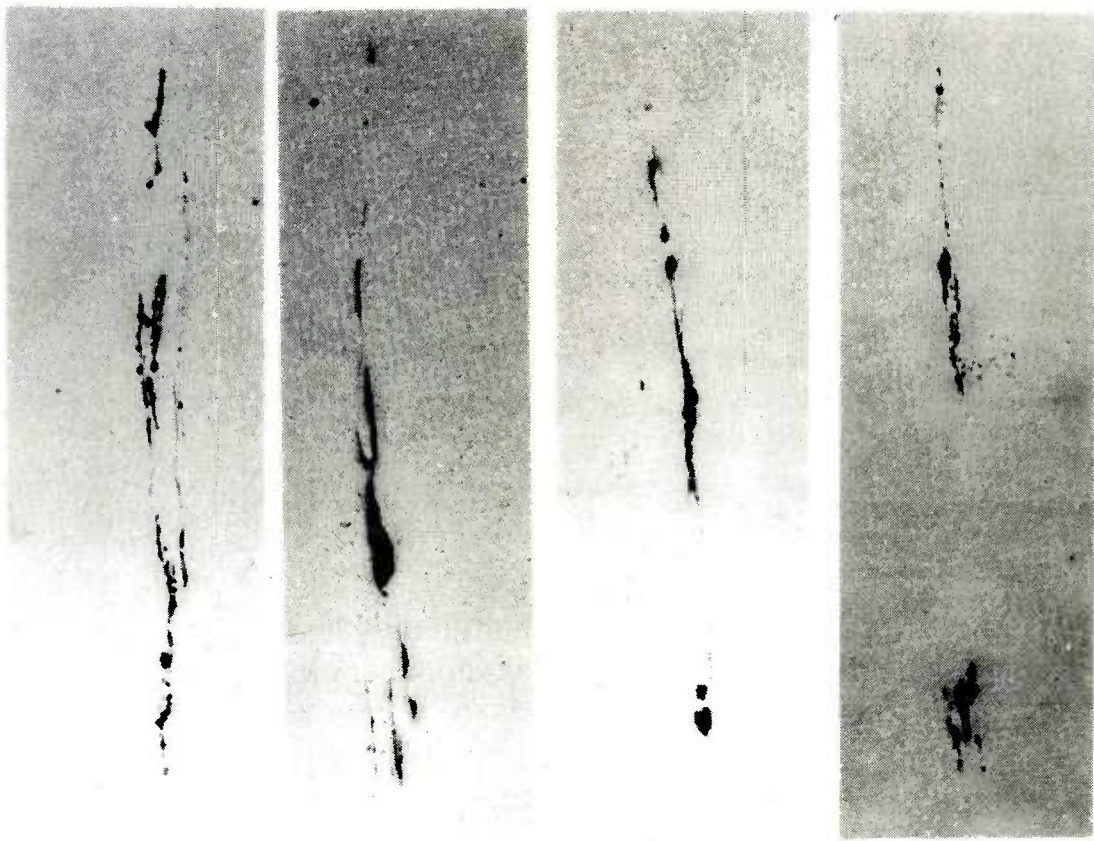


Figure 20. Typical Inclusions. 125x.

Bethlehem Steel

Inclusions



1X

1C

2T

10X

Figure 21. Typical Inclusions. 125x.

Heat Treatment

Scope of Work MFX-001 requires HF-1 steel to meet a yield strength of 827 MPa (120,000 PSI) and an elongation of 12%. In order to determine the temperature for Austenitization and tempering to attain these properties, the Isothermal Transformation diagram (fig. 22) was first consulted. Austenitization temperatures deemed acceptable for testing were 843°C (1550°F), 815°C (1500°F) and 804°C (1480°F). Soaking time was set at one hour.

Before tempering tests were begun, samples austenitized at the above temperatures were metallographically evaluated to determine the effect of these temperatures on the size of the martensite as-quenched platelets and the amount of retained austenite. Figures 23 thru 26 show the variation and figure 27 illustrates fine spots that appear when water is used for polishing and rinsing. All other samples were polished with an alcohol suspension of aluminum and subsequently rinsed in alcohol (anhydrous).

Tests 1 through 8 described below, were conducted on Billet 1AA of Republic Steel.

Test 1

Austenitized at 843°C (1550°F), for 1 hour.

Eight 1 inch diameter longitudinal coupons were austenitized at 843°C (1550°F). Of these, two were tempered at 593°C (1100°F), two at 638°C (1180°F), two at 677°C (1250°F) and two at 760°C (1400°F). Tempering time was one hour for all, followed by quenching in TexQuench 500 (Tex-Quench A) oil at 27°C (80°F). Tensile bars for these tests were standard specimens, machined to 0.505 inch. The mechanical properties attained at various tempering temperatures were extremely low and are plotted in figure 28.

Upon metallographic evaluation, small white areas were discovered in a coupon from this group which could be ferrite particles caused by slack quench, or small carbide due to insufficient austenitizing time (fig. 29).

Test 2

These white areas and the low mechanical properties led to the next stage of testing in which austenitizing time was increased to two hours to investigate the effects of time at temperature on the mechanical properties. The temperature (843°C/1550°F) used in the first series of tests was maintained for this series with a tempering temperature of 638°C (1180°F). No significant changes occurred in either mechanical properties or microstructure.

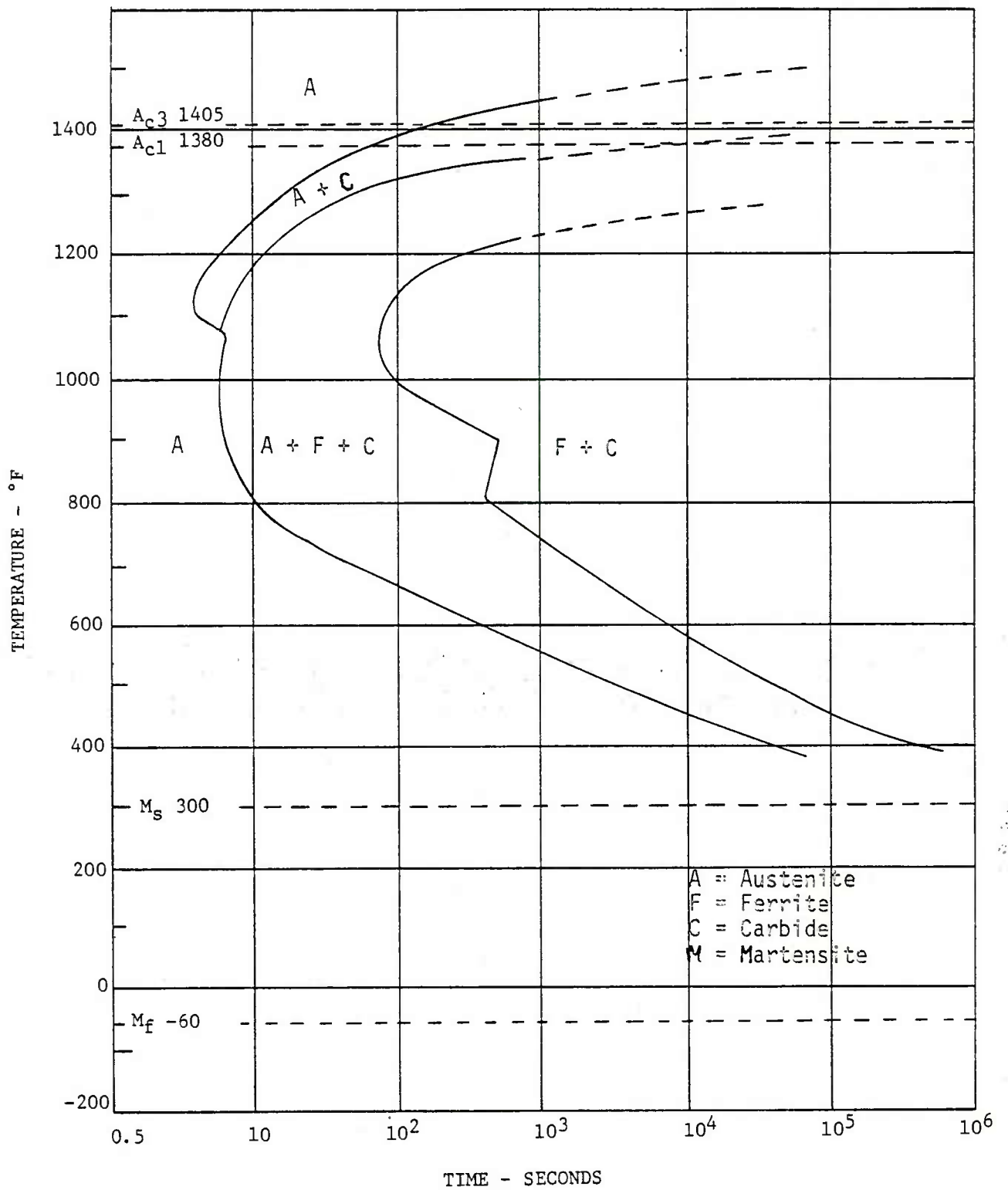


Figure 22.

ISOTHERMAL TRANSFORMATION DIAGRAM FOR HFI STEEL

Test 3

Again maintaining the 843°C (1550°F) austenitizing temperature and a one inch coupon, the next parameter to be examined was the quenchant. Texaco Oil Company specifies the fastest quench attainable with TexQuench A is 12.5 seconds at approximately 65°C (150°F) according to the G.M. Quenchometer Test. After a one hour soak, the coupon was quenched in TexQuench A at 65°C (150°F) and tempered at 638°C (1180°F).

There was no significant change in yield strength. Elongation increased from 12.5% to 14.5%. The microstructure (figure 30) revealed the same white areas observed in the initial series, in an untempered, martensite matrix. Rockwell C hardness was 63-64.

HF-1
As-Quenched Structures



Figure 23. Photomicrograph of untempered martensite with some retained austenite (white area) in sample austenitized at 843°C (1550°F). 1000x



Figure 24. Photomicrograph of untempered martensite with less retained austenite (white area) than Figure 23. This sample was austenitized at 829°C (1525°F). 1000x

Test 4

The next series was performed with coupons of 3/4 inch section thickness to improve the effect of quenching in oil. Initial results provided a yield strength of 800 MPa (116 ksi) and a 16% elongation, an improvement from previous tests. There was a marked decrease in the amount of white areas in the microstructure of the as-quenched samples. These white areas were not continuous, as were those in previous samples, leading to the conclusion that they are ferrite, produced by insufficient quench speed. These areas were later proved to be carbides.

Test 5

This series of tests held constant the 3/4" diameter coupon size, austenitizing temperature of 843°C (1550°F) and quench temperature 65°±5.5°C (150°F±10°F). Tempering temperatures were varied with acceptable results obtained at a tempering temperature between 593°C (1100°F) and 616°C (1140°F). For a plot of these results see figure 31. Because this temperature range is entirely too narrow to be reasonably maintained during production, the next series was run as an attempt to widen the range.

Test 6

Constants in this series were: austenitizing temperature of 804°C (1480°F) for one hour; quench in TexQuench A at 65°C (150°F). Again, tempering temperatures were varied. Acceptable results were achieved in the tempering range of 580°C (1075°F) to 640°C (2285°F) with yield strengths of 920 MPa (133 ksi) and 827 MPa (120 ksi). The elongations plotted for these yields were 13% and 15% respectively, (see figure 32). Coupons heat treated in this series of tests revealed a very fine, untempered martensite (figure 26) with a Rockwell C hardness of 61-62.

Test 7

In this series 3/4 inch diameter coupons were austenitized for one hour at 815°C (1500°F) and quenched in Tex Quench A at 65°C (150°F). Tempering temperatures were again varied and the results plotted in figure 33. All curves exhibit a sharp increase in yield strength and decrease in elongation at 753°C (1380°F), which is the lower critical (Ac) for HF-1. At this temperature, the coupons become partially reaustenitized.

Before further testing was undertaken, discussions were held at ARRADCOM during which it was determined to austenitize all further series at 915°C (1500°F) and to quench at 65°C (150°F) in Tex-Quench A.

HF-1
As-Quenched Structures



Figure 25. Photomicrograph of untempered martensite with very little amounts of retained austenite. This sample was austenitized at 815°C (1500°F). 1000x

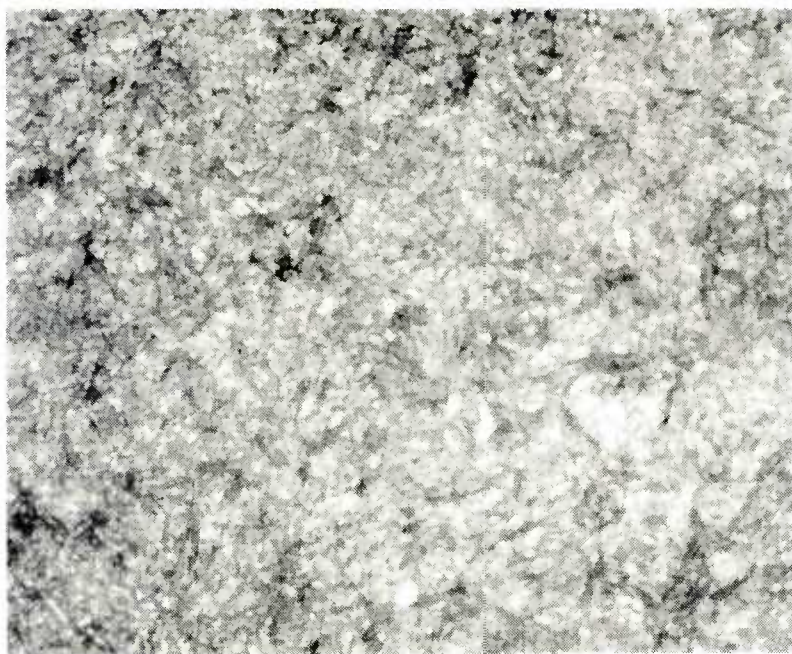


Figure 26. Photomicrograph of untempered martensite with very little amounts of retained austenite. This sample was austenitized at 804 °C (1480°F). 1000x

HF-1
As-Quenched Structures

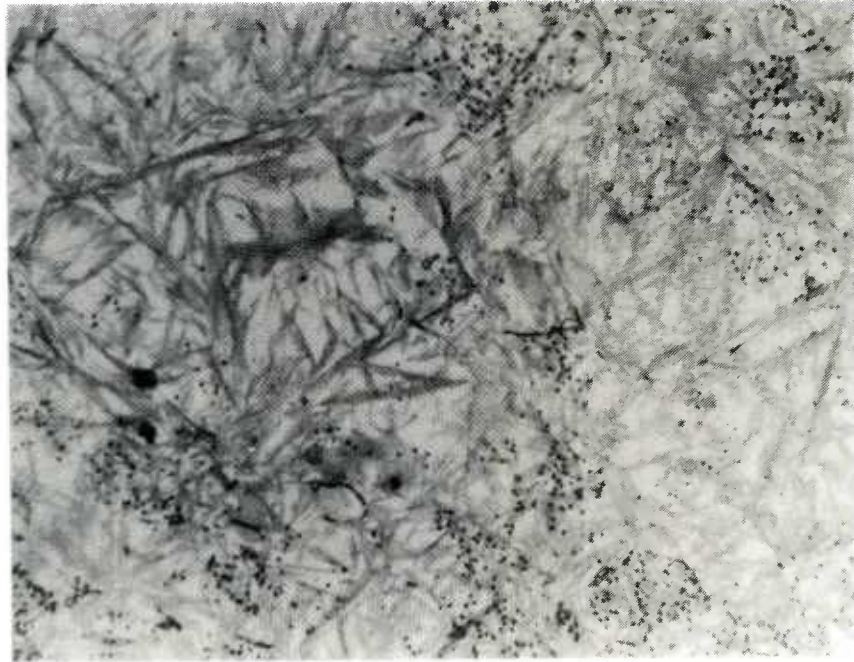


Figure 27. Photomicrograph of untempered martensite with black spot contamination from water polishing and rinsing. This sample was austenitized at 843°C (1550°F). 1000x

46 1320

10 X 10 TO 1 INCH DIA. (INCHES)
NEUFFEL & ESSER CO. WASH. D.C.

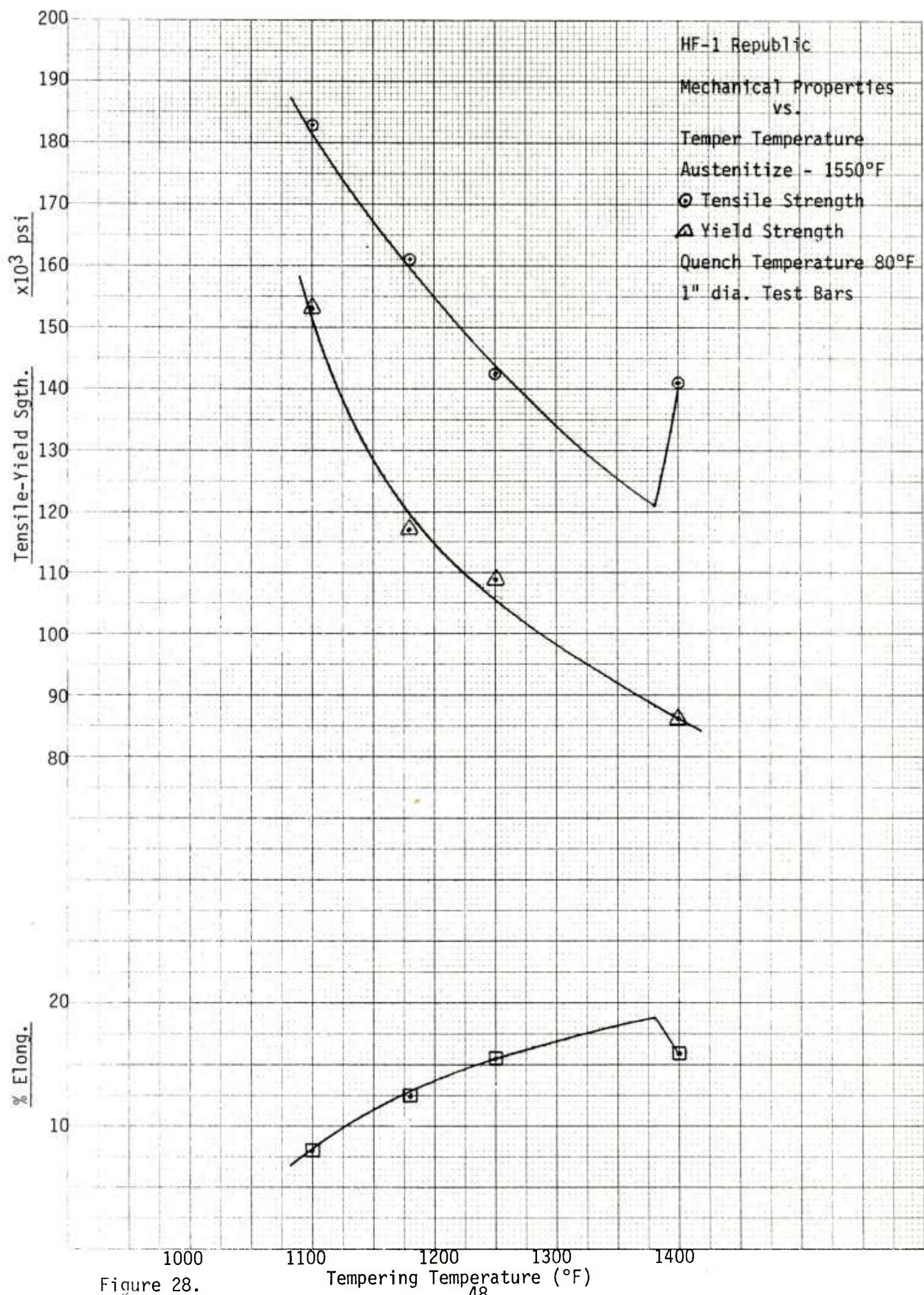


Figure 28.

HF-1



Figure 29. Photomicrograph showing white areas. 500x 2% Nital.

HF-1

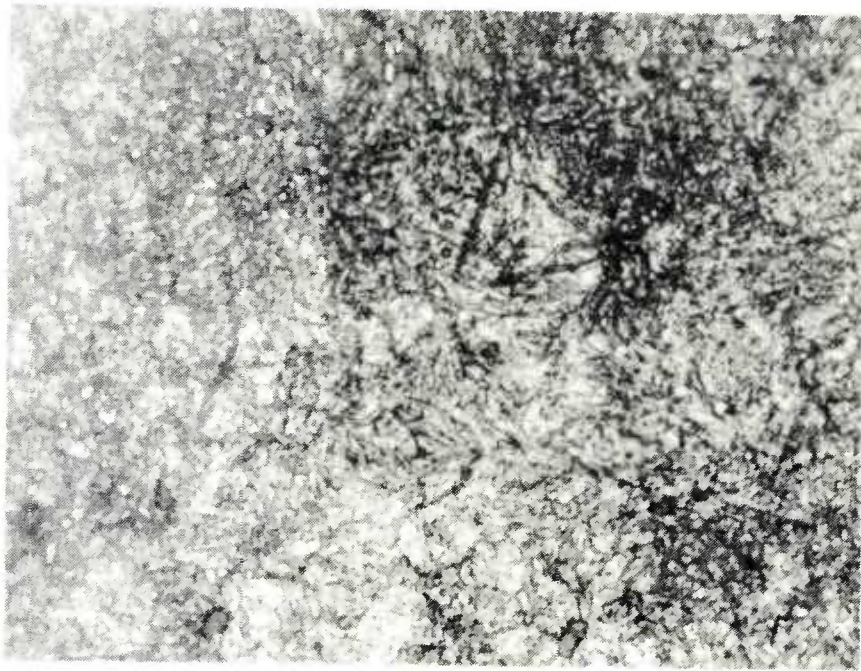


Figure 30. Photomicrograph showing white areas. 1000x 2% Nital.

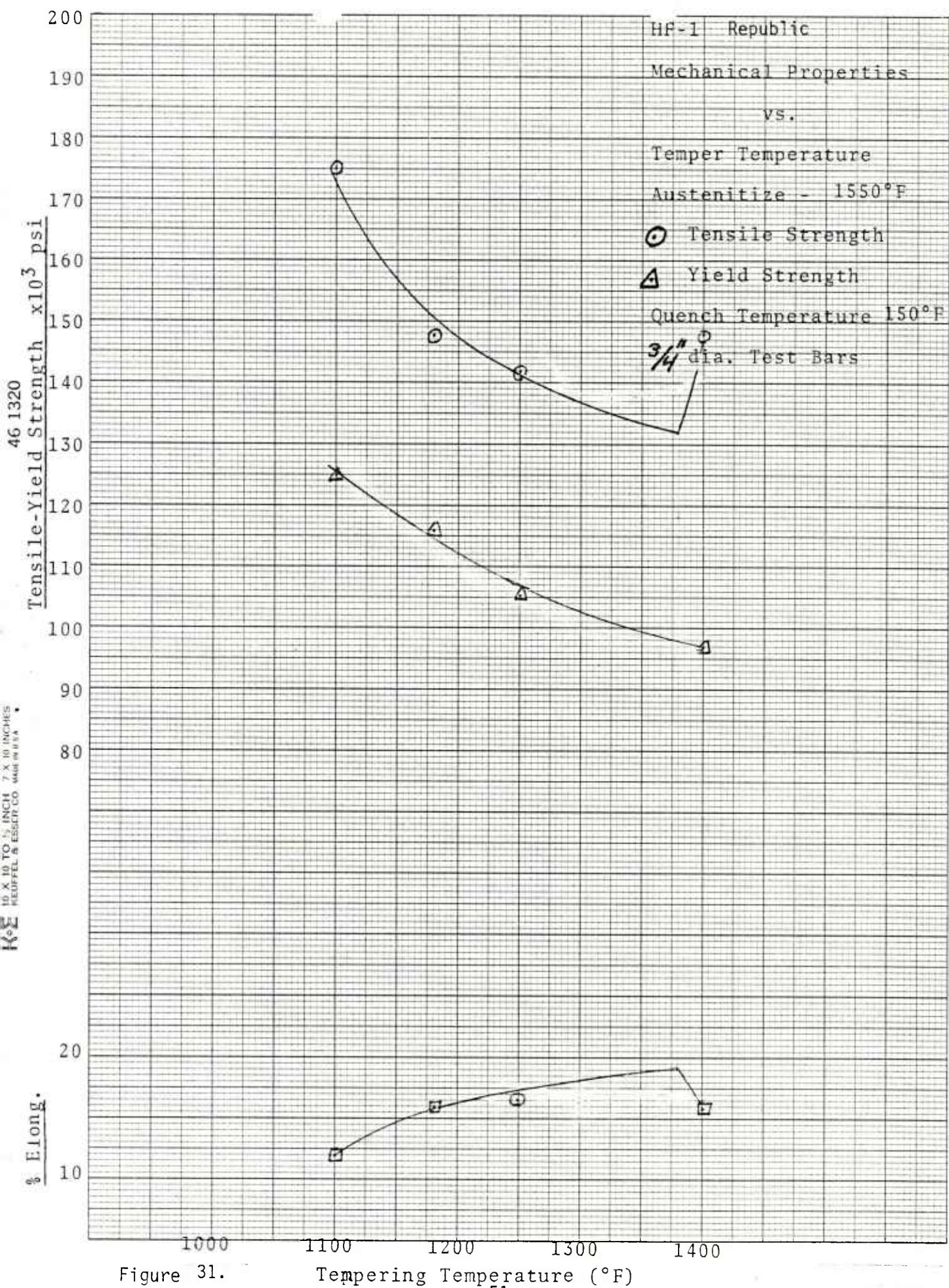
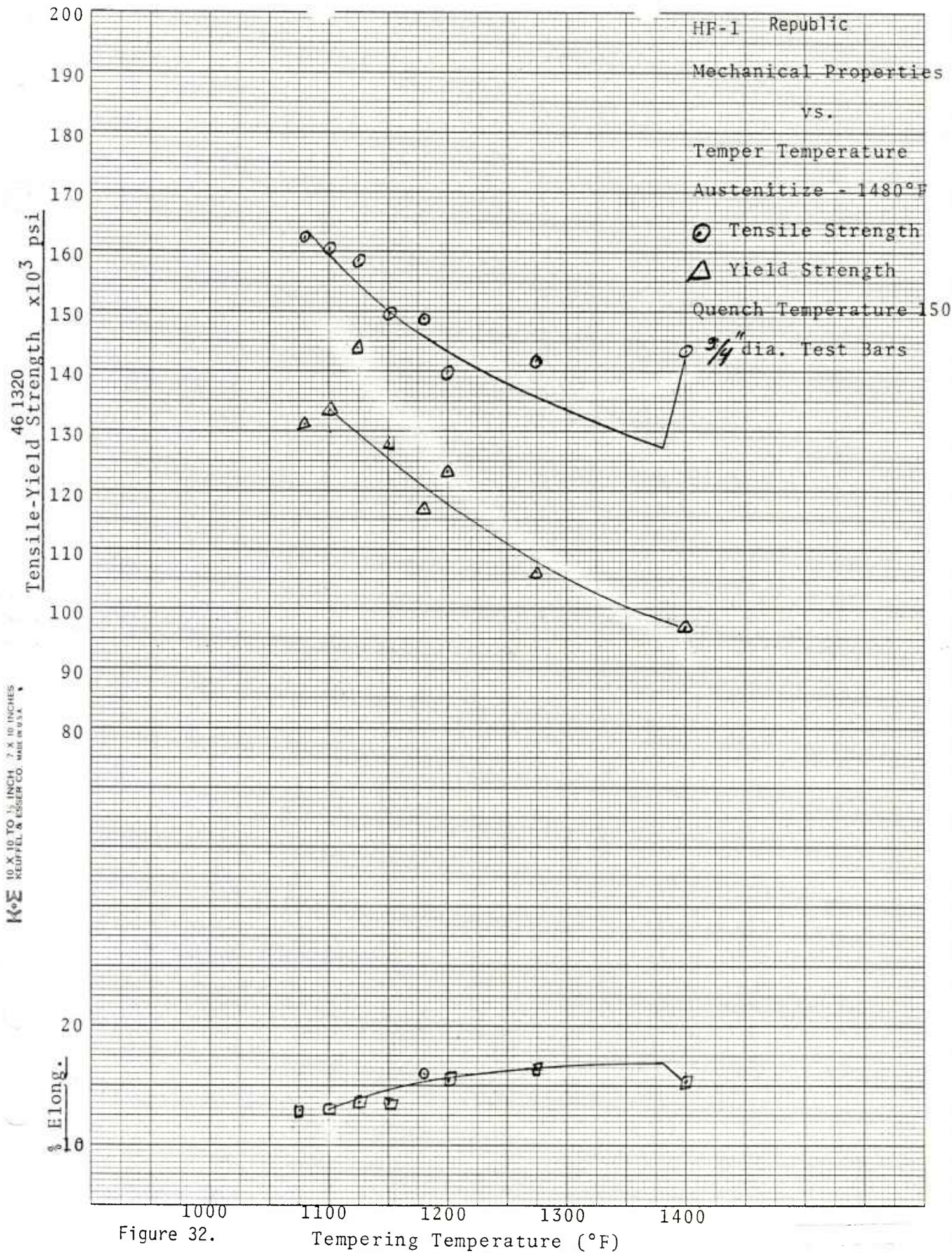
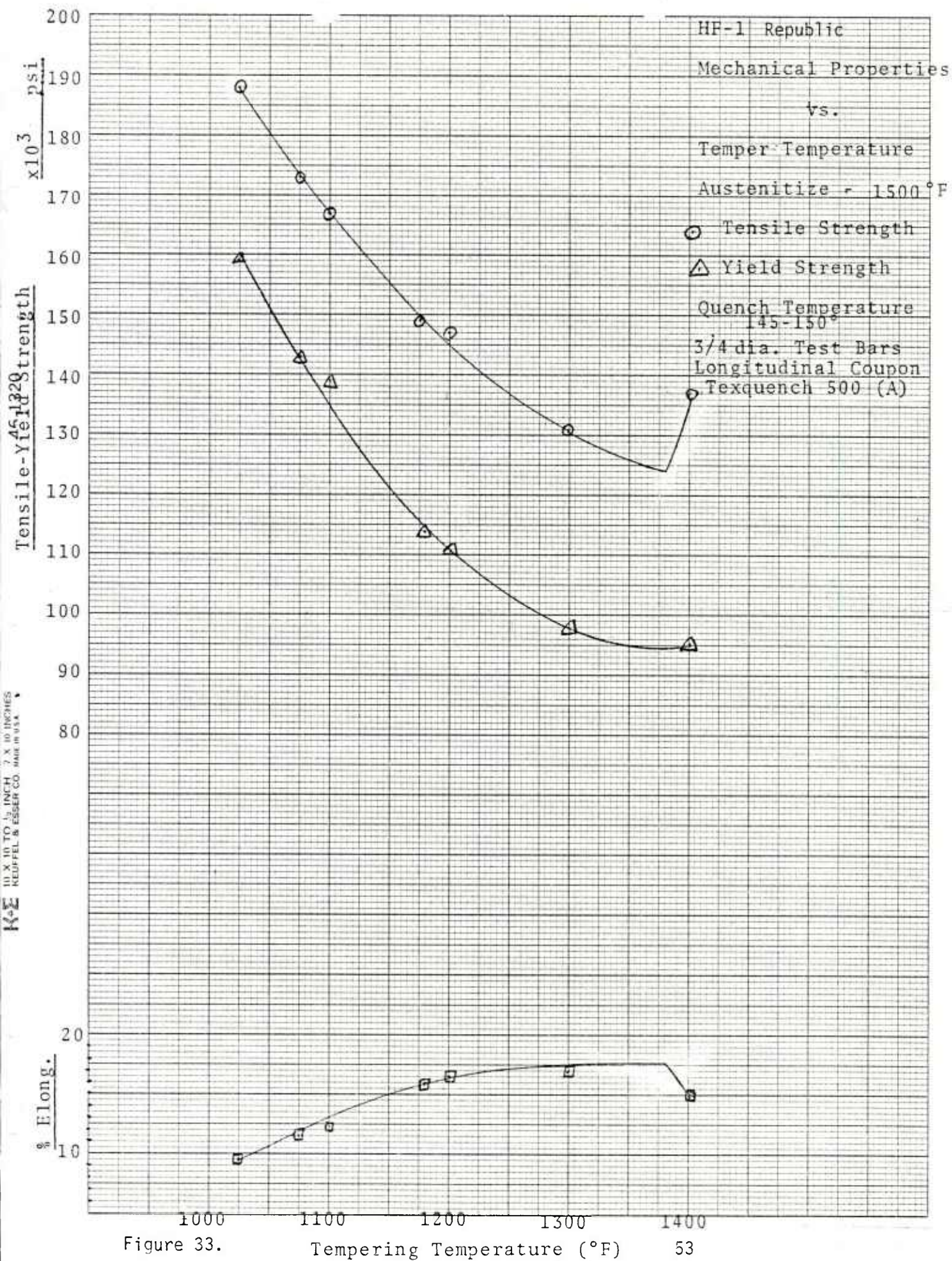
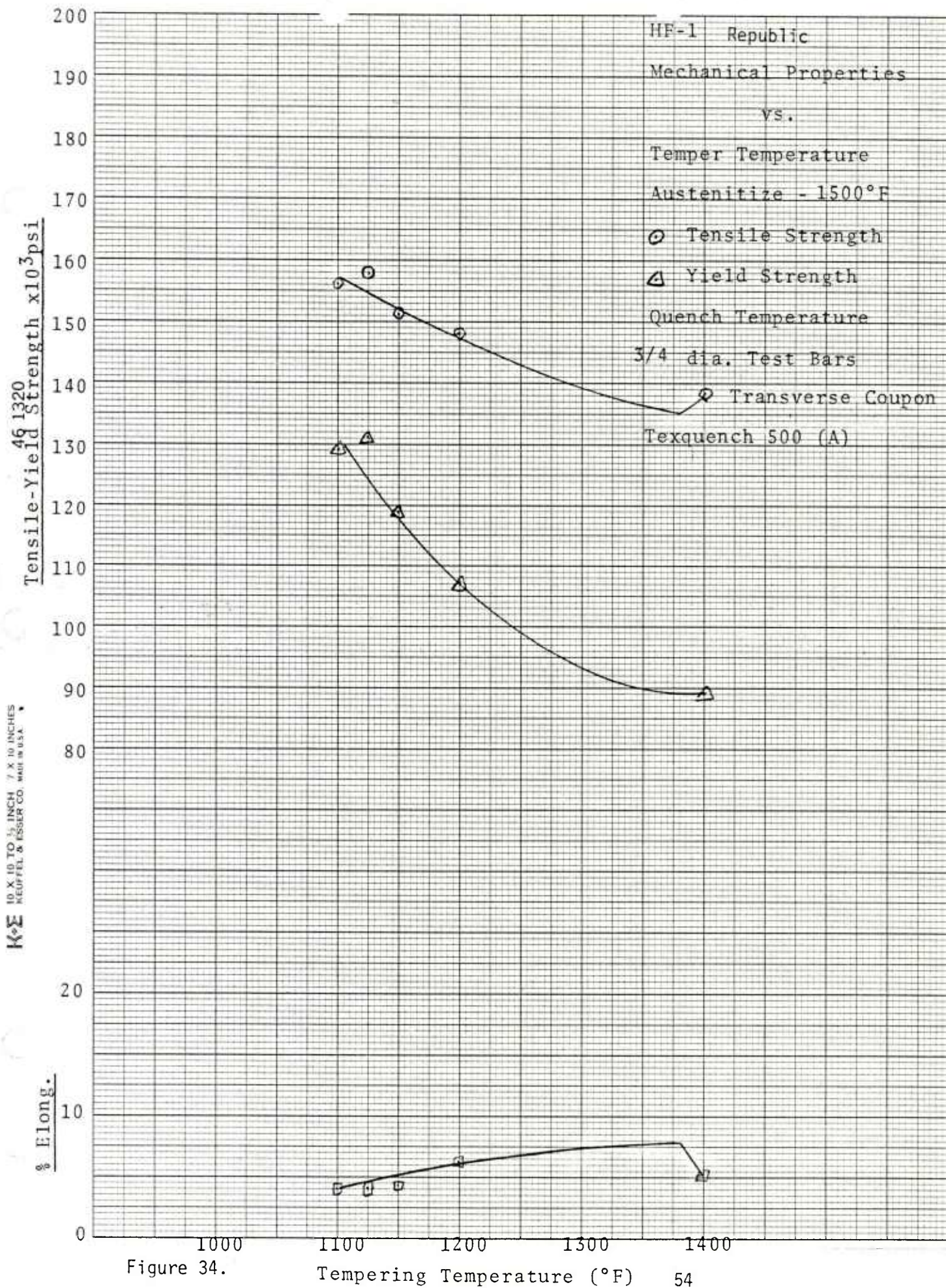
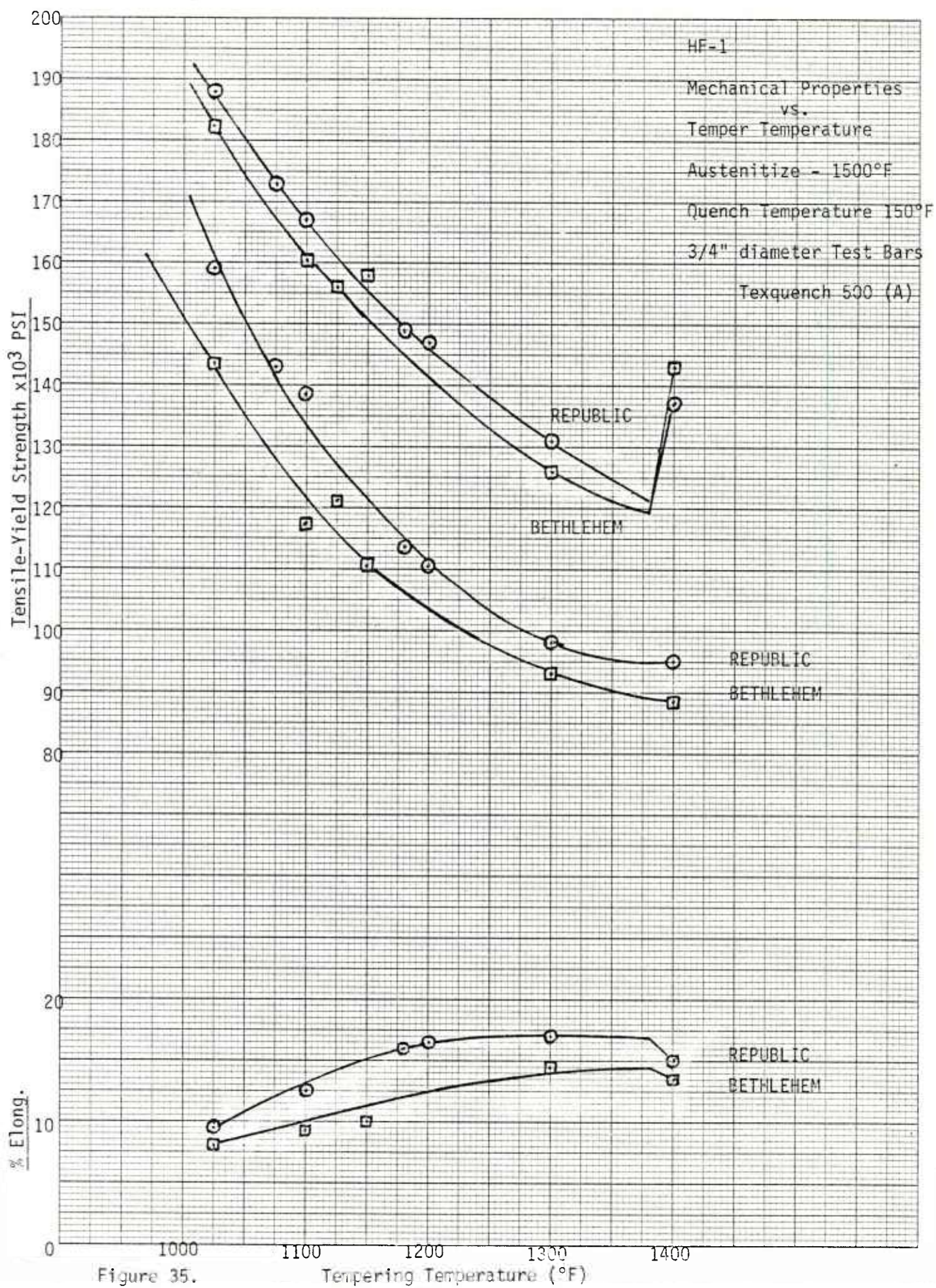


Figure 31.









Test 8

The final test on Republic was the heat treatment of transverse samples. The results are plotted in figure 34. Maximum elongation attainable within these parameters is 4.3% at 820 MPa (119 ksi). A tempering temperature of 607°C (1125°F) would seem to produce the best results for both transverse and longitudinal samples as shown in figure 33. Transverse yield would be approximately 903 MPa (131 ksi) with an elongation of 4.0%. Longitudinal yield would be 875 MPa (127 ksi) with an elongation of 14%. These results are the product of a hot rolled, as received condition and should be minimum obtainable.

The following tests were performed on both Republic and Bethlehem Steel. The heat treatment parameters used for these tests were:

Sample size: 3/4" longitudinal
 3/4" transverse
Austenitizing Temperature: 815°C (1500°F)
Austenitizing Time: 1 hour
Tempering Temperature: 607°C (1125°F)
Tempering Time: 1 hour
Quench Medium: TexQuench A
Quench Medium Temperature: 65°C (150°F)

Table 13 is a tabulation of the results of testing of Republic Steel. Tables 14 and 15 consist of the Bethlehem test results. The Republic Steel clearly produced a more uniform product than that of Bethlehem.

Figures H1 thru H20 illustrate a composite of a tensile bar, its' fracture and microstructure.

Experimental Problems

In the early stages of the project, the evaluation of as-quenched samples was performed by transporting the samples to the laboratory for metallographic sectioning immediately after austenitization and quench. The samples at this time were at a temperature of 65°C (150°F) to 71°C (160°F). An abrasive cut-off wheel was then used to remove a 1/4 inch section from one end. This operation is performed with the sample under water. Upon mounting these 1/4 inch sections for metallographic evaluation, no visual defects were observed. However, every sample was rejected for processing into tensile bars because of longitudinal cracking which apparently occurred during subsequent tempering. Because of this cracking problem the process was altered to temper all samples for use in tensile testing immediately after quenching.

One as-quenched sample, which had been polished and etched, cracked during metallographic evaluation with enough force to pop off of the inverted stage metallograph.

From these indications it is concluded that HF-1 must be tempered immediately after quenching. No intermediate operations which would subject HF-1 to a liquid medium before tempering should be allowed.

TABLE 15.

HF-1
Republic Steel

Sample	Aust °F	°C	Temper °F	°C	Sect.	Yield Sgth (psi)	Mpa	Tensile Sgth (psi)	Mpa	Elong. %	RA %	Hardness Rc
1AA	1500	815	1125	607	L	123005	848	166583	1148	12.0	26.9	33.2
1BA	1500	815	1125	607	L	137327	947	155885	1075	12.0	26.6	32.7
1BD	1500	815	1125	607	L	128860	888	159744	1101	11.0	29.7	34
20AA	1500	815	1125	607	L	120856	833	150802	1040	12.0	25.9	33
20BA	1500	815	1125	607	L	123805	854	164066	1131	12.0	22.8	32.9
20BD	1500	815	1125	607	L	120785	833	168092	1159	12.5	28.3	33.9
40AA	1500	815	1125	607	L	125818	867	165576	1142	12.0	23.5	32.8
40BA	1500	815	1125	607	L	117765	812	169099	1166	12.0	24.9	33.6
40BD	1500	815	1125	607	L	116725	805	166751	1150	12.5	24.6	33.4
1AA	1500	815	1125	607	T	131365	906	157841	1088	4.0	4.7	31
1BA	1500	815	1125	607	T	119654	825	152749	1053	4.5	1.6	31.8
1BD	1500	815	1125	607	T	128309	885	157841	1088	6.0	7.8	30.7
20AA	1500	815	1125	607	T	126685	873	153099	1056	4.5	5.7	32.9
20BA	1500	815	1125	607	T	129940	896	157553	1086	3.5	4.5	30.5
20BD	1500	815	1125	607	T	128309	885	161914	1116	7.0	10.9	31.9
40AA	1500	815	1125	607	T	122199	842	155804	1074	4.0	7.8	32.0
40BA	1500	815	1125	607	T	116090	800	153767	1060	3.0	2.3	31.4
40BD	1500	815	1125	607	T	128819	888	159877	1102	7.0	11.7	32

TABLE 16.

HF-1
Bethlehem Steel

Sample	Aust. °F—°C	Temper °F—°C	Sect.	Yield Sgth (psi) Mpa	Tensile Sgth (psi) Mpa	Elong. %	RA %	Hardness Rc
1T(box)	1500 815	1125 607	T	107658	742 143174	987	4.6	30.0
1C	1500 815	1125 607	T	122199	842 127800	881	1.2	32.9
1X	1500 815	1125 607	T	116090	800 149695	1032	4.0	33
2T	1500 815	1125 607	T	120216	829 147709	1018	7.3	29.5
2C	1500 815	1125 607	T	125254	864 134929	930	4.7	31.9
2X	1500 815	1125 607	T	115214	794 149457	1030	5.0	30.0
10T(box)	1500 815	1125 607	T	115322	795 128316	884	4.4	31.2
10C	1500 815	1125 607	T	121294	836 142857	985	2.4	32.3
10X	1500 815	1125 607	T	113034	779 157609	1086	1.6	29.0
11T	1500 815	1125 607	T	118232	815 149171	1028	1.7	31.6
11C	1500 815	1125 607	T	120672	832 132383	913	3.0	30.6
11X	1500 815	1125 607	T	127717	880 153261	1057	5.7	30.2
19T	1500 815	1125 607	T	115903	799 136927	944	1.2	29.2
19C	1500 815	1125 607	T	122360	844 129940	896	6.9	31.6
19X	1500 815	1125 607	T	111051	766 153100	1056	4.5	30.5
20T(box)	1500 815	1125 607	T	120652	832 141302	974	2.4	28.8
20C	1500 815	1125 607	T	111532	769 135896	937	2.0	29.4
20X	1500 815	1125 607	T	108895	751 145553	1003	6.5	28.3

TABLE 17.

HF-1
Bethlehem Steel

Sample	Aust °F	°C	Temper °F	°C	Sect.	Yield Sgth (psi)	Mpa	Tensile Sgth (psi)	Mpa	Elong. %	RA %	Hardness Rc
1T(box)	1500	815	1125	607	L	127796	881	154420	1065	10.0	21.2	32 Broke soon @ T.S.
1C	1500	815	1125	607	L	121196	836	154891	1068	9.0	18.1	33.5
1X	1500	815	1125	607	L	119145	822	165988	1144	8.5	15.3	32.6
2T	1500	815	1125	607	L	127831	881	166079	1145	10.0	20.0	31.8
2C	1500	815	1125	607	L	130369	899	161698	1115	10.0	16.0	32.5
2X	1500	815	1125	607	L	115752	798	160040	1103	12.0	23.5	32.2
10T(box)	1500	815	1125	607	L	120972	834	159535	1100	8.0	13.0	31.1 bad break
10C	1500	815	1125	607	L	135380	933	163563	1128	11.0	33.0	32.8
10X	1500	815	1125	607	L	122141	842	160083	1104	8.0	15.1	30.8
11T	1500	815	1125	607	L	120341	830	158147	1090	9.0	16.9	32.3 bad break @ neck
11C	1500	815	1125	607	L	127174	877	156522	1079	10.0	17.3	30.5 broke @ T.S.
11X	1500	815	1125	607	L	123536	852	158672	1094	9.0	33.0	32.4
19T	1500	815	1125	607	L	123805	854	158027	1089	6.5	8.9	31.2
19C	1500	815	1125	607	L	123805	854	160040	1103	9.5	17.1	31.9
19X	1500	815	1125	607	L	120785	833	157021	1096	12.0	26.2	30.9
20T(box)	1500	815	1125	607	L	121951	841	159067	1097	7.0	11.9	30.8
20C	1500	815	1125	607	L	124072	855	154825	1062	8.5	14.1	29.9
20X	1500	815	1125	607	L	109713	756	149471	1031	12.0	25.6	30.2

Metallographic Overview

Austenite Grain Size

In order to evaluate the probable reason for the significant variation in mechanical properties of the billets within the heat from Bethlehem Steel and between material from Republic Steel, all samples were etched with Wesley-Austin solution to reveal the prior austenitic grain boundary. The results are listed in Table 16 along with the percent elongation. From the table it can be inferred that larger grain size material generally results in lower elongation values.

It is suggested that the variation in percent elongation in the Bethlehem steel is due to the size of the prior austenitic grain size which is in turn indicative of the method of processing at the steel mill. This means that Bethlehem Steel's single conversion process (rolling from ingot to billet without cooling to room temperature) produces a wide variation in austenitic grain size as opposed to Republic Steel's double conversion (cooling to room temperature in the bloom stage and reheating to complete rolling) which produces a more uniform and smaller grain size. The size of the austenite grain is dependent on the temperature of the billet during the finish rolling operation and the temperature after the final rolling operation. It is understandable that the grain size of the Bethlehem Steel material is significantly larger than the material from Republic Steel since Bethlehem Steel began their final rolling operation with a billet temperature of 1204°C (2200°F) while Republic Steel's billet temperature was 1121°C (2050°F). The original Bethlehem Steel specification calls out a rolling temperature of 1121°C (2050°F). It is not clear at this time why the Lackawanna Plant of Bethlehem Steel did not adhere to their own specification.

Another reason for lower elongation values, as stated previously is a large amount of undissolved carbide present in the heat treated specimens. It is theorized that the heat treated structure of samples from Republic Steel show a better structure because of the double conversion process. This process produces a pseudo normalizing operation in the process which dissolves the carbides when the blooms are reheated from room temperature to 1121°C (2050°F) prior to final rolling and subsequent air cooling. The carbon content of most of the Bethlehem Steel billets is generally higher than that of Republic Steel's which contribute to the greater quantity of undissolved carbide in the heat treated samples from Bethlehem Steel.

It is therefore postulated that the possibility exists when material from Bethlehem Steel is heated to the proposed forging temperature of 1121°C (2050°F) the structure will be broken up and the mechanical properties will improve with their becoming more uniform. This must be proven and substantiated thru the use of metallographic techniques.

TABLE 18. Comparison of Austenitic Grain Size
versus Percent Elongation

<u>Supplier</u>	<u>Location</u>	<u>Figure</u>	<u>ASTM Grain Size No.</u>	<u>Elongation Percent</u>
Republic	1 TOP	J1	4.5	12.0
	1 MID	J2	4	12.0
	1 BOT	J3	3	11.0
	20 TOP	J4	3.5	12.0
	20 MID	J5	5	12.0
	20 BOT	J6	4	12.5
	40 TOP	J7	4.5	12.0
	40 MID	J8	4	12.0
	40 BOT	J9	3.5	12.5
Bethlehem	1 TOP	J10	0	10.0
	1 MID	J11	1	9.0
	1 BOT	J12	0.5	8.5
	2 TOP	J13	1.5	10.0
	2 MID	J14	0	10.0
	2 BOT	J15	2.5	12.0
	10 TOP	J16	1.5	8.0
	10 MID	J17	2	11.0
	10 BOT	J18	1	8.0
	11 TOP	J19	2	9.0
	11 MID	J20	2	10.0
	11 BOT	J21	2	9.0
	19 TOP	J22	1	6.5
	19 MID	J23	1.5	9.5
	19 BOT	J24	3	12.0
	20 TOP	J25	3.5	7.0
	20 MID	J26	2	8.5
	20 BOT	J27	4	12.0

Again, it is indicated that there is no significant difference between Bethlehem Steel's box cooled and furnace cooled material.

Figures J1 through J27 are photomicrographs of the Austenitic grain size as contained in Appendix J.

CONCLUSIONS

Alternate Cooling: No significant differences were observed between steel which was furnace cooled and the alternate slow-cooled steel.

Differences in heats: Republic Steel's HF-1 was more consistent in reaching minimum mechanical properties than Bethlehem's. The mean hardness of the Republic steel is higher than that of Bethlehem and significantly more consistent within the heat. In addition, the Republic steel seemed to have a higher hardness in the BD position, which is the middle of the ingot.

Special metallographic techniques must be employed as stated in this report.

HF-1 must be tempered immediately after quenching.

Appendix A

Purchase Orders



Chamberlain

Chamberlain Manufacturing Corporation
Scranton Army Ammunition Plant
156 Cedar Avenue, Scranton, Pennsylvania 18501
Telephone (717) 342-7801

ORDER DATE
5/27/80

THE ENTIRE NUMBER BELOW MUST
APPEAR ON ALL INVOICES, PACK-
ING SLIPS, CORRESPONDENCE, ETC.,
REFERRING TO THIS ORDER.

P.O. NO.
9157

PAGE 1 OF 1

BETHLEHEM STEEL CORPORATION
BETHLEHEM AREA SALES
B106 MARTIN TOWERS
BETHLEHEM, PENNSYLVANIA 18016

DELIVER TO
F/S
BILLET YARD

NOTIFY

3

DELIVERY REQUIRED
IN OUR PLANT

P.O. COMPLETED!

EQUISITION NO

7356

GOV'T CONTRACT NO.

DAAA09-74-C-4009

SHIP VIA

F.O.B.

ACCOUNT NUMBER

PROJECT #7106
1571-493

ITEM	QUANTITY	DESCRIPTION	Date Rec'd	Quantity	Del. Rec. No.
		CHANGE ORDER			
		INTERNAL CHANGE ORDER # 2			
		WITH REFERENCE TO THE ABOVE PURCHASE			
		ORDER #, PLEASE REVISE QUANTITY & PRICE			
		TO READ:			
		<u>FROM:</u>			
125 N.T.		HF1 STEEL, BASIC OXYGEN FURNACE			
		HOT ROLLED SEMI-FINISHED FORGING			
		QUALITY FINE GR. 5/8 X 5/8 RCS			
		\$503.00/N.T. \$62,875.00/LOT			
		JOMINY TEST REQUIREMENTS			
		\$ 2,500.00/LOT			
		<u>TO:</u>			
157.15NT		HF1 STEEL, BASIC OXYGEN FURNACE			
		HOT ROLLED SEMI-FINISHED FORGING			
		QUALITY FINE GR. 5/8 X 5/8 RCS			
		\$526.00/N.T. \$82,687.90/LOT			
		JOMINY TEST REQUIREMENTS			
		\$ 2,500.00/LOT			
		NEW TOTAL LOT PRICE \$85,187.90			
		EDWARD SOLOWIEJ			
		VICE-PRESIDENT/GENERAL MANAGER			
		DATE:			
		PER INV. 40501-485/80501-486 DTD. 11/13/79			

6-2-80 Comp 1972-2

X

X

DO-AG

X

X

SAAP #329

X CERTIFICATIONS MUST BE
MAILED SAME DAY SHIPMENT
IS MADE.

PJ/JIC
-Y

REMARKS:



12/12/79

THE ENTIRE NUMBER BELOW MUST
APPEAR ON ALL INVOICES, PACK-
ING SLIPS, CORRESPONDENCE, ETC.
REFERRING TO THIS ORDER.

9 1 5 7

PAGE 1 OF 1

BETHLEHEM STEEL CORPORATION BETHLEHEM AREA SALES 8106 MARTIN TOWERS 3TH. & EATON AVENUES BETHLEHEM, PENNSYLVANIA 18016	DELIVER TO F/S BILLET YARD	DELIVERY REQUIRED IN OUR PLANT
	NOTIFY # 3	SHIP BY 1/4/80

REQUISITION NO.	GOV'T CONTRACT NO.	SHIP VIA	ACCOUNT NUMBER
22457	DAAA89-74-C-4089	MILL-FRG. EQUALIZED TO NEAREST PRODUCING FT.	PROJECT 7106 1571-493

ITEM	QUANTITY	DESCRIPTION	Date Rec'd	Quantity	Del. Rec. No.
		CHANGE ORDER	3-11	77645	17837
		CHANGE ORDER # 1		(114 Pcs)	
		WITH REFERENCE TO THE ABOVE PURCHASE ORDER #, PLEASE REVISE MULT WEIGHT TO READ:	3-11	76765	17838
		FROM:		(115 Pcs)	
		BILLETS TO BE IN MULTIPLES OF 124[±] LBS. AND NOT TO EXCEED 18' IN LENGTH.	X	154,410.1	
		TO:		Testing	
		BILLETS TO BE IN MULTIPLES OF 80[±] LBS. AND NOT TO EXCEED 18' IN LENGTH.	X	157.15 N.T	
		*RESERVE OPTION TO CHANGE WEIGHT PRIOR TO ROLLING.		DO-A5	
		BALANCE OF ORDER TO REMAIN THE SAME.	X		
		CERTIFICATIONS MUST BE MAILED SAME DAY SHIPMENT X IS MADE.			
		PENNSYLVANIA STATE TAX DOES NOT APPLY.			

REMARKS:

Figure A2.



FOIA b (7) - EXEMPTED COPY

VENDOR BETHLEHEM STEEL CORP.

OF PURCHASE ORDER NO. 9257

EM	QUANTITY	DESCRIPTION	Date Rec'd	Quantity	Del Re
		3. COOLING			
		A. THE MATERIAL FROM THE FIRST, MIDDLE AND LAST USABLE INGOTS OF THE HEAT WILL BE SLOW-COOLED BY A METHOD <u>OTHER THAN FURNACE</u> . SPECIFY METHOD.			
		B. THE MATERIAL FROM ALL OTHER INGOTS WILL BE COOLED BY YOUR CONVENTIONAL FURNACE COOLING PRODEDURE FOR THIS STEEL ALLOY.			
		4. CERTIFICATION OF CHEMISTRY, IN ACCORDANCE WITH MIL-S-50783, WILL BE FURNISHED AND WILL INCLUDE:			
		A. LADLE ANALYSIS			
		B. CHECK ANALYSIS OF 1ST., MIDDLE AND LAST USABLE INGOTS.			
		C. CHECK ANALYSIS OF 2ND., 1ST. AFTER MIDDLE, AND NEXT TO LAST INGOTS.			
		5. JOMINY HARDENABILITY TESTS ON MATERIAL WILL BE MADE AND IDENTIFIED TO THE 1ST., 2ND., MIDDLE, 1ST. AFTER MIDDLE, NEXT TO LAST, AND LAST USABLE INGOTS (6 INGOTS). THREE JOMINY TESTS EACH INGOT REPRESENTING THE TOP, MIDDLE AND BOTTOM OF EACH INGOT. THE RESULTS OF THE JOMINY TESTS WILL BE CERTIFIED; THE TEST BARS AND DATA WILL BE FURNISHED TO THE CUSTOMER. TESTS TO BE IN ACCORDANCE WITH ASTM-A-285.			
		6. AT TIME OF SHIPMENT, AN INVENTORY OF THE HEAT WILL BE FURNISHED TO THE BUYER CONSISTING			

REMARKS:

VENDOR BETHLEHEM STEEL CORP.

OF PURCHASE ORDER NO. 9 1 5 7

EM	QUANTITY	DESCRIPTION	Date Rec'd	Quantity	Del Rec N
		OF:			
		A. HEAT IDENTIFICATION NUMBER			
		B. NUMBER OF INGOTS IN HEAT			
		C. IDENTIFICATION, BY INGOT NUMBER, OF THOSE			
		INGOTS COOLED AS IN 5A. ABOVE, DESCRIPTION			
		OF AND METHOD OF COOLING			
		D. METHOD OF CONVENTIONAL COOLING OF BALANCE			
		OF BILLETS; COMPLETE DESCRIPTION			
		E. NUMBER OF BILLETS FROM EACH INGOT			
		F. OTHER DATA CONSIDERED PERTINENT			
		7. SELLER WILL NOTIFY BUYER OF THE TIME/DATE OF			
		PRODUCING THIS HEAT SO THAT ARRANGEMENTS CAN			
		BE MADE FOR BUYER'S AND/OR GOVERNMENT REPRESENTATIVES TO BE PRESENT DURING THE PERIOD.			
		8. THIS MATERIAL WILL BE USED IN PERFORMANCE OF			
		A MM & T TEST PROGRAM UNDER A GOVERNMENT			
		C CONTRACT # DAAA09-74-C-4089. IT IS			
		DESIRED THAT YOUR NORMAL, ROUTINE PRACTICES			
		IN HANDLING THIS MATERIAL BE ADHERED TO AND			
		THAT NO SPECIAL PROCESSING, OTHER THAN			
		DETAILED ABOVE, BE EMPLOYED.			
		<i>Edward Solowiej</i>			
		EDWARD SOLOWIEJ			
		VICE-PRESIDENT/GENERAL MANAGER			
		DATE: <u>11-10-77</u>			
		PENNSYLVANIA STATE TAX DOES NOT APPLY.			
		<u>ENCLOSURES:</u>			
		AFFIRMATIVE ACTION FOR HANDICAPPED WORKERS			
		EQUAL EMPLOYMENT OPPORTUNITY			
		CERT. OF EQUAL EMPLOYMENT COMPLIANCE			
		CERT. OF NON-SEGREGATED FACILITIES			

REMARKS: AFF. ACTION FOR DISABLED VETS & VETS OF VIETNAM
CLEAN AIR & WATER CERTIFICATION
AFFIRMATIVE ACTION PROGRAM

PURCHASE ORDER



Chamberlain

Chamberlain Manufacturing Corporation
Scranton Army Ammunition Plant
156 Cedar Avenue, Scranton, Pennsylvania 18501
Telephone (717) 342-7801

ORDER DATE

12/12/79

THE ENTIRE NUMBER BELOW MUST
APPEAR ON ALL INVOICES, PACK-
ING SLIPS, CERTIFICATE OF ORIGIN, ETC.
REFERRING TO THIS ORDER.

P.O. NO.

9150

PAGE

1

OF

1

REPUBLIC STEEL CORPORATION
10 VALLEY FORGE EXECUTIVE MALL
530 SWEDES FORD ROAD
WAYNE, PENNSYLVANIA 19087

DELIVER TO

F/S
BILLET YD.

NOTIFY

3

DELIVERY REQUIRED
IN OUR PLANT

SHIP BY 1/4/80

EQUISITION NO.

22456

GOV'T CONTRACT NO.

DAAA09-74-C-4009

SHIP VIA

F.O.B.

MILL-FRT. EQUALIZED
TO NEAREST PROD. POINT

ACCOUNT NUMBER

PROJECT 7106
1571-493

ITEM QUANTITY

DESCRIPTION

Date Rec'd

Quantity

Del. Rec. No.

CHANGE ORDER

CHANGE ORDER # 1

WITH REFERENCE TO THE ABOVE PURCHASE
ORDER #, PLEASE REVISE MULT WEIGHT TO
READ:

FROM:

BILLETS TO BE IN MULTIPLES OF 120* LBS.
AND NOT TO EXCEED 18' IN LENGTH

TO:

BILLETS TO BE IN MULTIPLES OF 80* LBS.
AND NOT TO EXCEED 18' IN LENGTH.

*RESERVE OPTION TO REVISE WEIGHT PRIOR
TO ROLLING

BALANCE OF ORDER TO REMAIN THE SAME

X

X

X

X

DS-A5

CERTIFICATIONS TO BE
MAILED SAME DAY SHIPMENT
X IS MADE.

SAAP # 328

PENNSYLVANIA STATE TAX DOES NOT APPLY.

JPJ/JIC
1

REMARKS:

Chambre lain

Chamberlain Manufacturing Corporation
Scranton Army Ammunition Plant
156 Cedar Avenue, Scranton, Pennsylvania 18501
Telephone (717) 342-7801

11/13/79

THE ENTIRE NUMBER BELOW MUST
APPEAR ON ALL INVOICES, PACK-
ING SLIPS, CORRESPONDENCE, ETC.,
REFERRING TO THIS ORDER

1920.

9 4 5 8

PAGE

1

6

2

DELIVER TO
F/S
BILLET YD

NOTIFY

334

DELIVERY REQUIRED
IN OUR PLANT

SHIP BY 1/4/80

REPUBLIC STEEL CORPORATION
10 VALLEY FORGE EXECUTIVE HALL
530 SWEDSFORD ROAD
WAYNE, PENNSYLVANIA 19387

DITION NO.

GOV'T CONTRACT NO.

SHIP VIA

2354

DAAAC9-74-C-4009

F.O.B.

MILL-FREIGHT EQUALIZED
TO NEAREST PROD. POINT

ACCOUNT NUMBER	
----------------	--

ACCOUNT NUMBER
PROJ. 7105

1571-493

QUANTITY	DESCRIPTION	Date Rec'd	Quantity	Del. Rec. No.
1 HEAT (EST.WT.) (200 NT)	HF1 STEEL, BASIC OXYGEN FURNACE, HOT ROLLED, SEMI-FINISHED, FORGING QUALITY, FINE GRAIN 5½ X 5½ R.C.S. IN ACCORDANCE WITH SPECIFICATION MIL-S-50783 DATED 20 SEPT. 1973. CORNER RADIUS TO BE .75 OR ¾" DIAGONAL: 6.840 ± .090 INCHES. PRICE PER YOUR QUOTATION OF 23 AUG. 1979 \$25.00/CWT. \$100,000.00/LT.	L-11 L-21 1-21	3 fcs 126 109	162091 16435 16436
		X		
		X		DO-A5
	1. BILLETS ARE TO BE IN MULTIPLES OF 124 LBS. AND NOT TO EXCEED 18' IN LGTH. SHORT BILLETS PERMITTED IN MULTIPLES OF 124 LBS. RESERVE OPTION TO CHANGE WEIGHT PRIOR TO ROLLING.	X		
		X	SAAP # 328	
	2. EACH BILLET SHALL BE PERMANENTLY MARKED TO IDENTIFY: A. HEAT DESIGNATION B. INGOT NUMBER FROM WHICH ROLLED C. LOCATION WITHIN INGOT, I.E. 1ST., 2ND., 3RD., ETC.			CERTIFICATIONS MUST BE MAILED SAME DAY SHIPPED IS MADE.
		X		
	3. COOLING. THE MATERIAL WILL BE SLOW-			

BKS:

7.672C WT PER LINEAL INCH

MALE LENGTH 10.427"

Figure A7.

71

ROUTING - EXPEDITE COPY

VENDOR REPUBLIC STEEL CORPORATION

OF PURCHASE ORDER NO. 9158

EM	QUANTITY	DESCRIPTION	Date Rec'd	Quantity	Del Re
		COOLED BY YOUR USUAL PIT COOLING PROCEDURE.			
		4. CERTIFICATION OF CHEMISTRY IN ACCORDANCE WITH MIL-S-50783 WILL BE FURNISHED AND WILL INCLUDE:			
		A. LADLE ANALYSIS			
		B. CHECK ANALYSIS OF 1ST., MIDDLE AND LAST USABLE INGOTS.			
		5. JOMINY HARDENABILITY TESTS ON MATERIAL WILL BE MADE AND IDENTIFIED TO THE 1ST., MIDDLE AND LAST USABLE INGOTS (3 INGOTS). THREE JOMINY TESTS WILL BE MADE ON MATERIAL FROM EACH INGOT REPRESENTING THE TOP, MIDDLE AND BOTTOM OF EACH INGOT.			
		THE RESULTS OF THE JOMINY TESTS WILL BE CERTIFIED; THE TEST BARS AND DATA WILL BE FURNISHED TO THE CUSTOMER. JOMINY TESTS TO BE IN ACCORDANCE WITH ASTM-A-255.			
		6. AT TIME OF SHIPMENT, AN INVENTORY OF THE HEAT WILL BE FURNISHED TO BUYER, CONSISTING OF:			
		A. HEAT IDENTIFICATION NUMBER			
		B. NUMBER OF INGOTS IN HEAT			
		C. DESCRIPTION, COMPLETE, OF COOLING METHOD USED			
		D. NUMBER OF BILLETS FROM EACH INGOT.			
		E. OTHER DATA CONSIDERED PERTINENT			

REMARKS:

Figure A8.

ENDOR REPUBLIC STEEL CORPORATION

OF PURCHASE ORDER NO. 9158

M	QUANTITY	DESCRIPTION	Date Rec'd	Quantity	Del Rec No
		7. SELLER WILL NOTIFY BUYER OF THE TIME/DATE OF PRODUCING THIS HEAT OF STEEL SO THAT ARRANGEMENTS CAN BE MADE FOR BUYER'S AND/OR GOVERNMENT REPRESENTATIVES TO BE PRESENT DURING THIS PERIOD.			
		8. THIS MATERIAL WILL BE USED IN PERFORMANCE OF A MM & T TEST PROGRAM UNDER A GOVERNMENT CONTRACT #DAAA09-74-C-4009. IT IS DESIRED THAT YOUR NORMAL, ROUTINE, PRACTICES IN HANDLING THIS MATERIAL BE ADHERED TO AND THAT NO SPECIAL PROCESSING, OTHER THAN DETAILED ABOVE, BE EMPLOYED.			
					
		EDWARD SOLOWIEJ VICE-PRESIDENT/GENERAL MANAGER DATE: 7-16-77			
		PENNSYLVANIA STATE TAX DOES NOT APPLY.			
		ENCLOSURES:			
		AFFIRMATIVE ACTION FOR HANDICAPPED WORKERS			
		EQUAL EMPLOYMENT OPPORTUNITY			
		CERTIFICATE OF EQUAL EMPLOYMENT COMPLIANCE			
		CERTIFICATE OF NON-SEGREGATED FACILITIES			
		AFF. ACTION FOR DISABLED VETS & VETS OF VIETNAM			
		CLEAN AIR AND WATER CERTIFICATION			
		AFFIRMATIVE ACTION PROGRAM			
		COST ACCOUNTING STDS. P:2 91-379			
		DISCLOSURE STATEMENT			
		CERTIFICATE OF CURRENT COST OR PRICING DATE			

MARKS:

Figure A9.

Appendix B

Photographs of Process

HF-1

Republic Steel

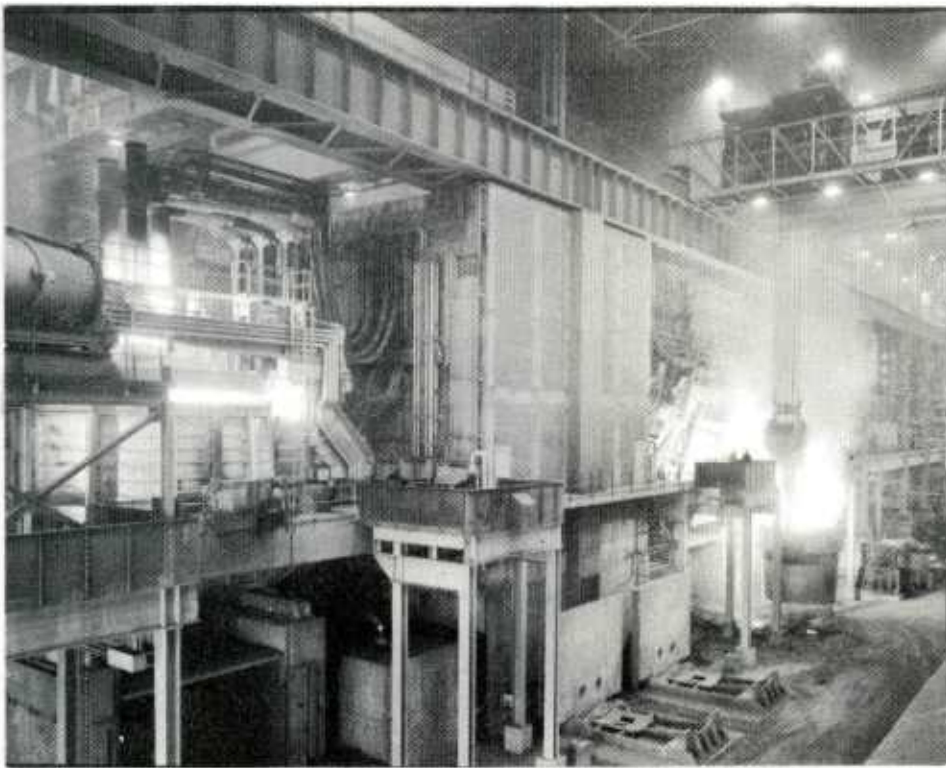


Figure B1. Electric Furnaces

HF-1
Republic Steel



Figure B2. Bottom Pour Ladle

HF-1
Republic Steel

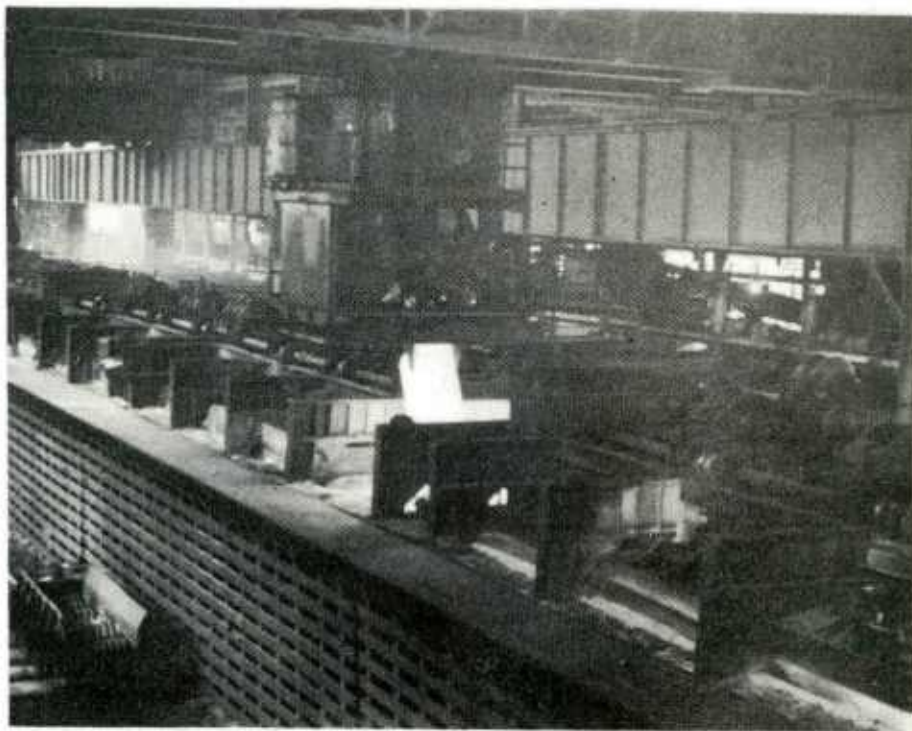


Figure B3. Ingot being Removed from Soaking Pits

HF-1

Republic Steel

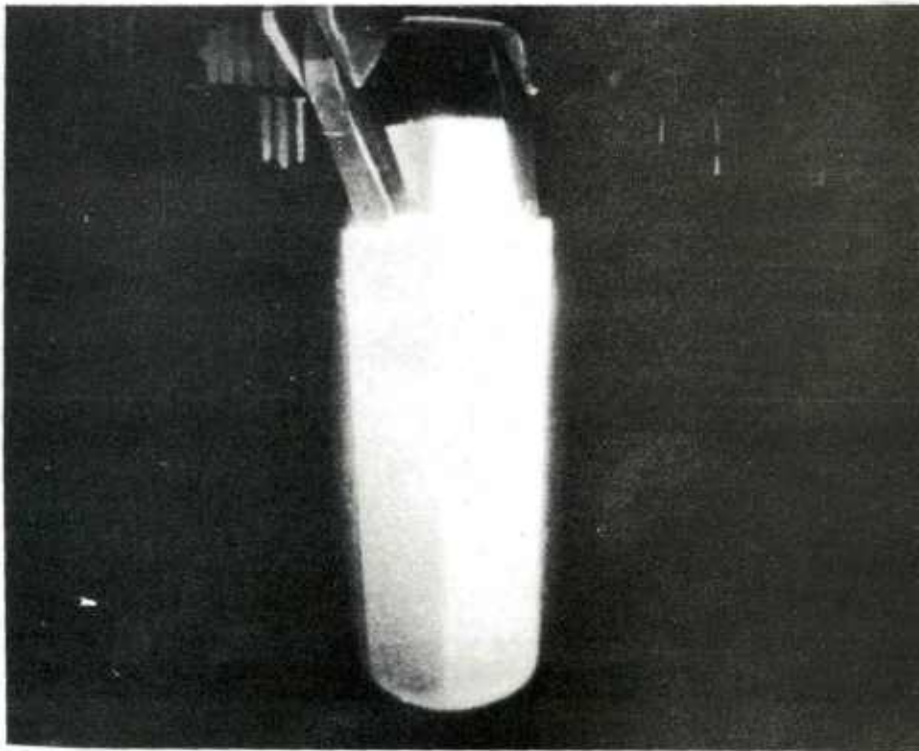


Figure B4. Ingot Being Transported to Blooming Mill

HF-1

Republic Steel

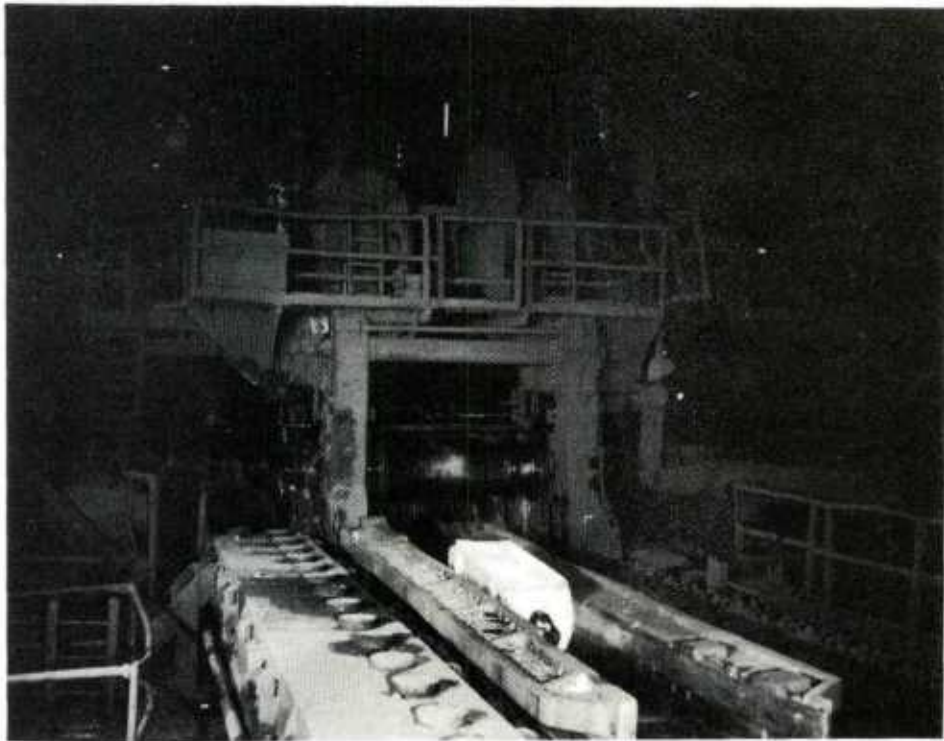


Figure B5. Ingot Being Rolled in 35 inch Blooming Mill

HF-1
Republic Steel

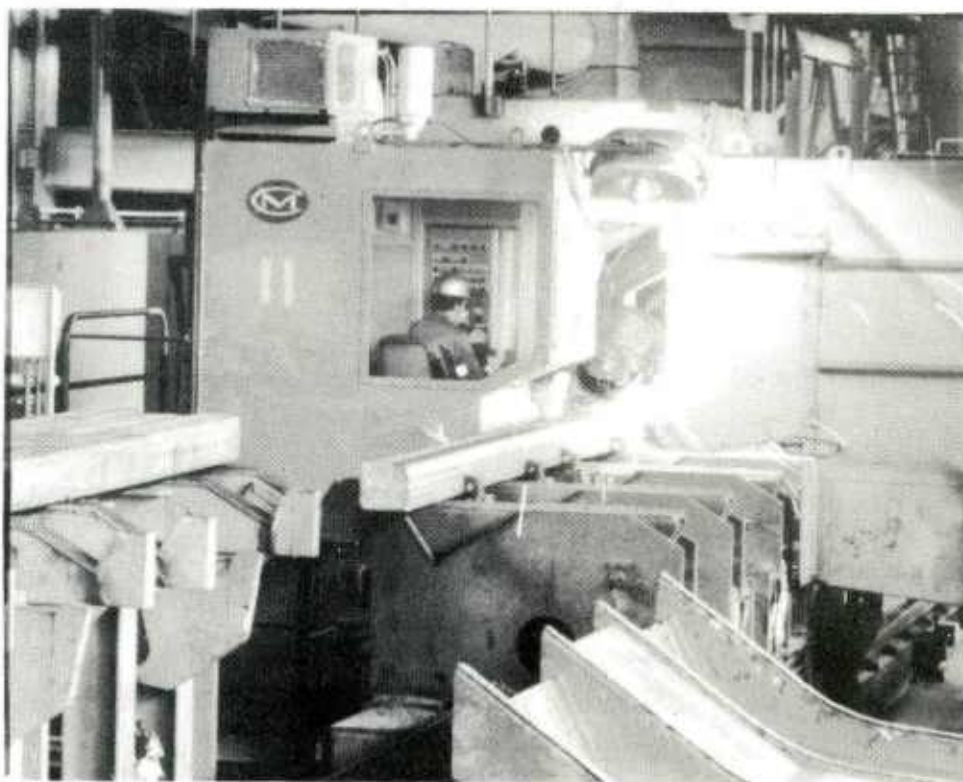


Figure B6. Grinding Blooms

HF-1

Republic Steel

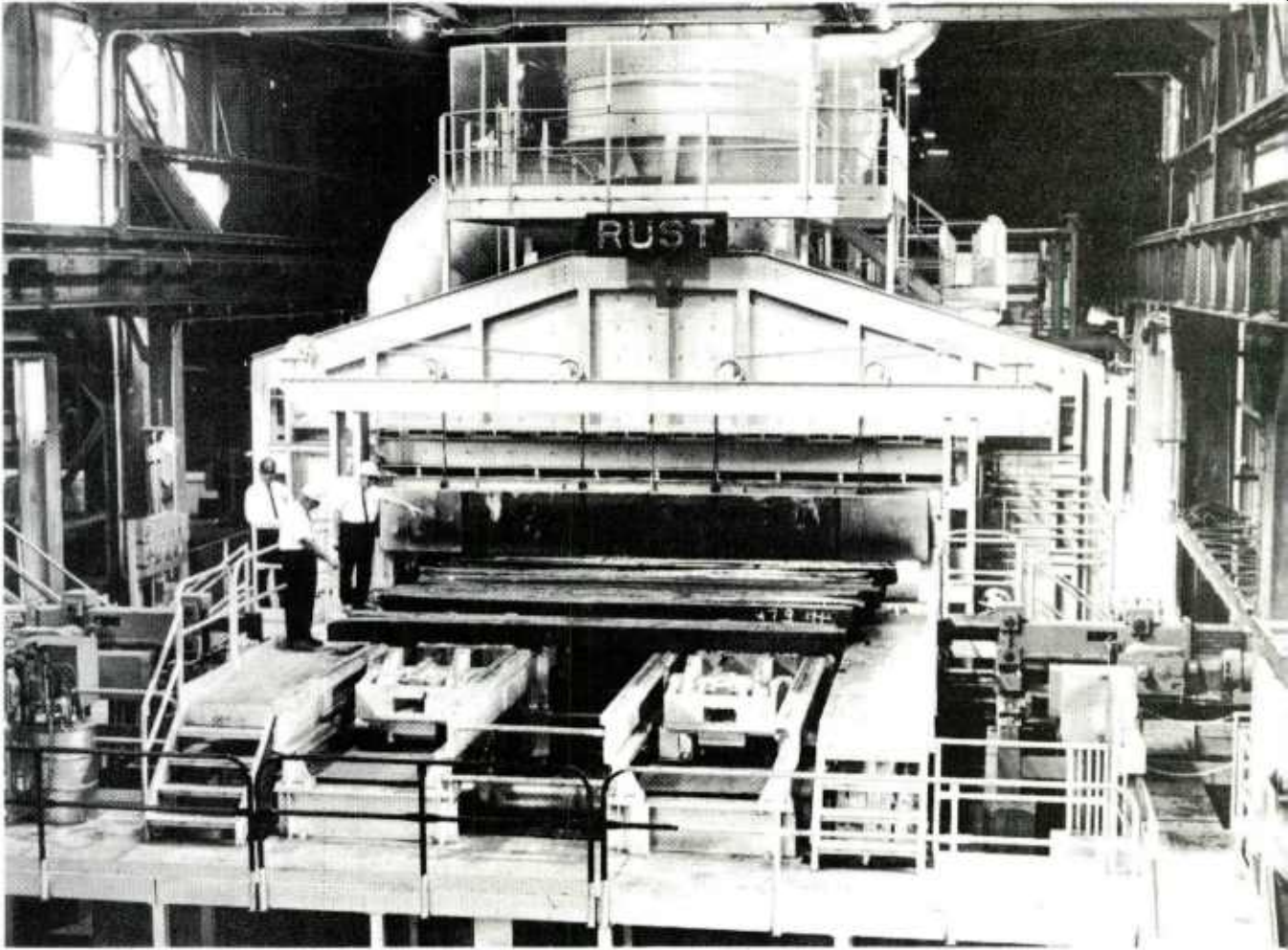


Figure B7. Bloom Reheat Furnace

HF-1

Republic Steel

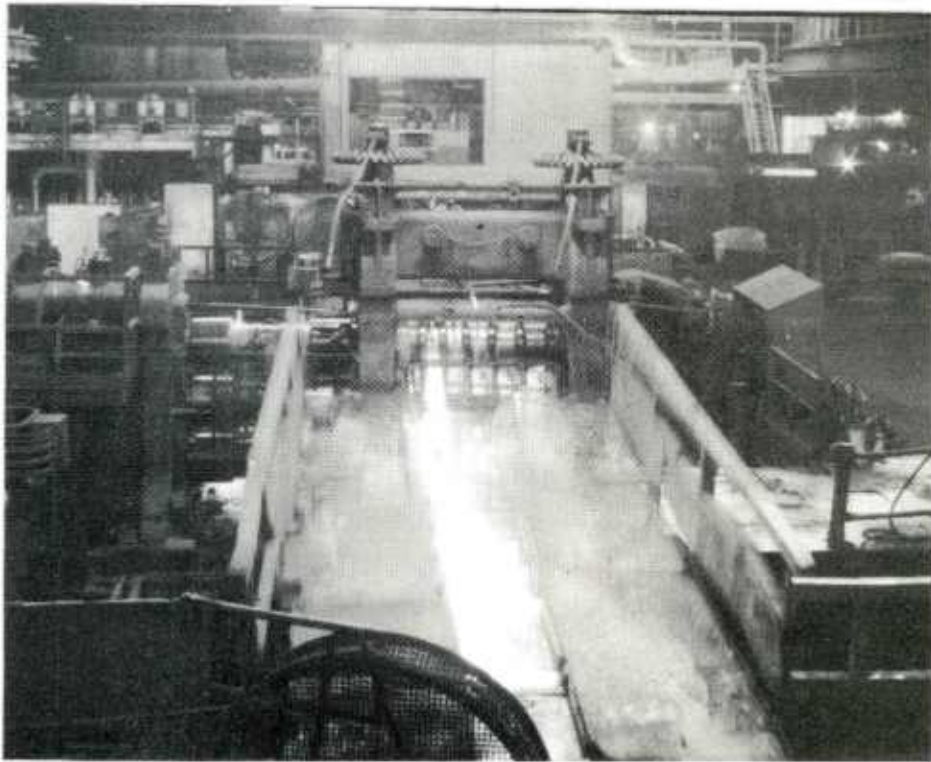


Figure B8. Exit Side: Seven Pass Reversing Mill

HF-1
Republic Steel



Figure B9. Exit Side: Finish Roll Stand

HF-1
Republic Steel

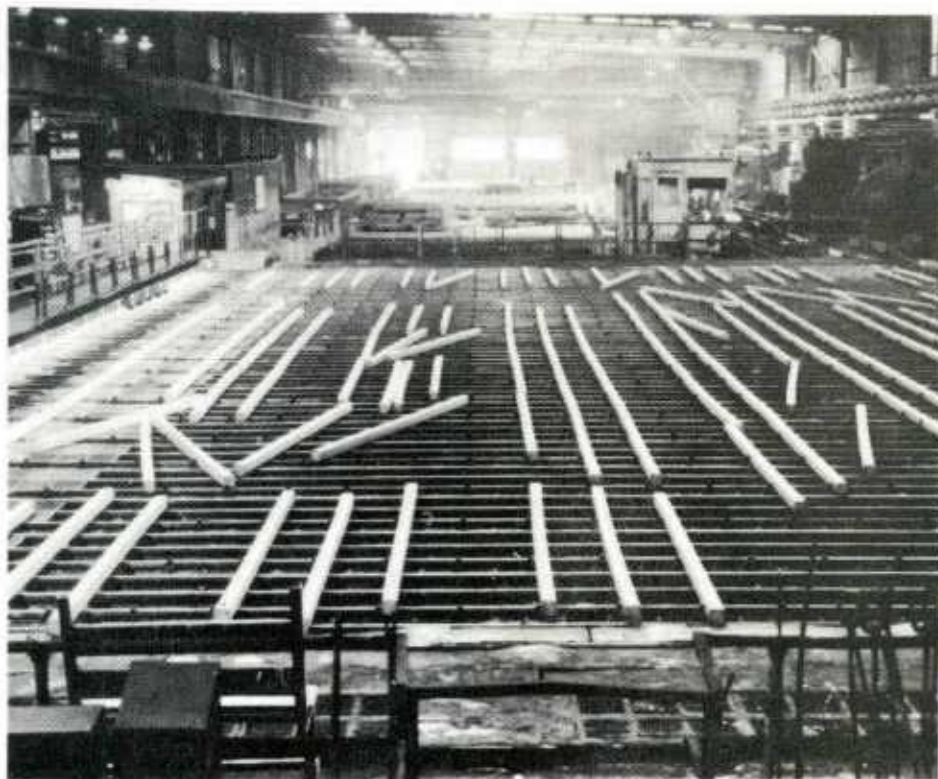


Figure B10 Run-Out Table for Preliminary Cooling Prior to Pit Cooling

HF-1
Republic Steel

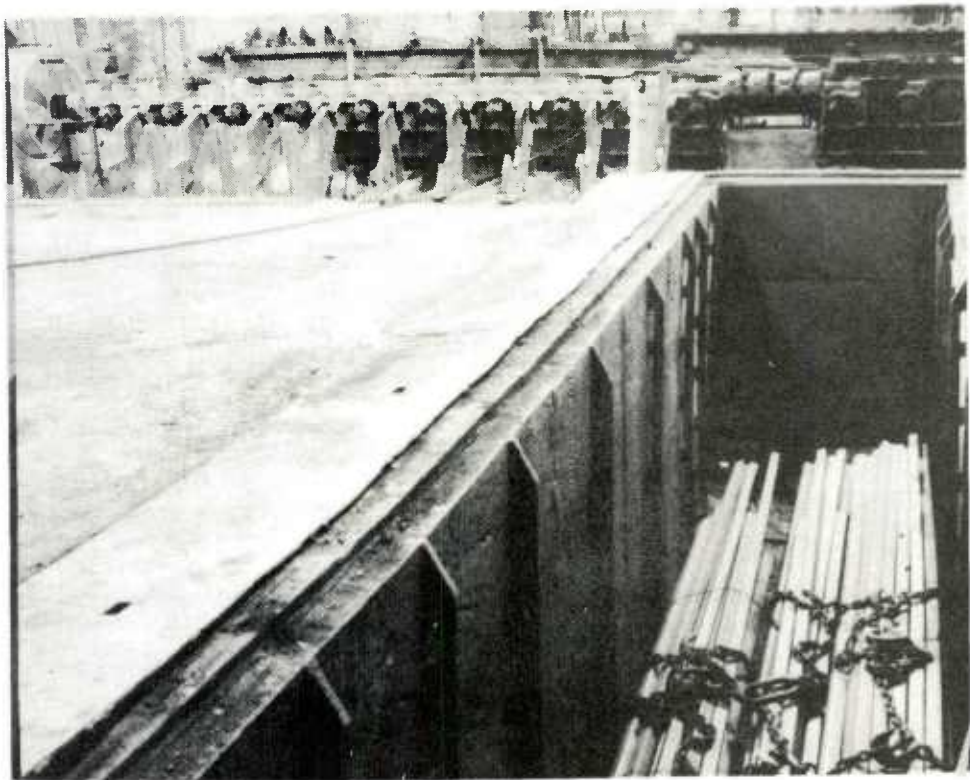


Figure B11. Billets in Cooling Pit

HF-1
Bethlehem Steel

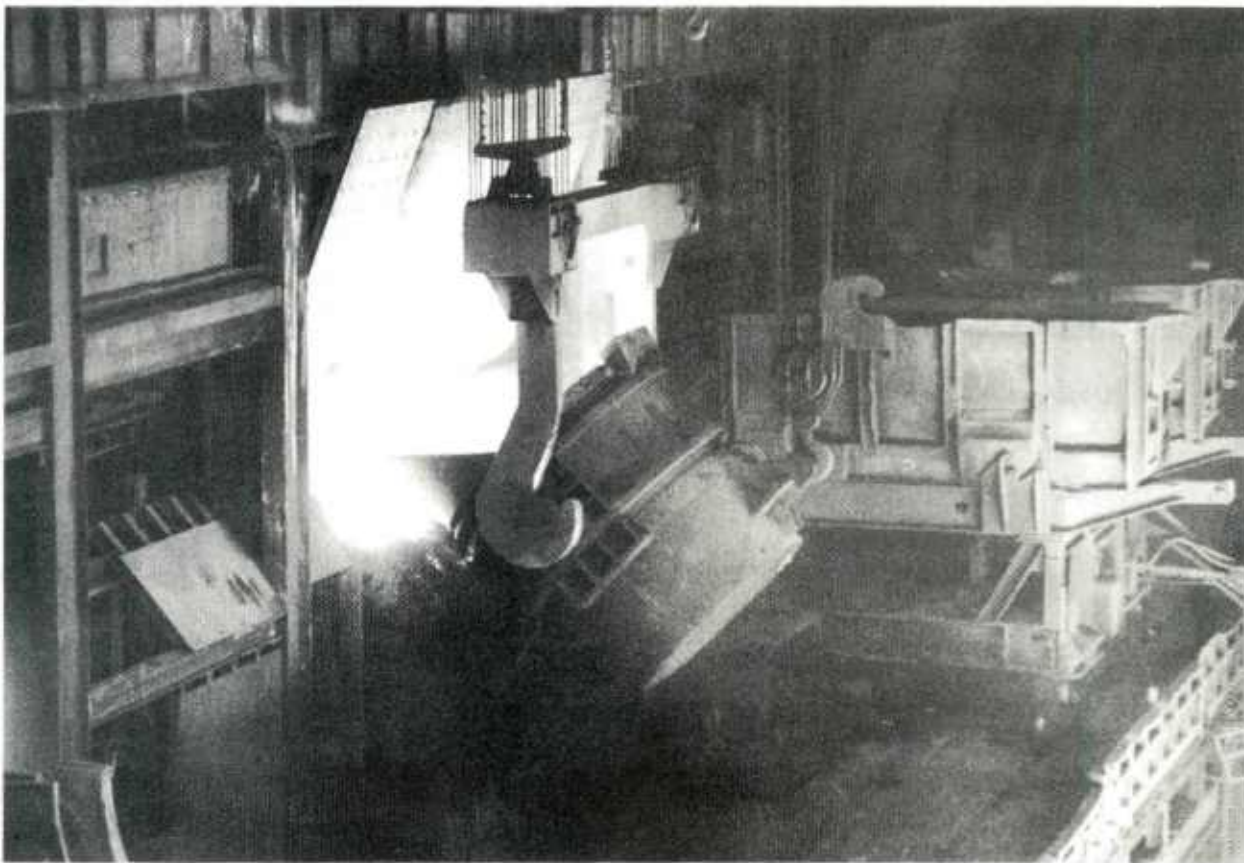


Figure B12. Charging the BOF with Liquid Metal

HF-1

Bethlehem Steel



Figure B13. Method of Teeming Ingots from A Bottom Pour Ladle

HF-1
Bethlehem Steel



Figure B14. Stripping Molds from Ingots

HF-1

Bethlehem Steel



Figure B15. Preparing to charge ingots into soaking pits

HF-1

Bethlehem Steel

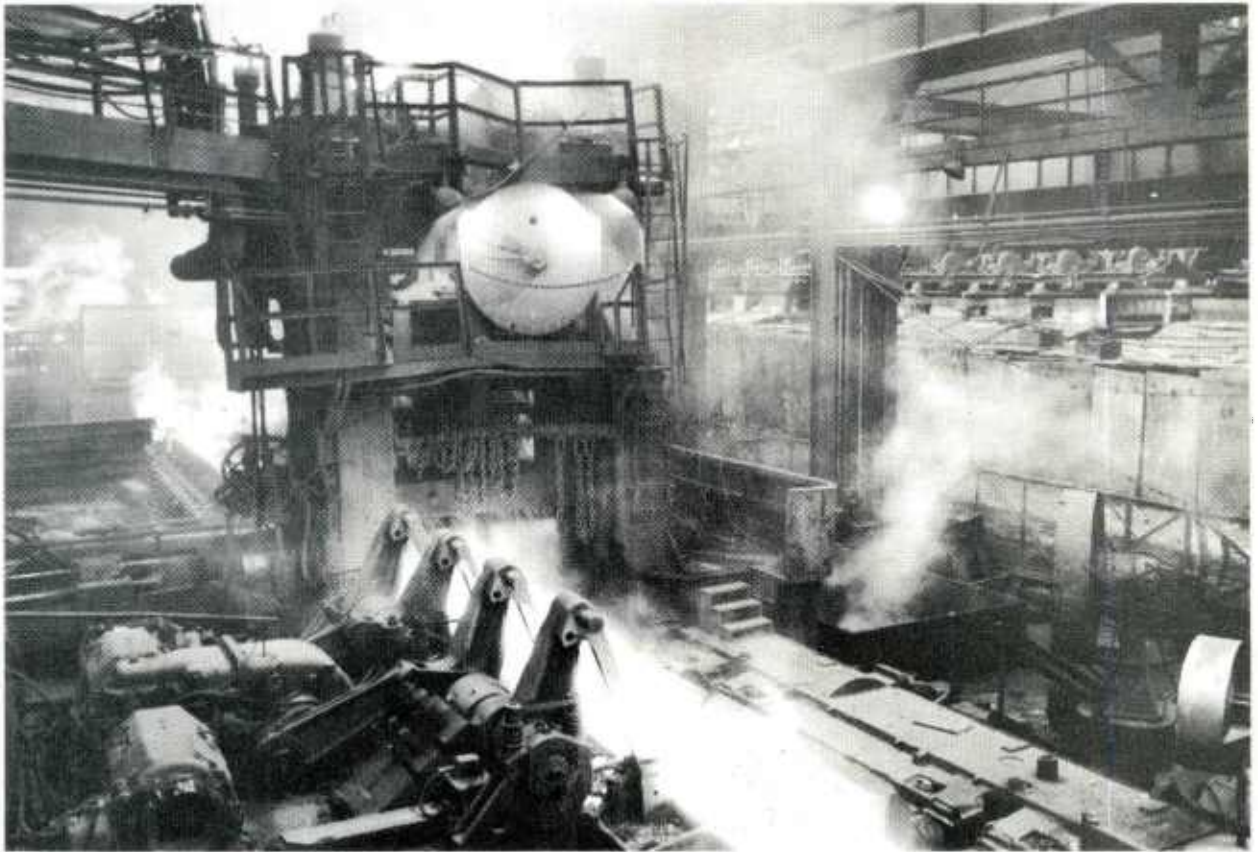


Figure B16. 44 inch Blooming Mill

HF-1
Bethlehem Steel

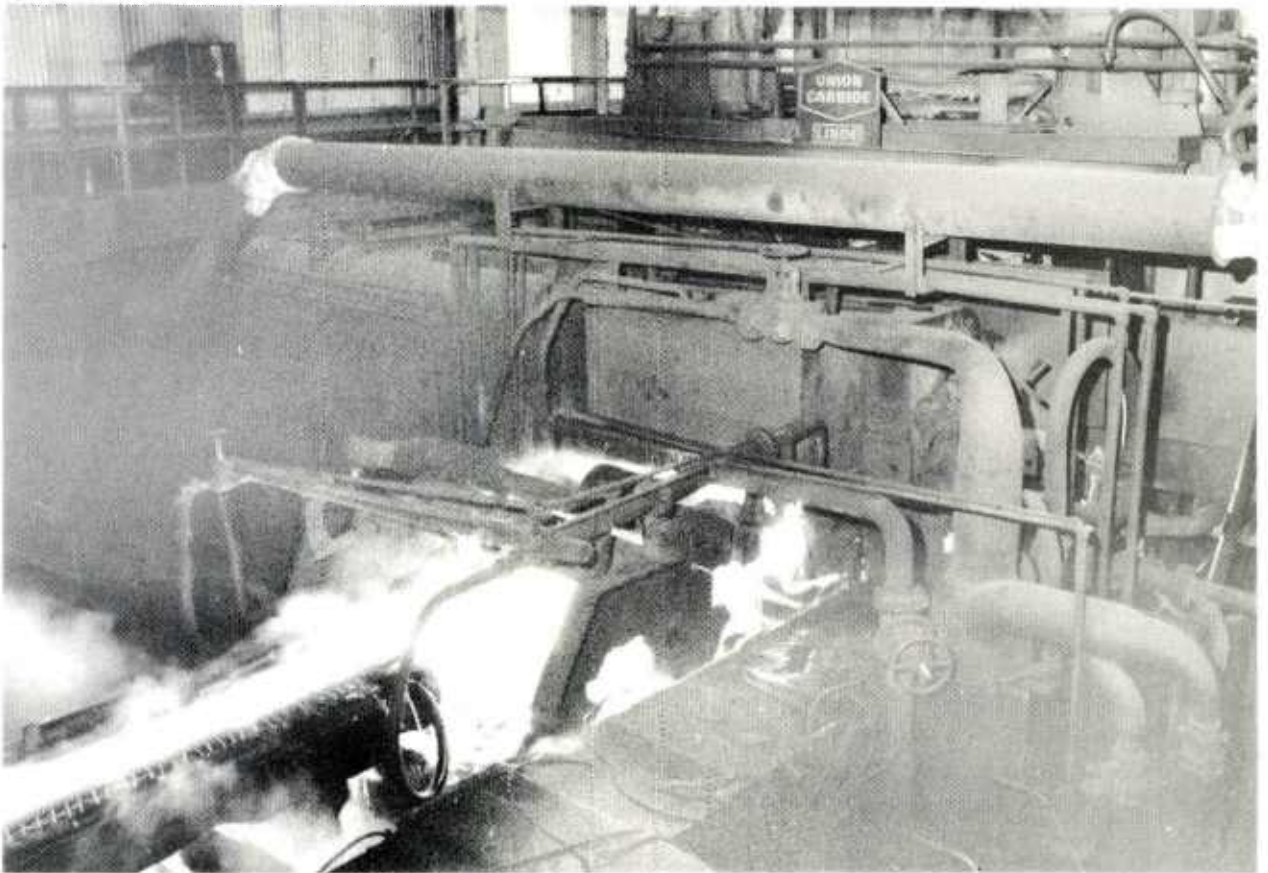


Figure B17. 44 inch Scarfer Removing Surface Defects

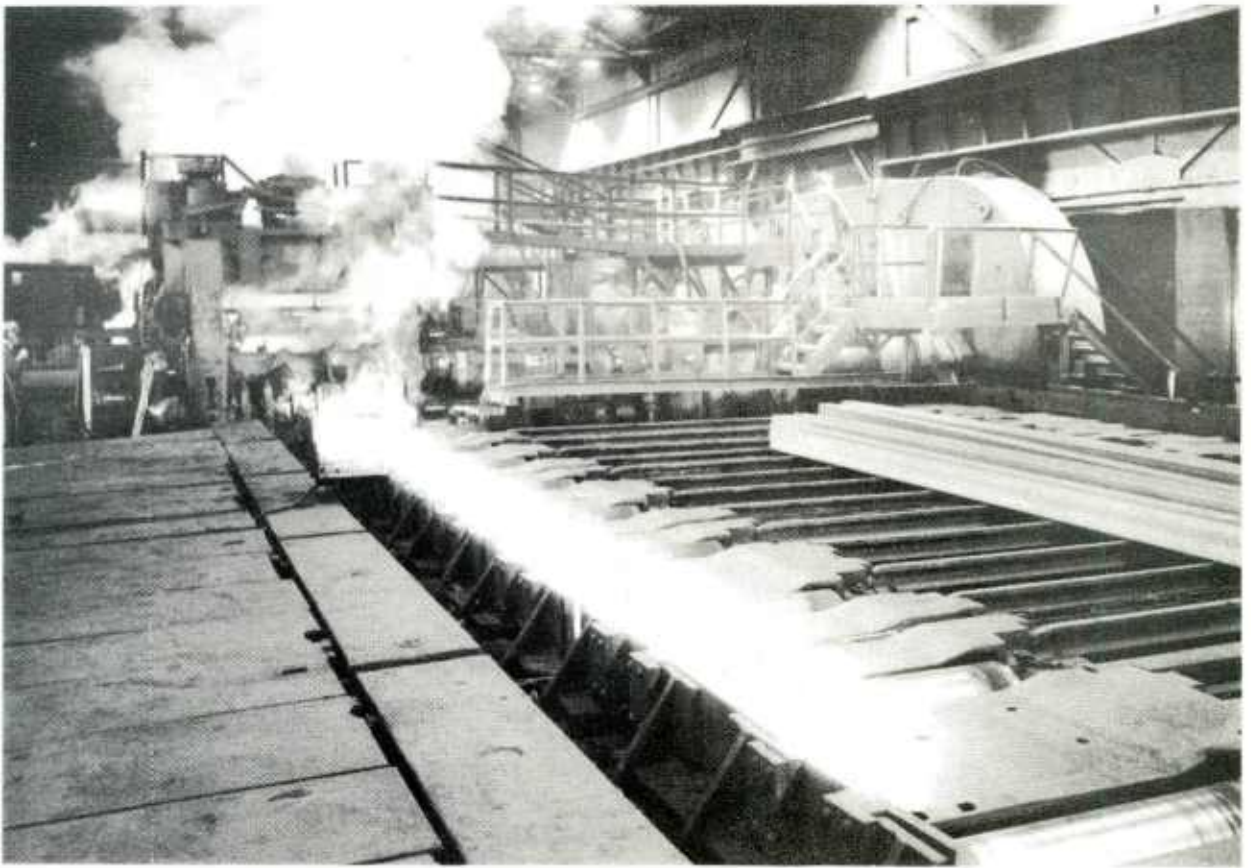
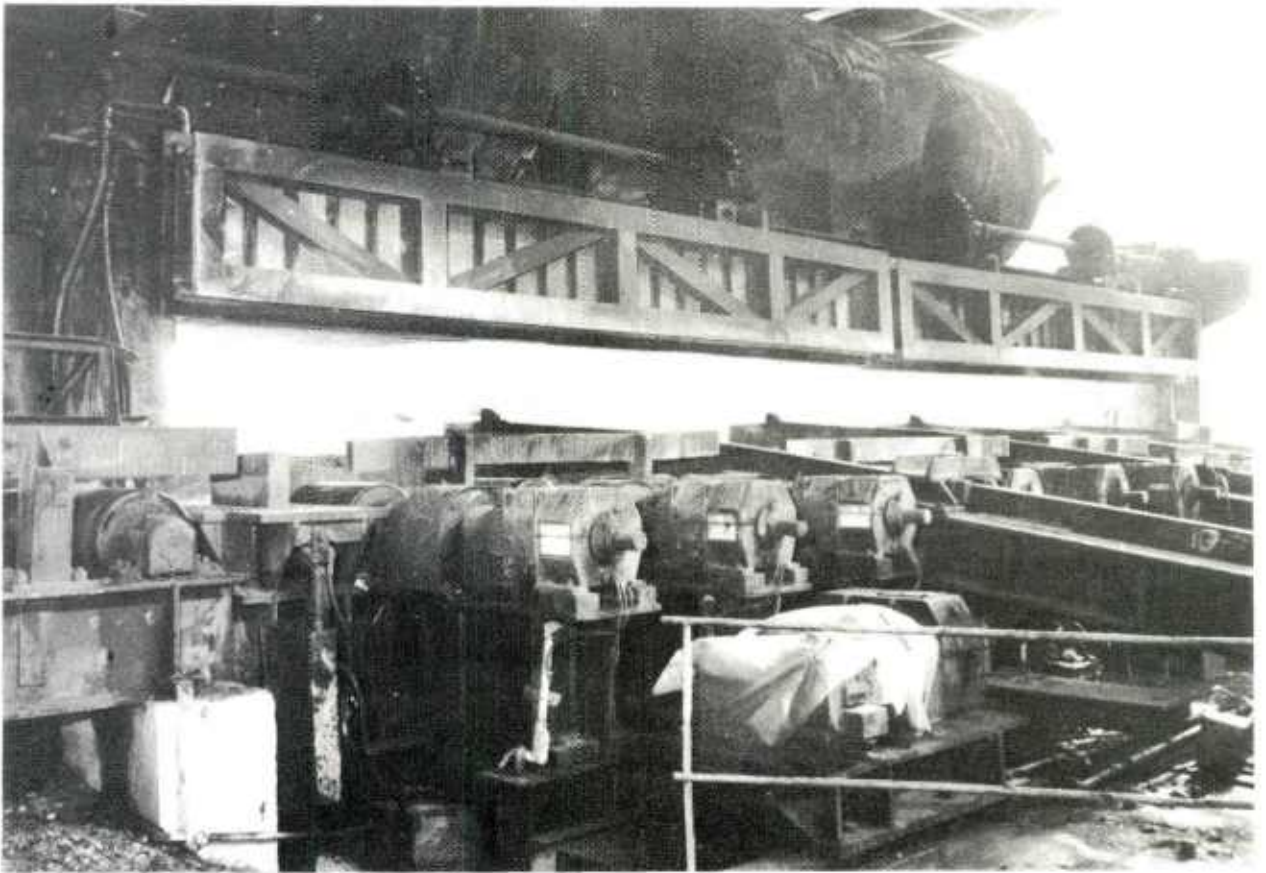


Figure B18. 30 inch Billet Mill



FigureB19. Reheat Furnace Between the 30 inch Billet Mill
and the 21 inch Billet Mill

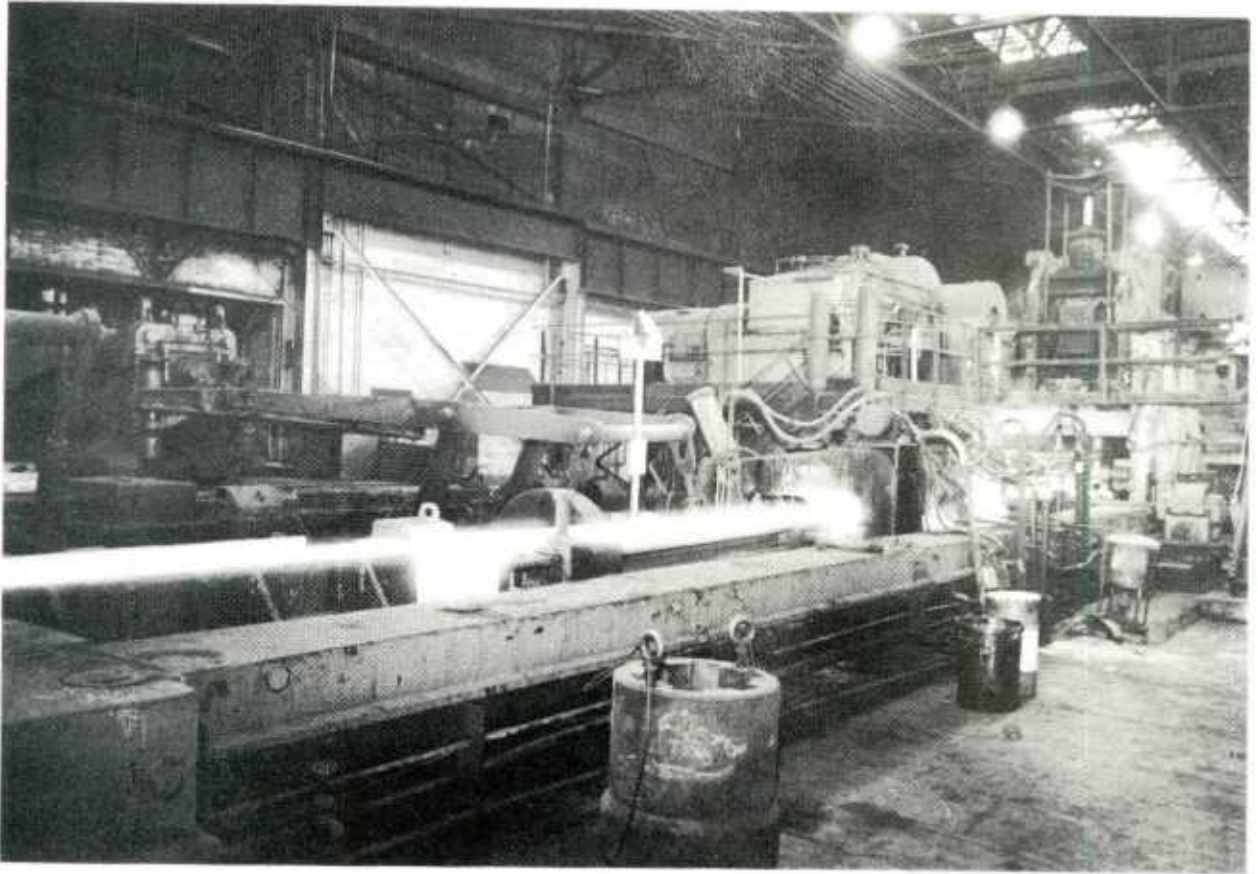


Figure B20. 21 inch Billet Mill Which Reduces Billets to Final
5 1/4 inch size.

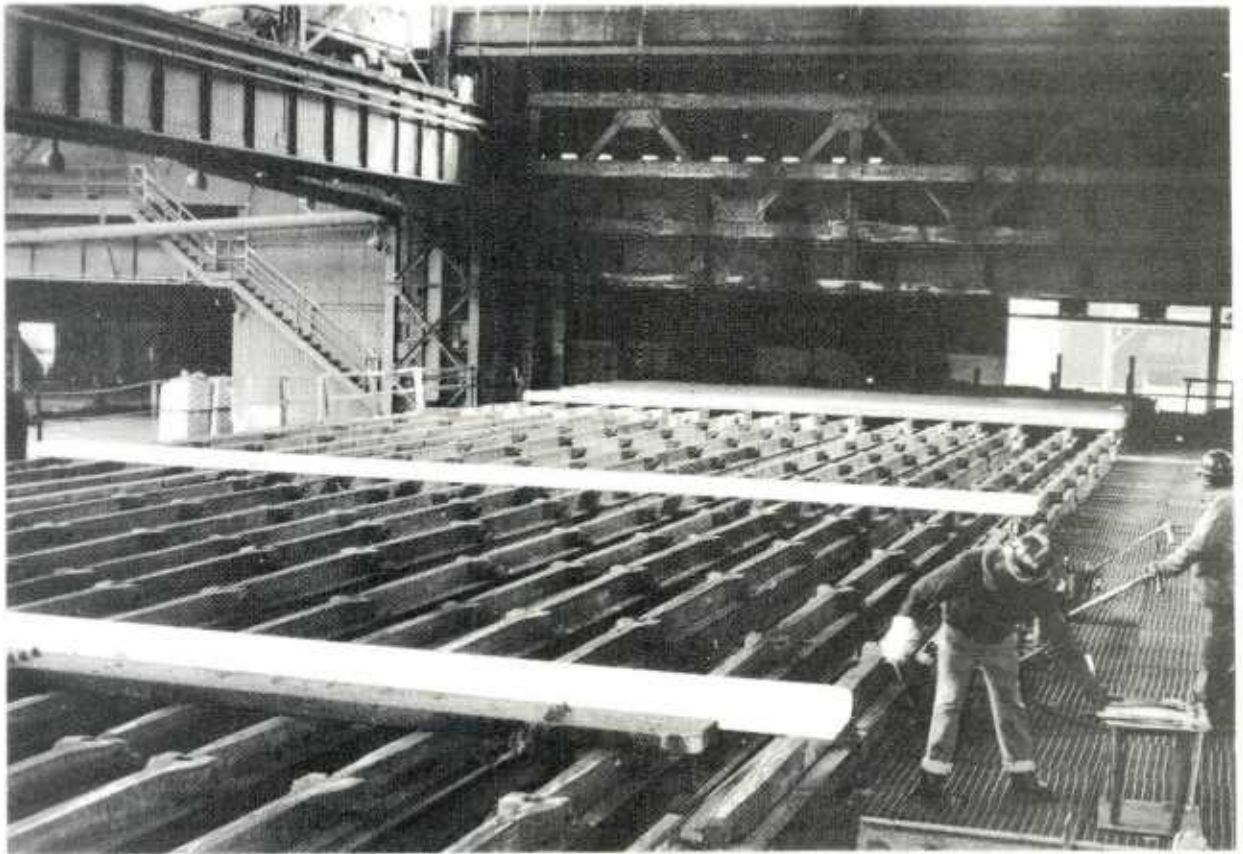


Figure B21. 21 inch Cooling Bed Which Air Cools Billets Prior to Final Slow Cool in Either Bung Furnace or Cooling Boxes

HF-1

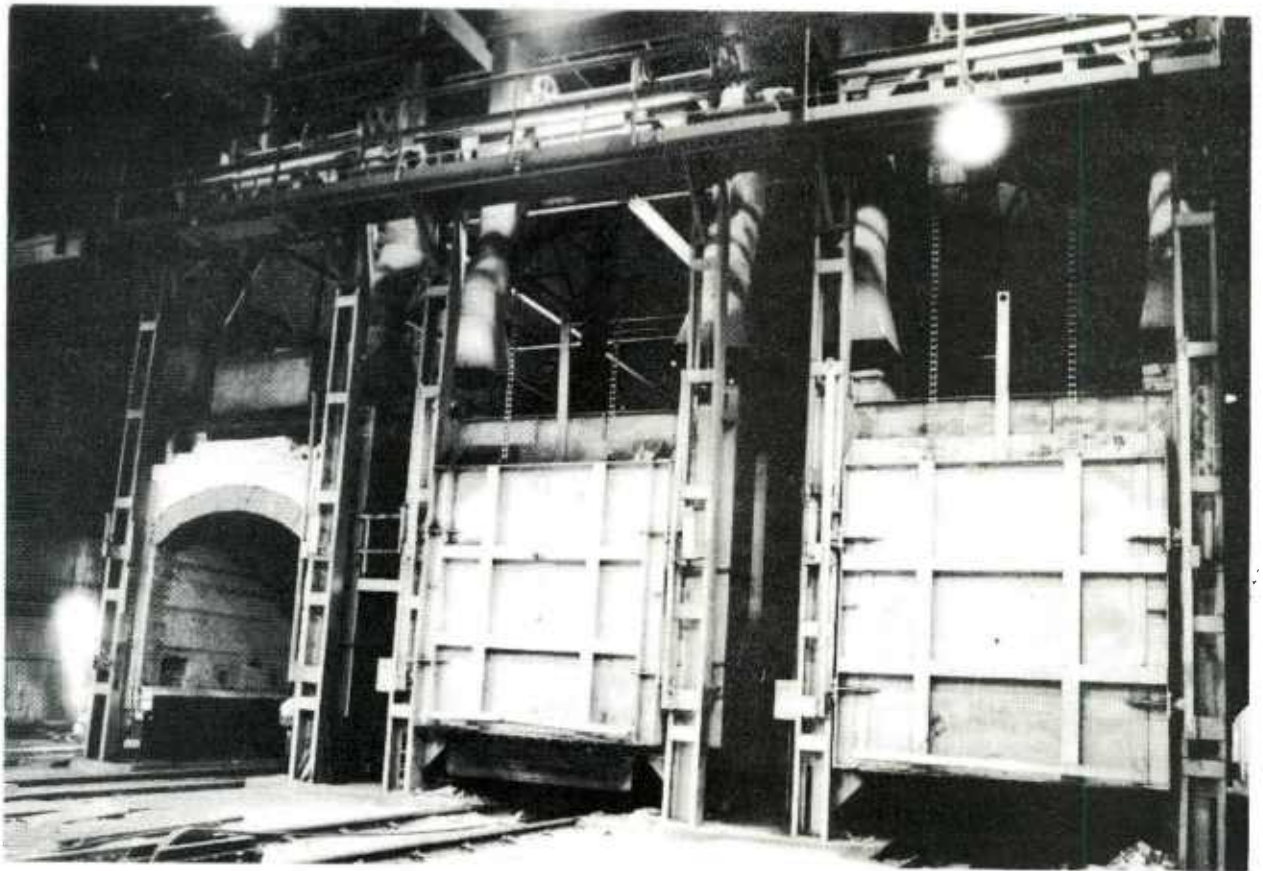


Figure B22. Bethlehem's Bung Furnace



Figure B23. Typical Cooling Boxes

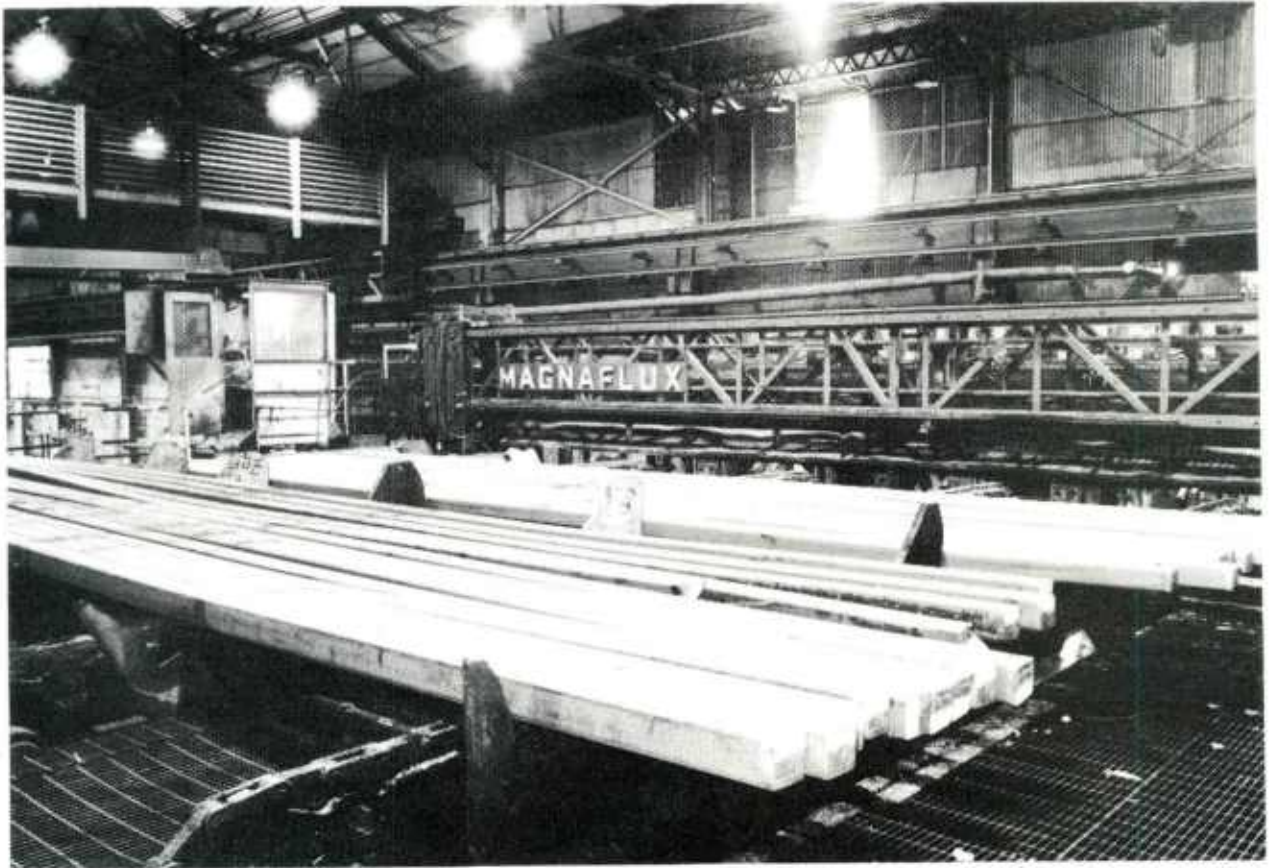


Figure B24. Bethlehem's Billet Magnaflux Operation

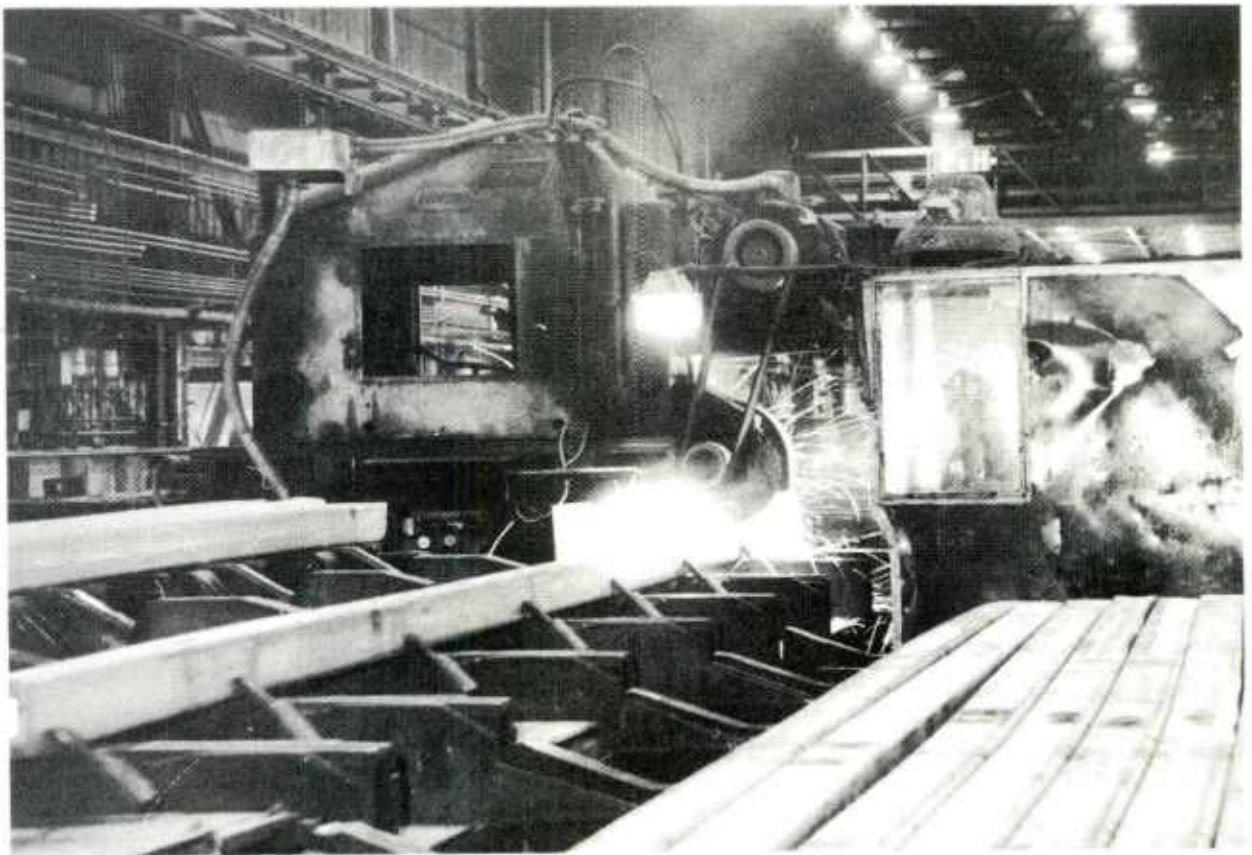


Figure B25. Bethlehem's Grinding Operation Which Removes Seams and Surface Defects Detected from the Magnaflux Operation



Figure B26. Republic Steel illustrating straight billets

HF-1



Figure B27. Bethlehem Steel Billet.

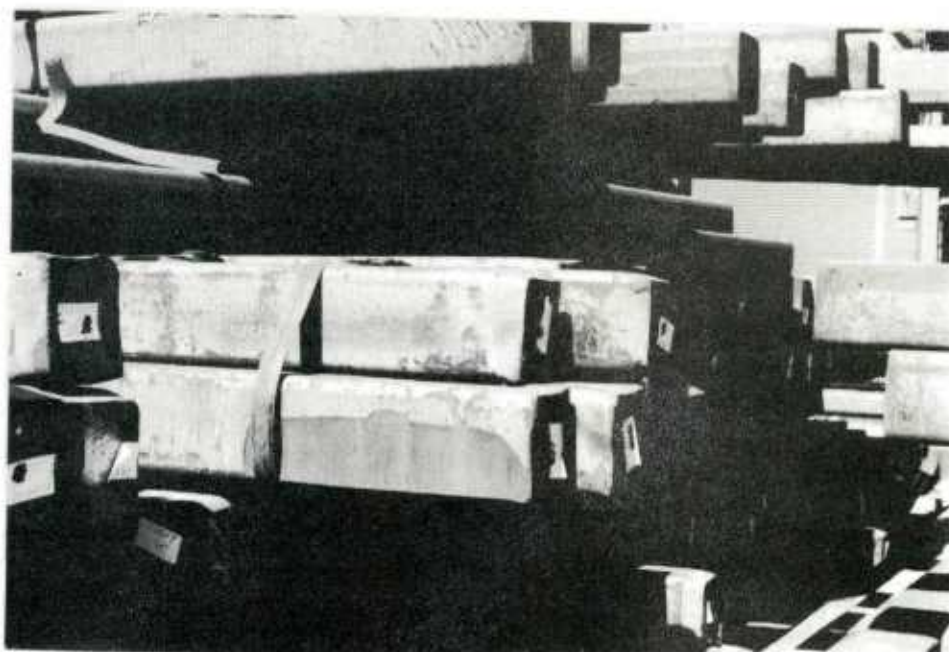


Figure B28. Illustration of Severe Grinding of Edge



Figure B29. Illustration of Hot-sawed Ends from Republic Steel

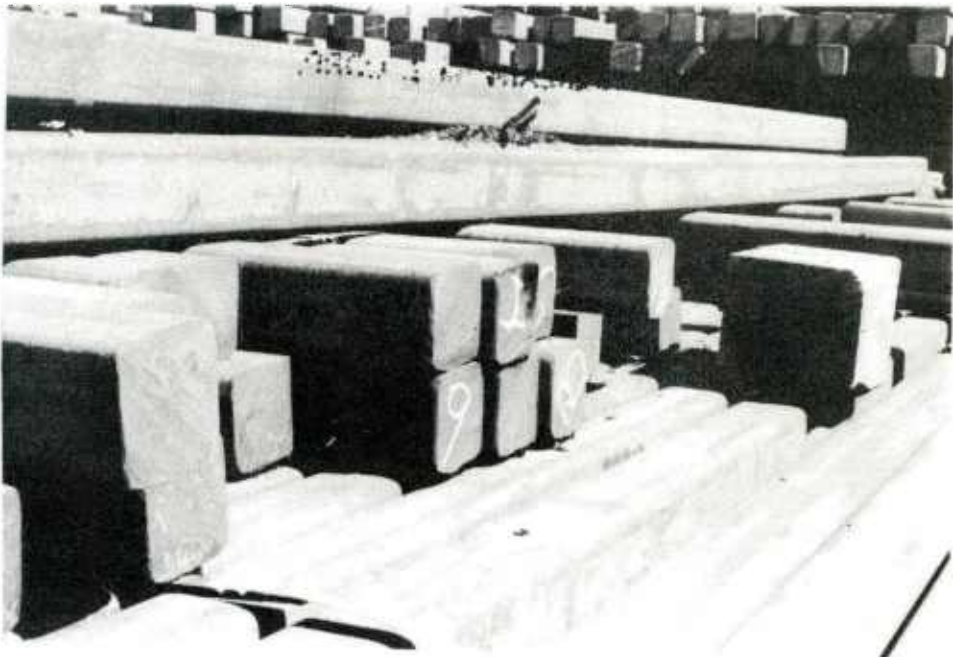


Figure B30. Another illustration of Republic Steel's Hot Sawed-Ends.

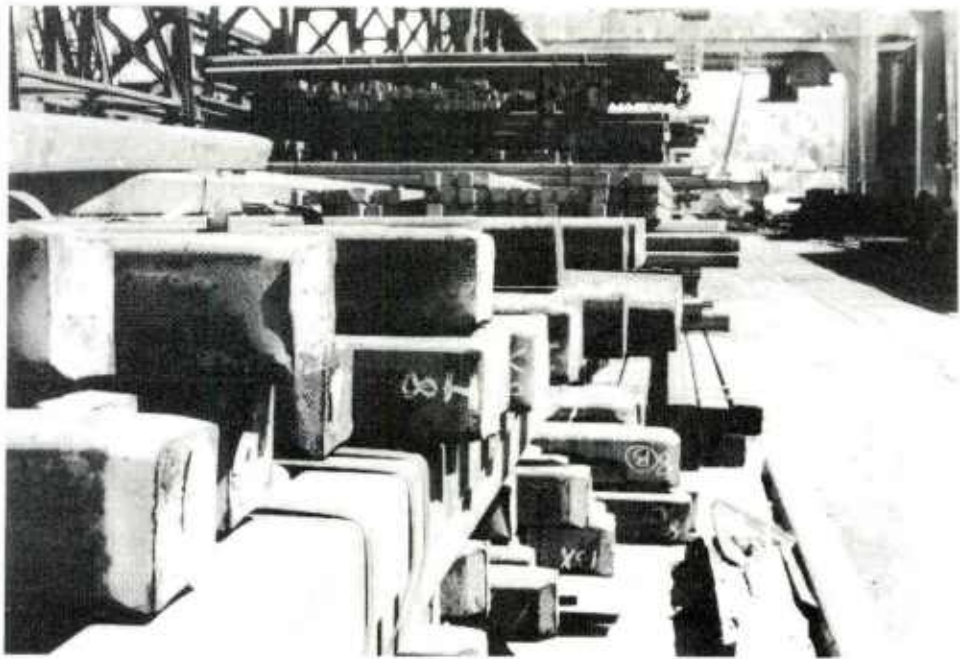


Figure B31. Illustration of Bethlehem's Hot Sheared Ends

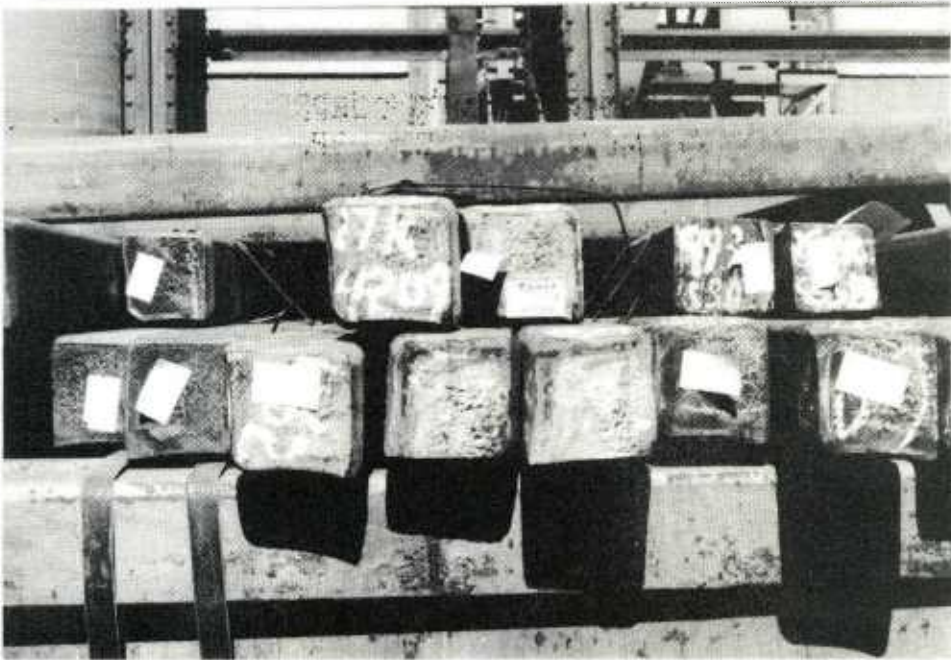
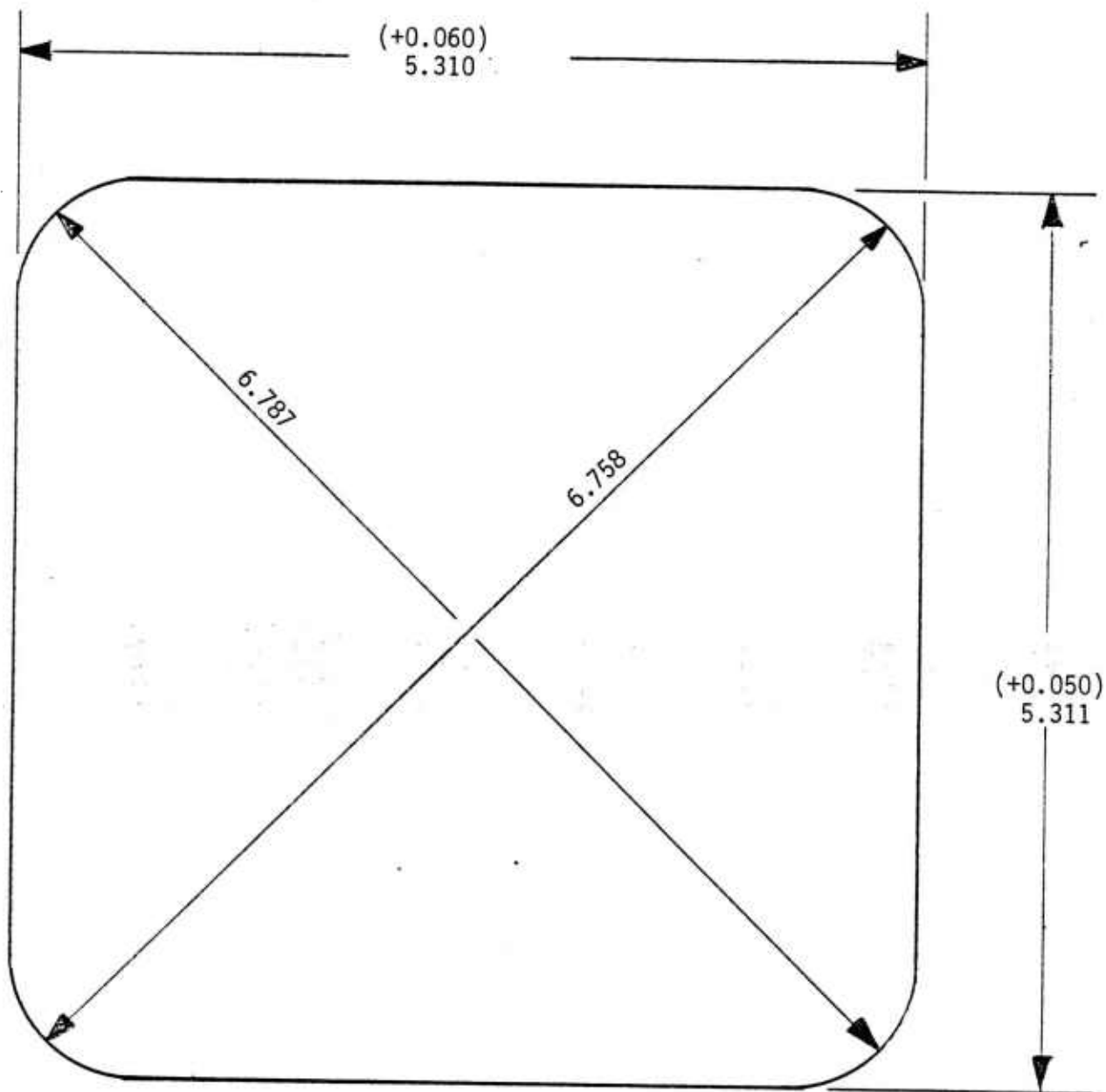


Figure B32. Illustration of Bethlehem's Hot Sheared Ends

Appendix C

Dimension of Cross Section



Republic Steel

Figure C1. Billet 1AA.

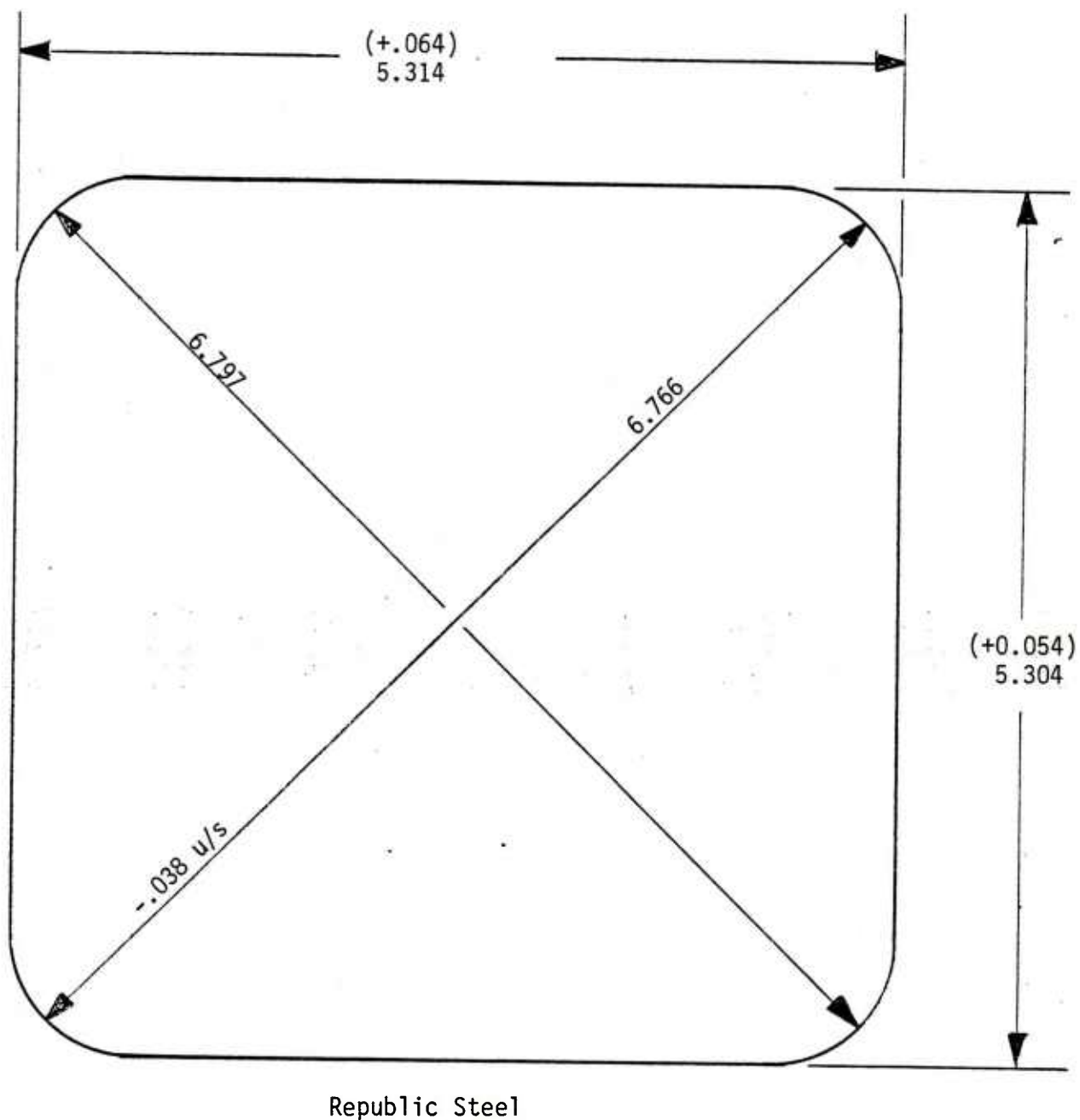


Figure C2. Billet 20BA.

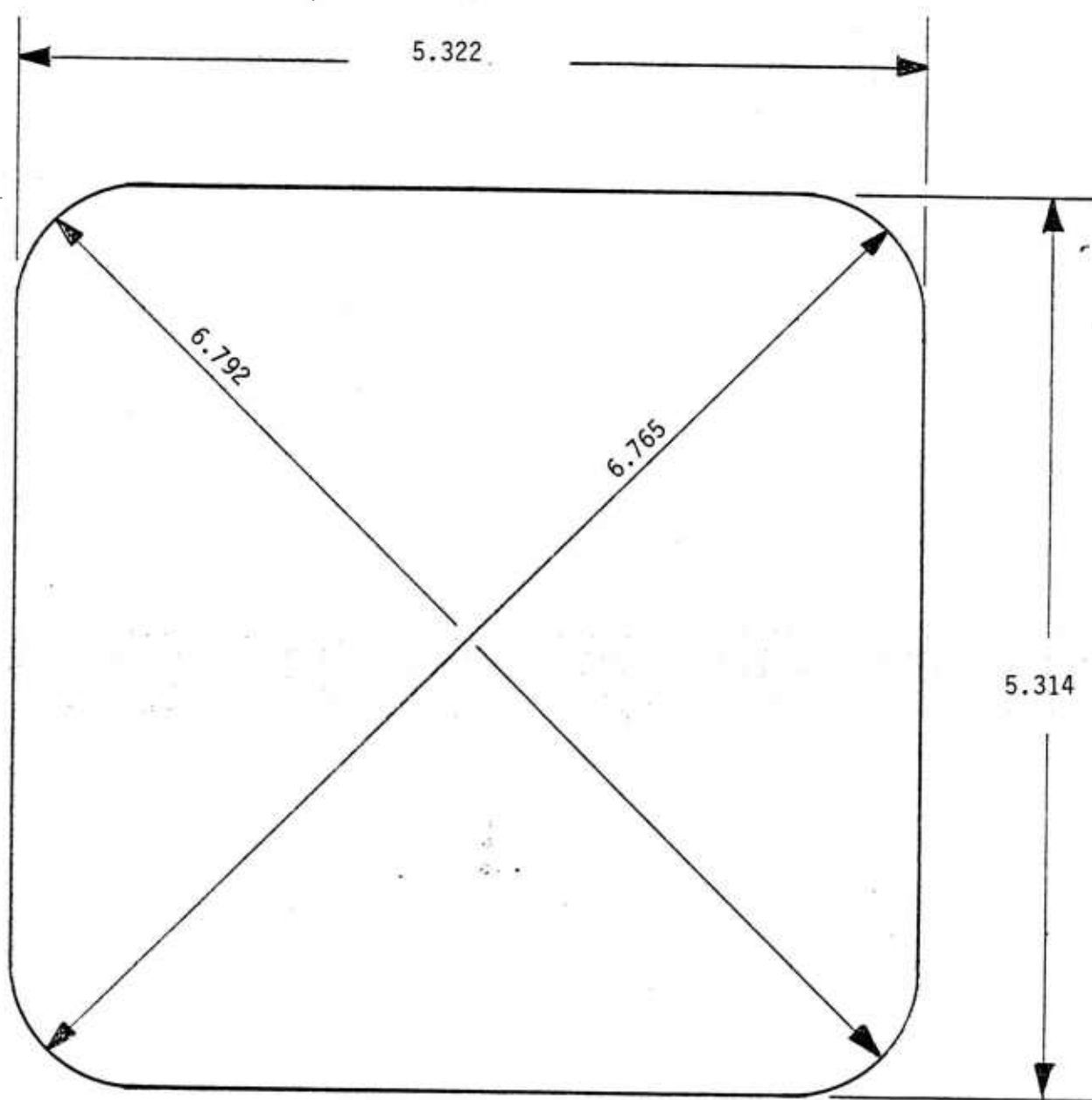
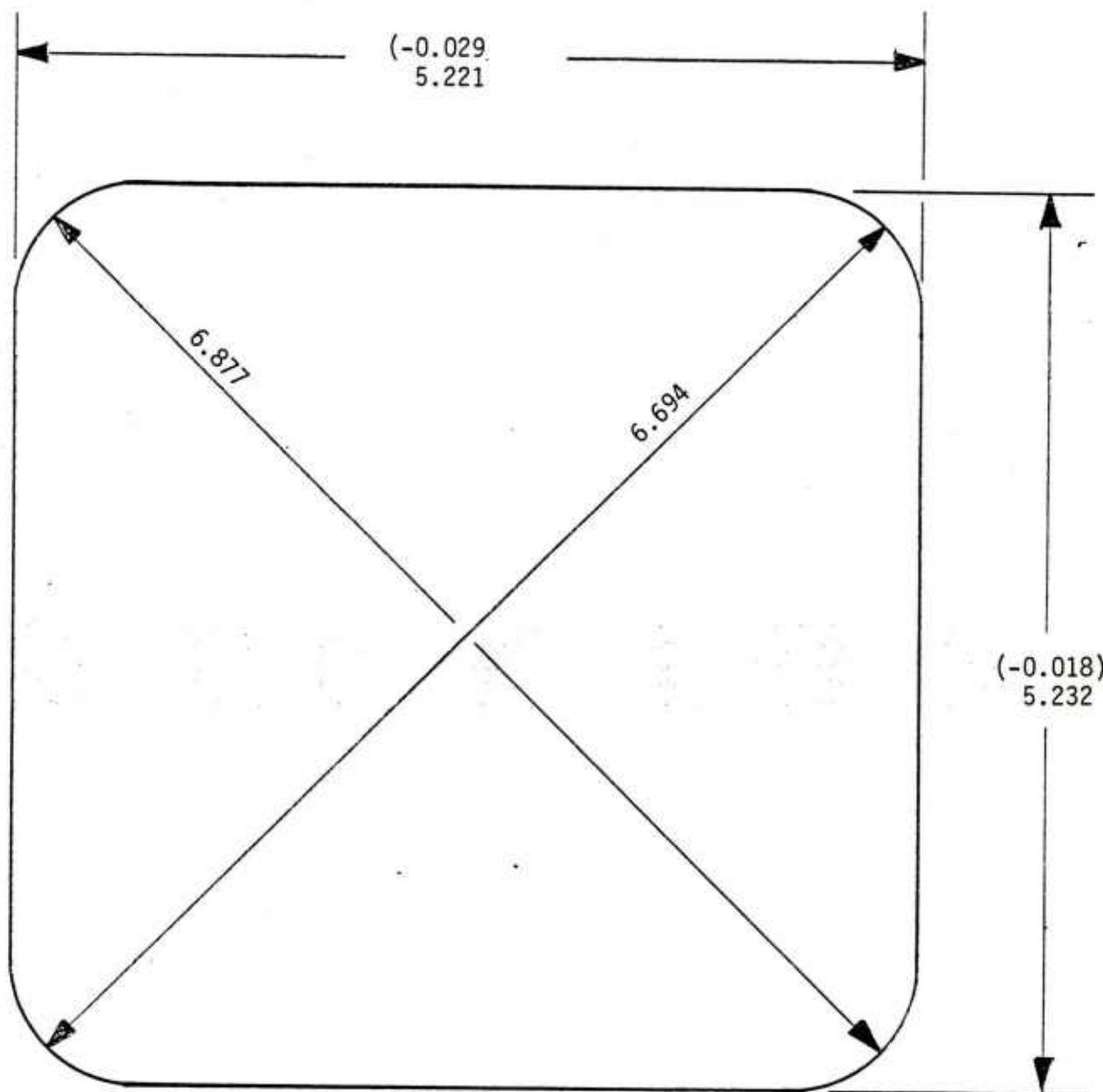
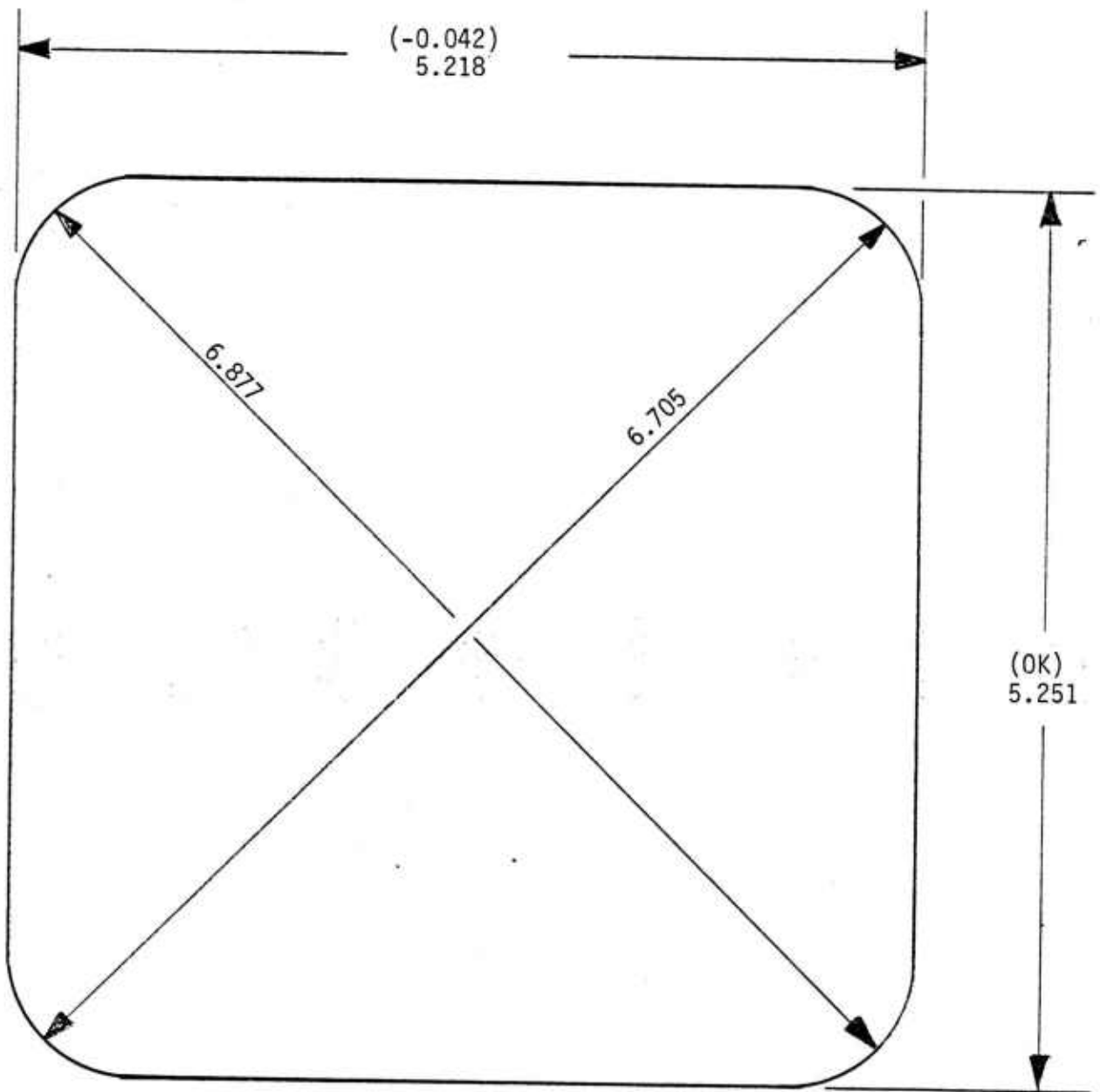


Figure C3. Billet 40BA.



Bethlehem Steel

Figure C4. Billet 11C.



Bethlehem Steel

Figure C5. Billet 20X.

$$5.250 \times 5.250 = \text{Cross Section}$$

$$6.804 + .090 = \text{Diagonal}$$

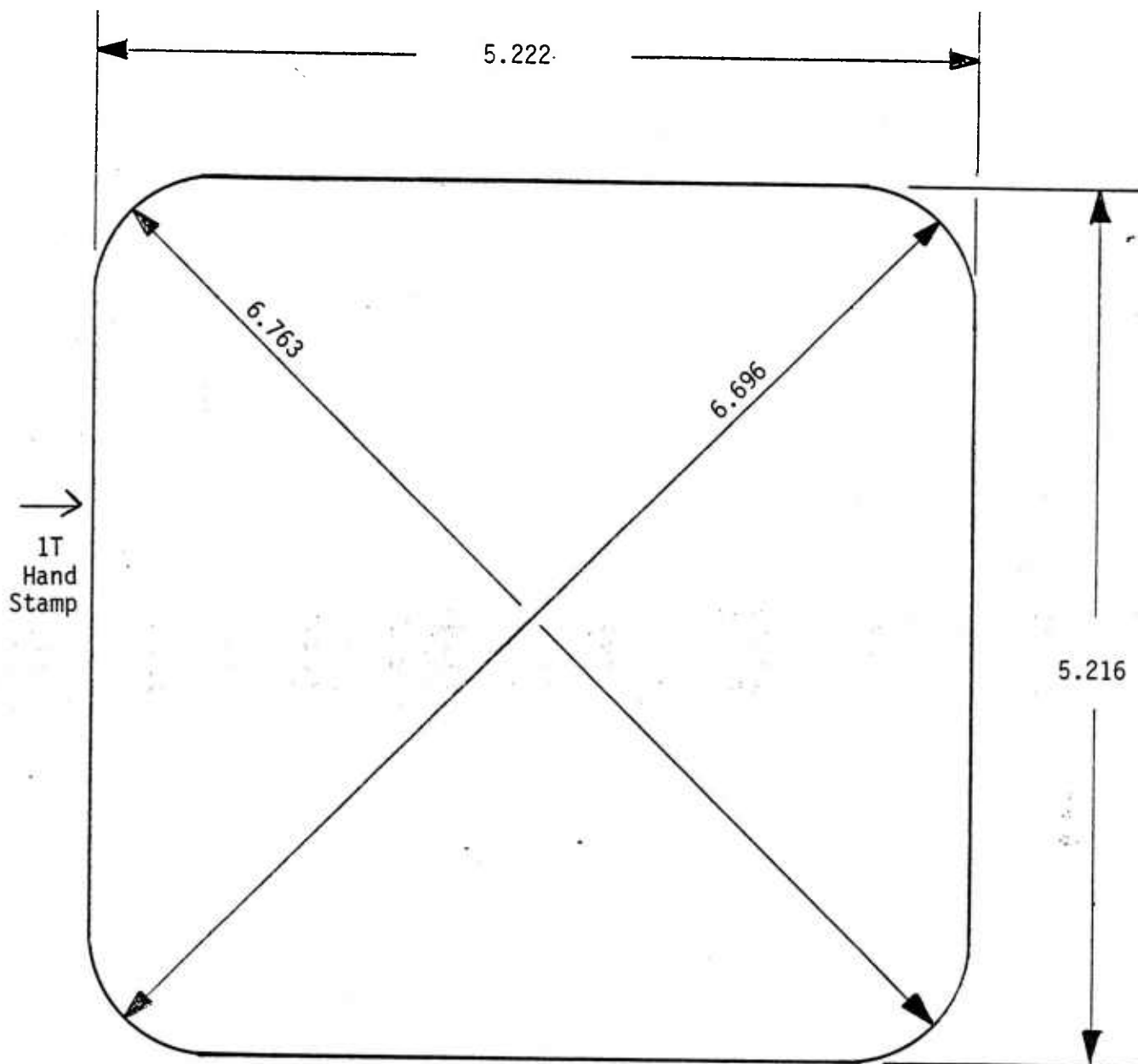


Figure C6. Billet 1T.

Appendix D

Photographs of Macro Cleanliness

Macro Cleanliness
Republic Steel

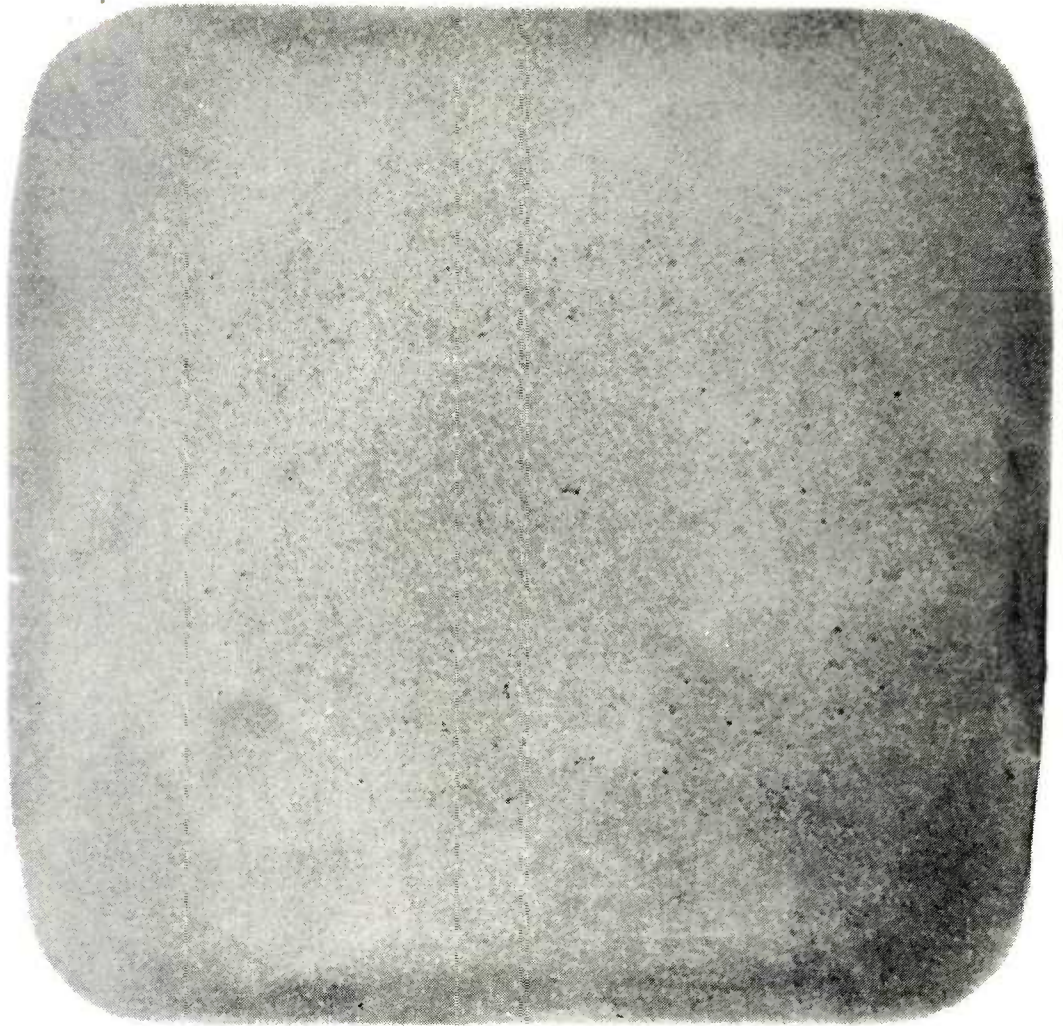


Figure D1. Billet 1AA.

Macro Cleanliness
Republic Steel



Figure D2. Billet 1BA.

Macro Cleanliness
Republic Steel

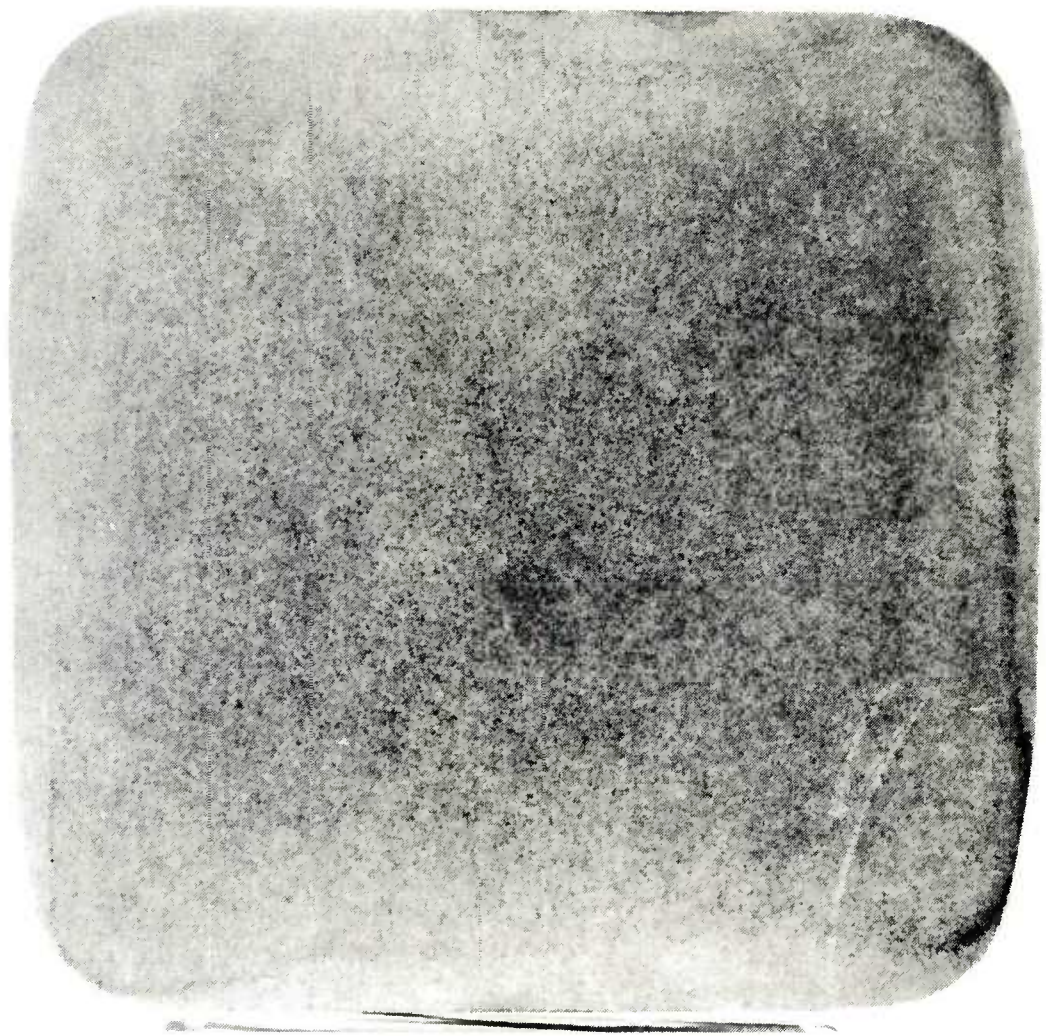


Figure D3. Billet 1BD.

Macro Cleanliness
Republic Steel

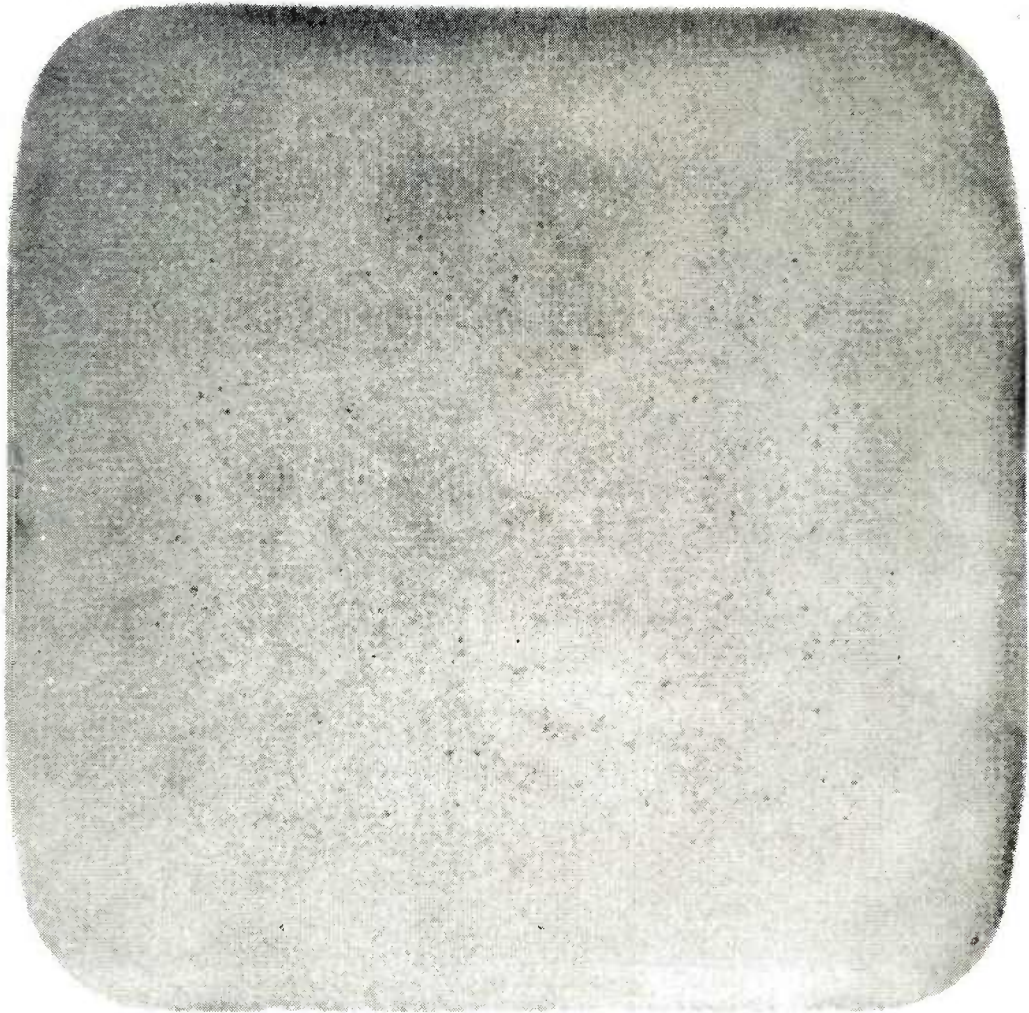


Figure D4. Billet 20AA.

Macro Cleanliness
Republic Steel



Figure D5. Billet 20BA.

Macro Cleanliness
Republic Steel



Figure D6. Billet 20BD.

Macro Cleanliness
Republic Steel

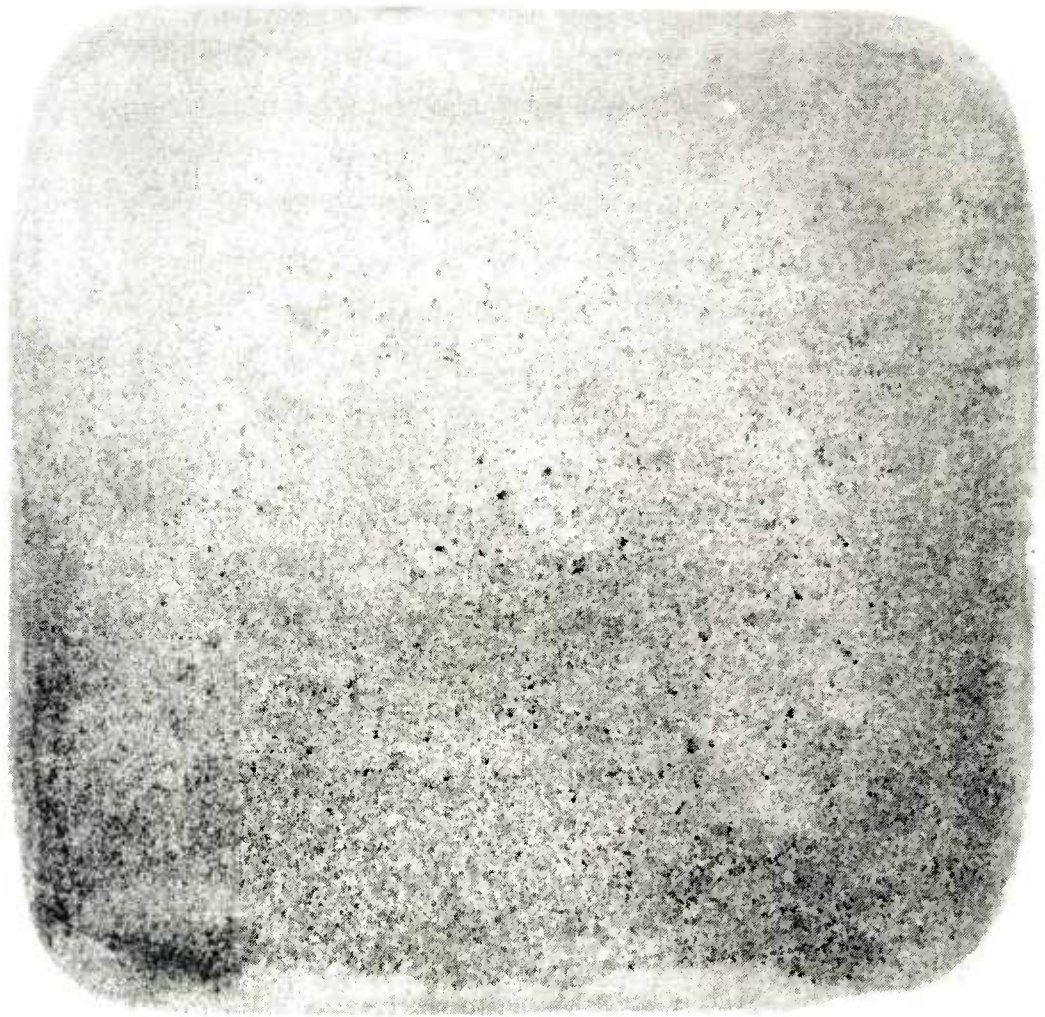


Figure D7. Billet 40AA.

Macro Cleanliness
Bethlehem Steel

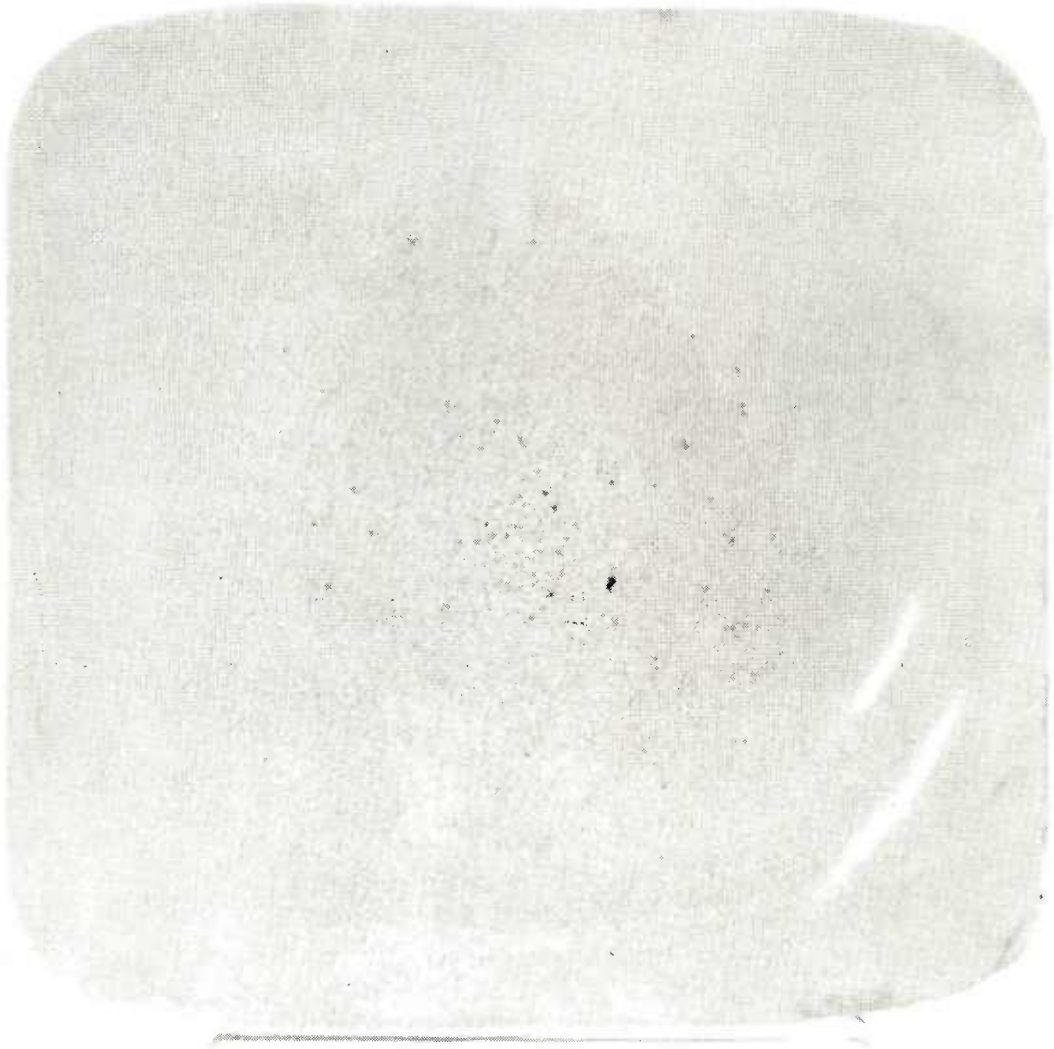


Figure D8. Billet 40BA.

Macro Cleanliness
Republic Steel

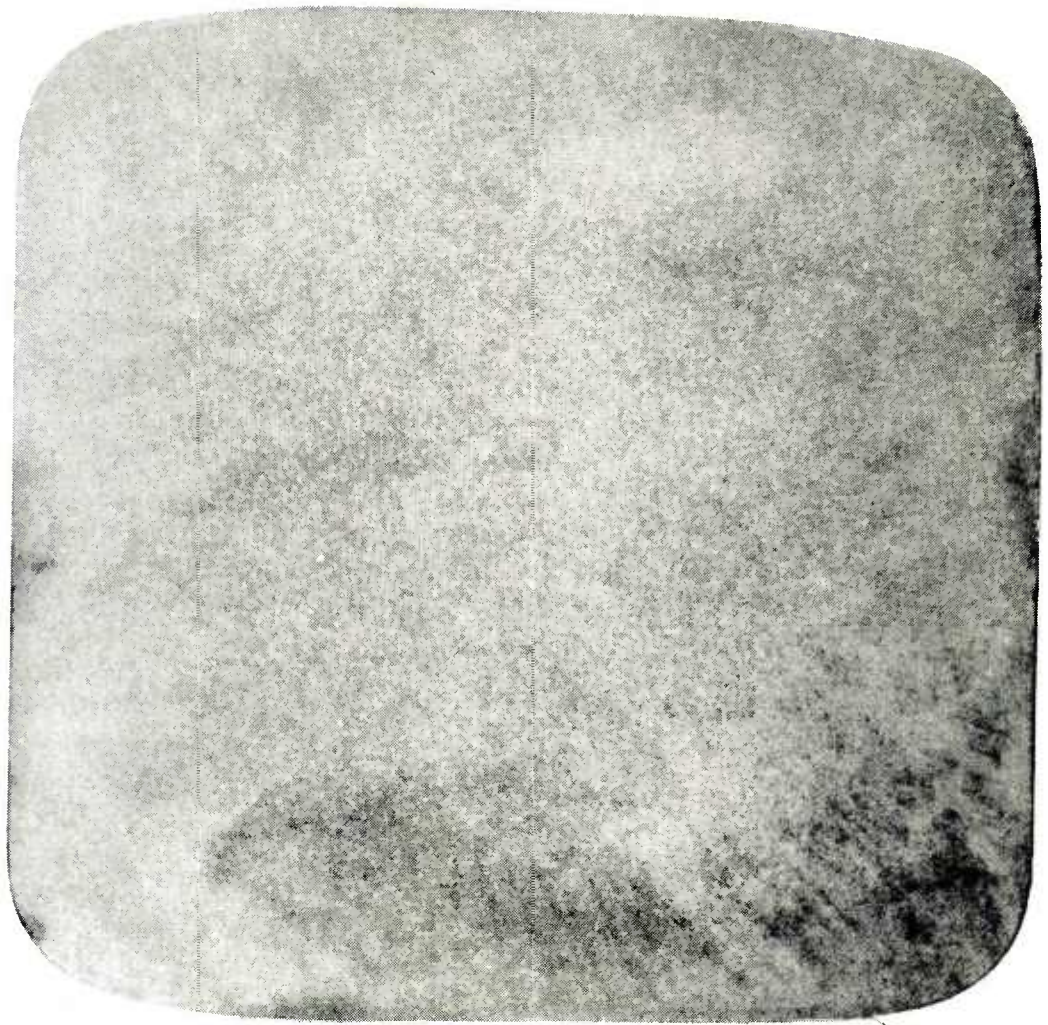


Figure D9. Billet 40BD.

Macro Cleanliness
Bethlehem Steel

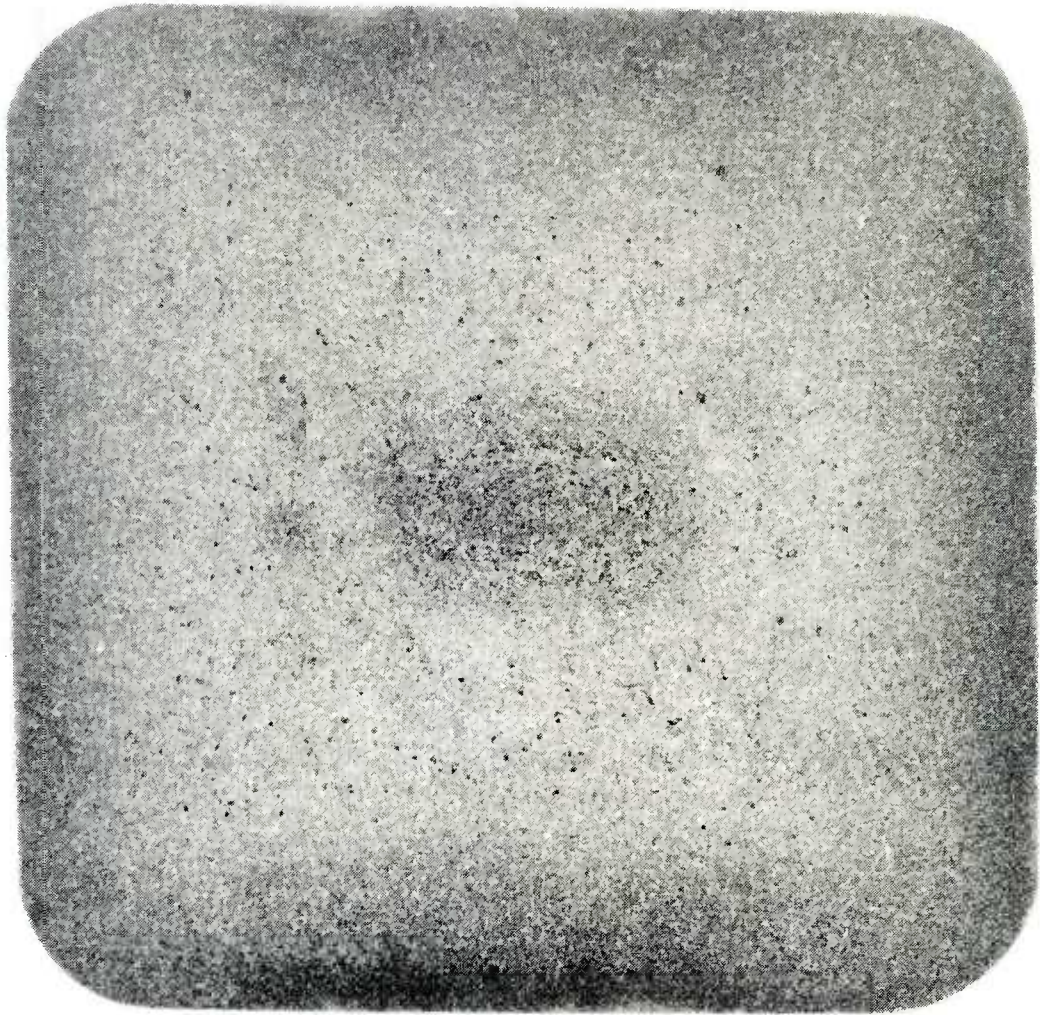


Figure D10. Billet 1T.

Macro Cleanliness
Bethlehem Steel

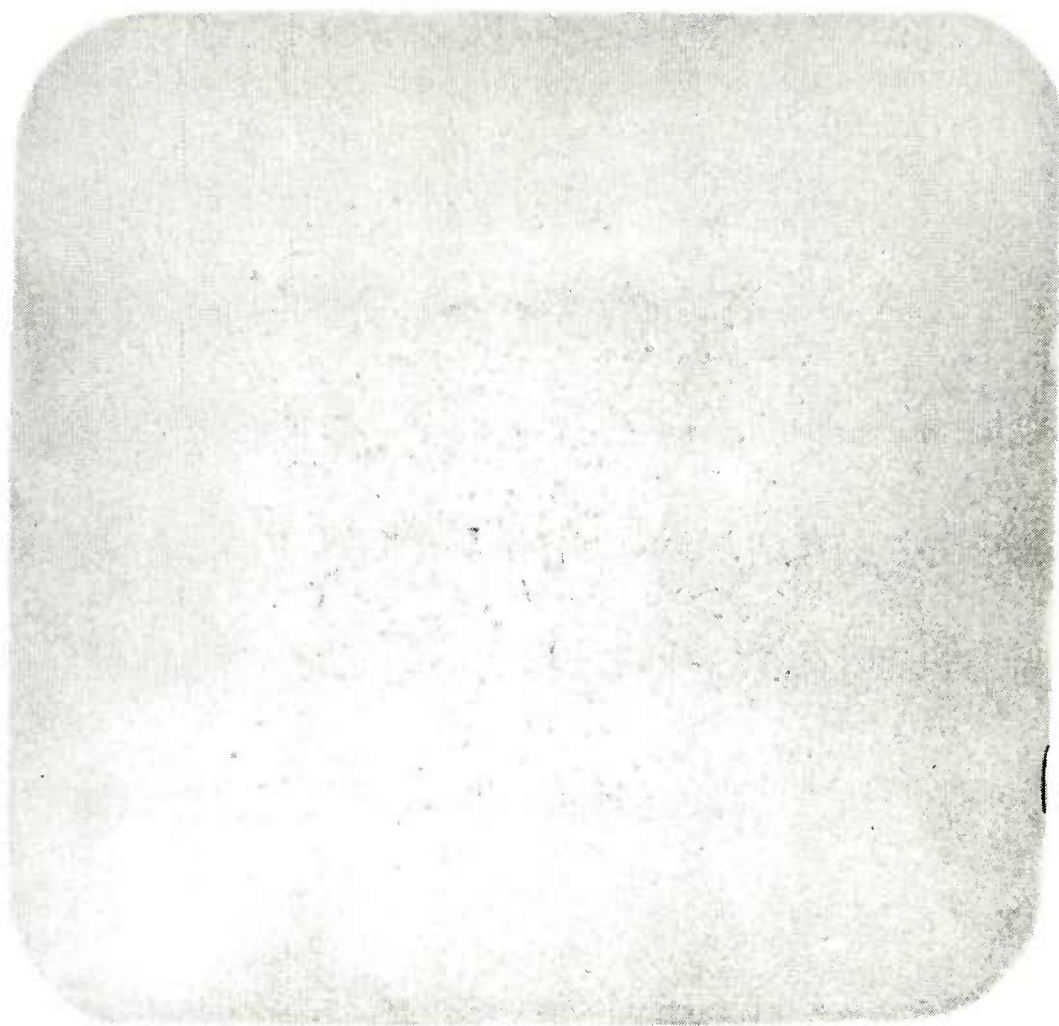


Figure D11. Billet 1C.

Macro Cleanliness
Bethlehem Steel

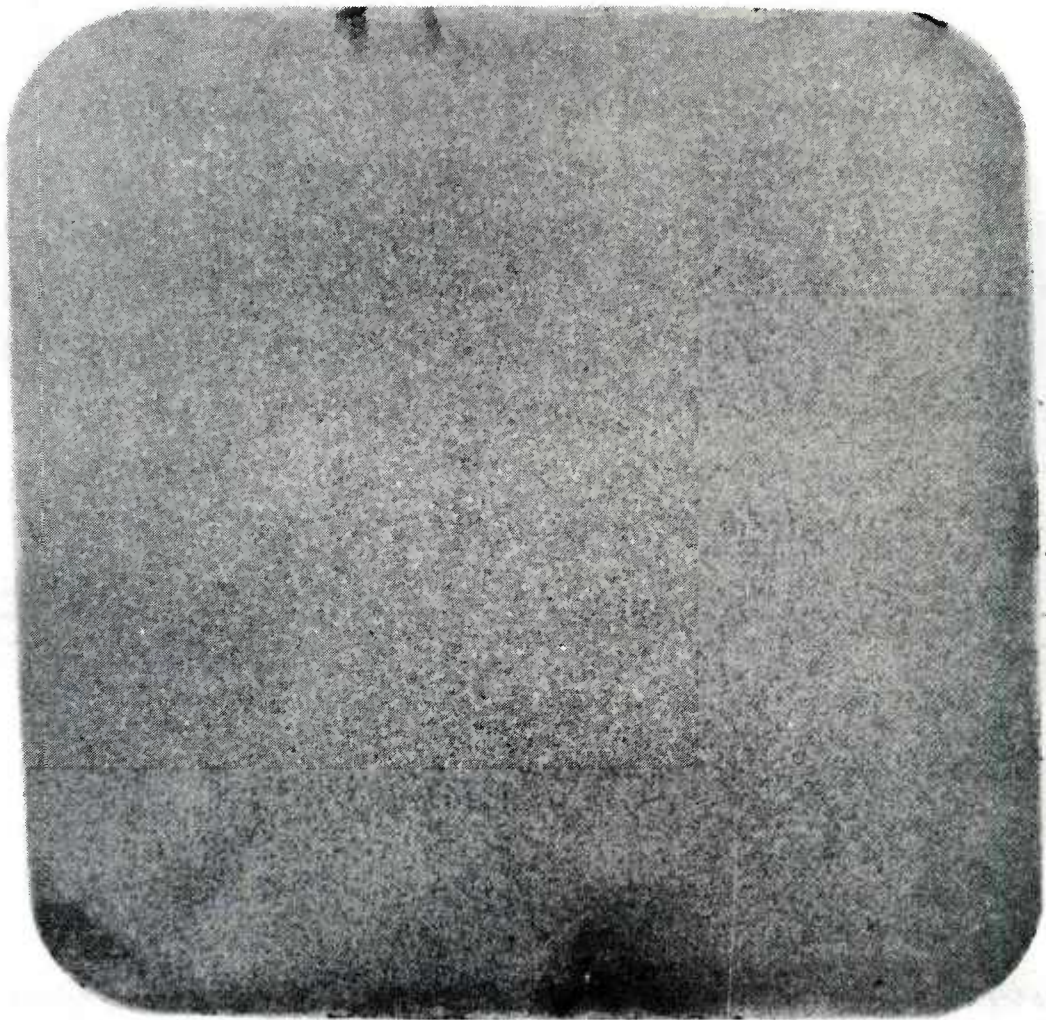


Figure D12. Billet 1X.

Macro Cleanliness
Bethlehem Steel

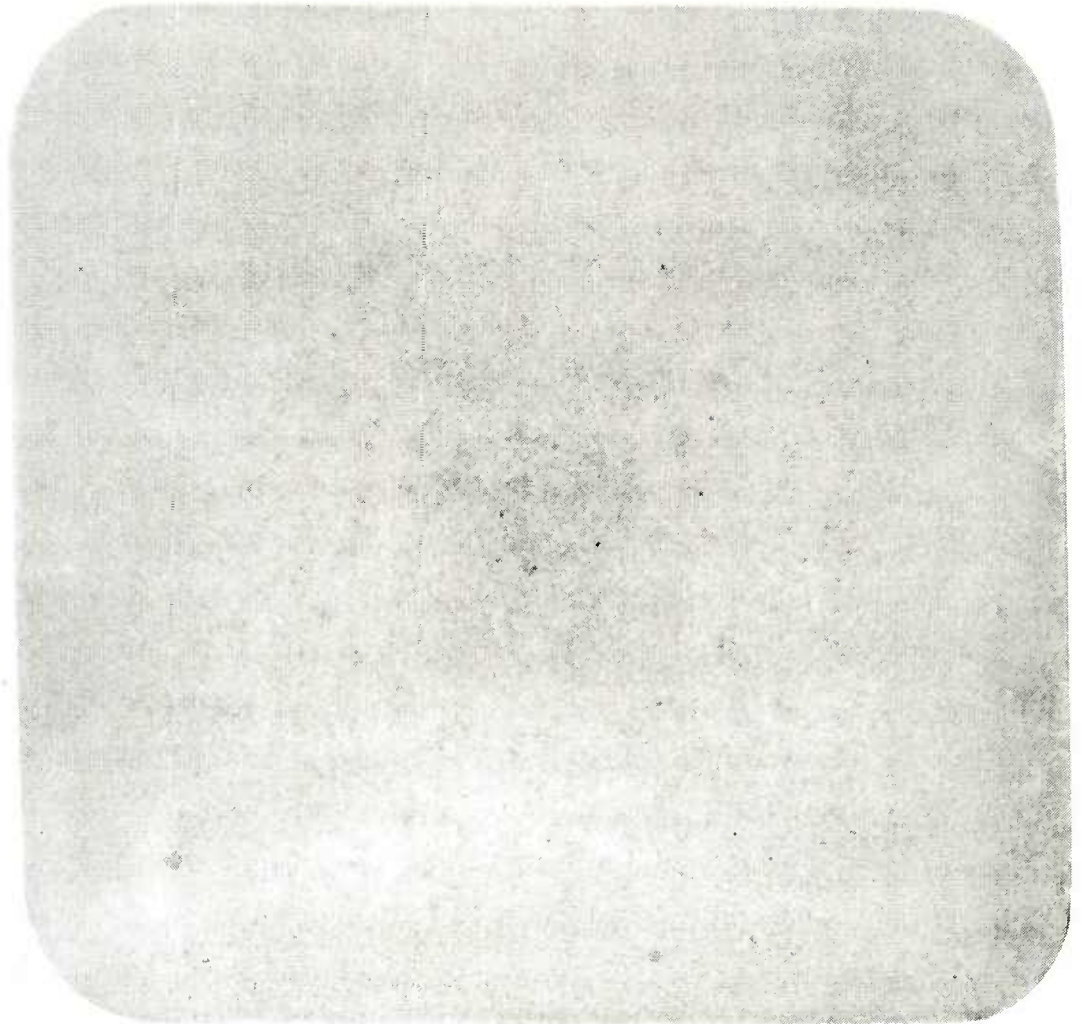


Figure D13. Billet 2T.

Macro Cleanliness
Bethlehem Steel

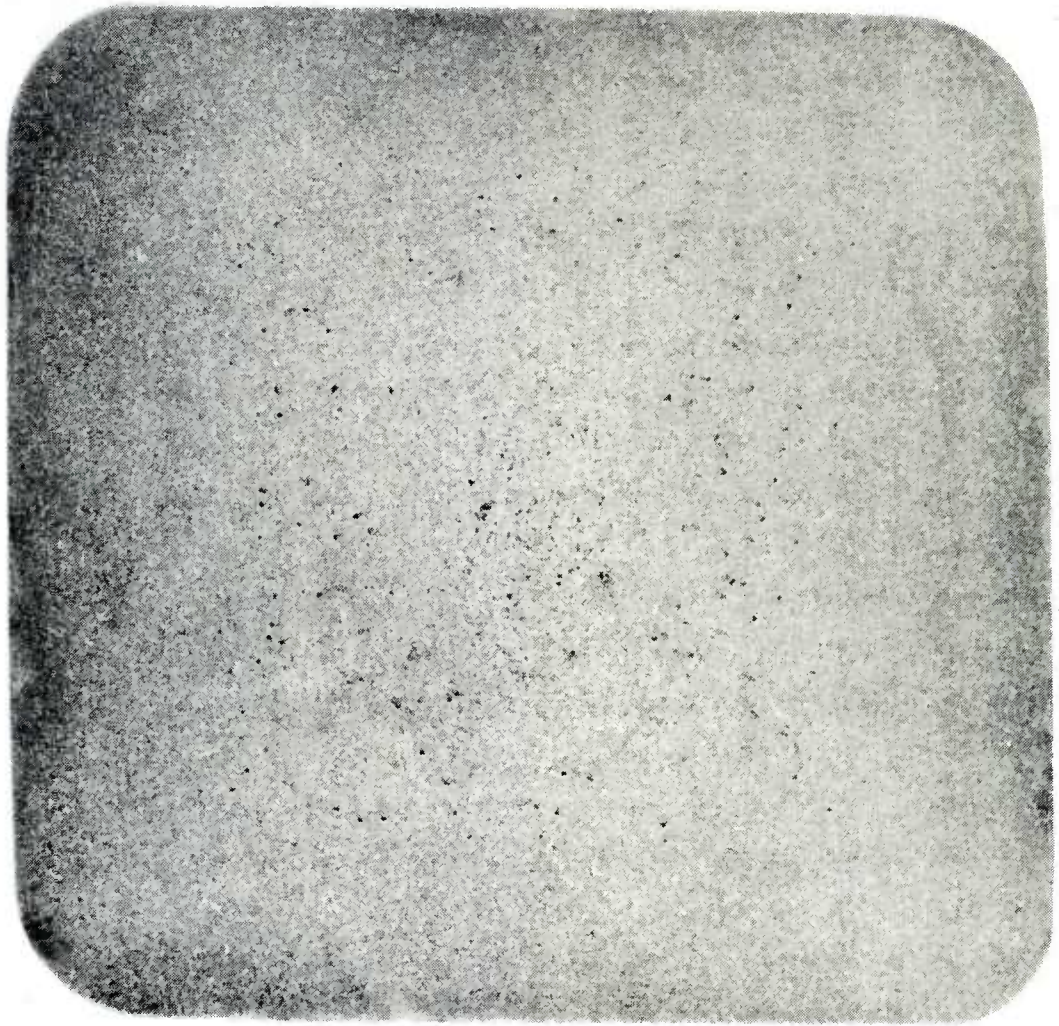


Figure D14. Billet 2C

Macro Cleanliness
Bethlehem Steel

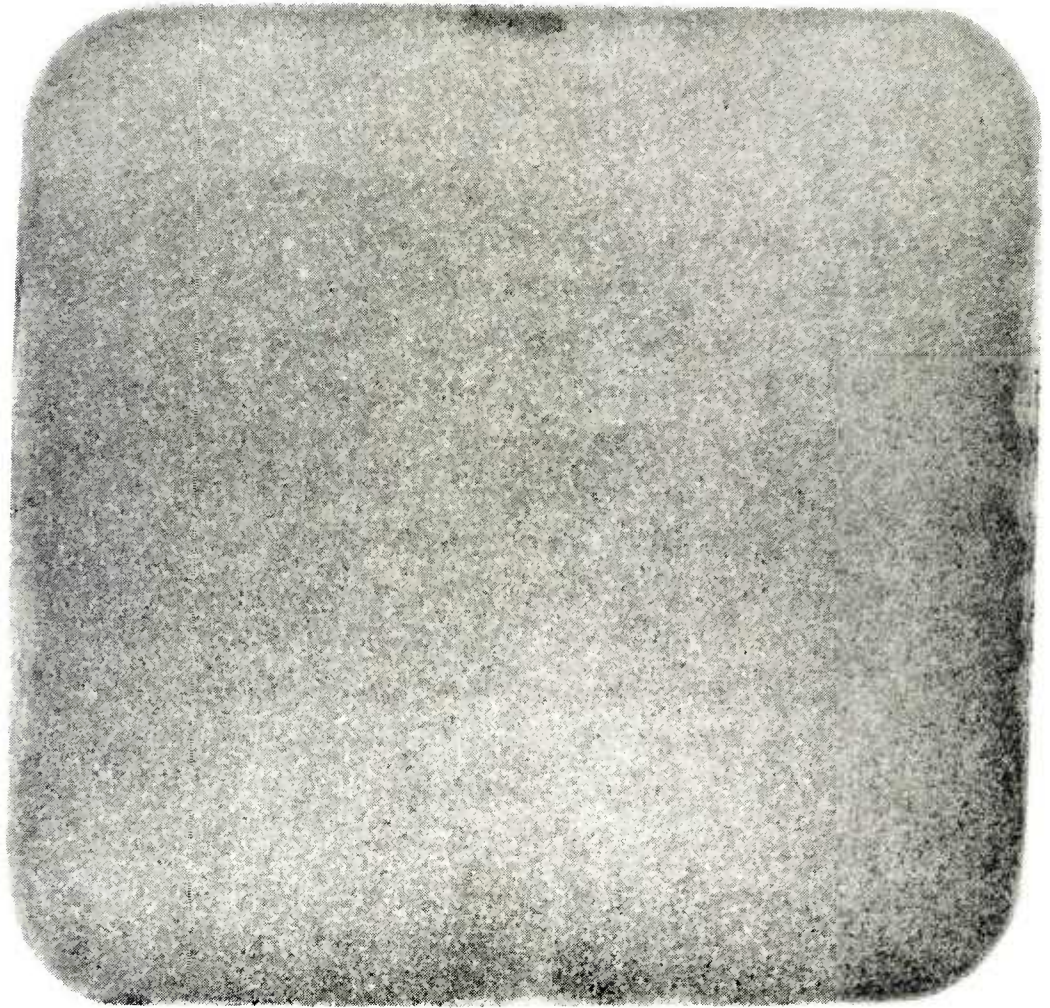


Figure D15. Billet 2X

Macro Cleanliness
Bethlehem Steel

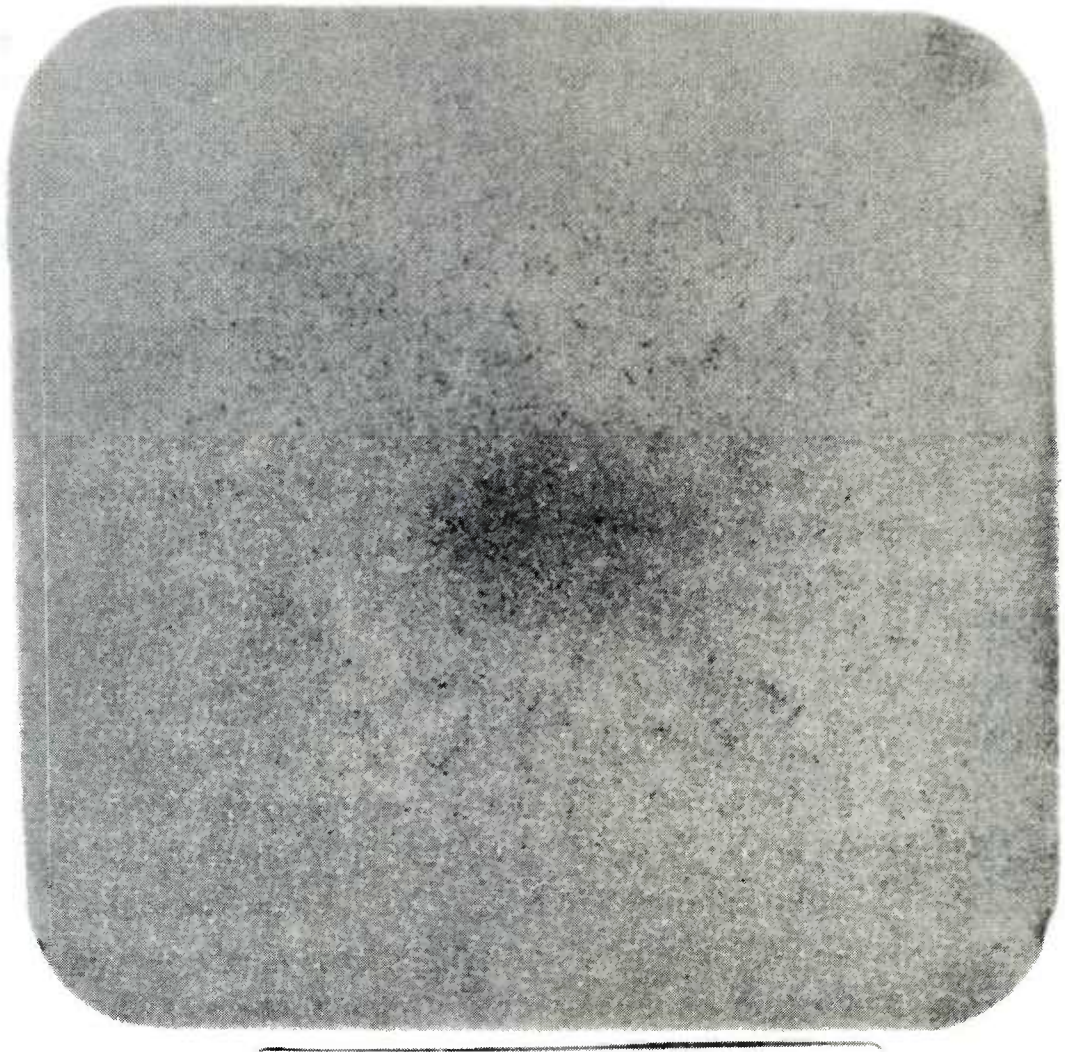


Figure D16. Billet 10T

Macro Cleanliness
Bethlehem Steel

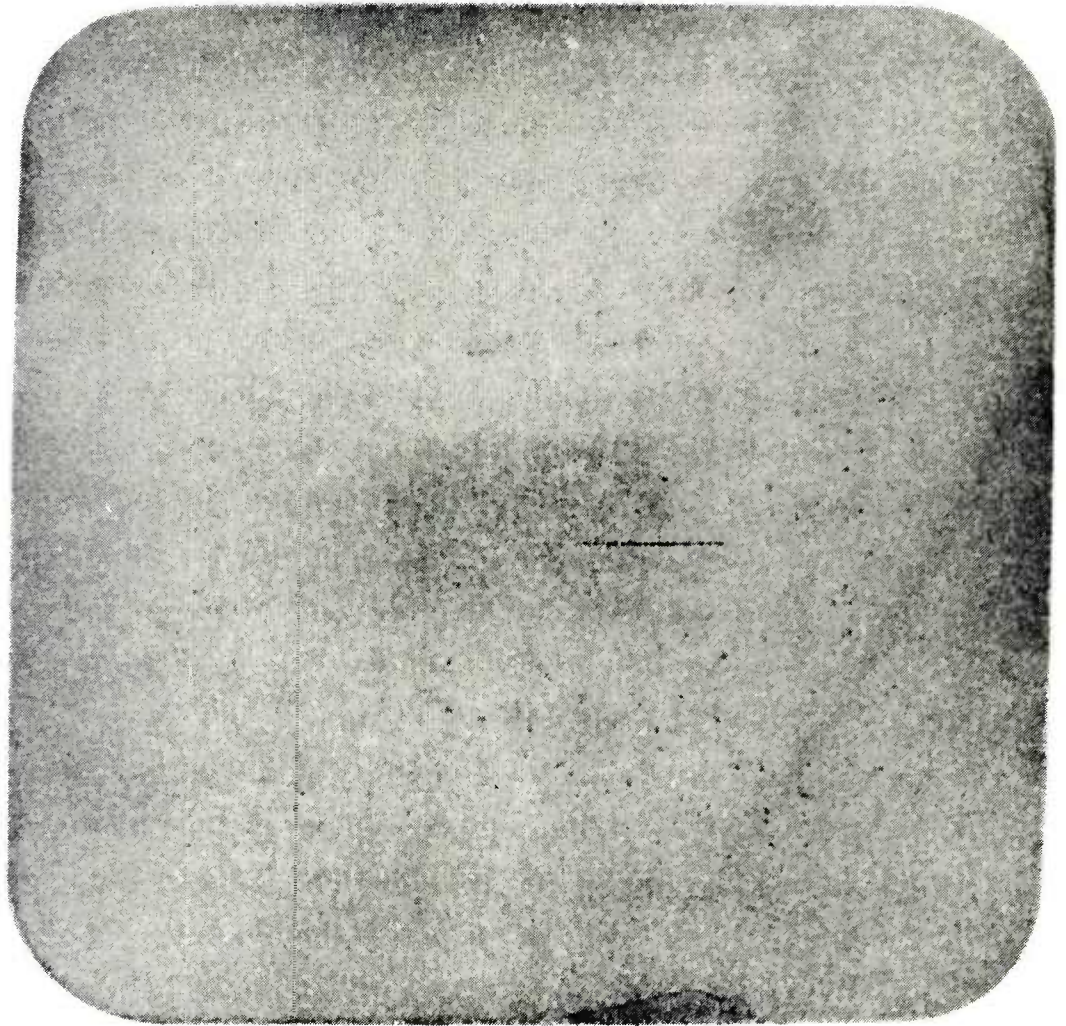


Figure D17. Billet 10C.

Macro Cleanliness
Bethlehem Steel

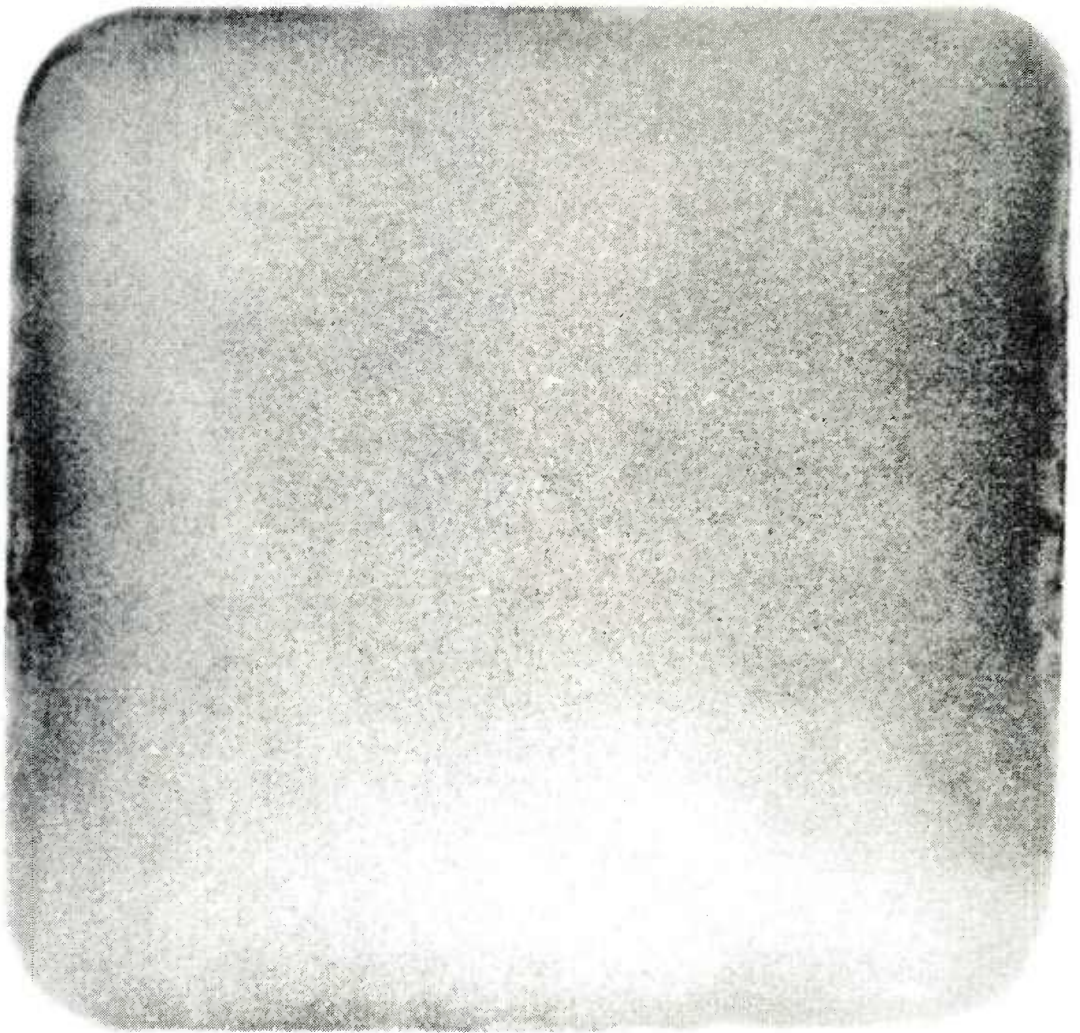


Figure D18. Billet 10X.

Macro Cleanliness
Bethlehem Steel



Figure D19. Billet 11T.

Macro Cleanliness
Bethlehem Steel

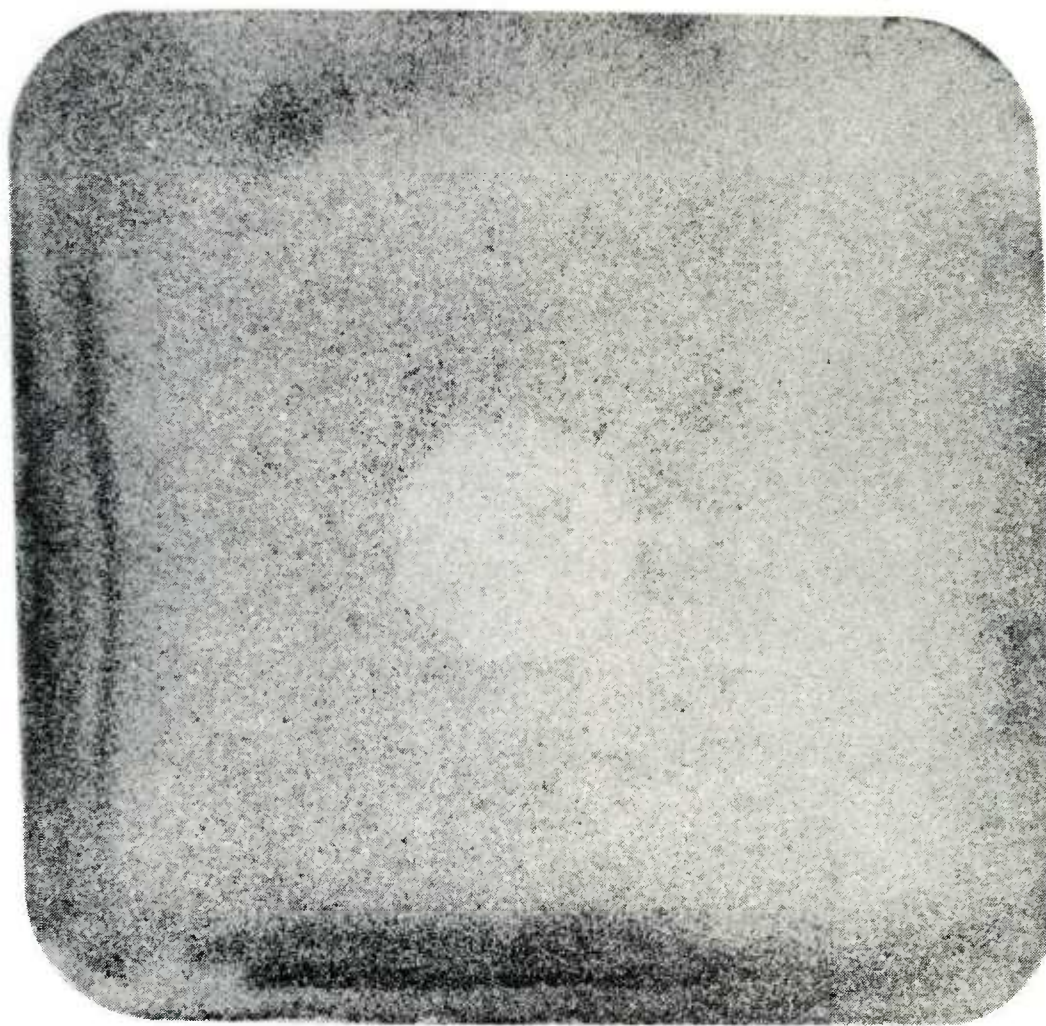


Figure D20. Billet 11C.

Macro Cleanliness
Bethlehem Steel

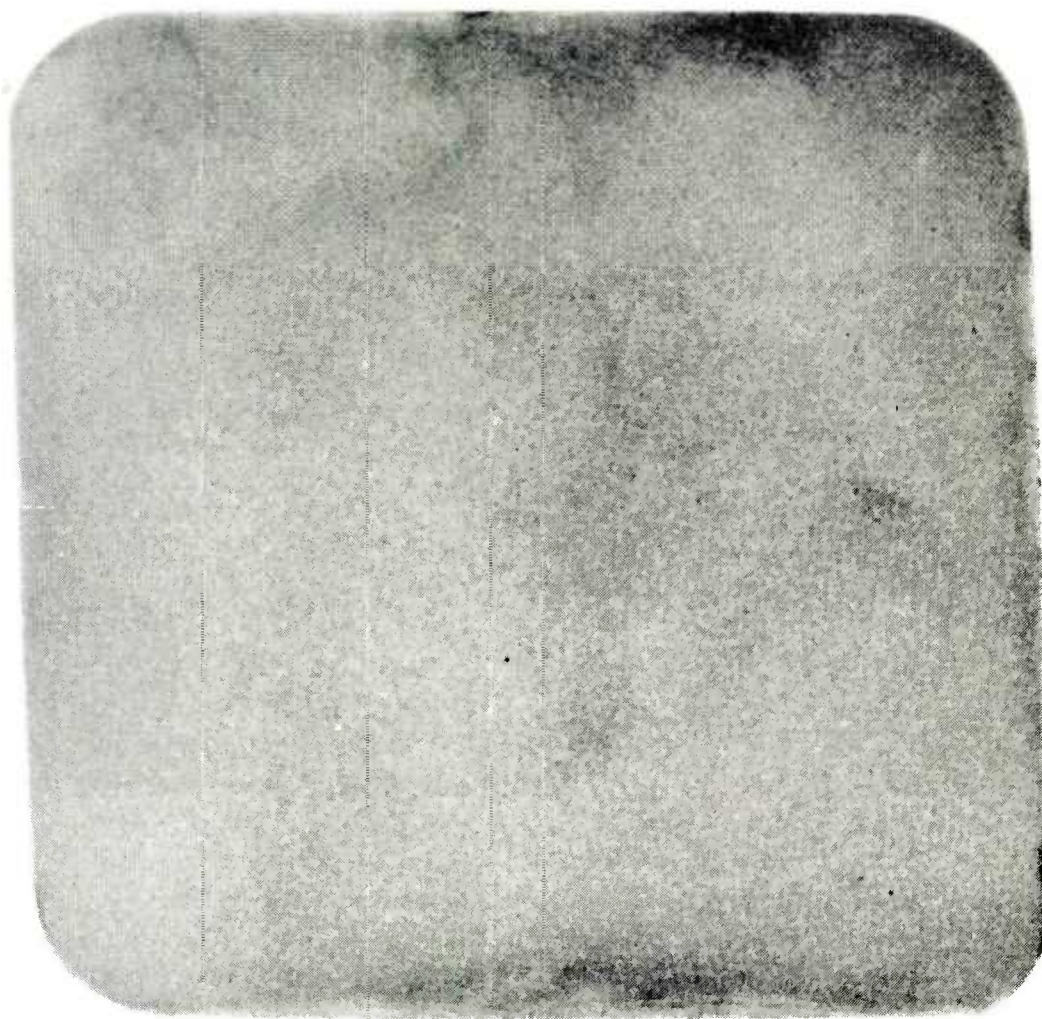


Figure D21. Billet 11X.

Macro Cleanliness
Bethlehem Steel

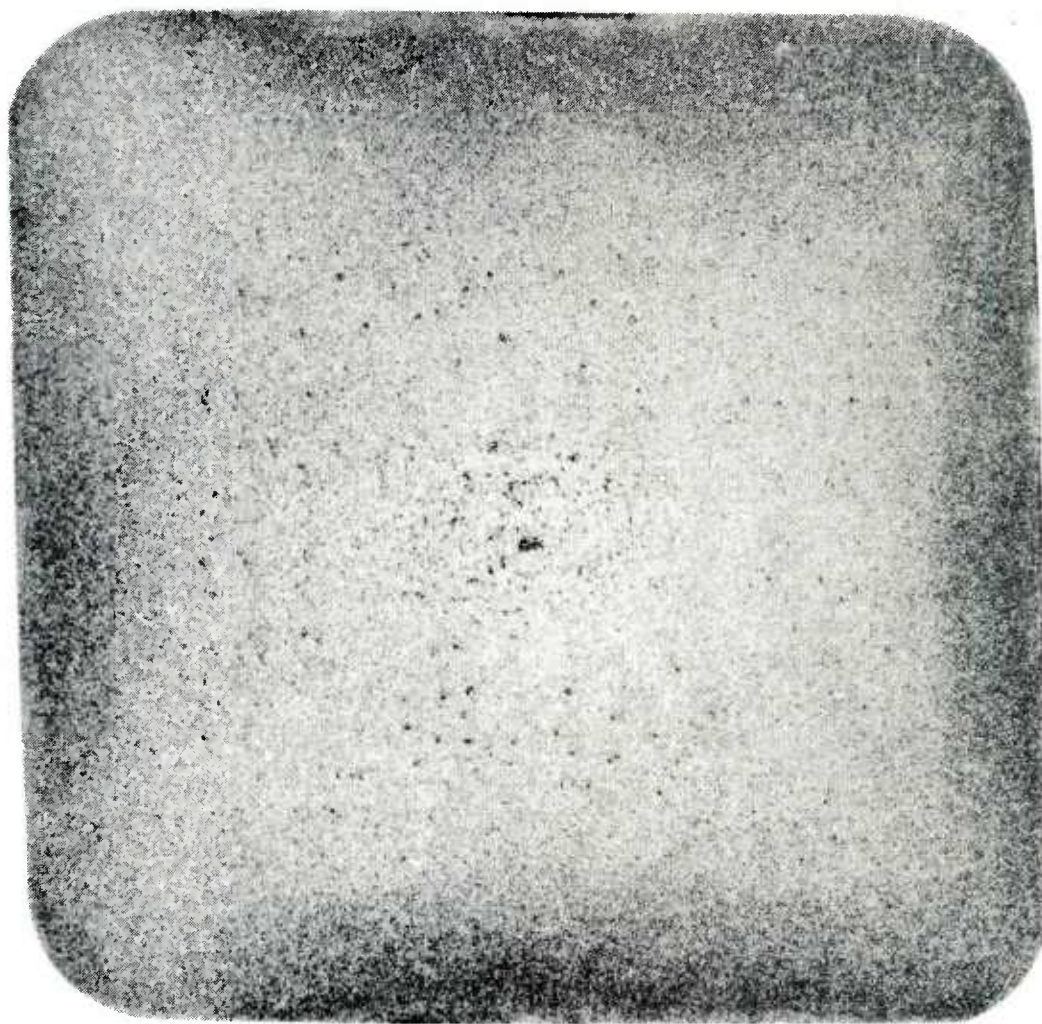


Figure D22. Billet 19T.

Macro Cleanliness
Bethlehem Steel



Figure D23. Billet 19C.

Macro Cleanliness
Bethlehem Steel

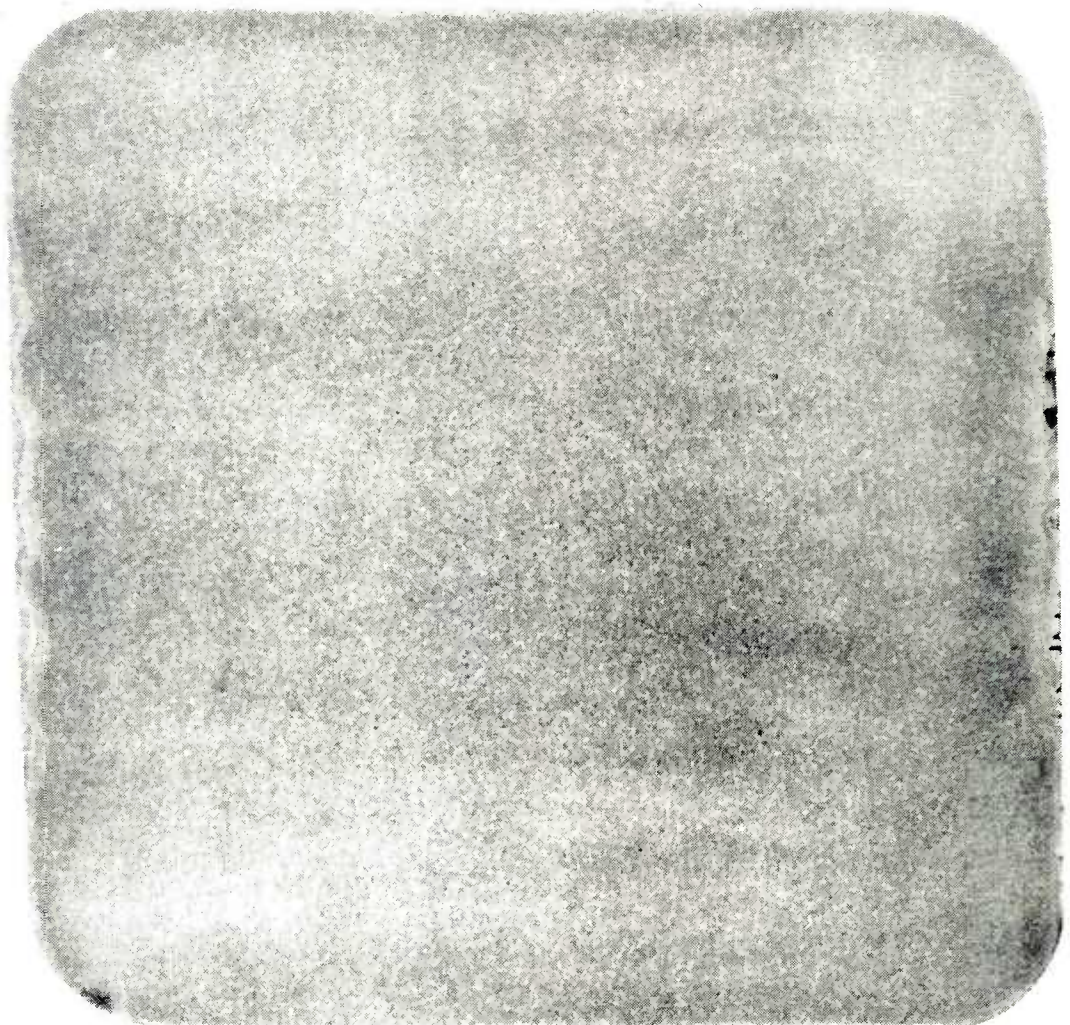


Figure D24. Billet 19X

Macro Cleanliness
Bethlehem Steel

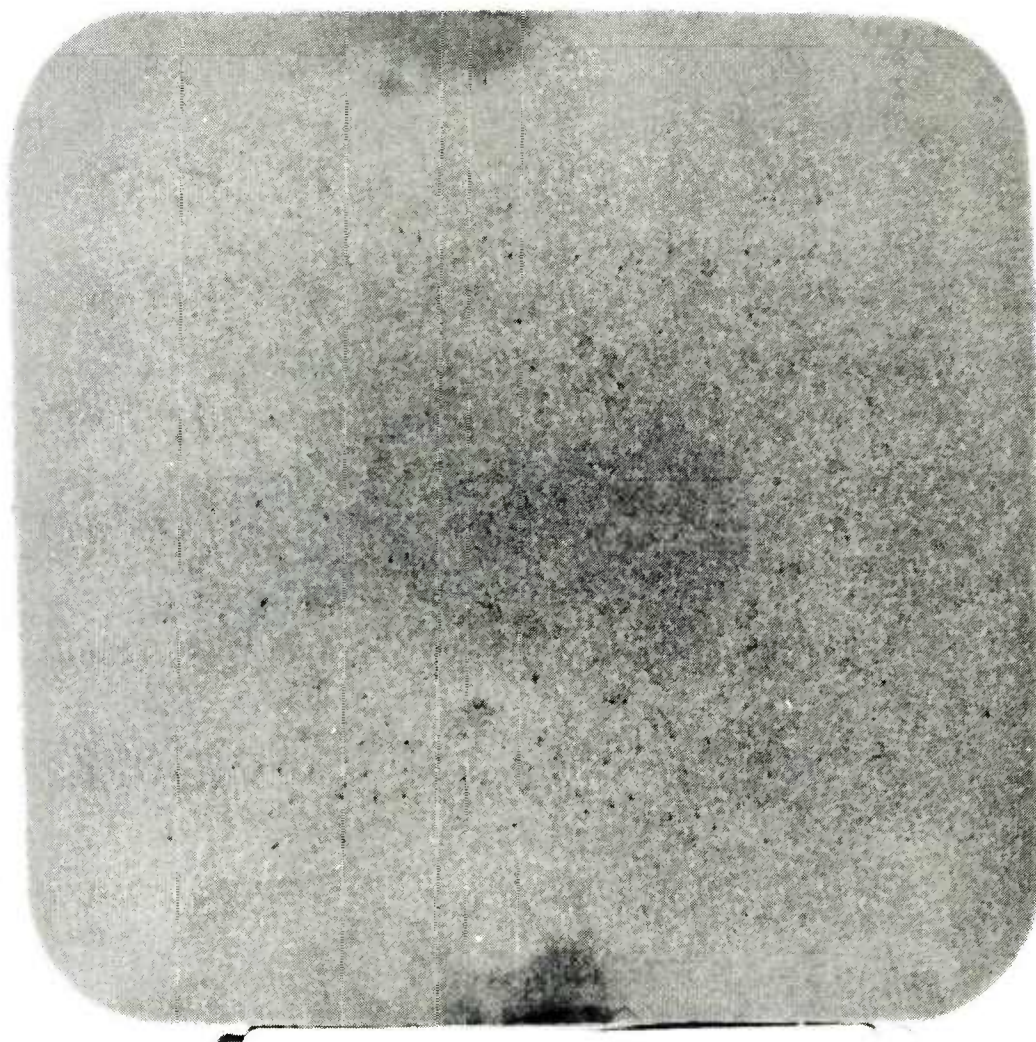


Figure D25. Billet 20T

Macro Cleanliness
Bethlehem Steel



Figure D26. Billet 20C.

Macro Cleanliness
Bethlehem Steel

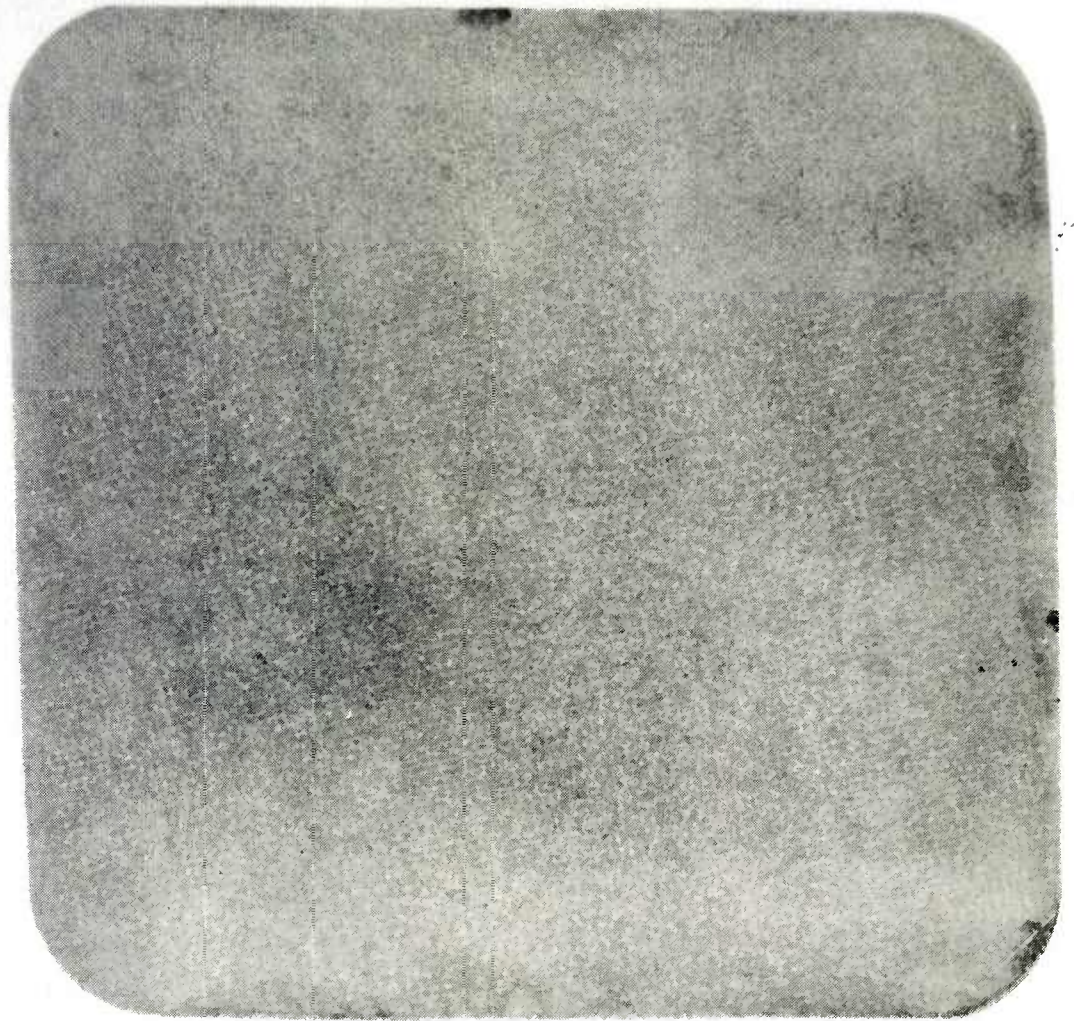
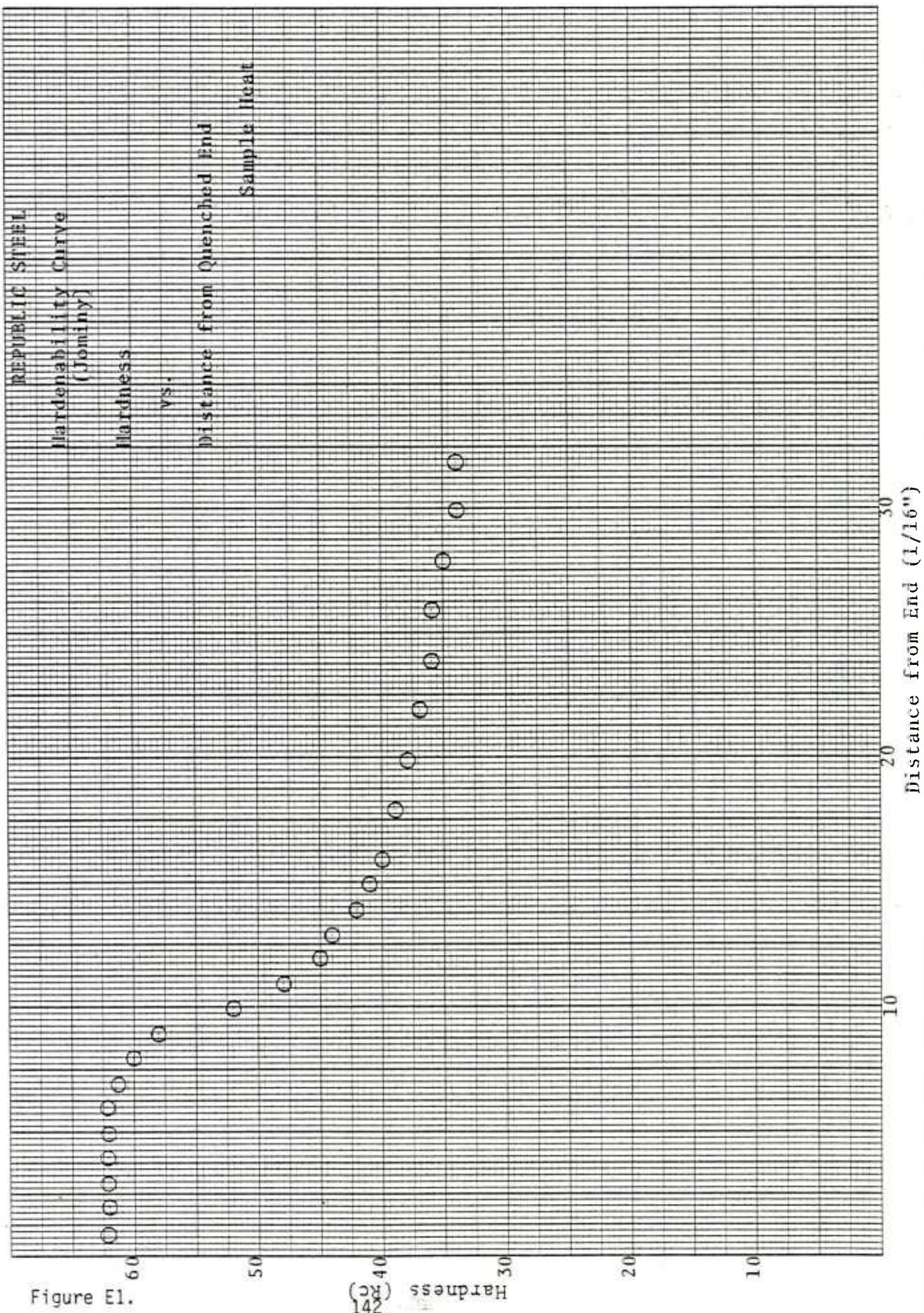


Figure D27. Billet 20X.

Appendix E

Jominy Hardenability



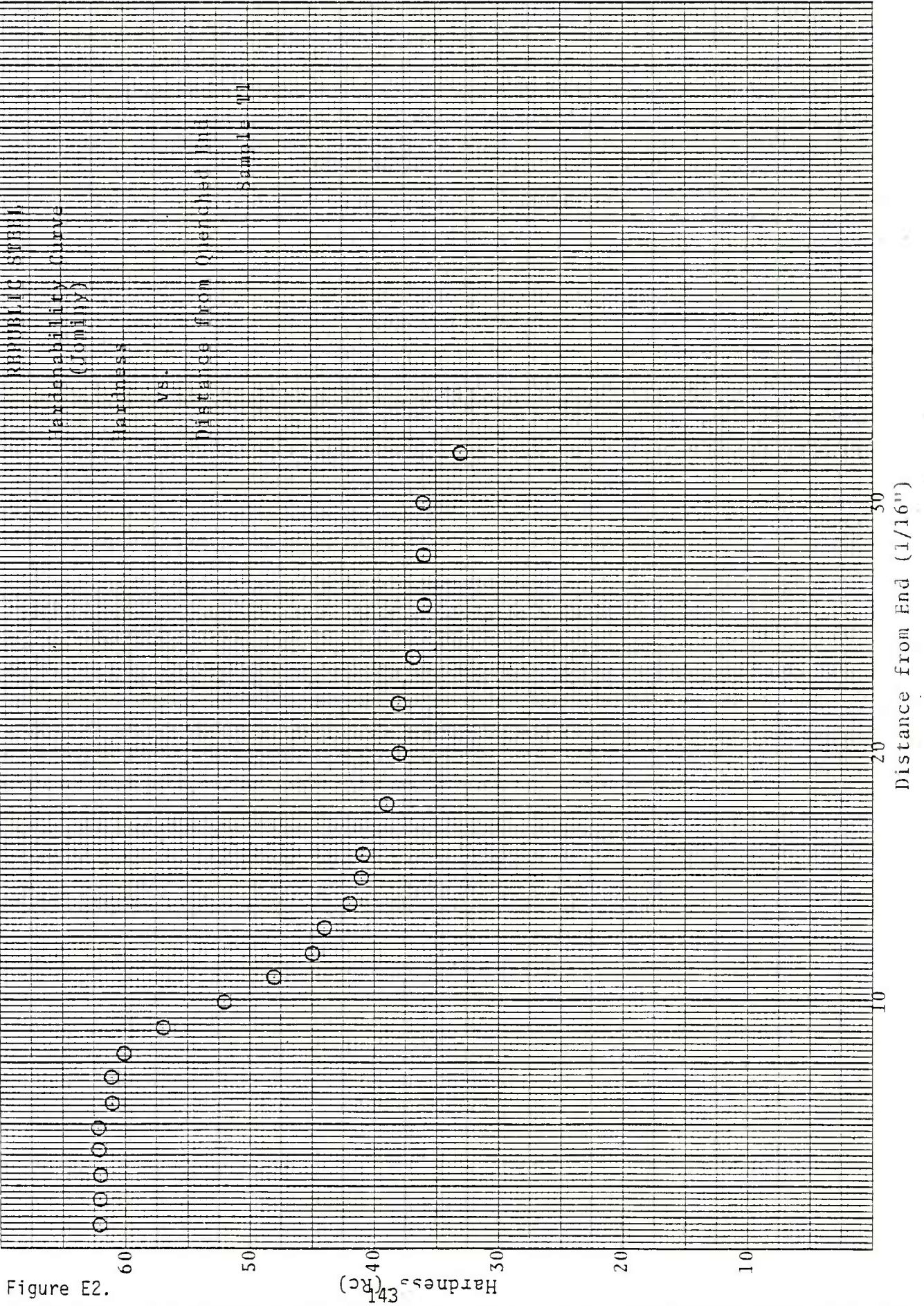


Figure E2.

Hardness (HRC)

Distance from End (1/16")

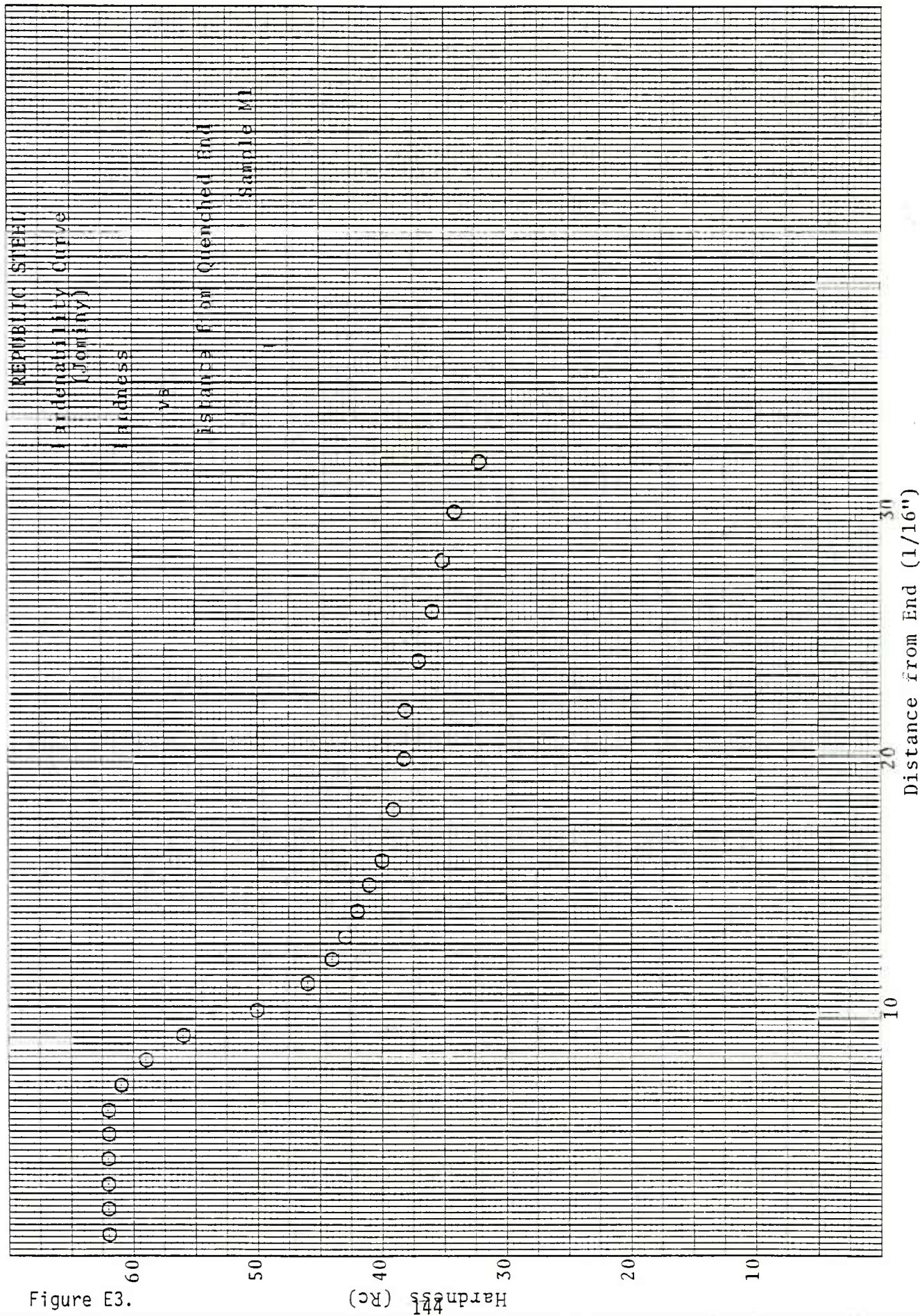


Figure E3.

Hardness (Rc)

Distance from End (1/16'')

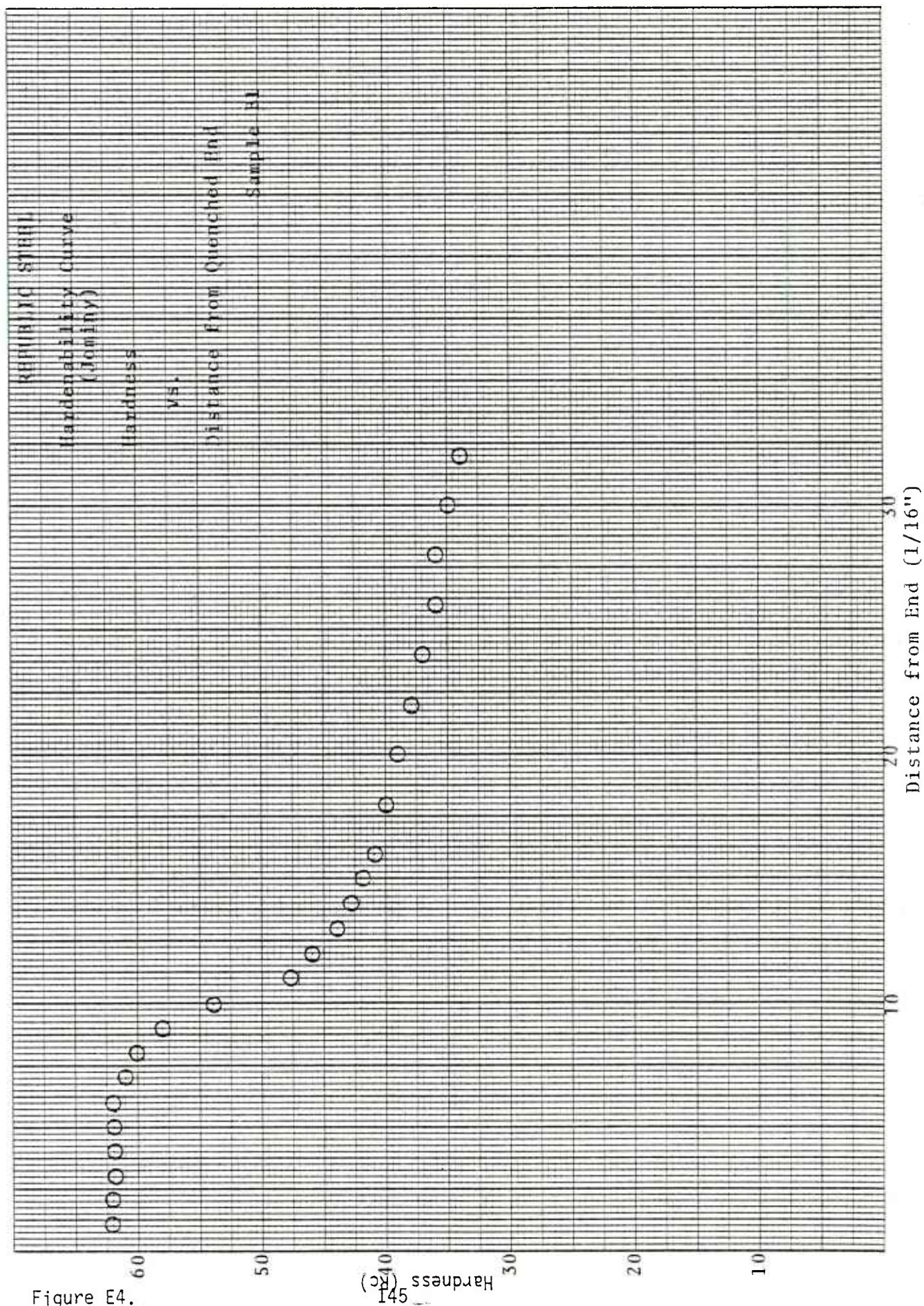


Figure E4.

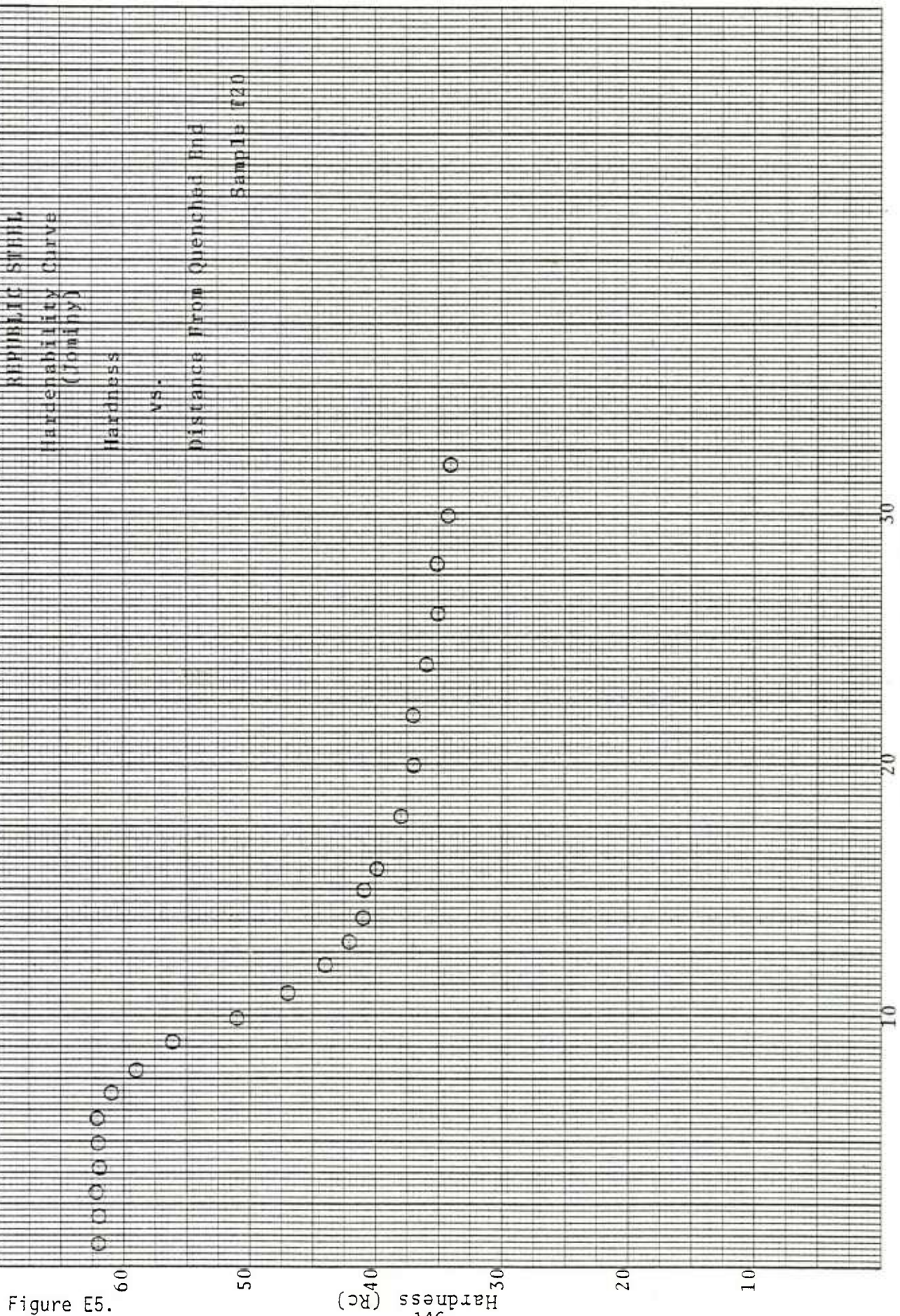


Figure E5.

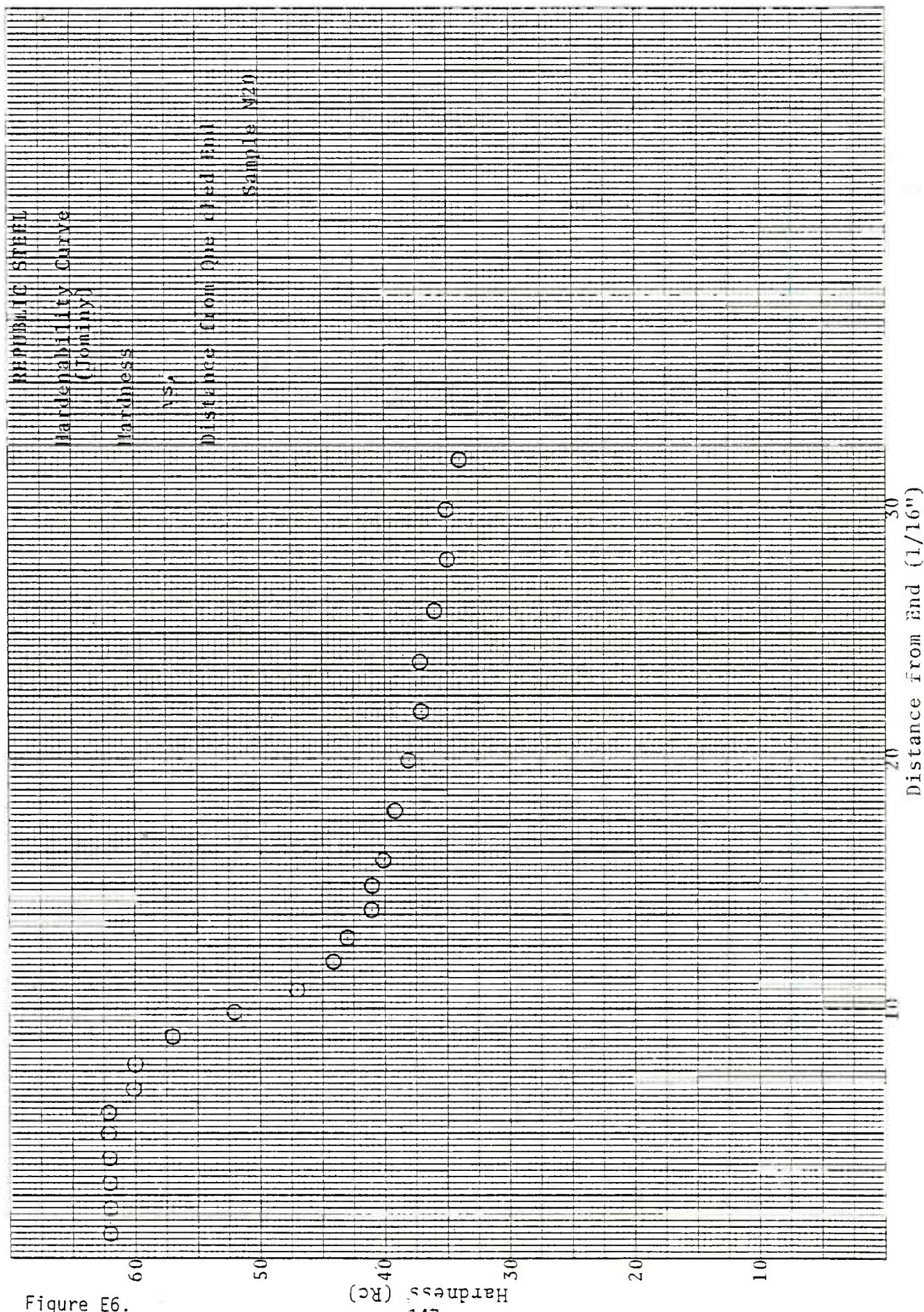


Figure E6.

Hardness (Rc)

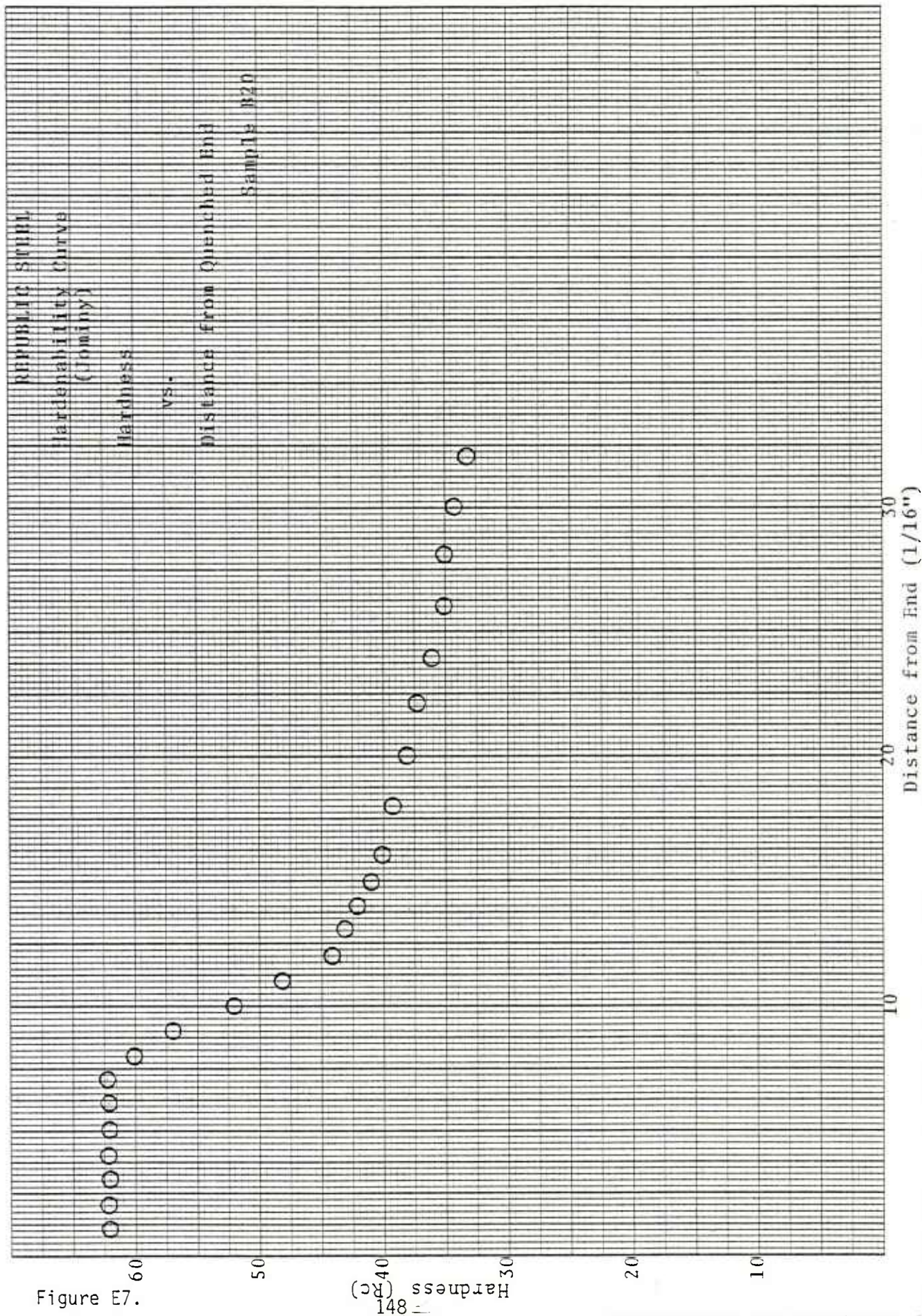
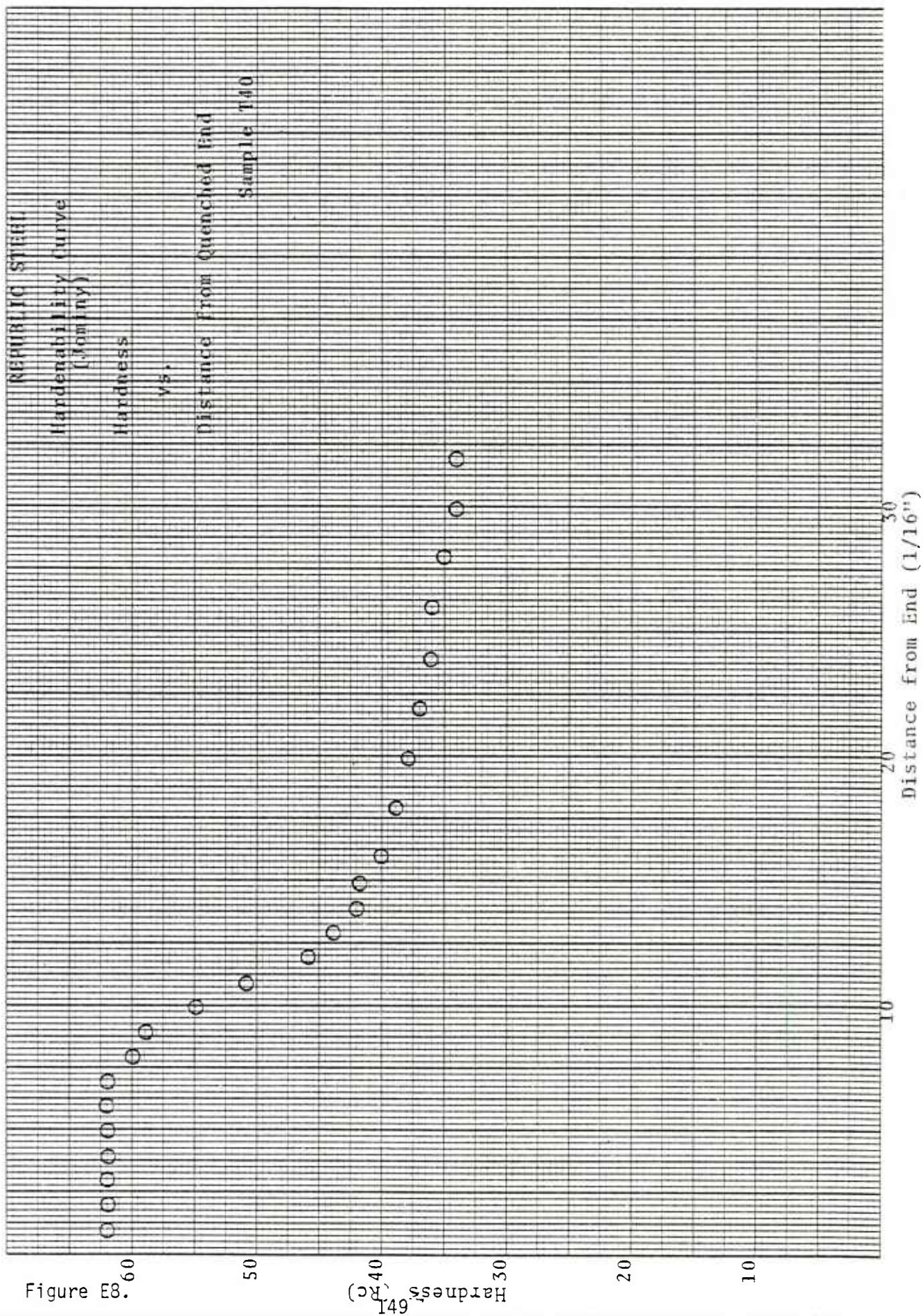


Figure E7.

148
Hardness (HRC)



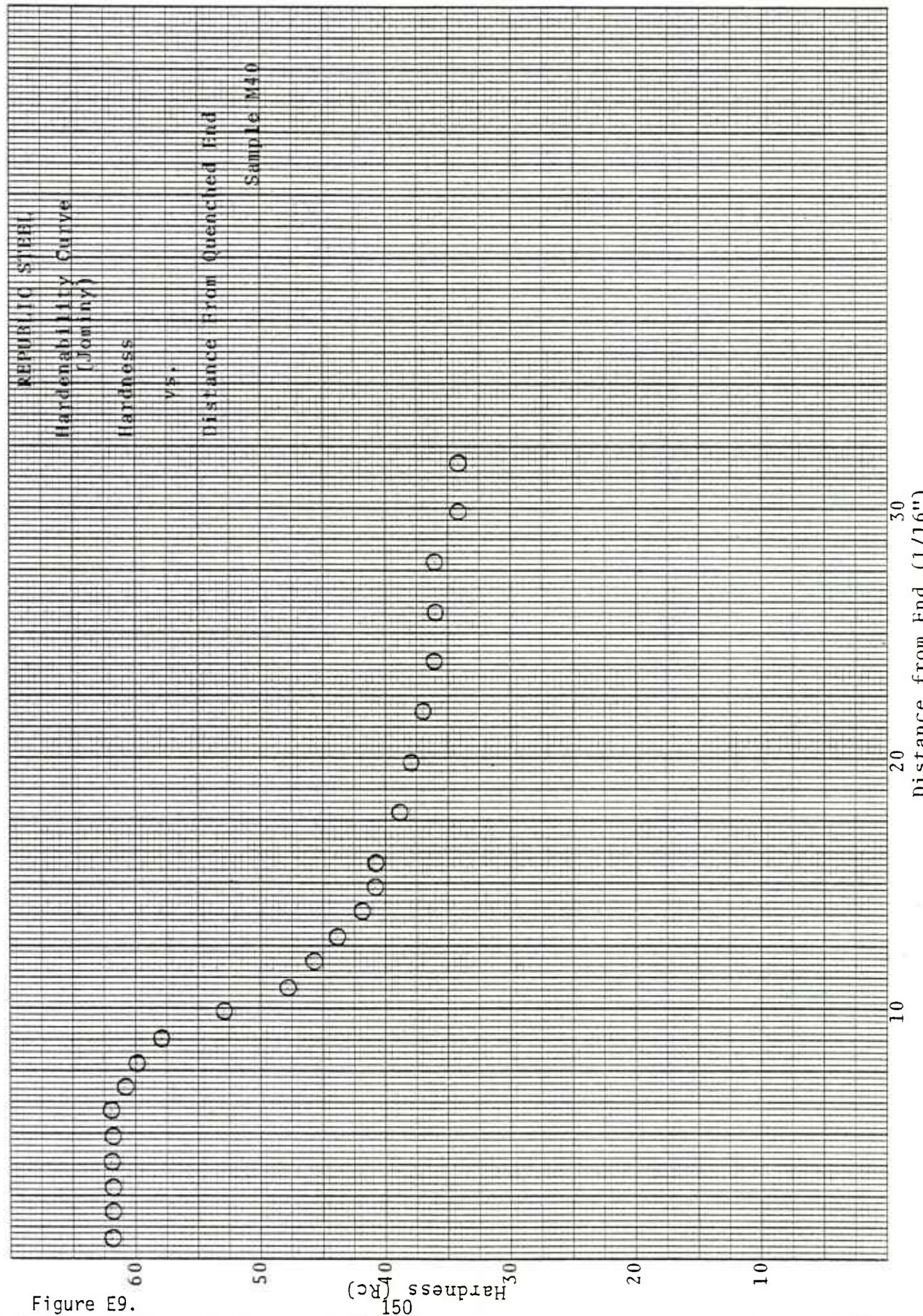


Figure E9.

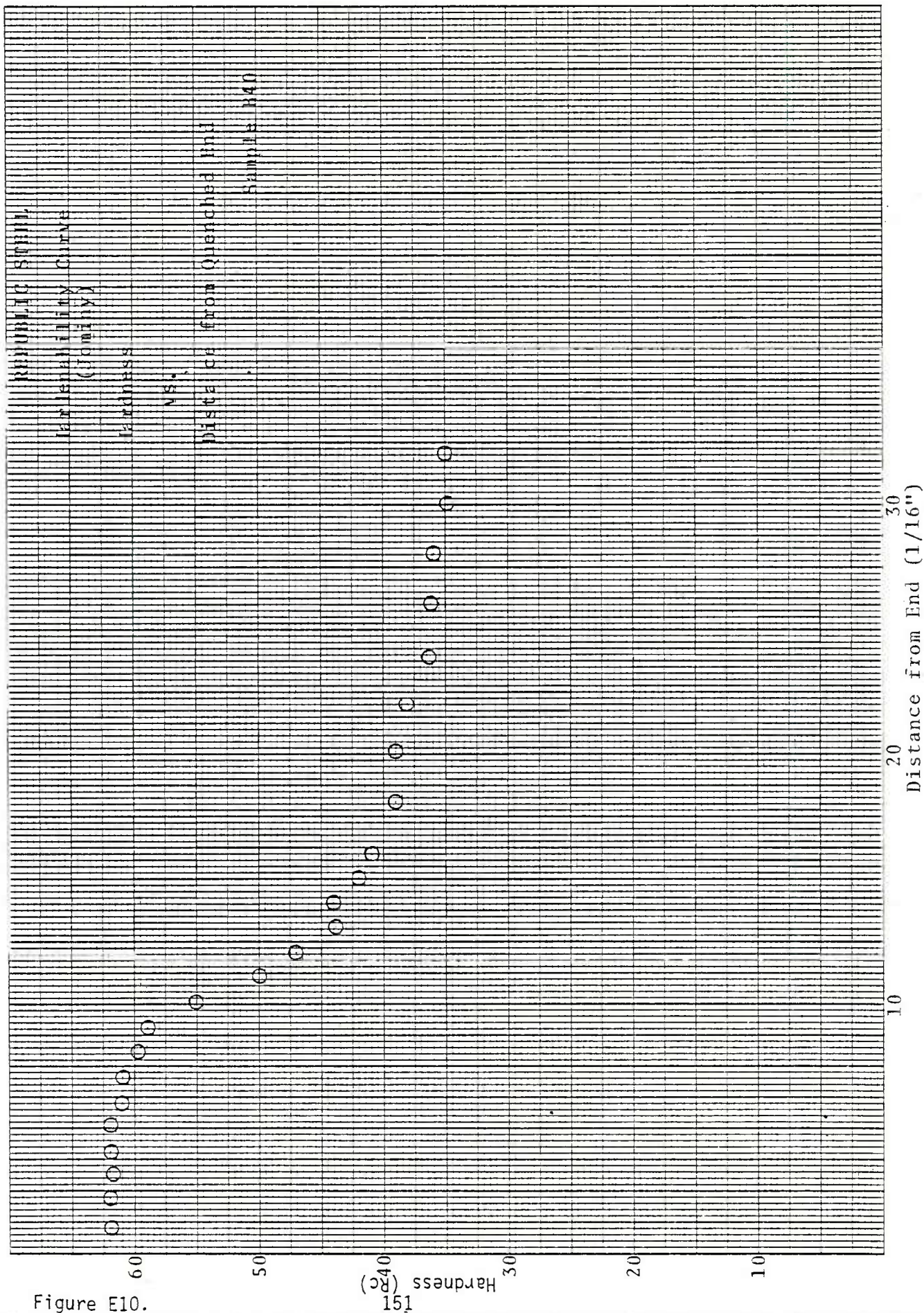
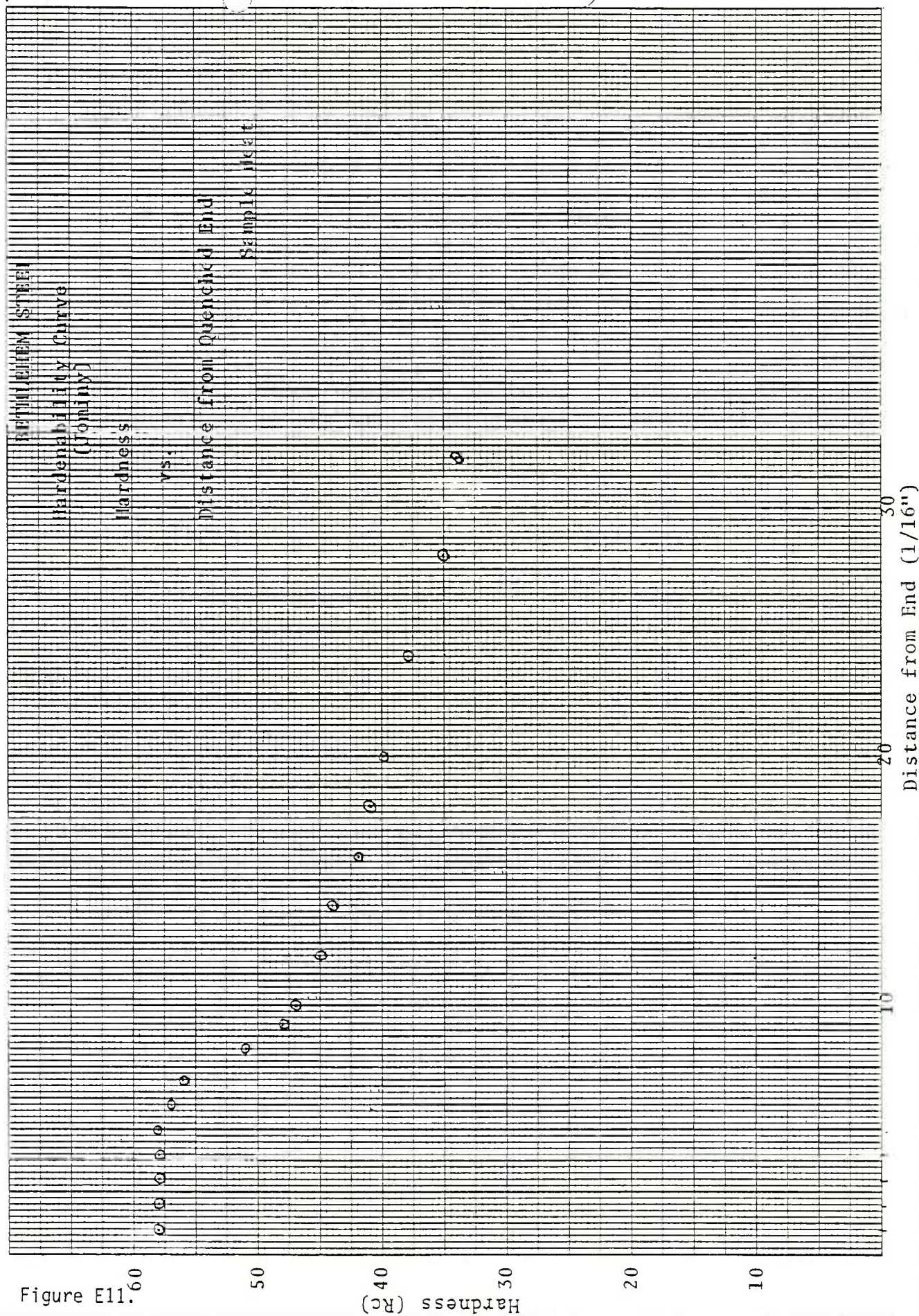


Figure E10.



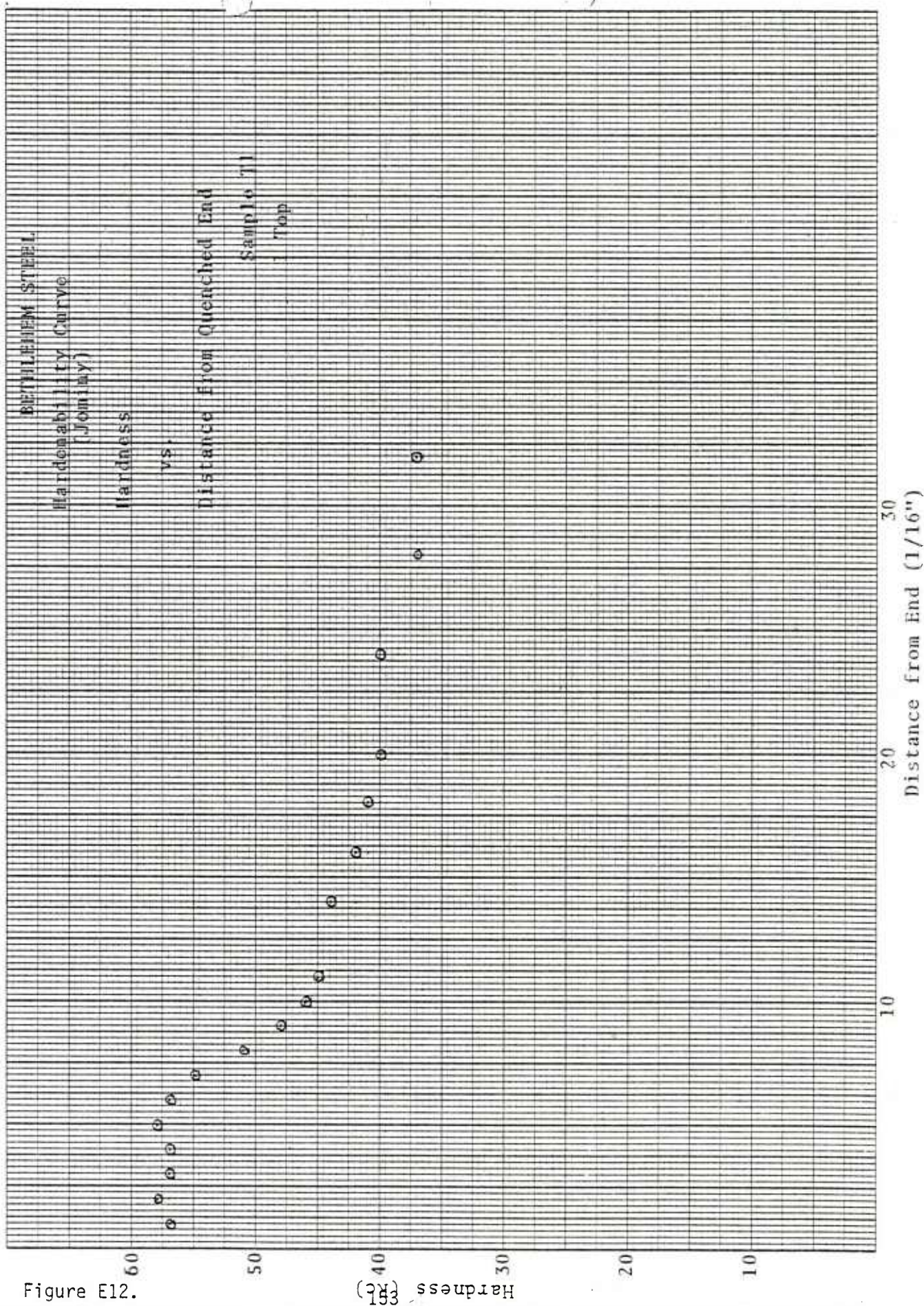


Figure E12.

Hardness (HRC)

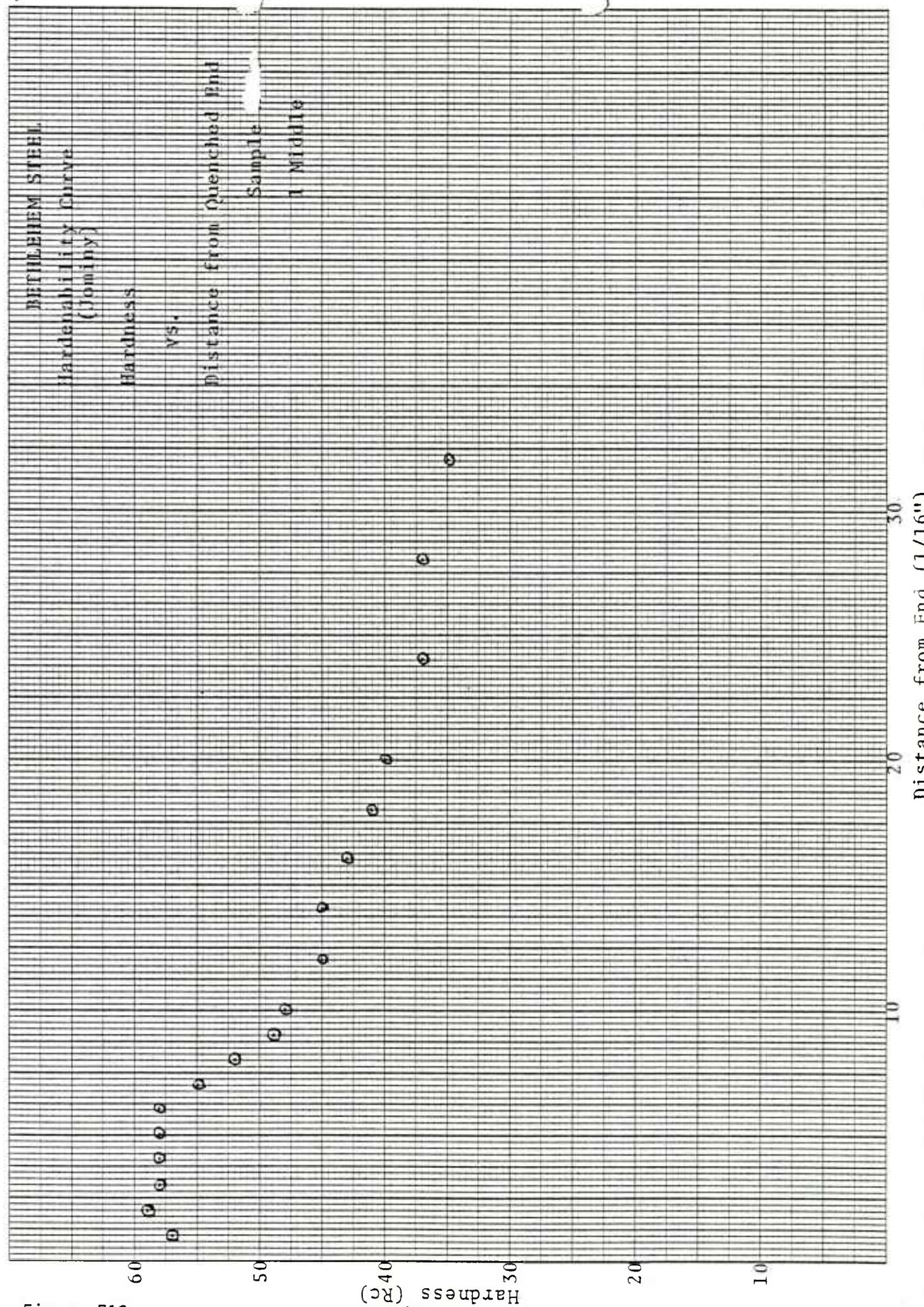
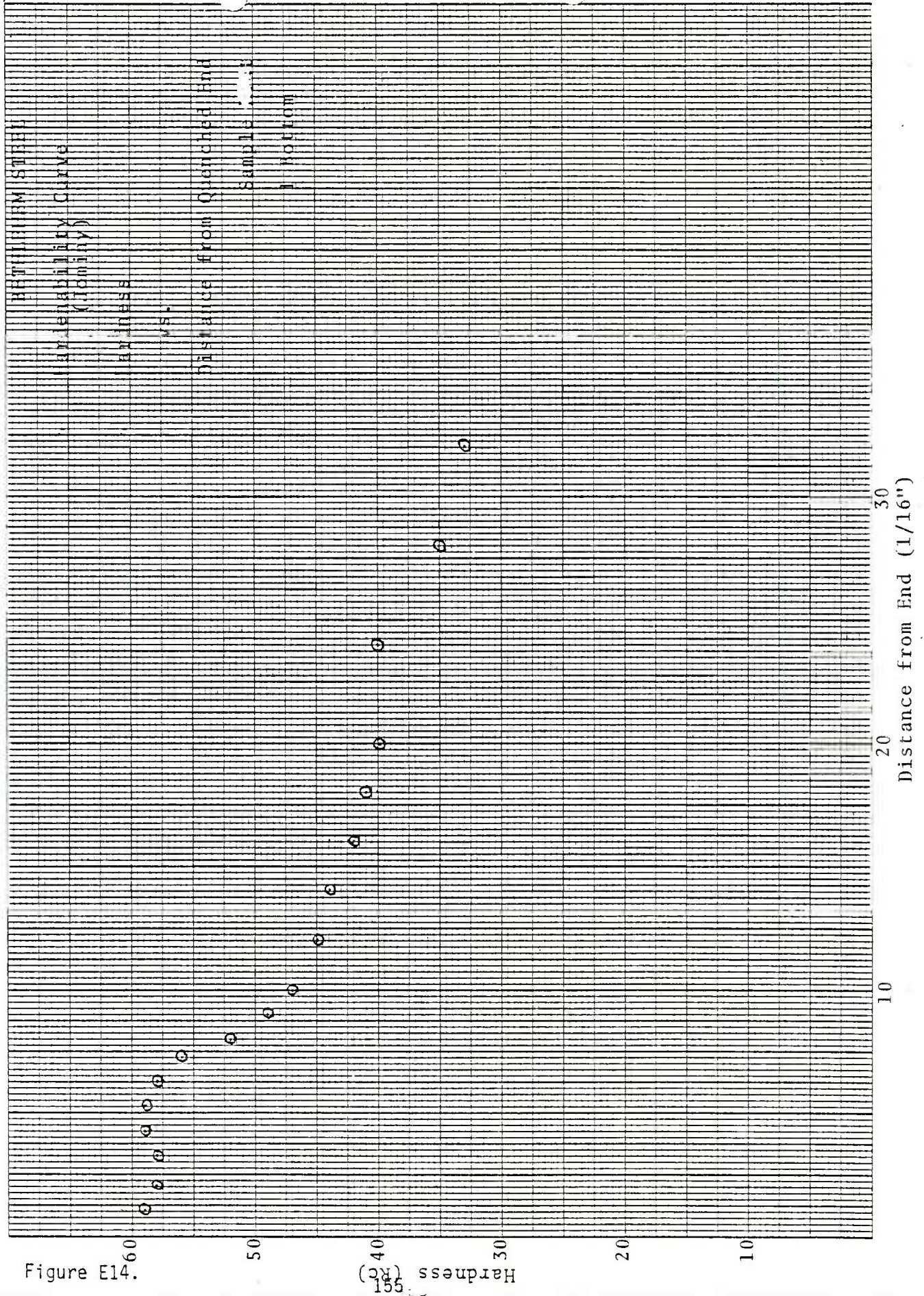
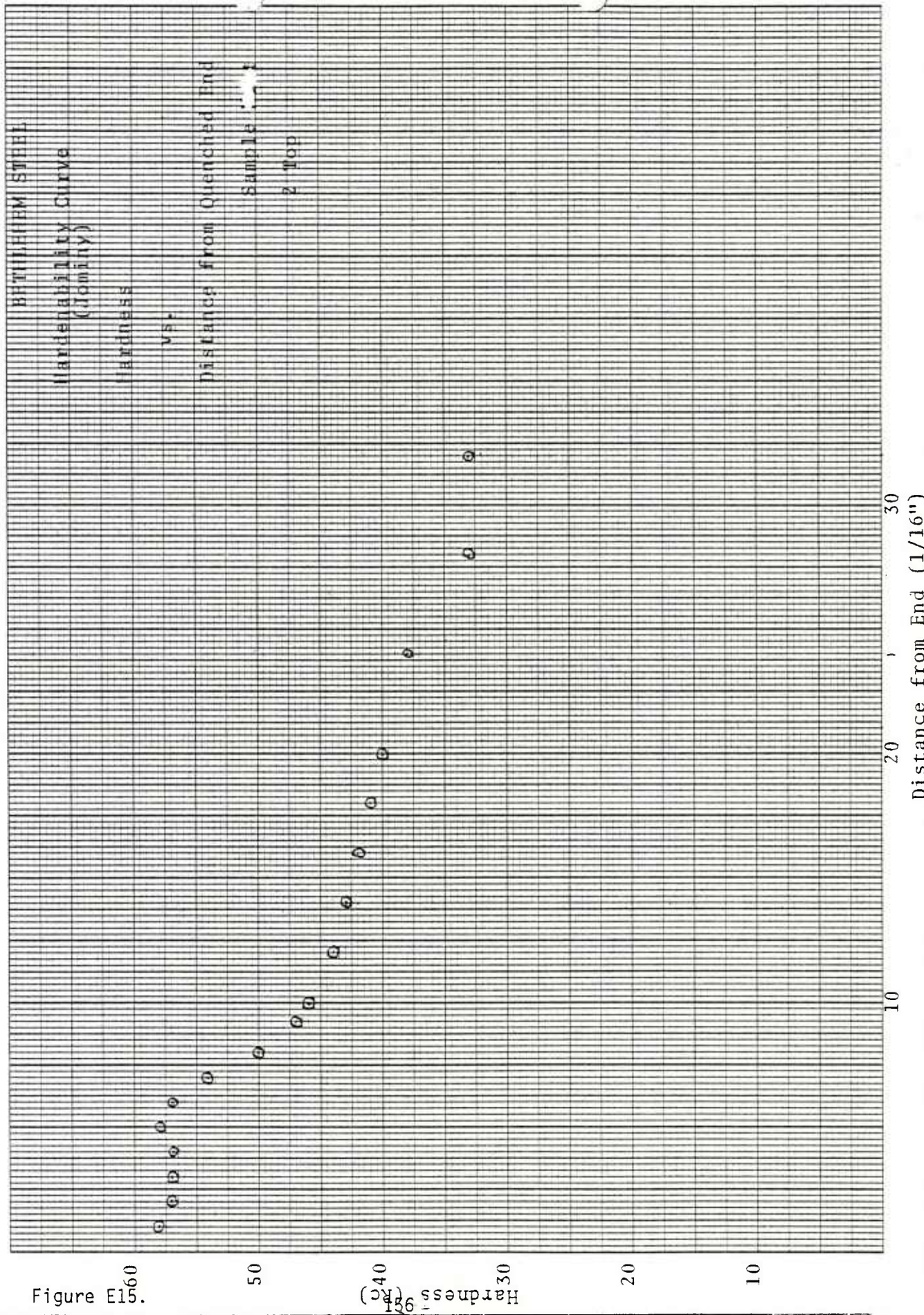
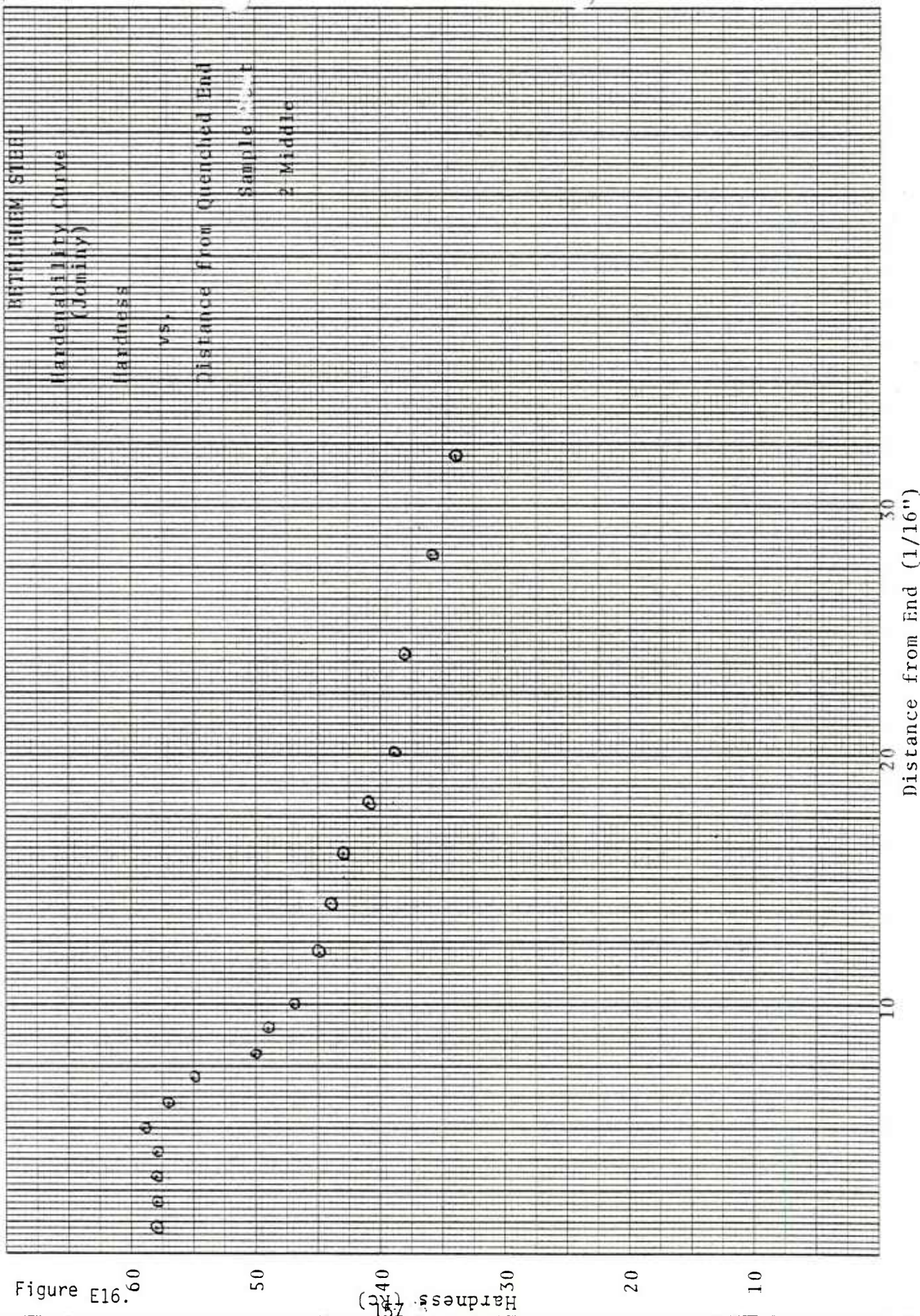


Figure E13.







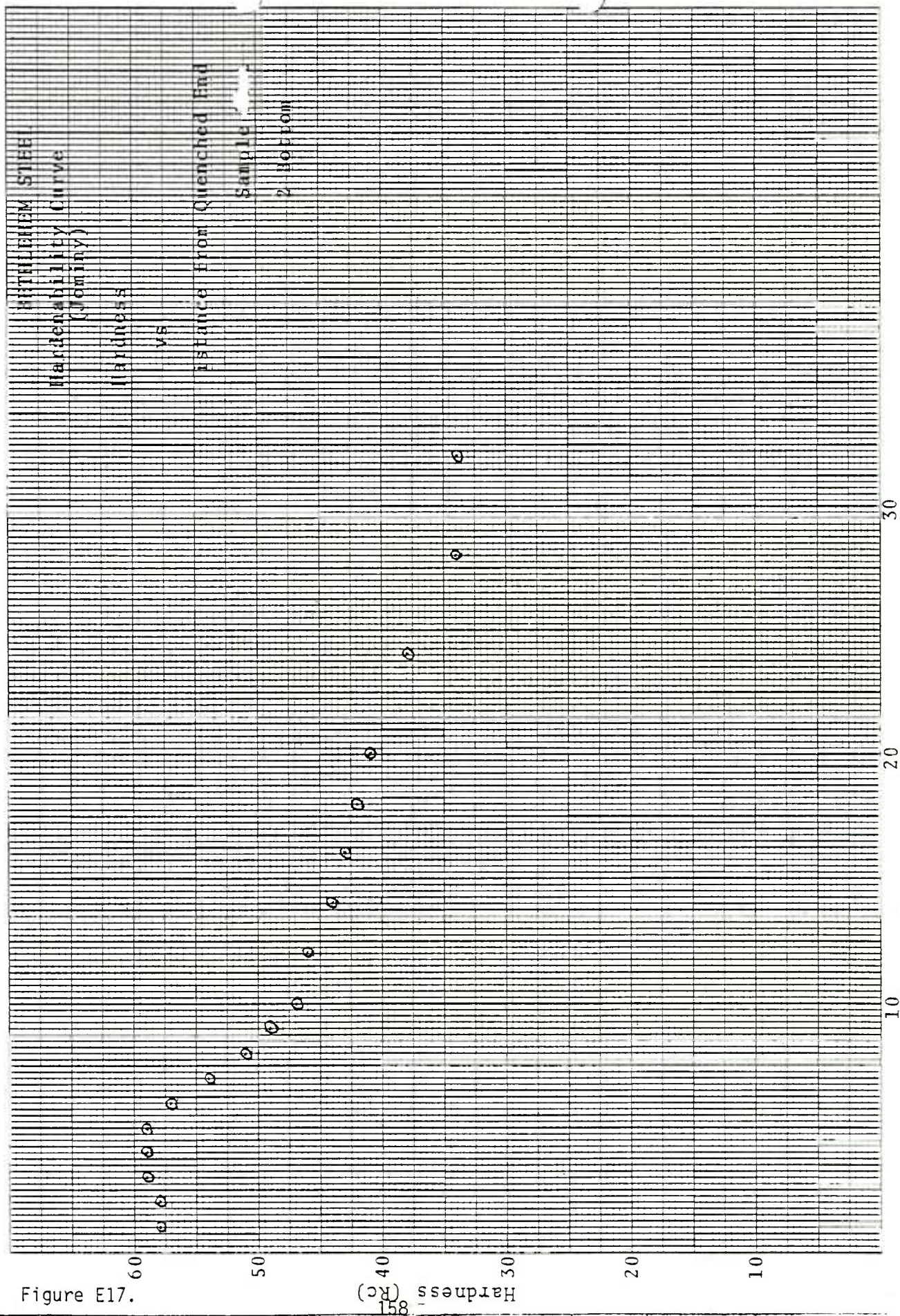


Figure E17.

Hardness (Rc)

Distance from End (1/16")

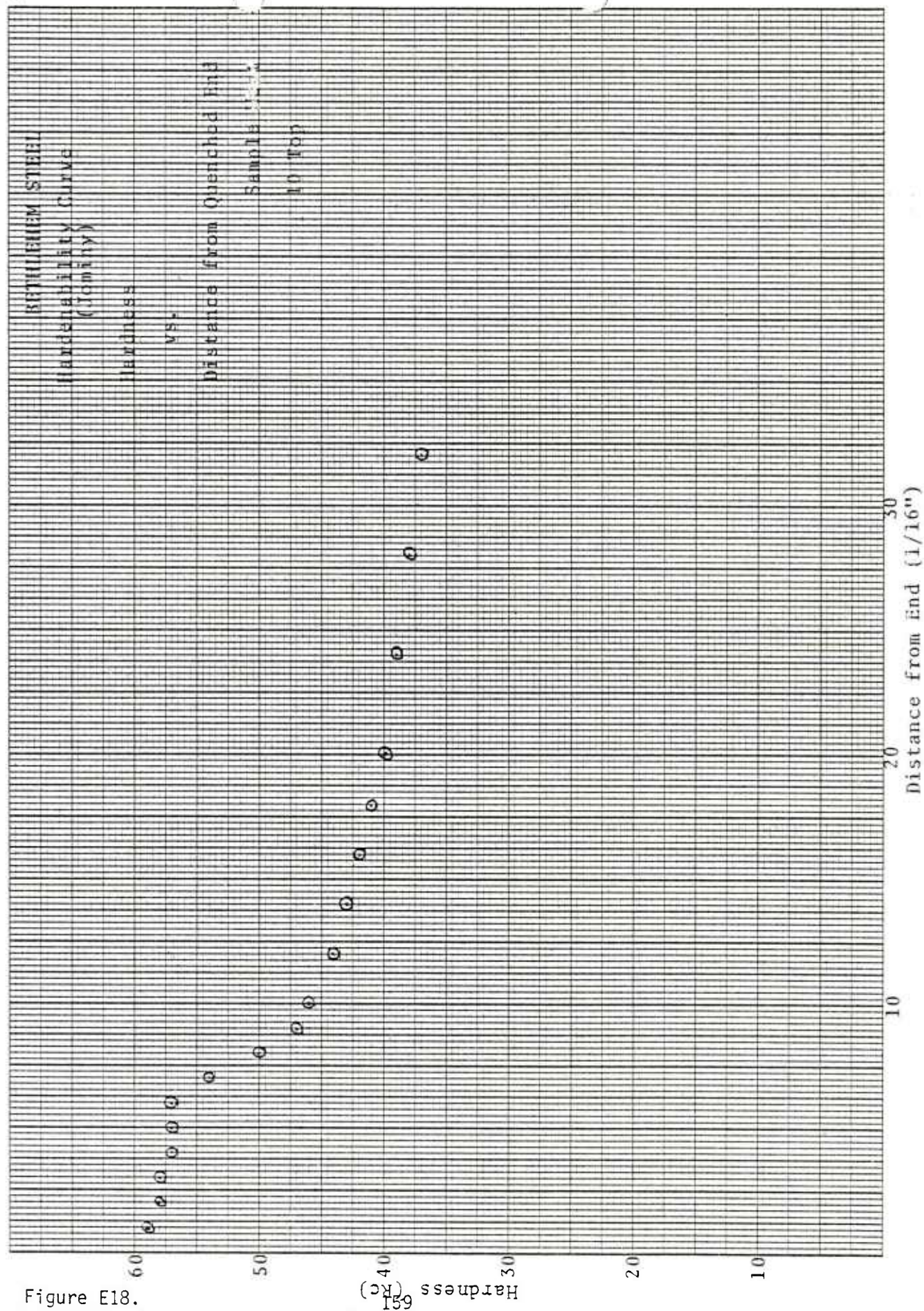
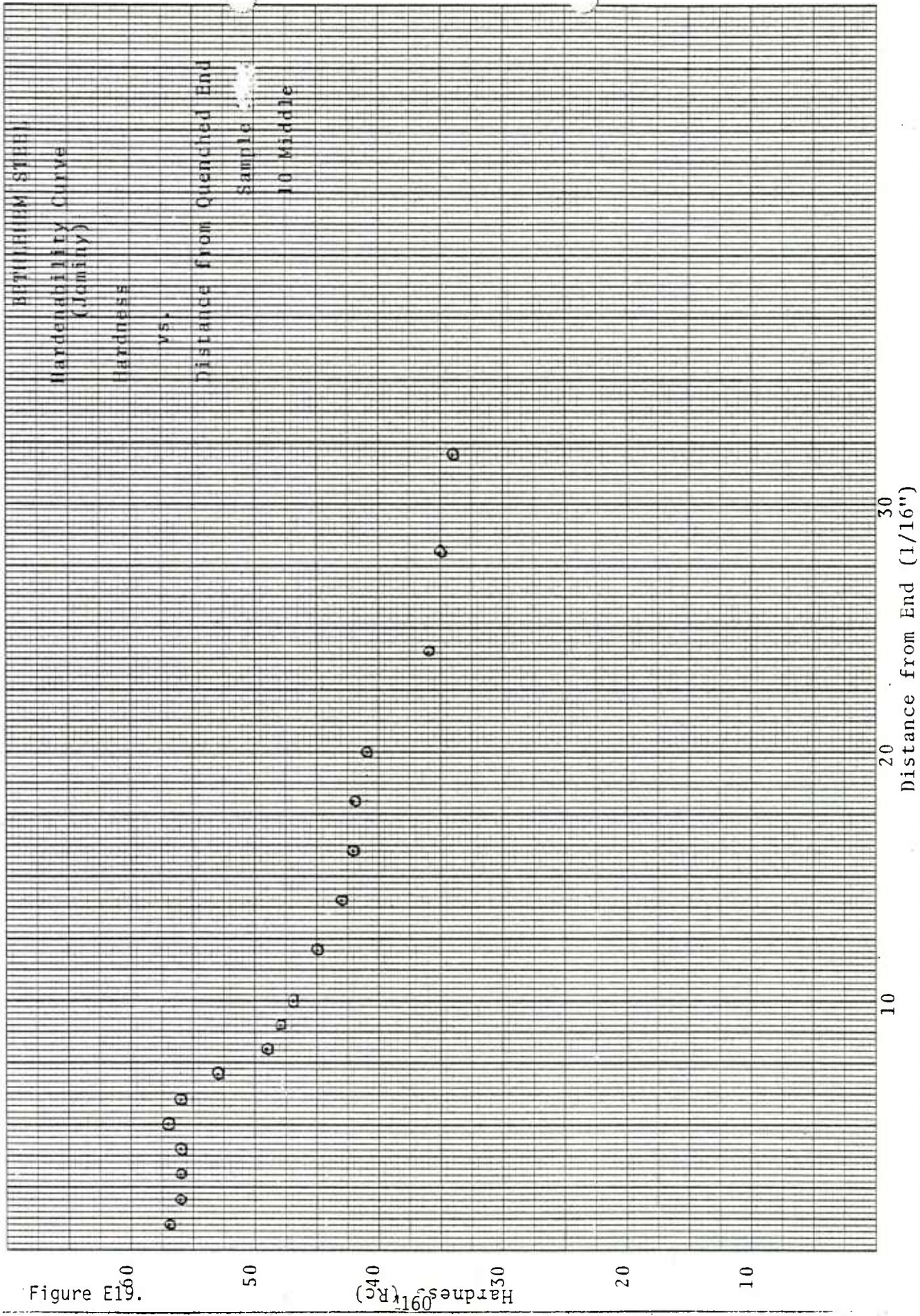


Figure E18.



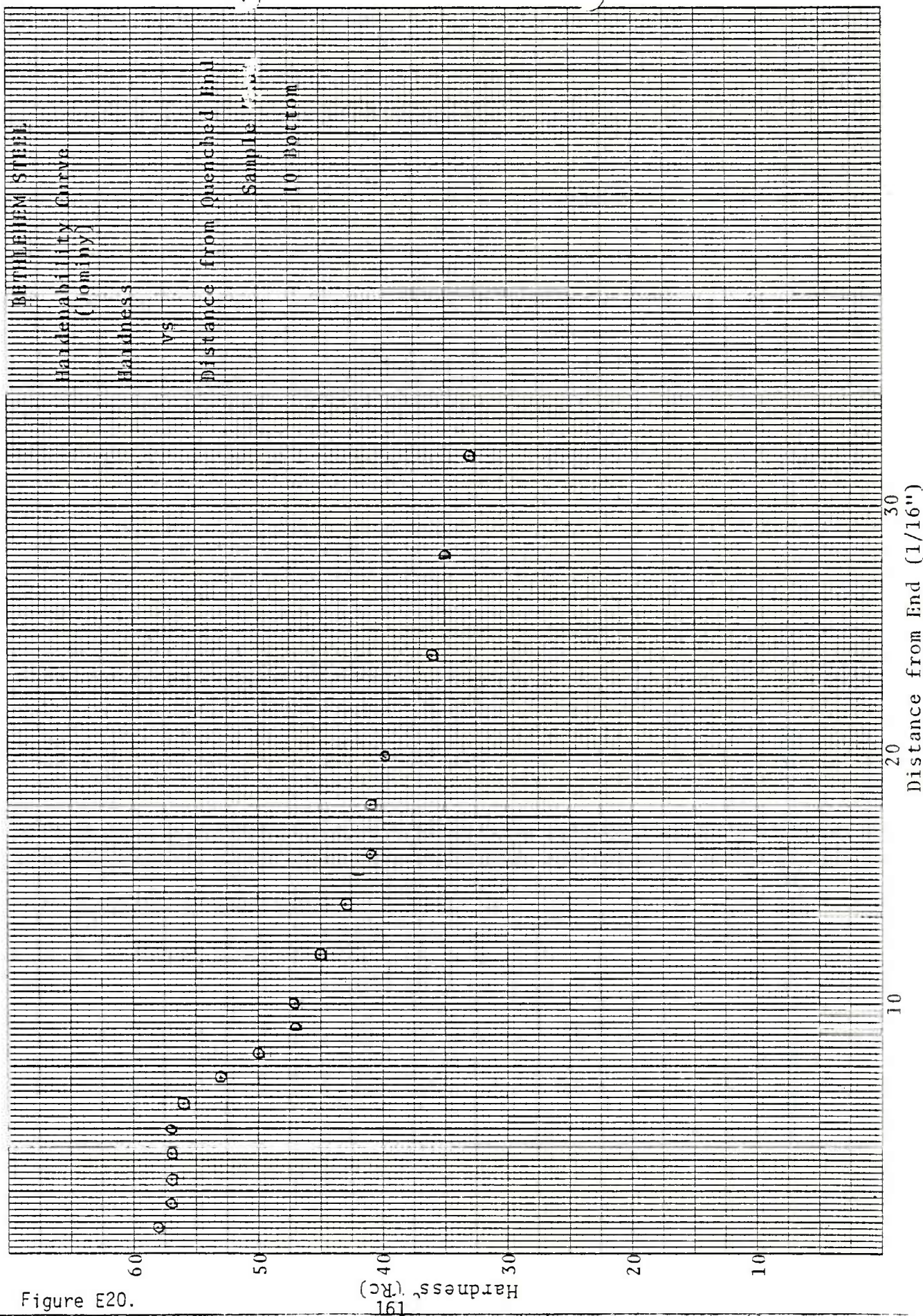
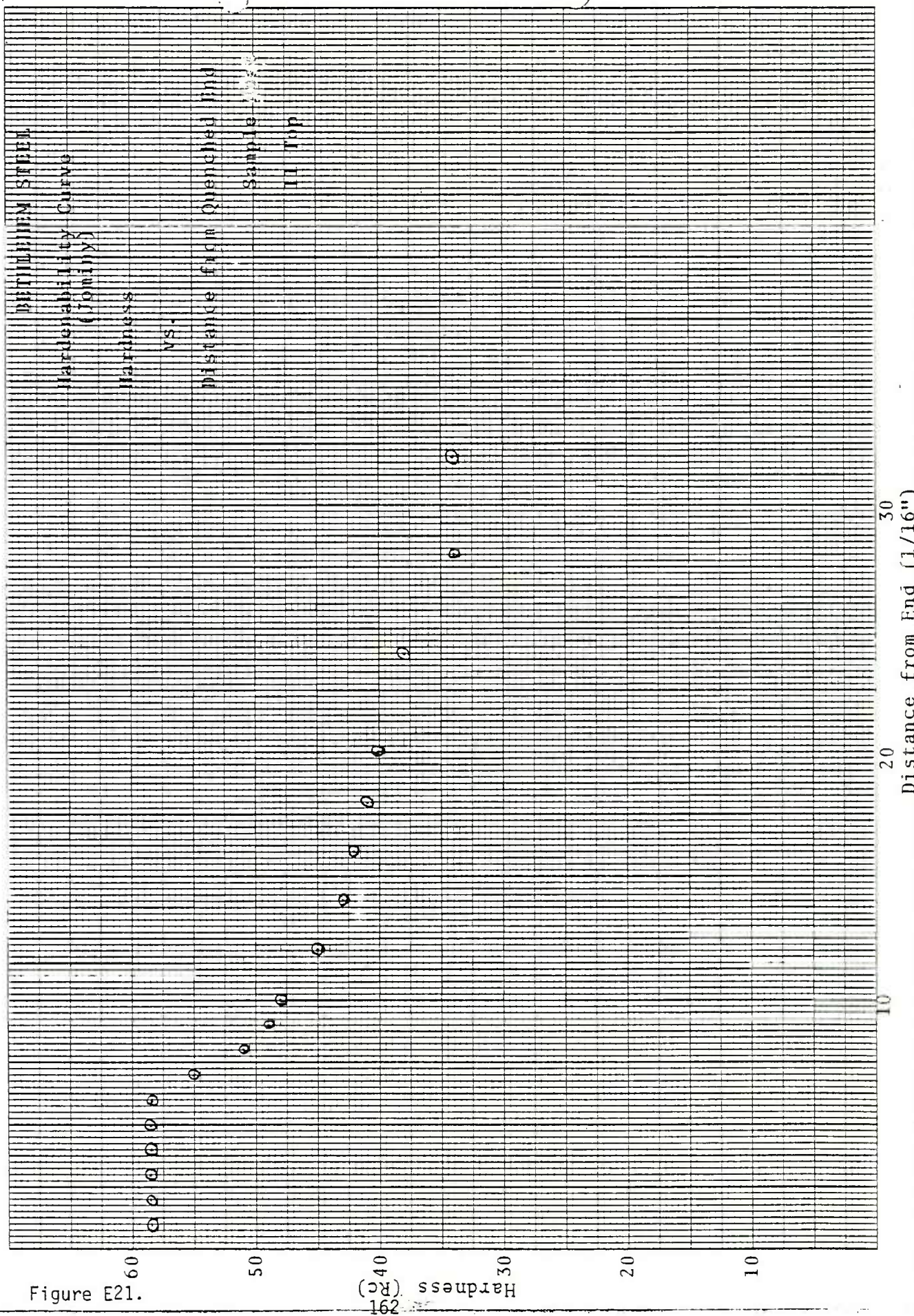


Figure E20.

Hardness (HRC)



RETAILER'S STEEL
Hardening Steel
(Tempered)
Hardness
V5.
Distance from Quenched End
Sample
11 Middle

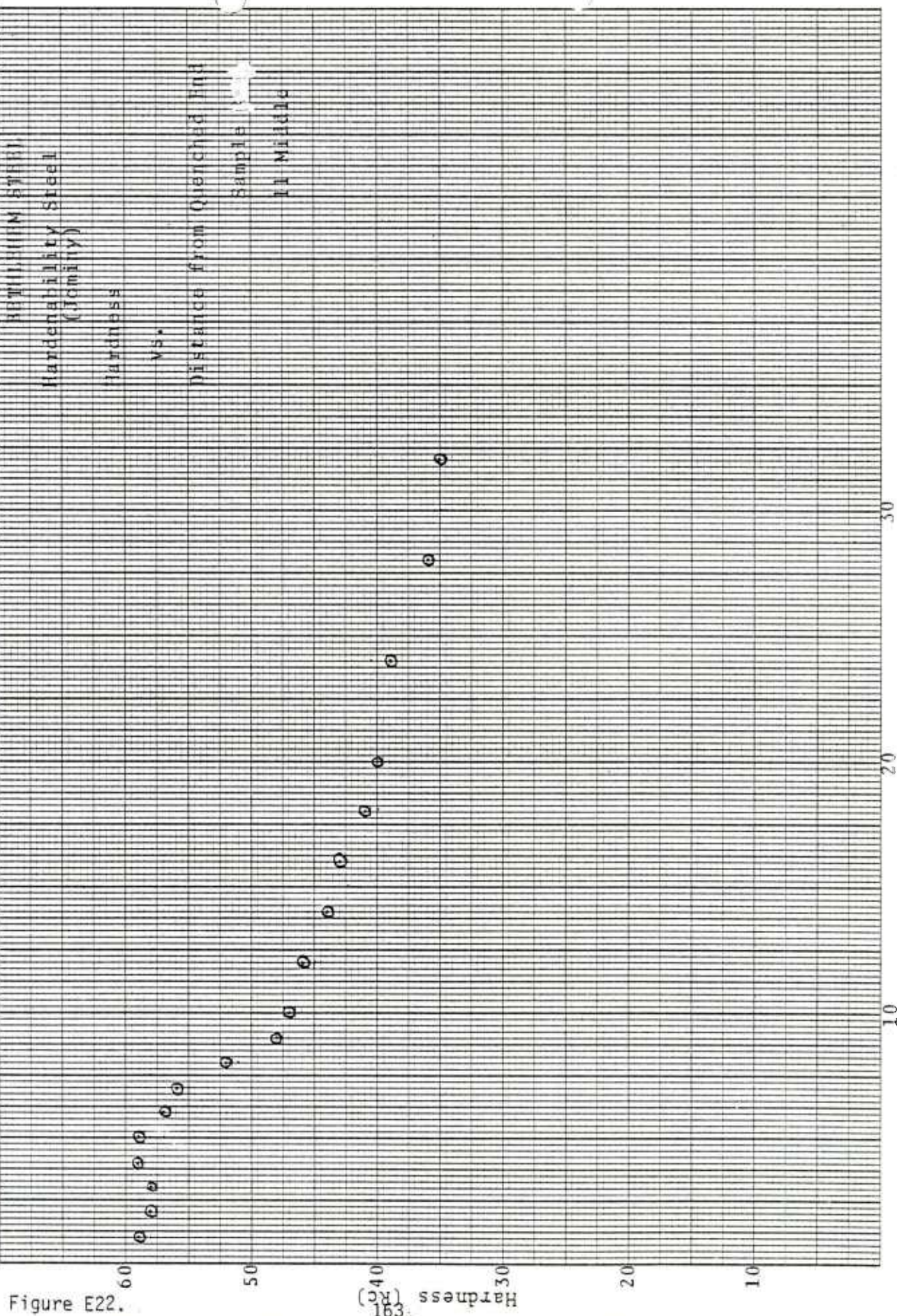


Figure E22.

Hardness (Rc)

Distance from End (1/16")

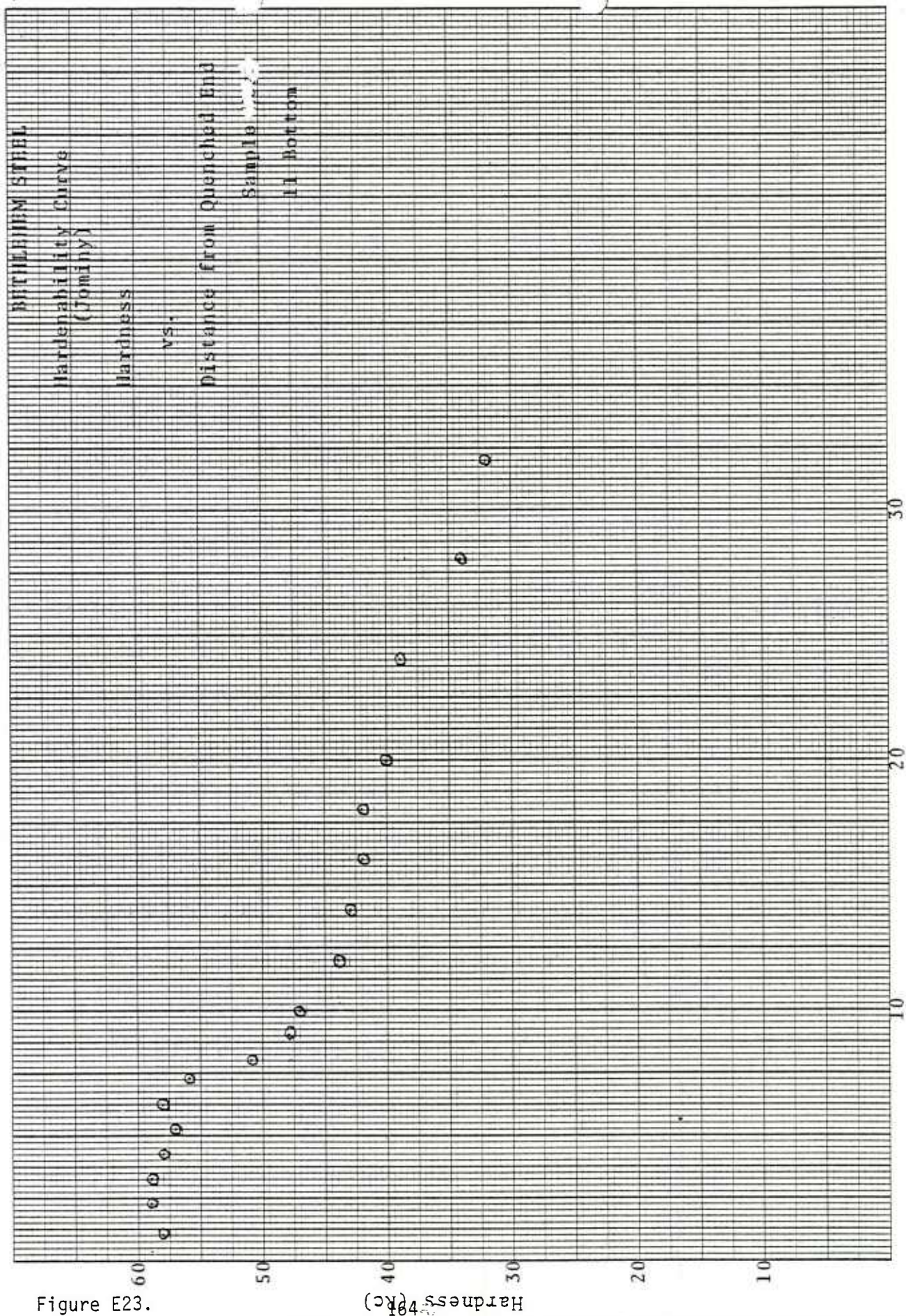


Figure E23.

Hardness (HRC)

Distance from End (1/16")

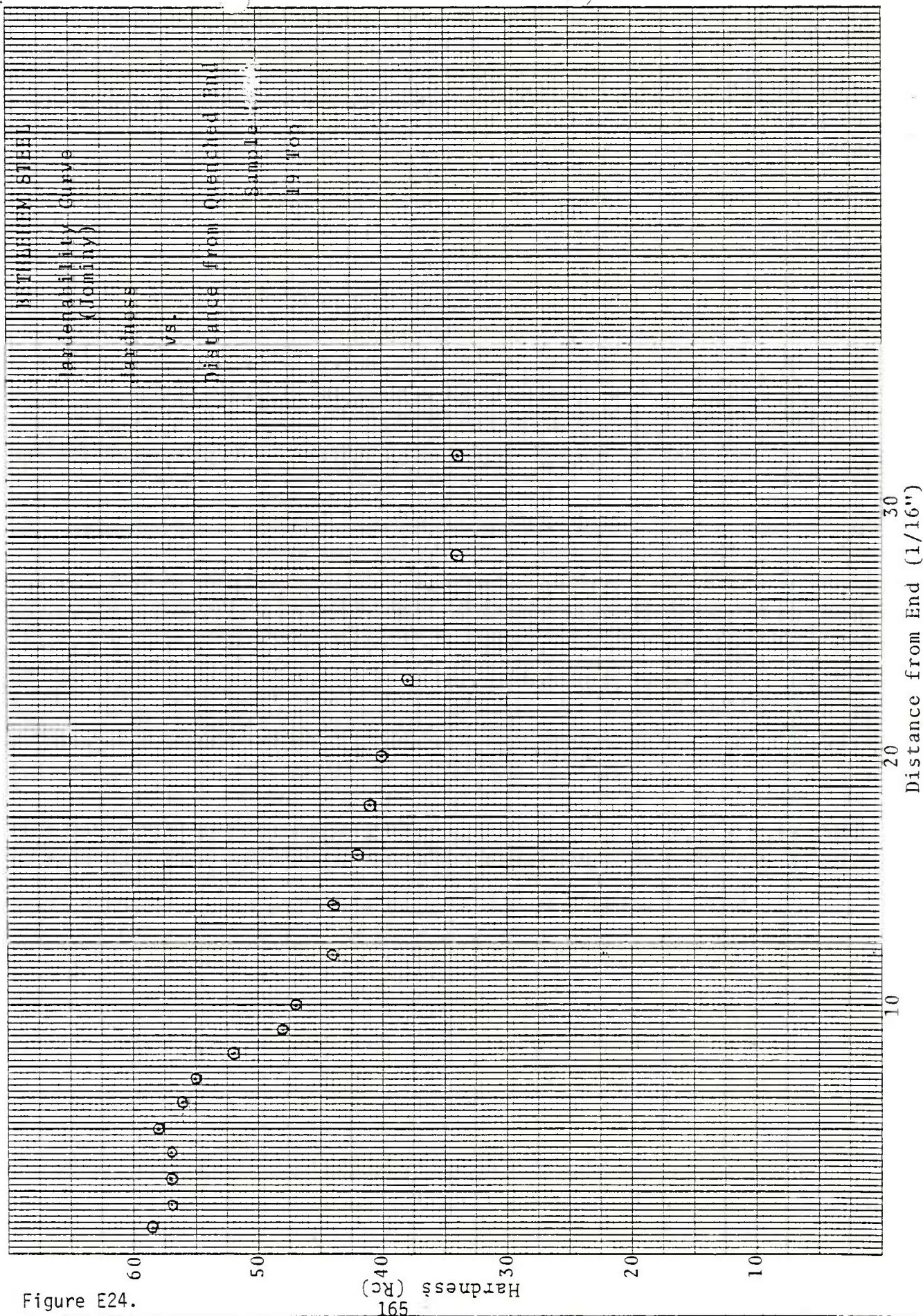


Figure E24.

Hardness (Rc)
165

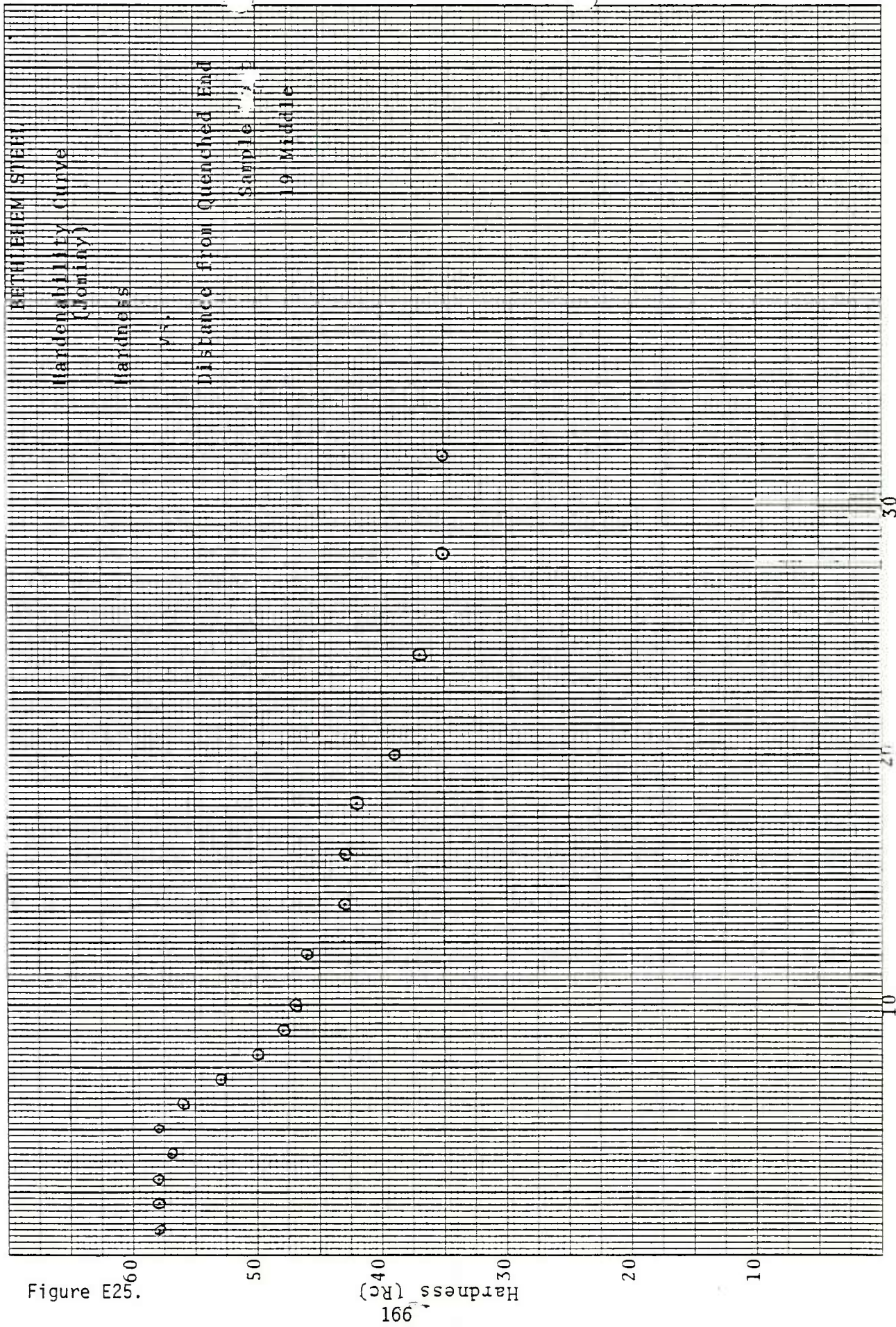


Figure E25.

169

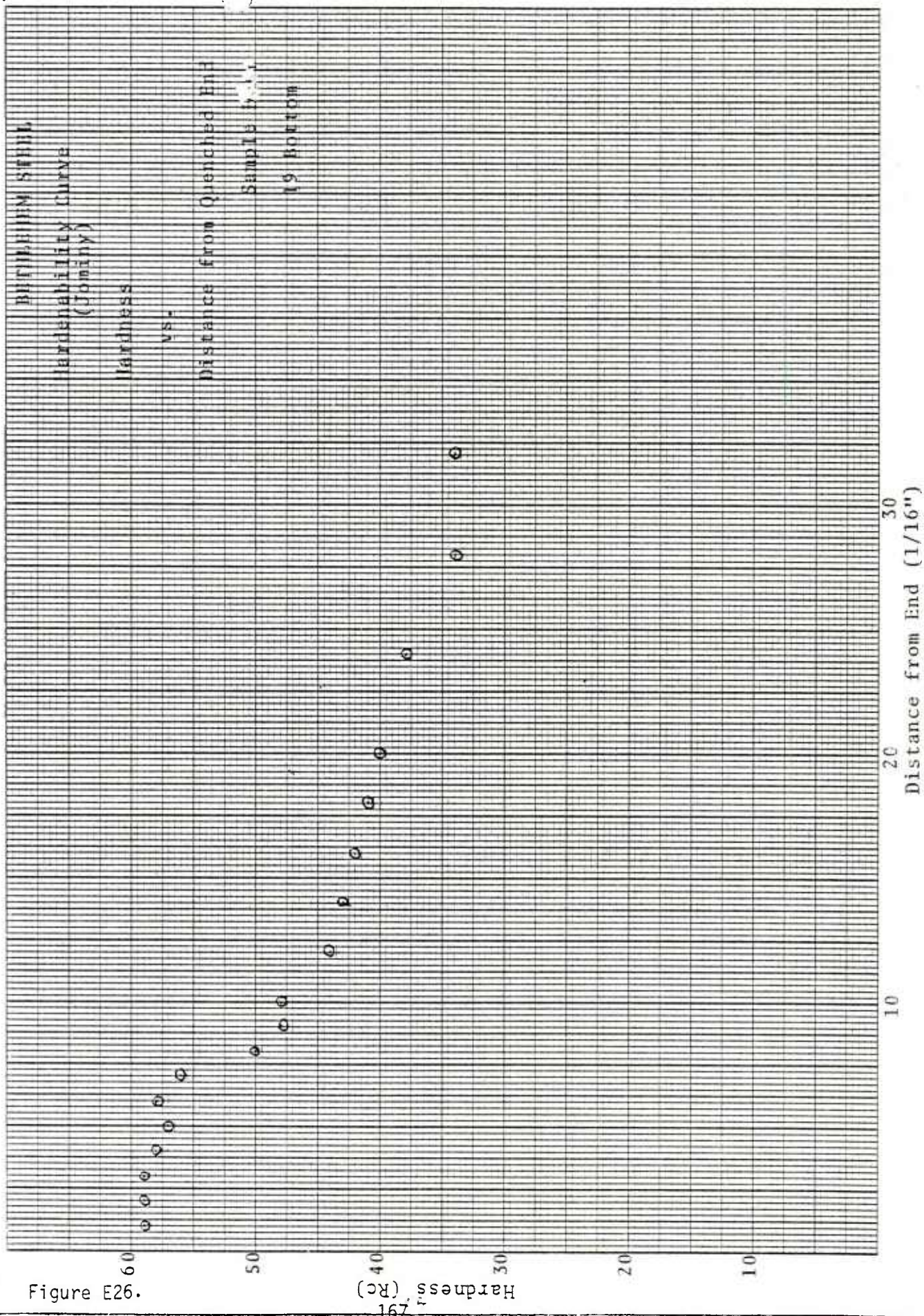


Figure E26.

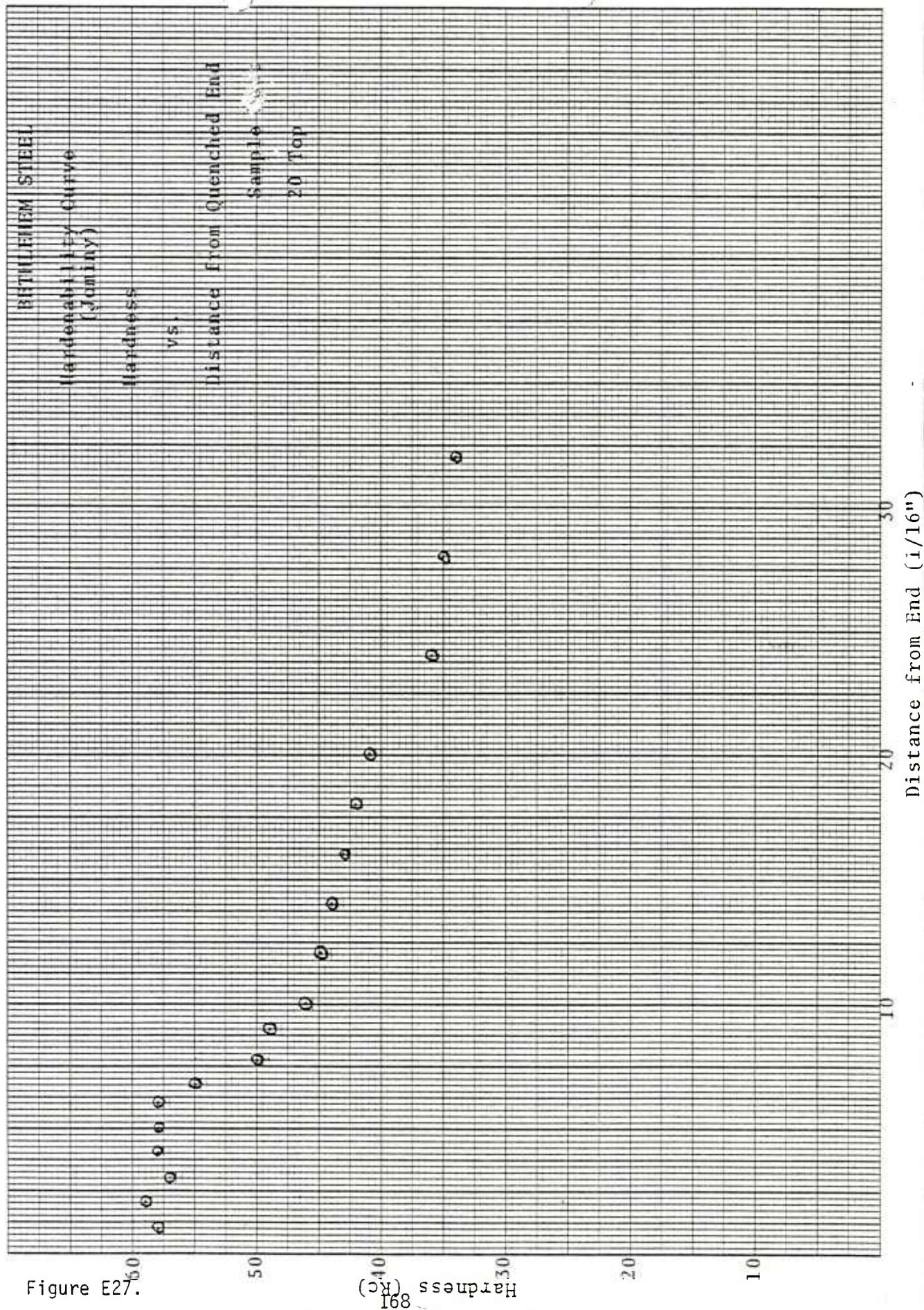


Figure E27.

Hardness (Kc)

Distance from End (in/16)

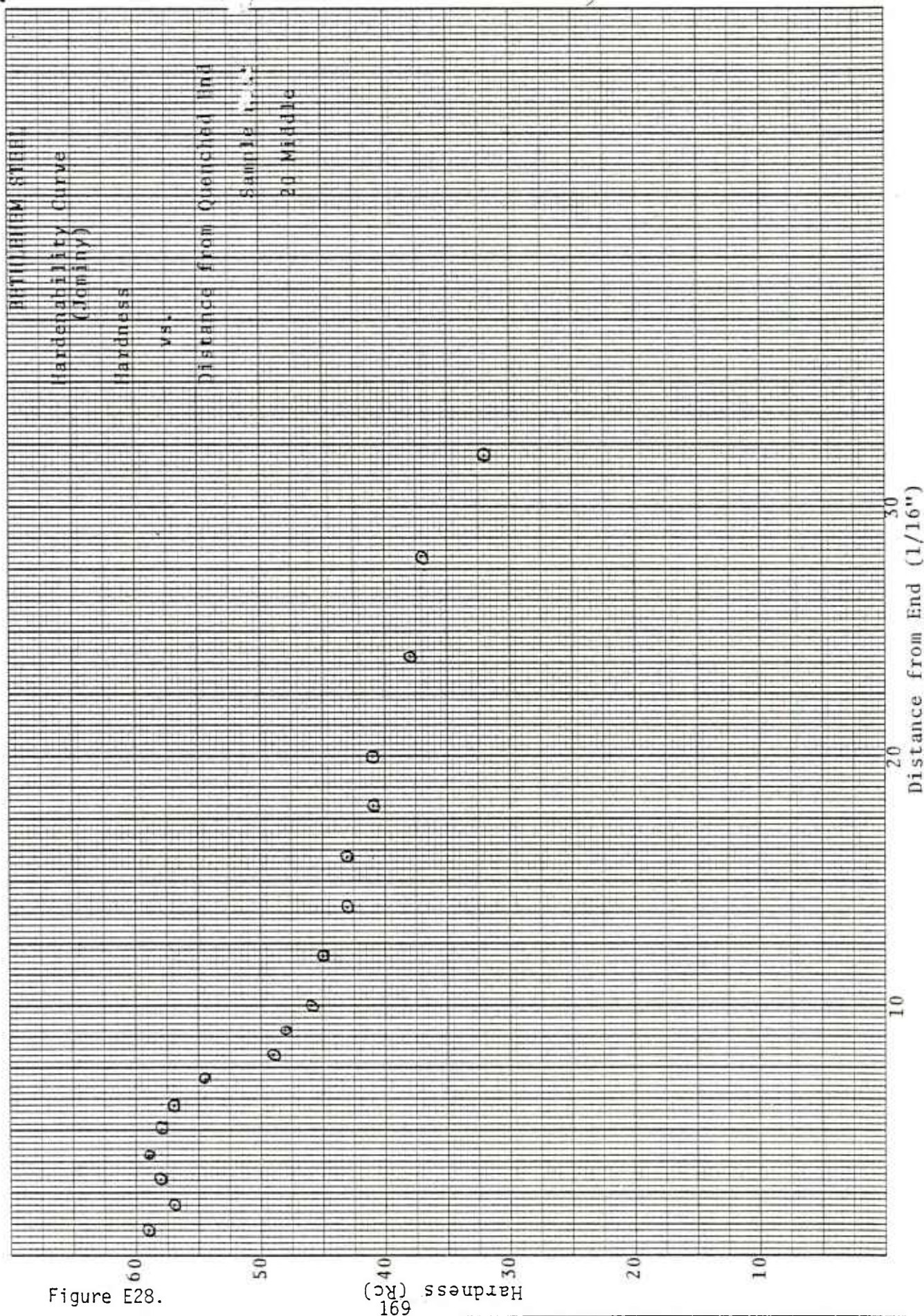
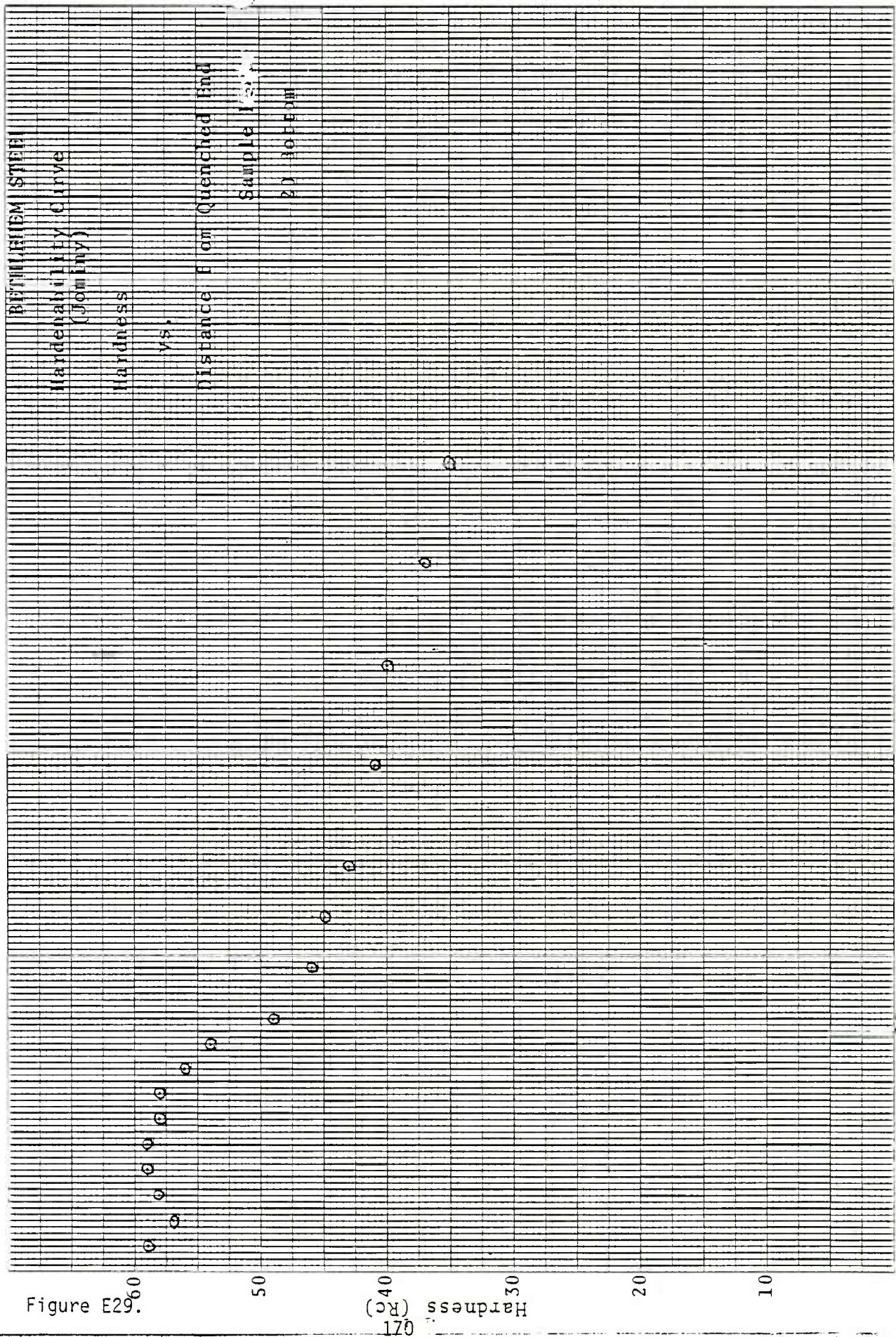


Figure E28.

Hardness (Rc)
169



Appendix F

Billet Cross Section Hardness Pattern

Calibration
63.1 ± 0.5
@ K 63.5

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

33.8	32.5	31.5	30.9	30.5	29.6	30.0	29.8	31.4	32.6
33.4	31.5	31.9	30.9	31.1	31.1	30.5	29.8	30.6	32.7
33.6	32.3	32.1	32.3	32.2	32.1	31.7	30.6	30.6	31.4
33.0	32.0	32.2	32.8	32.8	32.3	32.4	31.1	30.8	31.5
32.4	32.8	33.1	33.0	32.5	32.6	32.6	31.5	30.7	31.4
32.5	32.7	32.9	33.4	33.0	33.1	32.6	31.6	30.9	32.0
33.2	33.0	32.3	33.4	33.3	32.8	32.8	31.7	31.9	32.2
33.3	33.3	33.3	33.2	32.7	32.8	32.1	32.6	32.5	32.5
34.1	33.5	33.6	33.3	33.4	33.3	33.2	33.3	32.6	33.2
34.4	33.9	34.1	33.6	33.8	33.7	33.7	33.8	33.7	34.0

Mean 32.409

Standard Dev. 1.094

Figure F1.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005		
.00	± .010	TITLE BILLET 5½ X 5½ 1AA	
.0	± .020	DRH. L J F	DATE 5 22 81 SCALE FULL
FRAC.	± 1/32	CKD.	
ANGLE	± 1°	APPD.	

Calibration
56.2 ± 1.0
56.9

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

37.4	36.4	36.1	35.7	35.2	34.7	34.3	34.5	34.8	33.8
37.1	35.9	35.2	34.8	34.9	34.3	34.0	34.1	33.4	32.8
35.3	35.6	34.6	34.6	34.8	33.8	33.2	33.0	32.9	32.4
34.3	34.6	34.1	34.4	34.4	33.6	33.3	32.5	32.1	31.6
32.8	34.2	34.1	33.5	33.6	32.7	32.6	32.1	31.1	30.5
31.1	33.4	33.6	33.5	33.1	33.2	32.0	31.5	30.7	30.5
30.6	32.8	32.7	32.6	32.6	31.9	32.1	31.3	30.7	30.6
33.0	33.0	32.3	31.5	31.3	31.2	31.0	31.0	30.6	30.7
33.3	32.7	31.9	31.4	30.9	30.8	30.5	30.5	30.5	30.1
33.8	33.0	32.3	31.2	30.4	30.0	29.9	30.0	30.4	30.1

1BA

Mean 32.805

Standard Dev. 1.770

Figure F2.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005		
.00	± .010	TITLE BILLET 5½ X 5½ 1BA	
.0	± .020	DRN. L J F	DATE 5 22 81
FRAC.	± 1/32	CKD.	SCALE FULL
ANGLE	± 1°	APPD.	

Calibrated
33.2 ± 1.0
33.4

REVISIONS

SYM.	DESCRIPTION	BY	DATE	APPR.

38.7	39.8	39.0	38.8	38.5	38.8	38.8	37.6	37.2	36.9
39.5	39.8	38.9	38.5	38.4	39.5	39.5	38.3	37.5	36.6
39.9	39.5	39.0	38.7	38.4	38.6	38.7	38.9	38.8	37.5
40.0	40.0	39.1	38.8	38.5	38.3	39.0	38.6	38.9	37.7
40.1	39.4	39.3	38.8	38.4	38.4	38.2	39.1	39.1	38.5
40.0	39.5	39.0	38.7	38.7	38.3	38.3	38.2	39.5	39.2
39.7	39.7	39.2	38.6	38.4	39.0	38.5	38.3	39.3	39.4
39.6	39.4	39.2	38.5	38.5	38.7	38.9	38.7	38.2	39.0
39.8	39.6	38.8	38.5	38.7	38.7	38.6	38.1	38.1	37.5
40.1	39.6	39.4	39.2	39.0	38.8	38.4	38.7	37.3	38.0

1BD

Mean 38.80

Standard Dev. 0.700

Figure F3.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005		
.00	± .010	TITLE	
.0	± .020	BILLET 5½ x 5½ 1BD	
FRAC.	± 1/32	DRN. L J F	DATE 5 22 81
ANGLE	± 1°	CKD.	SCALE FULL
		APPD.	

Calibration
56.2 ± 1.0
55.6

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

29.8	29.9	29.9	31.9	30.2	31.5	31.3	33.0	33.9	33.4
29.5	30.4	32.6	33.0	32.2	32.0	32.4	32.2	33.5	34.2
30.5	30.9	33.6	33.8	33.0	32.0	34.0	34.6	33.5	35.0
30.2	33.6	33.5	32.9	32.0	34.0	33.0	33.0	33.7	34.1
31.0	33.7	32.3	35.0	33.2	34.8	34.6	33.4	33.8	36.0
31.1	30.6	34.0	33.9	33.7	35.5	35.4	35.5	33.8	36.1
33.4	34.2	35.1	35.0	34.8	35.0	36.0	34.0	33.7	35.9
33.7	34.5	33.0	33.0	35.0	33.4	35.8	36.2	34.1	35.2
34.0	34.0	32.9	35.0	33.0	33.4	36.0	34.2	34.5	34.7
36.1	35.6	36.0	35.7	33.7	35.9	34.0	34.6	35.1	35.0

20AA

Mean 33.575

Standard Dev. 1.659

Figure F4.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005		
.00	± .010	TITLE BILLET 5½ X 5½ 20AA	
.0	± .020	DRN. L J F	DATE 5 22 81 SCALE FULL
FRAC.	± 1/32	CKD.	
ANGLE	± 1°	APPD.	

Calibration
56.2 ± 1.0
56.5

REVISIONS

SYM.	DESCRIPTION	BY	DATE	APPR.

38.0	38.5	37.9	39.5	39.1	39.3	39.2	38.9	39.6	39.9
37.0	37.8	37.5	39.0	38.9	38.6	38.6	38.5	39.2	39.6
37.3	37.7	37.7	38.4	38.7	37.8	38.3	38.3	38.4	39.2
37.2	37.0	36.5	37.8	38.7	35.7	38.2	38.1	38.5	39.0
36.9	36.9	36.4	36.9	37.6	37.8	37.3	38.2	38.5	39.4
37.0	36.5	36.0	36.0	37.4	37.5	37.8	38.0	37.7	39.3
36.7	36.3	36.2	35.8	37.3	37.8	37.5	38.0	38.2	39.3
36.8	36.2	36.4	36.3	37.6	37.5	37.7	38.0	38.0	39.0
36.9	37.0	36.5	36.4	37.7	38.0	38.0	38.2	38.2	39.6
37.5	37.7	37.5	37.2	38.8	38.6	39.0	39.5	39.9	39.0

20BD

Mean Rc 37.892

Standard Dev. 1.020

Figure F5.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005		
.00	± .010	TITLE BILLET 5 1/4 X 5 1/4 20BD	
.0	± .020	DRN. L J F	DATE 5 22 81
FRAC.	± 1/32	CKD.	SCALE FULL
ANGLE	± 1°	APPD.	

Calibration
56.2 ± 1.0
55.8

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

29.5	30.4	30.0	30.5	30.7	30.8	30.6	31.9	32.9	33.2
30.6	30.8	30.7	31.3	31.5	31.3	31.7	32.0	32.7	33.5
30.6	30.8	31.1	31.7	31.4	31.8	32.2	32.4	32.4	33.6
30.3	31.2	31.7	31.4	32.3	32.0	32.0	33.1	32.1	32.9
30.7	31.8	31.5	32.0	32.6	33.3	32.1	32.7	32.7	32.8
31.3	31.9	31.8	32.7	32.7	33.1	32.8	33.2	33.0	33.2
31.8	32.6	32.6	32.8	32.9	33.1	33.4	33.5	33.3	33.6
33.2	33.0	32.8	33.0	33.7	33.7	33.8	34.2	33.5	34.6
34.2	33.8	33.4	33.8	33.2	34.2	34.8	34.6	34.2	34.8
35.0	34.5	33.9	33.8	33.2	33.6	33.1	33.8	33.9	34.5

20BA

Mean 32.554

Standard Dev. 1.218

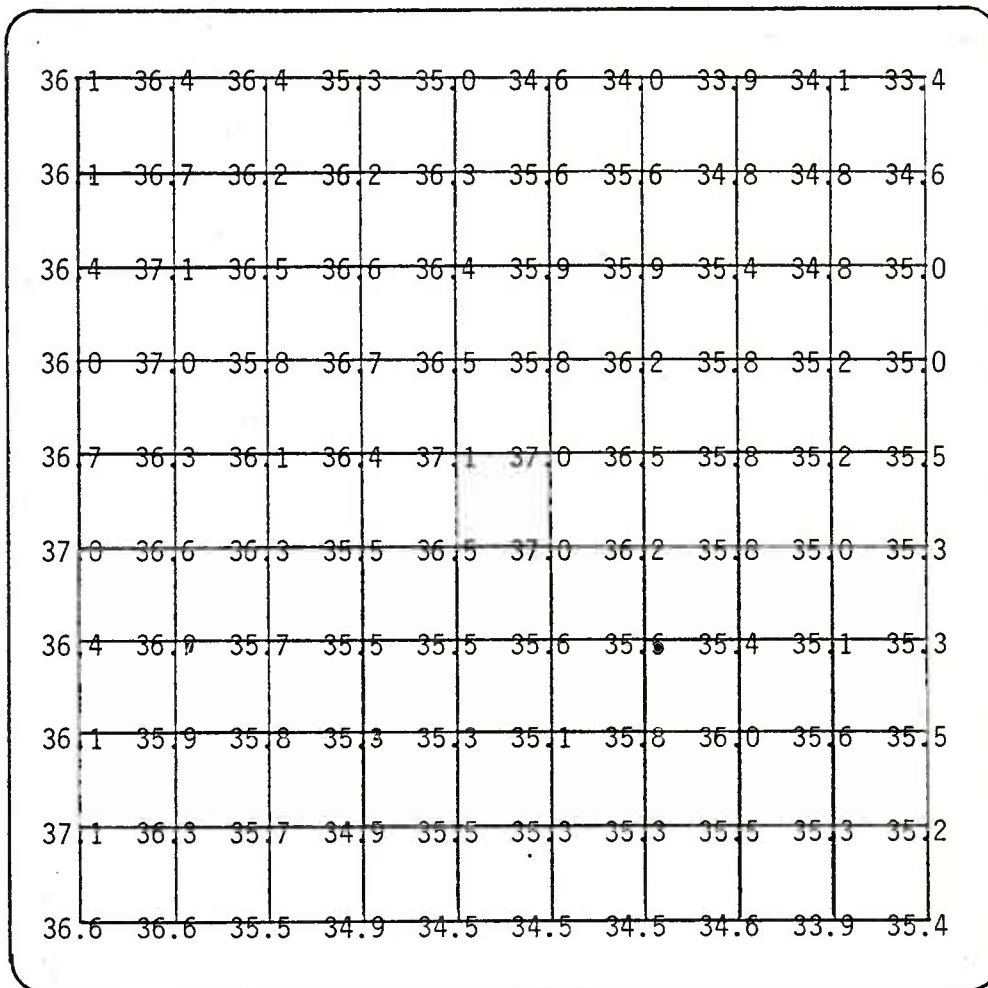
Figure F6.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant		
.000	± .005			
.00	± .010	TITLE BILLET 5½ X 5½ 20BA		
.0	± .020			
FRAC.	± 1/32	DRN. L J F	DATE 5 22 81	SCALE FULL
ANGLE	± 1°	CKD.		
		APPO.		

Calibration
56.2 ± 1.0
56.8

REVISIONS

SYM.	DESCRIPTION	BY	DATE	APPR.



Mean 35.692

Standard Dev. 0.792

Figure F7.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005	TITLE	
.00	± .010	BILLET 5 1/4 X 5 1/4 40AA	
.0	± .020	DRN. L J F	DATE 5 22 81
FRAC.	± 1/32	CKD.	SCALE FULL
ANGLE	± 1°	APPD.	

Calibration
56.2 ± 1.0
55.6

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

32.5	32.3	30.9	30.1	29.5	29.3	29.1	29.2	28.7	29.1
32.6	31.7	30.6	30.2	30.0	29.4	29.1	29.2	28.8	29.2
32.3	31.4	30.4	29.8	29.5	29.7	30.0	28.3	28.9	29.1
31.5	31.0	30.1	29.6	29.9	29.6	29.4	29.5	29.6	28.8
31.5	31.0	30.1	29.6	29.9	29.6	29.4	29.5	29.6	28.8
30.6	30.0	29.8	29.9	29.8	29.4	29.7	29.5	29.2	29.0
29.8	29.5	29.9	29.7	29.5	29.6	29.5	29.7	29.0	29.1
29.8	29.3	29.3	30.0	29.5	29.5	29.3	29.5	29.3	29.5
29.2	29.3	29.3	29.3	28.9	28.7	29.5	29.3	29.3	29.7
29.2	28.9	29.4	29.0	28.8	28.5	28.7	29.4	29.3	29.2

40BA

Mean 29.696

Standard Dev. 0.830

Figure F8.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005		
.00	± .010	TITLE BILLET 5½ X 5½ 40BA	
.0	± .020	DRN. L J F	DATE 5 22 81
FRAC.	± 1/32	CKD.	SCALE FULL
ANGLE	± 1°	APPD.	

Calibration
 35.0 ± 1.0
 34.6
 35.0

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

36.2	36.0	35.5	33.9	34.1	34.0	34.8	35.1	35.6	35.3
37.0	35.0	34.8	34.6	34.8	35.0	35.1	34.4	34.3	35.5
36.8	34.8	35.2	35.4	34.8	35.3	35.5	35.4	34.8	35.4
35.6	35.6	35.5	34.7	35.3	35.1	35.6	36.2	35.9	35.4
35.3	36.2	36.1	35.5	35.3	35.5	35.9	35.9	35.9	35.1
35.7	35.9	36.2	35.6	35.1	35.7	36.1	36.6	36.3	35.4
36.1	36.8	36.6	36.1	35.5	35.8	36.1	36.3	36.3	35.5
36.0	36.1	36.2	35.5	35.7	35.8	36.3	36.7	36.3	35.5
36.1	36.7	36.5	36.6	37.0	36.5	36.6	36.2	36.1	36.3
36.4	36.1	36.4	36.6	36.1	36.6	35.8	35.5	35.8	37.4

40BD

Mean Rc 35.728

Standard Dev. 0.688

Figure F9.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant		
.000	± .005			
.00	± .010	TITLE BILLET		
.0	± .020			
FRAC.	± 1/32	DRN. L J F	DATE 5 22 81	SCALE FULL
ANGLE	± 1°	CKD.		
		APPD.		

Calibration
Rc 35.0 ± 1.0

Calibrated 6-13-80
35.1

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

31.0	30.9	30.6	30.8	30.7	30.5	30.1	31.0	31.2	32.1
31.4	32.1	32.0	31.9	31.8	31.9	36.3	36.4	31.9	32.0
32.5	32.7	32.4	31.9	32.4	32.7	32.2	32.5	33.0	32.0
32.8	32.9	32.6	32.3	33.5	32.6	32.4	32.5	32.4	33.0
32.8	33.2	33.0	33.1	33.6	33.1	32.7	33.0	33.9	33.4
33.5	33.4	33.6	34.1	33.7	33.2	33.4	33.3	33.5	33.7
33.3	33.8	33.4	33.1	34.0	33.2	33.4	33.5	34.2	33.8
33.6	34.0	34.5	34.7	34.1	33.3	33.9	34.1	34.6	33.0
32.6	33.7	34.1	34.0	34.1	34.6	34.5	34.0	33.4	32.9
32.3	33.3	33.4	33.1	33.0	33.2	33.5	33.3	33.0	32.8

11

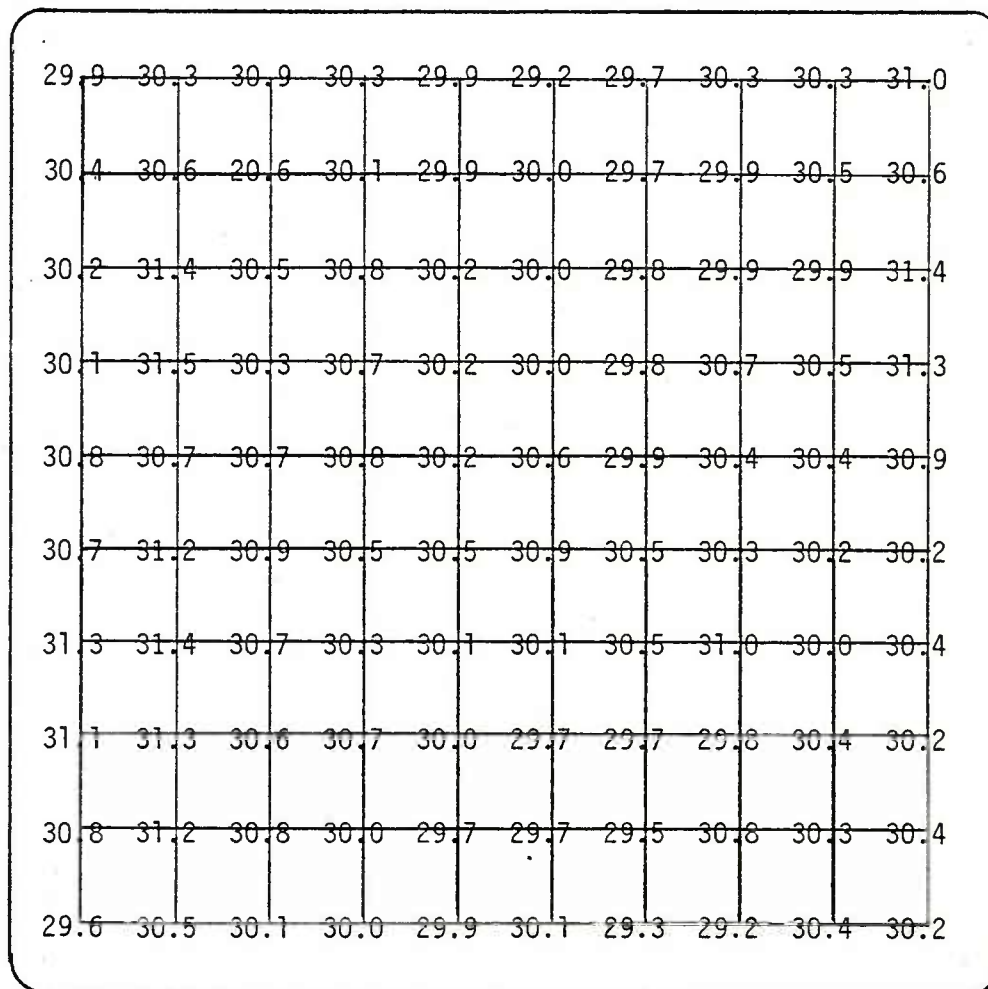
Mean 32.888
Standard Dev. 1.003

Figure F10

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant		
.000	± .005	TITLE BILLET		
.00	± .010			
.0	± .020			
FRAC.	± 1/32	DRN. L J F	DATE 5 22 81	SCALE FULL
ANGLE	± 1°	CKD.		
		APPD.		

Calibration:
Rc 35.0 ± 1.0
Calibrated
6-12-80
34.5

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.



Mean 30.366
Standard Dev. 0.504

Figure F11.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005	TITLE	
.00	± .010	BILLET	
.0	± .020	DRN. L J F	DATE 5 22 81
FRAC.	± 1/32	CKD.	SCALE FULL
ANGLE	± 1°	APPD.	

Calibrate
Rc 35.0 ± 1
Calibrated
35.2

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

27.5	29.4	29.5	28.7	28.5	28.5	28.4	28.2	29.2	30.2
28.2	29.0	29.9	28.2	28.6	29.1	28.5	29.6	29.9	30.6
28.3	29.3	29.0	29.1	29.6	28.5	29.1	30.4	30.0	30.3
28.2	30.0	29.6	29.3	28.5	29.7	29.1	29.9	30.1	31.3
29.4	30.1	29.4	29.0	28.8	29.5	29.4	30.3	29.7	30.0
30.4	29.0	29.6	28.4	28.9	28.7	29.0	29.4	29.6	29.5
30.0	30.3	30.0	30.1	29.1	28.9	29.0	29.5	28.0	29.9
30.2	29.6	29.8	29.8	29.0	28.7	29.7	29.7	28.7	29.7
30.6	30.1	29.5	28.8	28.7	29.0	28.5	28.7	27.6	29.9
30.8	30.1	29.6	29.0	28.1	29.0	28.2	27.5	28.7	29.4

1 X

Mean 29.302
Standard Dev. 0.737

Figure F12

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant		
.000	± .005	TITLE BILLET		
.00	± .010			
.0	± .020			
FRAC.	± 1/32	DRN. L J F	DATE 5 22 81	SCALE FULL
ANGLE	± 1°	CKD.		
		APPD.		

Calibration:
Rc 35.0 ± 1
Calibrated
34.8

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

30.5	30.6	31.3	30.5	31.0	31.9	32.6	32.2	32.4	32.3
30.7	30.7	31.8	31.2	31.7	30.9	32.6	31.3	31.7	31.6
29.8	31.7	32.2	31.6	32.5	31.3	31.0	31.3	31.4	31.6
30.2	31.6	31.1	31.7	32.7	32.8	30.9	31.2	31.3	31.4
30.6	31.1	31.5	32.1	32.3	32.0	32.7	31.1	31.2	30.8
30.0	30.8	31.1	31.8	31.7	32.5	31.4	31.6	31.1	30.3
29.8	30.5	30.1	30.7	31.0	31.2	31.0	30.4	30.1	30.2
29.2	31.7	30.0	30.0	30.6	30.7	30.1	29.7	29.4	28.9
28.7	28.9	29.8	30.2	29.9	30.1	32.5	31.0	29.0	29.1
28.4	29.1	29.4	29.2	29.1	28.8	28.7	28.8	29.0	28.7

21

Mean 30.802
Standard Dev. 1.118

Figure F13

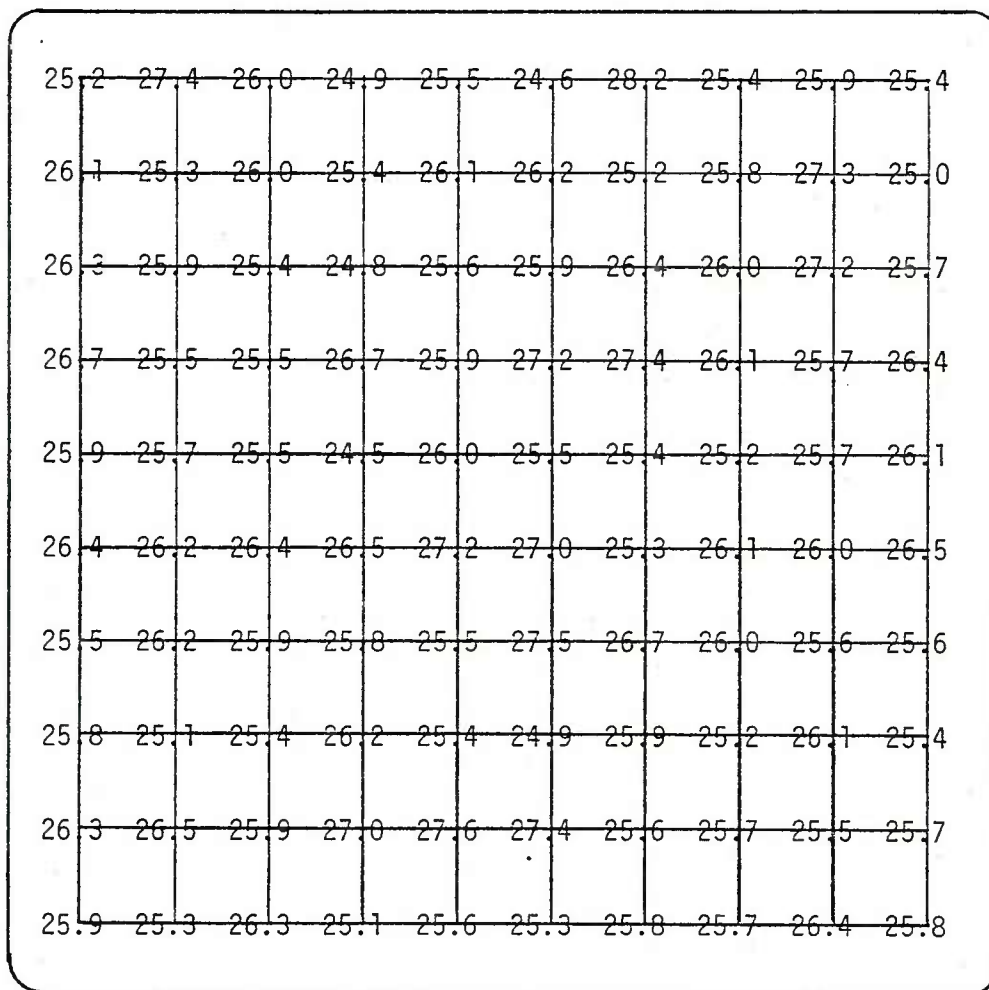
TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005	TITLE	
.00	± .010	BILLET	
.0	± .020	DRN. L J F	
FRAC.	± 1/32	DATE 5 22 81	SCALE FULL
ANGLE	± 1°	CKD.	
		APPD.	

Calibrated 6-27-80

STD Rc 35.0 ± 1
34.9

REVISIONS

SYM.	DESCRIPTION	BY	DATE	APPR.



Mean 25.974
Standard Dev. 0.728

Figure F14

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005	TITLE BILLET	
.00	± .010		
.0	± .020	DRN. L J F DATE 5 22 81 SCALE FULL	
FRAC.	± 1/32		
ANGLE	± 1°	CKD. _____ APPD. _____	

Calibrated
C 35.0 ± 1.0
35.0

Calibrated
C26.5 ± 1.0
26.3

REVISIONS

SYM.	DESCRIPTION	BY	DATE	APPR.

22.3	23.7	24.7	24.5	24.9	24.6	25.4	25.2	25.5	24.2
24.0	24.2	24.5	24.6	25.2	25.0	25.5	25.1	24.4	24.1
23.8	24.0	24.5	24.7	24.8	25.0	25.1	25.0	24.4	24.4
23.9	24.4	24.0	23.6	23.9	24.5	24.3	23.8	24.5	25.1
23.7	24.1	23.3	24.0	24.0	24.0	24.2	23.5	23.7	24.3
24.0	23.7	23.7	23.5	23.8	24.3	23.6	23.4	24.1	24.3
23.3	23.4	23.9	24.5	24.0	24.0	25.0	24.0	23.6	24.8
24.0	23.6	24.6	24.3	24.6	24.9	24.5	23.7	23.6	23.9
23.5	24.0	24.4	24.7	24.7	24.5	24.8	24.4	23.4	24.2
23.3	24.5	23.8	24.0	24.4	24.2	25.0	23.6	24.8	24.1

2
X

Mean 24.231
Standard Dev. 0.568

Figure F15

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant		
.000	± .005	TITLE BILLET		
.00	± .010			
.0	± .020	DRN. L J F DATE 5 22 81 SCALE FULL		
FRAC.	± 1/32			
ANGLE	± 1°	CKD. APPD.		

Calibrate
Rc 35.0 ± 1
6/16/80
34.4

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

31.1	31.3	30.6	30.6	30.0	29.5	29.6	29.5	29.8	29.1
31.0	31.4	30.7	30.7	30.9	29.9	29.7	29.9	30.0	29.5
31.0	31.5	31.5	31.1	30.5	30.5	30.5	29.9	30.5	30.1
31.1	32.2	31.3	31.0	31.0	30.9	30.3	30.3	29.5	30.2
31.6	31.7	31.5	30.9	31.7	31.1	30.5	29.8	30.2	29.8
31.5	31.8	31.0	30.8	31.0	31.7	30.7	30.2	29.9	29.7
31.7	31.8	31.3	31.4	31.3	31.1	30.2	31.1	30.3	30.1
31.1	31.5	30.7	30.9	30.9	31.3	30.4	30.0	29.7	29.4
30.7	31.3	30.7	29.6	30.4	30.7	29.7	30.0	29.2	29.0
30.5	29.6	30.5	29.5	29.7	30.5	29.8	29.5	28.9	28.6

10 - 1

Mean 30.514
Standard Dev 0.768

Figure F16

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant				
				TITLE BILLET		
		.000	± .005	DRN. L J F	DATE 5 22 81	SCALE FULL
		.00	± .010	CKD.		
		.0	± .020	APPD.		
FRAC.	± 1/32					
ANGLE	± 1°					

Calibrated
6-30-80
Rc 35.0 ± 1.0
34.7

REVISIONS

SYM.	DESCRIPTION	BY	DATE	APPR.

27.4	27.7	27.7	28.2	28.2	27.7	27.8	28.7	27.9	27.4
27.6	27.7	27.9	28.2	27.7	28.5	28.7	27.2	27.9	27.6
27.7	28.0	28.2	28.0	28.5	29.0	28.5	28.2	27.4	27.7
27.2	28.2	28.0	27.8	27.7	27.4	27.3	27.9	27.8	27.9
27.0	27.4	27.6	29.3	27.7	28.5	27.3	27.2	27.1	27.0
27.0	26.6	27.4	27.7	27.5	26.8	27.7	27.6	26.8	26.9
27.8	26.9	27.9	27.5	27.8	27.3	27.1	27.5	26.8	27.0
28.0	28.0	28.4	27.3	27.4	28.3	28.1	27.0	27.3	27.4
28.2	28.0	27.5	27.5	27.5	27.8	28.5	28.4	28.5	27.9
27.8	28.7	28.7	28.4	27.6	28.1	28.5	28.0	27.3	26.9

10 - C

Mean 27.758
Standard Dev. 0.543

Figure F17

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005	TITLE	
.00	± .010	BILLET	
.0	± .020	DRN. L J F	
FRAC.	± 1/32	DATE 5 22 81	SCALE FULL
ANGLE	± 1°	CKD.	
		APPD.	

Calibrate
Rc 35.0 ± 1
6-20-80
34.5

REVISIONS

SYM.	DESCRIPTION	BY	DATE	APPR.

30.1	29.7	29.5	29.8	29.0	29.1	29.2	29.7	29.2	29.6
30.2	29.4	29.4	29.1	29.0	29.4	29.9	30.0	30.1	30.1
30.2	30.1	29.9	30.0	29.7	30.0	29.8	29.6	30.5	31.2
30.9	30.0	29.9	30.0	30.0	29.9	29.8	30.0	30.4	30.5
30.8	29.6	30.0	30.4	30.0	30.6	30.0	30.4	31.1	31.5
30.7	29.5	30.3	30.0	30.0	29.9	30.5	30.7	30.5	30.9
30.5	29.4	30.4	30.4	30.7	30.0	30.6	30.2	30.5	31.3
30.4	29.8	30.5	29.6	29.6	29.4	30.2	29.8	29.9	31.0
30.7	29.8	29.9	29.3	29.0	29.5	29.2	29.8	30.3	31.0
29.7	29.7	29.5	29.2	28.8	29.4	30.0	30.0	30.3	31.0

10 X

Mean 30.016
Standard Dev. 0.562

Figure F18

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005	TITLE	
.00	± .010	BILLET	
.0	± .020	DRN. L J F	
FRAC.	± 1/32	DATE 5 22 81	SCALE FULL
ANGLE	± 1°	CKD.	
		APPD.	

Calibrated
6-26-80
Std. Rc 35.0 ± 1
34.5

REVISIONS

SYM.	DESCRIPTION	BY	DATE	APPR.

29.2	29.0	28.4	28.6	28.0	28.6	28.3	29.7	28.0	28.7
29.0	29.0	28.9	29.4	28.0	28.7	29.0	29.6	28.5	28.4
29.7	29.8	28.6	29.5	29.4	29.1	28.4	28.9	28.8	29.1
29.4	29.1	29.0	28.9	29.4	28.9	28.1	30.0	32.0	28.5
29.7	28.3	29.0	29.9	29.9	32.6	29.6	29.2	30.0	28.3
30.0	29.9	29.4	30.0	32.2	30.2	30.7	28.4	29.4	28.9
29.0	28.7	30.3	29.9	30.1	29.6	31.0	29.2	32.0	28.7
29.5	29.5	28.7	28.4	29.1	29.4	32.4	28.9	29.9	29.0
28.4	28.6	28.7	28.3	28.3	29.4	39.2	29.3	28.9	28.1
29.0	28.7	28.2	27.6	27.9	29.5	28.6	28.7	27.8	27.6

11 T

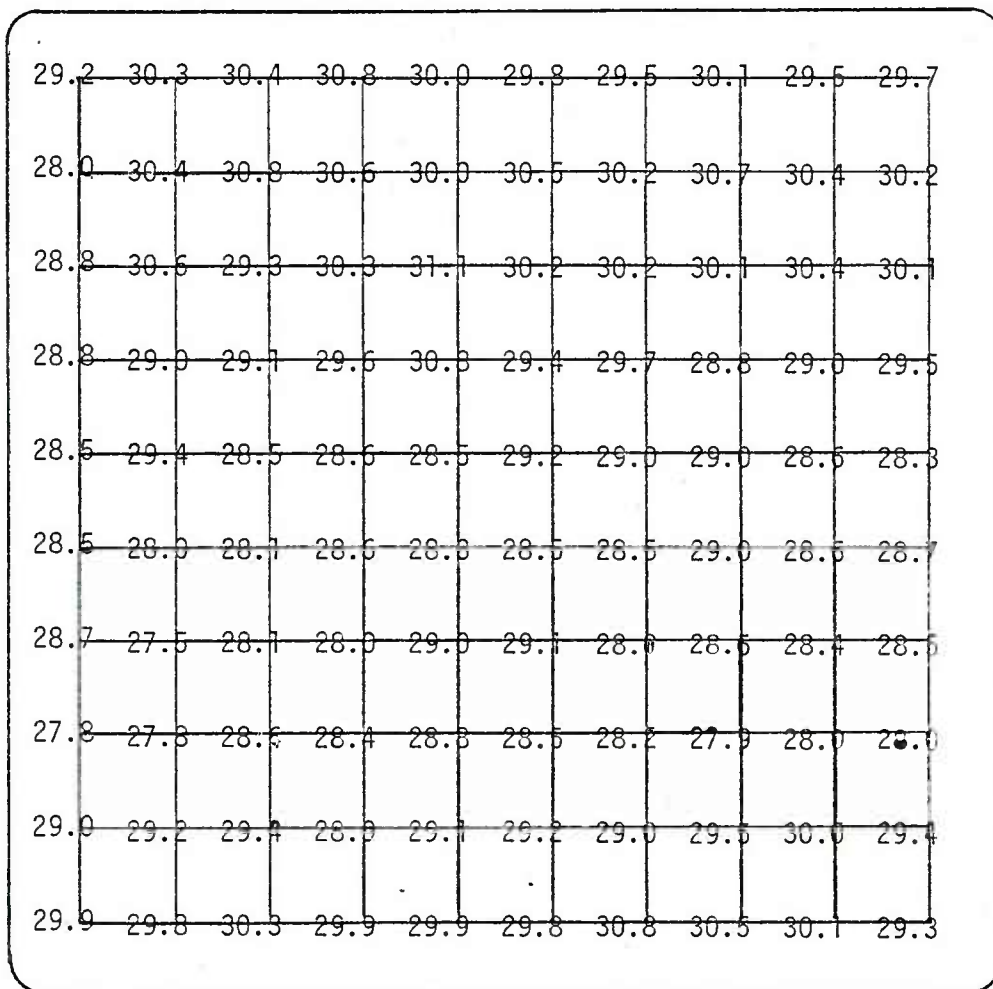
Mean 29.195
Standard Dev. 0.960

Figure F19.

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005	TITLE	
.00	± .010	BILLET	
.0	± .020	DRN. L J F	DATE 5 22 81
FRAC.	± 1/32	CKD.	SCALE FULL
ANGLE	± 1°	APPD.	

Calibrate
Rc 35.0 ± 1
Calibrated
35.7

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.



11 C

Mean 29.282
Standard Dev. 0.866

Figure F20

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant		
.000	± .005			
.00	± .010	TITLE BILLET		
.0	± .020	DRN. L J F	DATE 5 22 81	SCALE FULL
FRAC.	± 1/32	CKD.		
ANGLE	± 1°	APPD.		

Calibrate
Rc 35.0 ± 1.0
Calibrated 6-9-80
34.7

REVISIONS

SYM.	DESCRIPTION	BY	DATE	APPR.

28.6	30.0	30.6	30.0	30.3	30.6	29.5	30.7	29.9	30.2
29.2	30.1	30.5	29.7	30.0	30.2	29.7	30.7	30.0	29.8
29.5	29.7	29.7	29.5	30.3	29.5	29.0	29.2	28.5	29.0
29.9	29.0	30.3	29.0	29.9	29.2	29.5	28.9	29.0	29.1
30.4	30.2	30.1	29.5	29.6	30.5	29.7	29.2	29.2	30.1
30.2	31.1	30.4	30.0	30.2	29.9	29.5	28.8	29.0	29.7
30.1	30.9	30.4	30.3	30.1	30.8	30.0	30.1	30.0	29.2
30.1	30.6	30.6	30.4	30.9	30.5	31.0	30.6	29.9	30.0
30.5	30.7	31.4	31.8	31.3	30.9	31.0	31.0	30.9	29.8
29.7	30.1	31.5	31.5	31.6	31.4	31.6	31.2	30.6	30.0

11 X

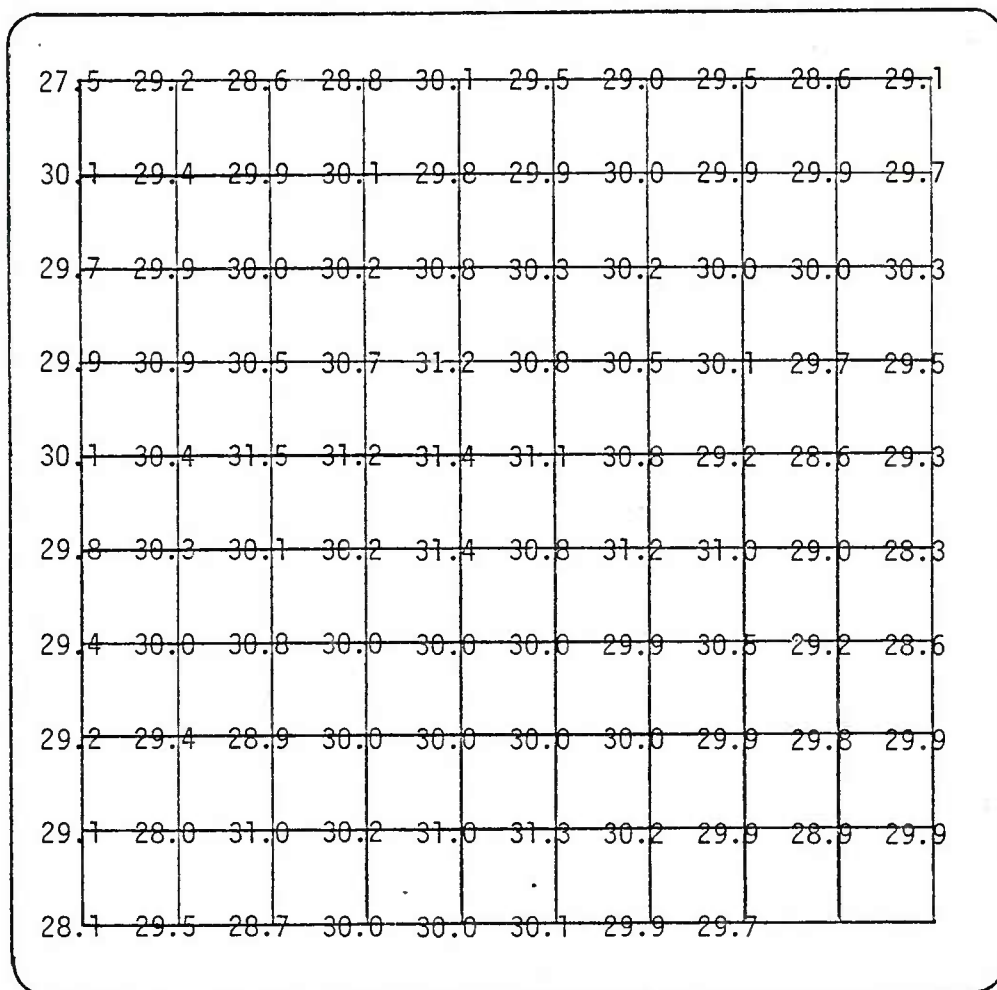
Mean 30.103
Standard Dev. 0.728

Figure F21

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005	TITLE	
.00	± .010	BILLET	
.0	± .020	DRN. L J F	DATE 5 22 81
FRAC.	± 1/32	CKD.	SCALE FULL
ANGLE	± 1°	APPD.	

Calibrate
Rc 35.0 ± 1
Calibrated
35.2

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.



Mean 29.893
Standard Dev. 0.775

Figure F22

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant		
.000	± .005	TITLE BILLET		
.00	± .010	DRN. L J F DATE 5 22 81 SCALE FULL		
.0	± .020	CKD. 		
FRAC.	± 1/32	APPD. 		
ANGLE	± 1°			

Calibrate
Rc 35.0 ± 1.0
Calibrated 6-11-80
34.8

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

29.1	30.7	31.1	31.5	31.1	31.0	31.1	31.6	30.3	30.8
30.8	30.6	31.1	30.9	30.4	30.2	30.2	31.3	31.0	30.5
30.4	30.5	29.9	31.5	29.5	31.2	30.5	30.6	31.0	30.2
30.1	29.4	29.9	29.8	29.5	30.6	30.5	30.4	29.7	29.2
30.2	29.3	30.1	30.3	30.4	29.9	30.1	30.1	28.5	29.2
28.8	29.5	29.2	29.3	30.2	29.4	28.6	29.1	27.2	28.6
28.1	28.4	29.9	28.9	30.5	29.2	28.7	29.2	29.0	29.6
28.8	29.5	28.8	28.0	28.8	29.8	28.9	29.2	29.9	29.2
28.8	29.3	30.2	29.8	30.6	30.0	30.2	28.8	29.8	29.0
29.8	29.9	29.6	29.1	29.5	29.0	29.5	29.2		

19 C

Mean 29.779
Standard Dev. 0.886

Figure F23

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005	TITLE	
.00	± .010	BILLET	
.0	± .020	DRN. L J F	DATE 5 22 81
FRAC.	± 1/32	CKD.	SCALE FULL
ANGLE	± 1°	APPD.	

Calibrate
Rc 35.0 ± 1.0
Calibrated 6-11-80
34.8

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

30.0	29.7	30.1	30.8	31.2	30.7	30.7	29.6	29.7	28.9
30.4	30.5	31.0	30.6	31.3	31.6	32.3	30.8	30.3	29.4
31.2	32.0	30.7	31.2	31.8	32.7	31.0	31.2	30.2	30.4
31.3	31.9	31.1	31.4	32.4	32.0	32.3	30.9	30.7	30.5
31.6	32.0	31.2	30.9	31.4	31.7	30.9	30.3	30.9	30.8
31.0	32.0	31.1	31.3	31.8	31.8	31.4	30.7	31.1	30.3
30.5	31.3	31.1	32.0	32.0	31.7	31.3	30.8	30.7	31.1
31.4	31.4	31.2	30.9	31.1	31.2	31.4	30.6	31.0	30.5
30.4	30.7	31.1	31.2	31.3	30.6	31.1	30.6	30.4	30.2
30.8	30.0	30.5	31.1	30.4	30.5	30.2	30.2	29.8	30.1

20 - 1

Mean 30.952
Standard Dev. 0.683

Figure F24

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005	TITLE	
.00	± .010	BILLET	
.0	± .020	DRN. L J F	DATE 5 22 81
FRAC.	± 1/32	CKD.	SCALE FULL
ANGLE	± 1°	APPD.	

Calibrate
Rc 35.0 ± 1
Calibrated
35.2

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

25.7	24.7	25.0	25.4	25.6	25.2	25.5	24.9	24.7	24.8
25.2	24.9	24.4	24.5	25.0	24.4	24.3	24.8	25.2	24.2
25.6	25.2	24.6	25.7	24.7	24.0	24.4	24.2	25.1	23.8
26.5	26.0	25.1	25.2	24.5	24.1	24.7	25.4	24.9	25.5
25.4	25.8	25.4	25.6	24.4	24.3	24.0	25.3	24.9	25.5
25.5	25.5	24.9	24.5	23.6	24.6	24.8	25.2	25.6	25.7
24.7	25.1	24.0	24.7	23.5	24.3	24.4	25.0	24.3	25.5
25.7	25.3	24.4	23.1	24.5	23.9	24.4	23.7	25.1	25.5
25.2	24.6	24.0	23.7	24.2	23.8	23.8	23.5	25.6	24.5
24.3	24.1	24.2	23.7	24.2	24.3	25.2	24.8	24.8	23.3

19 X

Mean 24.748
Standard Dev. 0.669

Figure F25

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant				
				TITLE BILLET		
		.000	± .005	DRN. L J F	DATE 5 22 81	SCALE FULL
		.00	± .010	CKD.		
		.0	± .020	APPD.		
FRAC.	± 1/32					
ANGLE	± 1°					

Calibrate
Rc 35.0 ± 1.0
Calibrated 6-11-80
34.8

REVISIONS				
SYM.	DESCRIPTION	BY	DATE	APPR.

29.7	30.7	31.1	31.1	31.3	31.7	31.2	31.7	30.5	30.5
30.2	30.2	30.8	30.4	30.5	30.7	31.5	31.0	31.5	30.3
30.8	29.9	31.0	30.7	31.3	31.6	31.2	31.0	31.1	30.6
29.9	29.7	31.1	30.8	31.1	31.5	31.5	30.3	30.3	30.1
30.2	29.5	30.6	30.0	30.8	30.2	30.5	30.6	30.0	30.0
29.7	29.0	30.3	30.0	30.8	30.5	30.4	30.0	29.7	29.5
30.0	29.7	30.4	29.7	30.6	30.2	30.0	30.0	30.3	29.7
29.8	27.6	30.2	29.8	30.0	30.5	30.4	30.3	29.6	29.4
30.3	30.6	30.6	29.6	30.4	30.5	30.0	30.4	30.7	29.8
30.8	30.3	31.1	30.2	30.8	30.4	30.9	31.0	30.6	30.4

20 C

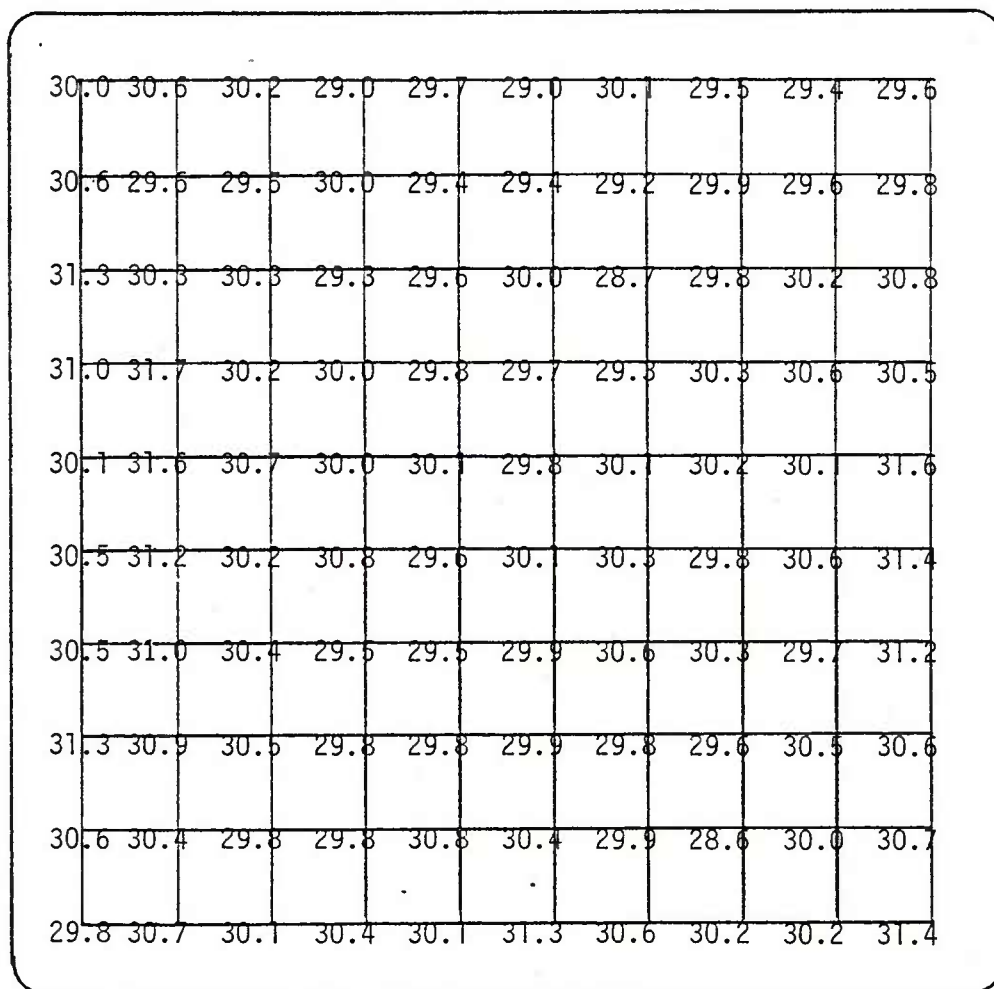
Mean 30.429
Standard Dev. 0.632
Figure F26

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant	
.000	± .005		
.00	± .010	TITLE BILLET	
.0	± .020	DRN. L J F	DATE 5 22 81
FRAC.	± 1/32	SCALE FULL	
ANGLE	± 1°	CKD.	
		APPD.	

Calibrate
Rc 35.0 1 1.0
Calibrated 6-9-80
34.5

REVISIONS

SYM.	DESCRIPTION	BY	DATE	APPR.



Mean 30.174
Standard Dev. 0.630

Figure F27

TOLERANCES UNLESS OTHERWISE SPECIFIED		 Chamberlain Chamberlain Manufacturing Corporation Scranton Army Ammunition Plant				
				TITLE BILLET		
		.000	± .005	DRN. L J F	DATE 5 22 81	SCALE FULL
		.00	± .010	CKD.		
		.0	± .020	APPO.		
FRAC.	± 1/32					
ANGLE	± 1°					

Appendix G

Photomicrographs of Edge Cross Section

Republic Steel
Picral Etchant
63x

Figure G1.

Top Billet of
1st Ingot



Figure G2.

Middle Billet of
1st Ingot



Figure G3.

Bottom Billet of
1st Ingot

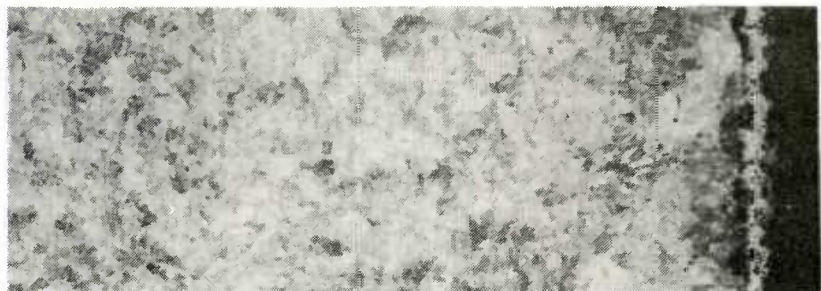


Figure G4.

Top Billet of
20th Ingot

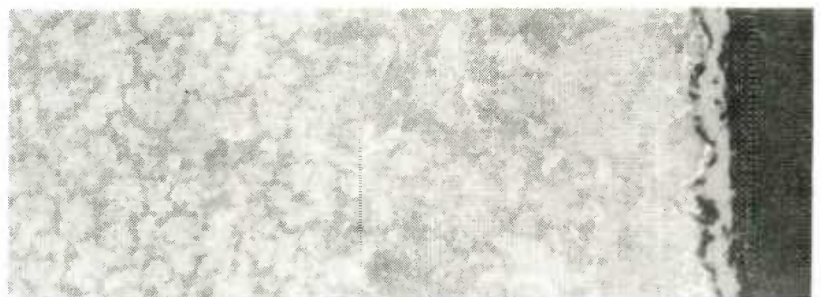
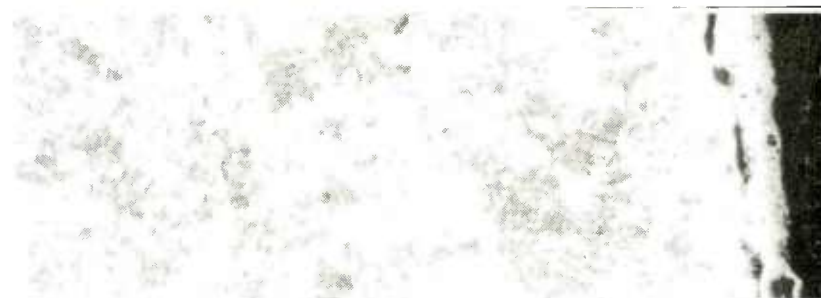


Figure G5.

Middle Billet of
20th Ingot



Republic Steel
Picral Etchant
63x

Figure G6.

Bottom Billet of
20th Ingot



Figure G7.

Top Billet of
40th Ingot

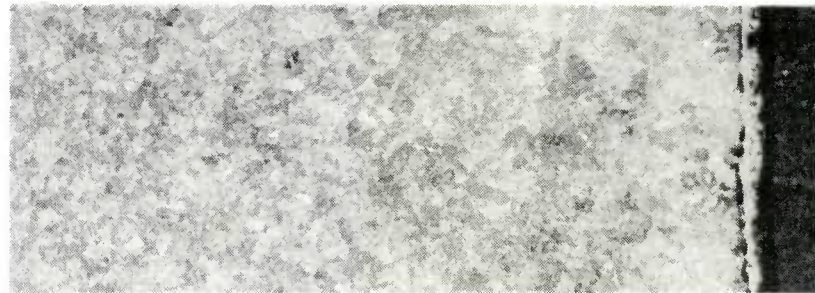


Figure G8.

Middle Billet of
40th Ingot

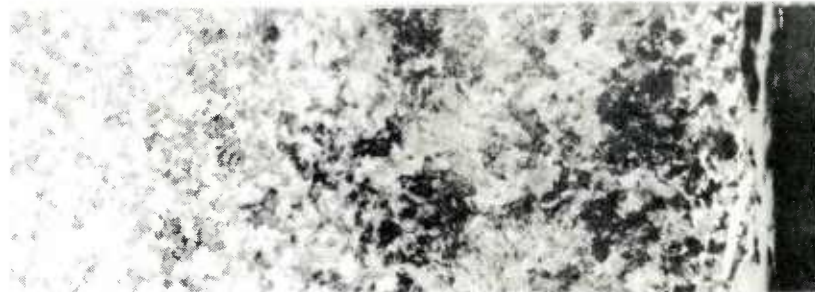


Figure G9.

Bottom Billet of
40th Ingot



Bethlehem Steel
Picral Etchant
63x

Figure G10.

1 Top

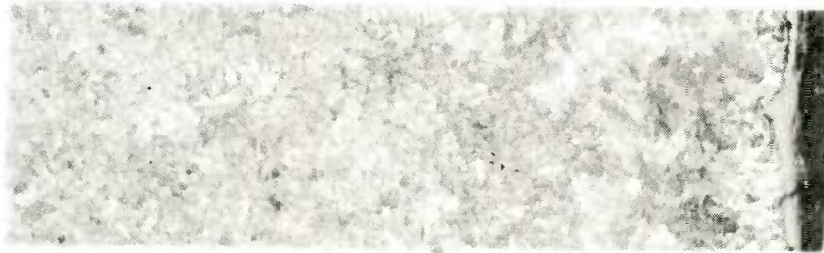


Figure G11.

1 Middle



Figure G12.

1 Bottom



Figure G13.

2 Top

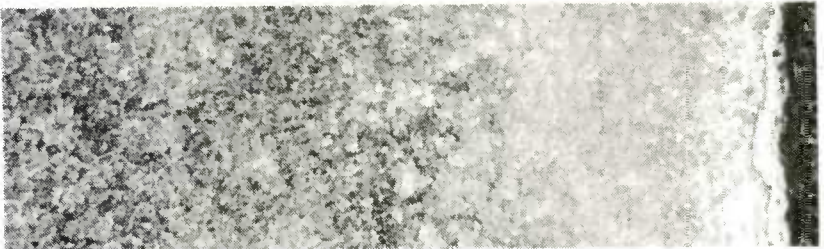


Figure G14.

2 Middle

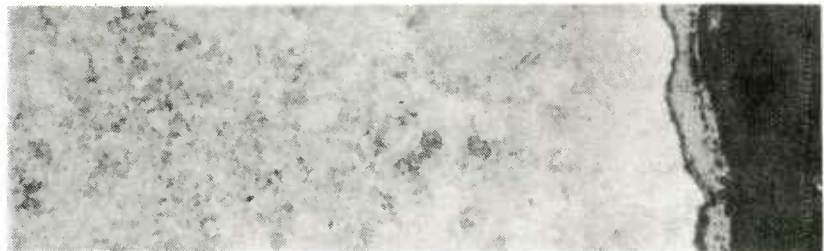


Figure G15.

2 Bottom



Bethlehem Steel
Picral Etchant
63x

Figure G16.

10 Top

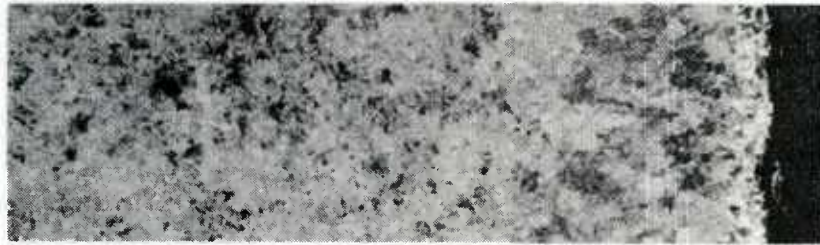


Figure G17.

10 Middle

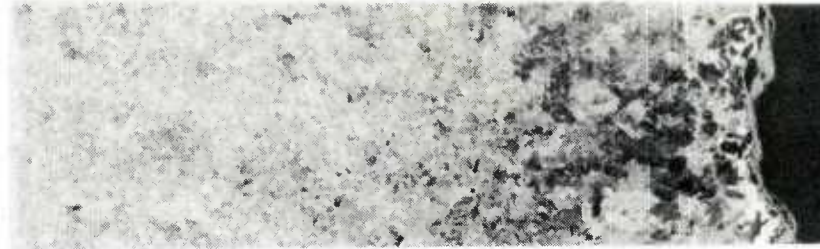


Figure G18.

10 Bottom



Figure G19.

11 Top



Figure G20.

11 Middle

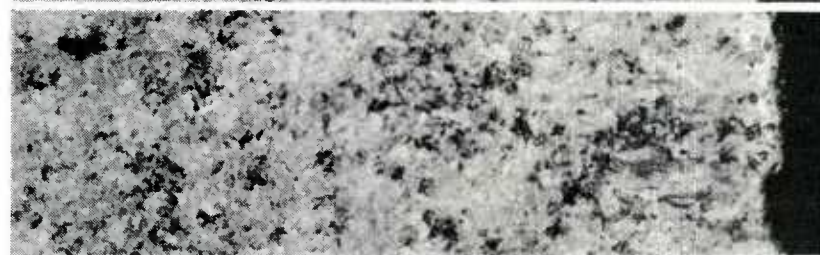


Figure G21.

11 Bottom



Bethlehem Steel
Picral Etchant
63x

Figure G22.

19 Top



Figure G23.

19 Middle

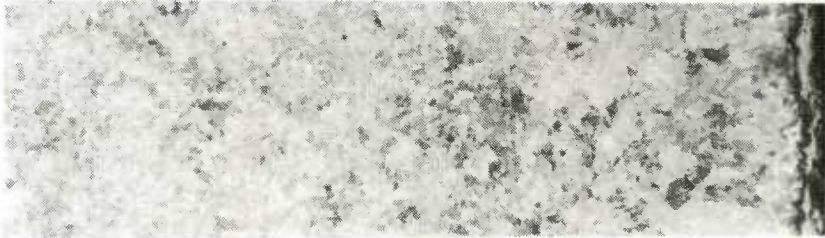


Figure G24.

19 Bottom

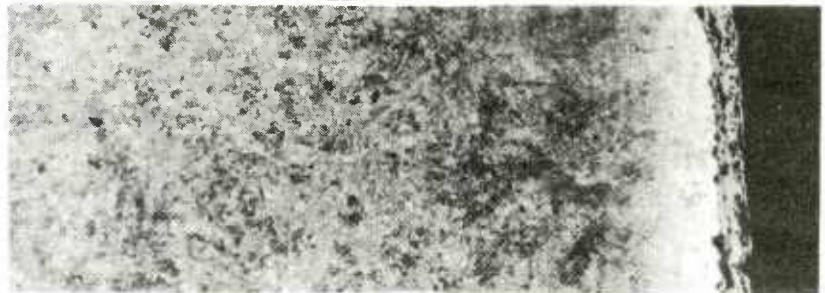


Figure G25.

20 Top



Figure G26.

20 Middle

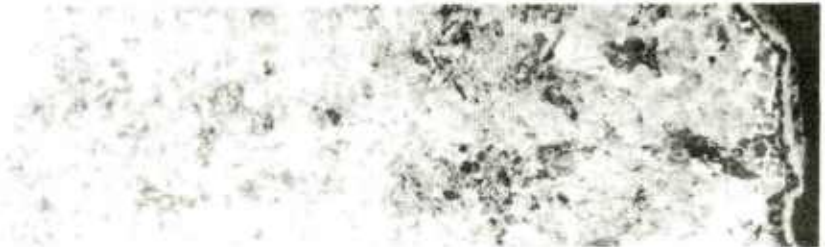


Figure G27.

20 Bottom



Appendix H

Photographs of Heat Treated Specimens

BETHLEHEM STEEL

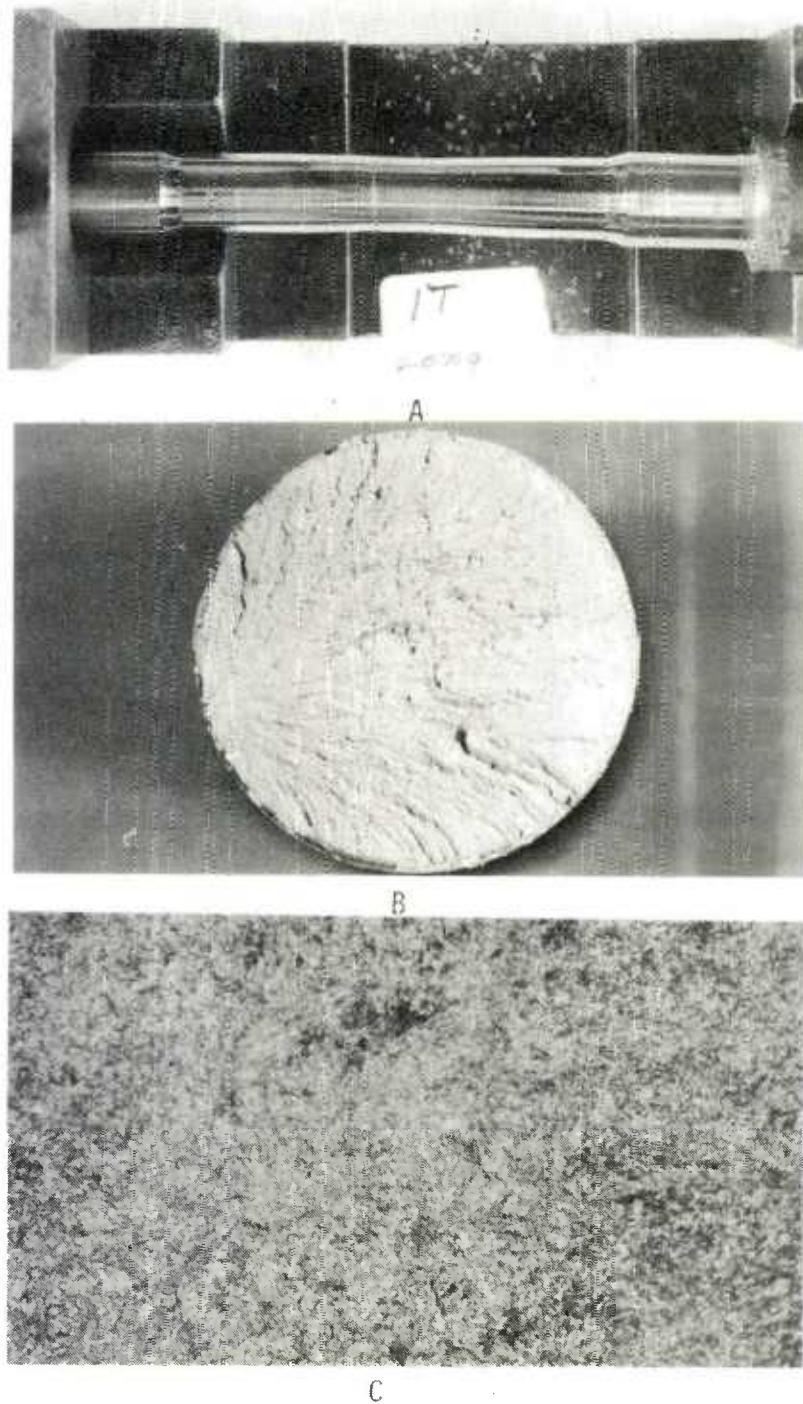
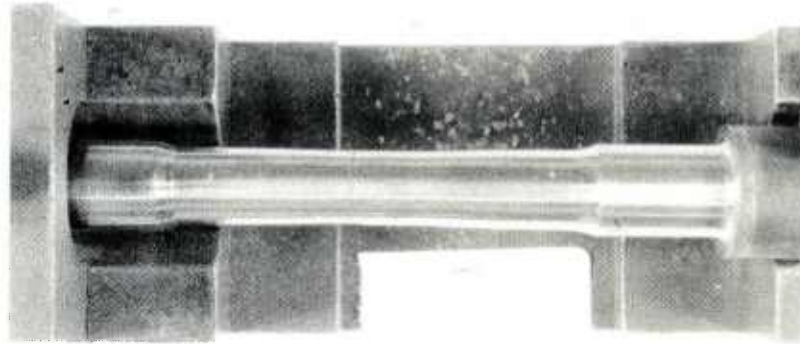
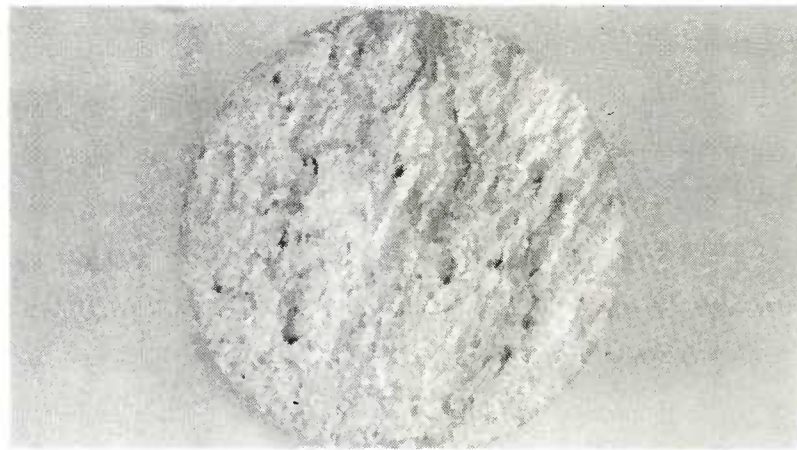


Figure H1. Bethlehem Steel Longitudinal Section of Billet 17.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

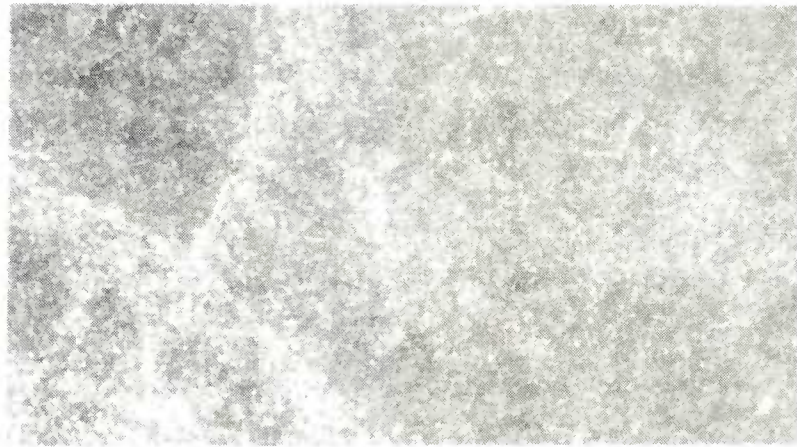
BETHLEHEM STEEL



A



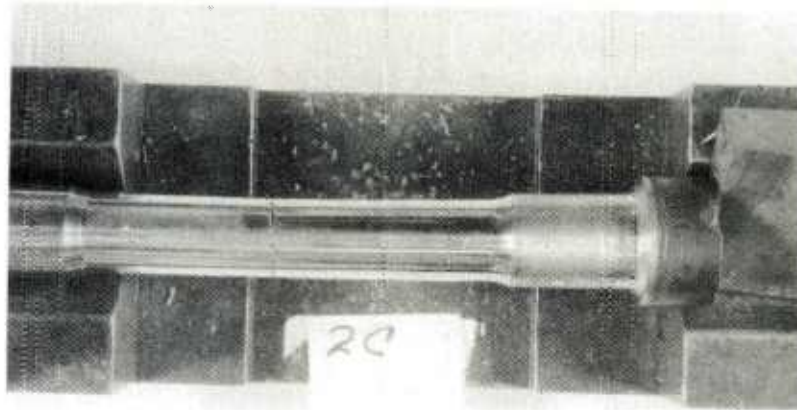
B



C

Figure H2. Bethlehem Steel Transverse Section of Billet 1T.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

BETHLEHEM STEEL



A



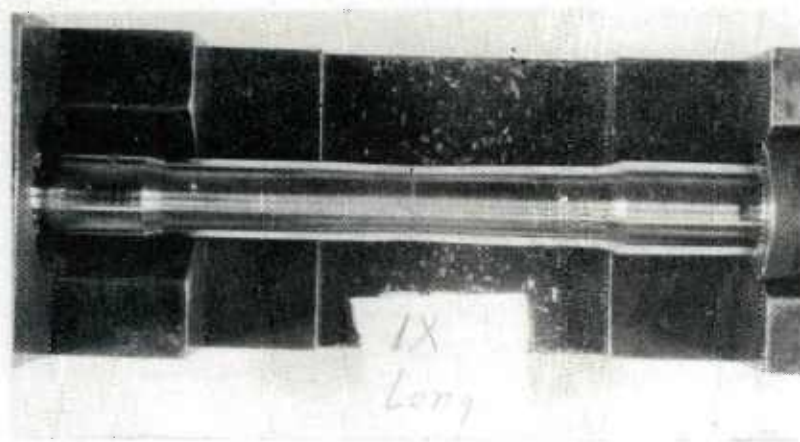
B



C

Figure H3. Bethlehem Steel Transverse Section of Billet 20.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

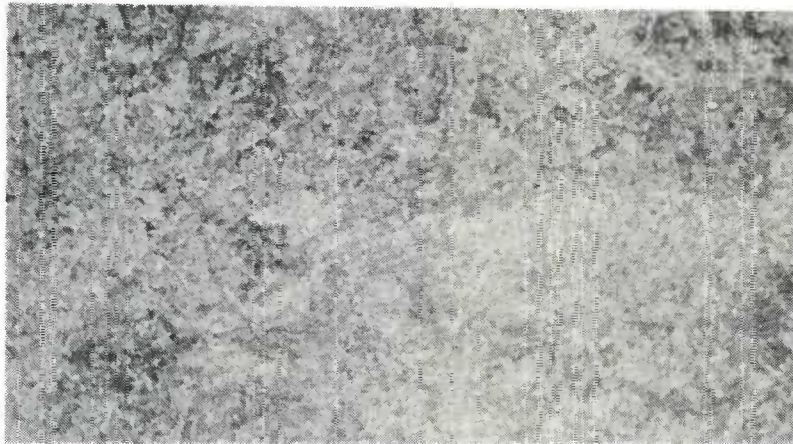
BETHLEHEM STEEL



A



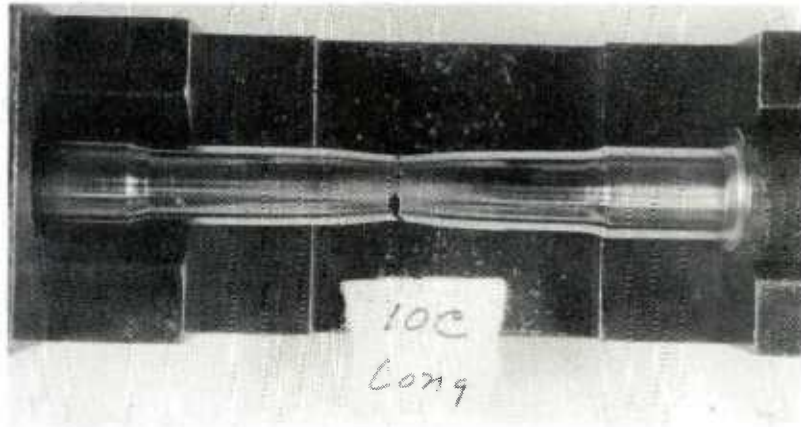
B



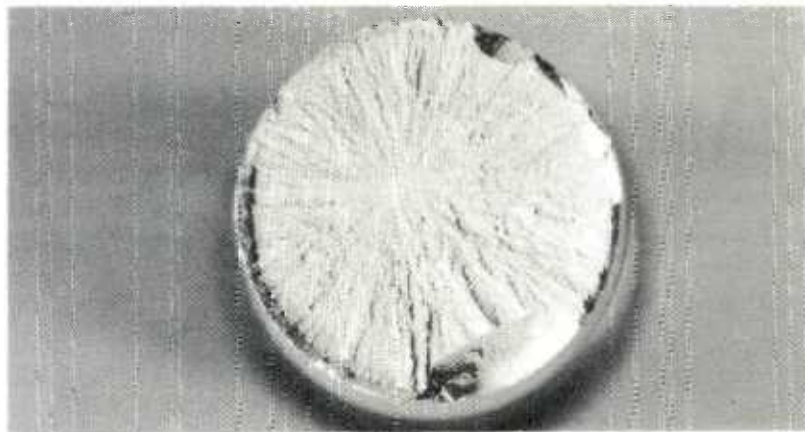
C

Figure H4. Bethlehem Steel Longitudinal Section of Billet 1X.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital

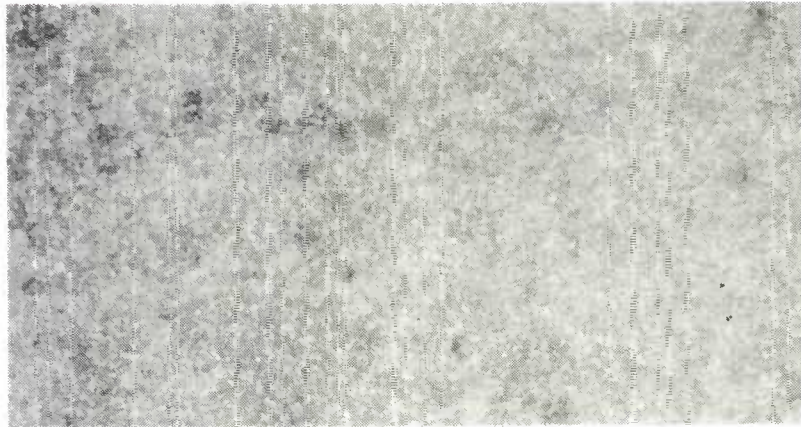
BETHLEHEM STEEL.



A



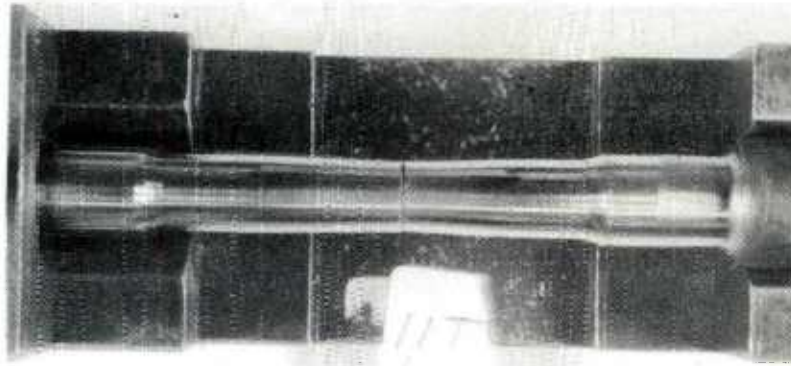
B



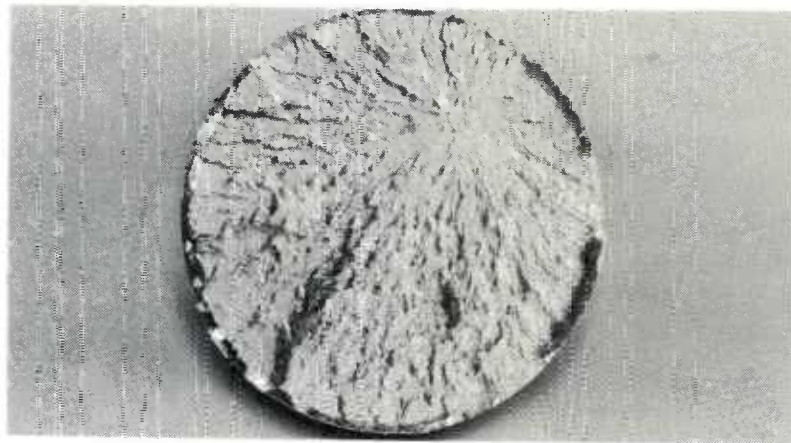
C

Figure H5. Bethlehem Steel Longitudinal Section of Billet 10C.
(a) Tensile Ear. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

BETHLEHEM STEEL



A



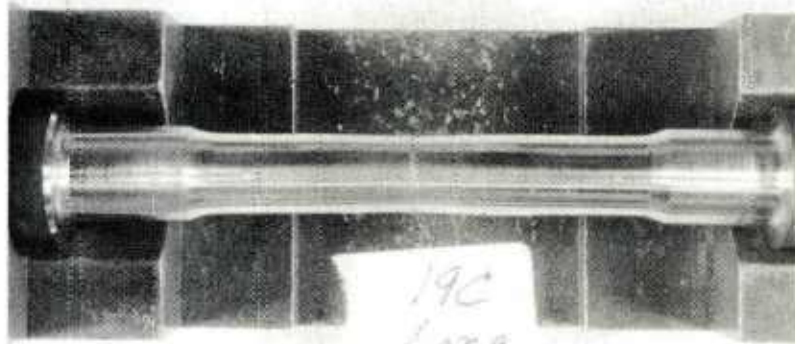
B



C

Figure H6. Bethlehem Steel Longitudinal Section of Billet 11T.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

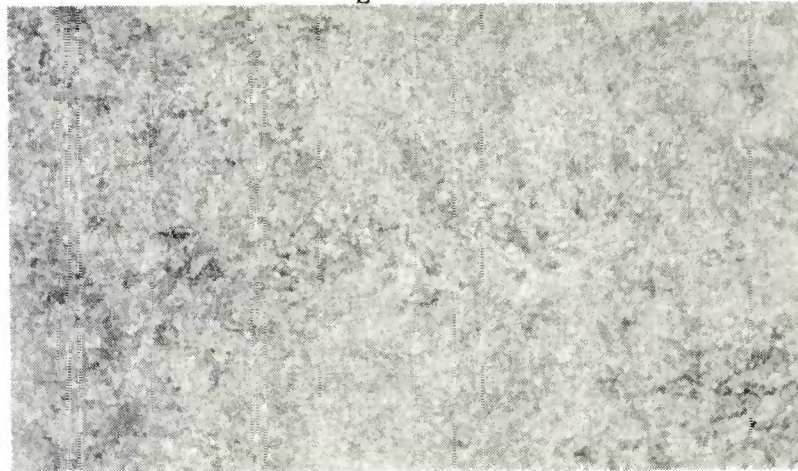
BETHLEHEM STEEL



A



B



C

Figure H7. Bethlehem Steel Longitudinal Section of Billet 19C.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

BETHLEHEM STEEL

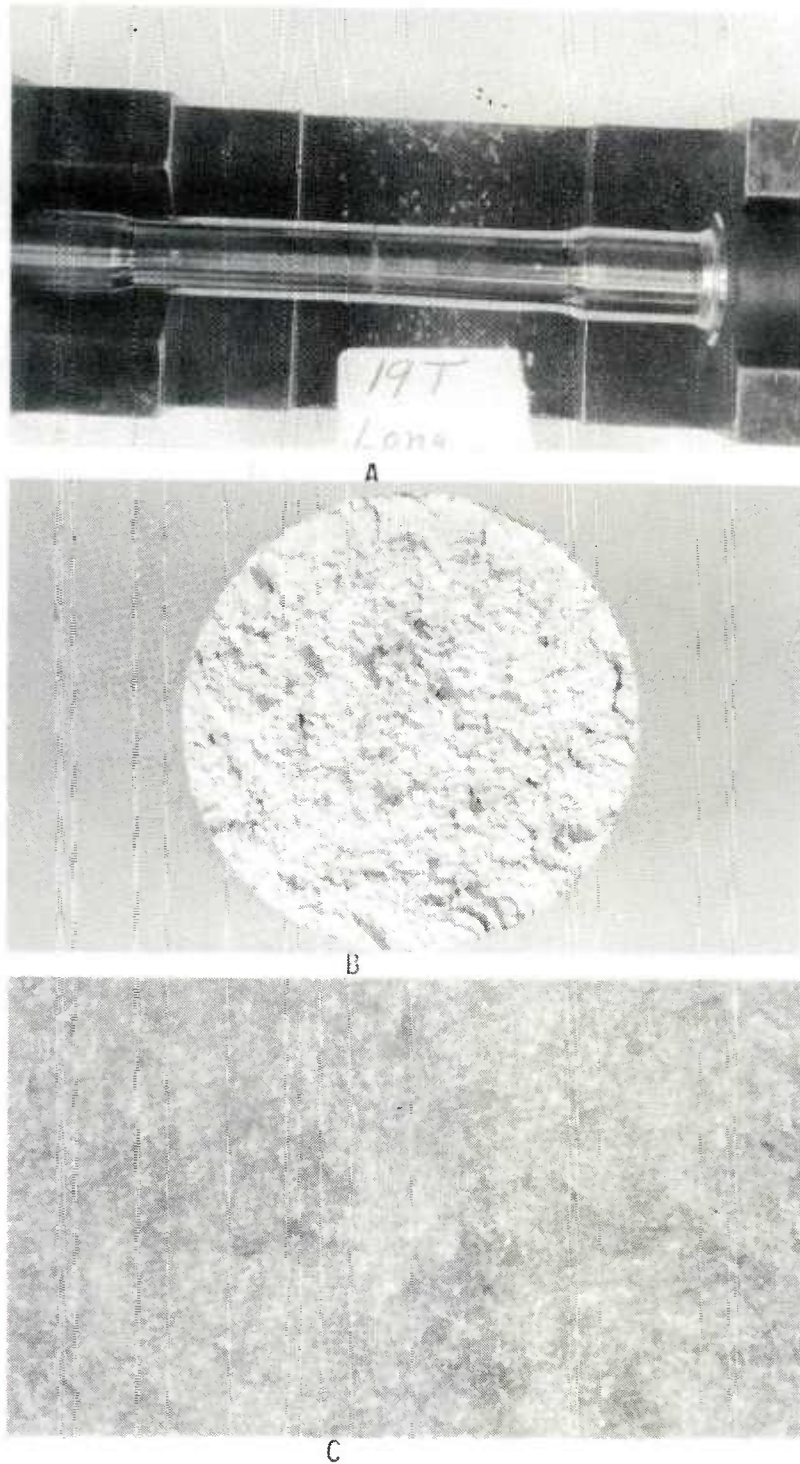
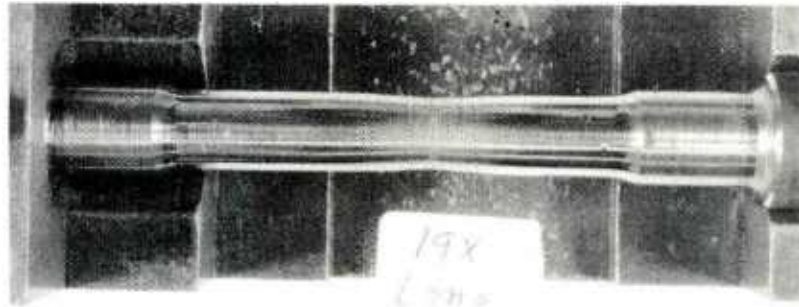
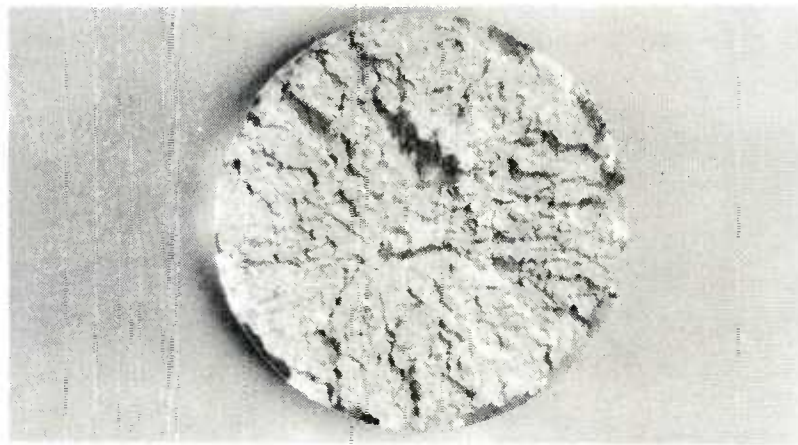


Figure H8. Bethlehem Steel Longitudinal Section of Billet 19T.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

BETHLEHEM STEEL



A



B



C

Figure H9. Bethlehem Steel Longitudinal Section of Billet 19X.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

BETHLEHEM STEEL

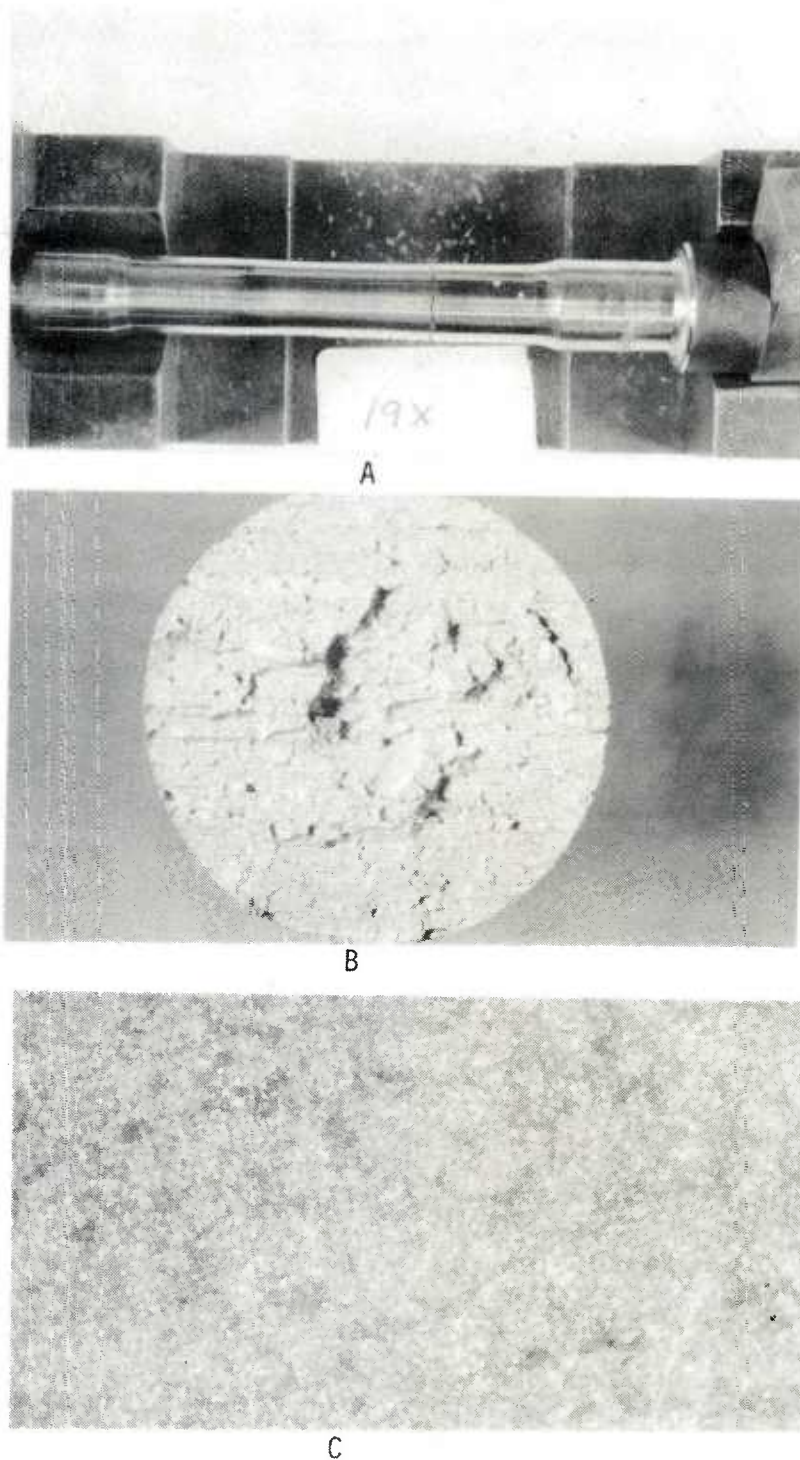
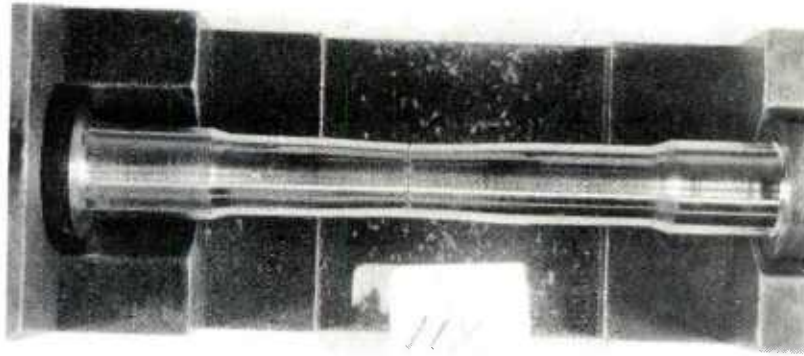
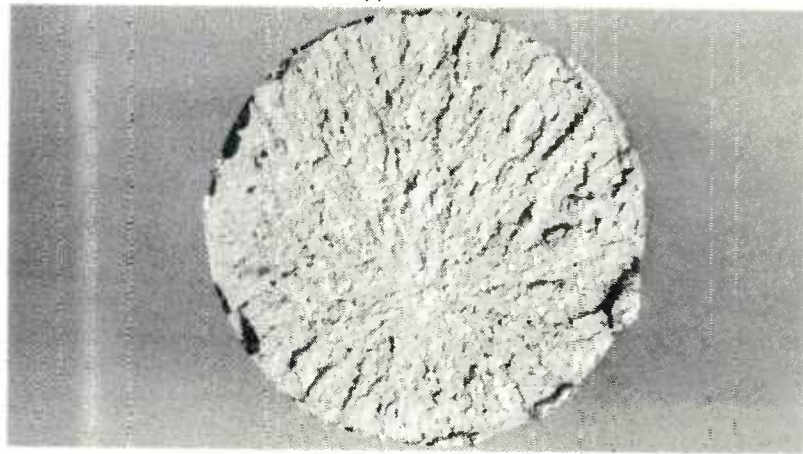


Figure H10. Bethlehem Steel Transverse Section of Billet 19X.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

BETHLEHEM STEEL



A



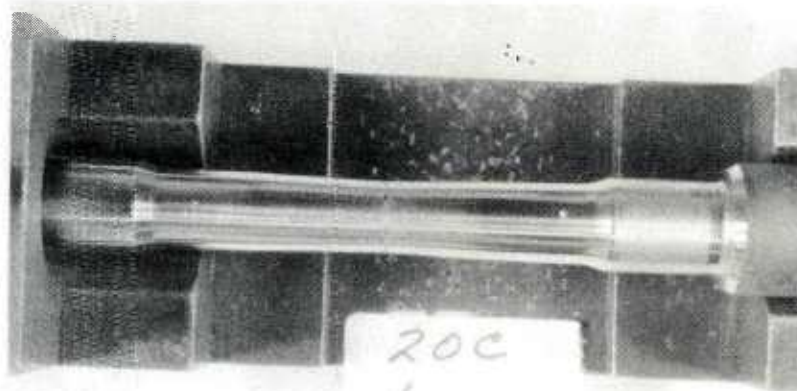
B



C

Figure H11. Bethlehem Steel Longitudinal Section of Billet 11X.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

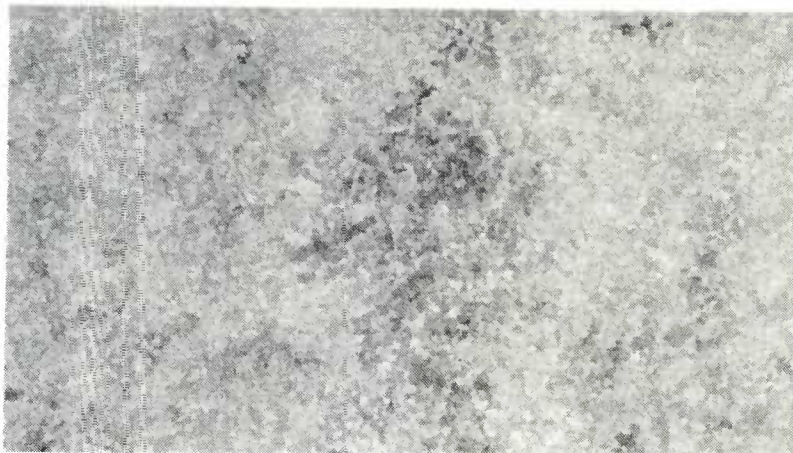
BETHLEHEM STEEL



A



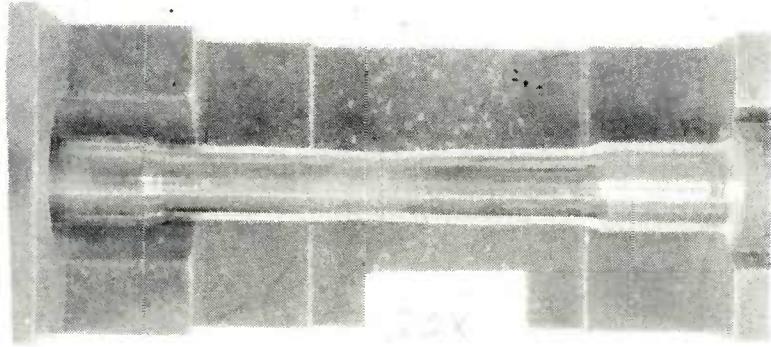
B



C

Figure H12. Bethlehem Steel Longitudinal Section of Billet 20C.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

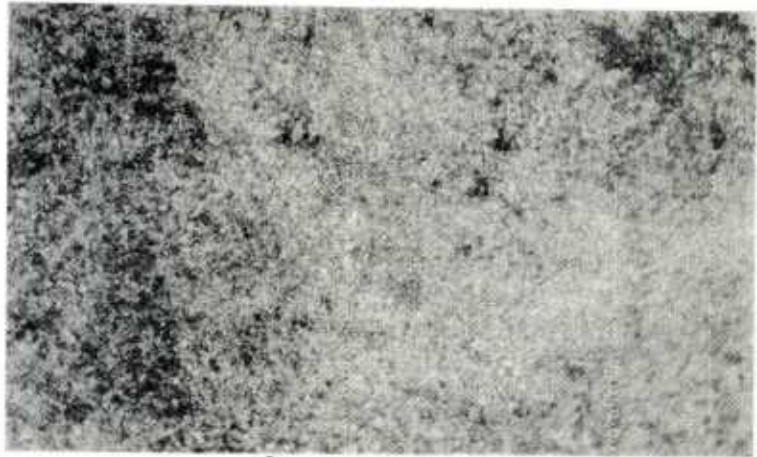
BETHLEHEM STEEL



A



B



C

Figure H13. Bethlehem Steel Longitudinal Section of Billet 20X.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

BETHLEHEM STEEL

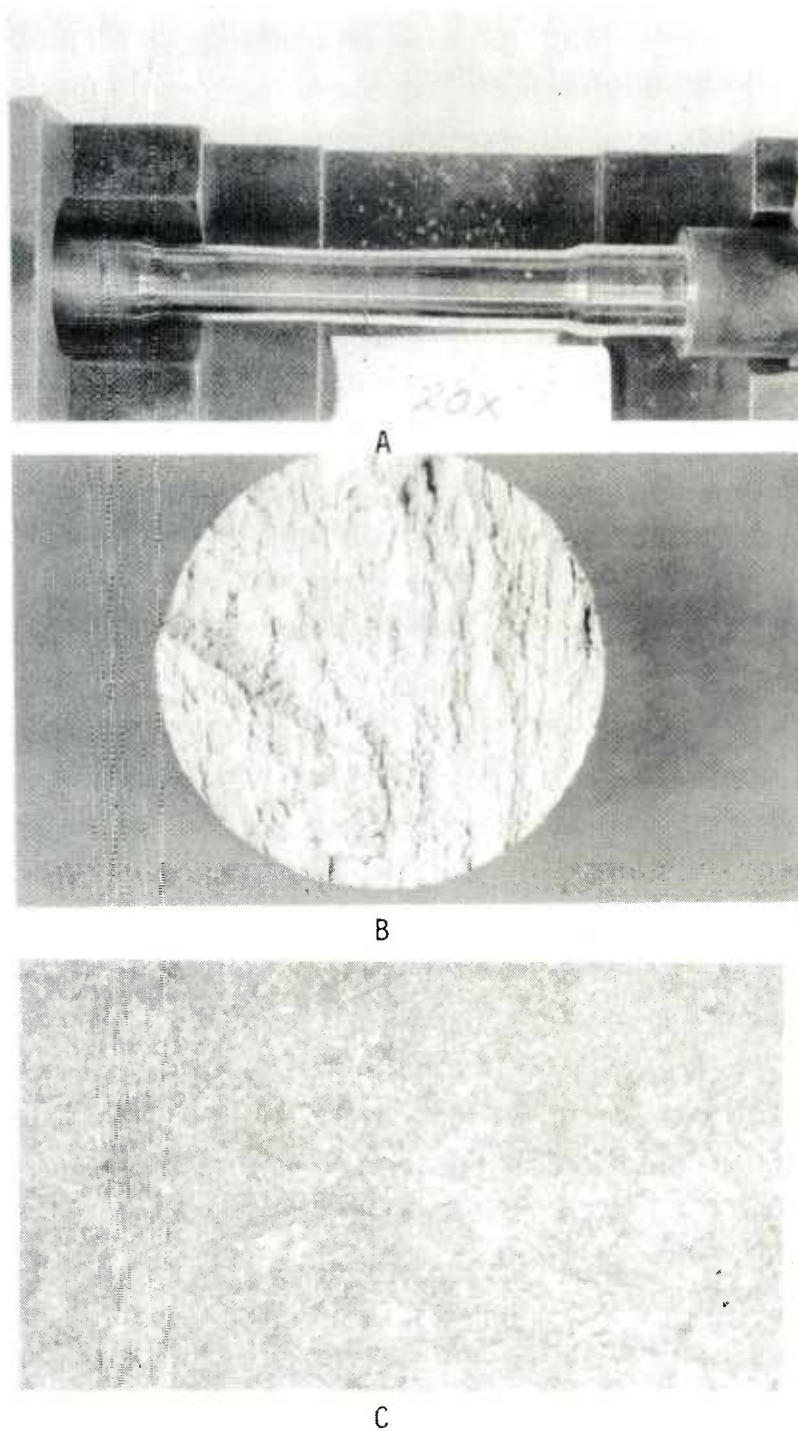
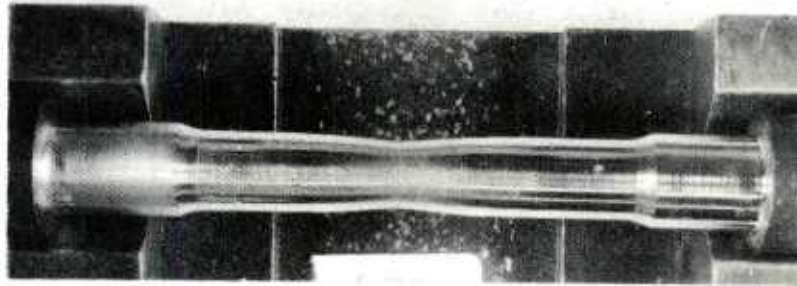
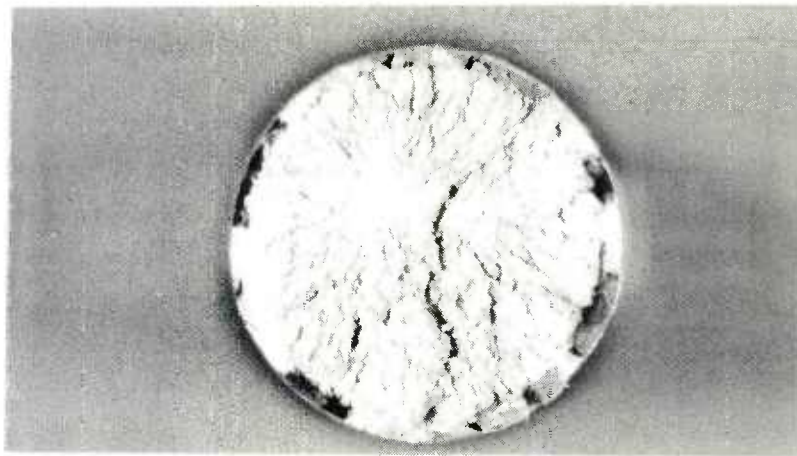


Figure H14. Bethlehem Steel Transverse Section of Billet 20X.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

REPUBLIC STEEL



A



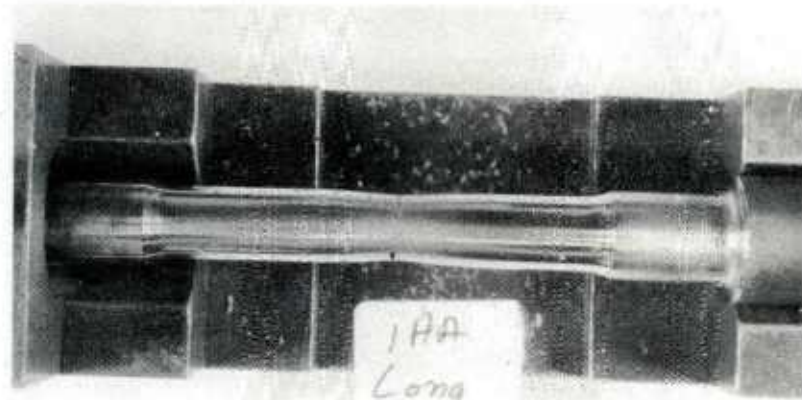
B



C

Figure H15. Republic Steel Longitudinal Section of Billet 1BD.
(a) Tensile Bar. 0.3x (b) Fractured Surface. 5x
(c) Heat Treatment. 1500x 2% Nital.

REPUBLIC STEEL



A



B



C

Figure H16. Republic Steel Longitudinal Section of Billet 14A.
(a) Tensile Bar. C.3x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

REPUBLIC STEEL

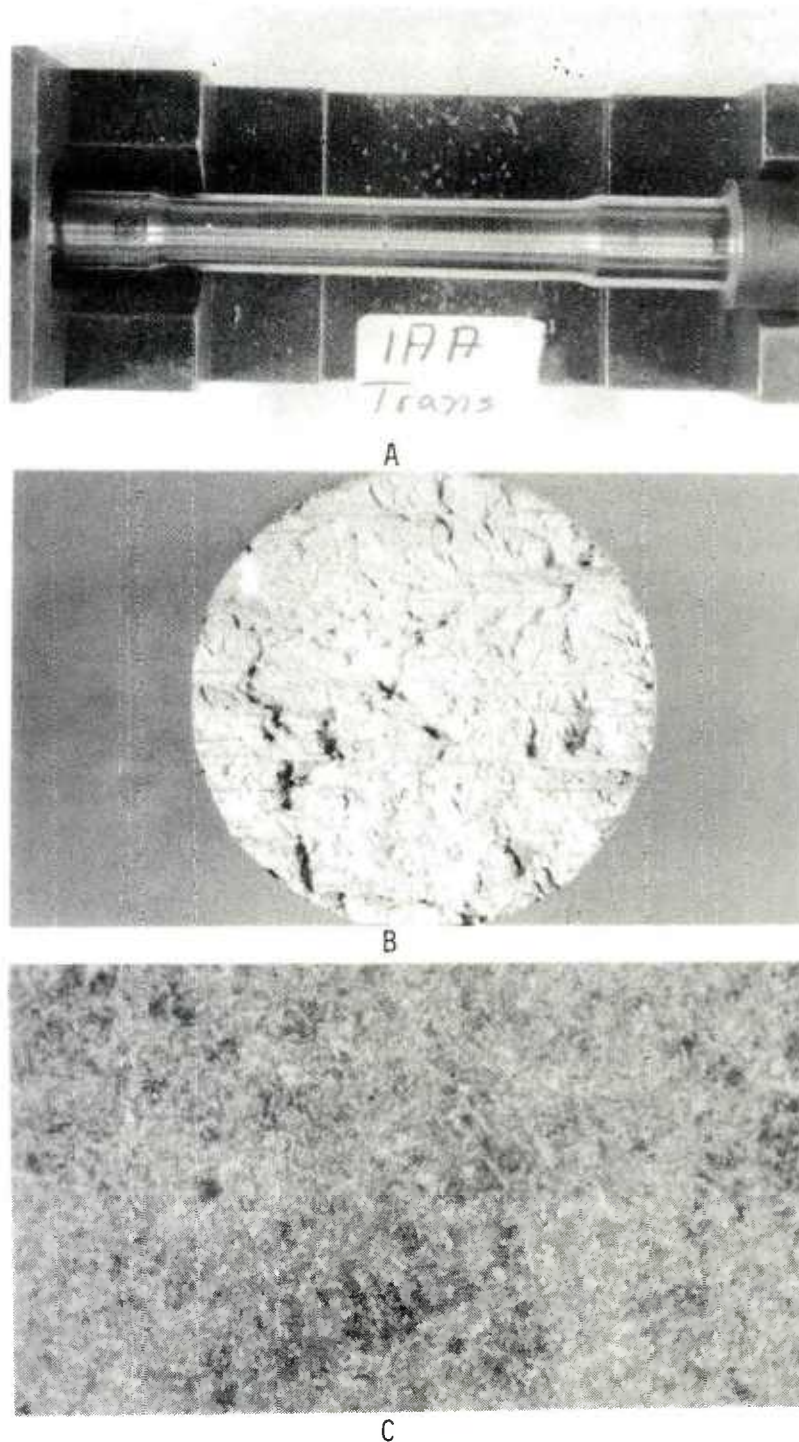
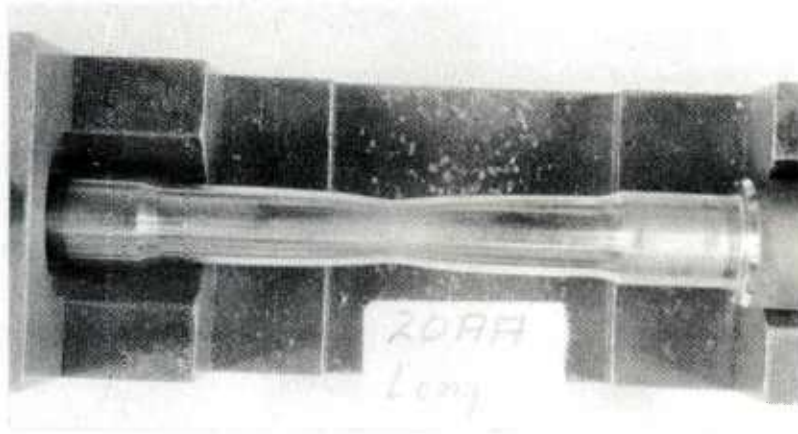


Figure H17. Republic Steel Transverse Section of Billet 1AA.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

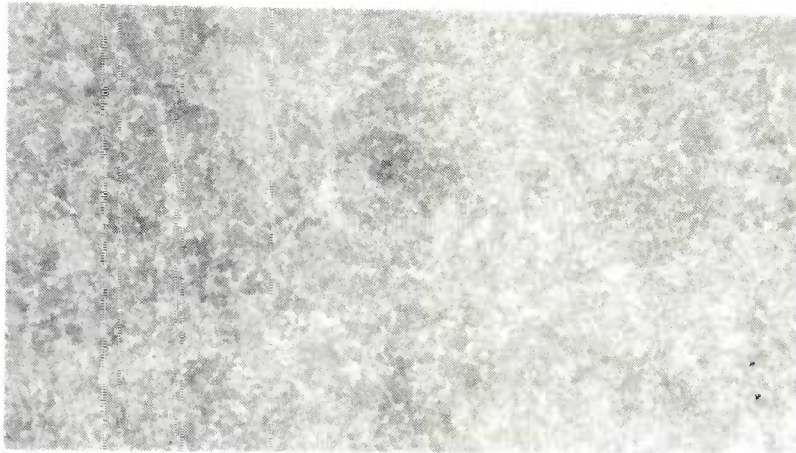
REPUBLIC STEEL



A



B



C

Figure H18. Republic Steel Longitudinal Section of Billet 20AA.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

REPUBLIC STEEL

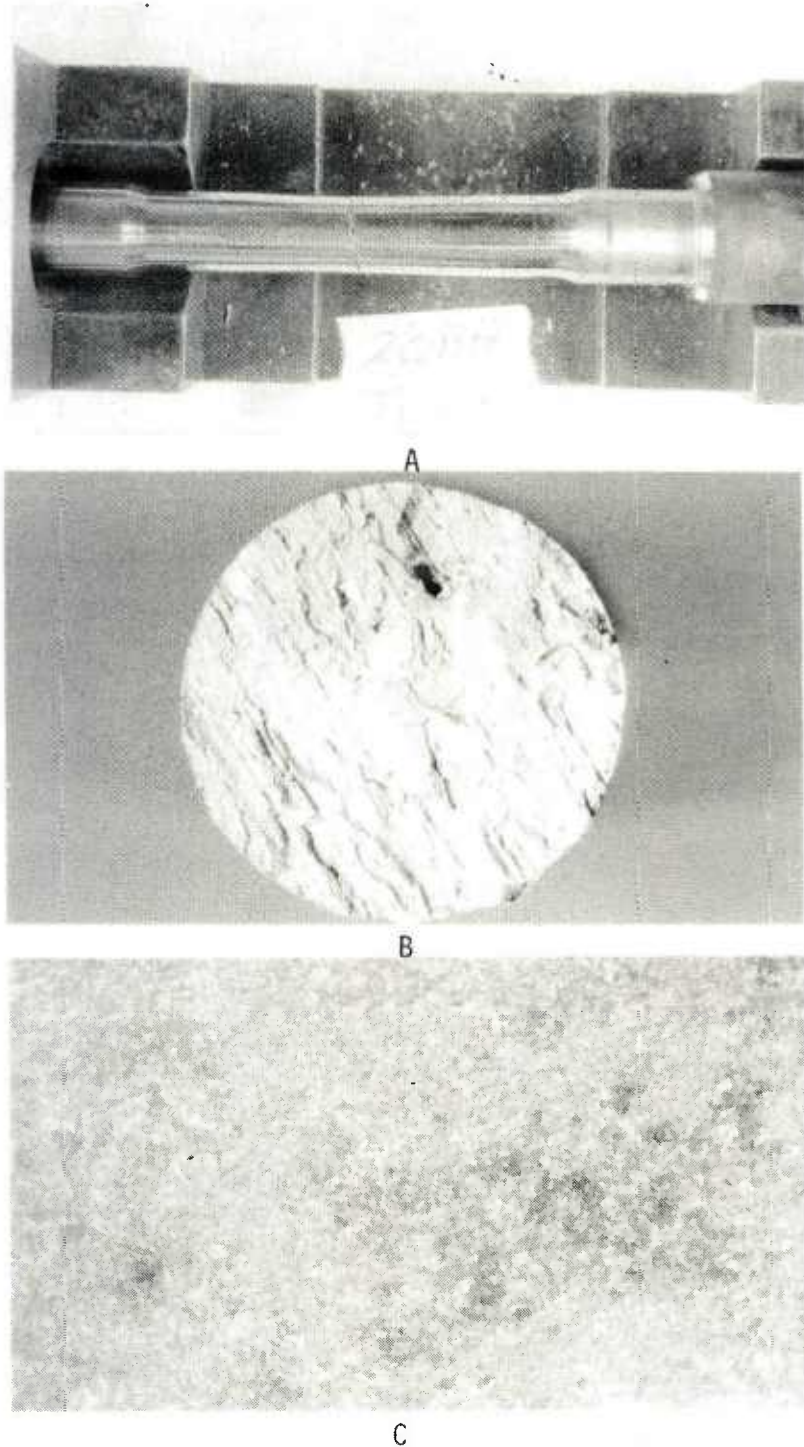
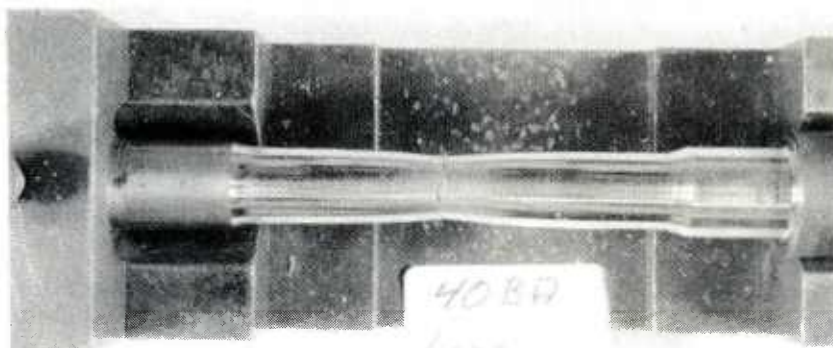
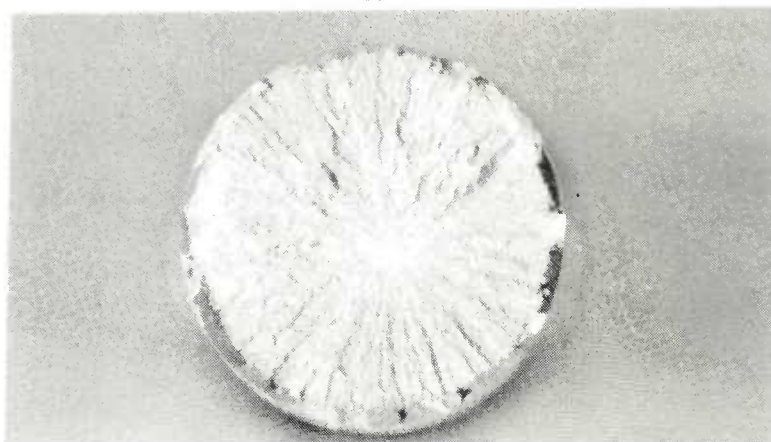


Figure H19. Republic Steel Transverse Section of Billet 20BA.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

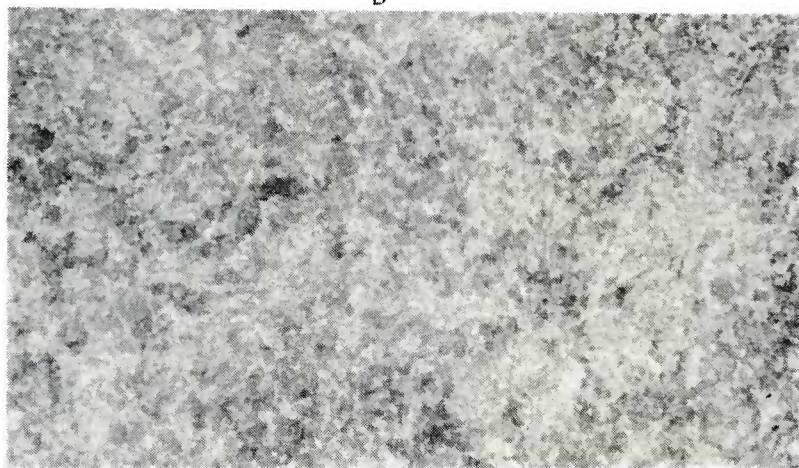
REPUBLIC STEEL



A



B



C

Figure H20. Republic Steel Longitudinal Section of Billet 40BA.
(a) Tensile Bar. 0.8x (b) Fractured Surface. 5x
(c) Heat Treatment. 500x 2% Nital.

Appendix I

Stress Strain Curves

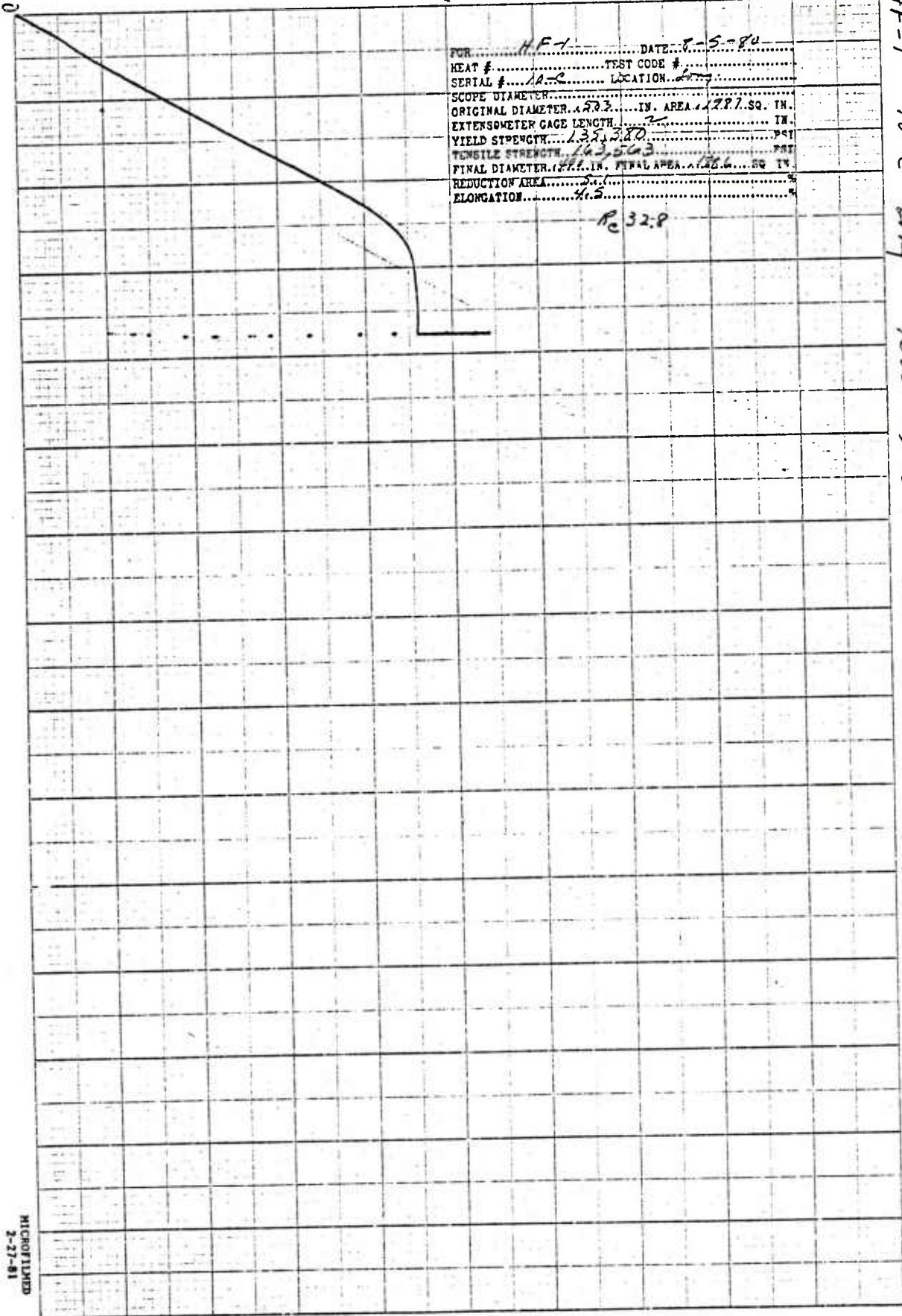
69000

88,800

HF-1 10-C 1570°F 2 hrs 1125°F 2 hrs
 1570°F 2 hrs 1125°F 2 hrs

FOR HF-1 DATE 8-5-80
 HEAT # 1A-2 TEST CODE # 10-C
 SERIAL # 1A-2 LOCATION 10-C
 SCOPE DIAMETER 0.075 IN. AREA 0.0045 SQ. IN.
 ORIGINAL DIAMETER 0.075 IN. AREA 0.0045 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 135,380 PSI
 TENSILE STRENGTH 143,500 PSI
 FINAL DIAMETER 0.075 IN. FINAL AREA 0.0045 SQ. IN.
 REDUCTION AREA 0.0 %
 ELONGATION 4.5 %

R_e 32.8



MICROFILMED
 2-27-81

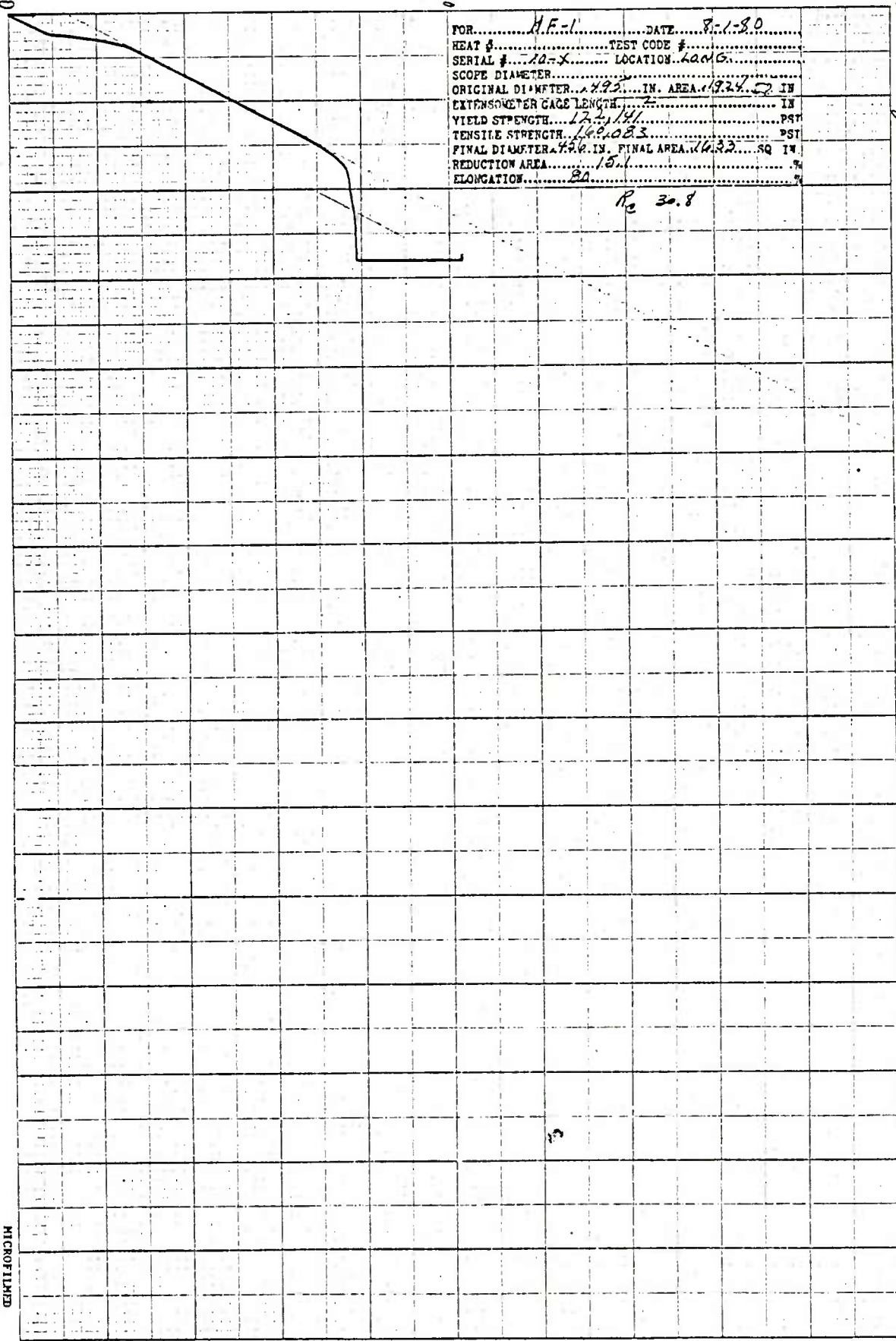
30,000

60,000

HF-1 longitudinal 10-X 1500°F 2hrs 1125°F 2hrs

FOR.....H.F.-1.....DATE.....8-1-80.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....10-X.....LOCATION.....6006.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER......492.....IN. AREA......1724.....SQ IN
 EXTENSOMETER GAGE LENGTH.....7.....IN
 YIELD STRENGTH.....172,141.....PST
 TENSILE STRENGTH.....169,083.....PST
 FINAL DIAMETER......440.....IN. FINAL AREA......1432.....SQ IN
 REDUCTION AREA.....15.1.....%
 ELONGATION.....20.....%

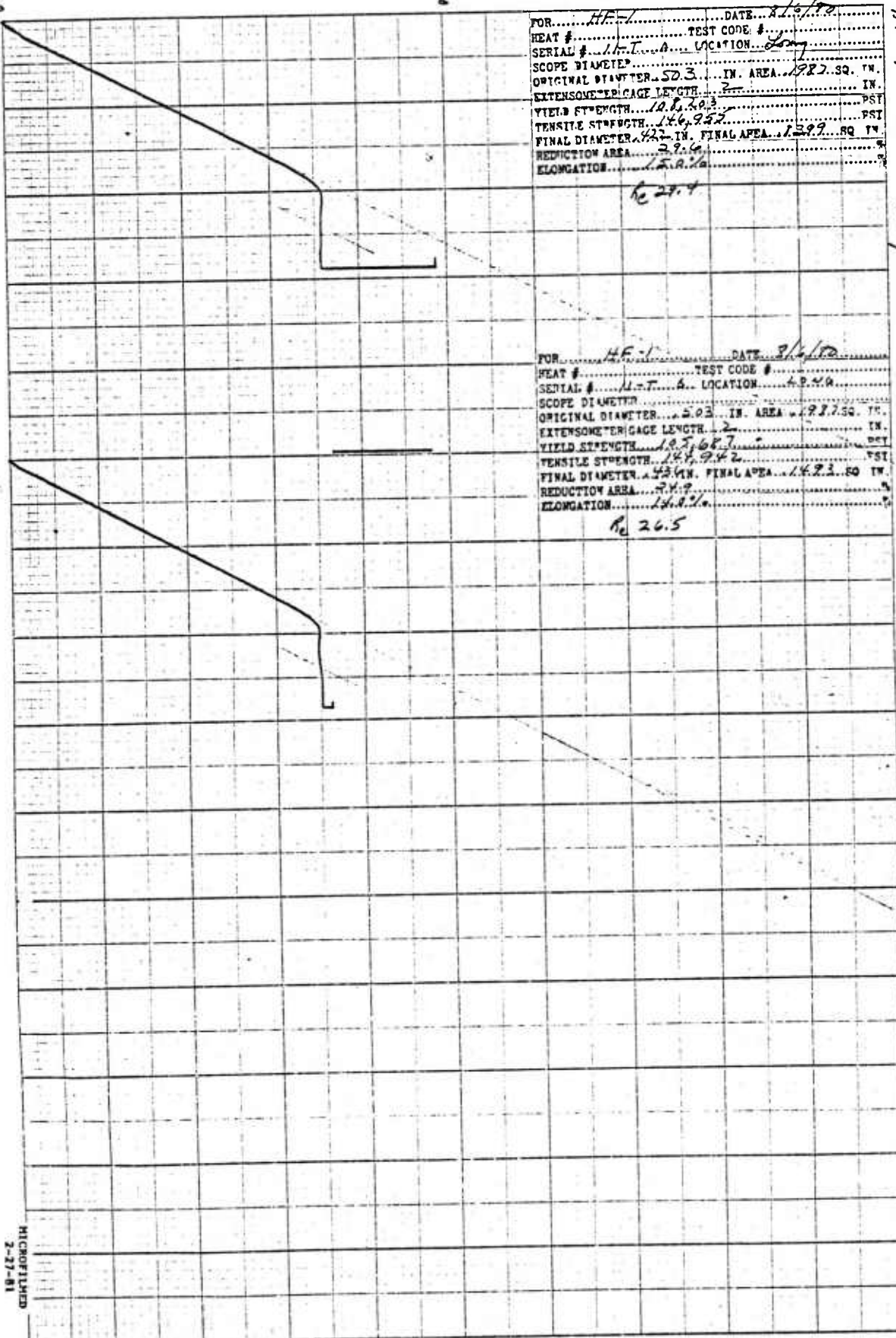
R_e 30.8



FOR HF-1 DATE 8/6/72
 HEAT # 11-T TEST CODE # 1
 SERIAL # 11-T-8 LOCATION Long
 SCOPE DIAMETER 50.3 IN. AREA 2027.30 IN.
 ORIGINAL DIAMETER 50.3 IN. AREA 2027.30 IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 106,603 PSI
 TENSILE STRENGTH 146,942 PSI
 FINAL DIAMETER 42.2 IN. FINAL AREA 1799.80 IN.
 REDUCTION AREA 2.9%
 ELONGATION 27.4%

FOR HF-1 DATE 8/6/72
 HEAT # 11-T TEST CODE # 1
 SERIAL # 11-T-8 LOCATION Long
 SCOPE DIAMETER 50.3 IN. AREA 2027.30 IN.
 ORIGINAL DIAMETER 50.3 IN. AREA 2027.30 IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 106,603 PSI
 TENSILE STRENGTH 146,942 PSI
 FINAL DIAMETER 42.2 IN. FINAL AREA 1799.80 IN.
 REDUCTION AREA 2.9%
 ELONGATION 26.5%

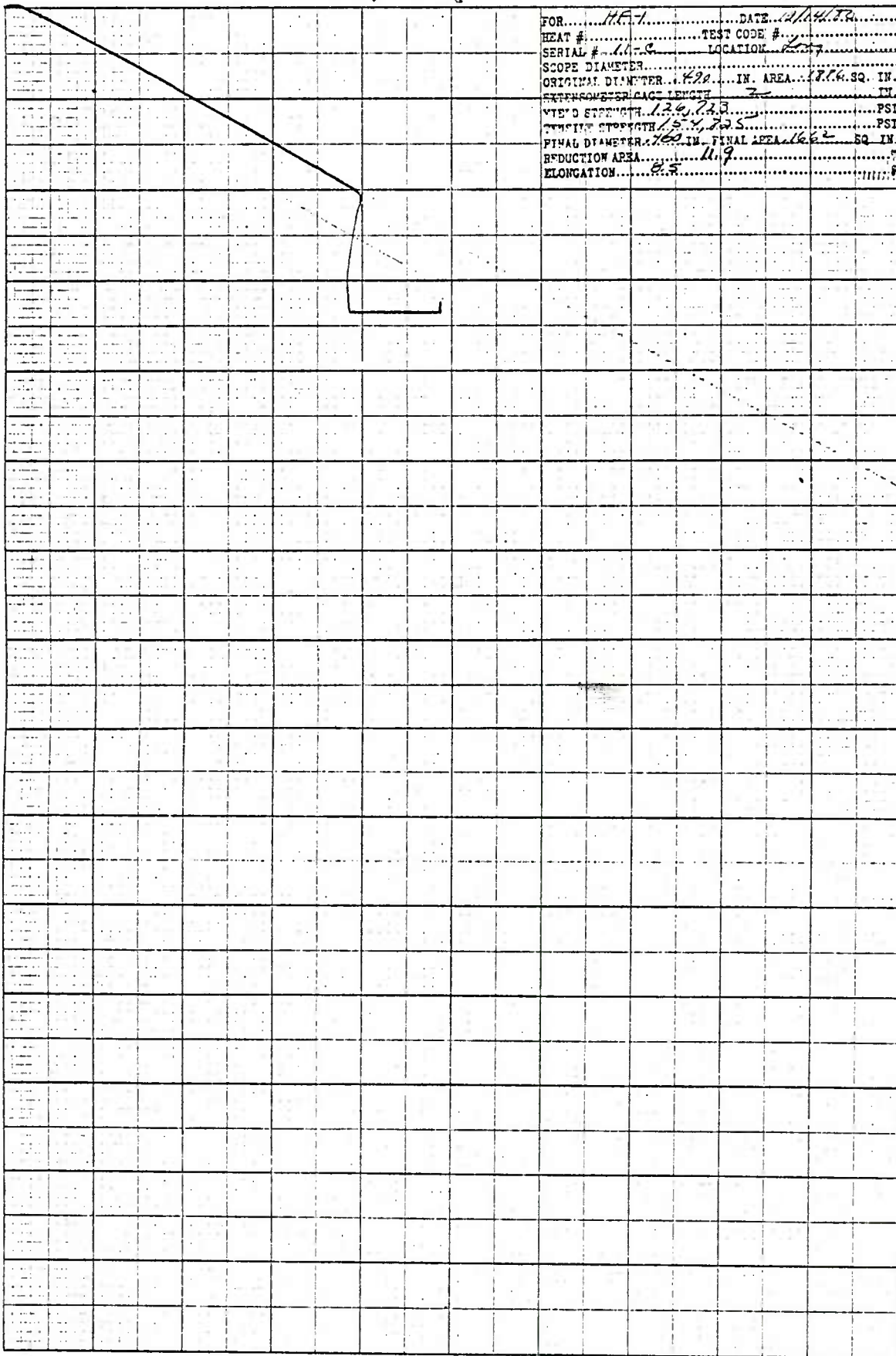
HF-1 11-T Long 1500°F 2hr 1200°F 2hr



60,000
 HF-1
 11-e
 longitudinal
 1500°F
 2hr
 1500°F
 11.75°F 2hr

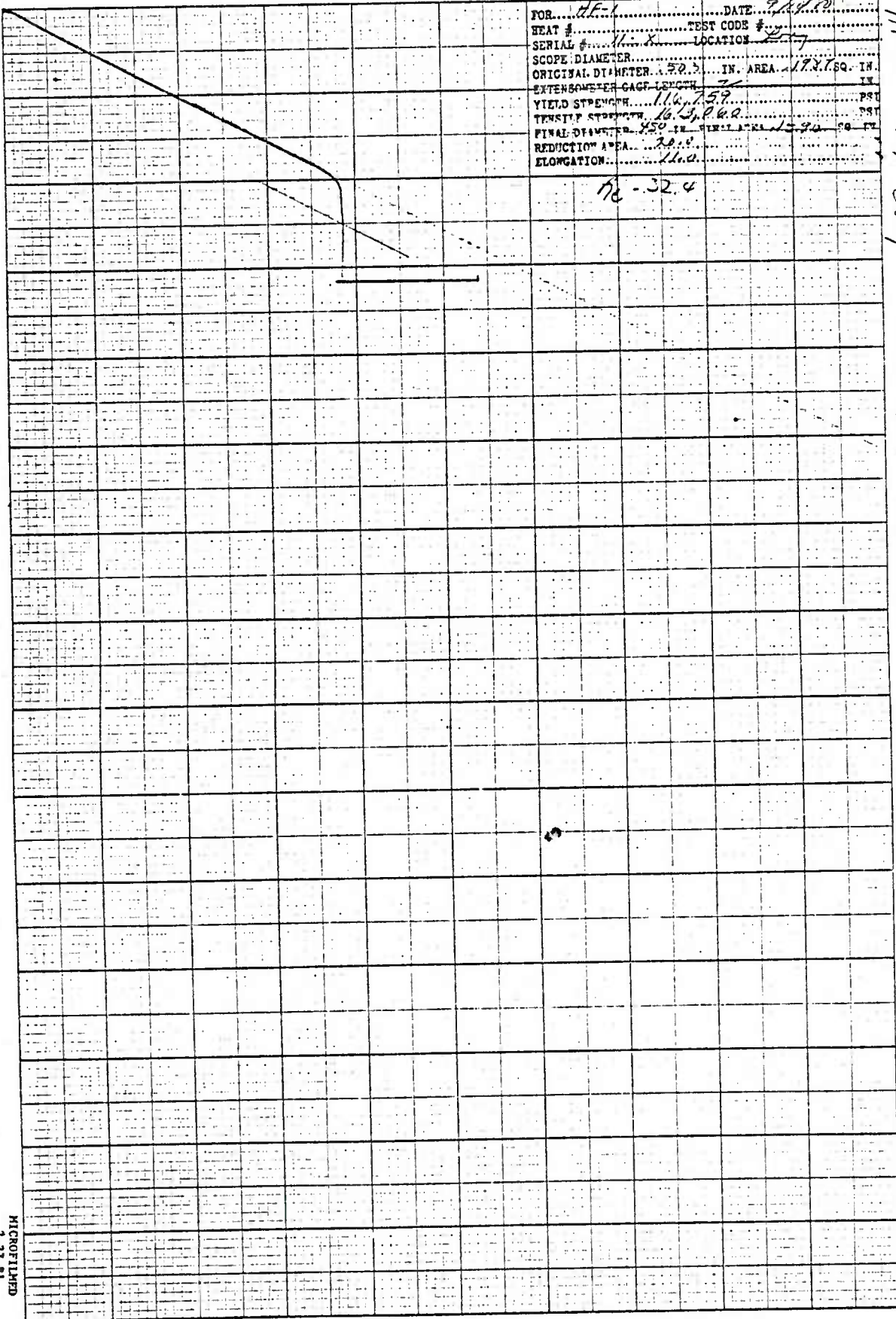
24,000
 30,000

FOR.....*HF-1*.....DATE.....*2/14/72*.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....*117-9*.....LOCATION.....*2-7*.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....*4.82*.....IN. AREA.....*18.6* SQ. IN.
 EXTENSOMETER GAGE LENGTH.....*2*.....IN.
 YIELD STRENGTH.....*126,000*.....PSI
 TENSILE STRENGTH.....*154,700*.....PSI
 FINAL DIAMETER.....*4.60*.....IN. FINAL AREA.....*16.6* SQ. IN.
 REDUCTION AREA.....*11.9*.....%
 ELONGATION.....*8.3*.....%



FOR HF-1 DATE 7/28/70
 HEAT # 11-1 TEST CODE # 2-7
 SERIAL # 11-1 LOCATION 2-7
 SCOPE DIAMETER 1.50 IN. AREA 17.37 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2.0 IN.
 YIELD STRENGTH 116,000 PSI
 TENSILE STRENGTH 163,000 PSI
 FINAL DIAMETER 0.50 IN. MIN. AREA 0.78 SQ. IN.
 REDUCTION AREA 55.6 %
 ELONGATION 11.0 %

72-32.4



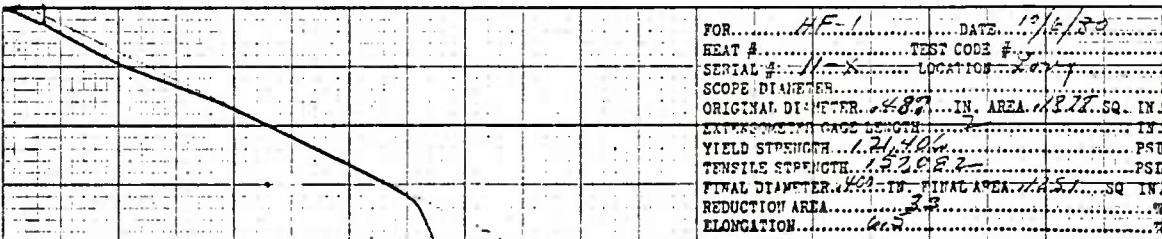
10,000

HF-1 11-1 2-7

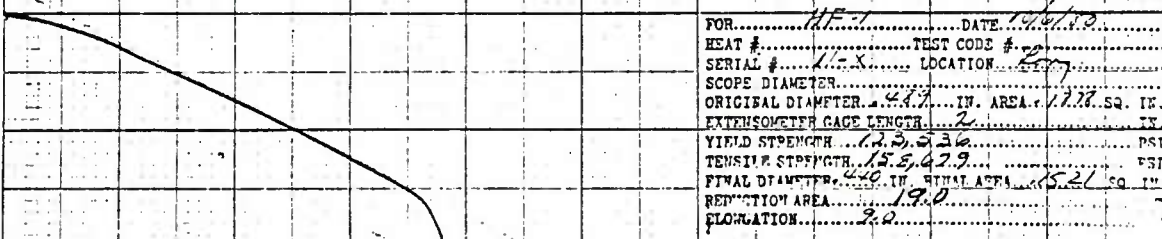
1500F 24in 140° 1125F 24in

24/30 30/30

6/100



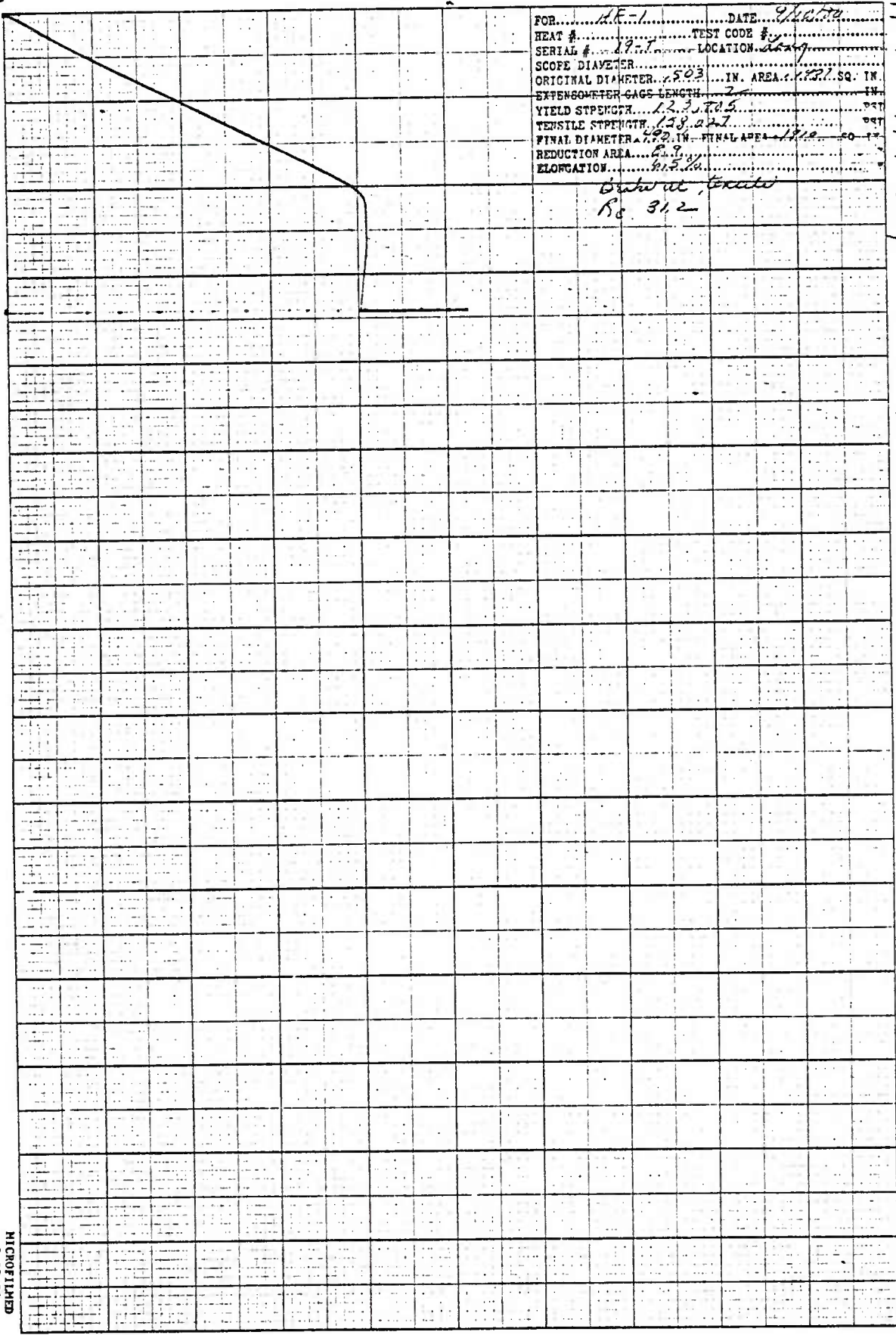
HF-1 11-X Long. Btth 1520°F Also tested 1150°F Also



60.000
 HF-1 19-T 1500°F 3000 8000 1400°F 1335°F 3000.

FOR.....*HF-1*.....DATE.....*9/20/74*
 HEAT #.....TEST CODE #.....
 SERIAL #.....*19-T*.....LOCATION.....*avg*
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....*5.03*.....IN. AREA.....*1.27* SQ. IN.
 EXTENSOMETER GAGE LENGTH.....*2*.....IN.
 YIELD STRENGTH.....*123,805*.....PSI
 TENSILE STRENGTH.....*128,027*.....PSI
 FINAL DIAMETER.....*7.82* IN. FINAL AREA.....*1.11* SQ. IN.
 REDUCTION AREA.....*6.89*.....
 ELONGATION.....*61.5*.....%

break at tensile
R₀ 31.2



30000
1

60,000

HF-1 19-C 800
1500°F 9Kilo
all oil 140°F 1125°F 2Kilo

FOR.....*HF-1*.....DATE.....*9-10-70*.....
HEAT #.....TEST CODE #.....
SERIAL #.....*19-C*.....LOCATION.....*Long*.....
SCOPE DIAMETER.....
ORIGINAL DIAMETER.....*5.02*.....IN. AREA.....*19.7* SQ. IN.
EXTENSOMETER GAGE LENGTH.....IN.
YIELD STRENGTH.....*123,305*.....PSI
TENSILE STRENGTH.....*160,000*.....PSI
FINAL DIAMETER.....*4.58* IN. MIN. AREA.....*16.4* SQ. IN.
REDUCTION AREA.....*17.6*.....%
ELONGATION.....*25.4*.....%

R_e 31.9

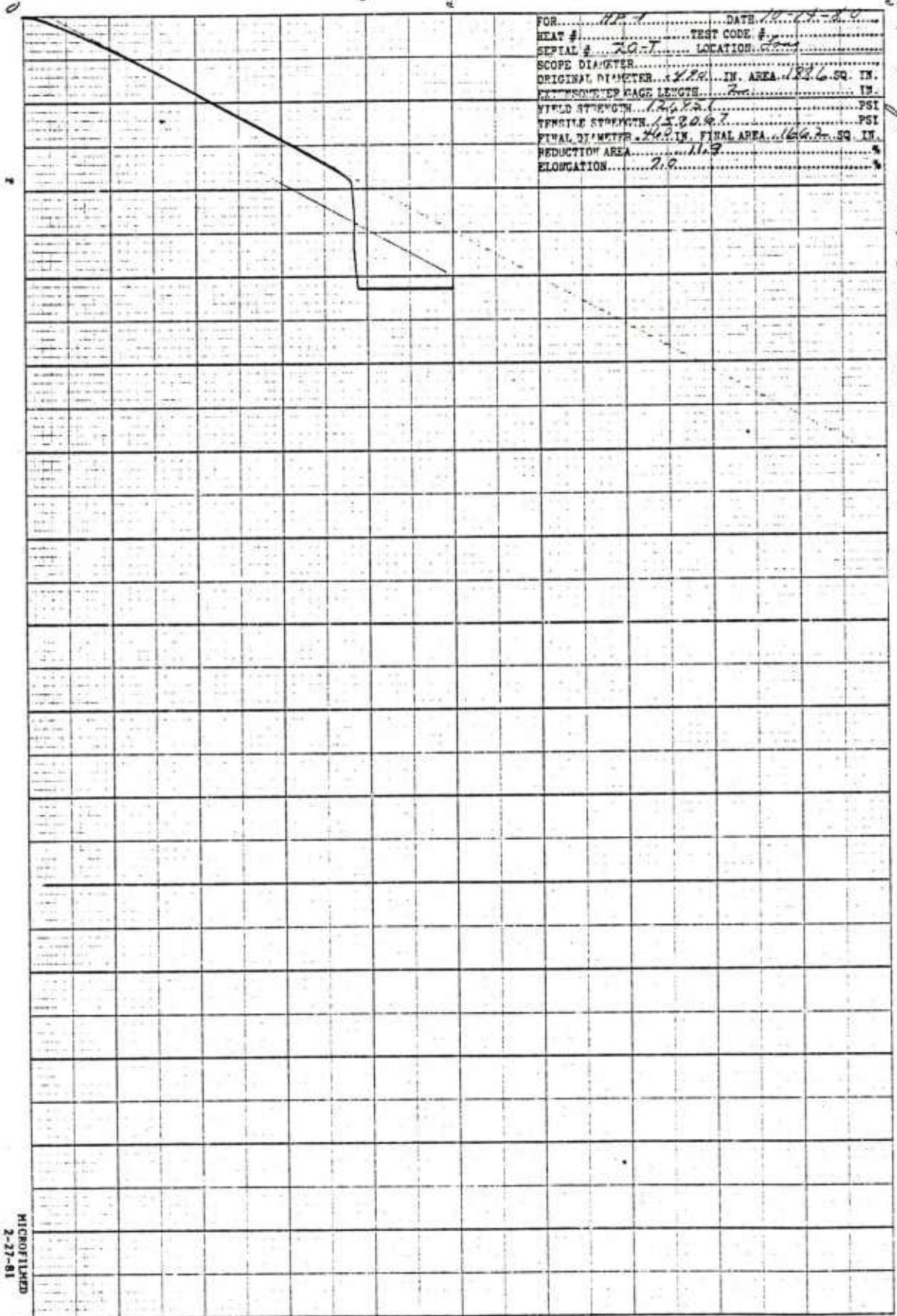
FOR.....(HF-1).....DATE.....9/10/70.....
HEAT #.....TEST CODE #.....
SERIAL #.....178.....LOCATION.....K-27.....
SCOPE DIAMETER.....
ORIGINAL DIAMETER.....50.3.....IN. AREA.....1977.56 SQ. IN.
EXTENSOMETER GAGE LENGTH.....IN.
YIELD STRENGTH.....130,282.....PSI
TENSILE STRENGTH.....157,921.....PSI
FINAL DIAMETER.....43.1 IN. FINAL AREA.....1466 SQ. IN.
REDUCTION AREA.....26.1.....
ELONGATION.....12.9%.....

Rc 309

60910 HF-1 19-X-Ring
15000F 27Ks
at load 1400F 11250F 27Ks

20-T Temp. 1570°F above 150°F 1135°F above 150°F

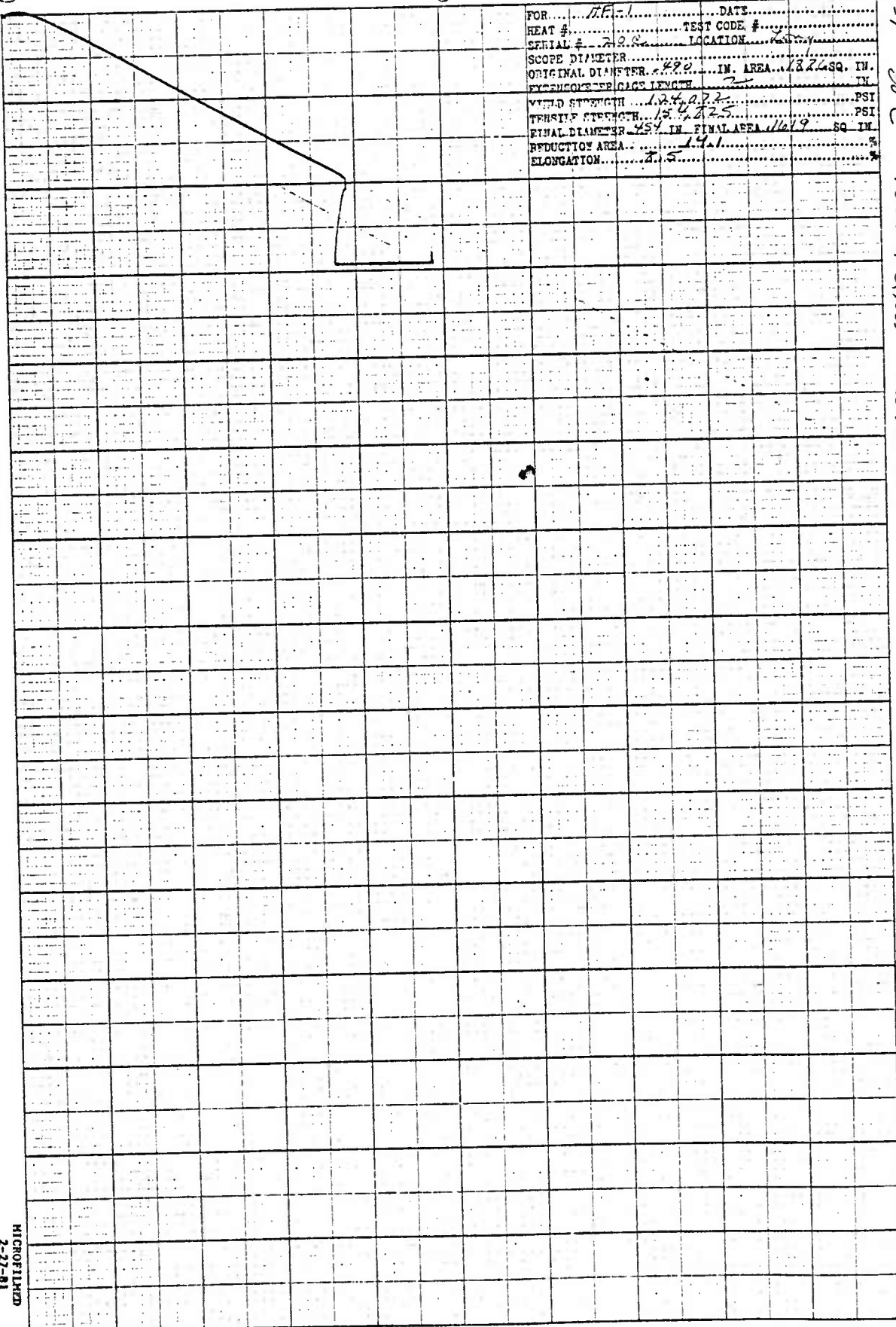
FOR.....*RP-1*.....DATE.....*11-24-80*
HEAT #.....TEST CODE #.....
SERIAL #.....*20-T*.....LOCATION.....
SCOPE DIAMETER.....
ORIGINAL DIAMETER.....*1.22* IN. AREA.....*1.16* SQ. IN.
EXTENDED GAGE LENGTH.....*2* IN.
YIELD STRENGTH.....*124,821* PSI
TENSILE STRENGTH.....*153,097* PSI
FINAL DIAMETER.....*0.6* IN. FINAL AREA.....*0.28* SQ. IN.
REDUCTION AREA.....*11.3*
ELONGATION.....*2.9*



39,120

60,000
 HF-1 30 C 1500° F 2 hrs
 6000 150° F
 1125° F 2 hrs

FOR... HF-1 ... DATE...
 HEAT #... 222 ... TEST CODE #...
 SERIAL #... 222 ... LOCATION...
 SCOPE DIAMETER... 4.20 ... IN. AREA... 13.26 SQ. IN.
 ORIGINAL DIAMETER... 4.20 ... IN. AREA... 13.26 SQ. IN.
 EXTENSION OF GAGE LENGTH... 2 ... IN.
 YIELD STRENGTH... 124,000 ... PSI
 TENSILE STRENGTH... 154,000 ... PSI
 FINAL DIAMETER... 4.54 ... IN. FINAL AREA... 16.19 ... SQ. IN.
 REDUCTION AREA... 1.91 ... %
 ELONGATION... 2.5 ... %

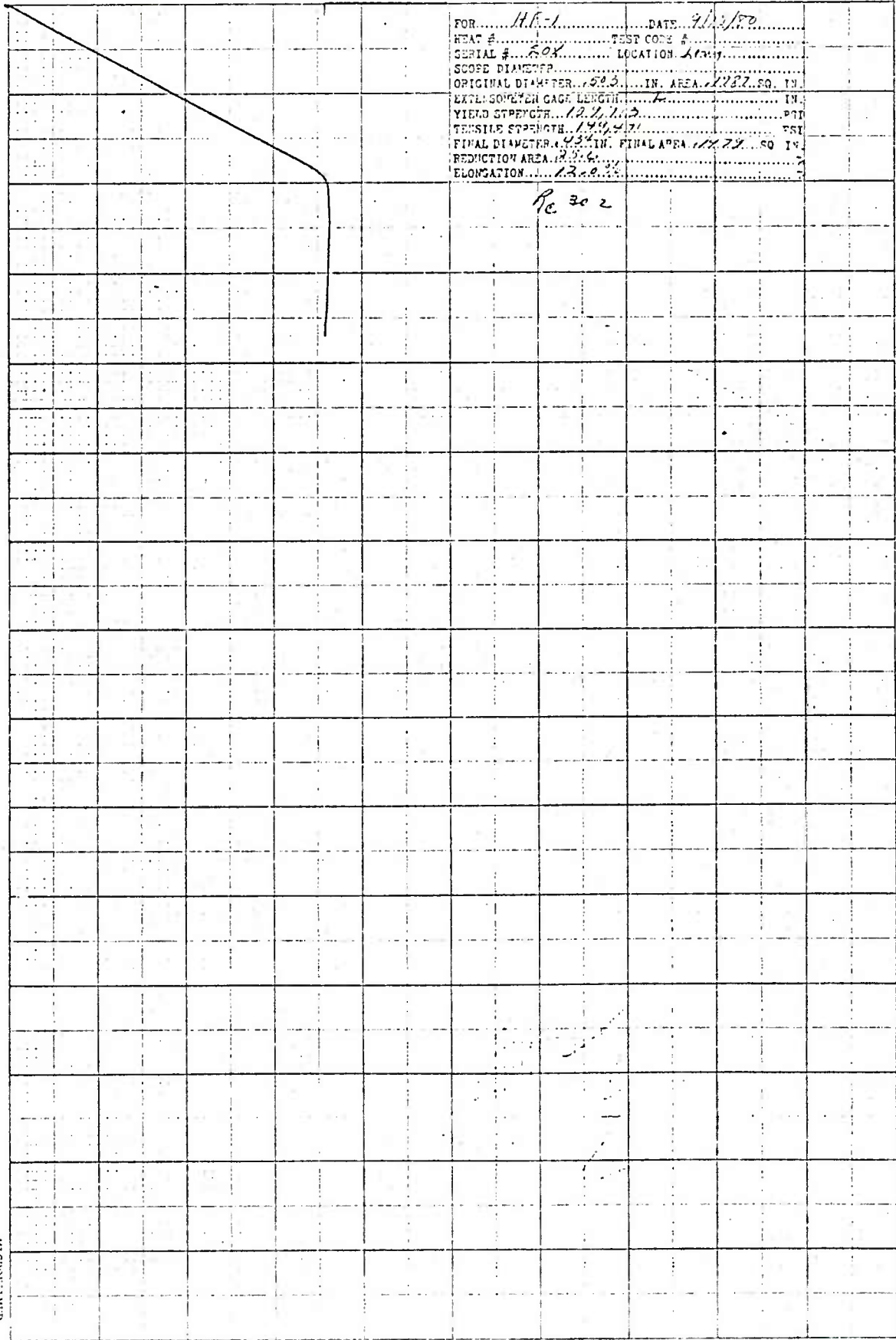


MICROFILMED
 2-27-81

20 X 1/2" HF-1
 1530°F
 1530°F
 1175°F 2Hw

FOR H.F.-1 DATE 9/12/80
 HEAT # 804 TEST CODE # 10010
 SERIAL # 804 LOCATION 10010
 SCOPE DIAMETER 1.00 IN. AREA 0.785 SQ. IN.
 EXTENSION GAGE LENGTH 1.00 IN.
 YIELD STRENGTH 100 PSI
 TENSILE STRENGTH 100 PSI
 FINAL DIAMETER 0.78 IN. FINAL AREA 0.47 SQ. IN.
 REDUCTION AREA 41.4 %
 ELONGATION 13.0 %

Pc 302



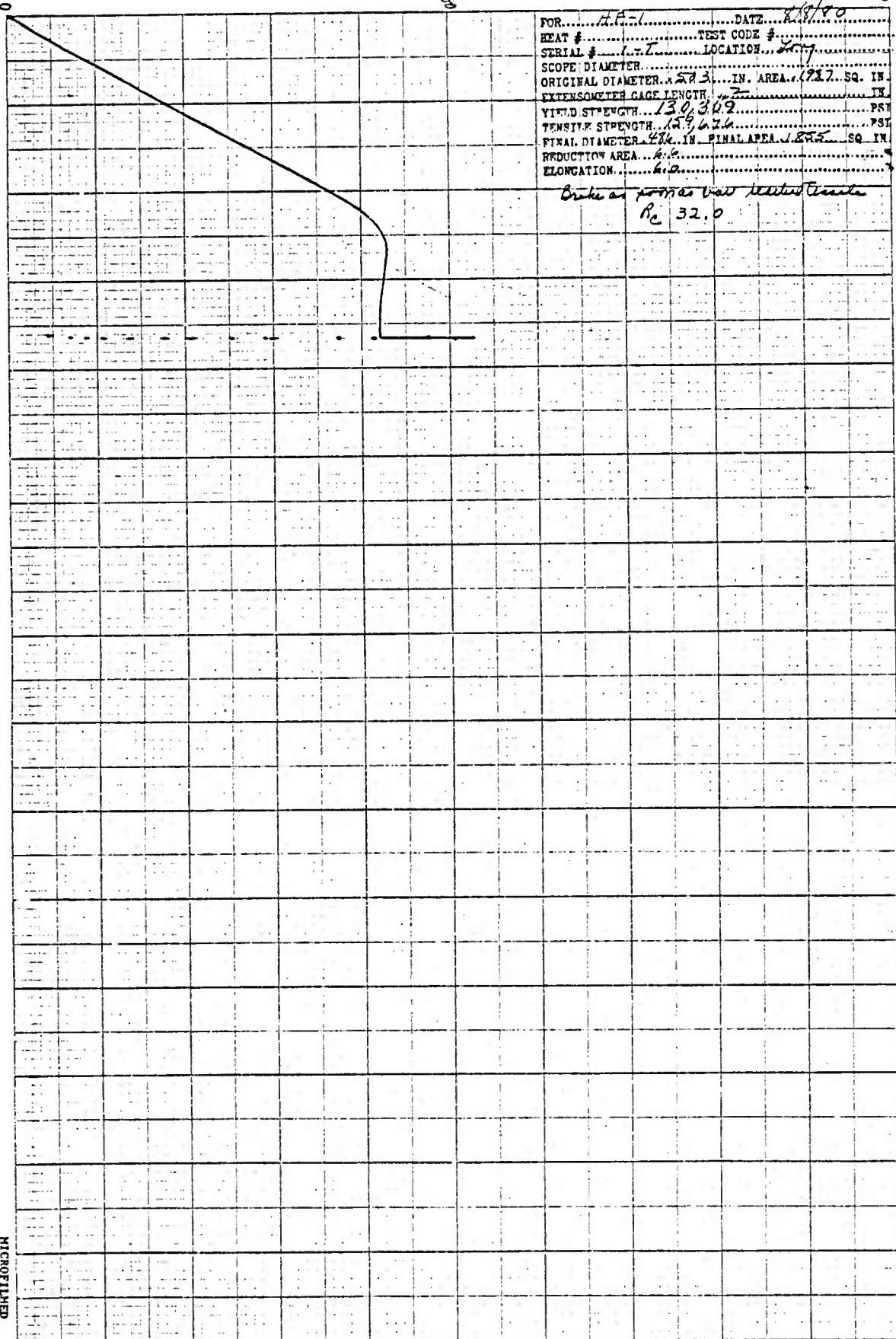
30,000

50,000

FOR Heat DATE 2/19/90
 HEAT # 1-1 TEST CODE # 207
 SERIAL # 1-1 LOCATION 207
 SCOPE DIAMETER 2.3 IN. AREA 17.2 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 130,309 PSI
 TENSILE STRENGTH 129,626 PSI
 FINAL DIAMETER 1.8 IN. FINAL AREA 1.8 SQ. IN.
 REDUCTION AREA 6.6
 ELONGATION 6.2

Brake as per as used tested tensile
 R_c 32.0

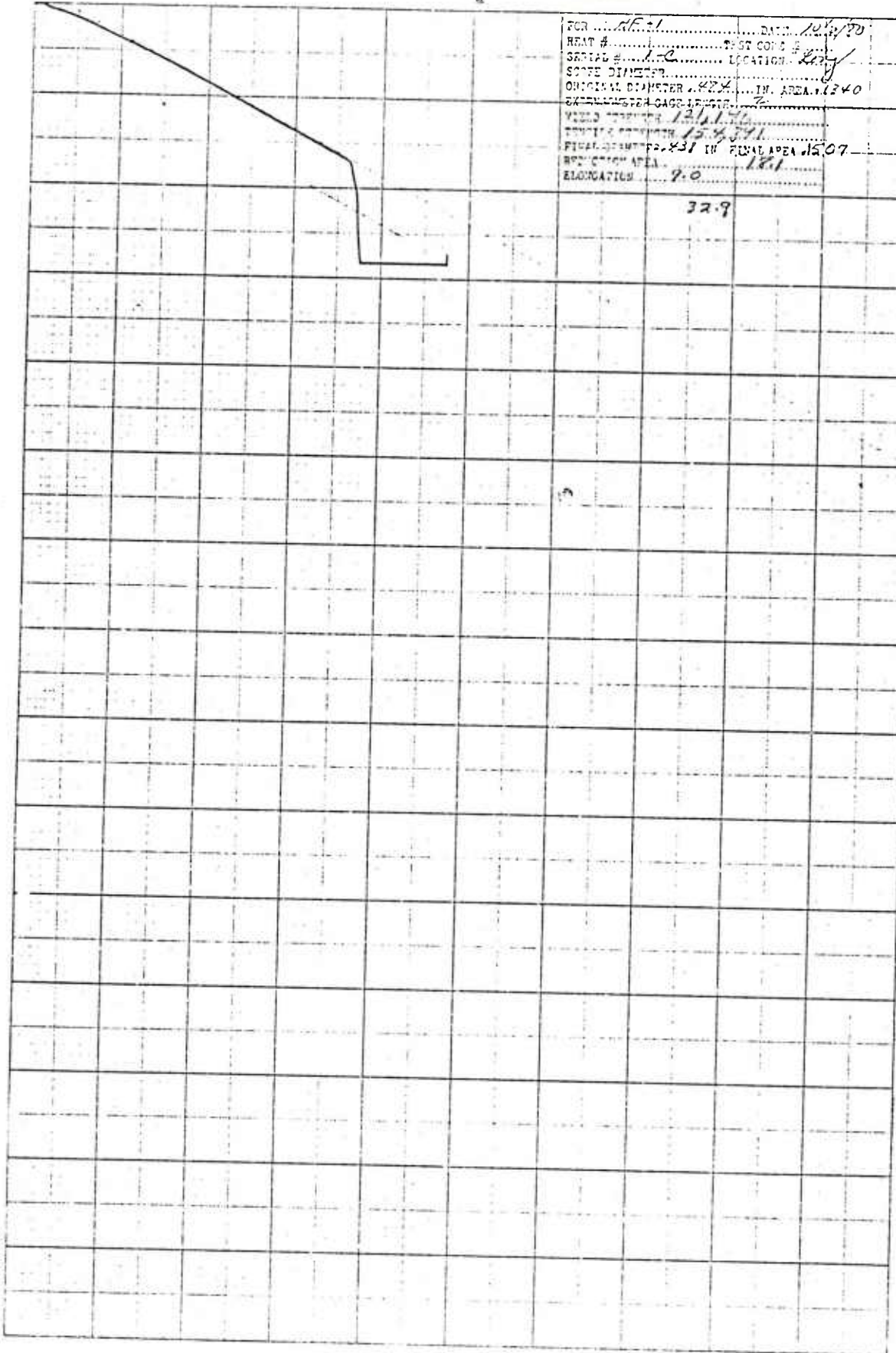
HF-1 1-T 1500°F 2 hrs oil 150° 11750°F 2 hrs



HF-1 1-C Long Bar 1533°F 2hr 11:35°F 2hr

FOR ...
 HEAT # ...
 SERIAL # ...
 SPEC. DIAMETER ...
 ORIGINAL DIAMETER ...
 EXTENDED DIAMETER ...
 YIELD STRENGTH ...
 TENSILE STRENGTH ...
 FINAL DIAMETER ...
 REDUCTION AREA ...
 ELONGATION ...

32.9

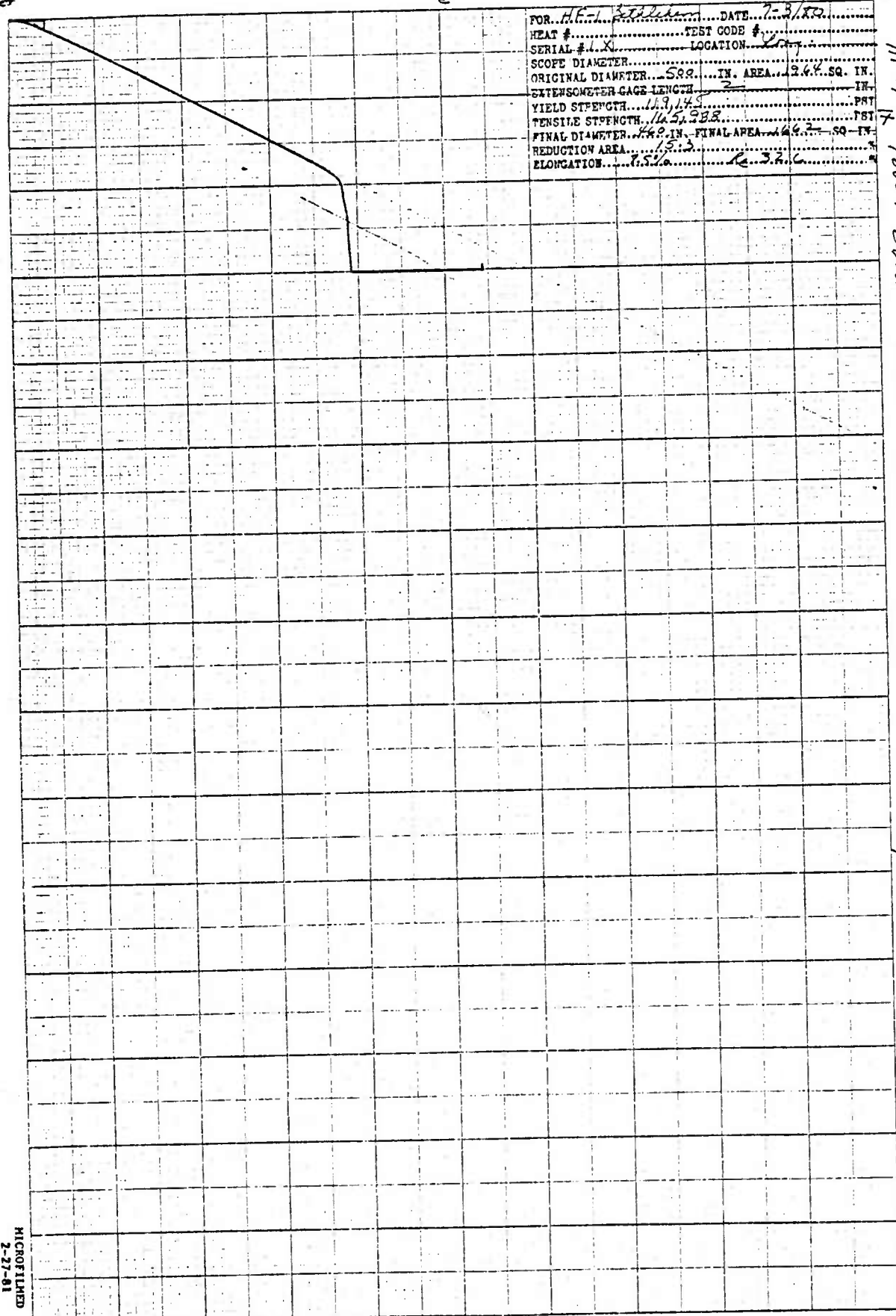


3.00

60,000

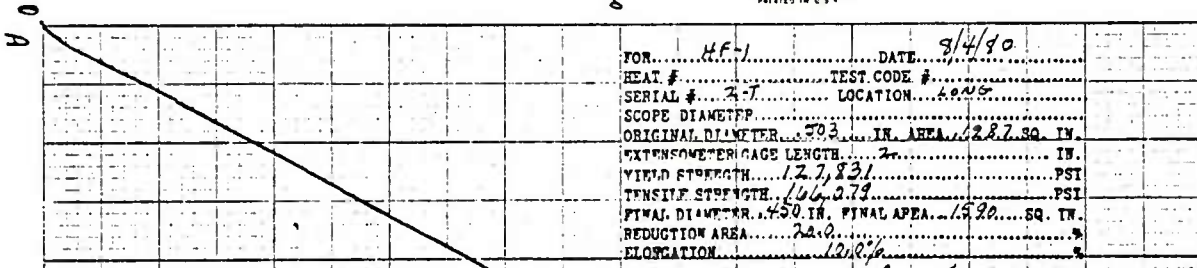
FOR *HF-1 Steel* DATE *7-8-52*
 HEAT # *1* TEST CODE # *1*
 SERIAL # *1* LOCATION *1*
 SCOPE DIAMETER *5.88* IN. AREA *2.47* SQ. IN.
 ORIGINAL DIAMETER *5.88* IN. AREA *2.47* SQ. IN.
 EXTENSOMETER GAGE LENGTH *2* IN.
 YIELD STRENGTH *11.9* KSI
 TENSILE STRENGTH *16.5* KSI
 FINAL DIAMETER *4.8* IN. FINAL AREA *1.46* SQ. IN.
 REDUCTION AREA *15.3* %
 ELONGATION *7.5* %

HF-1 1500°F 2hr steel 150°F 1125°F 2hr Long. Steel



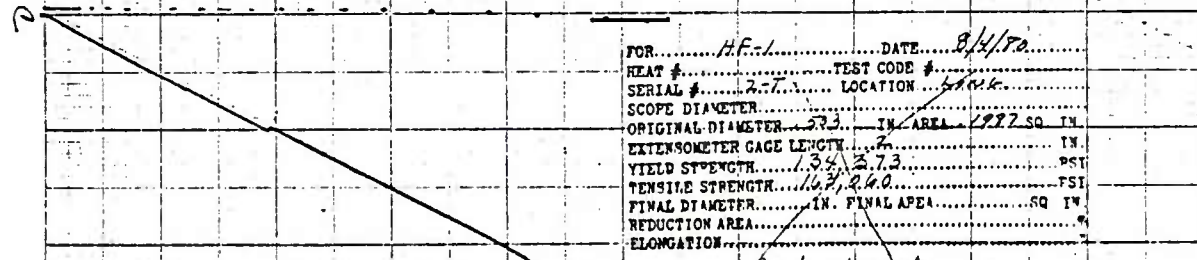
30,000

60,000



Re 31.8

HF-1 2T Both Sides. 1500°F. Air 1500°F. Air 1175°F. Air



Break at neck
Re 33.7

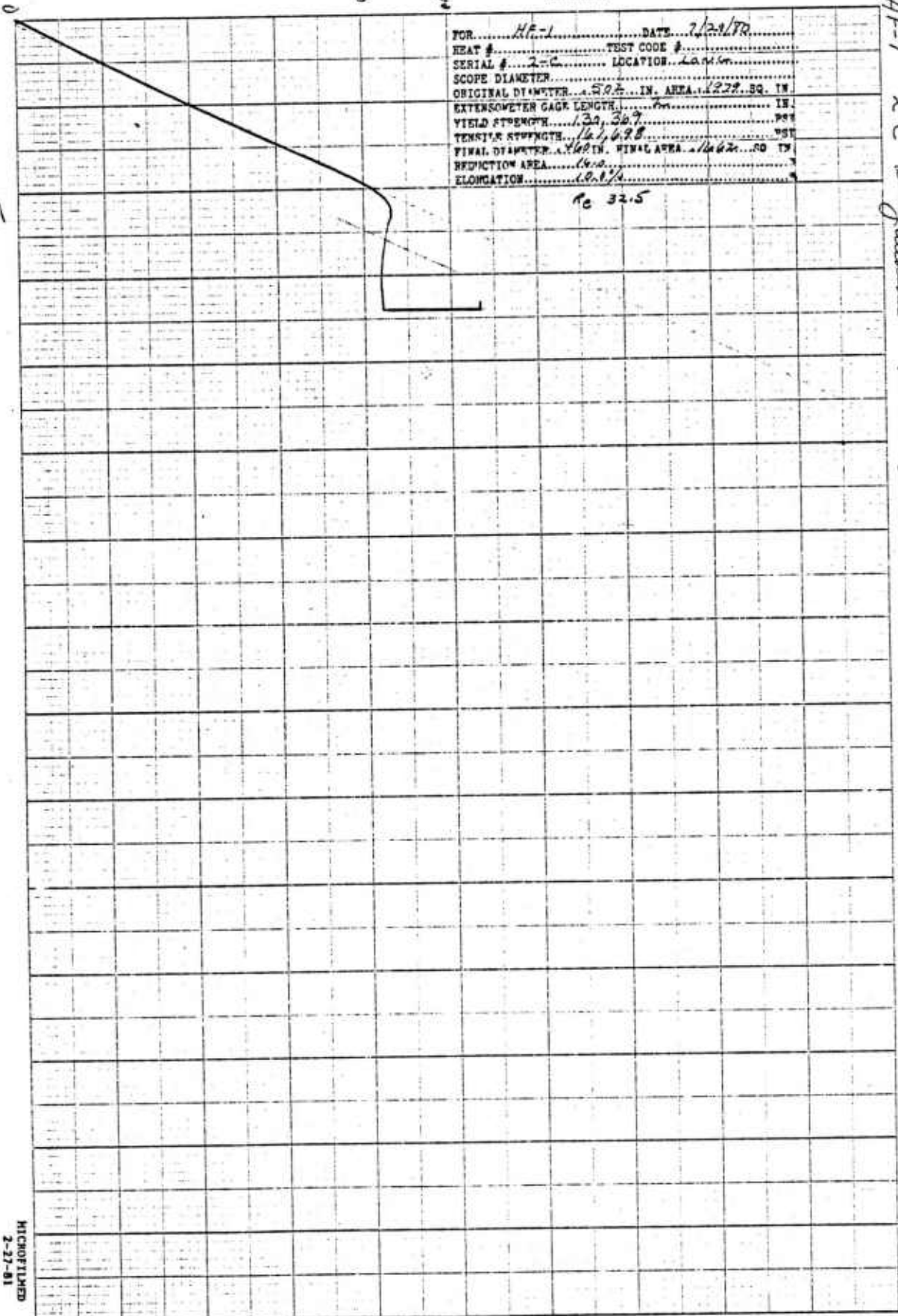
24,000

30,000

60,000
 HF-1 20 longitudinal 1500°F 24u Me. 0.2 1400°F 1125°F 24u

FOR HF-1 DATE 7/24/72
 HEAT # 2-C TEST CODE # 2-C
 SERIAL # 2-C LOCATION 2-C
 SCOPE DIAMETER 5.05 IN. AREA 222.50 IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 32.5 PSI
 TENSILE STRENGTH 161,698 PSI
 FINAL DIAMETER 4.60 IN. FINAL AREA 166.2 SQ IN.
 REDUCTION AREA 26.3
 ELONGATION 60.1%

R_e 32.5



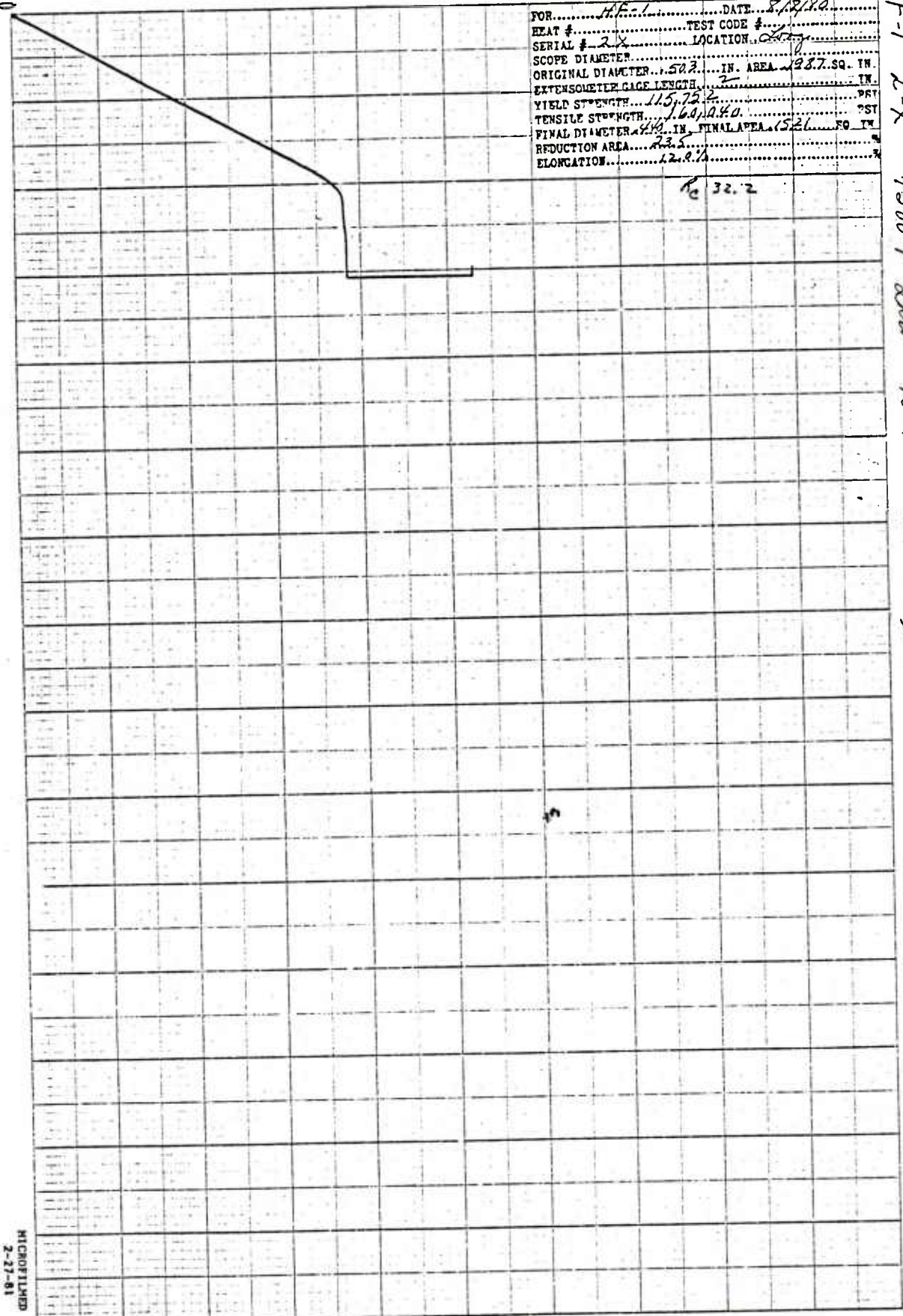
30,000

60,000

HF-1 2-X 1500°F 2Hrs 150°F 1135°F 2Hrs

FOR...*HF-1*...DATE...*8/18/70*...
 HEAT #...*2X*...TEST CODE #...*2*...
 SERIAL #...*2X*...LOCATION...*2X*...
 SCOPE DIAMETER...*1.502*...IN. AREA...*1987*...SQ. IN.
 ORIGINAL DIAMETER...*1.502*...IN. AREA...*1987*...SQ. IN.
 EXTENSOMETER GAGE LENGTH...*2*...IN.
 YIELD STRENGTH...*115,750*...PSI
 TENSILE STRENGTH...*164,040*...PSI
 FINAL DIAMETER...*1.492*...IN. FINAL AREA...*1526*...SQ. IN.
 REDUCTION AREA...*23.2*...%
 ELONGATION...*12.8*...%

R_e 32.2



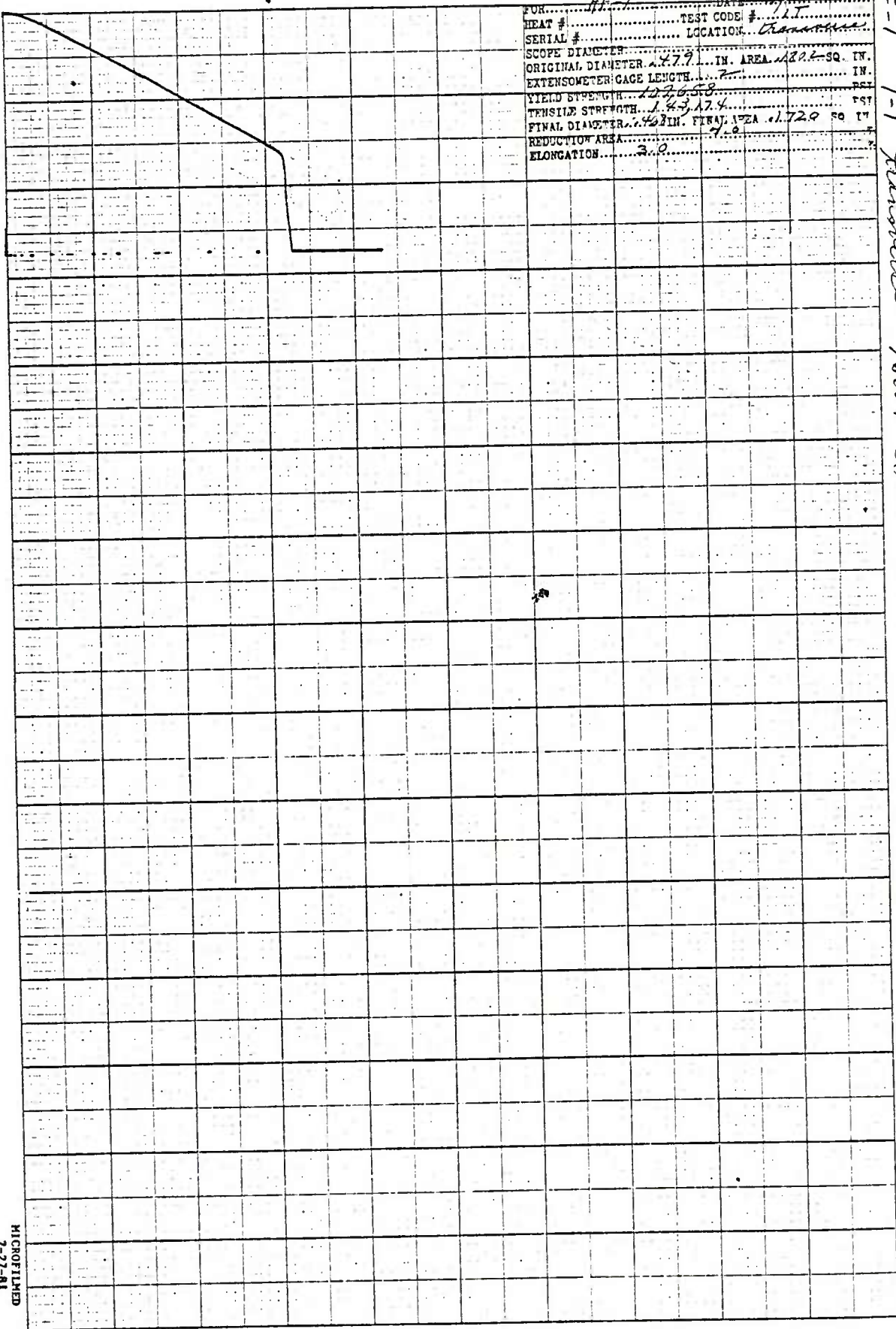
FOR... *HF-1* ... DATE *9/25/80*
 HEAT #... *10-1* ... TEST CODE #...
 SPECIAL #... *10-1* ... LOCATION...
 SCOPE DIAMETER...
 ORIGINAL DIAMETER... *4.91* ... IN. AREA... *18.93*
 EXTENSION OF GAGE LENGTH... *2*
 TENSILE STRENGTH... *124,913*
 TENSILE STRENGTH... *15,715.33*
 FINAL DIAMETER... *4.58* IN. FINAL AREA... *16.47*
 REDUCTION AREA... *13.0*
 ELONGATION... *20.0*

FOR... *HF-1* ... DATE *7/25/80*
 HEAT #...
 SPECIAL #... *10-1* ... LOCATION...
 SCOPE DIAMETER...
 ORIGINAL DIAMETER... *4.91* ... IN. AREA... *18.93*
 EXTENSION OF GAGE LENGTH... *2*
 TENSILE STRENGTH... *119,557*
 TENSILE STRENGTH... *14,448*
 FINAL DIAMETER... *4.36* IN. FINAL AREA... *14.93*
 REDUCTION AREA... *13.7*
 ELONGATION... *20.0*

*HF-1 10-1 10-1 1500°F 3400
 1500°F 3400
 1125°F 3400*

HF-1 1-T Transducer 1500°F 2kva old and 160°F 1105°F 2kva

FOR... HF-1... DATE... 11/11/70
 HEAT #... TEST CODE #... 1-T
 SERIAL #... LOCATION... Transducer
 SCOPE DIAMETER...
 ORIGINAL DIAMETER... 4.77 IN. AREA... 179.2 SQ. IN.
 EXTENSOMETER GAGE LENGTH... 2 IN.
 YIELD STRENGTH... 127,658 PSI
 TENSILE STRENGTH... 143,174 PSI
 FINAL DIAMETER... 2.43 IN. FINAL AREA... 1.729 SQ IN
 REDUCTION AREA... 7.8
 ELONGATION... 3.0



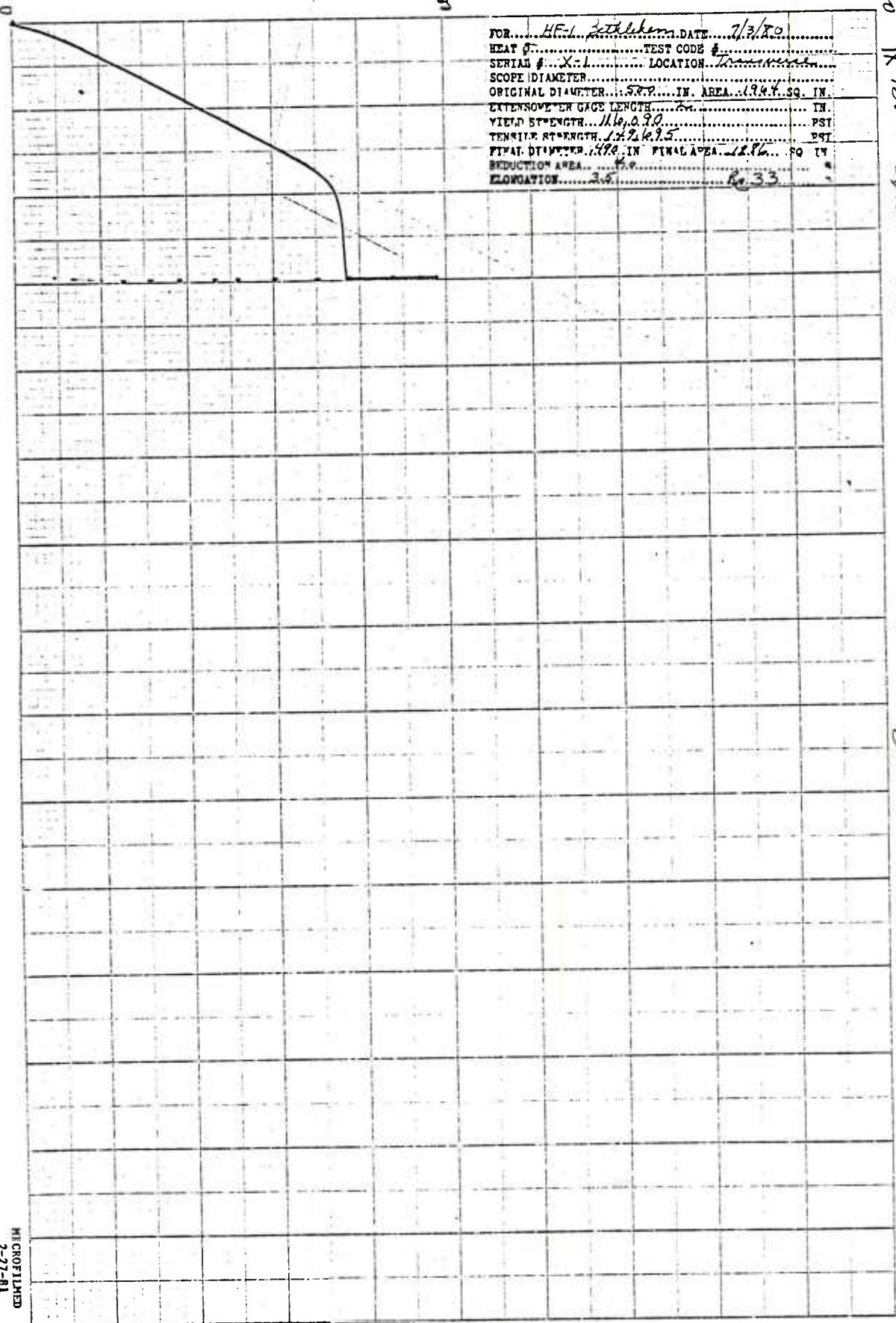
MICROFILMED 23
 2-27-81

30,000

FOR HE-1 DATE 1/29/60
HEAT # 1-C TEST CODE #
SERIAL # LOCATION PERMANENT
SCOPE DIAMETER
ORIGINAL DIAMETER 500 IN. AREA 194 SQ. IN.
LATHEMETER GAGE LENGTH 2 IN.
YIELD STRENGTH 123,182 PSI
TENSILE STRENGTH 127,820 PSI
FINAL DIAMETER 474 IN. FINAL AREA 1917 SQ. IN.
REDUCTION AREA 1.7 %
ELONGATION 2.0 %

R_c	32.7
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[illegible]

[illegible]

FOR HF-1 3000 DATE 7/3/80
HEAT # TEST CODE #
SERIAL # X-1 LOCATION Transverse
SCOPE DIAMETER
ORIGINAL DIAMETER 307.7 IN. AREA 1844.59 IN.
EXTENSIONER GAGE LENGTH 24 IN.
YIELD STRENGTH 116,000 PSI
TENSILE STRENGTH 122,825 PSI
FITUP DIAMETER 499.0 IN. FINAL AREA 1216 SQ IN
REDUCTION AREA 4.9
ELONGATION 24 633

60,000

2-110

30,000

FOR HF-1 DATE 9-25-80
 HEAT # 1 TEST CODE # 1
 SERIAL # 1 LOCATION 1
 SCOPE DIAMETER 1.464 IN. AREA 18.22 SQ. IN.
 ORIGINAL DIAMETER 1.464 IN. AREA 18.22 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 129,716 PSI
 TENSILE STRENGTH 142,707 PSI
 FINAL DIAMETER 1.468 IN. FINAL AREA 18.29 SQ. IN.
 REDUCTION AREA 1.3
 ELONGATION 2.5

$R_c = 27.5$

FOR HF-1 DATE 9-25-80
 HEAT # 1 TEST CODE # 1
 SERIAL # 1 LOCATION 1
 SCOPE DIAMETER 1.497 IN. AREA 18.63 SQ. IN.
 ORIGINAL DIAMETER 1.497 IN. AREA 18.63 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 117,019 PSI
 TENSILE STRENGTH 140,361 PSI
 FINAL DIAMETER 1.492 IN. FINAL AREA 18.76 SQ. IN.
 REDUCTION AREA 2.5
 ELONGATION 2.5

$R_c = 29.6$

HF-1 2-7

Flareware

1550°F 2 hrs

at 150°F

1125°F 2 hrs

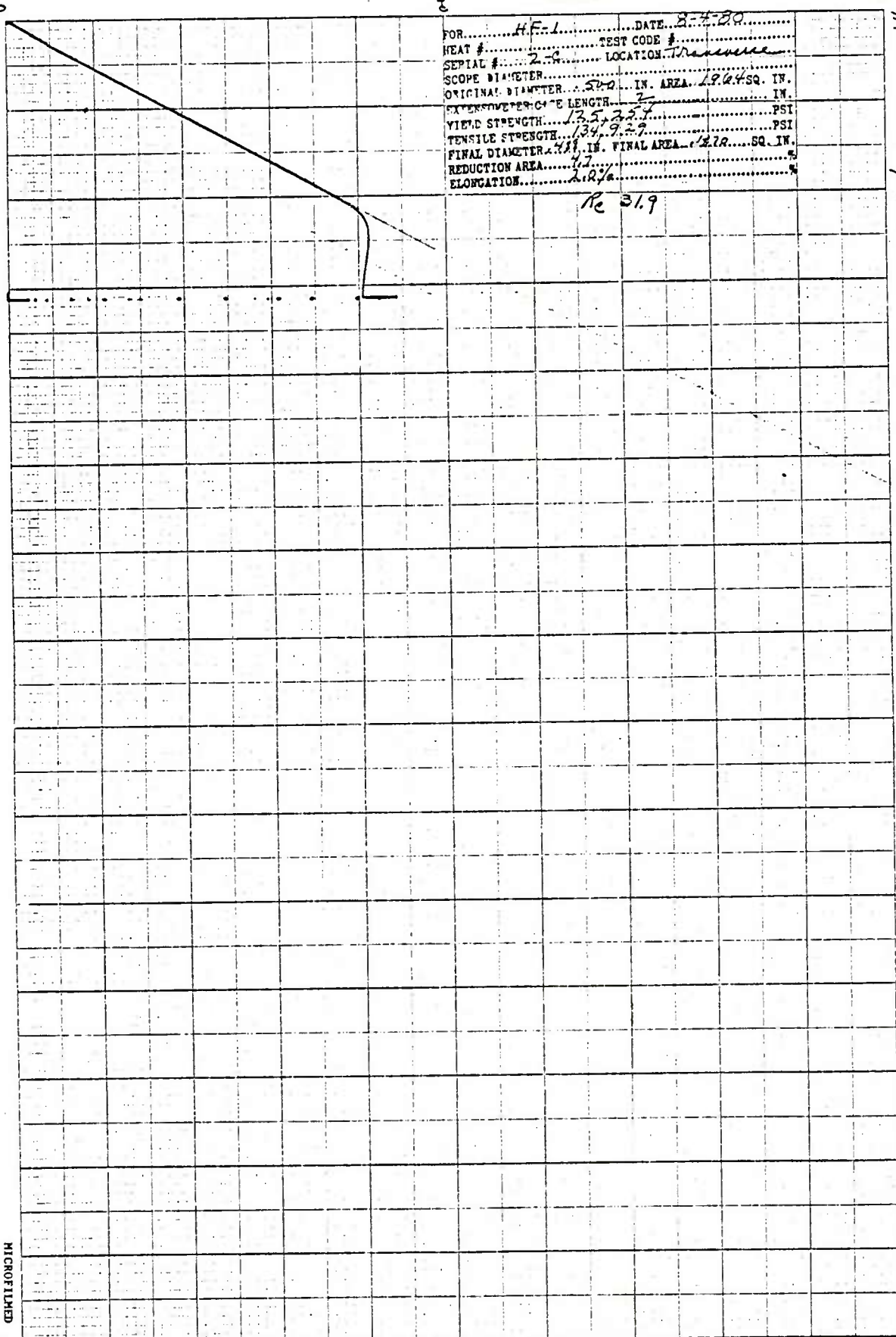
31.9

60,000

HF-1 2-C Parameter 1500°F 2hrs old and 140°F 1125°F 2hrs

FOR.....HF-1.....DATE 8-4-59.....
HEAT #.....TEST CODE #.....
SPECIAL #.....2-A.....LOCATION.....
SCOPE DIAMETER.....5/16.....IN. AREA 19.04 SQ. IN.
ORIGINAL DIAMETER.....5/16.....IN. AREA 19.04 SQ. IN.
EXTENSOMETER GAGE LENGTH.....2.....IN.
YIELD STRENGTH.....135,337.....PSI
TENSILE STRENGTH.....134,929.....PSI
FINAL DIAMETER.....4.11.....IN. FINAL AREA 13.22 SQ. IN.
REDUCTION AREA.....42.....%
ELONGATION.....2.27%.....%

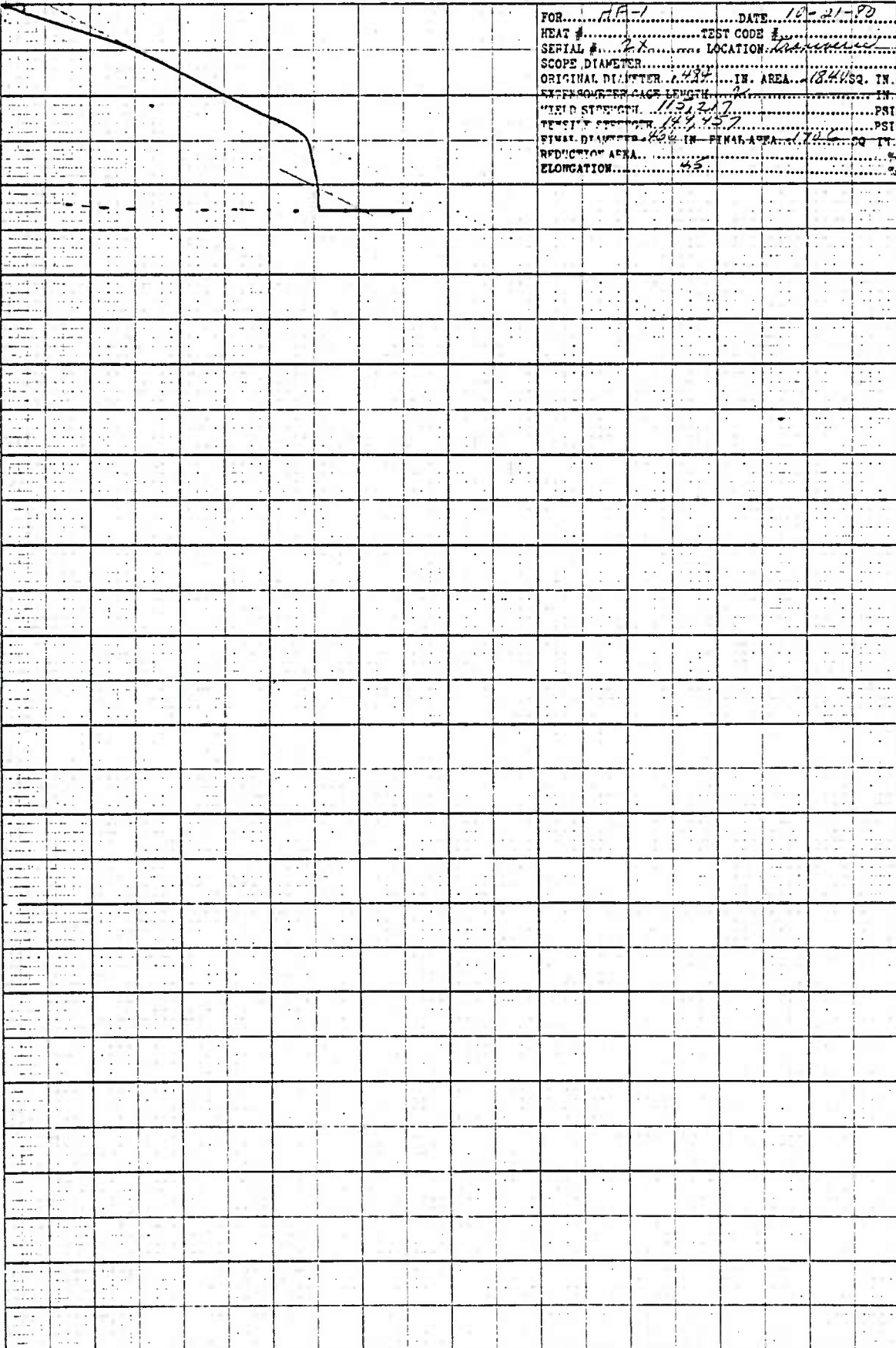
R_e 31.9



3000

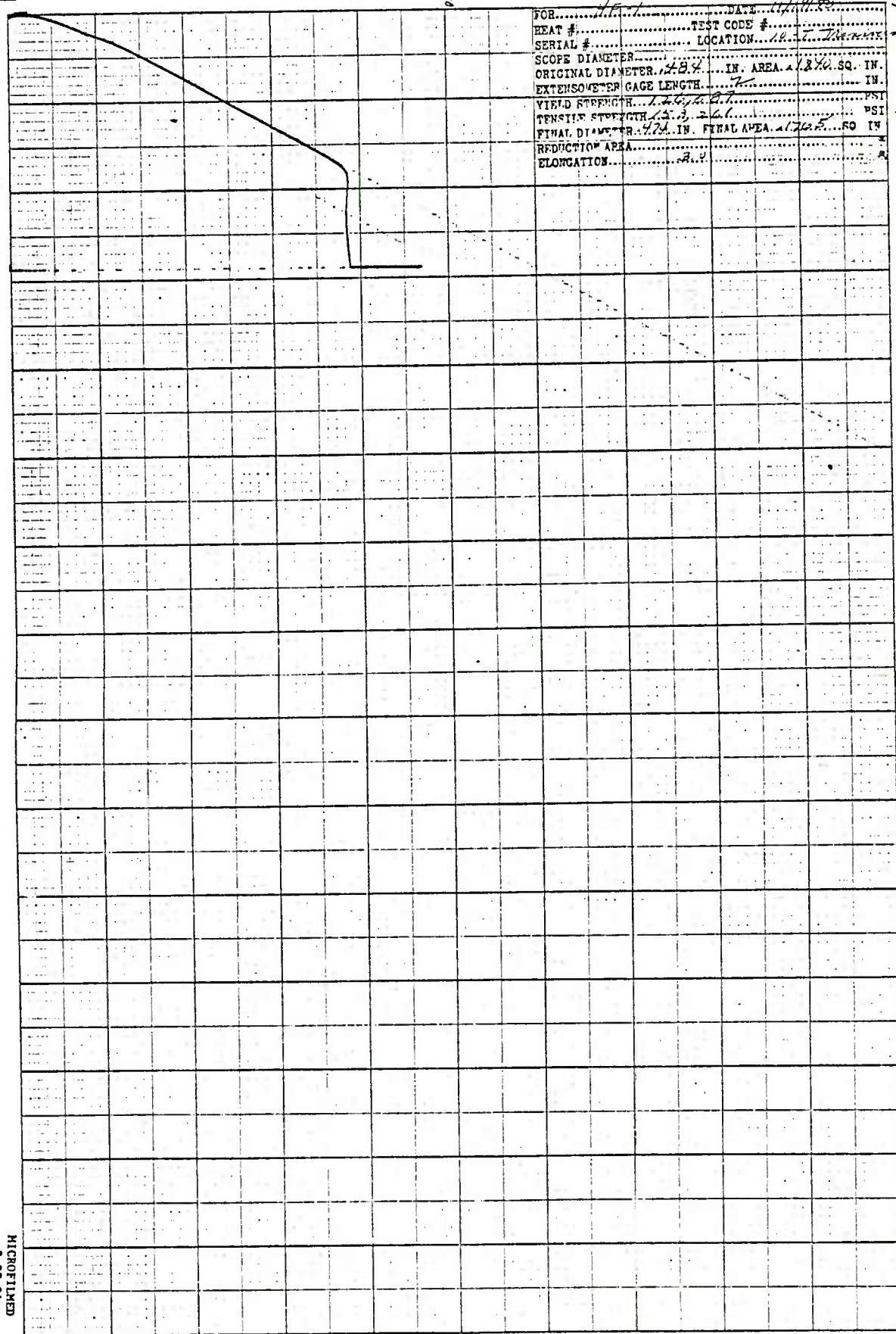
2X HF-1 Bulk 1500°F 1125°F 2X
 60000

FOR... HF-1... DATE... 10-21-90
 HEAT #... TEST CODE #...
 SERIAL #... 2X... LOCATION...
 SCOPE DIAMETER...
 ORIGINAL DIAMETER... 4.34... IN. AREA... 18.44 SQ. IN.
 EXTENSION CAGE LENGTH...
 YIELD STRENGTH... 115,247... PSI
 TENSILE STRENGTH... 128,457... PSI
 FINAL DIAMETER... 4.34... IN. FINAL AREA... 17.46... SQ. IN.
 REDUCTION AREA...
 ELONGATION... 43...



60,000
 H-F-V
 10-T
 1800°F
 2400
 2400 1400°F
 1125°F 2400

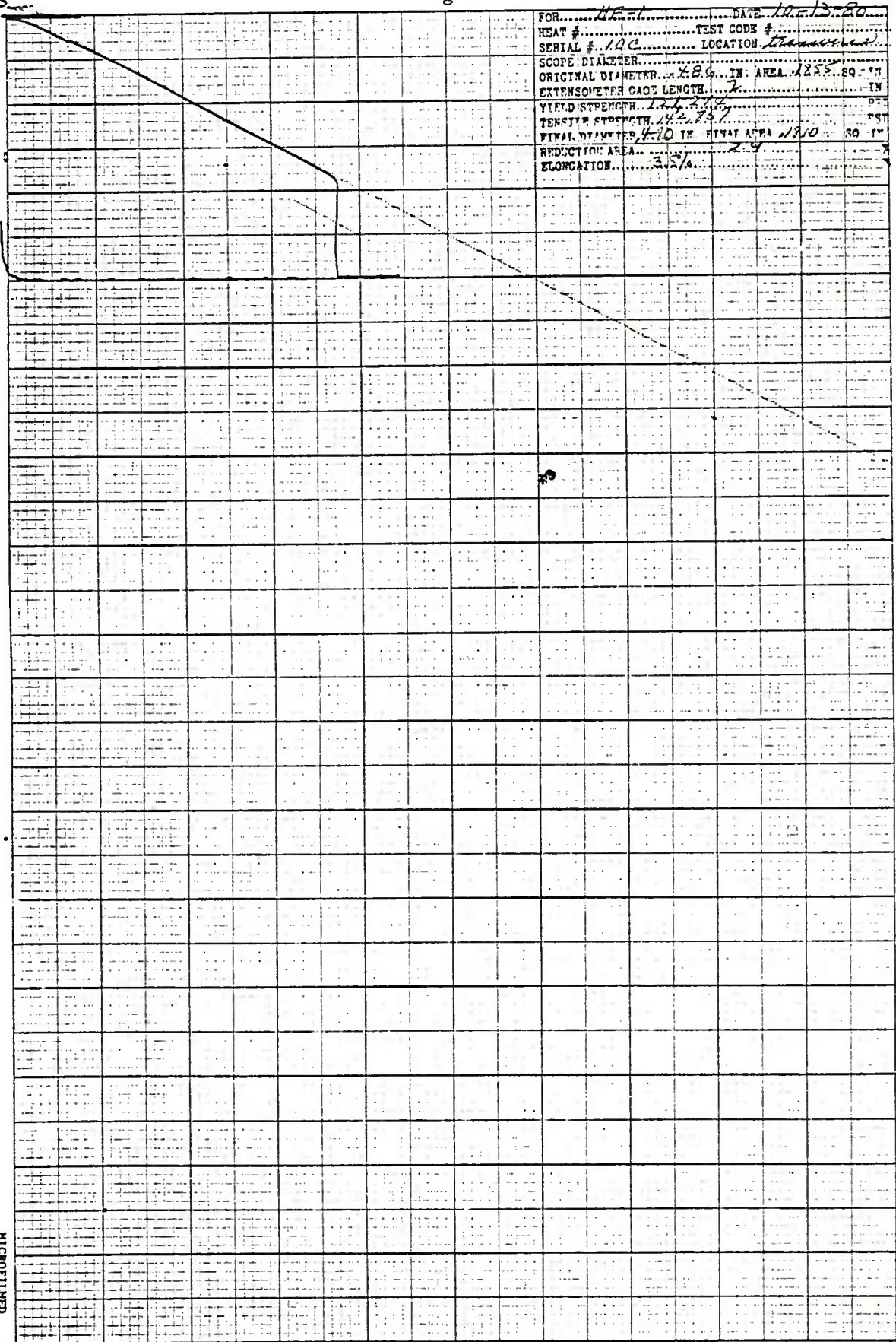
FOR...
 HEAT #...
 SERIAL #...
 SCOPE DIAMETER...
 ORIGINAL DIAMETER...
 EXTENSOMETER GAGE LENGTH...
 YIELD STRENGTH...
 TENSILE STRENGTH...
 FINAL DIAMETER...
 REDUCTION AREA...
 ELONGATION...



30000

HF-1
 60000
 Bull. 1500F 2hu all at 150F, 11750F 2hu 10C transverse

FOR... HF-1 ... DATE 10-13-80
 HEAT #... .. TEST CODE #...
 SERIAL #... 100 ... LOCATION transverse
 SCOPE DIAMETER... ..
 ORIGINAL DIAMETER... 4.89 IN. AREA... 1855.80 IN.²
 EXTENSOMETER GAGE LENGTH... 2 IN.
 YIELD STRENGTH... 142,237 PSI
 TENSILE STRENGTH... 142,237 PSI
 FINAL DIAMETER... 4.10 IN. FINAL AREA... 1310 IN.²
 REDUCTION AREA... 29 %
 ELONGATION... 35 1/8 %

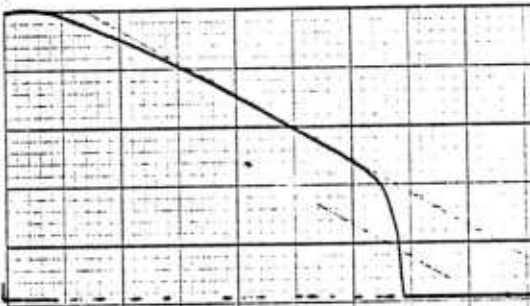


69020

HF-1
15000psi
140F
1125 F240

39.810

FOR... HF-1... DATE... 10/4/70
HEAT #... TEST CODE #...
SERIAL #... 10-X... LOCATION...
SCOPE DIAMETER...
ORIGINAL DIAMETER... 4.84... IN. AREA... 18.4 SQ. IN.
EXTENSOMETER GAGE LENGTH... 2... IN.
YIELD STRENGTH... 110,500... PSI
TENSILE STRENGTH... 143,826... PSI
FINAL DIAMETER... 4.18 IN. FINAL AREA... 17.52 SQ. IN.
REDUCTION AREA...
ELONGATION... 5.5



FOR... HF-1... DATE... 10/4/70
HEAT #... TEST CODE #...
SERIAL #... 10-X... LOCATION...
SCOPE DIAMETER...
ORIGINAL DIAMETER... 4.84... IN. AREA... 18.4 SQ. IN.
EXTENSOMETER GAGE LENGTH... 2... IN.
YIELD STRENGTH... 110,500... PSI
TENSILE STRENGTH... 143,826... PSI
FINAL DIAMETER... 4.18 IN. FINAL AREA... 17.52 SQ. IN.
REDUCTION AREA...
ELONGATION... 5.5



20.000

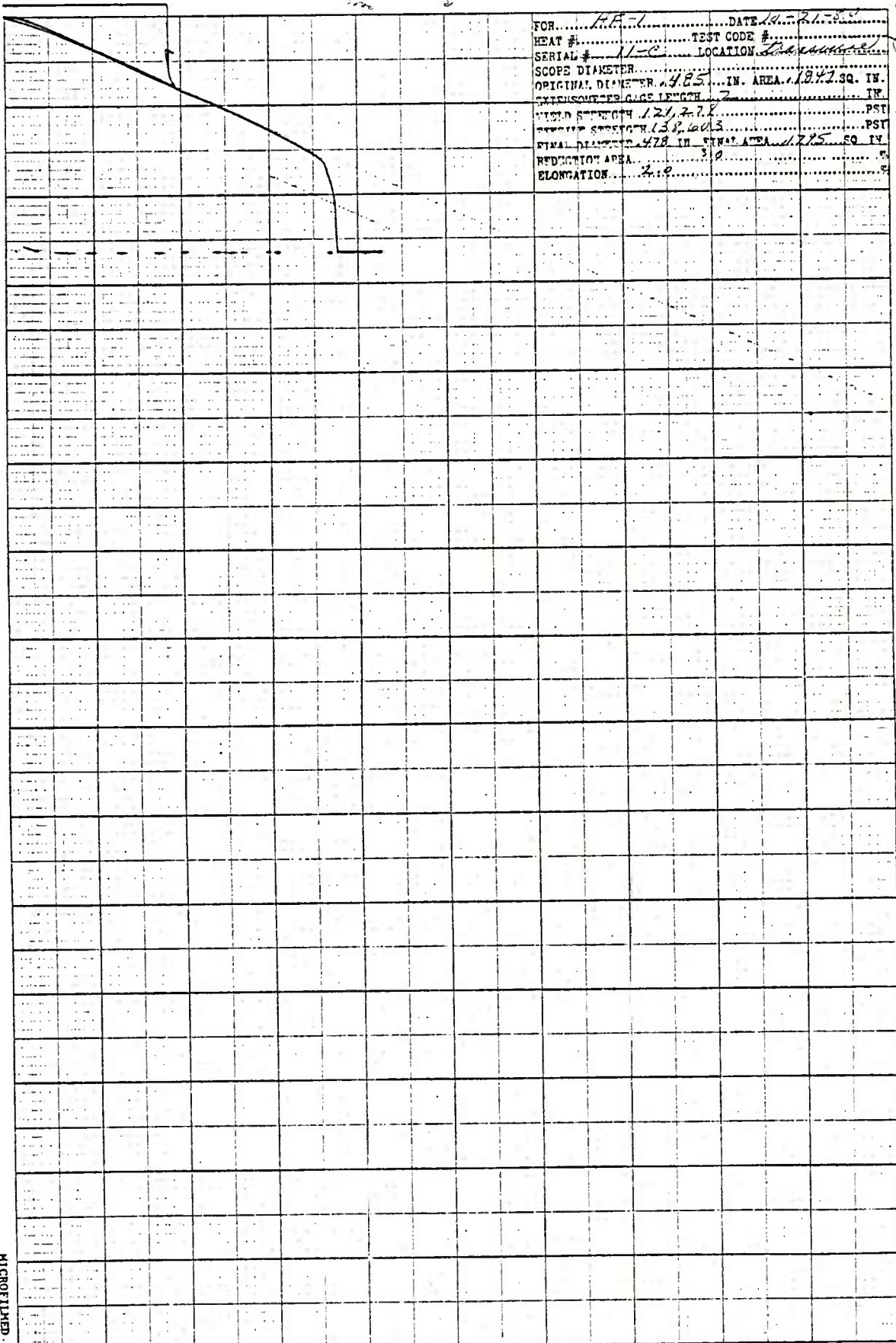
HC-1	11-T	luminescence	1500° F	2 hrs	Red and 140° F	1125° F	2 hrs
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MICROFILMED 32

11-C Ball Temperature 1500°F Shear 1125°F 2 hrs

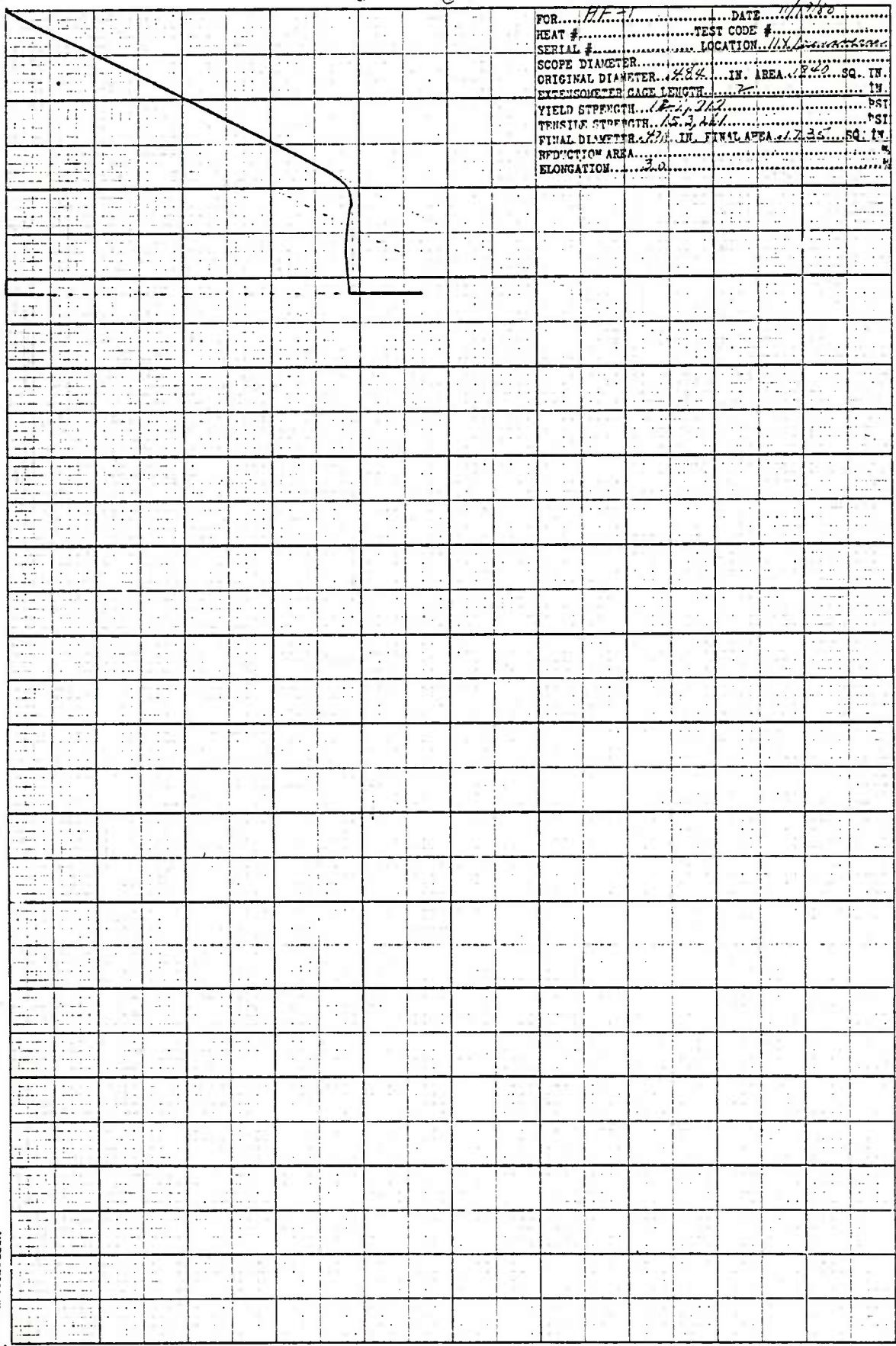
FOR HA-1 DATE 11-21-80
 HEAT # 11-C TEST CODE # 11-C
 SERIAL # 11-C LOCATION 11-C
 SCOPE DIAMETER 4.85 IN. AREA 18.47 SQ. IN.
 ORIGINAL DIAMETER 4.85 IN. AREA 18.47 SQ. IN.
 EXTENSION GAGE LENGTH 2 IN.
 YIELD STRENGTH 121,278 PSI
 TENSILE STRENGTH 138,603 PSI
 FINAL DIAMETER 4.78 IN. FINAL AREA 17.75 SQ. IN.
 REDUCTION AREA 3.9
 ELONGATION 2.9



2000
2000

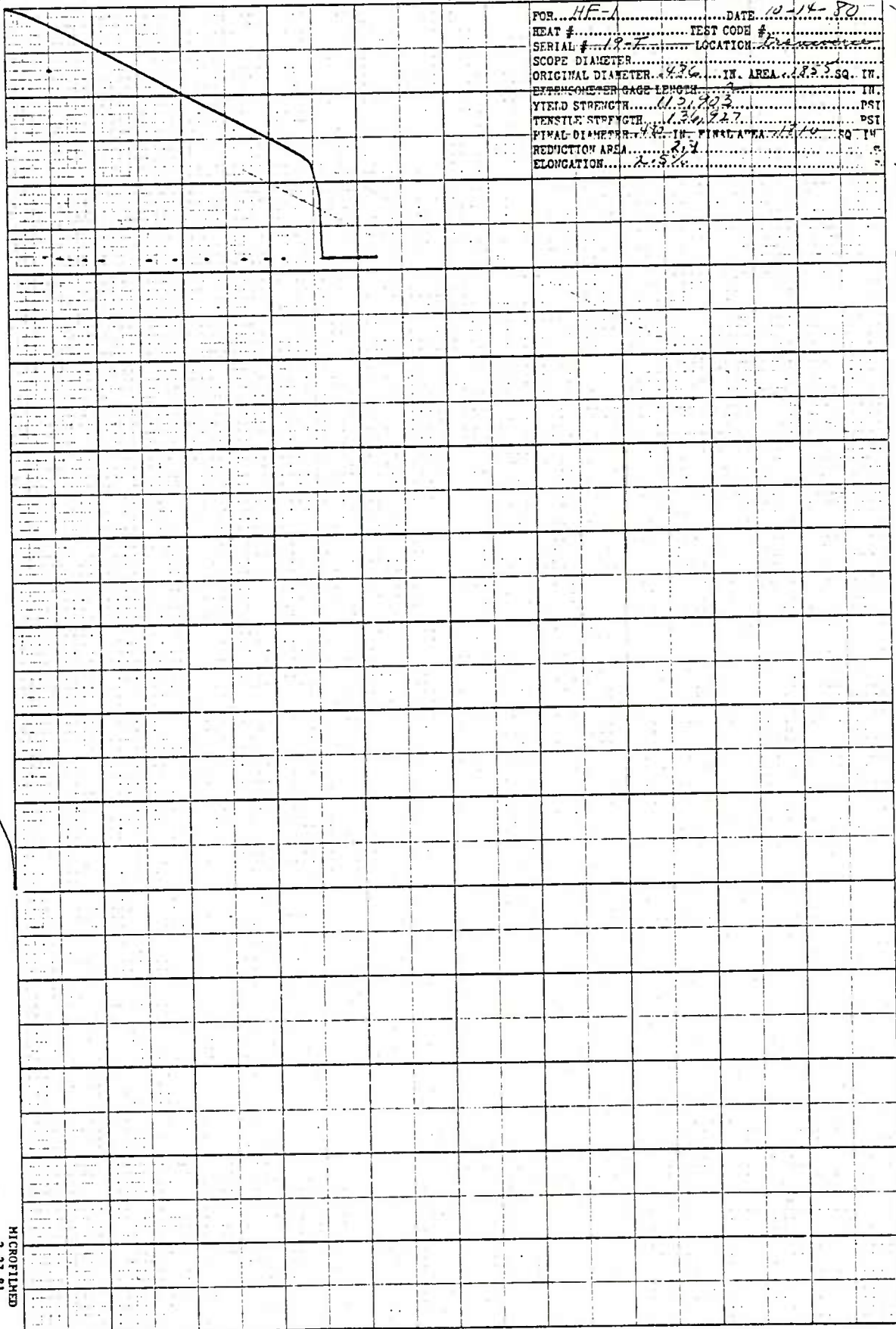
10000 11 X Bolt 15800 lbs at 140°F 11250 lbs

FOR.....	DATE.....
HEAT #.....	TEST CODE #.....
SERIAL #.....	LOCATION.....
SCOPE DIAMETER.....	
ORIGINAL DIAMETER.....	IN. AREA.....
EXTENSOMETER GAGE LENGTH.....	IN.
YIELD STRENGTH.....	PSI
TENSILE STRENGTH.....	PSI
FINAL DIAMETER.....	IN. FINAL AREA.....
REDUCTION AREA.....	
ELONGATION.....	



19-T
19000
1500° 2hrs
1500° 2hrs
125°F 2hrs

FOR... *HF-1* ... DATE *10-14-80*
HEAT #... TEST CODE #...
SERIAL #... LOCATION...
SCOPE DIAMETER...
ORIGINAL DIAMETER... *4.36* ... IN. AREA... *14.83* ... SQ. IN.
EXTENSOMETER GAGE LENGTH... IN.
YIELD STRENGTH... *112,893* ... PSI
TENSILE STRENGTH... *113,827* ... PSI
FINAL DIAMETER... *4.42* ... IN. FINAL AREA... *15.40* ... SQ. IN.
REDUCTION AREA... *2.57* ...
ELONGATION... *2.57* ...

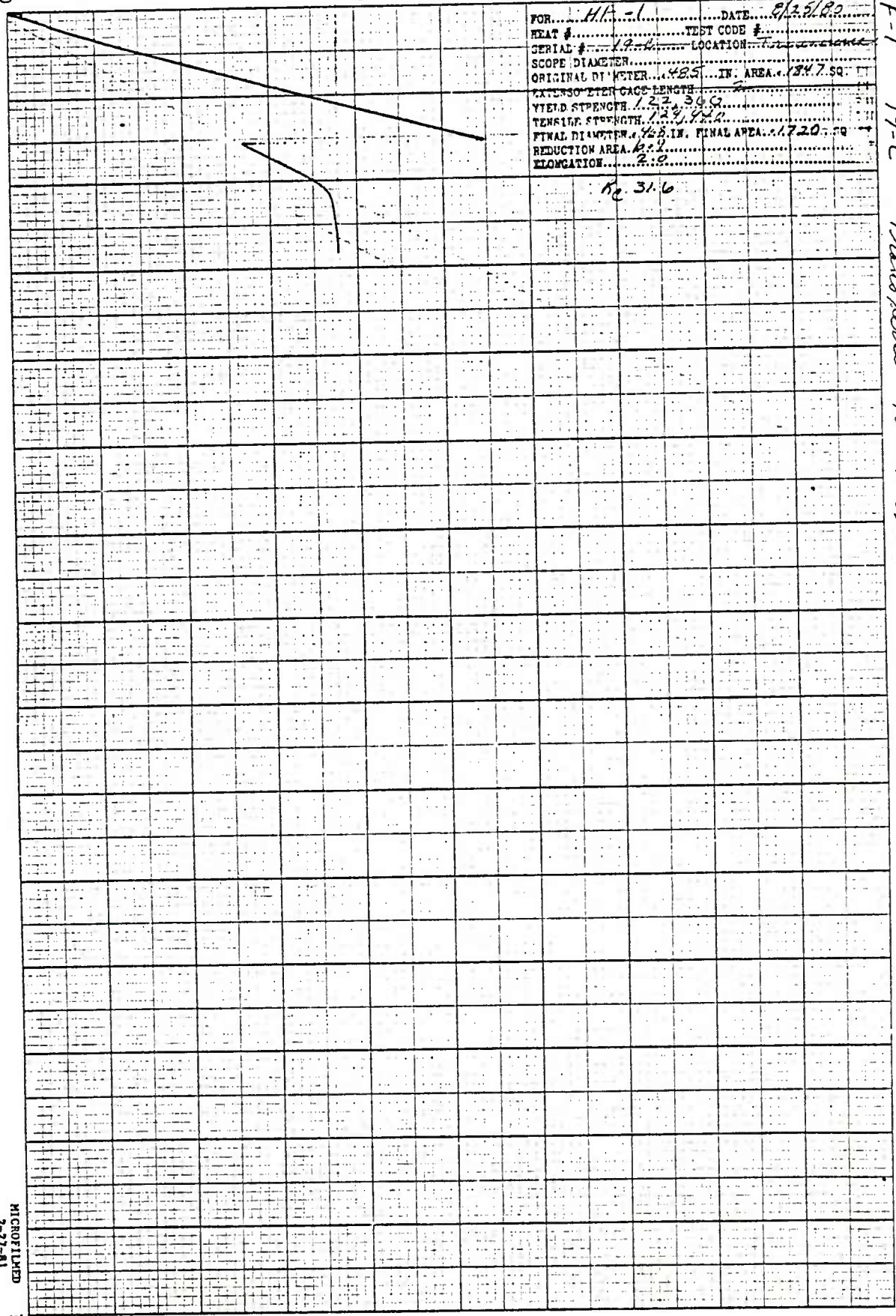


60,000
 HF-1 19-C Transverse 1500°F Anne Rel 1800°F 1125°F Anne

30,000
 1000

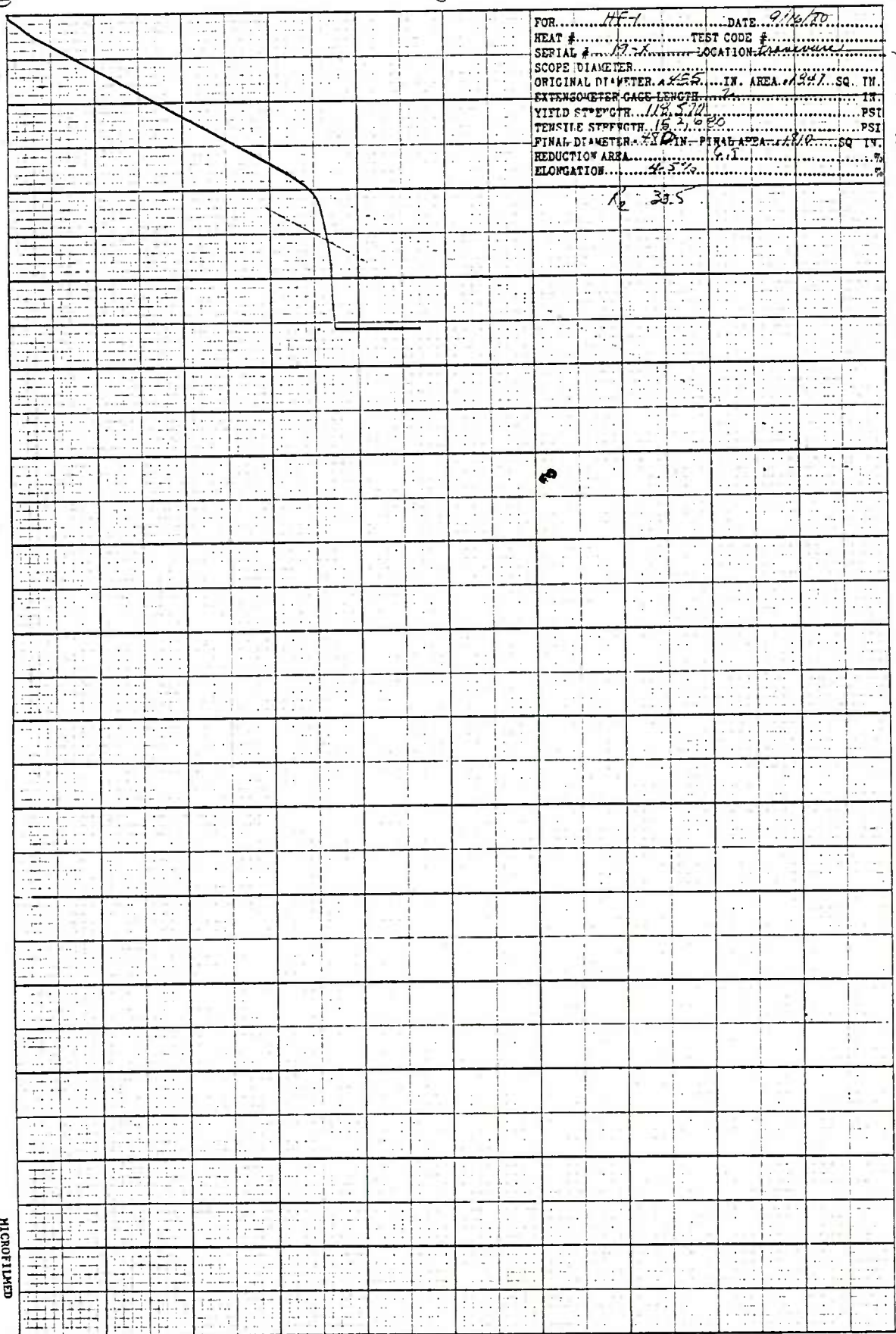
FOR: HA-1 DATE: 2/25/80
 HEAT #: 19-C TEST CODE: 19-C
 SERIAL #: 19-C LOCATION: 19-C
 SCOPE DIAMETER: 1.25 IN. AREA: 1.547 SQ
 ORIGINAL DIAMETER: 1.25 IN. AREA: 1.547 SQ
 EXTENSION GAGE LENGTH: 2 IN.
 YIELD STRENGTH: 122 PSI
 TENSILE STRENGTH: 122 PSI
 FINAL DIAMETER: 1.25 IN. FINAL AREA: 1.720 SQ
 REDUCTION AREA: 2.2
 ELONGATION: 2.2

Re 31.6



HF-1 19-X
 1500°F 2hrs
 1400°F
 1125°F 2hrs

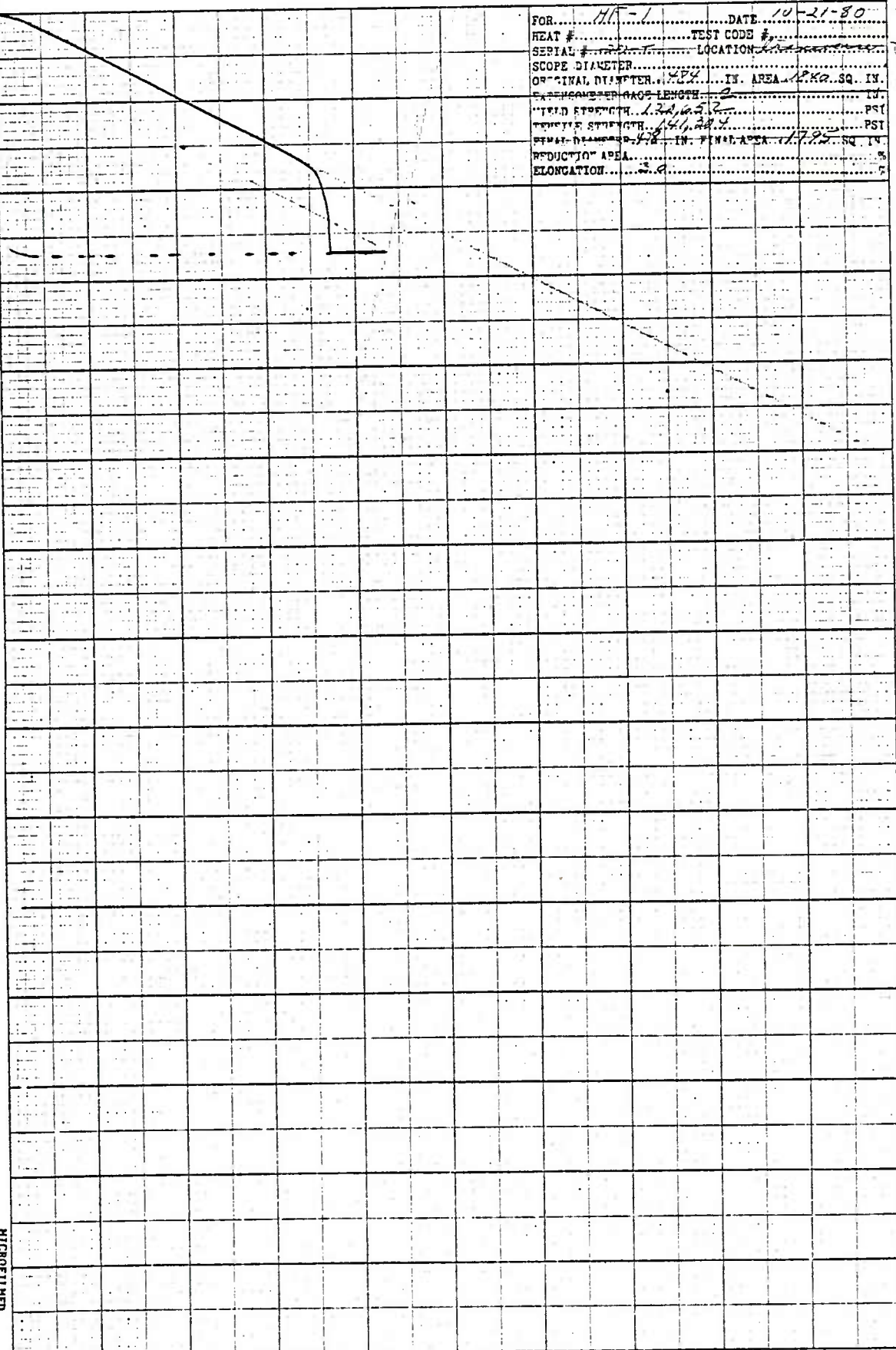
FOR.....
 HEAT #.....
 SERIAL #.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....IN. AREA.....SQ. IN.
 EXTENSOMETER GAGE LENGTH.....IN.
 YIELD STRENGTH.....PSI
 TENSILE STRENGTH.....PSI
 FINAL DIAMETER.....IN. FINAL AREA.....SQ. IN.
 REDUCTION AREA.....%
 ELONGATION.....%



24T

24T Bar 1500°F after 0.8 and 1.50°F 1125°F

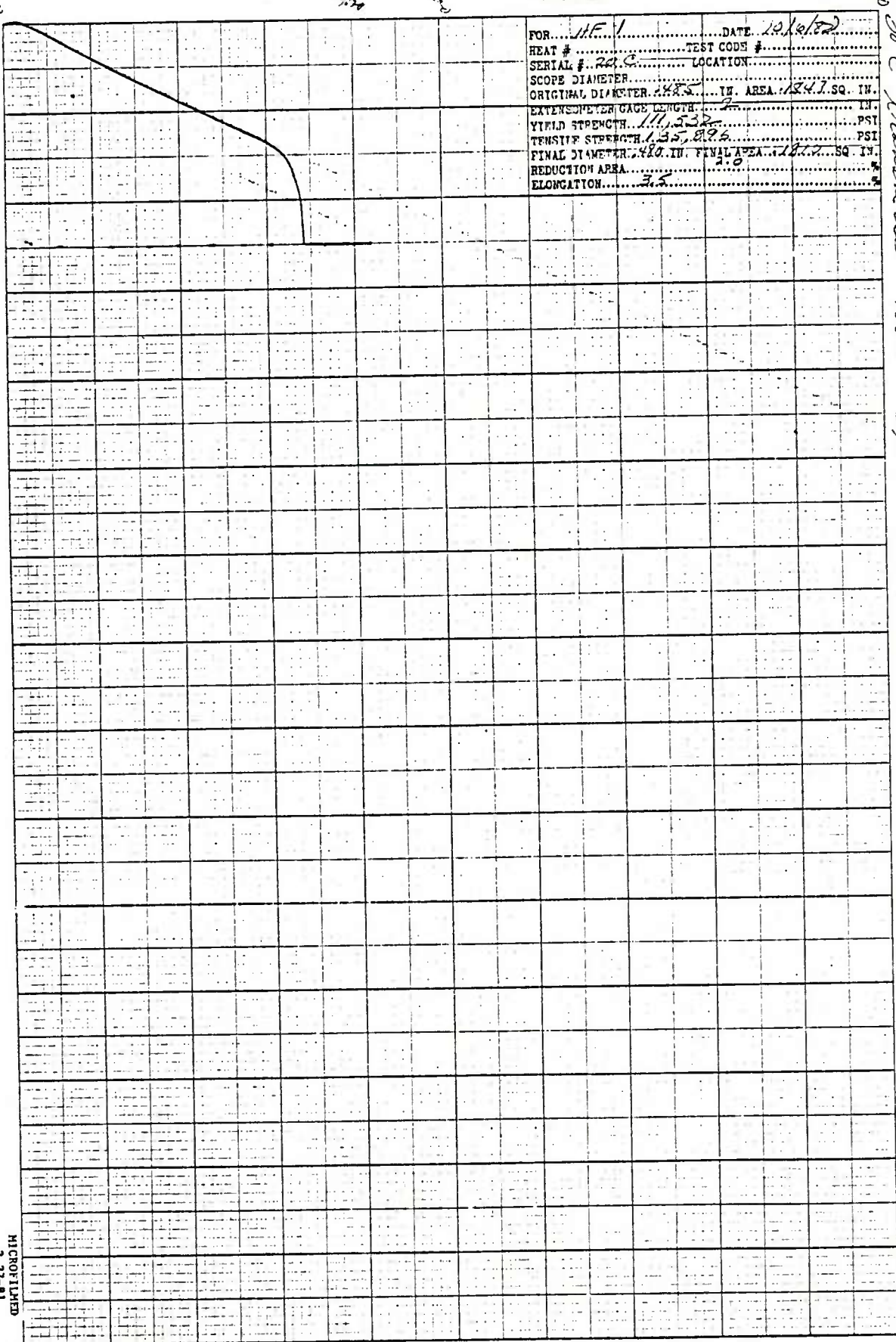
FOR.....	DATE.....
HEAT #.....	TEST CODE #.....
SERIAL #.....	LOCATION.....
SCOPE DIAMETER.....	IN. AREA.....
ORIGINAL DIAMETER.....	IN. AREA.....
ENGINEERED GAGE LENGTH.....	IN. AREA.....
TENSILE STRENGTH.....	PSI
YIELD STRENGTH.....	PSI
REDUCTION AREA.....	%
ELONGATION.....	%



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 2-27-81

HF-1 30 c Transverse
1500°F 2400
150°F 2400
1125°F 2400

FOR... HF 1... DATE 10/2/82
HEAT #... TEST CODE #...
SERIAL #... 221 C... LOCATION...
SCOPE DIAMETER...
ORIGINAL DIAMETER... 4.825... IN. AREA... 18.47 SQ. IN.
EXTENSOMETER GAGE LENGTH... 2... IN.
YIELD STRENGTH... 111,532... PSI
TENSILE STRENGTH... 135,826... PSI
FINAL DIAMETER... 4.80 IN. FINAL AREA... 18.12 SQ. IN.
REDUCTION AREA... 1.8...
ELONGATION... 3.5...

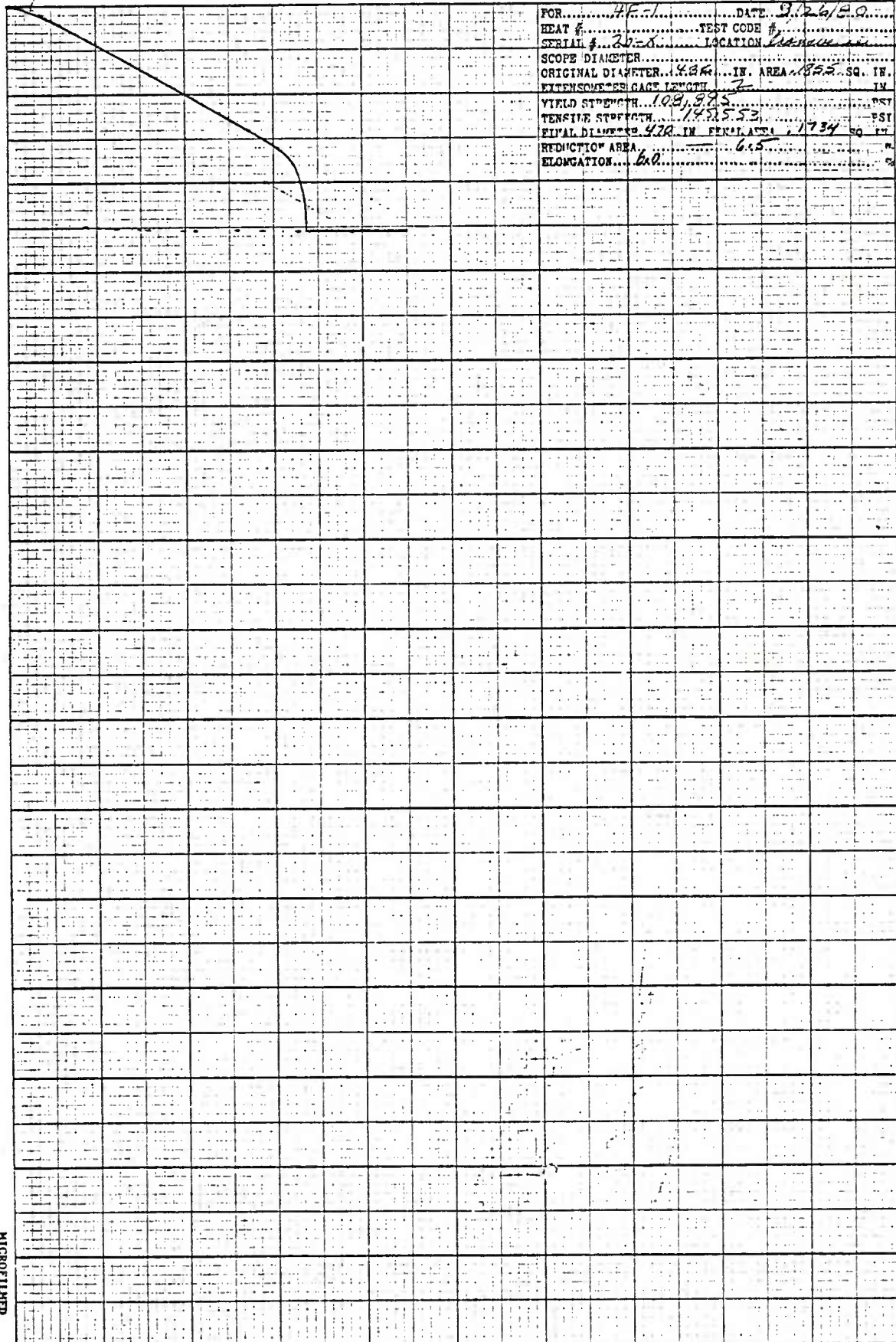


24-74
 3/1/78

50,000

FOR.....HF-1.....DATE.....2/26/80.....
 HEAT #.....20-8.....TEST CODE #.....1.....
 SERIAL #.....20-8.....LOCATION.....1000000.....
 SCOPE DIAMETER.....4.84.....IN. AREA.....185.5.....SQ. IN.
 EXTENSOMETER GAGE LENGTH.....2.....IN.
 YIELD STRENGTH.....108,885.....PSI
 TENSILE STRENGTH.....145,553.....PSI
 TENSILE DIAMETER.....4.70.....IN. TENSILE AREA.....17.34.....SQ. IN.
 REDUCTION AREA.....6.5.....%
 ELONGATION.....6.0.....%

HF-1
 20-X Transducer
 1500F 2kva
 60 and 150°F
 1125°F 2kva



30000

60,000

HF-1 1 AA long.

1500°F also release 1500°F

1125°F 2 hrs

FOR..... H.F.-1..... DATE..... 9/12/80.....
HEAT #..... TEST CODE #.....
SERIAL #..... 1 AA..... LOCATION..... Long.....
SCOPE DIAMETER.....
ORIGINAL DIAMETER..... 50.3..... IN. AREA..... 198.7 SQ. IN.
EXTENSOMETER GAGE LENGTH..... IN.
YIELD STRENGTH..... 123,000..... PSI
TENSILE STRENGTH..... 146,500..... PSI
FINAL DIAMETER..... 48.0 IN. FINAL AREA..... 185.7 SQ. IN.
REDUCTION AREA..... 26.9.....
ELONGATION..... 12.0.....

10 38.2

FOR..... H.F.-1..... DATE..... 9/12/80.....
HEAT #..... TEST CODE #.....
SERIAL #..... 1 AA..... LOCATION..... Long.....
SCOPE DIAMETER.....
ORIGINAL DIAMETER..... 50.3..... IN. AREA..... 198.7 SQ. IN.
EXTENSOMETER GAGE LENGTH..... IN.
YIELD STRENGTH..... 123,000..... PSI
TENSILE STRENGTH..... 146,500..... PSI
FINAL DIAMETER..... 48.0 IN. FINAL AREA..... 185.7 SQ. IN.
REDUCTION AREA..... 26.9.....
ELONGATION..... 12.0.....

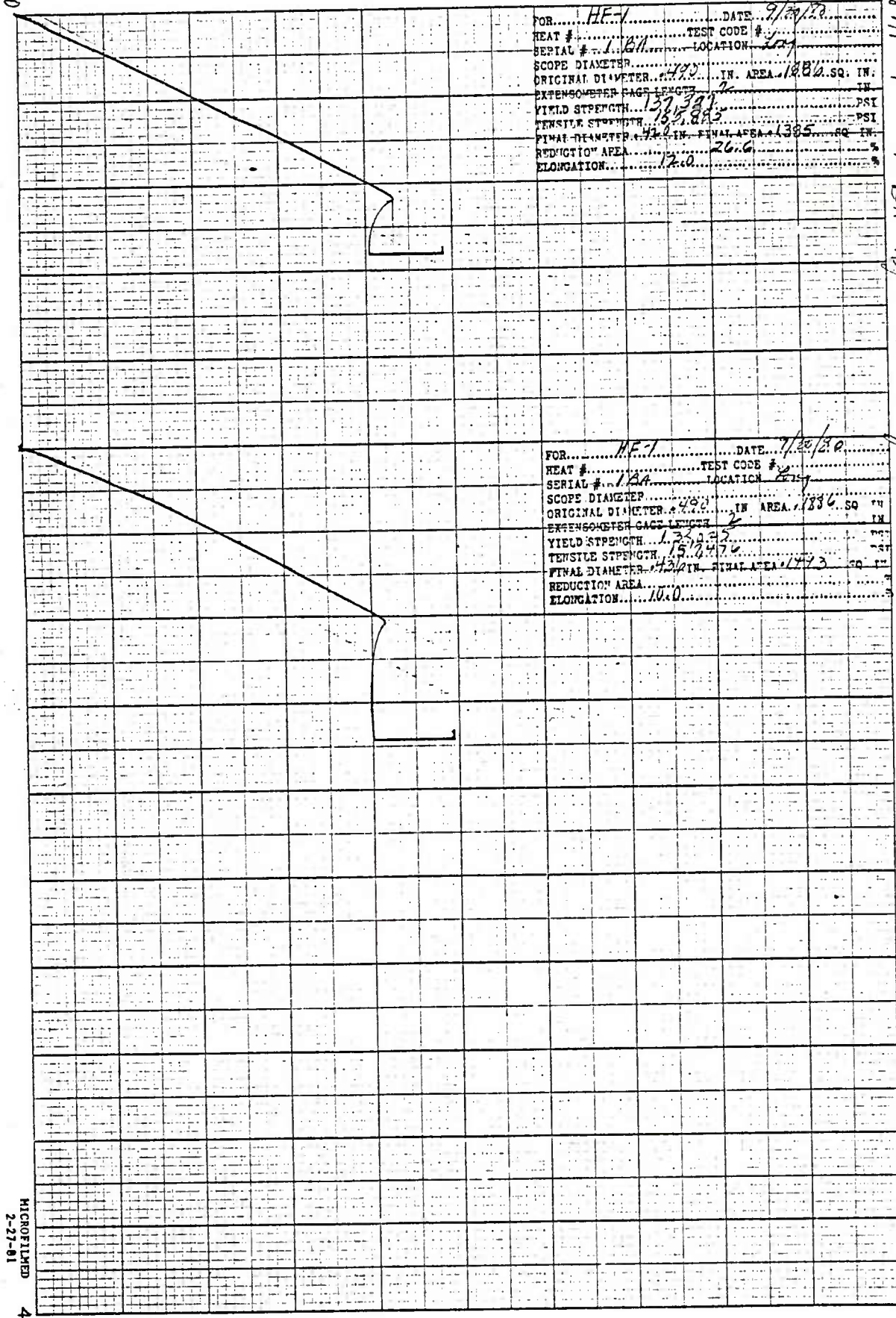
10 34.0

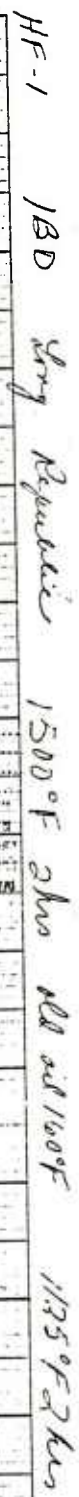
3,400
 3,100

60100 HF-1
 1-BA
 1570°F
 1600°F
 1125°F

FOR... HF-1... DATE 9/29/20
 HEAT #... TEST CODE #...
 SERIAL #... 1-BA... LOCATION...
 SCOPE DIAMETER...
 ORIGINAL DIAMETER... 4.42 IN. AREA... 15.86 SQ. IN.
 EXTENSOMETER GAGE LENGTH...
 YIELD STRENGTH... 137,391 PSI
 TENSILE STRENGTH... 165,843 PSI
 FINAL DIAMETER... 4.22 IN. FINAL AREA... 13.85 SQ. IN.
 REDUCTION AREA... 26.6%
 ELONGATION... 12.0%

FOR... HF-1... DATE 7/20/20
 HEAT #... TEST CODE #...
 SERIAL #... 1-BA... LOCATION...
 SCOPE DIAMETER...
 ORIGINAL DIAMETER... 4.42 IN. AREA... 15.86 SQ. IN.
 EXTENSOMETER GAGE LENGTH...
 YIELD STRENGTH... 135,000 PSI
 TENSILE STRENGTH... 152,476 PSI
 FINAL DIAMETER... 4.22 IN. FINAL AREA... 14.43 SQ. IN.
 REDUCTION AREA...
 ELONGATION... 10.0%

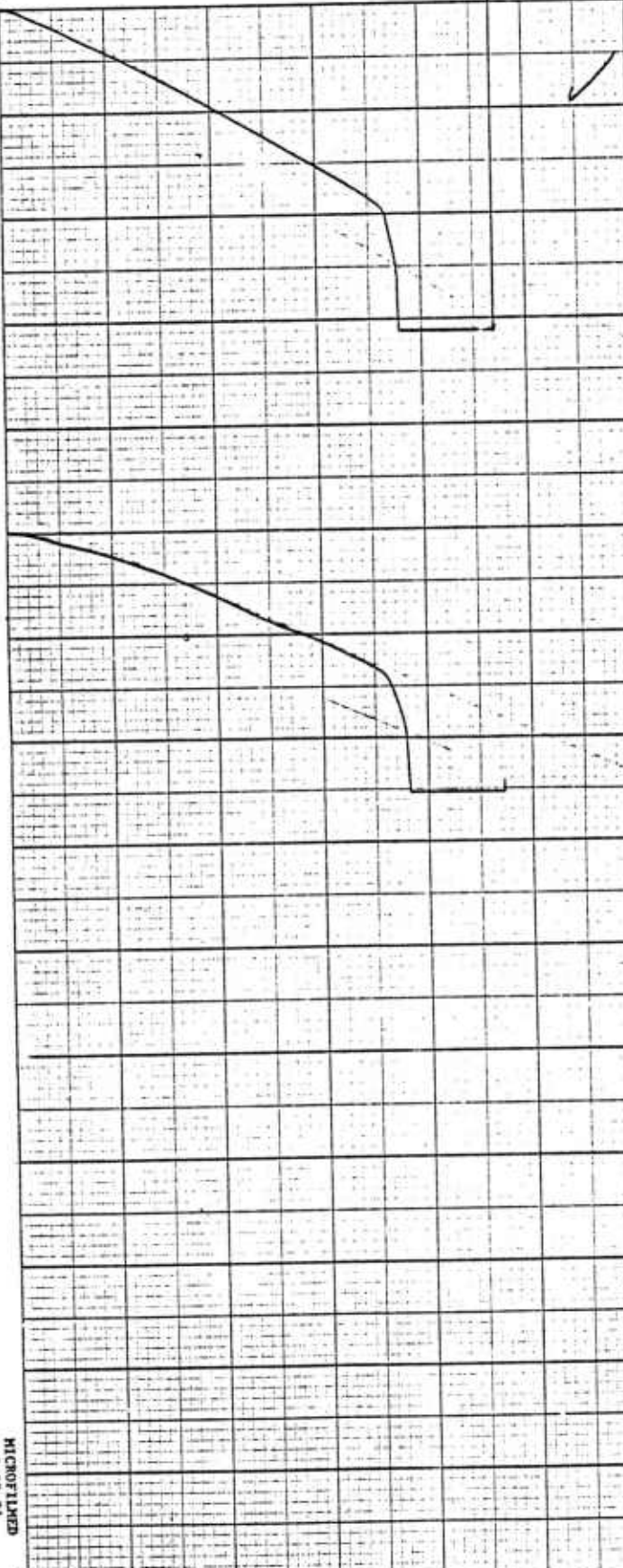




FOR HF-1 DATE 10-4-82
 HEAT # 3044 TEST CODE # 101
 SERIAL # 3044 LOCATION 101
 SCOPE DIAMETER 1.27 IN. AREA 127.9 SQ. IN.
 ORIGINAL DIAMETER 1.27 IN. AREA 127.9 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 120,000 PSI
 TENSILE STRENGTH 150,000 PSI
 FINAL DIAMETER 0.8 IN. FINAL AREA 50.3 SQ. IN.
 REDUCTION AREA 25.9
 ELONGATION 12.0

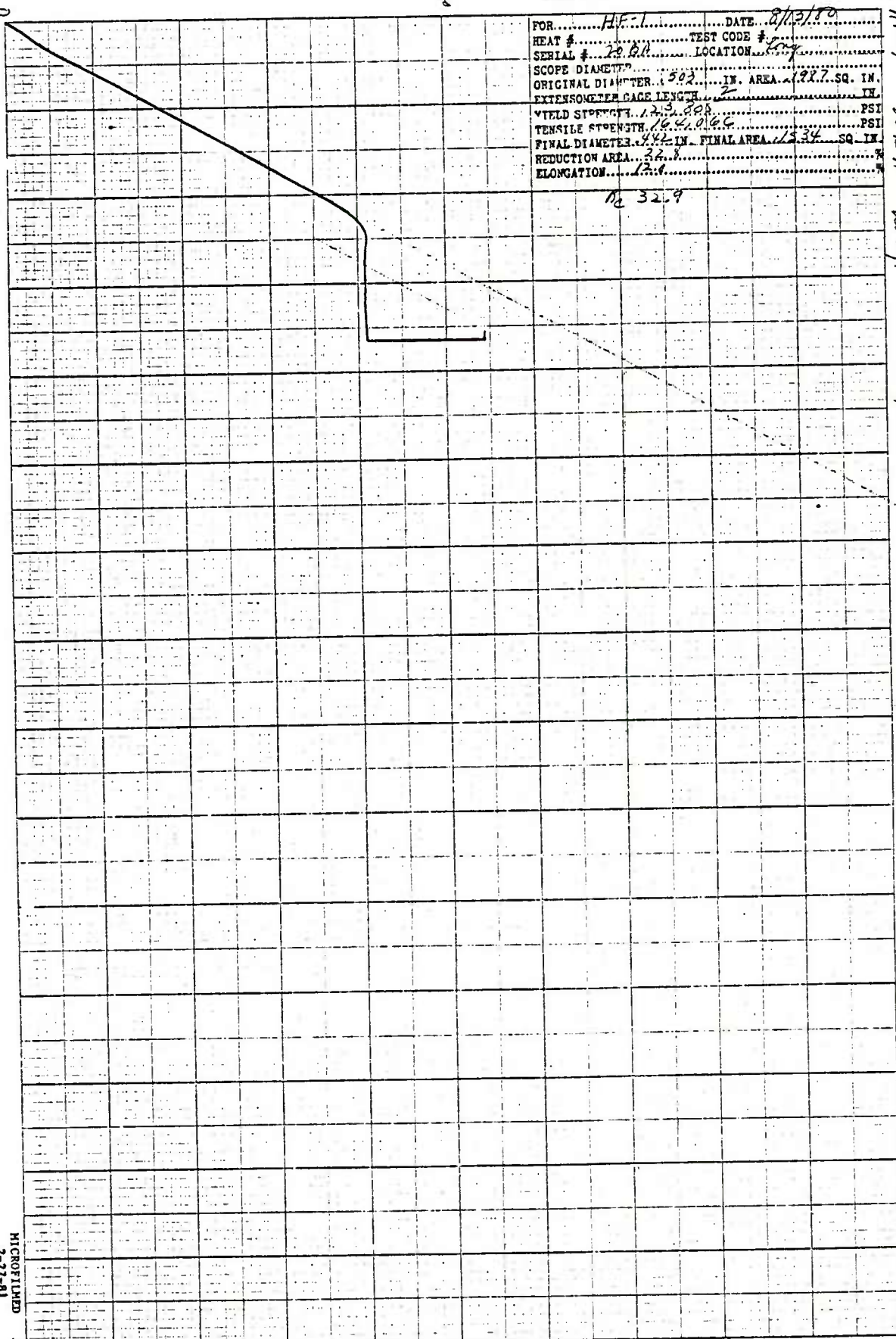
FOR HF-1 DATE 10-4-82
 HEAT # 3044 TEST CODE # 101
 SERIAL # 3044 LOCATION 101
 SCOPE DIAMETER 1.27 IN. AREA 127.9 SQ. IN.
 ORIGINAL DIAMETER 1.27 IN. AREA 127.9 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 120,000 PSI
 TENSILE STRENGTH 150,000 PSI
 FINAL DIAMETER 0.8 IN. FINAL AREA 50.3 SQ. IN.
 REDUCTION AREA 25.9
 ELONGATION 12.0

HF-1 3044 101
 150°F 240
 160°F
 1175°F 240



60,000

HF-1 20 BA dry. 1500°F 2 hrs old acid 140°F 1175°F 2 hrs

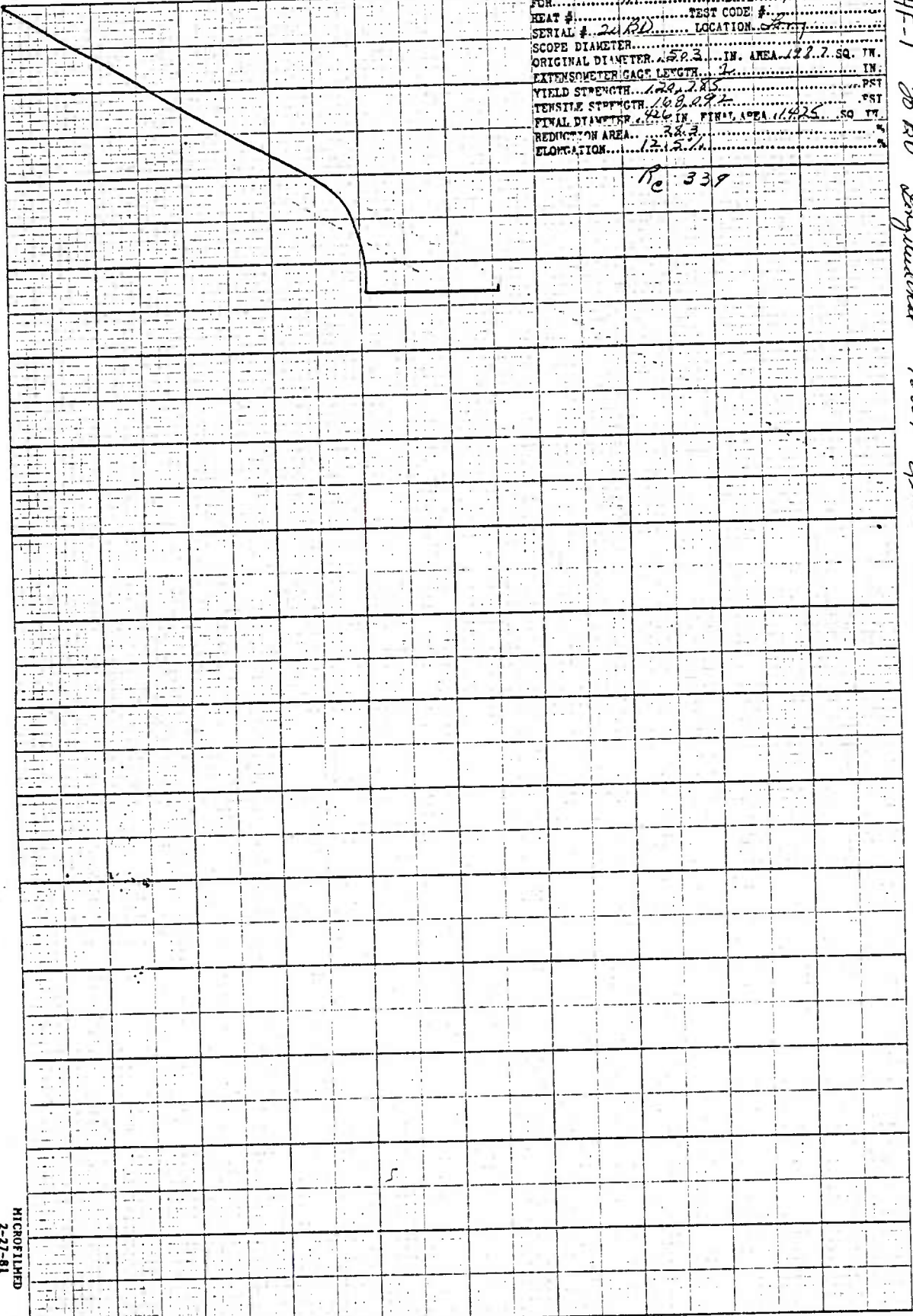


$n = 32.9$

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2-27-81

FOR.....*HF-1*.....DATE.....*2/24/79*.....
HEAT #.....TEST CODE #.....
SERIAL #.....*24 RD*.....LOCATION.....*24 RD*.....
SCOPE DIAMETER.....*5.2*.....IN. AREA.....*122.7* SQ. IN.
EXTENSOMETER GAGE LENGTH.....*2*.....IN.
YIELD STRENGTH.....*122,285*.....PSI
TENSILE STRENGTH.....*108,292*.....PSI
FINAL DIAMETER.....*4.6* IN. FINAL AREA.....*114.25* SQ. IN.
REDUCTION AREA.....*28.3*.....%
ELONGATION.....*12.5*.....%

Pc 339



60000
HF-1 20 RD longitudinal 1500F also held 150F 11250F also

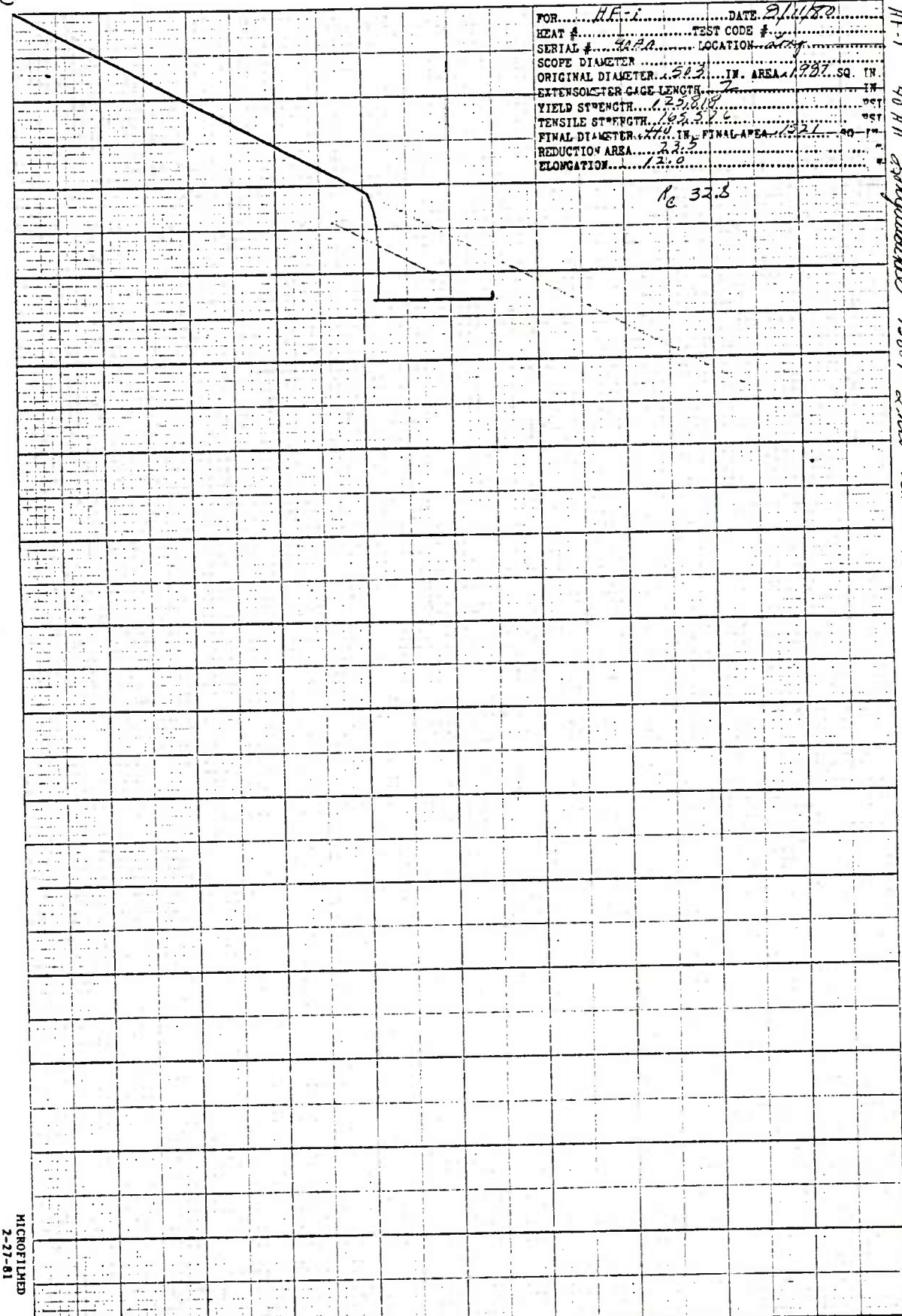
60000

2000

FOR.....*HF-1*.....DATE.....*2/1/52*.....
HEAT #.....TEST CODE #.....
SERIAL #.....*412A*.....LOCATION.....*atg*.....
SCOPE DIAMETER.....
ORIGINAL DIAMETER.....*2.13*.....IN. AREA.....*1.787* SQ. IN.
EXTENSOMETER GAGE LENGTH.....*2*.....IN.
YIELD STRENGTH.....*125,800*.....PSI
TENSILE STRENGTH.....*165,500*.....PSI
FINAL DIAMETER.....*2.74* IN. FINAL AREA.....*1.821* SQ. IN.
REDUCTION AREA.....*23.5*.....
ELONGATION.....*12.0*.....

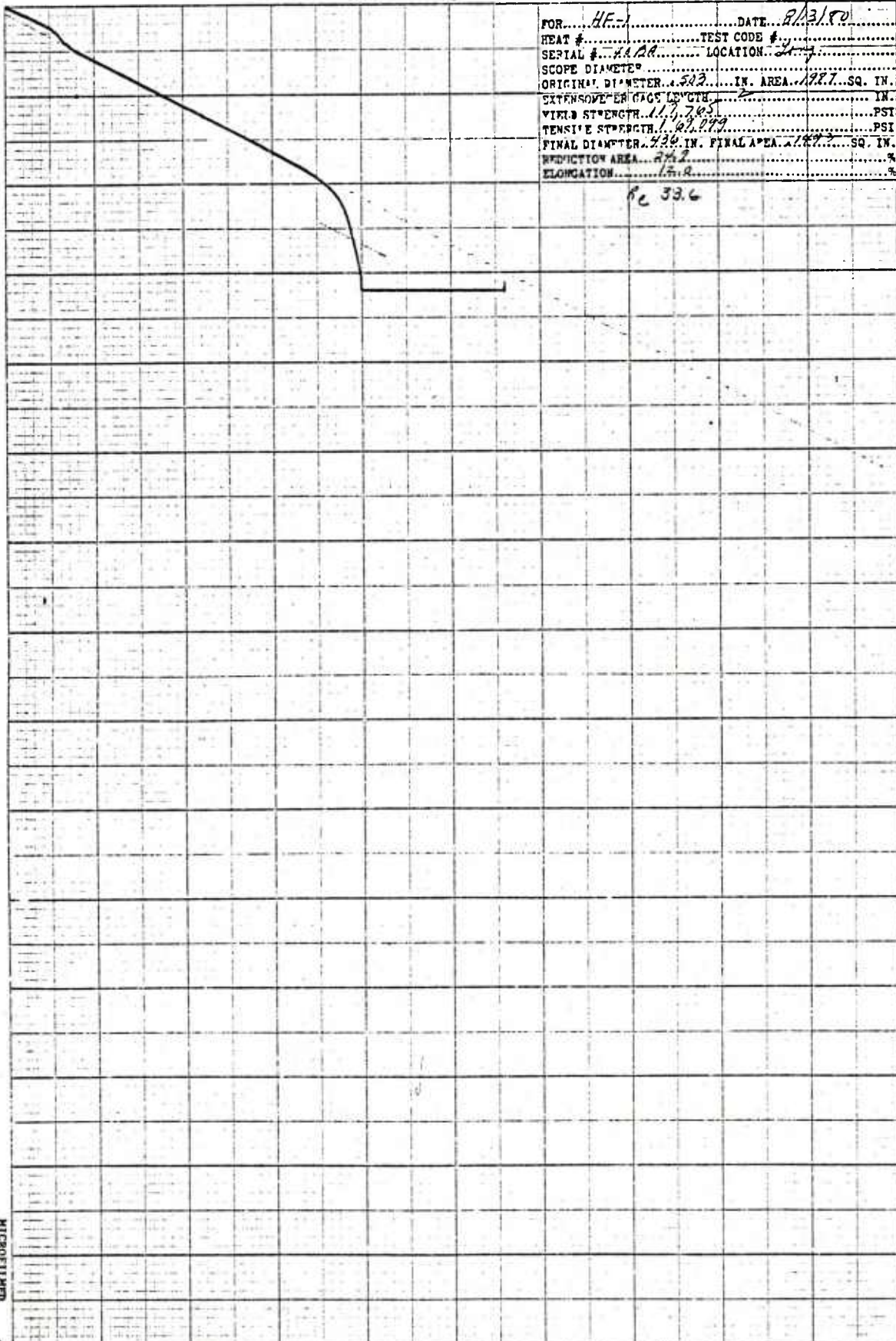
Mc 32.8

HF-1 40 AN longitudinal 1500F 2 hrs anneal 1400F 11.25F 2 hrs



HF-1	40 B1	Very	1320 F	2 hrs	old oil	1320 F	11.35 F	3 hrs
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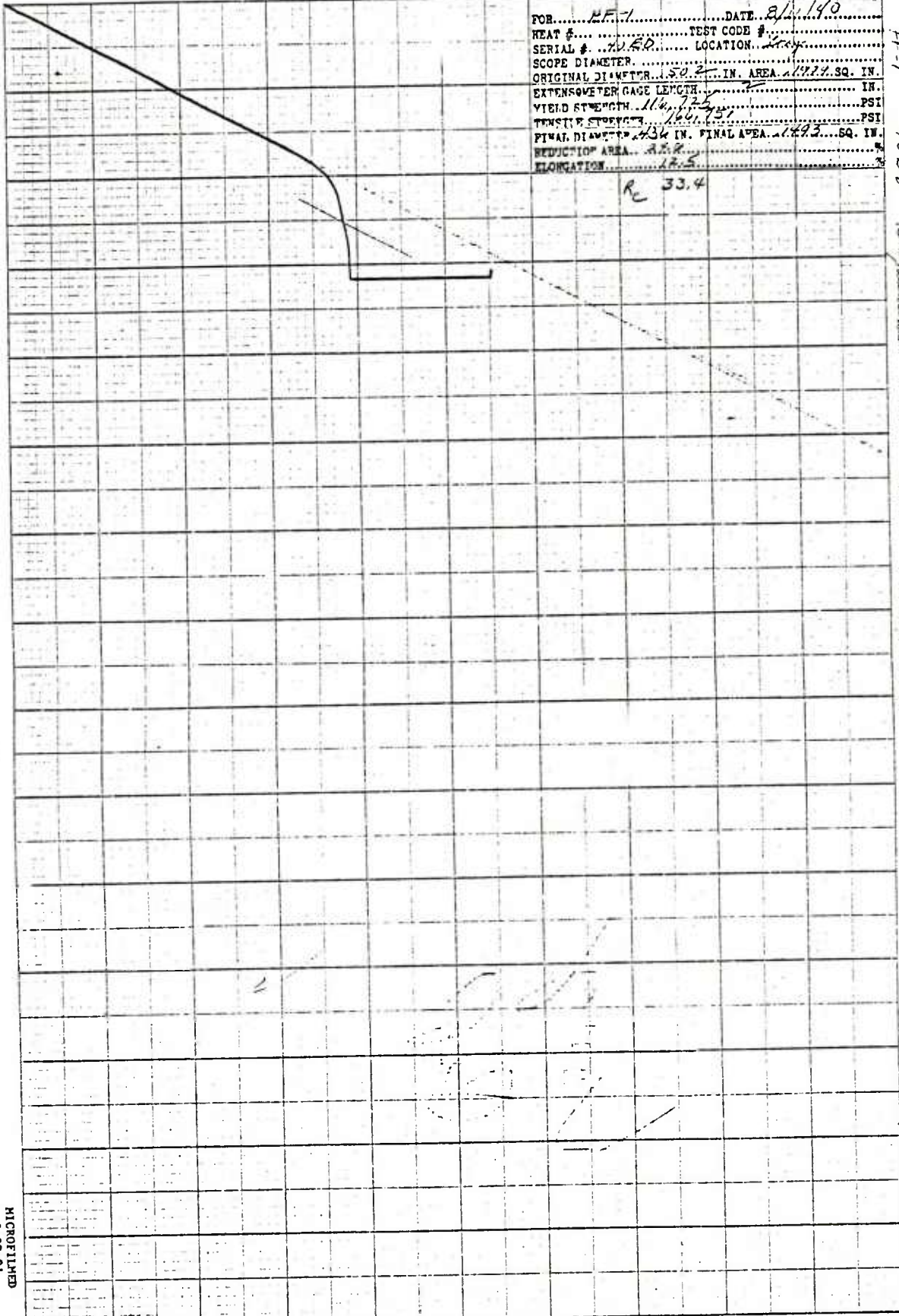
$\rho_c = 33.6$



4-B

FOR.....*AF-1*.....DATE.....*2/1/40*.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....*1050*.....LOCATION.....*2nd*.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....*1.50*.....IN. AREA.....*1.7671*.....SQ. IN.
 EXTENSOMETER GAGE LENGTH.....IN.
 YIELD STRENGTH.....*114,725*.....PSI
 TENSILE STRENGTH.....*104,725*.....PSI
 FINAL DIAMETER.....*1.34*.....IN. FINAL AREA.....*1.4223*.....SQ. IN.
 REDUCTION AREA.....*18.8*.....%
 ELONGATION.....*12.5*.....%

Re 33.4

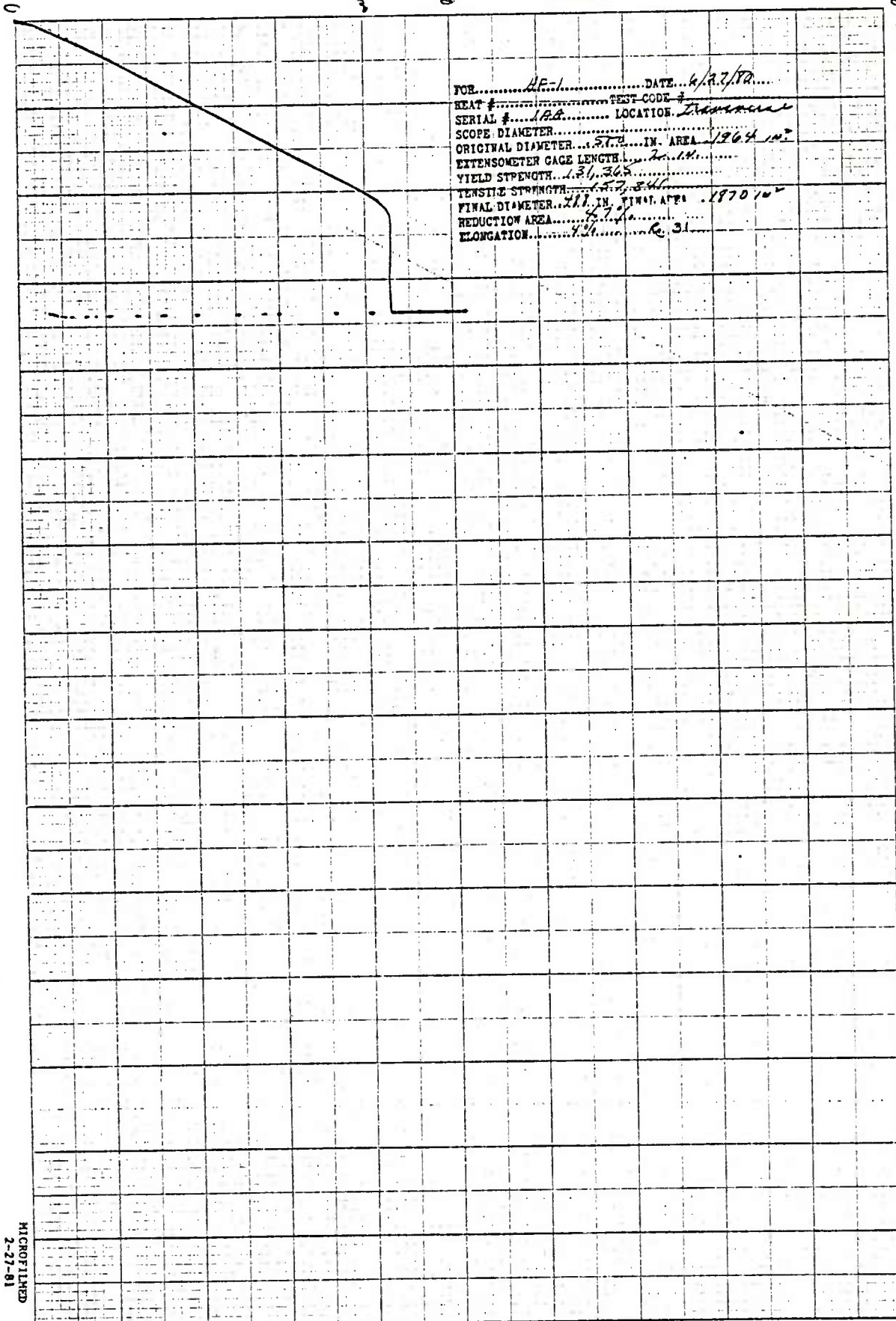


100,000
1F-1
4080
Hydrostatic 1500F 3hrs
Static 1500F
11350F 2hrs

2-27-81

60,000
 HF-1 17A Diameter
 1500 F 2 lbs
 1600 F
 1735 F 2 lbs

FOR.....*HF-1*.....DATE.....*4/27/72*.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....*188*.....LOCATION.....*Diameter*.....
 SCOPE DIAMETER.....*5.72*.....IN. AREA.....*1964 in²*.....
 ORIGINAL DIAMETER.....*5.72*.....IN. AREA.....*1964 in²*.....
 EXTENSOMETER GAGE LENGTH.....*20.14*.....
 YIELD STRENGTH.....*131, 365*.....
 TENSILE STRENGTH.....*157, 846*.....
 FINAL DIAMETER.....*2.11*.....IN. FINAL AREA.....*1870 in²*.....
 REDUCTION AREA.....*5.72*.....
 ELONGATION.....*4.21*.....%.....*31*.....

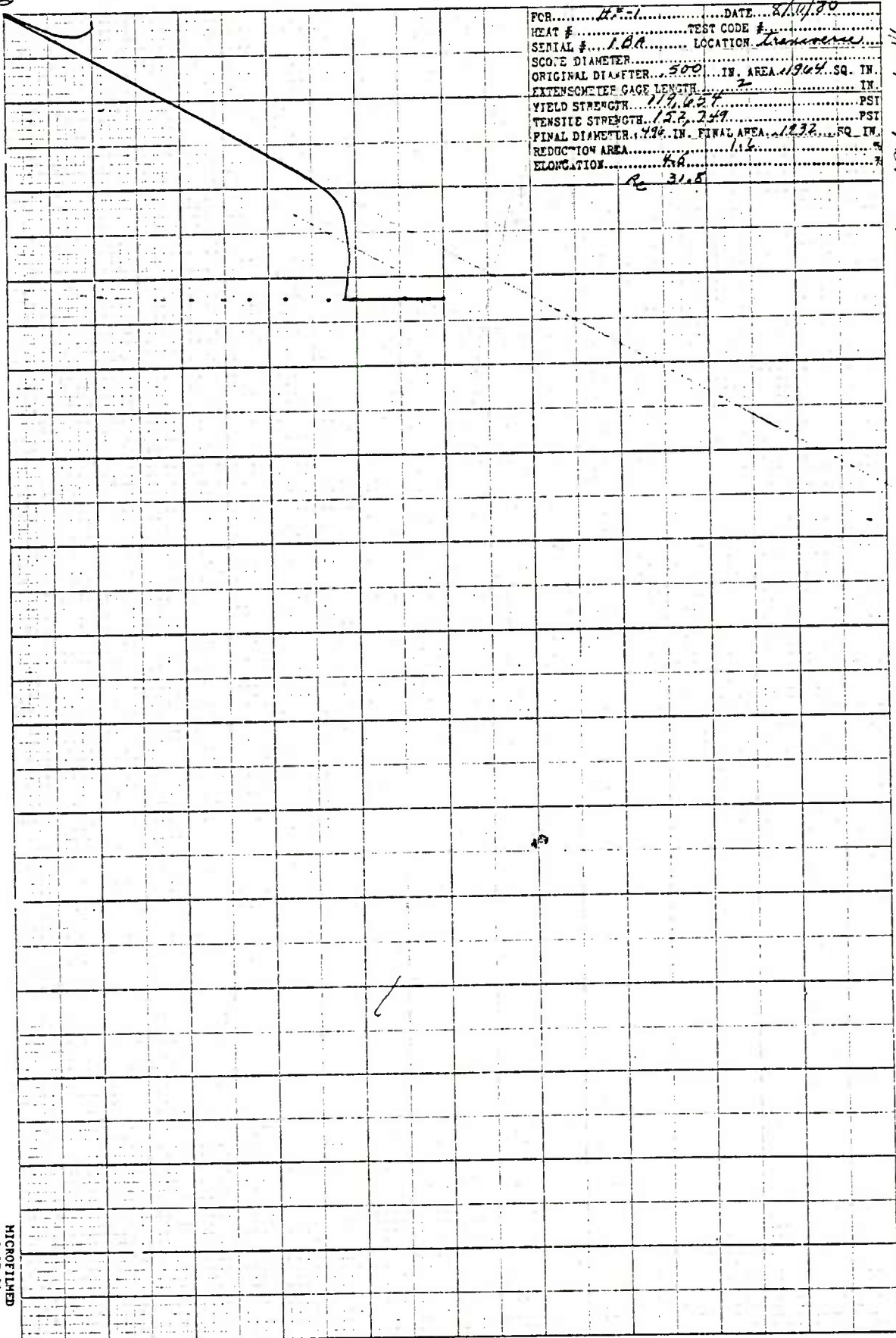


3000

6000

FOR.....#1.....DATE.....8/11/70
 HEAT #.....TEST CODE #.....
 SERIAL #.....1.0A.....LOCATION.....Transverse
 SCOTCH DIAMETER.....
 ORIGINAL DIAMETER.....500.....IN. AREA.....1964.....SQ. IN.
 EXTENSOMETER GAGE LENGTH.....2.....IN.
 YIELD STRENGTH.....119,424.....PSI
 TENSILE STRENGTH.....152,247.....PSI
 FINAL DIAMETER......792.....IN. FINAL AREA.....1232.....SQ. IN.
 REDUCTION AREA......60.....
 ELONGATION......31.5.....

HF-1 10A Transverse 1500F 24in side 1400F 1135F 24in



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 2-27-81

24000

34000

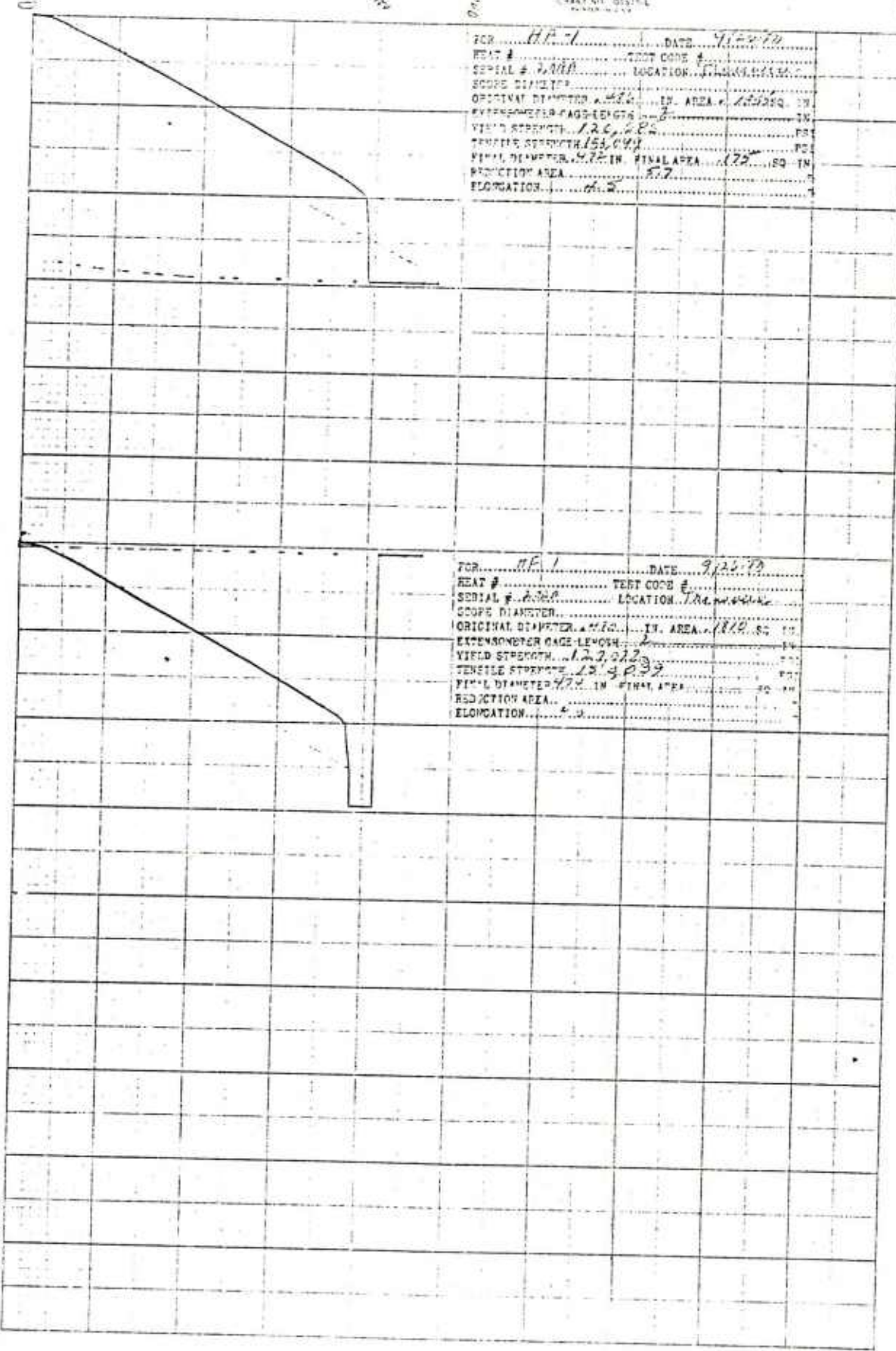
6000

FOR HF-1 DATE 9/5/67
HEAT # 100 TEST CODE # 100
SERIAL # 100 LOCATION 100
SCOPE DIAMETER 2.2 IN. AREA 1.92 SQ. IN.
EXTENSOMETER GAGE LENGTH 2 IN.
YIELD STRENGTH 132,300 PSI
TENSILE STRENGTH 132,300 PSI
FINAL DIAMETER 1.81 IN. FINAL AREA 1.18 SQ. IN.
REDUCTION AREA 7.8
ELONGATION 10.0

Re 30.7

HF-1 1BD Dot transducer 1500F 2Kw old oil 150°F 1125°F 2Kw

60110 HF-1 230 MP Transverse Hydraulic 1500 PSI 100% Final 11.35% Elong



FOR HF-1 DATE 9/25/70
HEAT # 1000 TEST CODE # 1000
SERIAL # 1000 LOCATION 1000
SCOPE DIAMETER 1.25 IN. AREA 1.55 SQ. IN.
EXTENSOMETER GAGE LENGTH 2 IN.
YIELD STRENGTH 120,000 PSI
TENSILE STRENGTH 150,000 PSI
FINAL DIAMETER 0.75 IN. FINAL AREA 0.44 SQ. IN.
REDUCTION AREA 71.2 %
ELONGATION 11.35 %

FOR HF-1 DATE 9/25/70
HEAT # 1000 TEST CODE # 1000
SERIAL # 1000 LOCATION 1000
SCOPE DIAMETER 1.25 IN. AREA 1.55 SQ. IN.
EXTENSOMETER GAGE LENGTH 2 IN.
YIELD STRENGTH 120,000 PSI
TENSILE STRENGTH 150,000 PSI
FINAL DIAMETER 0.75 IN. FINAL AREA 0.44 SQ. IN.
REDUCTION AREA 71.2 %
ELONGATION 11.35 %

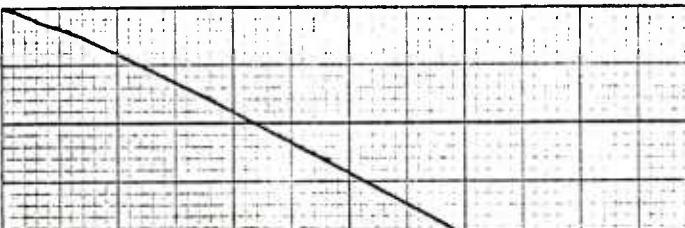
MICROFILMED
2-27-81

53

60,000

2474 30,000

FOR HF-1 DATE 2/27/50
 HEAT # 1 TEST CODE 1
 SERIAL # 25134 LOCATION Hammer
 SCOPE DIAMETER 4.86 IN. AREA 185.7 SQ. IN.
 EXTENSOMETER GAGE LENGTH 7 IN.
 YIELD STRENGTH 129,840 PSI
 TENSILE STRENGTH 152,100 PSI
 FINAL DIAMETER 4.76 IN. FINAL AREA 82.17 SQ. IN.
 REDUCTION AREA 55.53 %
 ELONGATION 3.5 %



FOR HF-1 DATE 9/24/50
 HEAT # 1 TEST CODE 1
 SERIAL # 25134 LOCATION Hammer
 SCOPE DIAMETER 4.86 IN. AREA 185.7 SQ. IN.
 EXTENSOMETER GAGE LENGTH 7 IN.
 YIELD STRENGTH 129,840 PSI
 TENSILE STRENGTH 152,100 PSI
 FINAL DIAMETER 4.76 IN. FINAL AREA 82.17 SQ. IN.
 REDUCTION AREA 55.53 %
 ELONGATION 3.5 %



HF-1 20 BN Hammer 1500°F 1185°F 2474

HOUSTON INSTRUMENT
 11111 FORT HOUSTON, TEXAS
 CHART NO. 101217-L
 PRINTED IN U.S.A.

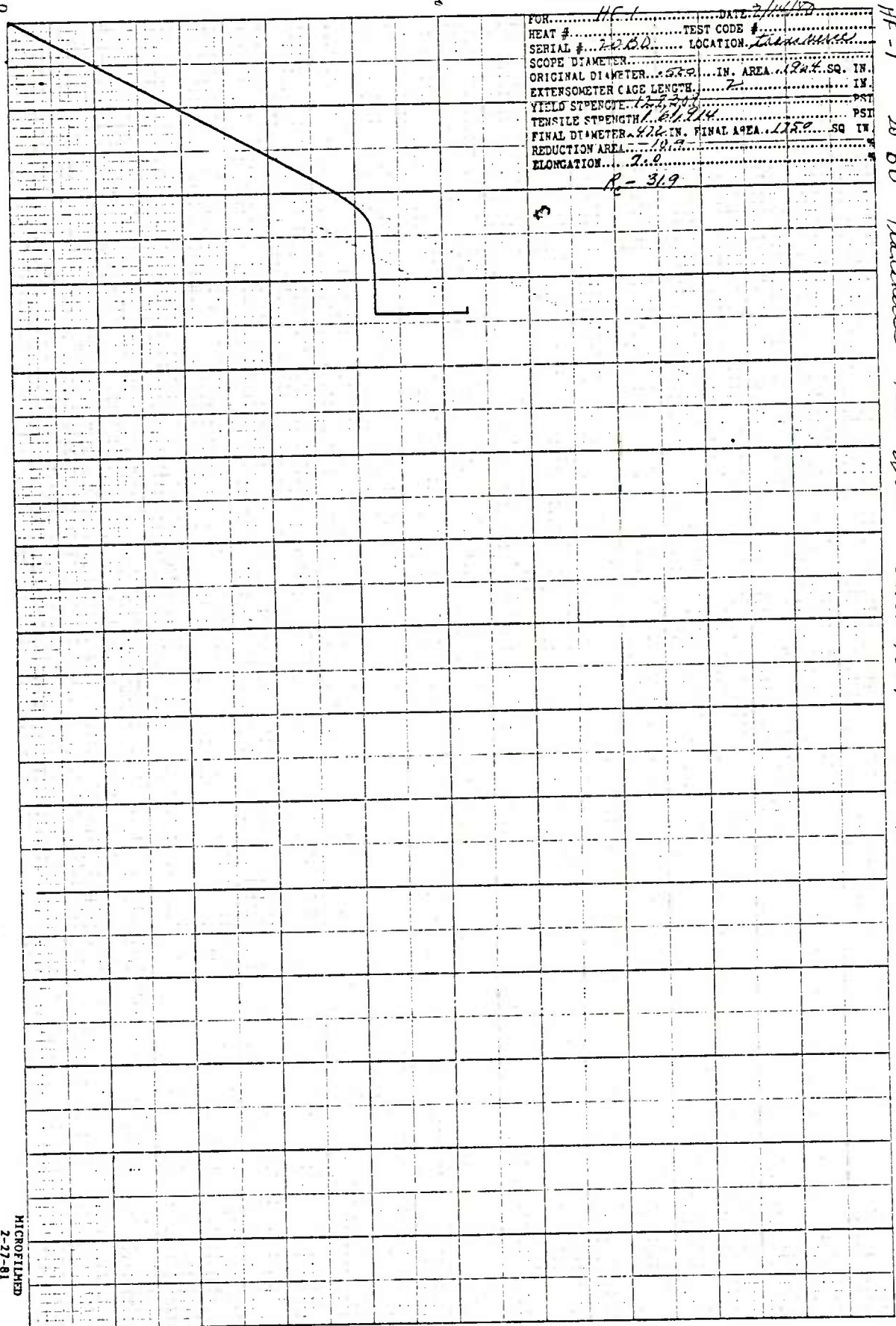
60,000

30,000

HF-1 20 BD Transverse 1500°-24in 440il 150°F 1135° 24in

FOR.....HF-1.....DATE.....2/14/50.....
 HEAT #.....2030.....TEST CODE #.....2030.....
 SERIAL #.....2030.....LOCATION.....Transverse.....
 SCOPE DIAMETER.....5.79.....IN. AREA.....12.4.....SQ. IN.
 ORIGINAL DIAMETER.....5.79.....IN. AREA.....12.4.....SQ. IN.
 EXTENSOMETER GAGE LENGTH.....2.....IN.
 YIELD STRENGTH.....61,914.....PSI
 TENSILE STRENGTH.....61,914.....PSI
 FINAL DIAMETER.....4.22.....IN. FINAL AREA.....12.5.....SQ. IN.
 REDUCTION AREA.....12.5.....SQ. IN.
 ELONGATION.....2.0.....%

$R_c = 31.9$

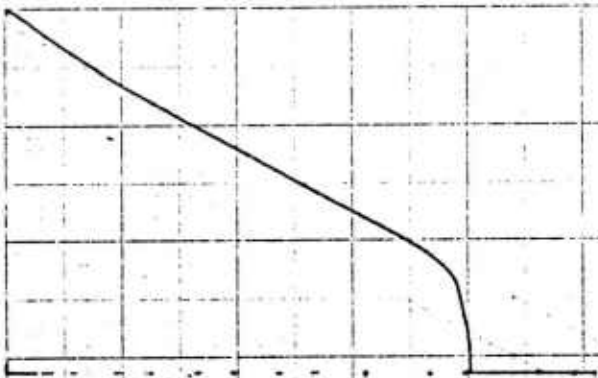


MICROFILMED
 2-27-81

55

ROSTON INSTRUMENT
 1000 TON
 GRAVITY 100 LBS

FOR... *HF-1* ... DATE *7/1/50*
 HEAT... *404* ... TEST CODE *5*
 SERIAL... *404* ... LOCATION *1000 TON*
 SCOPE DIAMETER... *1.5* IN. AREA *1.96* SQ. IN.
 EXTENSOMETER GAGE LENGTH... *2* IN.
 YIELD STRENGTH... *173,197* PSI
 TENSILE STRENGTH... *155,304* PSI
 FINAL DIAMETER... *.472* IN. FINAL AREA... *1.210* SQ. IN.
 REDUCTION AREA... *7.8* %
 ELONGATION... *4.8* %



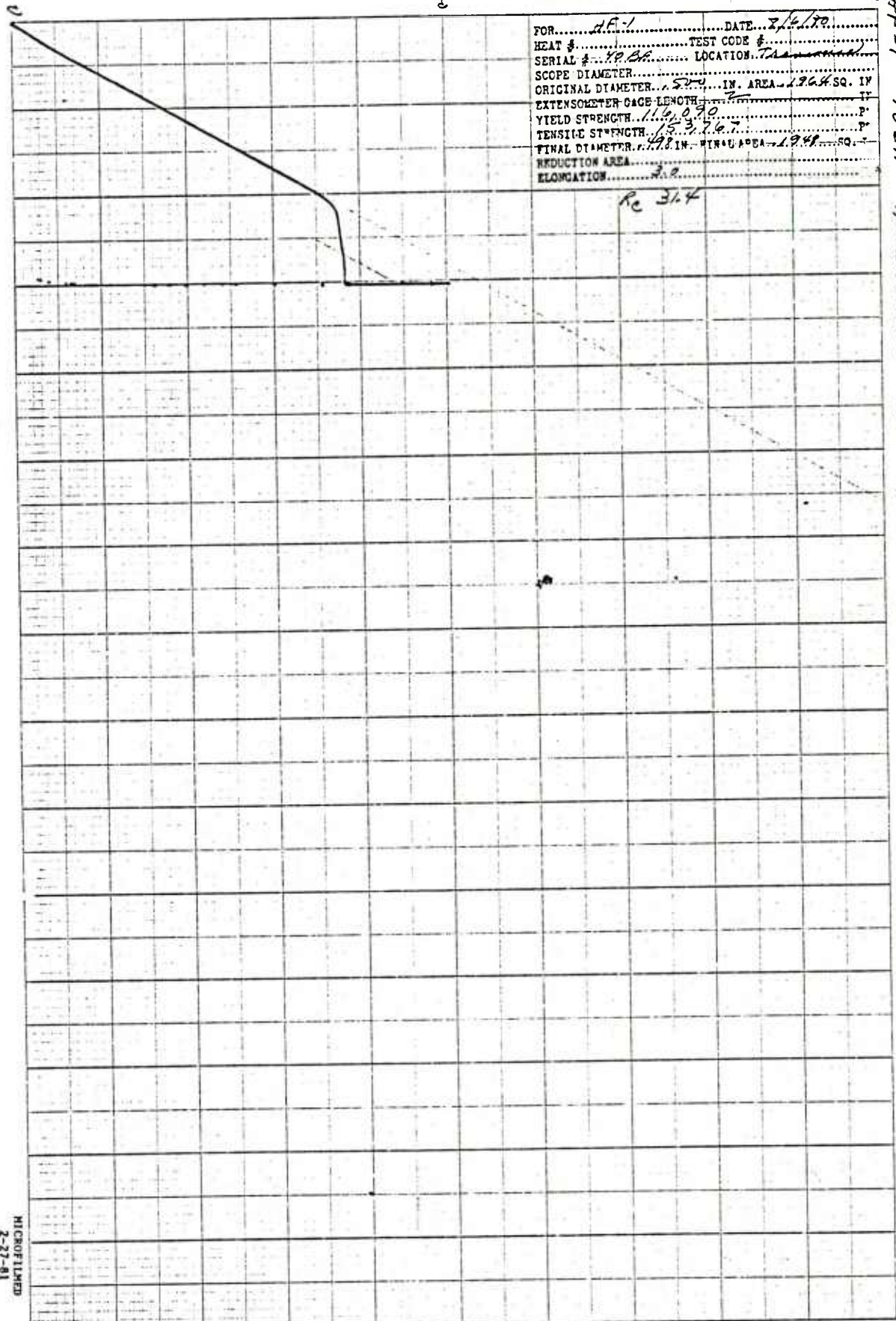
410 H H HF-1 fracture 1500°F 2 lbs add 140°F 1125°F 2 lbs

60,000
 HF-1 908A Transducer 1500°F 2Kia 2000 150°F 1125°F 2Kia

31.00

FOR... *4.5.1* ... DATE... *2/6/70*
 HEAT #... TEST CODE #...
 SERIAL #... *49.84* ... LOCATION... *Tasmania*
 SCOPE DIAMETER...
 ORIGINAL DIAMETER... *5.2* IN. AREA... *1.764* SQ. IN.
 EXTENSOMETER GAGE LENGTH...
 YIELD STRENGTH... *116,070* P.
 TENSILE STRENGTH... *153,747* P.
 FINAL DIAMETER... *4.78* IN. FINAL AREA... *1.949* SQ.
 REDUCTION AREA...
 ELONGATION... *3.2*

Rc 31.4



MICROFILMED
 2-27-81

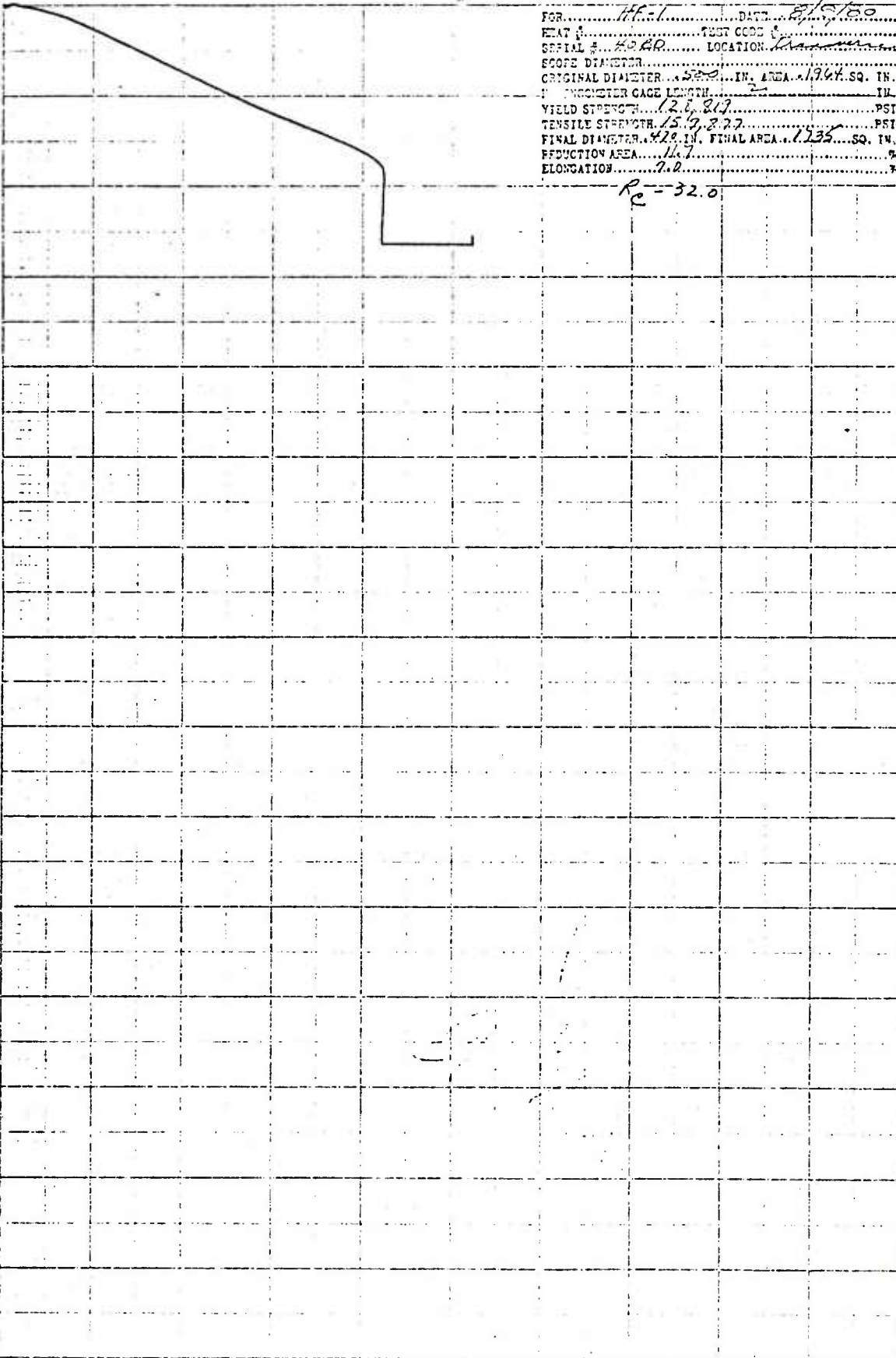
WELDING EXPERIMENT

DATE: 8/5/80
 TEST CODE: HF-1
 LOCATION: 4080

FOR: HF-1
 HEAT: 4080
 SERIAL: 4080
 SCOPE DIAMETER: 5.25 IN.
 ORIGINAL DIAMETER: 5.25 IN. AREA: 1.967 SQ. IN.
 INSTRUMENT GAGE LENGTH: 2 IN.
 YIELD STRENGTH: 12.8, 21.7 PSI
 TENSILE STRENGTH: 15.7, 22.7 PSI
 FINAL DIAMETER: 4.25 IN. FINAL AREA: 1.135 SQ. IN.
 REDUCTION AREA: 11.7 %
 ELONGATION: 7.2 %

$R_c = 32.0$

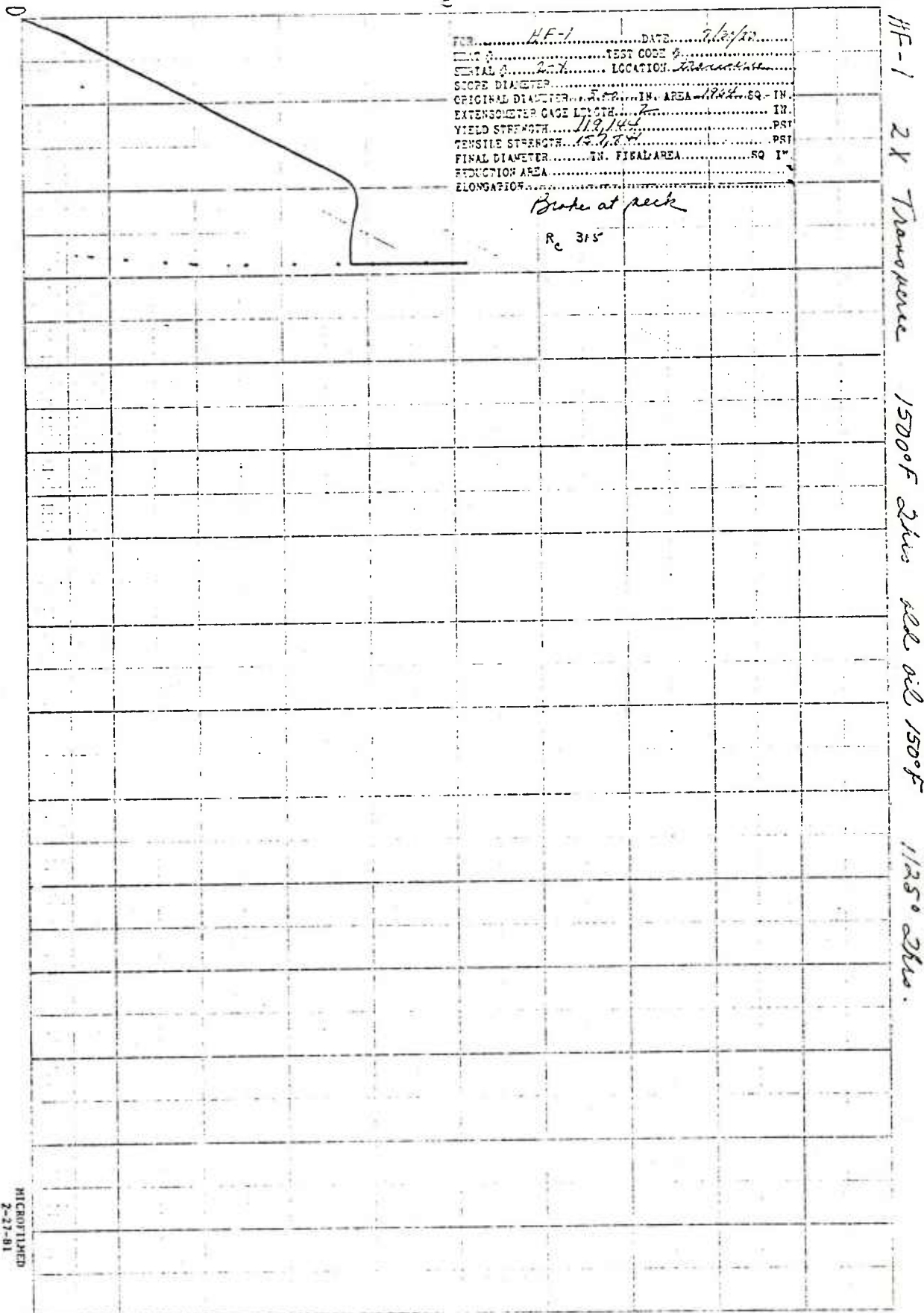
HF-1 4080
 1500 F 24hr
 old oil 150F
 11250 24hr



MICROFILMED
 2-77-81

20,000

60,000



30,000

60,000 HF-1 1-T Transducer 1500°F-24u 002 out 150°F 1125°F 24u0

Break before reaching
cycle point

Rc 32.6

MICROFILMED
2-27-81
60

2400
 2010

60102 HF-1 Transducer 10-T 1500F 2400 add 1500F 11250F 2400

FOR HE-1 DATE 7/29/50
 HEAT # 18-1 TEST CODE # 18-1
 SERIAL # 18-1 LOCATION Transducer
 SCOPE DIAMETER 4.95 IN. AREA 19.24 SQ. IN.
 ORIGINAL DIAMETER 4.95 IN. AREA 19.24 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2.0 IN.
 YIELD STRENGTH 124,600 PSI
 TENSILE STRENGTH 124,600 PSI
 FINAL DIAMETER 1.4 IN. FINAL AREA 1.54 SQ. IN.
 REDUCTION AREA 92.2%
 ELONGATION 32.5%

Broken at neck
 R_e 32.5

60,000

HF-1

10-C

Thermocouple

1500°F 2 hrs

dead 150°F

1125°F 2 hrs

FOR H.F.-1 DATE 7/30/50
 HEAT # 10-2 TEST CODE # 10-2
 SERIAL # 10-2 LOCATION transverse
 SCOPE DIAMETER 2.00 IN. AREA 3.14 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 35.3 PSI
 TENSILE STRENGTH 35.3 PSI
 FINAL DIAMETER 1.98 IN. FINAL AREA 3.08 SQ. IN.
 REDUCTION AREA 3.14
 ELONGATION 3.14

Broken before yield point
 Re 35.3

60,000

30,000

HF-1 10-X Thermoplastic 1500°F 2hr 1400°F 1500°F 1125°F 2hr

FOR HF-1 DATE 7/20/70
 HEAT # 10-X TEST CODE # 1
 SERIAL # 10-X LOCATION 10-X
 SCOPE DIAMETER 2.5 IN. AREA 19.6 SQ. IN.
 ORIGINAL DIAMETER 2.5 IN. AREA 19.6 SQ. IN.
 EXTENSION CAGE LENGTH 2 IN.
 GAGE LENGTH 12.7 IN. PSI
 TENSILE STRENGTH 12.7 IN. PSI
 FINAL DIAMETER 2.5 IN. FINAL AREA 19.6 SQ. IN.
 REDUCTION AREA 2.5 IN. PSI
 ELONGATION 2.5 IN. PSI

Break at peak
Pc 31.5

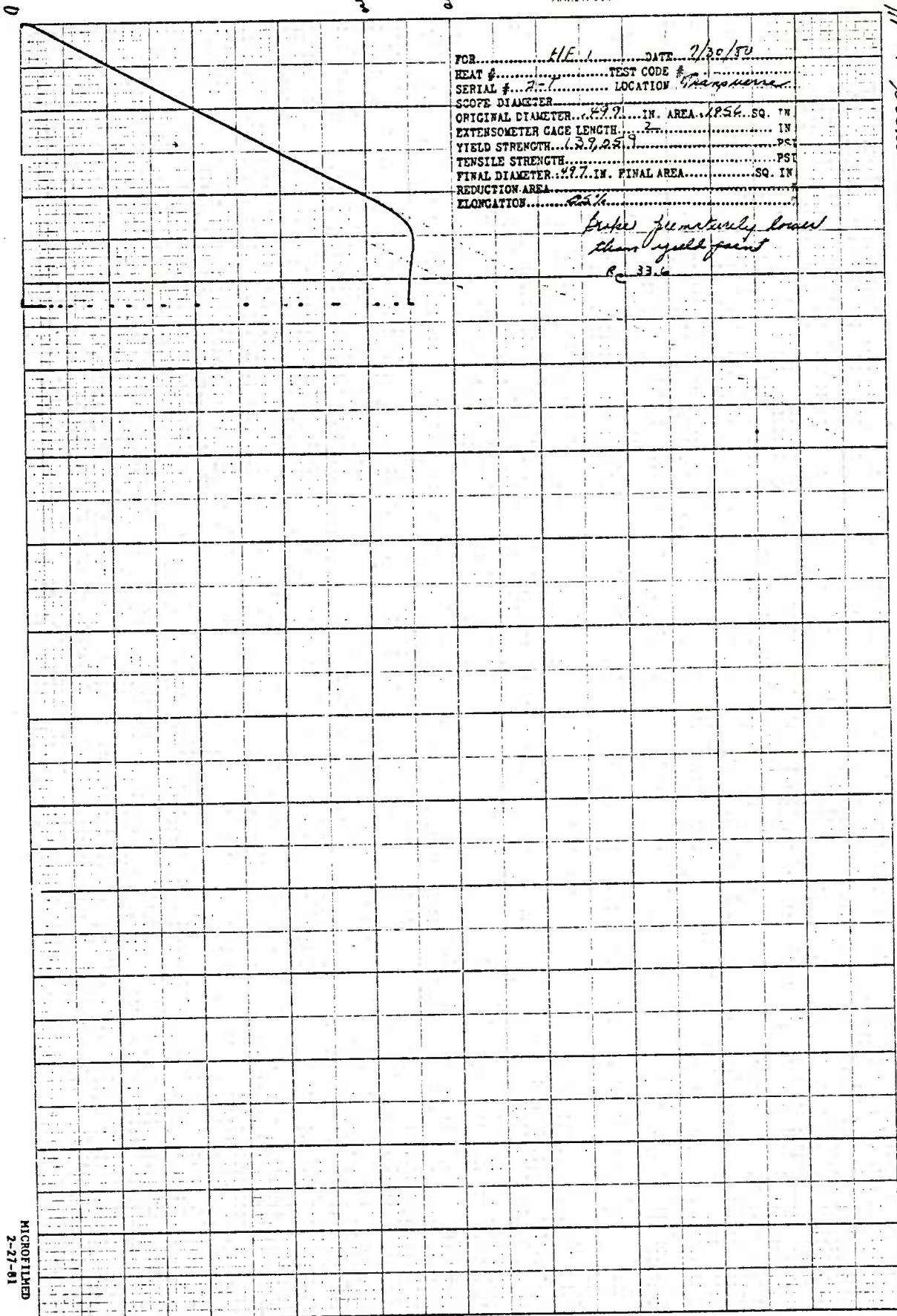
30,000
 20,000

60,000

FOR.....*H/E-1*.....DATE.....*2/20/50*.....
 HEAT #.....*7-1*.....TEST CODE #.....
 SERIAL #.....*7-1*.....LOCATION.....*Transducer*.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....*2.97*.....IN. AREA.....*1.856*.....SQ. IN.
 EXTENSOMETER GAGE LENGTH.....*2*.....IN.
 YIELD STRENGTH.....*139,259*.....PSI
 TENSILE STRENGTH.....
 FINAL DIAMETER.....*2.77*.....IN. FINAL AREA.....
 REDUCTION AREA.....
 ELONGATION.....*24%*

*Proper prematurely lower
 than yield point
 R_e 33.6*

H/E-1 Maximize 2-T 1500 F_{th} all at 150°F 1125°F 2 hrs



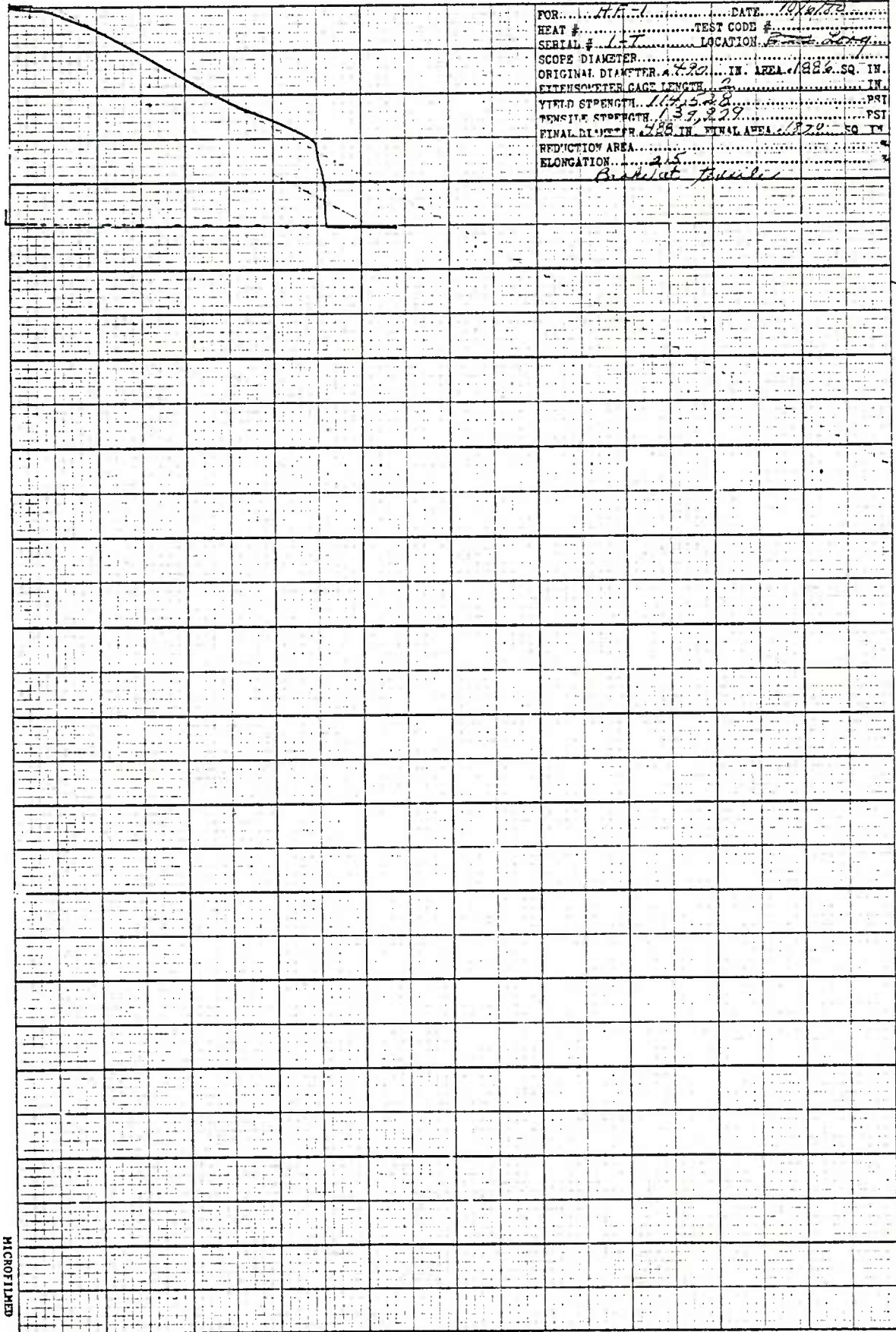
24.70 28.80

11F-1 1-T 1500°F 2100 6000 1500°F 1125°F 2100 1125°F 2100

FOR..... DATE.....
HEAT #..... TEST CODE #.....
SERIAL #..... LOCATION *Random*
SCOPE DIAMETER.....
ORIGINAL DIAMETER *.43* IN. AREA..... SQ IN
EXTENSOMETER GAGE LENGTH..... IN
YIELD STRENGTH..... PSI
TENSILE STRENGTH..... PSI
FINAL DIAMETER..... IN FINAL AREA..... SQ IN
REDUCTION AREA.....
ELONGATION.....

FOR *11F-1* DATE *10/1/70*
HEAT #..... TEST CODE #.....
SERIAL # *1-T* LOCATION *2209*
SCOPE DIAMETER.....
ORIGINAL DIAMETER *.439* IN. AREA *.1518* SQ IN
EXTENSOMETER GAGE LENGTH *2* IN
YIELD STRENGTH *21.7* PSI
TENSILE STRENGTH *21.2* PSI
FINAL DIAMETER *.434* IN. FINAL AREA *.1479* SQ IN
REDUCTION AREA *21.2*
ELONGATION *10.0*

FOR H.T. DATE 10/16/62
 HEAT # 1-T TEST CODE #
 SERIAL # 1-T LOCATION Bottom
 SCOPE DIAMETER 2
 ORIGINAL DIAMETER 4.20 IN. AREA 13.82 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 114,500 PSI
 TENSILE STRENGTH 137,229 PSI
 FINAL DIAMETER 2.26 IN. FINAL AREA 3.92 SQ. IN.
 REDUCTION AREA 2.5
 ELONGATION Break at Neck

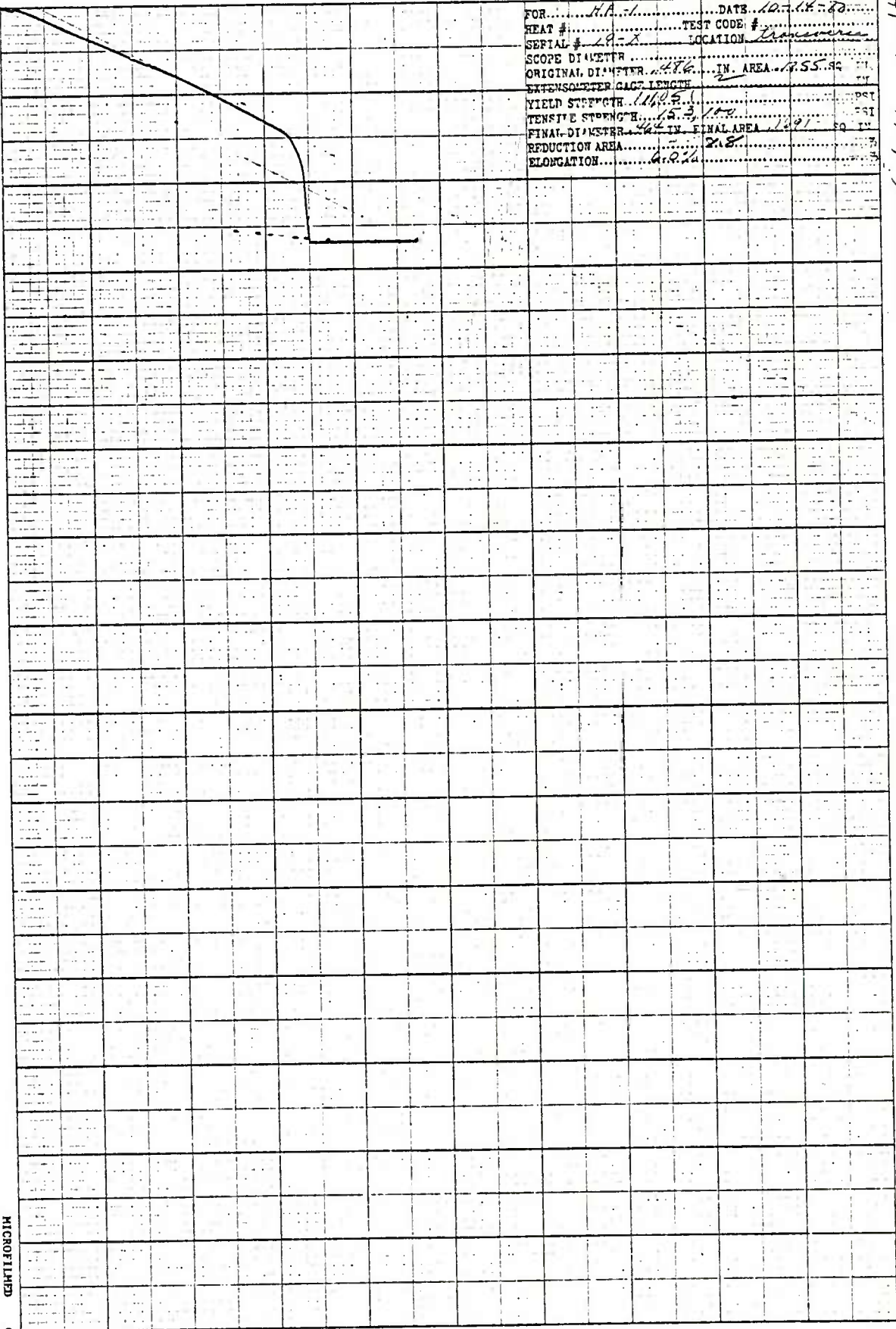


100,000
 HF-1
 1-T
 All Long
 1500°F
 2000
 1600°F
 1125°F
 2000

60,200

HF-1 19-X Transverse

FOR... H.A. 1... DATE... 10-16-80
 HEAT #... TEST CODE #...
 SERIAL #... 19... LOCATION... Transverse
 SCOPE DIAMETER...
 ORIGINAL DIAMETER... 4.86... IN. AREA... 7.55 sq in.
 EXTENSIONER GAGE LENGTH...
 YIELD STRENGTH... 110.5... PSI
 TENSILE STRENGTH... 15.3... PSI
 FINAL DIAMETER... 4.42... IN. FINAL AREA... 7.41... sq in.
 REDUCTION AREA... 2.8...
 ELONGATION... 2.2%



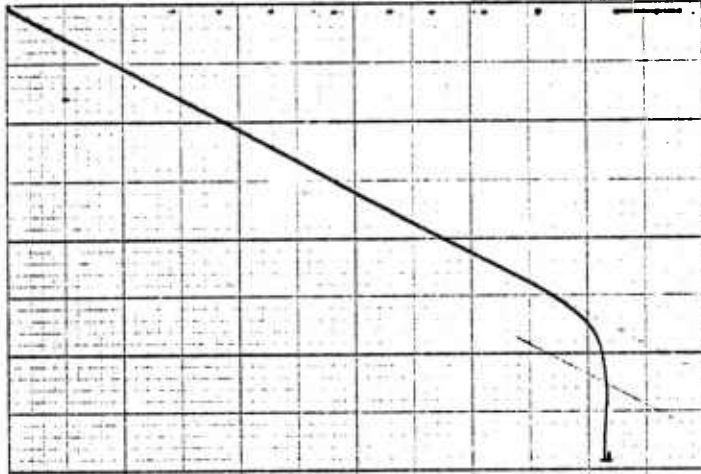
MICROFILMED
 2-27-81
 67

66000

3.80

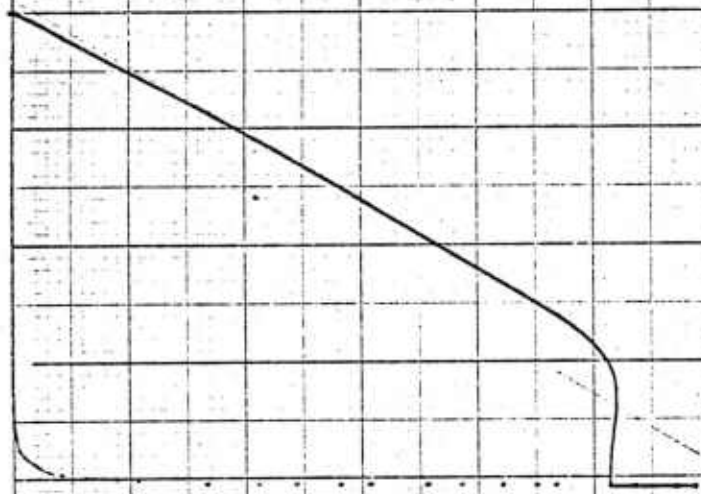
FOR.....*HF-1*.....DATE.....*8/12/80*.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....*11-1*.....LOCATION.....*2027*.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....*5.82*.....IN. AREA.....*1922.5* SQ. IN.
 EXTENSOMETER GAGE LENGTH.....*2*.....IN.
 YIELD STRENGTH.....*12.6*.....KSI
 TENSILE STRENGTH.....*12.7*.....KSI
 FINAL DIAMETER.....IN. FINAL AREA.....
 REDUCTION AREA.....
 ELONGATION.....

Break near the neck
Rc 36.2



FOR.....*HF-1*.....DATE.....*8/12/80*.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....*11-1*.....LOCATION.....*2027*.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....*5.82*.....IN. AREA.....*1922.5* SQ. IN.
 EXTENSOMETER GAGE LENGTH.....*2*.....IN.
 YIELD STRENGTH.....*15.2*.....KSI
 TENSILE STRENGTH.....*15.2*.....KSI
 FINAL DIAMETER.....IN. FINAL AREA.....
 REDUCTION AREA.....
 ELONGATION.....

Break near the neck
Rc 36.5



HF-1
11-1
1500°F 2027
old oil 140°F
1100°F 2027

FOR: HF-1 DATE: 8/14/80
 HEAT # 2 TEST CODE # 2
 SERIAL # 2 LOCATION: 2
 SCOPE DIAMETER: 1.87 IN. AREA: 2.87 SQ. IN.
 ORIGINAL DIAMETER: 1.87 IN. AREA: 2.87 SQ. IN.
 EXTENSOMETER GAGE LENGTH: 2 IN.
 YIELD STRENGTH: 18.4 PSI
 TENSILE STRENGTH: 18.4 PSI
 FINAL DIAMETER: 1.87 IN. FINAL AREA: 2.87 SQ. IN.
 REDUCTION AREA: 1.87 IN.
 ELONGATION: 2.87 IN.

R₀ 35.5

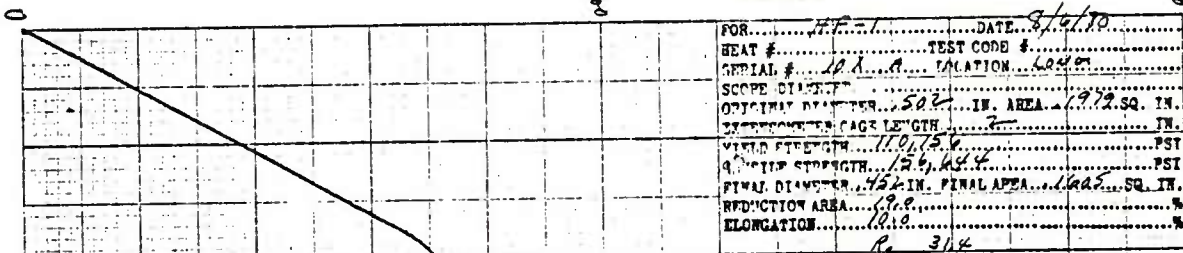
FOR: HF-1 DATE: 8/14/80
 HEAT # 2 TEST CODE # 2
 SERIAL # 2 LOCATION: 2
 SCOPE DIAMETER: 1.87 IN. AREA: 2.87 SQ. IN.
 ORIGINAL DIAMETER: 1.87 IN. AREA: 2.87 SQ. IN.
 EXTENSOMETER GAGE LENGTH: 2 IN.
 YIELD STRENGTH: 18.4 PSI
 TENSILE STRENGTH: 18.4 PSI
 FINAL DIAMETER: 1.87 IN. FINAL AREA: 2.87 SQ. IN.
 REDUCTION AREA: 1.87 IN.
 ELONGATION: 2.87 IN.

R₀ 36.3

HF-1 2 - 30 1500°F plus hold 150°F 1025°F plus long

30100

60100

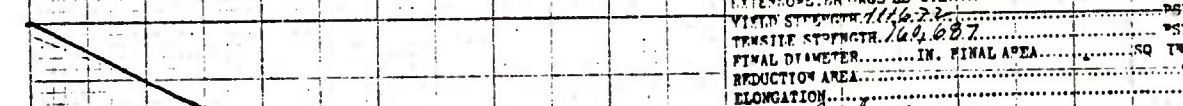


HF-1 10 x drag.

1500°F Anne

all cool 140°F

1150°F 2 hrs



Break at peak
 R_c 28.5

MICROFILMED
 2-27-81

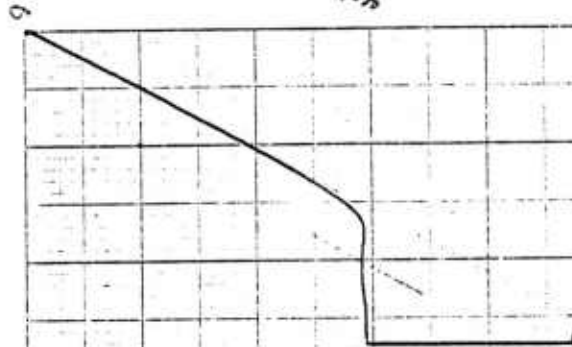
HF-1 19-C 24.2
 1500°F 24.2
 1400°F 24.2
 1400°F 24.2

FOR..... HF-1..... DATE 3-5-80
 HEAT #..... TEST CODE #.....
 SERIAL #..... 19-C..... LOCATION 24.2
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER 5.03 IN. AREA 19.82 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 28,225 PSI
 TENSILE STRENGTH 28,225 PSI
 FINAL DIAMETER 4.82 IN. FINAL AREA 14.52 SQ. IN.
 REDUCTION AREA 26.3
 ELONGATION 14.0%

Pc 24.2

FOR..... HF-1..... DATE 3-5-80
 HEAT #..... TEST CODE #.....
 SERIAL #..... 19-C..... LOCATION 24.2
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER 5.03 IN. AREA 19.82 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 28,225 PSI
 TENSILE STRENGTH 28,225 PSI
 FINAL DIAMETER 4.82 IN. FINAL AREA 14.52 SQ. IN.
 REDUCTION AREA 26.3
 ELONGATION 14.0%

Pc 24.2



60,000

0

1000

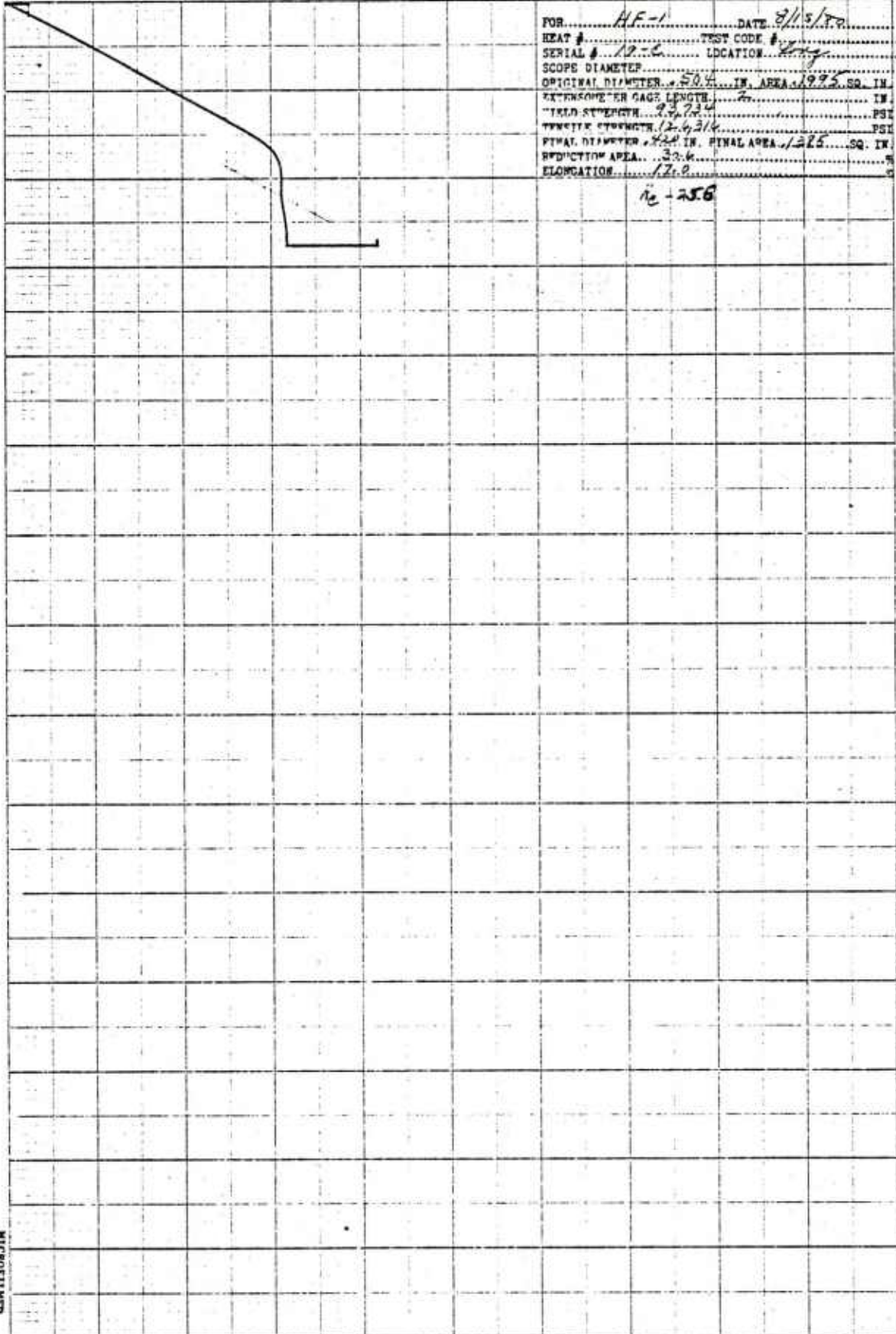
2000

3000

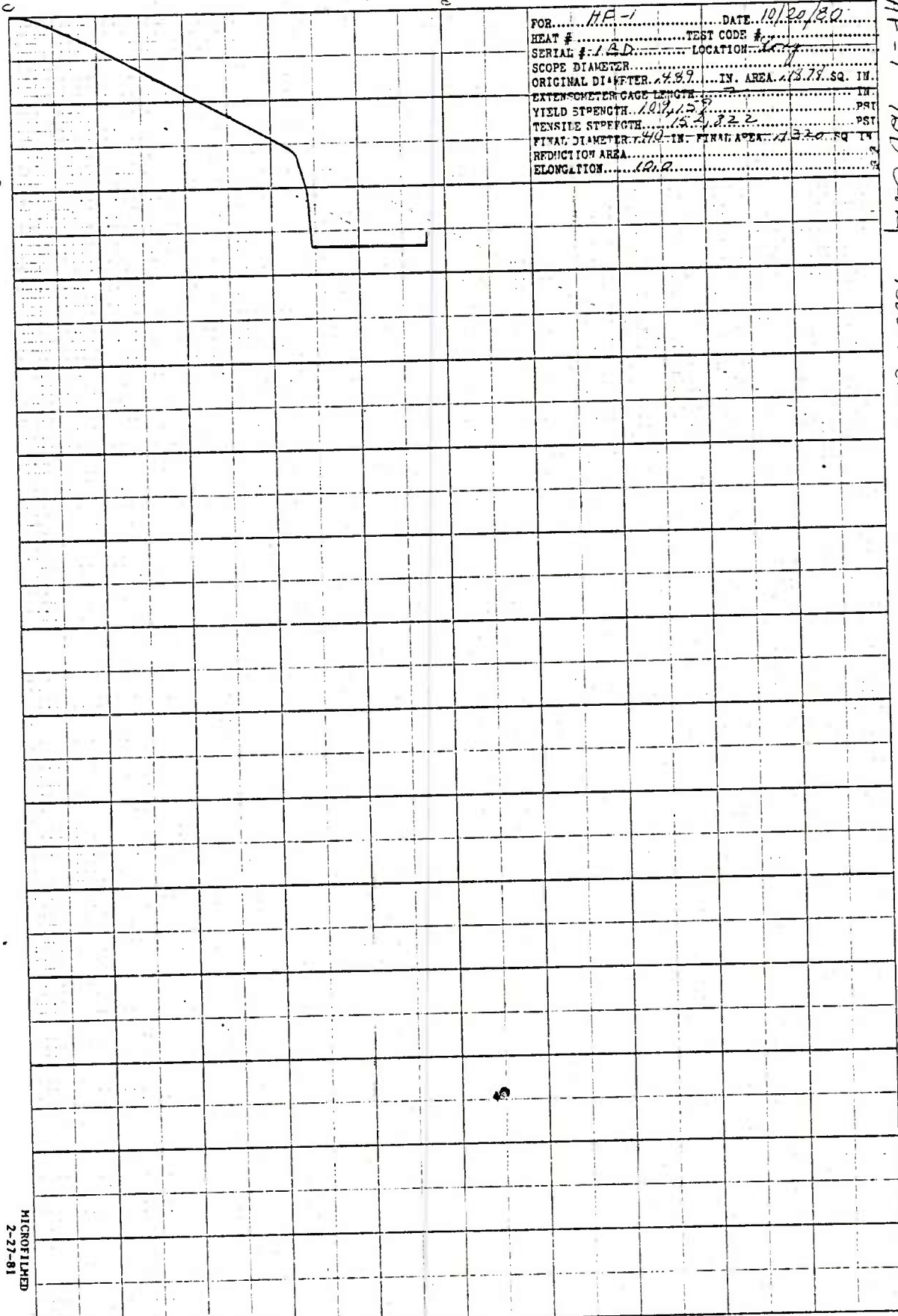
FOR HF-1 DATE 8/15/70
HEAT # 12-2 TEST CODE # 277
SERIAL # 12-2 LOCATION 277
SCOPE DIAMETER 50.4 IN. AREA 1995 SQ. IN.
ORIGINAL DIAMETER 50.4 IN. AREA 1995 SQ. IN.
EXTENSOMETER GAGE LENGTH 2 IN.
YIELD STRENGTH 93,234 PSI
TENSILE STRENGTH 124,314 PSI
FINAL DIAMETER 42.8 IN. FINAL AREA 1325 SQ. IN.
REDUCTION AREA 33.6 SQ. IN.
ELONGATION 12.0 %

12-258

HF-1 1-17-C Aug 15 1970 2100 Old mt '50's 1300 F. 2 hrs



60,000 11F-1 1BD Long 1500°F 2 hrs old and 1500°F 11/25" 2 hrs



FOR... HP-1 ... DATE 10/20/80
 HEAT #... .. TEST CODE #... ..
 SERIAL # 13D ... LOCATION 107
 SCOPE DIAMETER... ..
 ORIGINAL DIAMETER 4.89 ... IN. AREA 18.77 SQ. IN.
 EXTENSOMETER GAGE LENGTH... ..
 YIELD STRENGTH 101,158 ... PSI
 TENSILE STRENGTH 122,222 ... PSI
 FINAL DIAMETER 4.40 IN. FINAL AREA 13.20 SQ. IN.
 REDUCTION AREA... ..
 ELONGATION... 12.2 ...

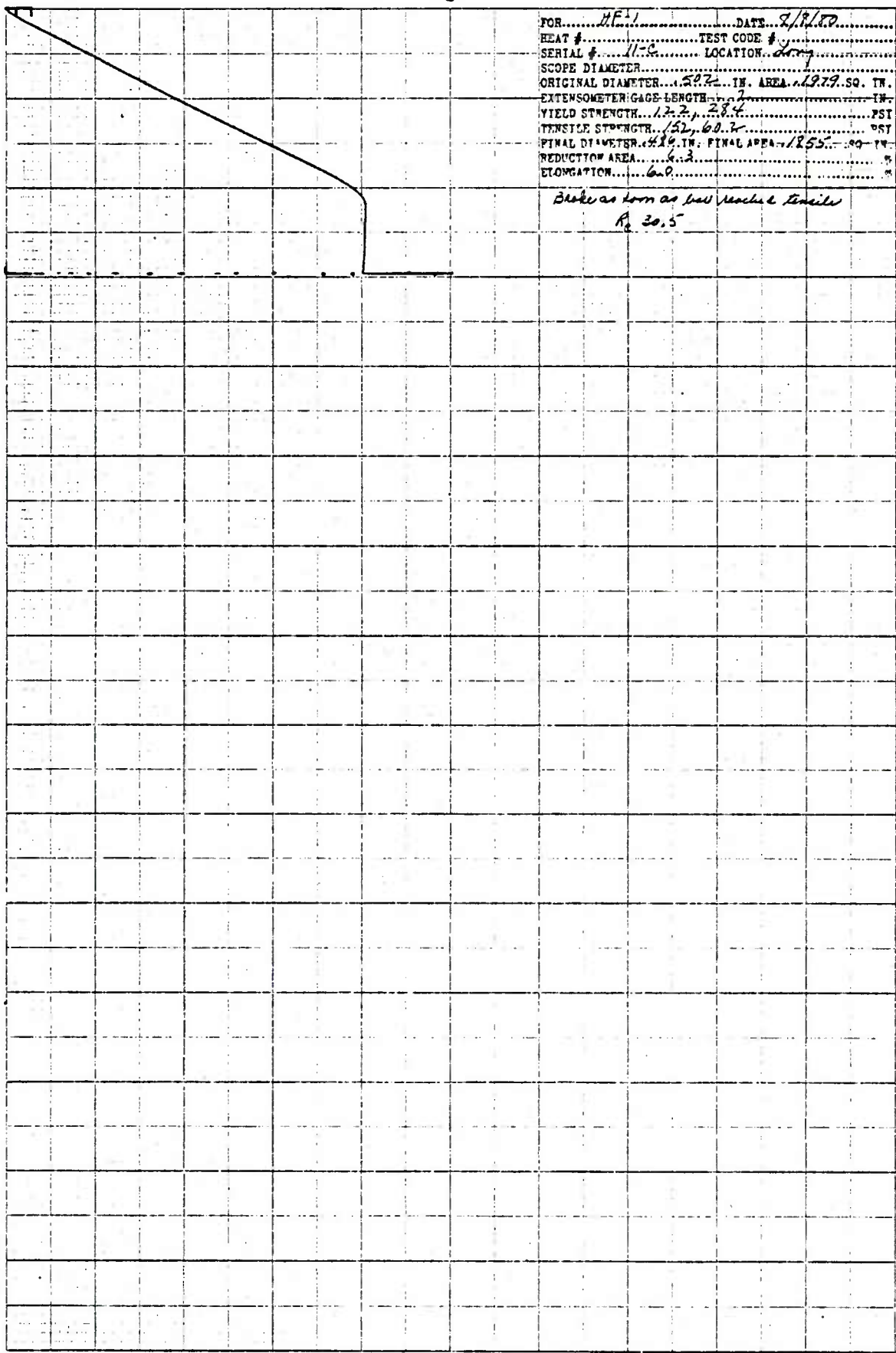
MICROFILMED
 2-27-81
 73

60,000

30,000

FOR.....*HF-1*.....DATE.....*2/9/80*.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....*11-2*.....LOCATION.....*2079*.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....*20.72*.....IN. AREA.....*1979.50*.....IN.
 EXTENSOMETER GAGE LENGTH.....*2*.....IN.
 YIELD STRENGTH.....*17.2*.....*28.4*.....PSI
 TENSILE STRENGTH.....*52*.....*60.7*.....PSI
 FINAL DIAMETER.....*19.10*.....IN. FINAL AREA.....*1855*.....*89.74*.....
 REDUCTION AREA.....*6.3*.....
 ELONGATION.....*60*.....

Stake as soon as has reached tensile
R₀ 30.5



HF-1
11-2
2079
1500°F 2 1/2 hrs
red oil 150°
1175°F 2 hrs

HF-1 11-7 Butl Jny 1500F 2hrs 24.0 160F 11850F 2hrs

FOR.....HF-1.....DATE.....10/6/80
HEAT #.....TEST CODE #.....
SERIAL #.....11-7.....LOCATION.....
SCOPE DIAMETER.....
ORIGINAL DIAMETER......489.....IN. AREA.....12.78 SQ. IN.
EXTENSOMETER GAGE LENGTH.....7.....IN.
YIELD STRENGTH.....11.8.....PSI
TENSILE STRENGTH.....15.2.....PSI
FINAL DIAMETER.....IN. FINAL AREA.....SQ. IN.
REDUCTION AREA.....
ELONGATION.....

Break at neck

FOR.....HF-1.....DATE.....10/6/80
HEAT #.....TEST CODE #.....
SERIAL #.....11-7.....LOCATION.....
SCOPE DIAMETER.....
ORIGINAL DIAMETER......489.....IN. AREA.....12.78 SQ. IN.
EXTENSOMETER GAGE LENGTH.....7.....IN.
YIELD STRENGTH.....11.8.....PSI
TENSILE STRENGTH.....15.2.....PSI
FINAL DIAMETER.....IN. FINAL AREA.....SQ. IN.
REDUCTION AREA.....
ELONGATION.....

MICROFILMED
2-27-81

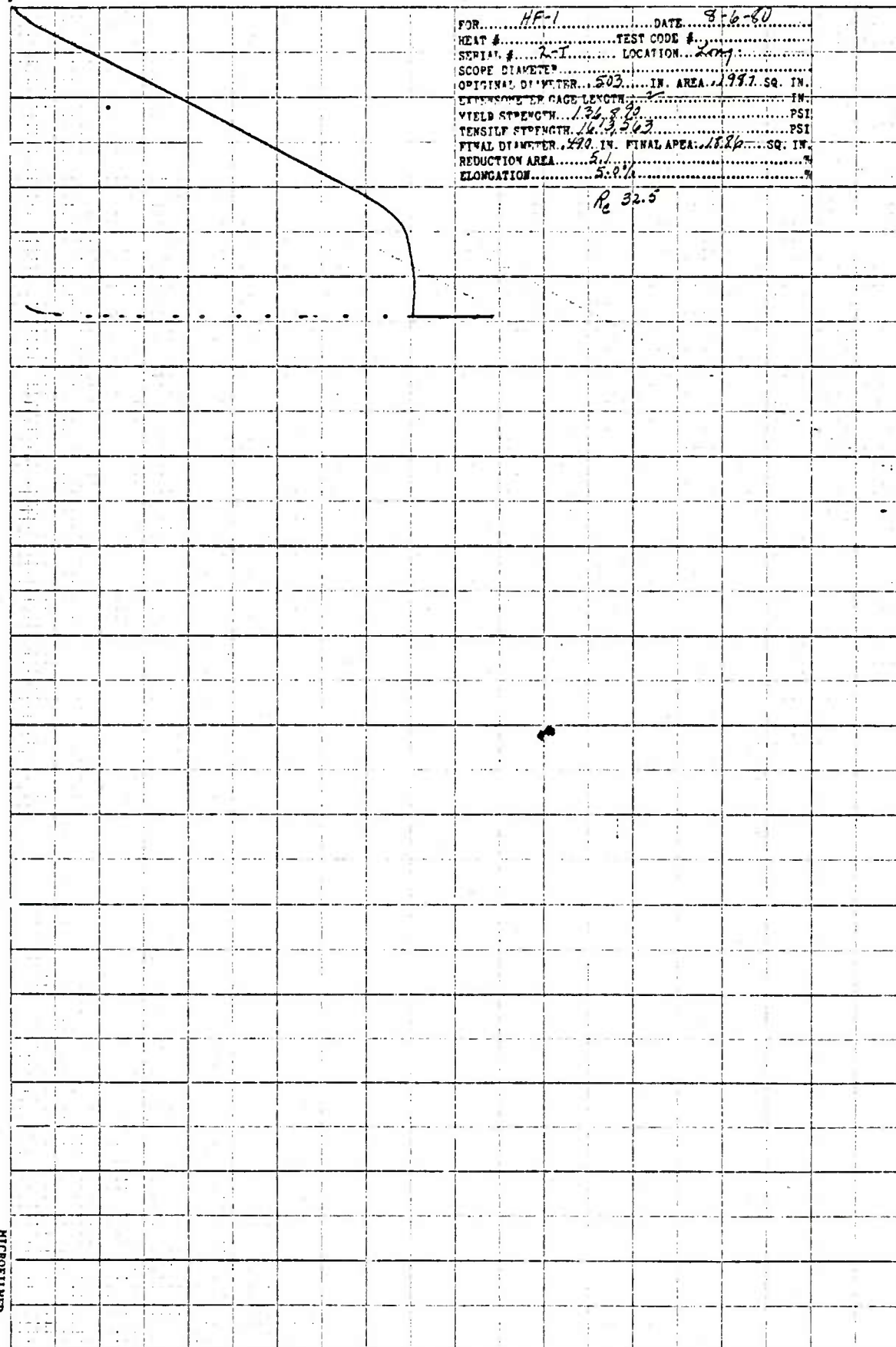
75

3100

60,000 HF-1 2-T Long 1500 PSI 2000 PSI 1500 PSI 1125 PSI

FOR... HF-1... DATE... 8-6-60
HEAT #... TEST CODE #...
SERIAL #... 2-T... LOCATION... Long
SCOPE DIAMETER...
ORIGINAL DIAMETER... 503... IN. AREA... 198.7 SQ. IN.
EXTENSOMETER GAGE LENGTH...
YIELD STRENGTH... 134,800... PSI
TENSILE STRENGTH... 121,300... PSI
FINAL DIAMETER... 490... IN. FINAL AREA... 188.0 SQ. IN.
REDUCTION AREA... 5.1...
ELONGATION... 5.0...

R₀ 32.5

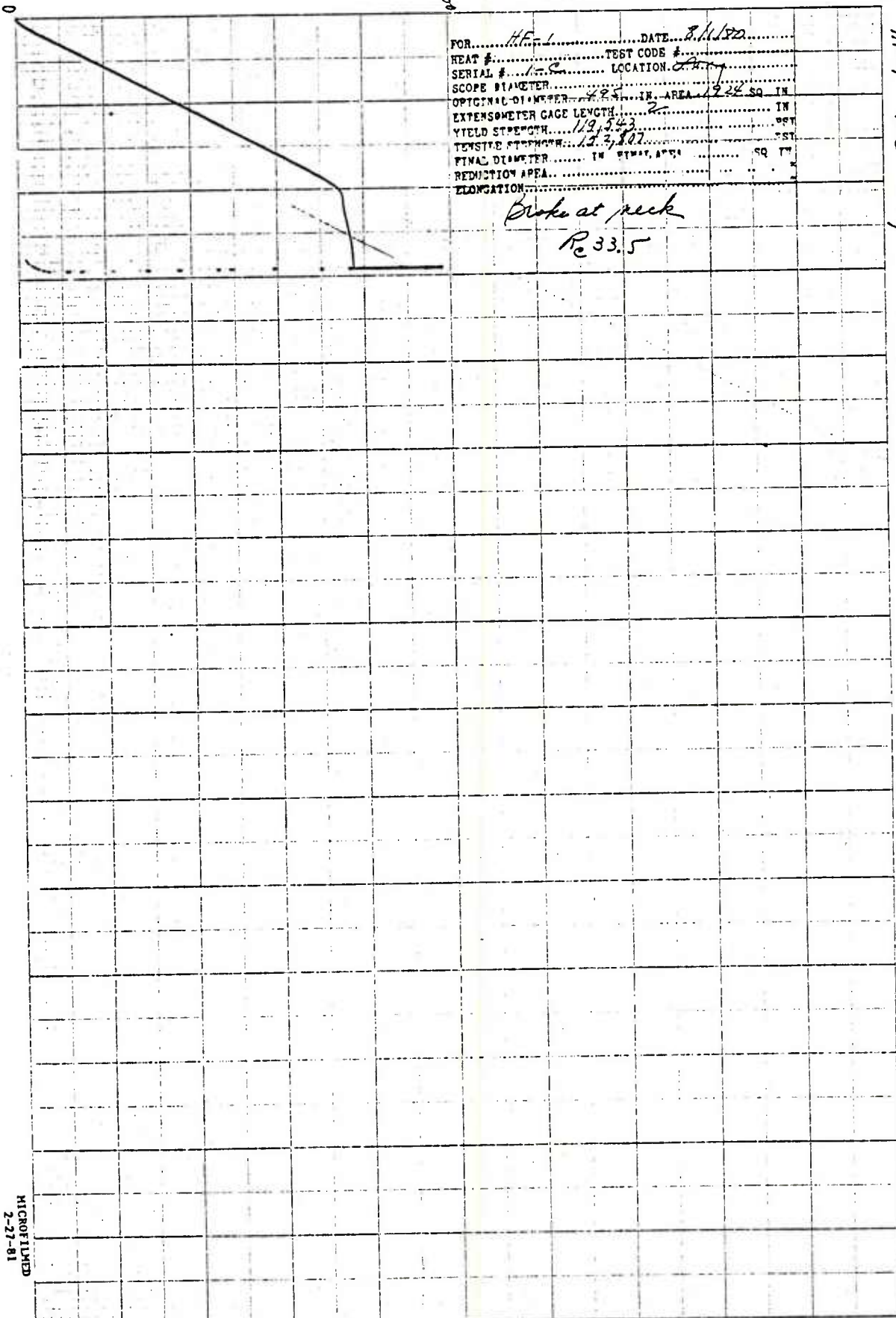


60,000

HF-1 1-C Long. 1500°F 2 hrs 02 load 1500°F 1125°F 2 hrs

FOR... HF-1... DATE... 8/11/80...
HEAT #... TEST CODE #...
SERIAL #... 1-C... LOCATION... Long.
SCOPE DIAMETER... 4.85... IN. AREA... 12.24 SQ IN
ORIGINAL DIAMETER... 4.85... IN. AREA... 12.24 SQ IN
EXTENSOMETER GAGE LENGTH... 2...
YIELD STRENGTH... 119,543... PSI
TENSILE STRENGTH... 123,807... PSI
FINAL DIAMETER... IN. AREA... SQ IN
REDUCTION AREA...
ELONGATION...

Broke at peak
R_e 33.5



MICROFILMED
2-27-81

77

50,000

60,000

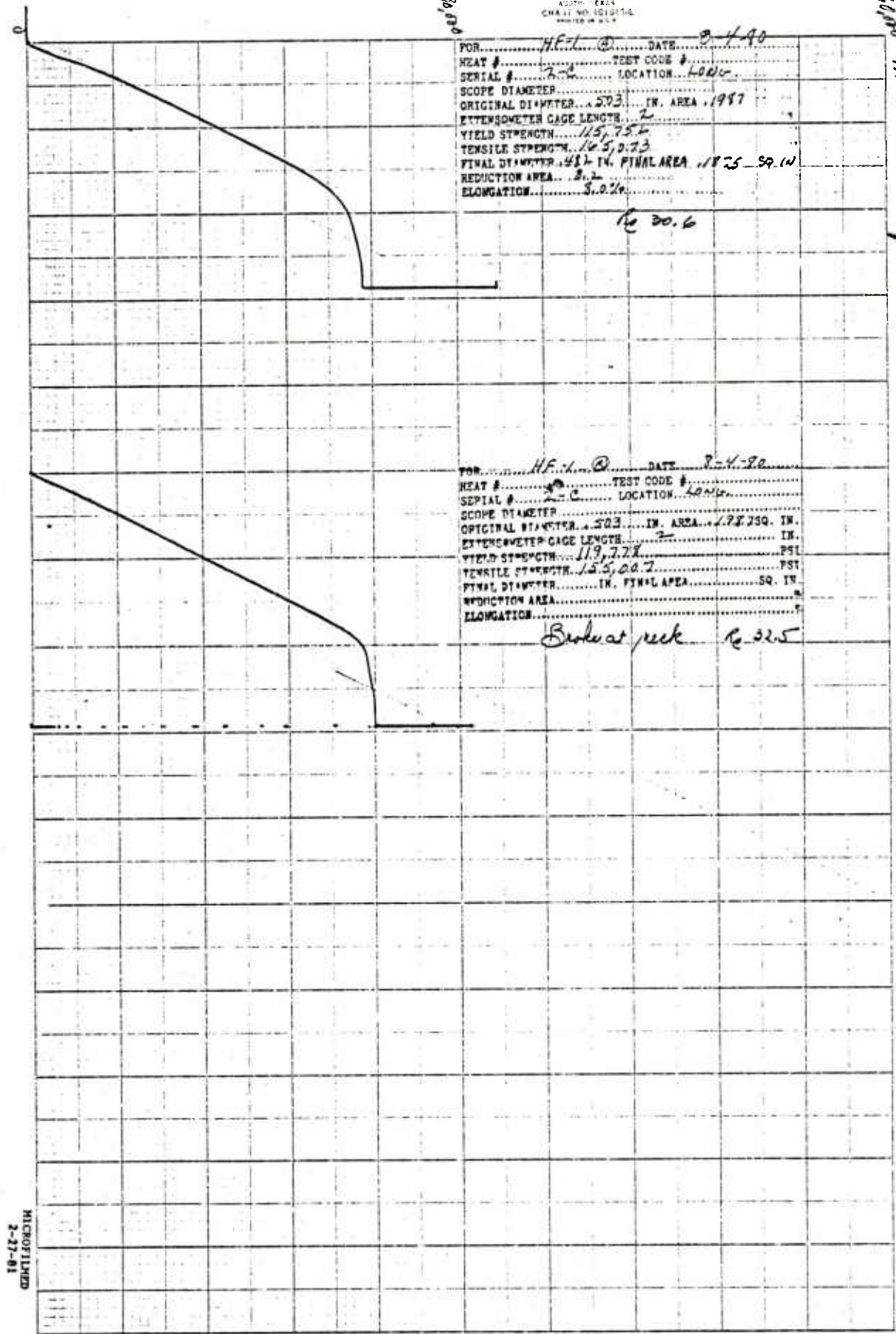
FOR.....HF-1.....DATE.....8-4-90.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....2-6.....LOCATION.....L-200.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....5.03.....IN. AREA.....1.987.....
 EXTENSOMETER GAGE LENGTH.....2.....IN.
 YIELD STRENGTH.....115,754.....PSI
 TENSILE STRENGTH.....145,023.....PSI
 FINAL DIAMETER.....4.81.....IN. FINAL AREA.....1.825.....SQ. IN.
 REDUCTION AREA.....3.2.....
 ELONGATION.....3.02.....%

R_e 30.6

FOR.....HF-1.....DATE.....8-4-90.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....2-6.....LOCATION.....L-200.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....5.03.....IN. AREA.....1.98730.....IN.
 EXTENSOMETER GAGE LENGTH.....2.....IN.
 YIELD STRENGTH.....113,778.....PSI
 TENSILE STRENGTH.....155,002.....PSI
 FINAL DIAMETER.....IN. FINAL AREA.....SQ. IN.
 REDUCTION AREA.....
 ELONGATION.....

Break at peak R_e 32.5

HF-1 2C temp. 1500°F 2hrs
 old oil 140°F 1100°F 2hrs



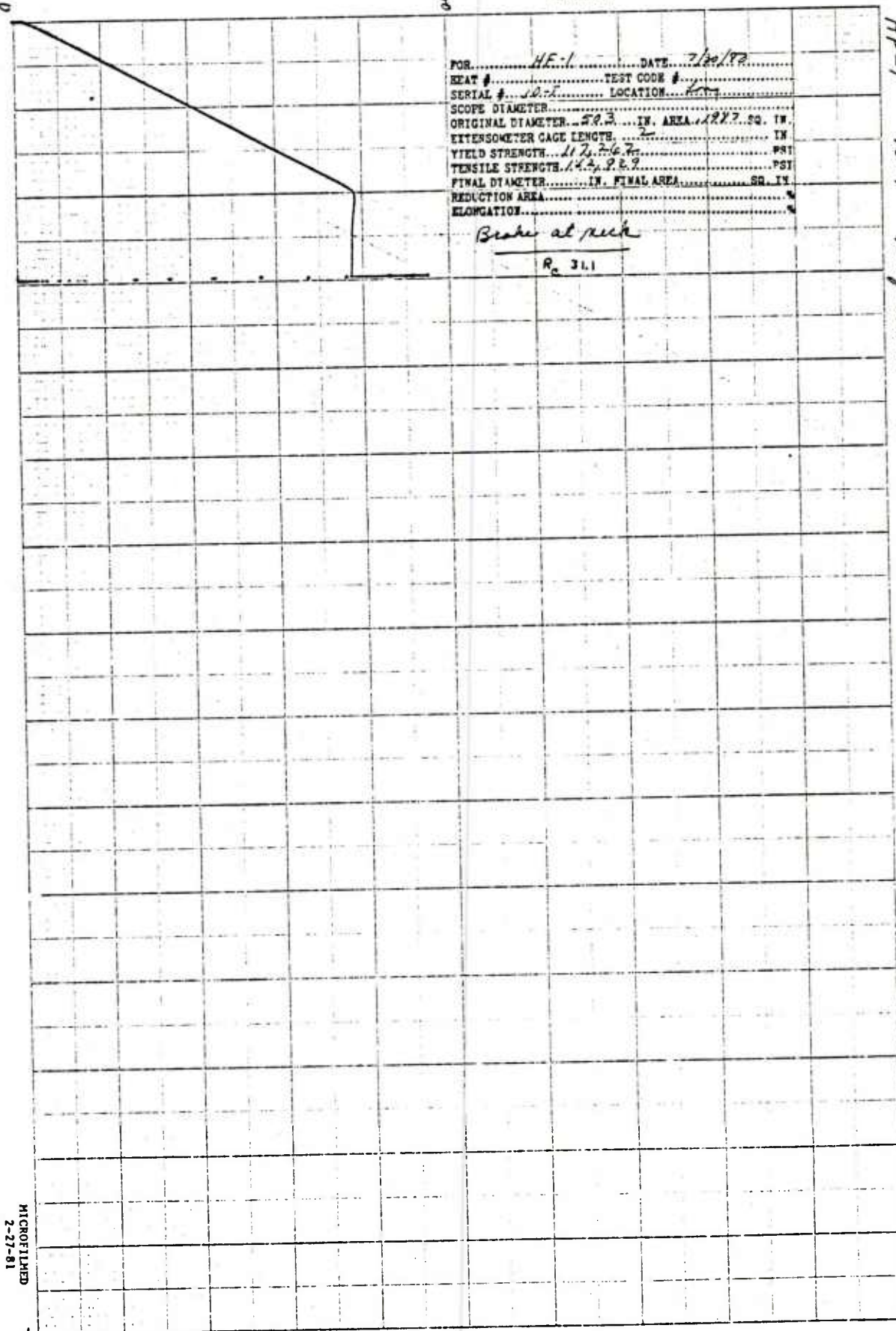
30,000

60,000

HF-1 10-T Longitudinal 1500°F Air Anneal 1500°Kw. 1125°F Air.

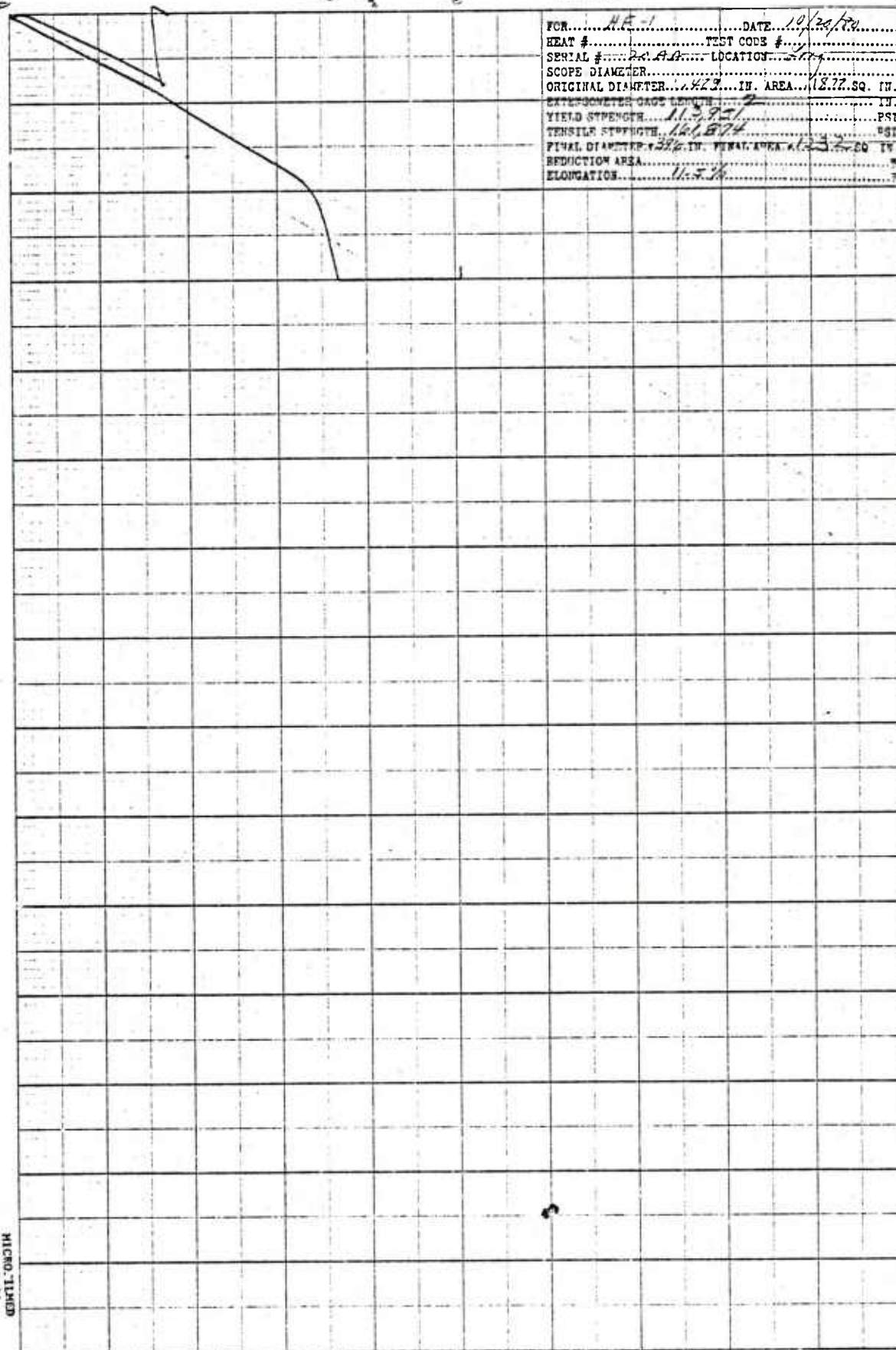
FOR.....HF-1.....DATE.....7/20/72.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....10-1.....LOCATION.....HF-1.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....2.83.....IN. AREA.....2.27.....SQ. IN.
 EXTENSOMETER GAGE LENGTH.....2.....IN.
 YIELD STRENGTH.....112,767.....PSI
 TENSILE STRENGTH.....142,929.....PSI
 FINAL DIAMETER.....IN. FINAL AREA.....SQ. IN.
 REDUCTION AREA.....
 ELONGATION.....

Break at neck
R_m 31.1



MICROFILMED
 2-27-81
 79

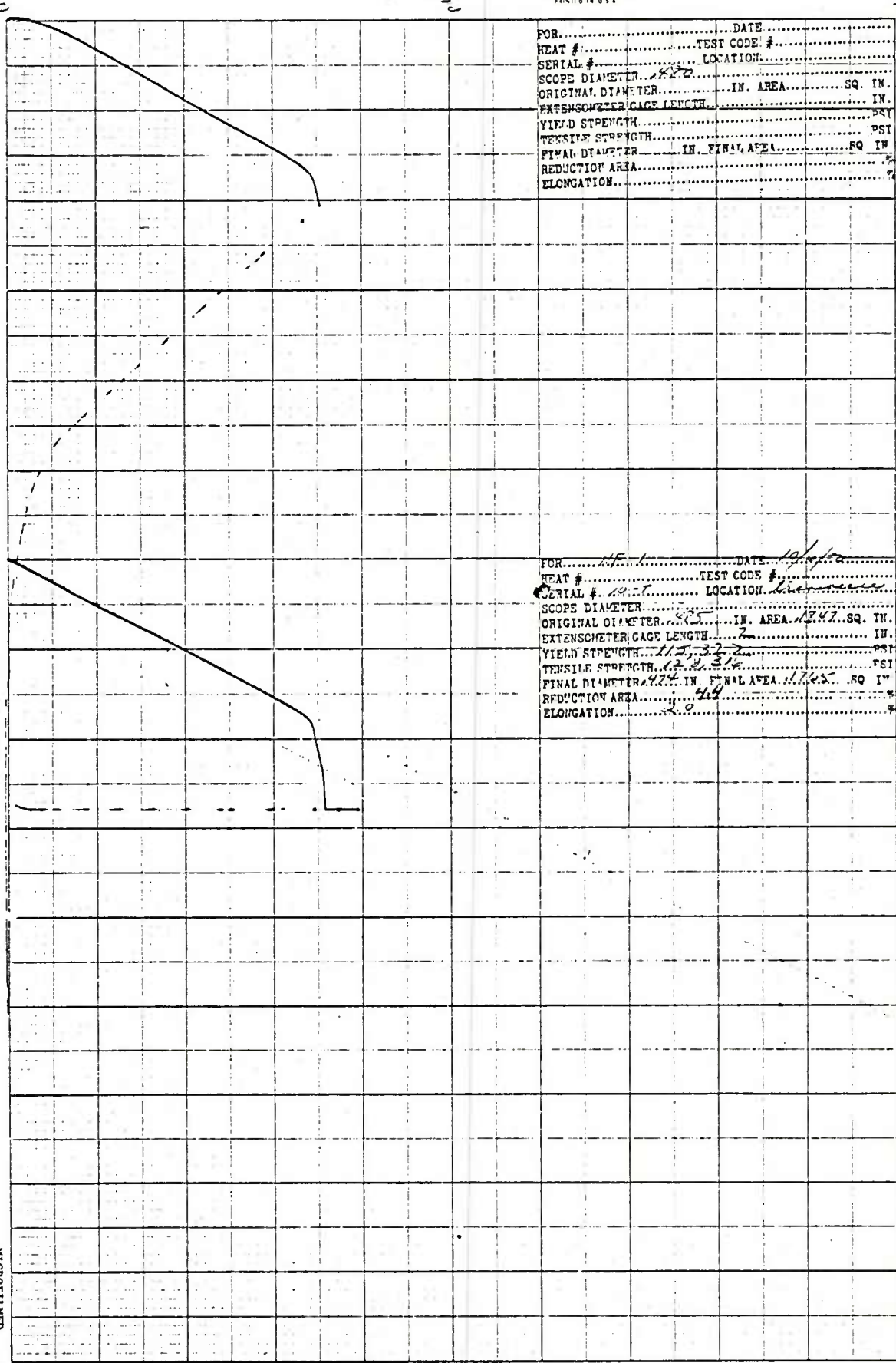
FOR.....*45-1*.....DATE.....*10/24/70*.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....*26-148*.....LOCATION.....*270g*.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....*1.423*.....IN. AREA.....*12.72* SQ. IN.
 EXTENSOMETER GAGE LENGTH.....*2*.....IN.
 YIELD STRENGTH.....*115,851*.....PSI
 TENSILE STRENGTH.....*161,874*.....PSI
 FINAL DIAMETER.....*0.382* IN. FINAL AREA.....*0.23* SQ. IN.
 REDUCTION AREA.....
 ELONGATION.....*11.7*%



60000 30 A 1500 F 2 hrs 1125 F 2 hrs old and 1500 F

60,000 HF-1
 10-7
 1500°F
 2 1/2 in
 600 to 1500°F
 1/8" of carbon transverse

3 1/2 in



FOR..... DATE.....
 HEAT #..... TEST CODE #.....
 SERIAL #..... LOCATION.....
 SCOPE DIAMETER..... IN. AREA..... SQ. IN.
 ORIGINAL DIAMETER..... IN. AREA..... SQ. IN.
 EXTENSOMETER GAGE LENGTH..... IN.
 YIELD STRENGTH..... PSI
 TENSILE STRENGTH..... PSI
 FINAL DIAMETER..... IN. FINAL AREA..... SQ. IN.
 REDUCTION AREA.....
 ELONGATION.....

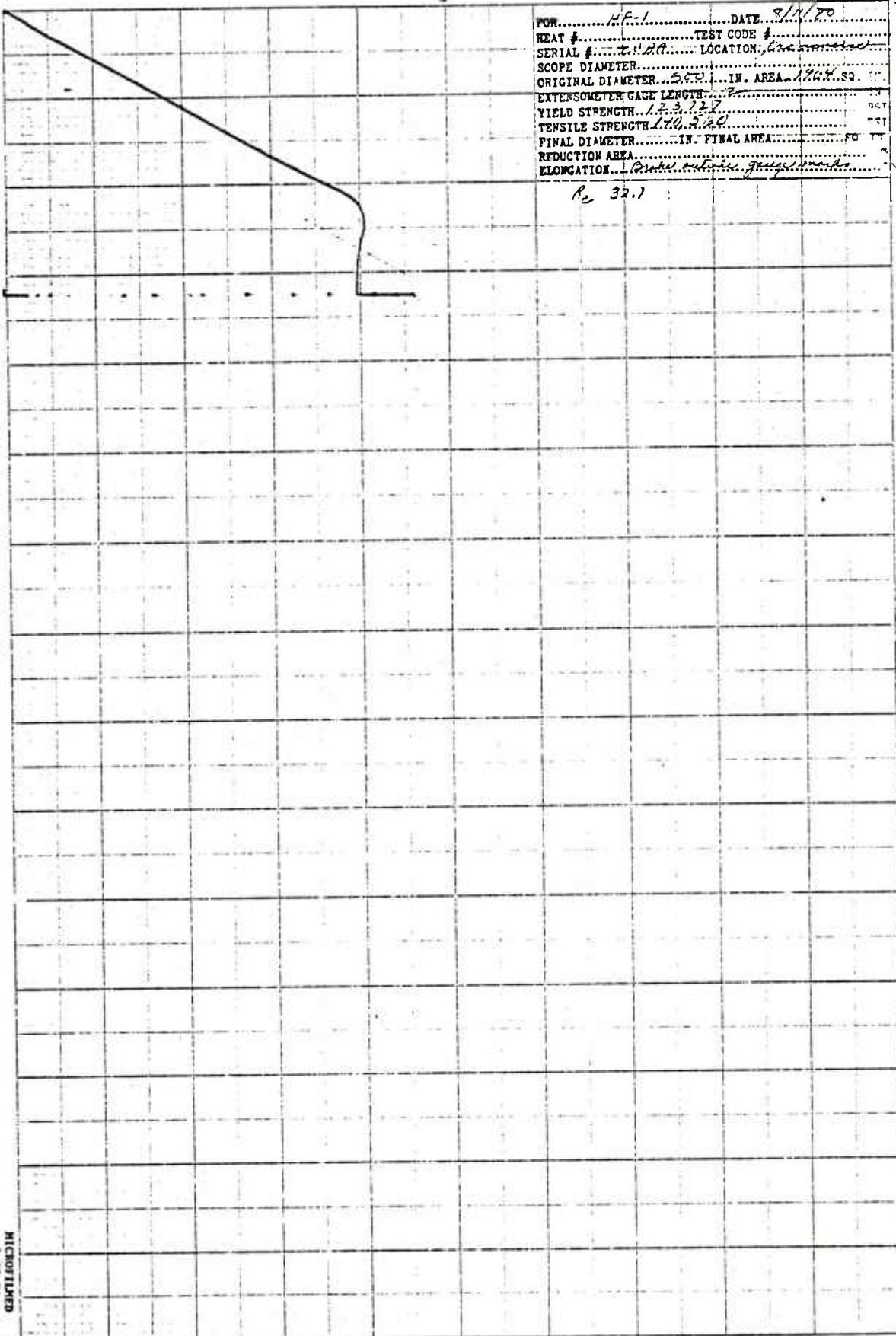
FOR..... DATE.....
 HEAT #..... TEST CODE #.....
 SERIAL #..... LOCATION.....
 SCOPE DIAMETER..... IN. AREA..... SQ. IN.
 ORIGINAL DIAMETER..... IN. AREA..... SQ. IN.
 EXTENSOMETER GAGE LENGTH..... IN.
 YIELD STRENGTH..... PSI
 TENSILE STRENGTH..... PSI
 FINAL DIAMETER..... IN. FINAL AREA..... SQ. IN.
 REDUCTION AREA.....
 ELONGATION.....

32,100

69,000

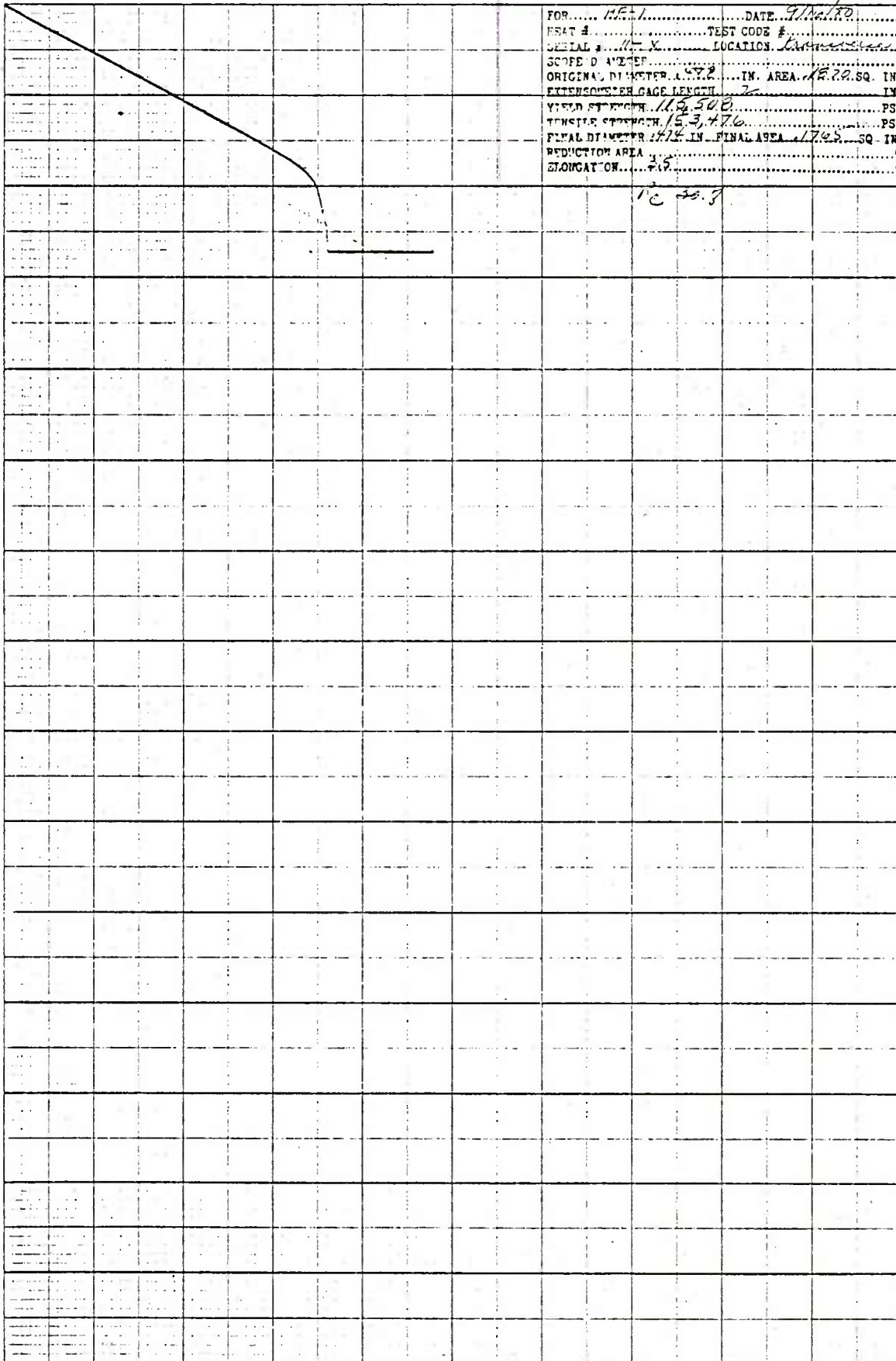
FOR HF-1 DATE 8/11/70
 HEAT # 2122 TEST CODE # 1000
 SERIAL # 2122 LOCATION 1000
 SCOPE DIAMETER 5.00 IN. AREA 19.64 SQ. IN.
 EXTENSOMETER GAGE LENGTH 2 IN.
 YIELD STRENGTH 17.3 KSI
 TENSILE STRENGTH 17.3 KSI
 FINAL DIAMETER 5.00 IN. FINAL AREA 19.64 SQ. IN.
 REDUCTION AREA 0.00 %
 ELONGATION 0.00 %

R_e 32.1



HF-1 3019 Hex nut 15000 lbs 3600 1000 11357 lbs

HF-1
11-11-11
1370°F. 2 hrs
1173°F. 2 hrs

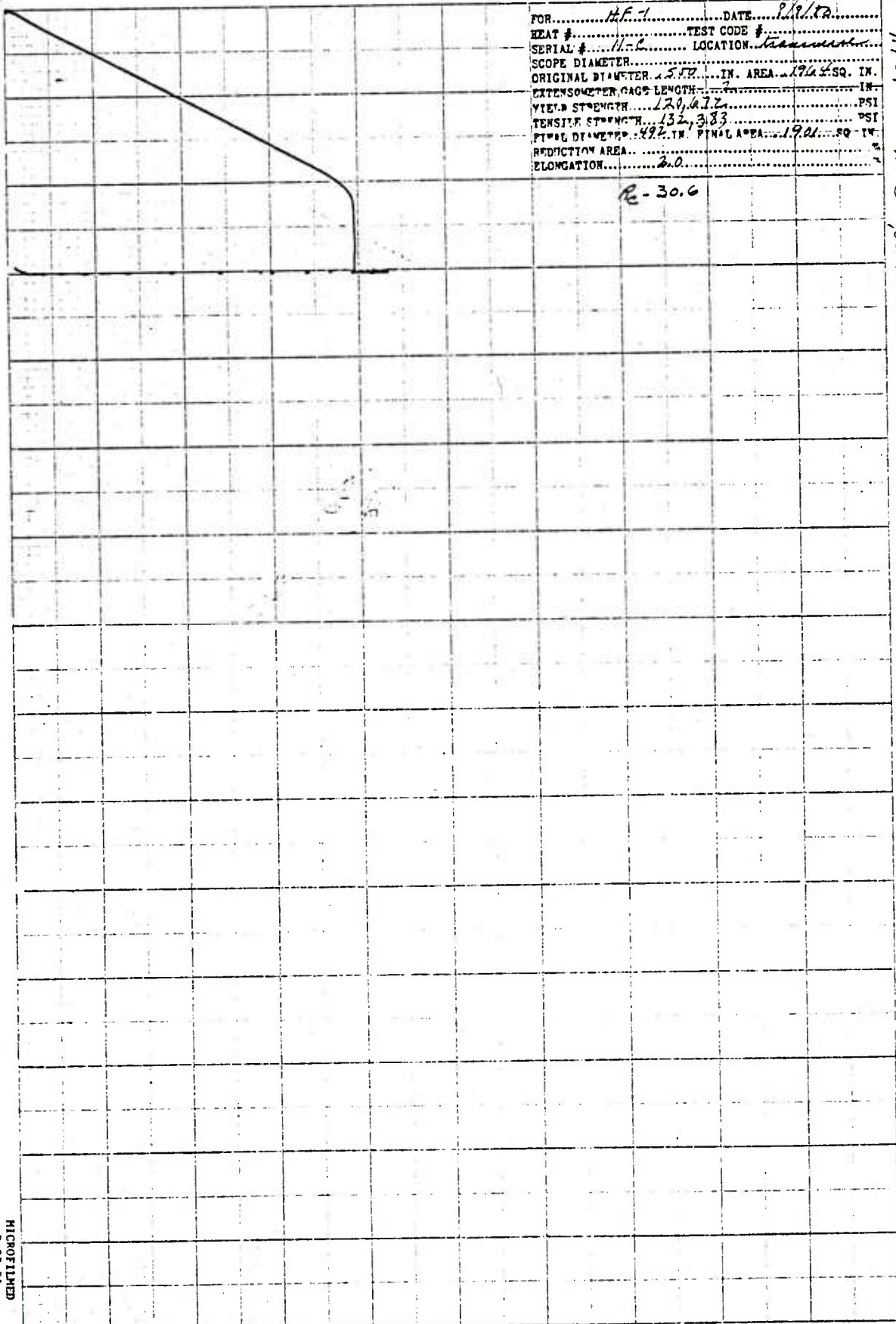


FOR.....*HF-1*.....DATE.....*9/16/80*
TEST #.....TEST CODE #.....
SERIAL #.....*11-11*.....LOCATION.....*11-11*
SCOPE D AREA.....*11.5*.....IN. AREA.....*11.5* SQ. IN.
EXTENSIONER GAGE LENGTH.....*2*.....IN.
YIELD STRENGTH.....*115,500*.....PSI
TENSILE STRENGTH.....*153,470*.....PSI
FINAL DIAMETER.....*1.75* IN. FINAL AREA.....*1.75* SQ. IN.
REDUCTION AREA.....*1.75*.....SQ. IN.
ELONGATION.....*1.75*.....%

100,000

FOR.....*HF-1*.....DATE.....*2/2/72*.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....*11-2*.....LOCATION.....*transverse*.....
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....*1.58*.....IN. AREA.....*1.94* SQ. IN.
 EXTENSOMETER GAGE LENGTH.....*2*.....IN.
 YIELD STRENGTH.....*129,612*.....PSI
 TENSILE STRENGTH.....*132,383*.....PSI
 FINAL DIAMETER.....*.49* IN. FINAL AREA.....*1.94* SQ. IN.
 REDUCTION AREA.....
 ELONGATION.....*2.0*

E-30.6



60,000

HF-1

11-2

transverse

15,000 2 1/2 hrs

1800/50°F

1125°F 2 hrs

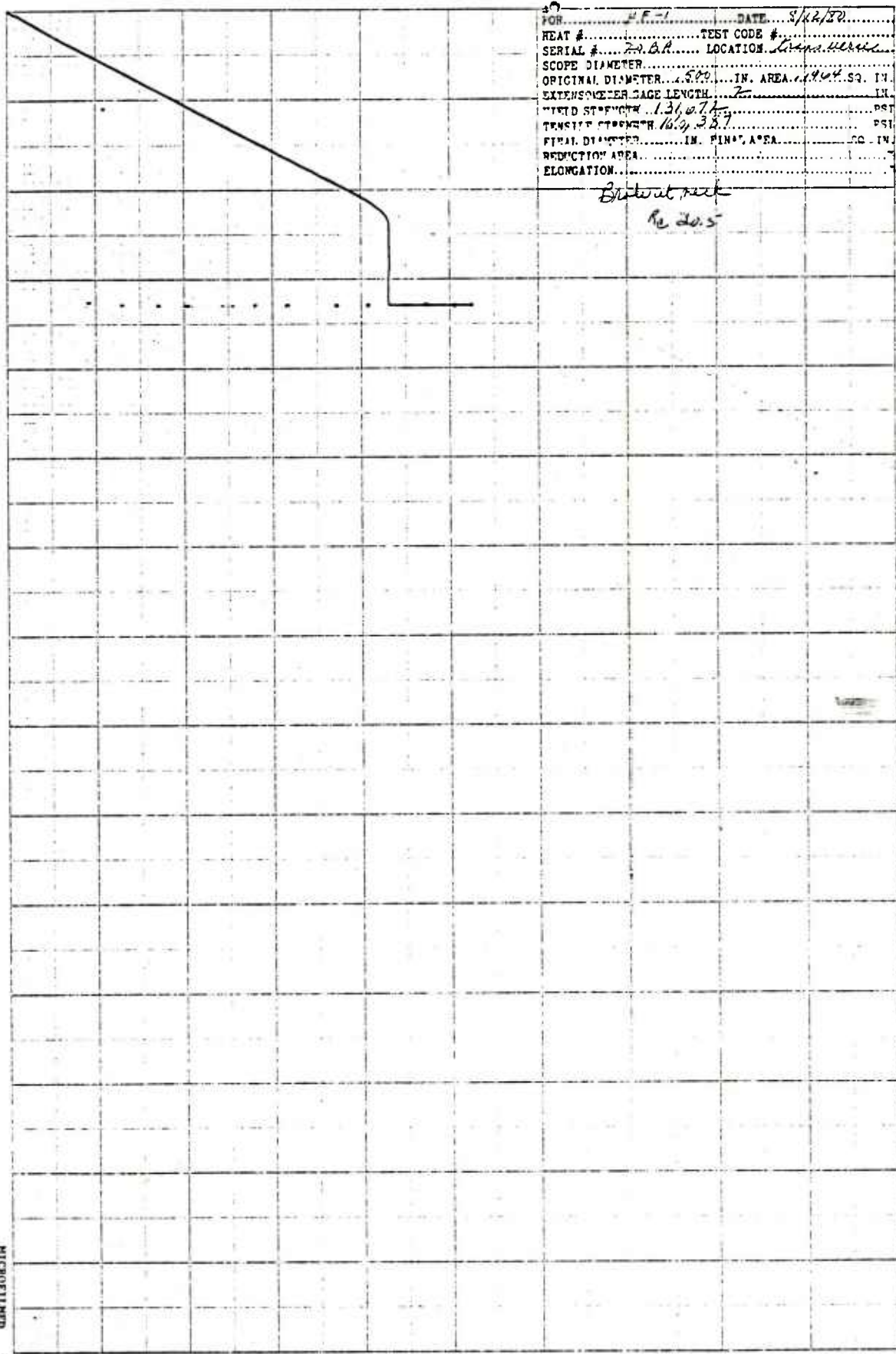
30120

62100

FOR	DATE
HEAT #	TEST CODE #
SERIAL #	LOCATION
SCOPE DIAMETER	
ORIGINAL DIAMETER	IN. AREA
EXTENSOMETER GAGE LENGTH	IN
TENSILE STRENGTH	PSI
TENSILE STRENGTH	PSI
FINAL DIAMETER	IN. MIN. AREA
REDUCTION AREA	%
ELONGATION	%

Broken at neck
 Re 20.5

HF-1
 2013A
 Brass
 1320F
 2013A
 1135F
 2013A



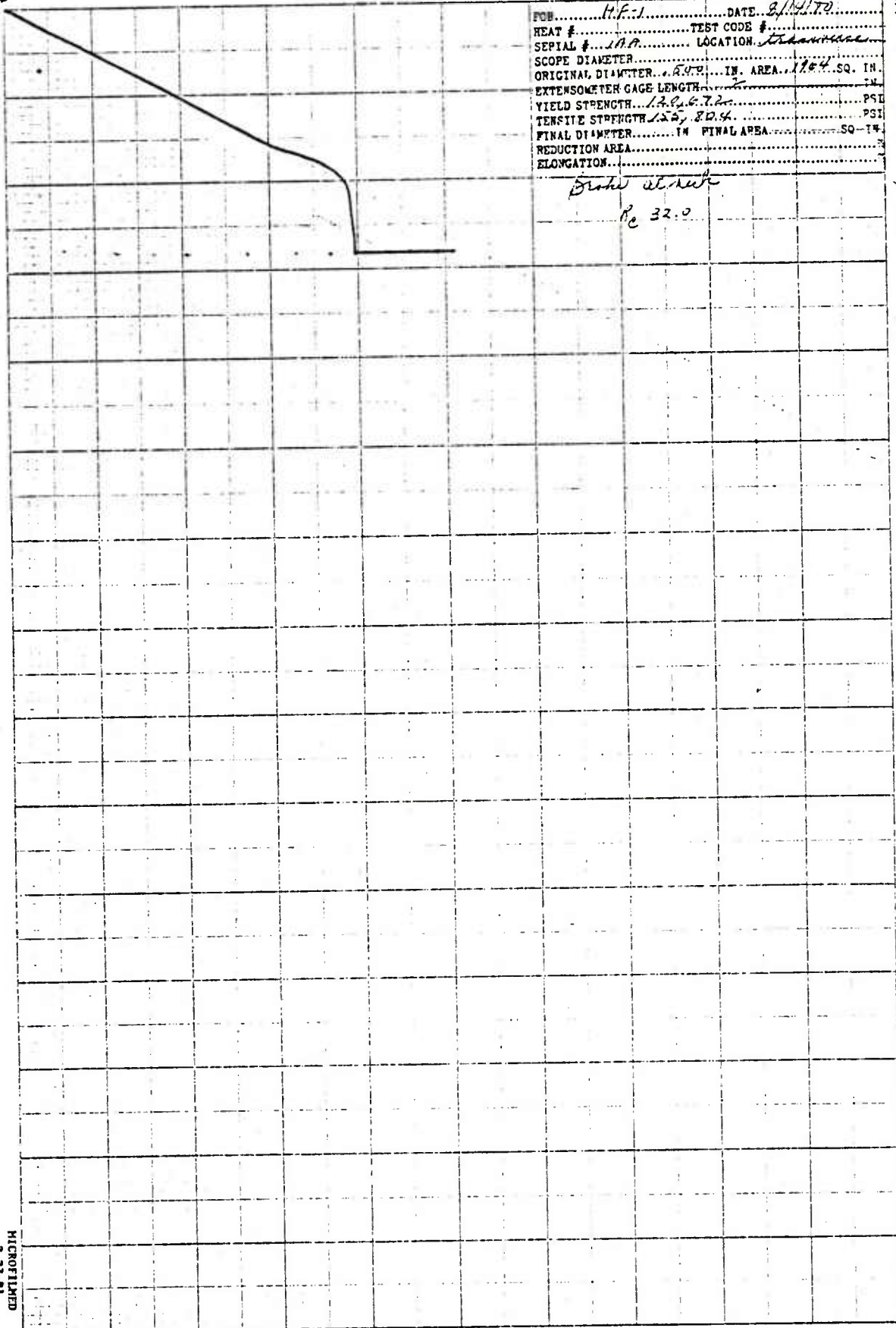
31.00

11.00

FOR.....H.F.-1.....DATE 2/14/70.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....11A.....LOCATION Tennessee
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER.....IN. AREA.....SQ. IN.
 EXTENSOMETER GAGE LENGTH.....IN.
 YIELD STRENGTH.....PSI
 TENSILE STRENGTH.....PSI
 FINAL DIAMETER.....IN. FINAL AREA.....SQ. IN.
 REDUCTION AREA.....
 ELONGATION.....

Broken at neck
 Pc 32.0

11A-1 11A Tennessee 1500°F thru about 140°F 1135°F thru



60,000

HF-1
10X
1500F
5/10
6600
150F
1135F

FOR.....HF-1.....DATE.....9/19/50.....
HEAT #.....TEST CODE #.....
SERIAL #.....12-X.....LOCATION.....12-X.....
SCOPE DIAMETER.....4.75.....IN. AREA.....853 SQ. IN.
ORIGINAL DIAMETER.....4.75.....IN. AREA.....853 SQ. IN.
EXTENSOMETER GAGE LENGTH.....2.....IN.
YIELD STRENGTH.....171,670.....PSI
TENSILE STRENGTH.....156,295.....PSI
FINAL DIAMETER.....4.00 IN. FINAL AREA.....1254 SQ. IN.
REDUCTION AREA.....6.0.....
ELONGATION.....29.0.....

R_e 29.0

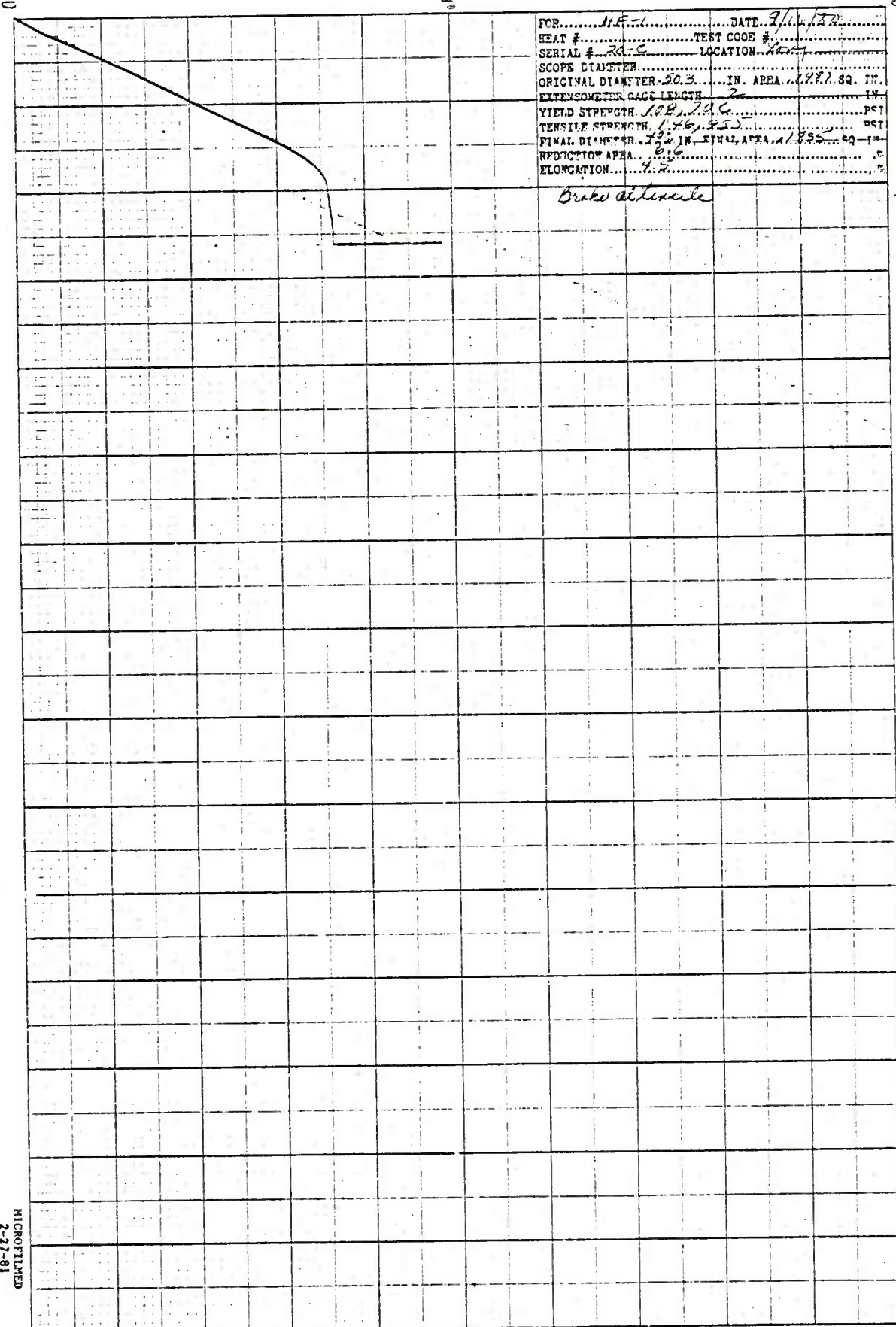
FOR.....HF-1.....DATE.....9/19/50.....
HEAT #.....TEST CODE #.....
SERIAL #.....12-X.....LOCATION.....12-X.....
SCOPE DIAMETER.....4.75.....IN. AREA.....853 SQ. IN.
ORIGINAL DIAMETER.....4.75.....IN. AREA.....853 SQ. IN.
EXTENSOMETER GAGE LENGTH.....2.....IN.
YIELD STRENGTH.....171,670.....PSI
TENSILE STRENGTH.....156,295.....PSI
FINAL DIAMETER.....4.00 IN. FINAL AREA.....1254 SQ. IN.
REDUCTION AREA.....6.0.....
ELONGATION.....29.0.....

311

HF-1
 20-C
 1500F
 11250F
 2400

FOR.....HF-1.....DATE...9/16/52.....
 HEAT #.....TEST COOE #.....
 SERIAL #...20-C...LOCATION...1500F...
 SCOPE DIAMETER.....
 ORIGINAL DIAMETER...20.3.....IN. AREA...1.887 SQ. IN.
 EXTENSOMETER GAGE LENGTH.....IN.
 YIELD STRENGTH...108,000.....PSI
 TENSILE STRENGTH...146,000.....PSI
 FINAL DIAMETER...19.4 IN. FINAL AREA...1.885 SQ. IN.
 REDUCTION AREA...0.5%
 ELONGATION...7.2%

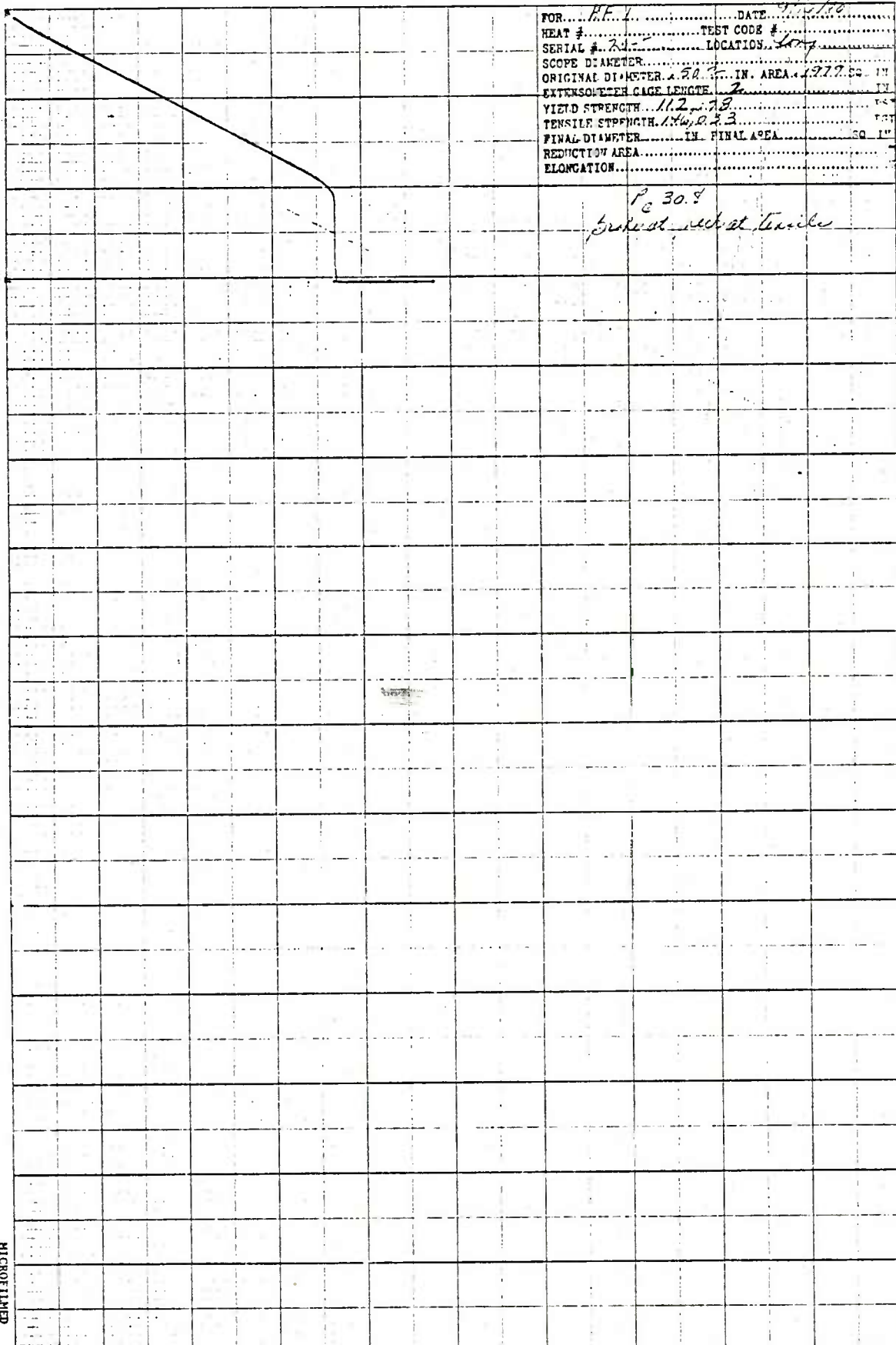
Brake at tensile



66070
HF-1 20-T 1500°F 2hrs 612 mil 150T 1125' 2 hrs

FOR *PE-1* DATE *9/15/60*
HEAT # *21* TEST CODE #
SERIAL # *21* LOCATION *20T*
SCOPE DIAMETER
ORIGINAL DIAMETER *2.0* IN. AREA *3.1416* IN.
EXTENSOMETER GAGE LENGTH *2* IN.
YIELD STRENGTH *11.2* IN. *23*
TENSILE STRENGTH *11.4* IN. *23*
FINAL DIAMETER *1.8* IN. FINAL AREA
REDUCTION AREA
ELONGATION

PE 30.8
Subst. not tested



To _____ Date _____
From _____ Subject _____

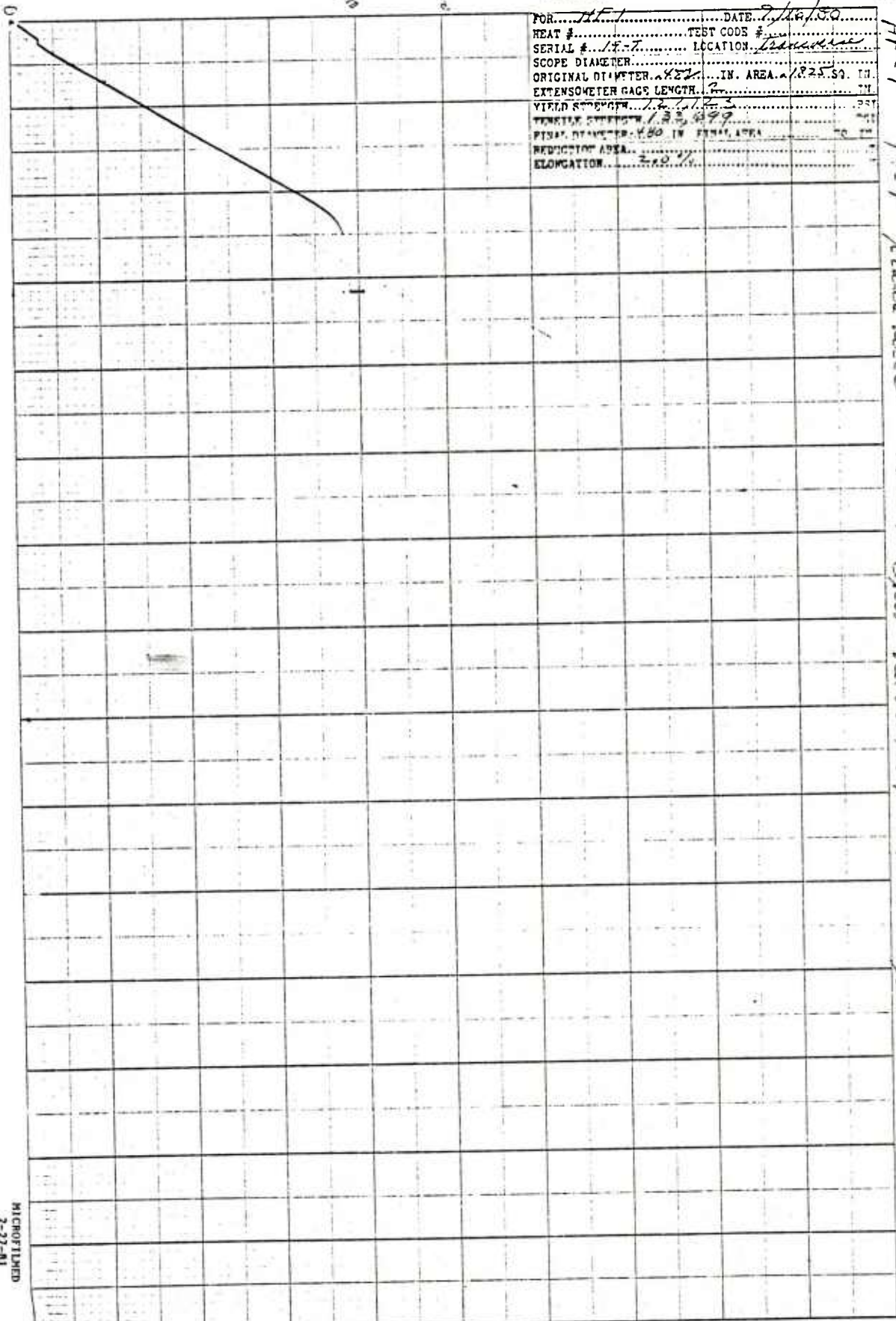
#F-1 Steel
Republic Steel

Sample	Heat	Temp	Set	Yield	Strength	Tensile	Elong %	RA	Asph
20BD	1500	1125°	(T)	128309	161914	70	10.9	31.9	31.9
1AA	1500	1125°	T	128309	161914	70	10.9	31.9	31.9
20BA	"	"	T	131672	160387	"	"	30.5	30.5
20AA	"	"	T	123727	140560	"	"	32.7	32.7
1BA	"	"	T	119654	152749	4.5	"	31.8	31.8
40BD	"	"	T	128819	159877	7.0	11.7	32	32
1BD	"	"	T	128309	157841	6.0	7.8	30.7	30.7
40BA	"	"	T	116090	153767	3.0	7.8	31.4	31.4
40AA	"	"	T	122199	155804	4.0	7.8		
20BA	1500	1125°	L	123805	164066	12.0	22.8	32.9	32.9
40BA	"	"	L	117765	169099	12.0	24.9	33.6	33.6
1AA	"	"	L	123005	166583	12.0	26.9	33.2	33.2
1AA	"	"	L	124308	168093	13.0	26.7	34	34
20BD	1500	"	L	120785	168092	12.5	28.3	33.9	33.9
40BD	"	"	L	116725	166751	12.5	24.6	33.4	33.4
40AA	"	"	L	125818	165576	12.0	23.5	32.8	32.8

HOUSTON INSTRUMENT
 11111 SOUTH LOOP W
 SUITE 100, TEXAS
 CHART NO. 100-1515
 PRINTED IN U.S.A.

60,000
 HF-1
 10-T
 Transverse
 1500°F
 24hr
 1100°F
 24hr

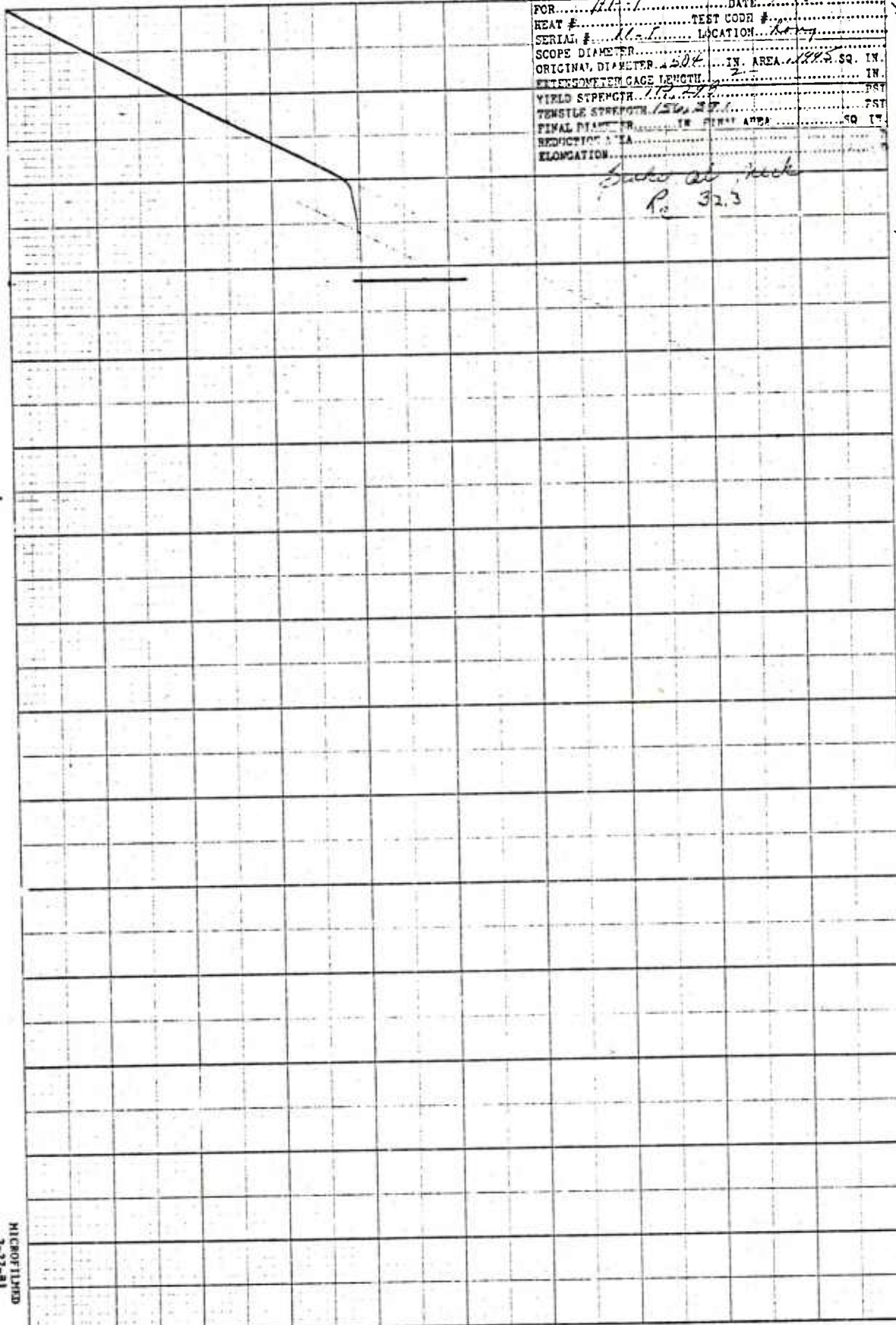
FOR...*HF-1*...DATE...*7/16/50*
 HEAT #...*12-7*...TEST CODE #...*12-7*
 SERIAL #...*12-7*...LOCATION...*Transverse*
 SCOPE DIAMETER...*1.25*...IN. AREA...*1.25*...IN.
 ORIGINAL DIAMETER...*1.25*...IN. AREA...*1.25*...IN.
 EXTENSOMETER GAGE LENGTH...*1.25*...IN.
 YIELD STRENGTH...*12,500*...PSI
 TENSILE STRENGTH...*12,500*...PSI
 FINAL DIAMETER...*1.25*...IN. FINAL AREA...*1.25*...IN.
 REDUCTION AREA...*2.00*...%
 ELONGATION...*2.00*...%



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 2-27-81

FOR.....*11-1*.....DATE.....*2-10-80*.....
HEAT #.....*11-1*.....TEST CODE #.....*11-1*.....
SERIAL #.....*11-1*.....LOCATION.....*11-1*.....
SCOPE DIAMETER.....*11-1*.....IN. AREA.....*11-1* SQ. IN.
ORIGINAL DIAMETER.....*11-1*.....IN. AREA.....*11-1* SQ. IN.
EXTENSION GAGE LENGTH.....*11-1*.....IN.
YIELD STRENGTH.....*11-1*.....PSI
TENSILE STRENGTH.....*11-1*.....PSI
FINAL DIAMETER.....*11-1*.....IN. FINAL AREA.....*11-1* SQ. IN.
REDUCTION OF AREA.....*11-1*.....%
ELONGATION.....*11-1*.....%

Failure at neck
R₀ 32.3



60,000
11-1
11-T
1500°F
140°F
1135°F

609000

FOR... *H-1* ... DATE *7/20/50*
 HEAT #... TEST CODE #...
 SERIAL #... LOCATION *LEAK TEST*
 SCOPE DIAMETER...
 ORIGINAL DIAMETER... *2.25* IN. AREA... *3.98* sq. in.
 EXTENSOMETER GAGE LENGTH...
 YIELD STRENGTH... *120,000* psi
 TENSILE STRENGTH...
 FINAL DIAMETER... IN. FINAL AREA...
 REDUCTION OF AREA...
 ELONGATION...

Make 17.5% reduction

H-1

20-T

Leak test

1500°F

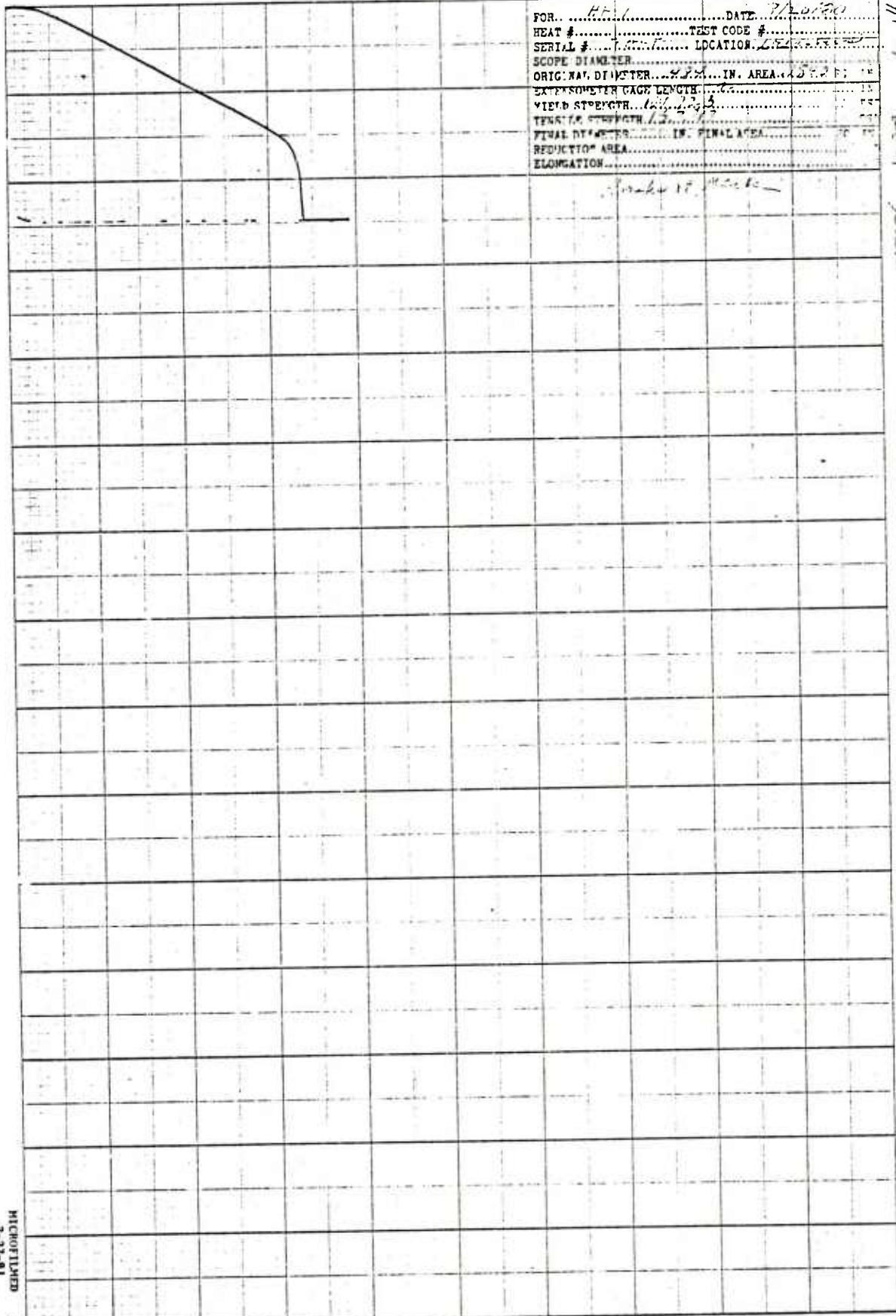
24 hr

at 1500°F

1500°F

1125°F

24 hr

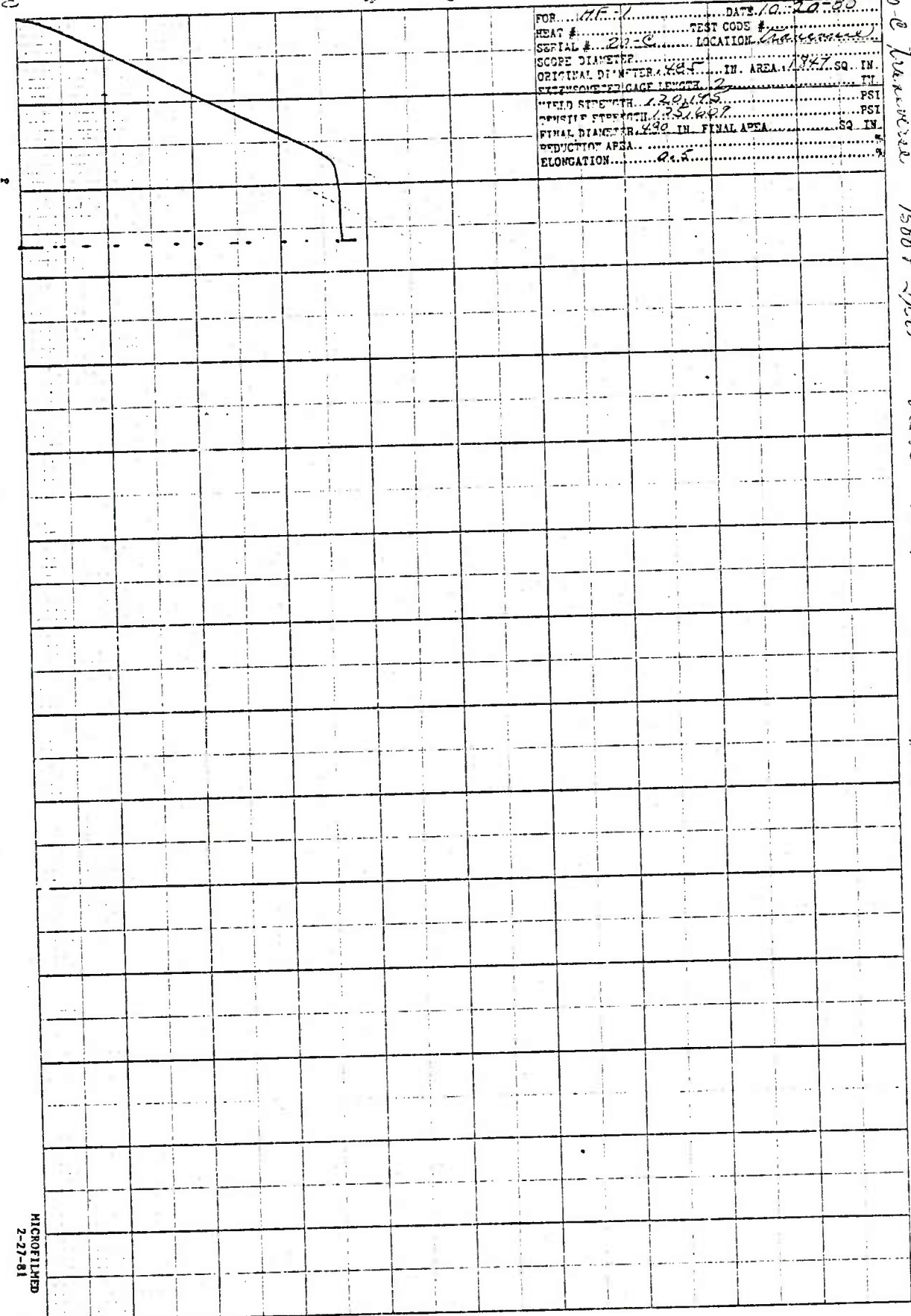


MICROFILMED
 7-27-81
 93

69000

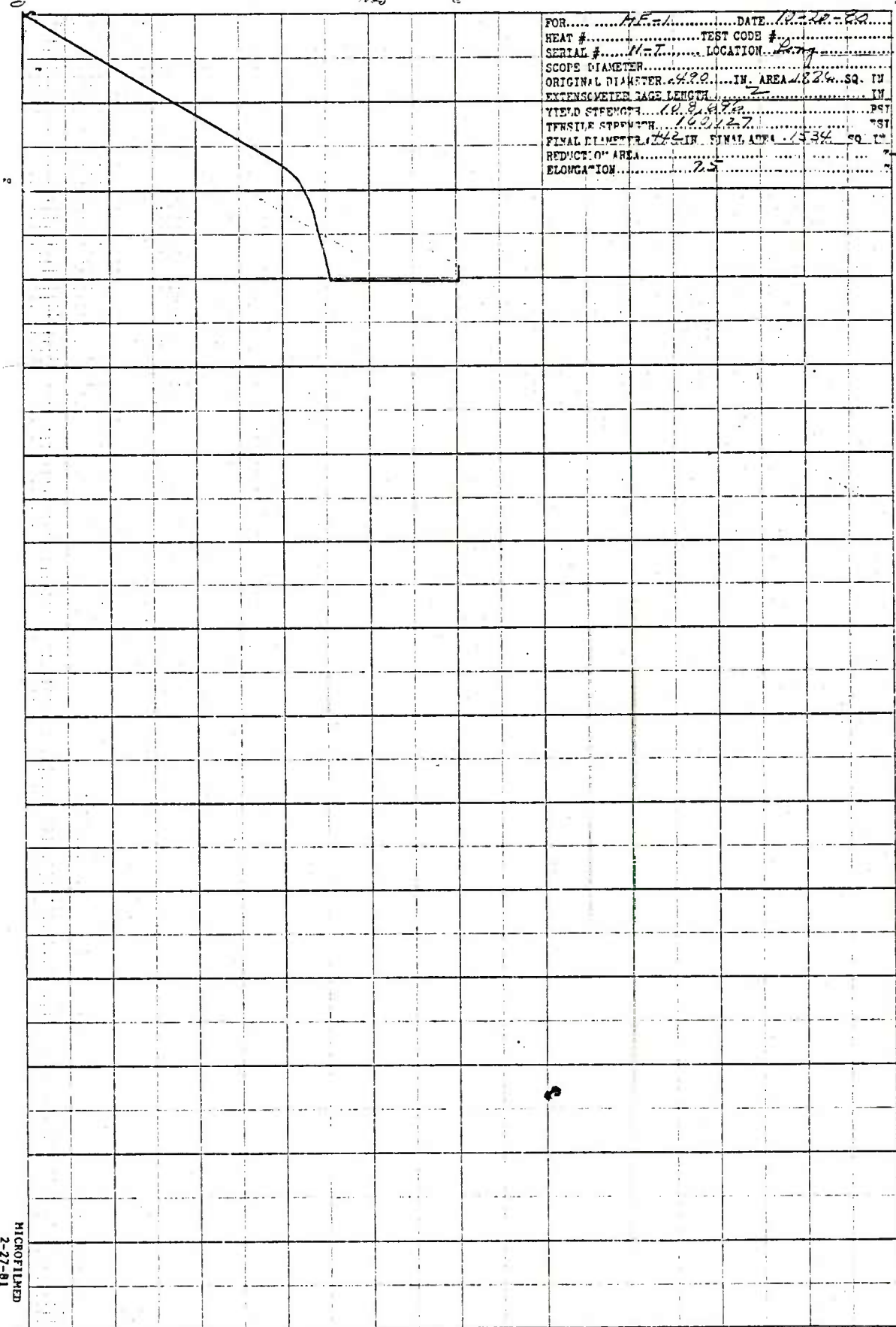
20°C *transverse* 1500°F *2400* 660°F *1500°F* 1175°F *2400*

FOR *7F-1* DATE *10-20-80*
 HEAT # *217-9* TEST CODE # *217-9*
 SERIAL # *217-9* LOCATION *217-9*
 GAGE DIAMETER *1.39* IN. AREA *1.92* SQ. IN.
 ORIGINAL DIAMETER *1.39* IN. AREA *1.92* SQ. IN.
 GAGE LENGTH *2* IN.
 TENSILE STRENGTH *138,000* PSI
 YIELD STRENGTH *138,000* PSI
 FINAL DIAMETER *1.39* IN. FINAL AREA *1.92* SQ. IN.
 REDUCTION OF AREA *0.0* %
 ELONGATION *0.0* %



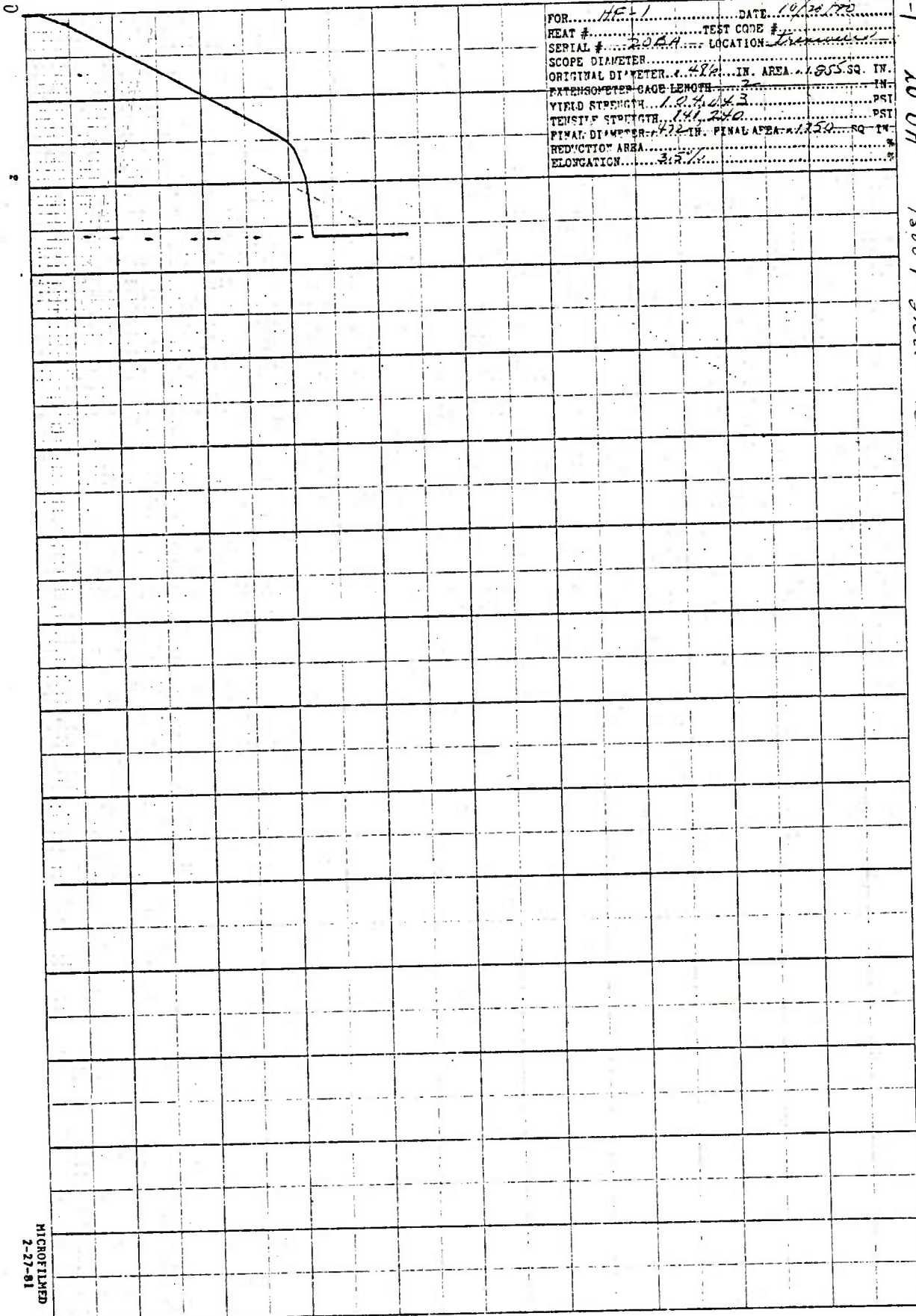
11 T Longo 1500°F Also at 150°F 1125°F Also

FOR.....*Heat*.....DATE.....*10-22-62*.....
HEAT #.....*10-7*.....TEST CODE #.....
SERIAL #.....*10-7*.....LOCATION.....*Long*.....
SCOPE DIAMETER.....*1.0*.....IN. AREA.....*0.785*.....SQ. IN.
ORIGINAL DIAMETER.....*0.88*.....IN. AREA.....*0.608*.....SQ. IN.
EXTENSOMETER GAGE LENGTH.....*2*.....IN.
YIELD STRENGTH.....*100,000*.....PSI
TENSILE STRENGTH.....*100,000*.....PSI
FINAL DIAMETER.....*0.74*.....IN. FINAL AREA.....*0.424*.....SQ. IN.
REDUCTION OF AREA.....*46*.....%
ELONGATION.....*25*.....%



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2-27-81
95

HF-1
20 BA
1500°F 2 hrs
150°F 150°F
1125°F 2 hrs
Thermocouple

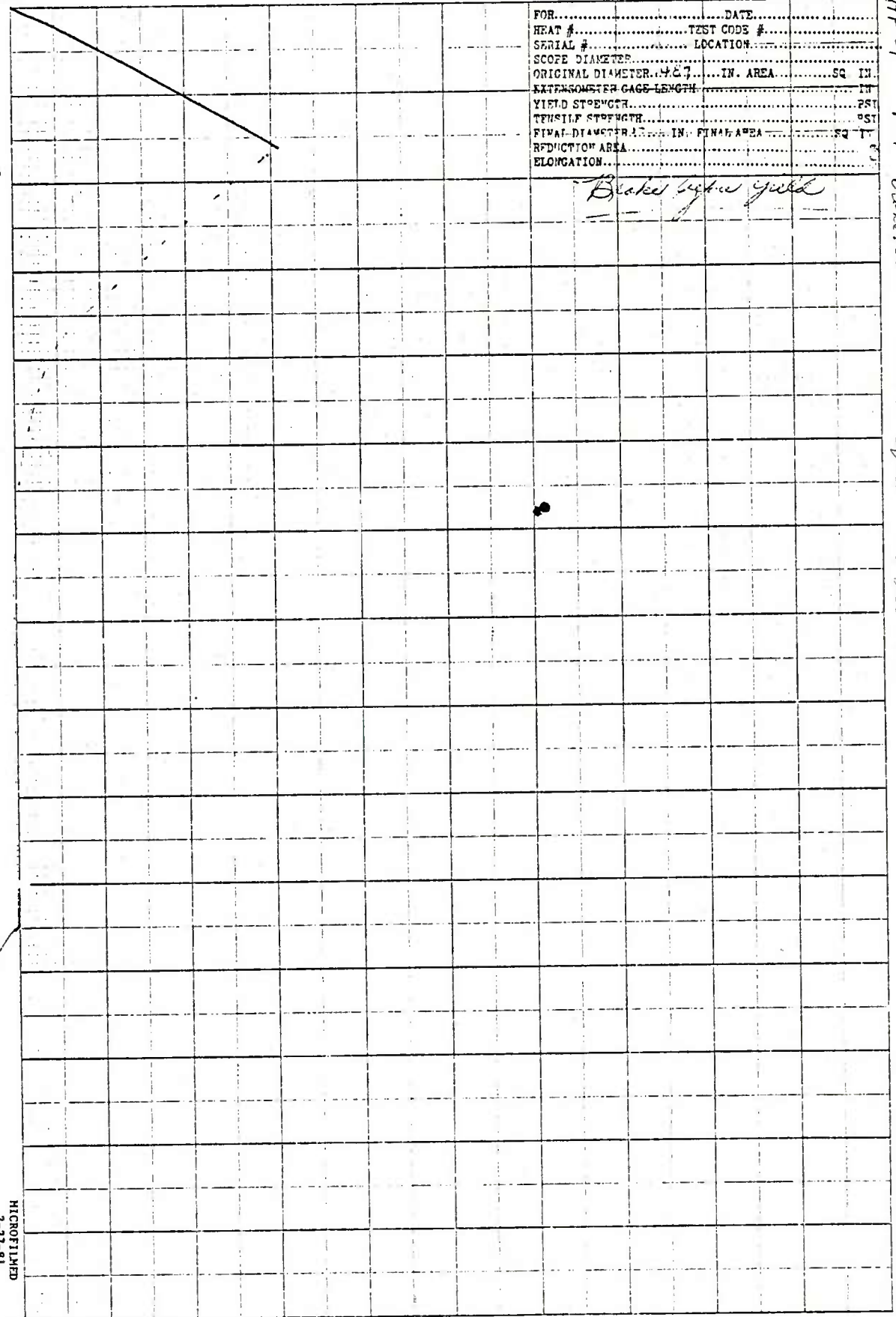


FOR... HF-1... DATE... 10/22/70
HEAT #... TEST CODE #...
SERIAL #... 20 BA... LOCATION...
SCOPE DIAMETER...
ORIGINAL DIAMETER... 4 1/2 IN. AREA... 1.55 SQ. IN.
EXTENSOMETER GAGE LENGTH... IN.
YIELD STRENGTH... 19,400 PSI
TENSILE STRENGTH... 19,400 PSI
FINAL DIAMETER... 4 1/2 IN. FINAL AREA... 1.55 SQ. IN.
REDUCTION AREA...
ELONGATION... 25.1%

600°HF-1 1-T Transverse 15000F 3/16 600 and 1500F 1125F after

FOR.....	DATE.....
HEAT #.....	TEST CODE #.....
SERIAL #.....	LOCATION.....
SCOPE DIAMETER.....	
ORIGINAL DIAMETER.....IN.	AREA.....SQ IN.
EXTENSOMETER GAGE LENGTH.....	
YIELD STRENGTH.....	PSI
TENSILE STRENGTH.....	PSI
FINAL DIAMETER.....IN.	FINAL AREA.....SQ IN.
REDUCTION AREA.....	
ELONGATION.....	

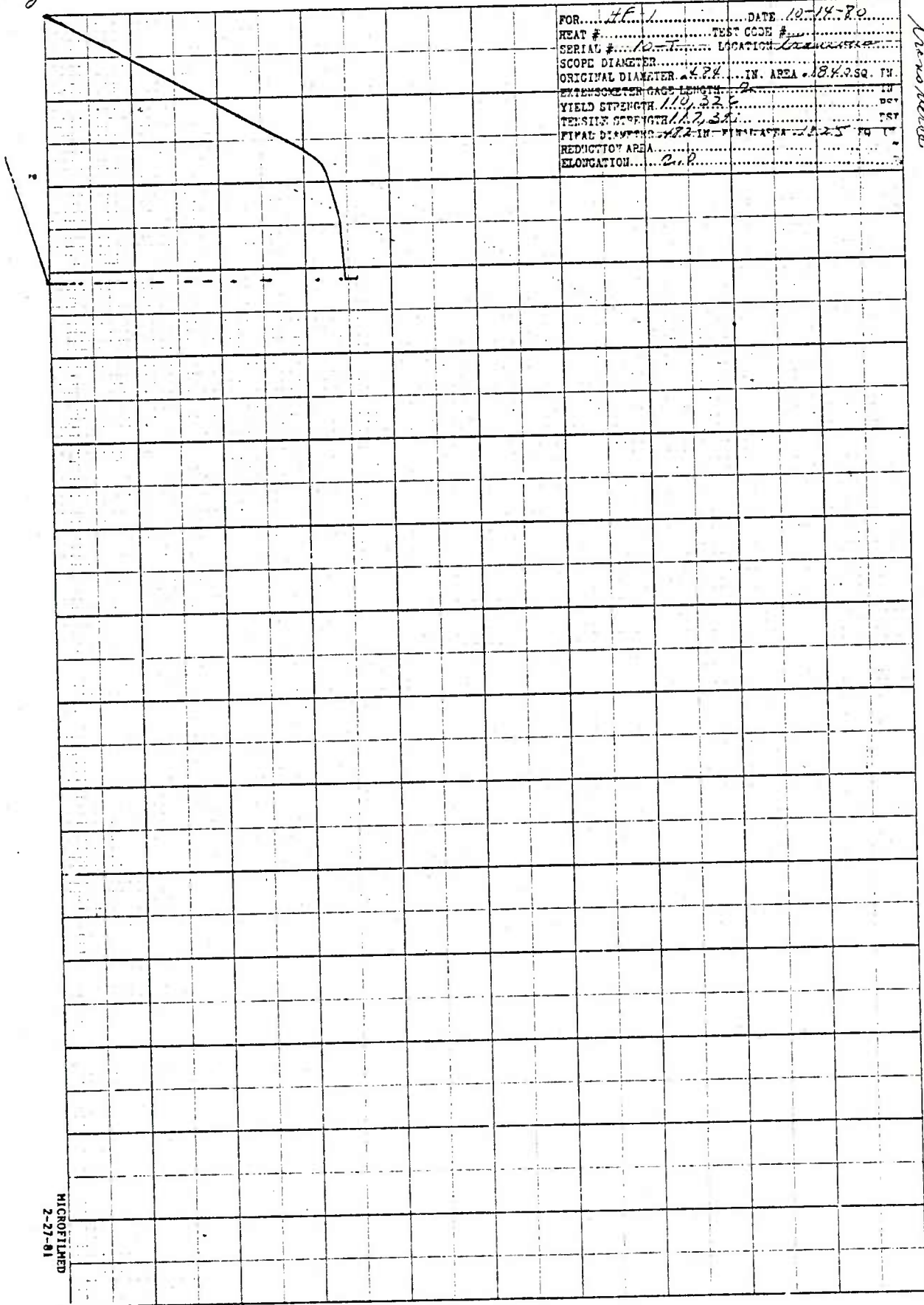
Broken before yield



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2-27-81

10-T
60,000
Kilograms

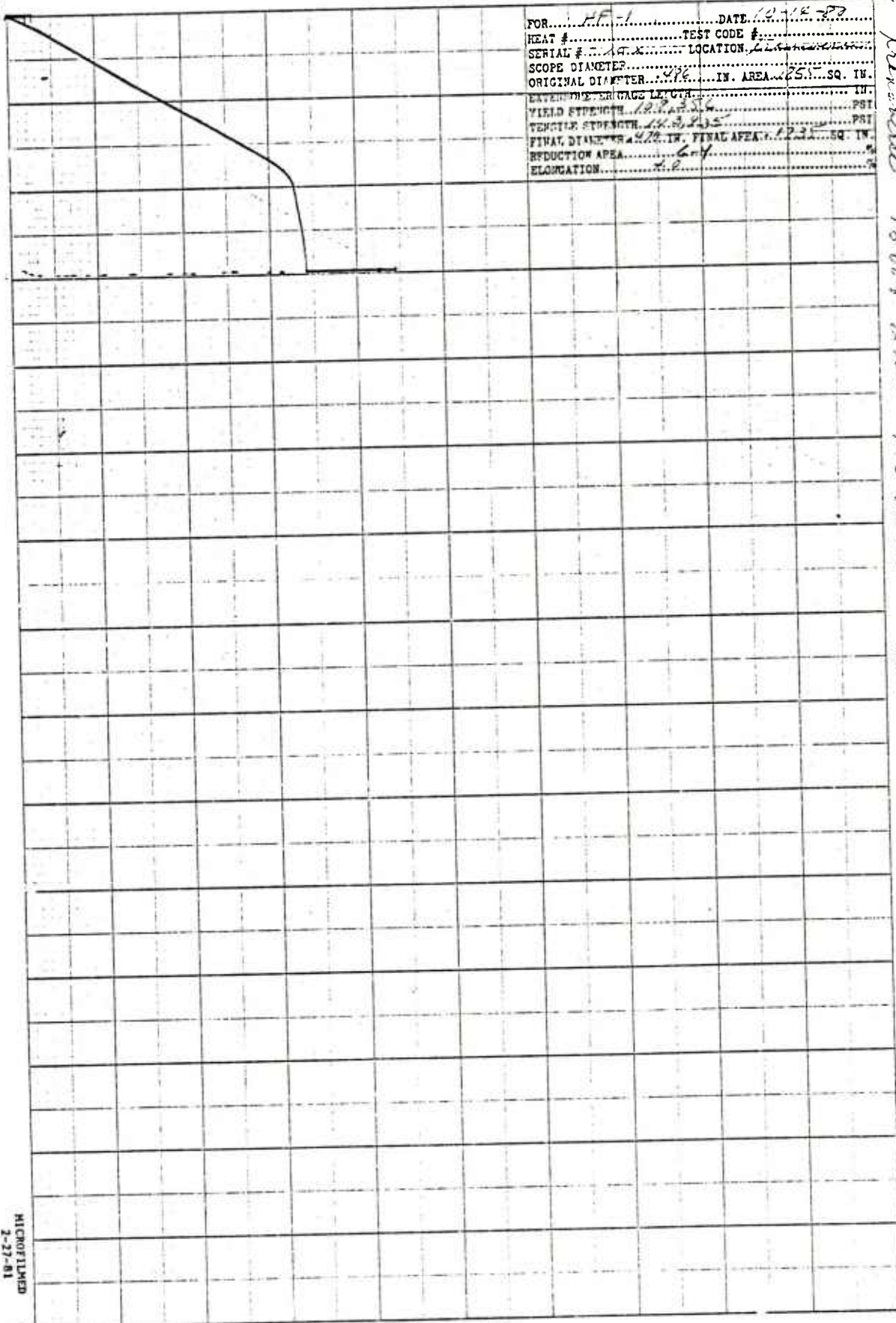
FOR... *LF 1* ... DATE *10-14-70*
 HEAT #... TEST CODE #...
 SERIAL #... *10-T* ... LOCATION *transverse*
 SCOPE DIAMETER...
 ORIGINAL DIAMETER *4.74* IN. AREA *18.49* SQ. IN.
 EXTENSOMETER GAGE LENGTH *2* IN.
 YIELD STRENGTH *110,325* PSI
 TENSILE STRENGTH *112,341* PSI
 FINAL DIAMETER *1.82* IN. FINAL AREA *1.25* SQ. IN.
 REDUCTION OF AREA...
 ELONGATION... *2.8*



10 Y
 10/10/80
 Kierman

FOR.....*10 Y*.....DATE.....*10-10-80*.....
 HEAT #.....TEST CODE #.....
 SERIAL #.....LOCATION.....*10 Y*.....
 SCOPE DIAMETER.....*4.75*.....IN. AREA.....*28.5*.....SQ. IN.
 ORIGINAL DIAMETER.....*4.75*.....IN. AREA.....*28.5*.....SQ. IN.
 EXTENSION GAGE LENGTH.....IN.
 YIELD STRENGTH.....*100*.....PSI
 TENSILE STRENGTH.....*100*.....PSI
 FINAL DIAMETER.....*4.75*.....IN. FINAL AREA.....*28.5*.....SQ. IN.
 REDUCTION AREA.....*6.4*.....
 ELONGATION.....*2.0*.....

180°F 2 hrs 150°F 2 hrs 1125°F 2 hrs



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 2-27-81
 50

10-25
 60000

FOR HF-1 DATE 10/4/70
 HEAT # 10-2 TEST CODE # 10-2
 SERIAL # 10-2 LOCATION 10-2
 SCOPE DIAMETER 1.25 IN. AREA 1.25 SQ IN
 ORIGINAL DIAMETER 1.25 IN. AREA 1.25 SQ IN
 EXTENSOMETER GAGE LENGTH 2 IN
 YIELD STRENGTH 11.2 KSI
 TENSILE STRENGTH 12.2 KSI
 FINAL DIAMETER 1.25 IN. FINAL AREA 1.25 SQ IN
 REDUCTION AREA 1.25 SQ IN
 ELONGATION 6.0 %

HF-1
 1500°F
 1500°F
 1500°F

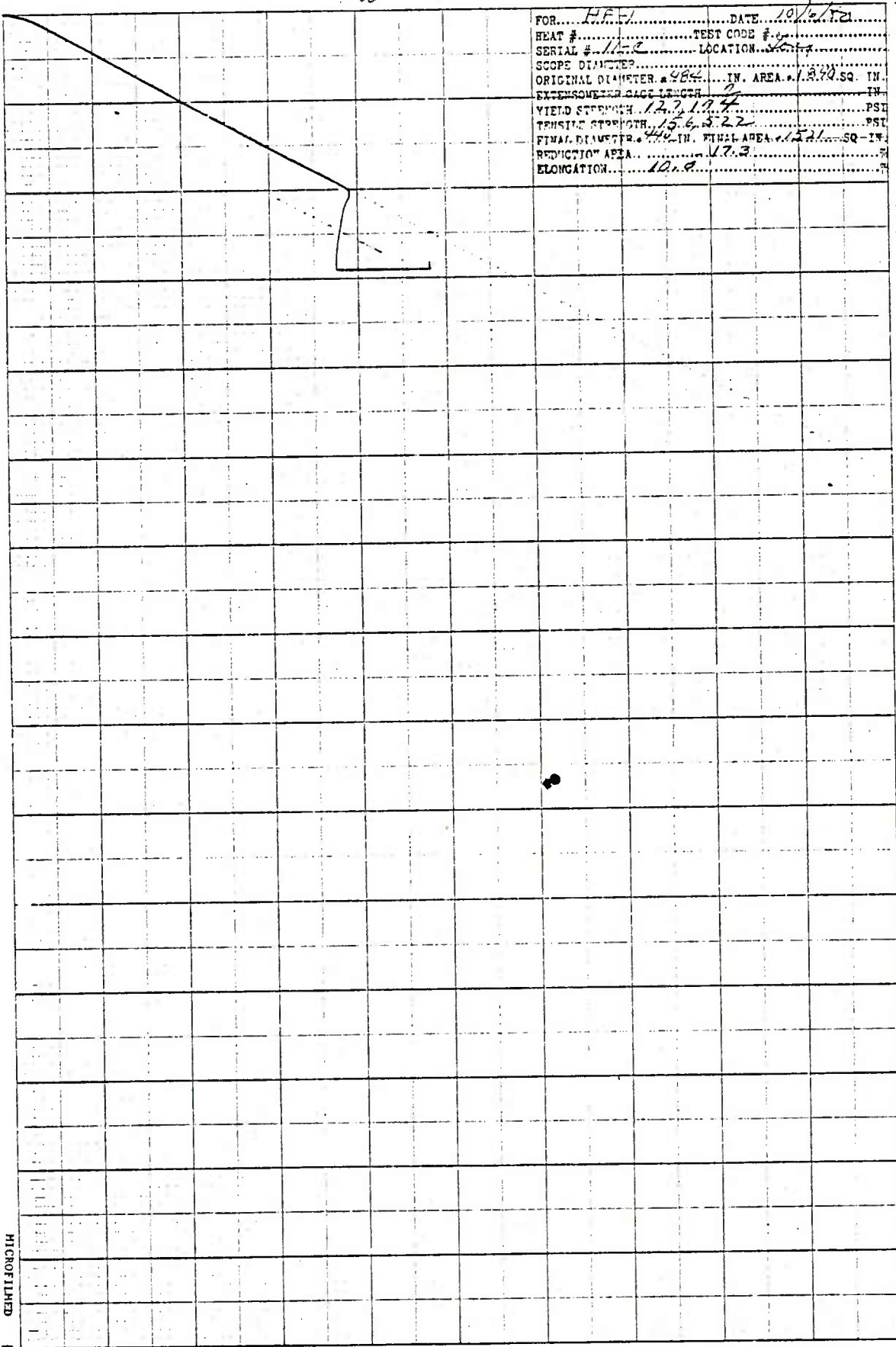
FOR HF-1 DATE 10/4/70
 HEAT # 10-2 TEST CODE # 10-2
 SERIAL # 10-2 LOCATION 10-2
 SCOPE DIAMETER 1.25 IN. AREA 1.25 SQ IN
 ORIGINAL DIAMETER 1.25 IN. AREA 1.25 SQ IN
 EXTENSOMETER GAGE LENGTH 2 IN
 YIELD STRENGTH 11.2 KSI
 TENSILE STRENGTH 12.2 KSI
 FINAL DIAMETER 1.25 IN. FINAL AREA 1.25 SQ IN
 REDUCTION AREA 1.25 SQ IN
 ELONGATION 6.0 %

11 25 of 3000

6/20/72

HF-1 11-2 Gen Bul 1500°F 2kpsi 62.8 mil 11.35°F 2kpsi

FOR... HFE-1... DATE... 10/15/72
 HEAT #... TEST CODE #...
 SERIAL #... 11-2... LOCATION...
 SCOPE DIAMETER...
 ORIGINAL DIAMETER... 484... IN. AREA... 1.270 SQ. IN.
 EXTENSIONED GAGE LENGTH... 2... IN.
 YIELD STRENGTH... 12.7, 13.4... PSI
 TENSILE STRENGTH... 15.6, 15.22... PSI
 FINAL DIAMETER... 446... IN. FINAL AREA... 1.221 SQ. IN.
 REDUCTION AREA... 17.3...
 ELONGATION... 10.9...

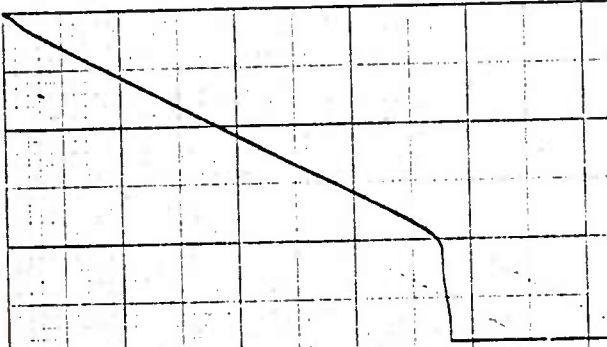


74.20
 28.00

30413
30410

2-1
60,000
HF-1
15,000 PSI
20,000 PSI
11,250 PSI

FOR.....	DATE.....
HEAT #.....	TEST CODE #.....
SERIAL #.....	LOCATION.....
SCOPE DIAMETER.....	
ORIGINAL DIAMETER.....	IN. AREA.....
EXTENSOMETER GAGE LENGTH.....	IN.
YIELD STRENGTH.....	PSI
TENSILE STRENGTH.....	PSI
FINAL DIAMETER.....	FINAL AREA.....
REDUCTION AREA.....	
ELONGATION.....	



Appendix J

Austenitic Grain Size

Austenitic Grain Size
Republic Steel

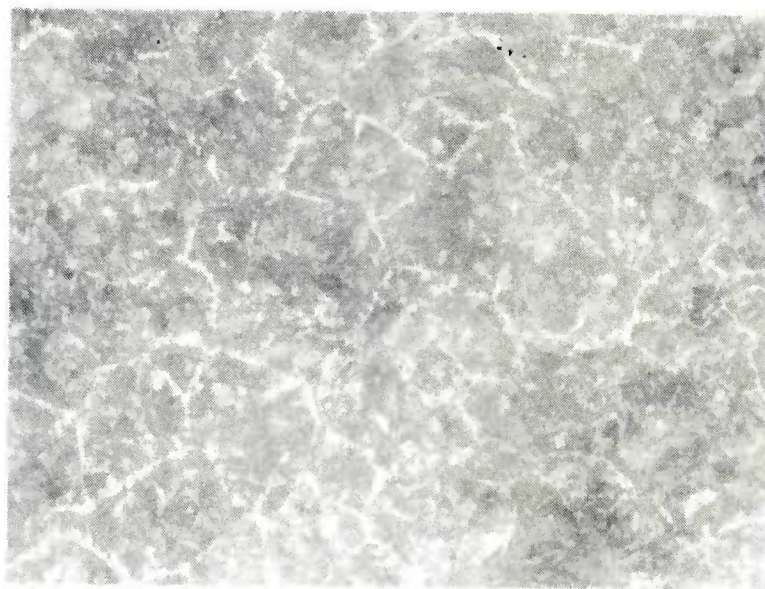


Figure J1. Billet 1AA 125x Wesley-Austin Solution

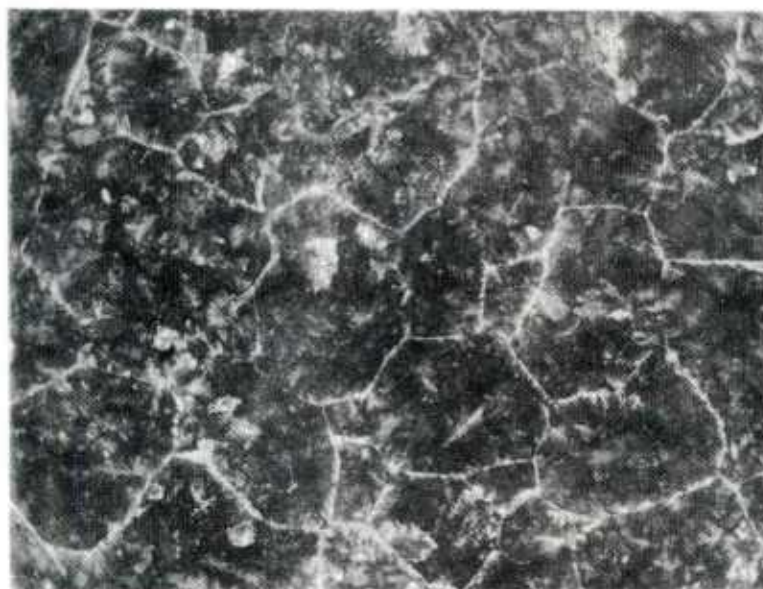


Figure J2. Billet 1BA 125x Wesley-Austin Solution

Austenitic Grain Size
Republic Steel

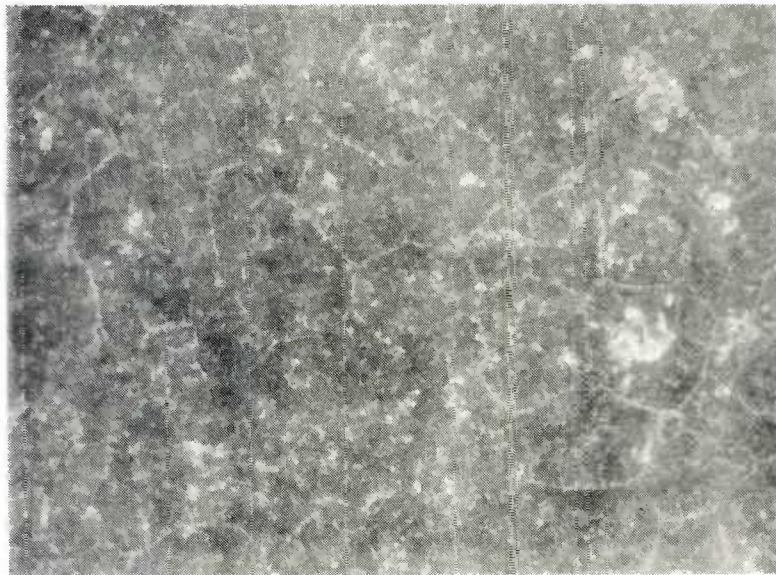


Figure J3. Billet 1BD 125x Wesley-Austin Solution



Figure J4. Billet 20AA 125x Wesley-Austin Solution

Austenitic Grain Size
Republic Steel



Figure J5. Billet 20BA 125x Wesley-Austin Solution

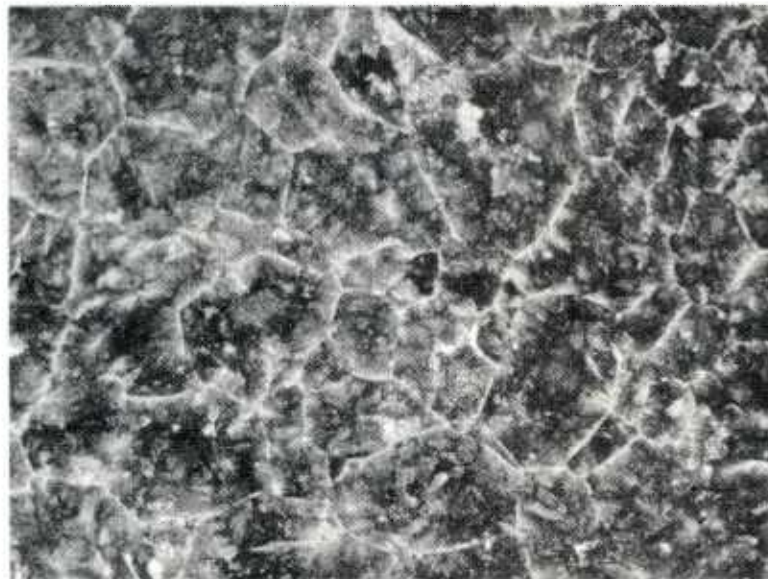


Figure J6. Billet 20BD 125x Wesley-Austin Solution

Austenitic Grain Size
Republic Steel



Figure J7. Billet 40AA 125x Wesley-Austin Solution



Figure J8. Billet 40BA 125x Wesley-Austin Solution

Austenitic Grain Size
Republic Steel



Figure J9. Billet 40BD 125x Wesley-Austin Solution

Austenitic Grain Size
Bethlehem Steel



Figure J10 Billet 1T 125x Wesley-Austin Solution



Figure J11 Billet 1C 125x Wesley-Austin Solution

Austenitic Grain Size
Bethlehem Steel

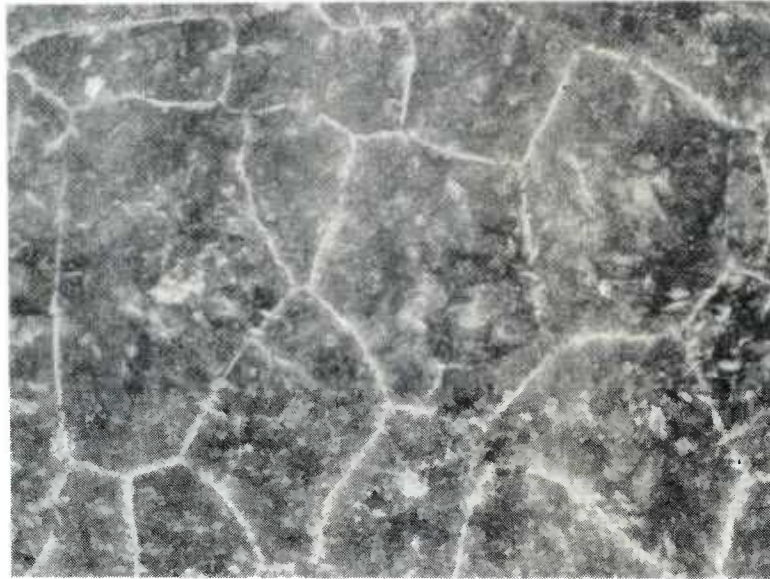


Figure J12 Billet 1X 125x Wesley-Austin Solution

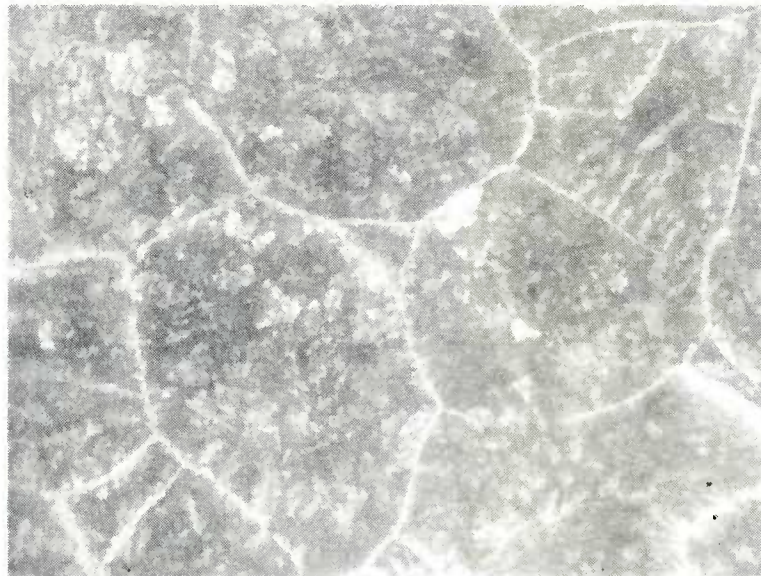


Figure J13 Billet 2T 125x Wesley-Austin Solution

Austenitic Grain Size
Bethlehem Steel



Figure J14 Billet 2C 125x Wesley-Austin Solution

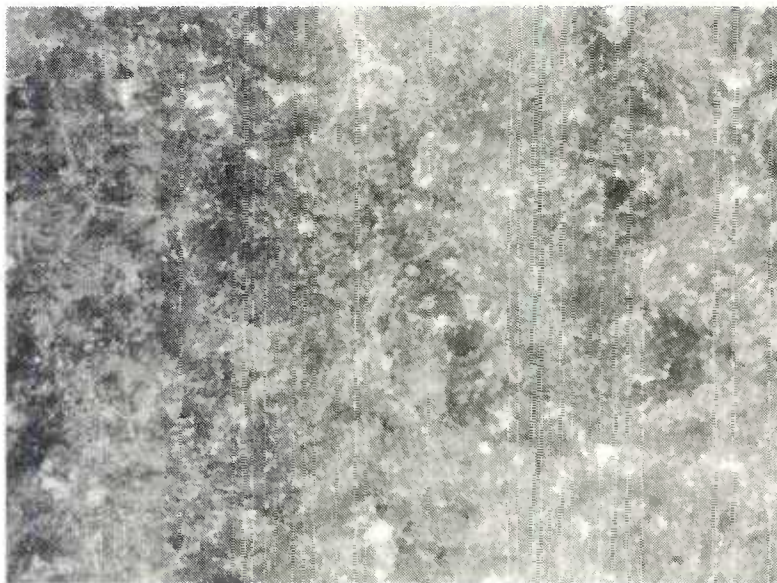


Figure J15 Billet 2X 125x Wesley-Austin Solution

Austenitic Grain Size
Bethlehem Steel

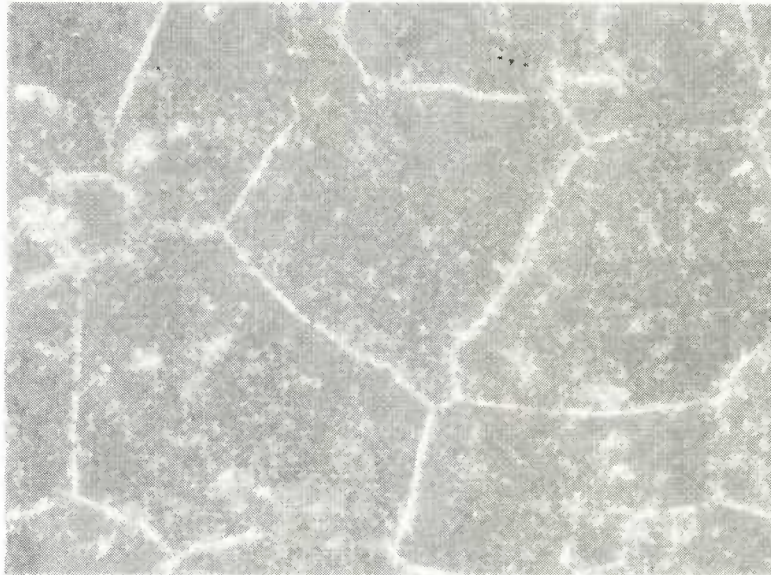


Figure J16 Billet 10T 125x Wesley-Austin Solution



Figure J17 Billet 10C 125x Wesley-Austin Solution

Austenitic Grain Size
Bethlehem Steel



Figure J18 Billet 10X 125x Wesley-Austin Solution



Figure J19 Eillet 11T 125x Wesley-Austin Solution

Austenitic Grain Size
Bethlehem Steel

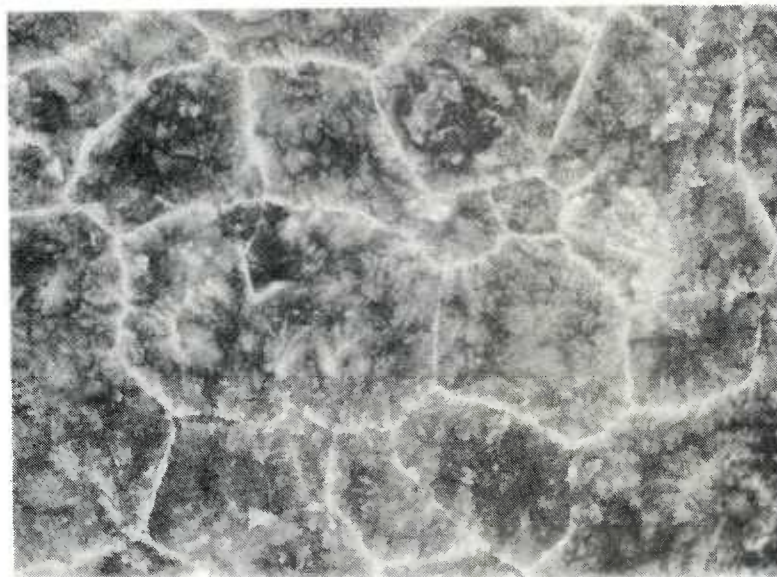


Figure J20 Billet 11C 125x Wesley-Austin Solution



Figure J21 Billet 11X 125x Wesley-Austin Solution

Austenitic Grain Size
Bethlehem Steel

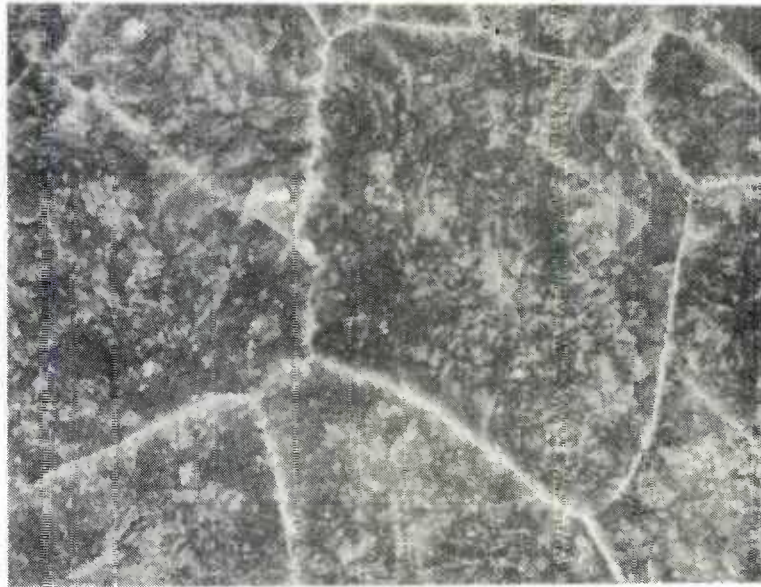


Figure J22 Billet 19T 125x Wesley- Austin Solution



Figure J23 Billet 19C 125x Wesley-Austin Solution

Austenitic Grain Size
Bethlehem Steel

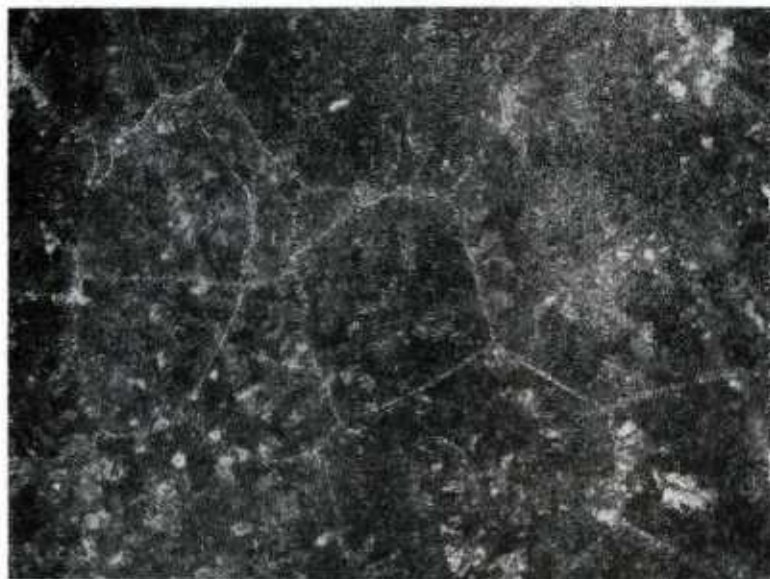


Figure J24 Billet 19X 125x Wesley-Austin Solution

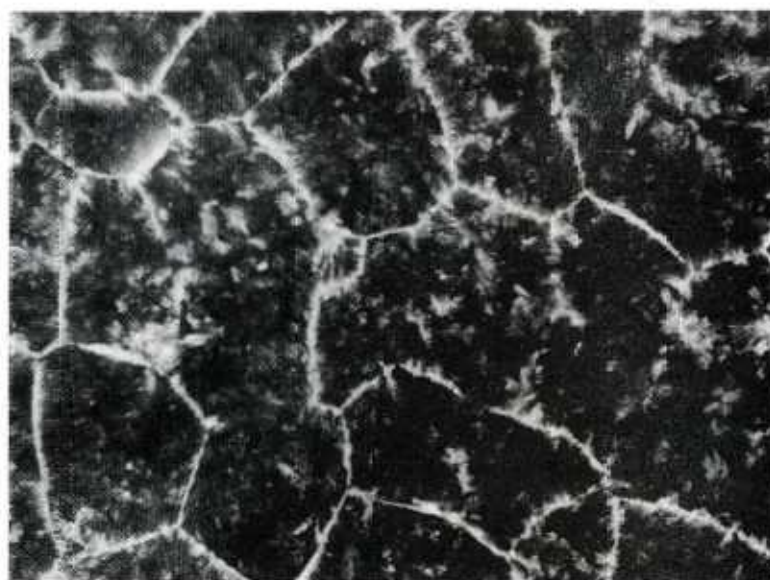


Figure J25 Billet 20T 125x Wesley-Austin Solution

Austenitic Grain Size
Bethlehem Steel

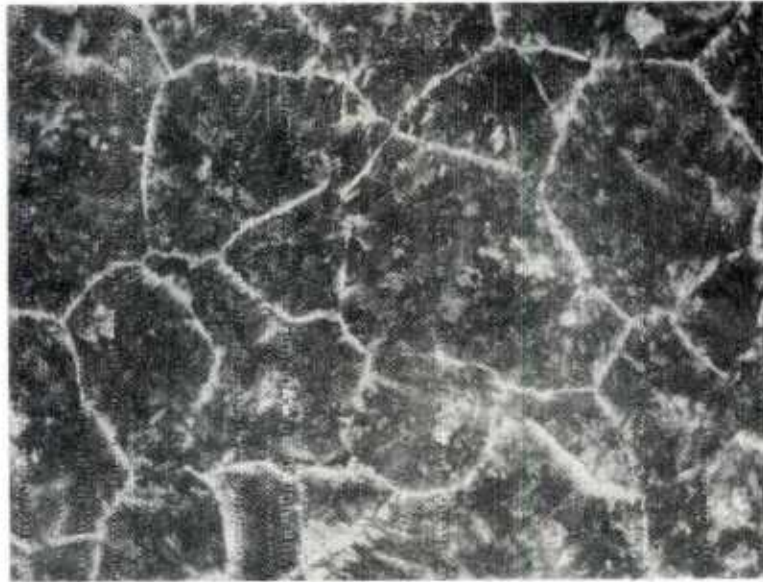


Figure J26 Billet 20C 125x Wesley-Austin Solution

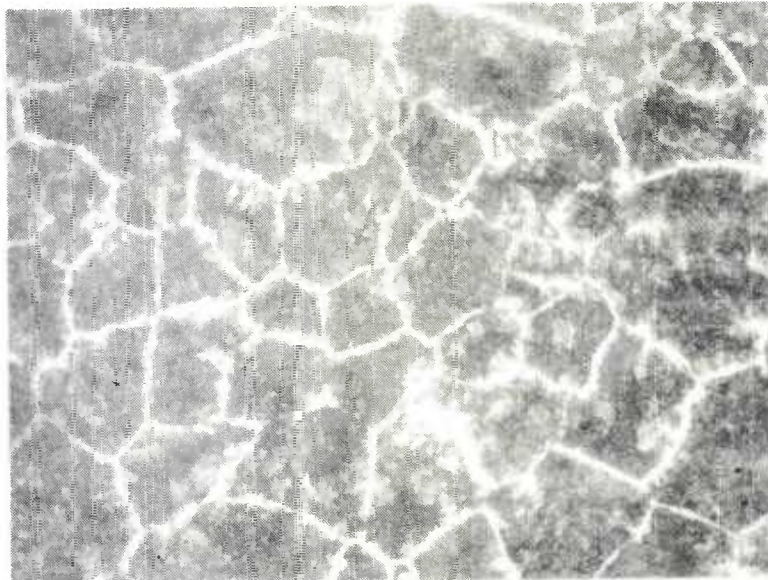


Figure J27 Billet 20X 125x Wesley-Austin Solution

APPENDIX K: Etchant Formulae

1. Wesley - Austin Solution

10 parts H_2SO_4 (Sulfuric Acid)

10 parts HNO_3 (Nitric Acid)

10 parts H_2O (Water)

Sample turns black and grain boundary is outlined in white, not burned.

2. 2% Nital Reagent

2 parts HNO_3 (Nitric Acid)

100 parts Ethanol or Methanol

3. Picral Etchant

10 grams Picric Acid

100 ml Ethanol (95%) or Methanol (95%)

4. Macro Etch

50% HCl (Hydrochloric Acid)

50% H_2O (Water)

at 77°C (170°F)

DISTRIBUTION

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U. S. Army Armament Research and Development Command

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DRDAR-CGL (1) (Building 3)

DRDAR-LCU-M (20)

DRCPM-PBM-MA (2)

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