CHAMBERLAIN MANUFACTURING Corporation

WATERLOO, IOWA

FINAL ENGINEERING REPORT

INVESTIGATION OF NEW SAWING CONCEPT

CONTRACT DAAA25-70-C-0353

Submitted: 29 May 1970

Submitted To

Commanding Officer Frankford Arsenal
SMUFA - J4400
Philadelphia, Pennsylvania 19137

RESEARCH and DEVELOPMENT DIVISION

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Submitted By: John J. Bergstrom
General Manager
Research & Development Division

COPY 16 OF 25

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ABSTRACT

Using a new concept bar-cutoff machine (Goellner Saw), approximately 240,000 square inches of representative steels were cut in a Phase I study to prove feasibility of operation as a billet-separation method in the manufacture of large caliber projectiles.

The results show that 12,000 to 20,000 square inches may be severed efficiently and economically using a single, carbide-tipped, circular blade. Documented operation cycles for this machine range from 3.5 to 5 times faster than band saw and segmental cold-saw operations. Clean, square-cut billet ends yield process-control advantages for projectile forging operations unattainable with the current nick and break method of billet separation.

A Phase II Program to operate the saw in a production-oriented environment is recommended for conclusive verification as a production machine.

1. INTRODUCTION

1.1 This final technical report documents services rendered under Contract DAAA25-70-C-0353, "Investigation of New Sawing Concept," under the technical supervision of Frankford Arsenal. The new concept references the Goellner bar-cutoff saw and associated tooling. The manufacturer of the saw is Metalcut, Division of Paramount Textile Machinery Company. Proclaimed advantages include fast cutting speeds, long blade life and improved quality of cutoff interfaces. Chamberlain Manufacturing Corporation has conducted a preliminary evaluation of this saw as a potential billet-separation device in the manufacture of large caliber projectiles.

2. PURPOSE

2.1 The purpose of this investigation has been to verify feasibility of the Goellner saw operation leading, in turn, to a more fully comprehensive test program under a controlled production-oriented environment. To this end, an appraisal has been made of the saw's performance including both tooling wear and process-control implications. The specific objectives of this study are listed below.

2.1.1 <u>Saw Endurance</u>

a. Determine the saw blade life by evaluating the number of cuts per blade sharpening and number of sharpenings per blade. Reasonable saw performance is assumed. Abuse of the blade with prolonged, excessive loading is not an objective.

b. Determine loading of the saw motor as a function of blade life. Establish, if possible, a "load increase factor" defining the limit of blade wear which dictates blade removal and resharpening.

c. Determine the effect on blade life from prolonged service past the wear point for normal blade resharpening as determined from Section a, above.

2.1.2 <u>Saw Performance</u> (as commensurate to reasonable saw blade life)

a. Determine the maximum speed of cut (precise time to cut the bar corresponding to square inches per unit of time).

b. Determine the maximum speed of cutting series of billets including bar and saw indexing, or the time per billet over extended operation.

c. Determine, with respect to <u>Quality of Cut</u>, the accuracy of billet length over full indexing operation, the perpendicularity of the cut interface to the bar stock, the kerf width, and the work-hardening depth of cut interfaces.

d. Determine, with respect to b, above, an estimate of the required man-hours per saw cut thus yielding an estimate of the number of saws that may be overseen by one operator.

e. Determine downtime constants such as the time to change saw blades and time to load bar stock into cutting position.

2.2 With respect to both main objectives stated above, determine an economic comparison with the nick and break bar separation method. As practically achievable under laboratory conditions for operation of the Goellner saw prototype, information derived shall indicate relative efficiencies of production.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

Presented below are the conclusions of this study for the feasibility evaluation of the Goellner saw.

1. Projections of production rates in pieces per hour are generally three times greater than for band saws or circular, segmental cold-saws. Actual cutting time per cycle on identical stock ranges up to five times faster.

   a. In this study Goellner cycle times (complete cutting cycle) for anticipated production operation ranged from 50 seconds on AISI 4340 steel to 57 seconds on AISI 1561 to 29 seconds on AISI 1030.

   b. Cutting rates on the Goellner saw are high, varying from 53 to 56 square inches per minute on AISI 4340 or 1561 steels to 76 inches per minute on the softer 1030 steel and to 35 inches per minute on the harder PR2 steel.

2. The following are direct comparisons with the nick and break method of billet separation. The bar stock considered is the 6-inch RCS 1561 used to fabricate the 175-mm, M437 or 155-mm, M107 Projectiles.

   a. A sawed billet results in a more defect-free forging cavity, hence fewer rejects and less expended effort for reclaim. The finish of the cut surface is considered very good compared with the end of a billet produced by the nick and break method.

   b. Less manpower is required for sawed-billet production. Two (2) men operating six saws (8 saws are considered capacity, 4 per man) can produce billets requiring five men operating two nick and break systems. The result is 60% less labor.

   c. Tooling costs for sawing are higher but the total cost per cut is figured at about 14 cents for either method when considering both direct labor and tooling. Indirect costs were not considered.

d. The sample size of processed sawed billets was too small to determine significant differences regarding forging concentricities or material savings attributable to accurately cut, square billet ends.

3. Inherent machine downtime is minimal for projected production operation. Downtime for machine maintenance during the study was light, especially considering that the test machine was the only existing prototype. However, it is noted that the indexing mechanism on this machine was too light-weight to handle 6-inch steel bar automatically.

4. Over 400 cuts per blade can be expected in production-cutting of 6-inch RCS 1561 steel before resharpening. This corresponds to over 14,000 square inches.

   a. For 6-1/4 inch Rd 4340, expected blade life can be 325 cuts or over 10,000 square inches compared to 3,900 square inches per blade on a Heller saw cutting the same production stock.

   b. For 4-inch RCS or 5-inch Rd 1030, 1,000 to 850 cuts respectively, or about 17,000 square inches can be expected. This compares to 10,000 square inches of production stock on a Heller blade or to 8,300 (4-inch) to 11,000 (5-inch) square inches on a band saw blade (high speed steel, Thermorized).

5. Removing blades before excessive chipping occurs will make possible six to eight sharpenings per blade before retipping becomes necessary.

   a. Cutting with a blade worn past its blade life results in rapid deterioration due to excessive chipping. Therefore, the timing for tool change is important for maximum life.

   b. The expected "load increase factor" on the spindle motor before blade change for the steels tested and for the machine settings of best operation are:

4340 (6-1/4 inch Rd)	- 30-33%
1561 (6-inch RCS)	- 50-55%
1030 (4-inch RCS, 5-inch Rd)	- 30-40%

6. Proper grinding of the blade is critical to blade life, particularly the side-dubbing which intentionally removes the sharp leading edges.

7. The grades of carbide teeth used in this test program exhibit a tendency to "wear out" by eventual chipping rather than by a gradual erosion process. This characteristic is dependent upon the steel grade being sawed.

8. Special steels such as 9260, 1340 and PR2 can be cut with the Goellner saw, however, limited stock prevented determinations of blade life.

9. The accuracy of billet length can be expected to be better than .090 inch maximum deviation. Wafer cutting in the program resulted in .187 inch maximum deviation, which is much better than the 1/4 to 2-inches deviation common with the nick and break method of bar separation.

10. Perpendicularity of the cuts to the bar stock is good when a sharp and properly ground blade is used. Unbalanced wear or a poor initial grind can cause drifting of the blade while in the cut. Hand-dubbing the blade with an ordinary dressing stone while on the machine can correct this occasional deficiency.

11. The amount of material loss in the kerf is dependent on blade width and workpiece cross-section. The blade width nominally is 1/4-inch. Wear and subsequent sharpening reduces kerf loss accordingly.

12. High inherent hardness of the workpiece adversely affects blade life. Work-hardening of the cut interface can be expected but is considered negligible.

3.2 Recommendations

3.2.1 A Phase II program is recommended to confirm the production-cutting application of the Goellner saw by actual operation in a projectile production plant. Four months operation of a production model saw is suggested to establish the basis for justification of large-scale implementation of this billet separation method in the manufacture of large caliber projectiles.

3.2.2 A site recommended for installation, operation and evaluation of the saw is the Chamberlain-operated Scranton Army Ammunition Plant in Scranton, Pennsylvania. The saw could operate concurrently with Scranton's nick and break method of billeting to separate 6-inch RCS 1561 stock. These billets would be fabricated into the 175-mm, M437 and 155-mm, M107 Projectiles currently in production at Scranton.

3.2.3 The general objectives of such a program would be to optimize functional operation of the saw, to evaluate the effect of sawed billets on process-control and to establish precise costs of production operation. Optimizing the saw's operation would be guided by the results of the completed feasibility study. However, because only one steel grade is involved, greater exploitation of the variables of tooling and machine settings can be pursued. Determinations of the effect on process-control would involve the monitoring of all relevant forging and machining operations and the analysis of data derived. The third objective would require a thorough analysis of all production costs, both direct and indirect. The ultimate differences between competitive bar separation methods lie not only in the actual parting process but also in the effect on later processes because of the physical properties of the billet as it is transformed into a finished product.

4. TEST MACHINE DESCRIPTION

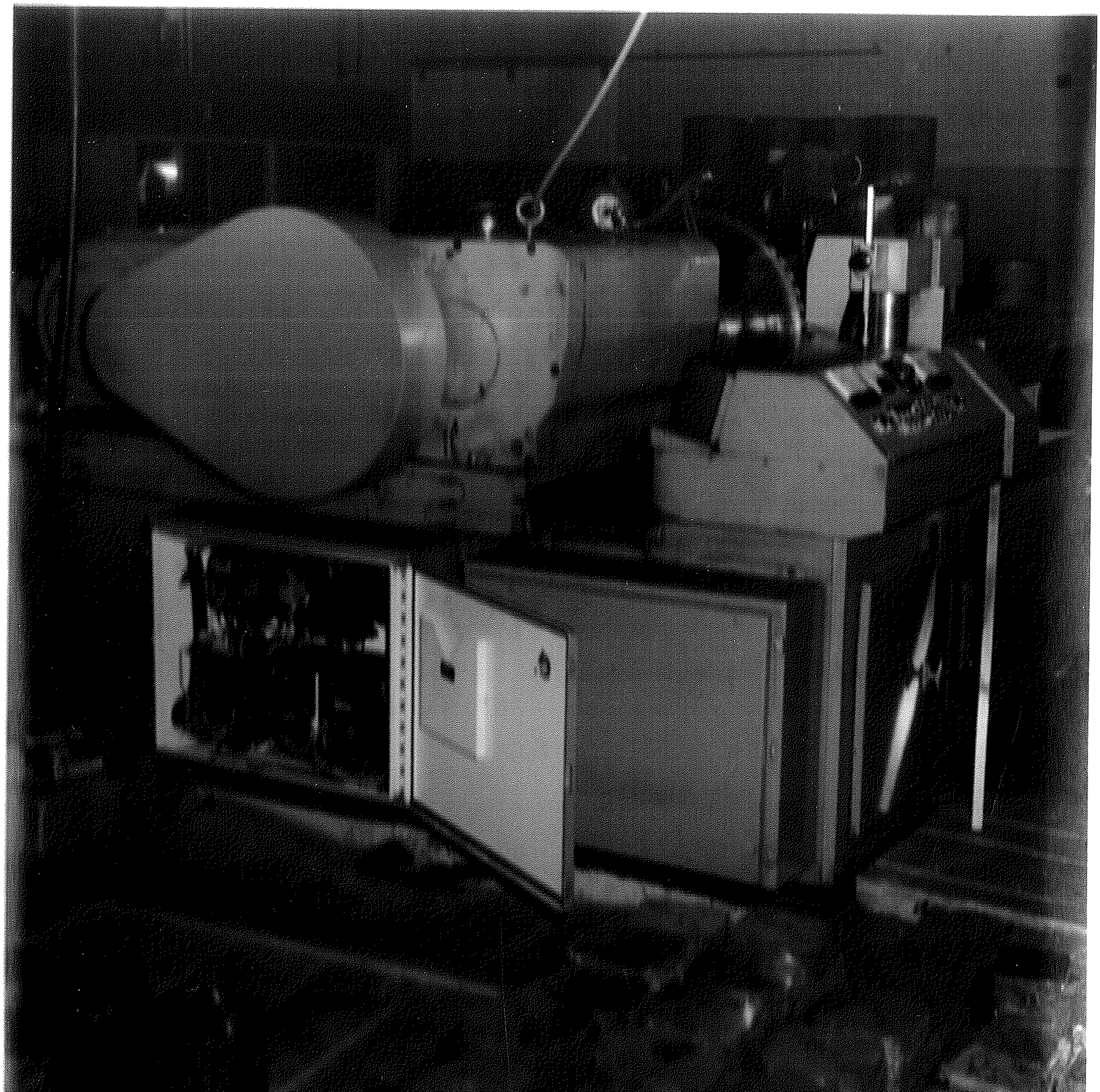
4.1 The Goellner saw evaluated in this test program is unique in design. This machine is the first prototype and, at the time of this study, the only Goellner saw in existence. Reference Photographs C1455, 1458, 1459 and 1460 on Pages 10 through 13.

4.2 Features of the test machine are several. Circular blades with carbide teeth are employed which rotate downward through a rigidly-supported workpiece holder. A clamp-down system restrains the workpiece with a force of 14,000 pounds. A special gib system on the moving head effectively reduces vibration to enhance saw performance and prolong blade wear life. The head is activated by a power screw system to eliminate erratic feeding and breakthrough problems generally associated with the more common hydraulic systems. Because of the carbide blade usage, an anti-backlash is incorporated in the drive system.

4.3 The blades, ranging up to 36-inches in diameter, possess alternately positioned primary and secondary teeth. The primary tooth removes a center chip approximately .150-inch wide. The secondary tooth, located on a slightly smaller blade diameter, removes a chip about .050-inch wide from each side of the primary cut. Photograph C1453 on Page 14 illustrates typical chip formation from an actual sample cut. The teeth are ground with a negative rake, an uncommon feature of cold-saw tooling. Through blade design and proper saw operation the heat of chip formation is dissipated primarily into the chip rather than the workpiece or the blade.

4.4 As with most prototypes, the test machine has several shortcomings which, according to the manufacturer, are to be corrected in the first production machines. Specifically, the 25 horsepower motor is not sufficient power for the saw (the production saw will have 50 horsepower); the automatic indexing system is too light to handle six-inch round-corner-square (RCS) or larger bar stock (the production saw will handle up to 12-inch RCS); and the electrical controls could permit machine abuse if left unattended. The production saw will have fool-proof controls in that an automatic shutdown will occur if the spindle motor is overloaded as with a damaged blade.

(Text continued on Page 15)



PHO PHOTOGRAPH C-1455

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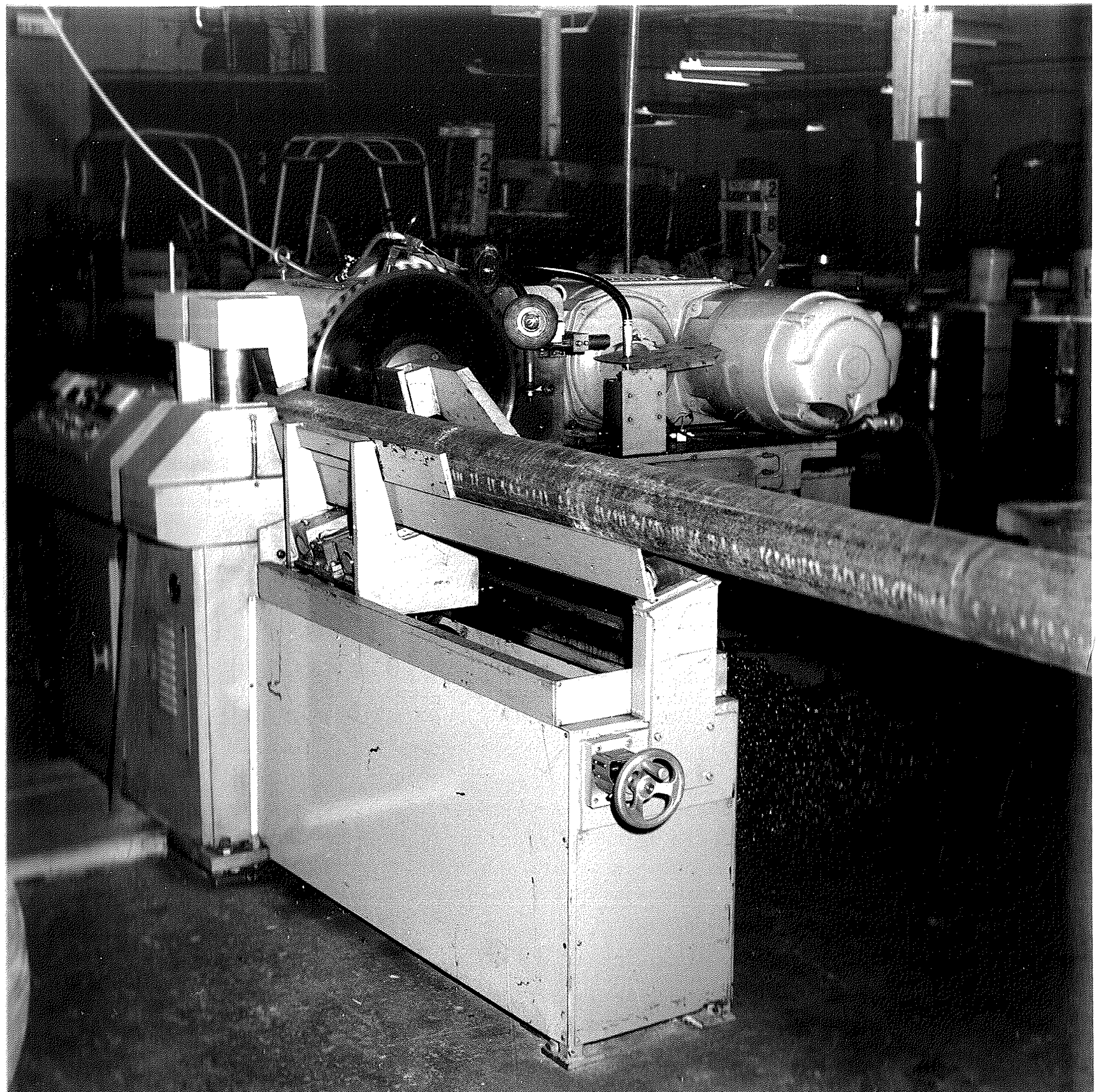
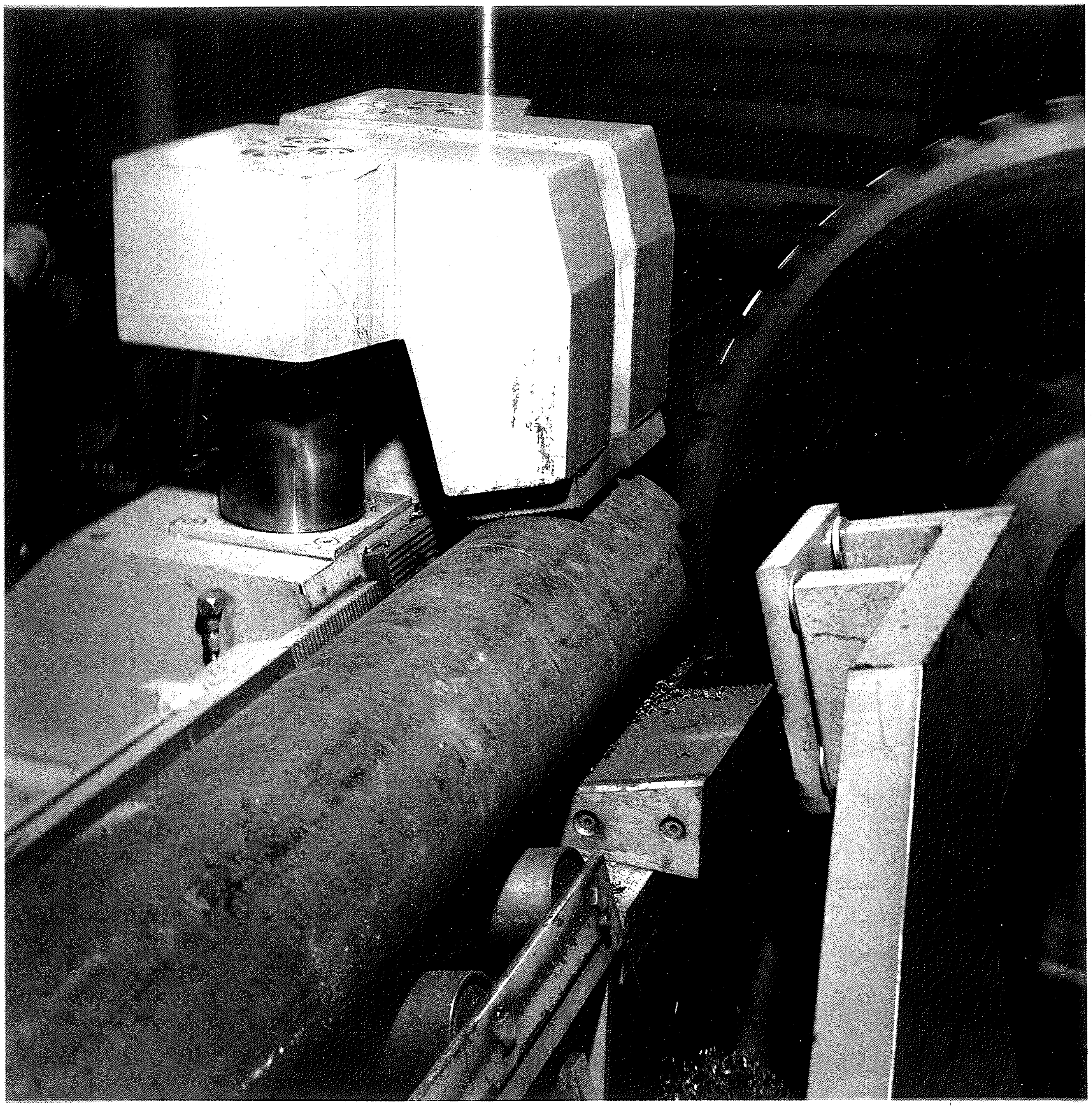


PHOTOGRAPH C-1458

CHAMBERLAIN MANUFACTURING CORP.

PHOTOGRAPH C-1459

CHAMBERLAIN MANUFACTURING CORP.



PHOTOGRAPH C-1460

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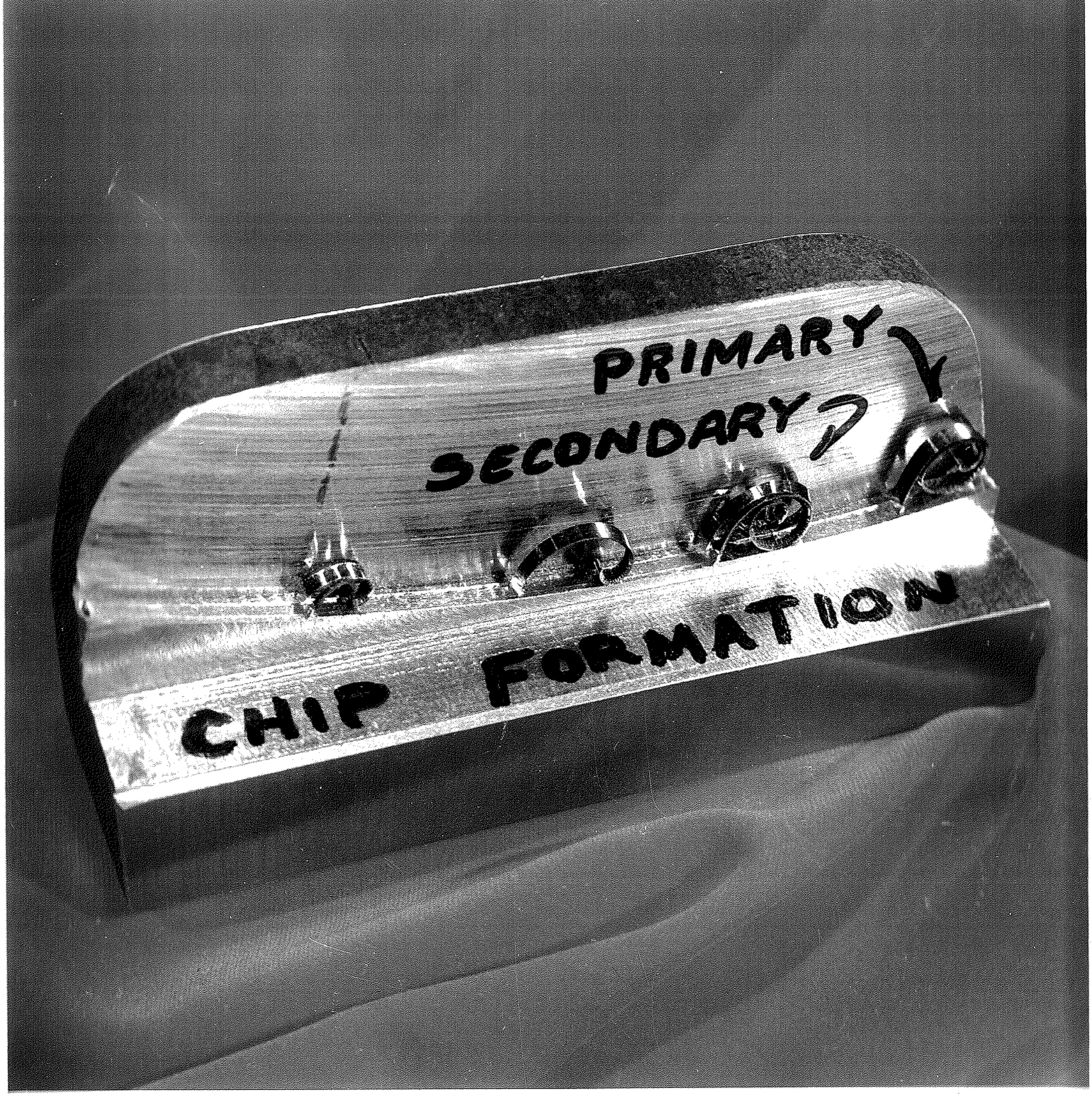


Photo No. 1453 CUTAWAY VIEW OF WAFER ILLUSTRATING CHIP FORMATION

5. PROCEDURE

5.1 General

5.1.1 A test program was followed in which approximately 9,200 cuts were made on six grades of bar steels. This test stock, ranging in cross-sectional size from 4-inch RCS to 6-1/4 inch round (Rd) was representative of material currently used or planned for large caliber projectile manufacture. Both the tooling (saw blades) and the saw operation were varied to achieve best results. Several blades were worn down through successive tests and subsequent sharpenings in order to accumulate blade life data. With the exception of several tests on production bar stock, all test bars were cut into 1/2-inch thick wafers rather than normal-length billets. This permitted the greatest number of cuts from available stock, economically yielding the most data.

5.1.2 Fifty-four (54) bars of 6-inch RCS 1561 steel were shipped from the mill supplier for Chamberlain's Scranton facility for billet-separation using the Goellner saw. These were cut into 702 billets of approximately 17-1/4 inch length and then were sent to Scranton for subsequent fabrication into the 175-mm, M437 Projectile. The effect on process-control resulting from square-ended billets was monitored and evaluated.

5.2 Test Variables

5.2.1 In conjunction with the stated objectives, the variables of tooling (blades), saw operation and bar stock steels were investigated. The saw operation included basically saw blade speed and feed. The bar stock steels used in this study are shown in Table I. Test blades were either 50 or 60 toothed and all except one were ground with an 18° negative rake angle. It was assumed at the start of the test program that all test blades would be nominally 26-inches in diameter and possess cutting teeth of identical size and quality of grind.

5.3 Documentation

5.3.1 Each test sequence was monitored and the following information was recorded on approximately every tenth to twentieth cut:

Table I. - TEST MATERIAL

STEEL GRADE	CONDITION	HEAT CODE	HARDNESS RANGE	COMPOSITION C	Mn	P	S	Si	Ni	Cr	Mo	Cu	Su
4340	6¼ Rd. Annealed	6776424 Republic Steel	R"B" 92-96	.42	.80	.015	.025	.32	1.74	.85	.23		
1561	6 RCS As-Rolled	190084 Wheeling-Pitt	R"B" 95-99	.60	.96	.015	.030	.19					
1561[1]	6 RCS As-Rolled	293854 Wheeling-Pitt	R"B" 95-99	.60	1.01	.010	.019	.24	.02	.02	.01	.05	.006
1030[2]	4 RCS	79R678 U.S. Steel	R"B" 80-83	.29	.67	.008	.024	.20					
1030[2]	5 Rd.	J83438 U.S. Steel &	R"B" 80-83	.28	.79	.015	.024	.24					
		6320044 Republic		.30	.82	.015	.025	.27					
1340	4 RCS	1714075 Frankford	R"B" 94-98	.38/ .43	1.60/ 1.90								
9260	4 RCS	A700300 Frankford	R"C" 30-35	.56/ .64	.75/ 1.00			2.00	.04	.07			
PR2	4 RCS	3101075 Frankford	R"C" 30-35	.43/ .48	1.35/ 1.65	.025	.025	3.00/ 3.50					

[1] Scranton Production Steel - Bar Stock Separated Into Billets

[2] Waterloo Production Steel - Bar Stock Separated Into Billets

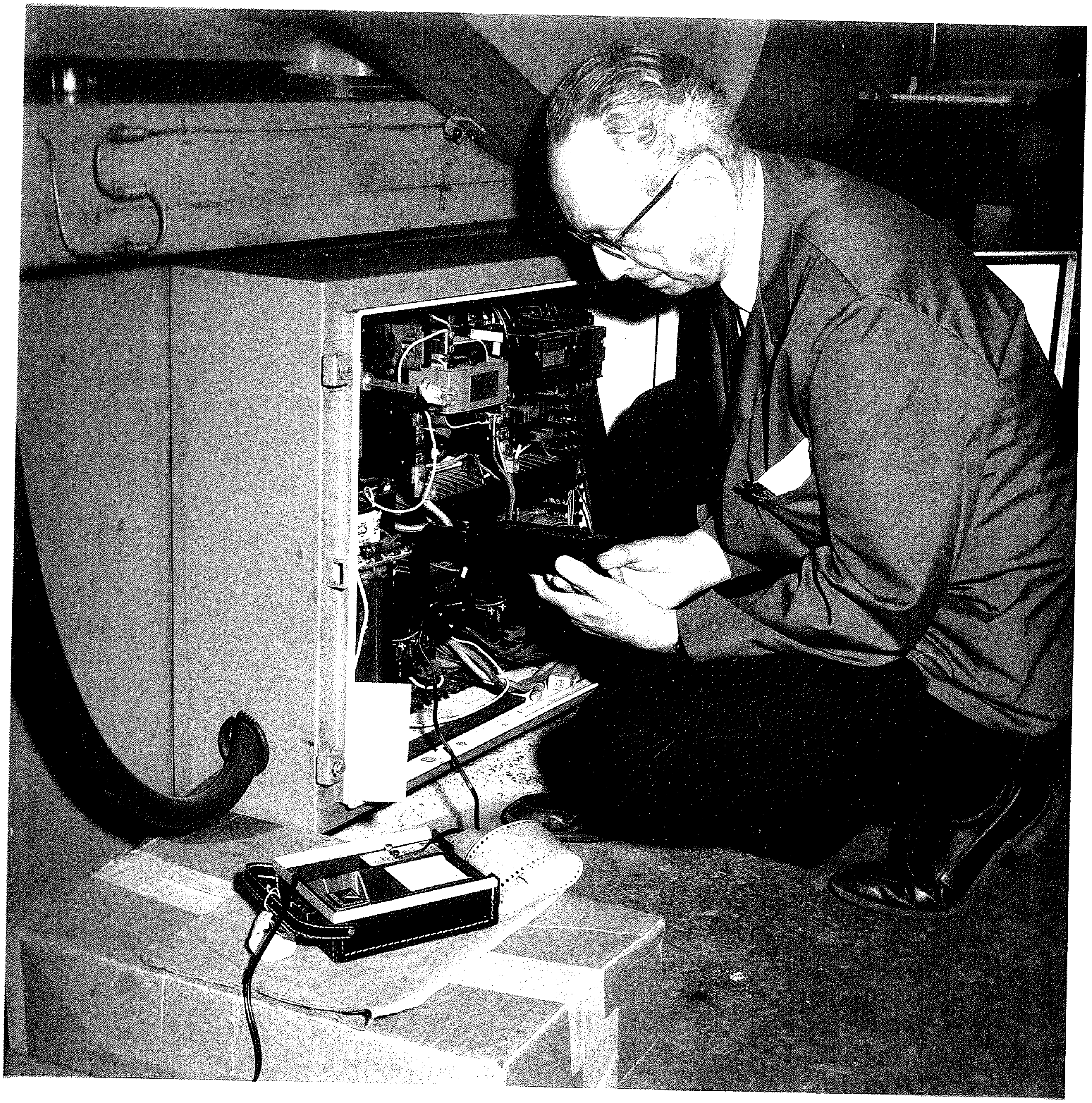
1. Time-to-saw (seconds)
2. Spindle motor load (amps)
3. Perpendicularity of cut (inches)

Tools used to obtain this data included a stopwatch, two ammeters and an inspection square. One of the meters was equipped with a chart recorder which was used to record the amperage and cycle time on each cut. Reference Photograph C1457 on Page 18.

5.3.2 Periodically during each test sequence the machine was stopped and the saw blade was inspected visually for wear and for evidence of chipping. All blades were dimensionally inspected before and after each test and the data recorded. These data would reflect tooth wear and, in the case of successive sharpenings on the same blade, indicate total blade life or the number of sharpenings per blade before retipping with new carbide inserts is necessary. Before the initial cut each blade had three (3) sets of teeth marked, each set being one primary tooth and an adjacent secondary tooth. The marked sets were located approximately 120° apart. For inspection, each tooth was measured for maximum width across the cutting face and for maximum height. The latter was a radial measurement referenced from the blade spindle hole diameter.

5.3.3 Data pertinent to time-study evaluations were accumulated. Recorded inputs to determine operator time per cut included machine cycle time and downtime to change worn blades, load cutting stock and generally maintain machine operability.

5.3.4 Samples of the test wafers were measured after the completion of all testing to determine workpiece thickness, hardness and surface finish. The thickness data, recorded from five distinct locations on every tenth wafer from three representative tests, gauged the accuracy of the machine indexing mechanism and served to indicate perpendicularity of the cut interface. Hardness data were recorded from five locations on the cut interface as well as from beneath the surface. This enabled determinations regarding work-hardening and the effect of bar hardness on saw blade performance and life. Surface finish data were used to indicate the physical condition of the parted surface. It is this surface which significantly affects the cavity condition of the drawn projectile forging.



PHOTOGRAPH C-1457

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5.3.5 A trip was made to Chamberlain's Scranton plant to monitor shell fabrication from billets cut using the Goellner saw. Process control information was noted as affected by the smooth-finished and square-cut interfaces of the sawed billets. In addition, data regarding the cost per cut for Scranton's nick and break billet separation method were obtained for an efficiency comparison with the Goellner saw.

5.3.6 Both still and motion picture photography were used to document machine operation and test results. The stills appear herein and the documentary film will have been provided the cognizant Technical Supervisor at Frankford Arsenal. High-speed films were taken also to observe chip formation and the cutting action in general. Again, typical films have been provided to the Technical Supervisor.

6. RESULTS

6.1 A total of 9,227 cuts, equivalent to 241,550 square inches of sawed area, was made on six (6) grades of steel. A breakdown of the number of cuts, the number of blades used and the average number of square inches per blade is shown on Table II, "Sawed Area," Page 21. Except for the production billet separation on 1030 steel (3,569 cuts) and on Scranton's 1561 steel (652 cuts), all cuts resulted in 1/2-inch thick wafers. Test wafers of the six grades of steel are pictured by Photograph C1452 on Page 22. Wafers representative of the beginning and the end of typical tests are shown. Photograph C1454 on Page 23 illustrates the typical primary and secondary chips resulting from each test steel.

6.2 Table III, "Individual Test Results," summarizes data recorded on the monitoring sheets used for each test sequence. This tabulation groups individual tests with respect to the grade of steel sawed rather than the sequence of testing. Included are: the number of cuts and corresponding sawed area, the actual time for the test blade to cut through the steel bar, the blade description, the machine settings of saw operation, and remarks pertinent to the results of each test. Measurements regarding perpendicularity of cut are tabulated only on the monitor sheets. The spindle speed refers to the rotational speed of the saw blade which, along with the known blade diameter, determines the surface feed of the blade against the workpiece. The spindle speed plus the known number of effective teeth on the test blade plus the establishment of the feed rate of the saw head all determine the tooth load. Tooth load is simply the amount of material removed by each "effective" blade tooth. Because each test blade consists of two types of teeth (primary and secondary), a 50 or 60 tooth blade is considered to have 25 or 30 "effective" teeth, respectively, considering that load is on both primary and secondary at the same time. In the blade description column, the blade number is followed by the diameter (26-inches), the negative rake angle (15° or 18°) and the number of teeth (50 or 60). Blades repeated in the column signify reuse after resharpening. Each reused blade was sharpened with the same negative rake angle.

(Text continued on Page 25)

Table II. - SAWED AREA

Bar Stock (Steel)	No. of Cuts	Total Sawed Area (square inches)	No. of Blade Sharpenings Consumed	Mean Sawed Area Per Sharpening (square inches)
6¼ In. Rd. 4340	2,789	87,880	11	7,990 (10,250/7)
6 In. RCS 1561	2,119	74,170	8	9,270 (14,140/4)
5 In. Rd. 1030 4 In. RCS 1030	2,353) 1,216)	67,120	4	16,780
4 In. RCS 1340	340	5,610	1*	5,610
4 In. RCS PR2	210	3,470	1*	3,470
4 In. RCS 9260	200	3,300	2*	1,650
TOTAL	9,227	241,550	27	8,946 (13,030/15)

* Insufficient Stock To Wear Out Blades.

( ) Mean Value/No. of Blade Sharpenings Considered To Be Best Data For Validity.

Photo No. 1452 TYPICAL TEST WAFERS

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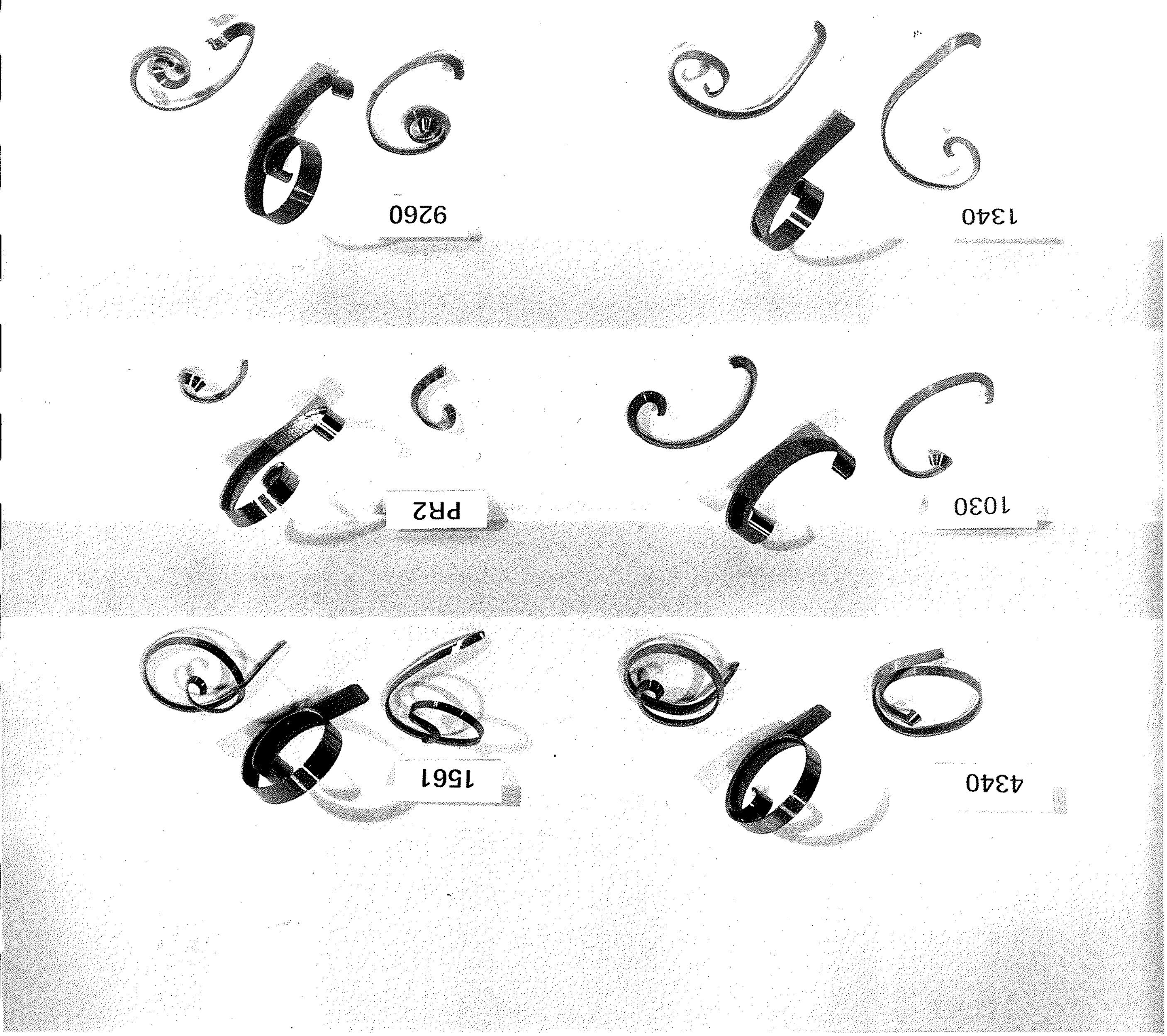


Photo No. 1454

TYPICAL CHIPS
(Primary Chip and Two Secondaries per Steel Grade)

Table III.- INDIVIDUAL TEST RESULTS

TEST NO.	TEST STEEL	TEST SEQUENCE	NO. OF CUTS	SAWED AREA (Sq. In.)	TIME TO SAW (Sec.)	BLADE NO. & DESCRIPTION	SAW OPERATION SPINDLE SPEED (rpm)	BLADE FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (In.)	REMARKS
1	4340-6½ Rd	1	230	7,250	28	L9066(26-18-50)*	70	14	480	.008	High tooth load suspected.
2	"	2	230	7,250	28	L9067(26-18-50)	70	14	480	.008	Repeat test with another blade.
3	"	4	60	1,890	27	L9066	70	14	480	.008	Insufficiently sharpened blade.
4	"	5	88	2,770	27	L9067	70	14	480	.008	Insufficiently sharpened blade.
20	"	6	214	6,740	27½	B9079(26-15-60)	70	14	480	.008	Excessive drifting, poor side dub.
1a	"	7	280	8,820	33	K9108(26-18-50	60	12	410	.008	Test 1 w/speed and feed change.
2a	"	8	290	9,140	33	K9107(26-18-50)	60	12	410	.008	Test 2 w/speed and feed change.
3a	"	12	410	12,920	38	K9108	60	10½	410	.007	Best results to date.
4a	"	14	391	12,320	31½/30½	K9107	60	10½/12½	410	.007/.0085	High load shortened life.
21	"	17	150	4,730	32	L9067	60	10½	410	.007	Suspect hard bar stock.
6	"	22	446	14,050	35	K9108	60	10½	410	.007	Repeat Test 3a, same blade.
5	1561-6RCS	3	110	3,850	27	M8094(26-18-60)	60	14½	410	.008	High tooth load suspected.
5a	"	9	27	950	29	M8096(26-18-60)	60	13	410	.0072	.009 load damaged early.
5b	"	10	350	12,250	39	K9110(26-18-50)	55	9½	380	.007	Hand-dubbing employed.
7	"	13	420	14,700	38	L9066	55	9½	380	.007	.007 load decided good.
30	"	19	560	19,600	38	K9110	55	9½	380	.007	Hand-dubbing employed.
10	"	20	138	4,830	33	M8096	55	11½	380	.007	Scranton steel cut to hold weight
			286	10,010	"	B9108(26-18-60)	"	"	"	"	and yield square ends. Blade M8094
			228	7,980	"	M8094	"	"	"	"	still usable.
913	1340-4RCS	11	340	5,610	22	B9108	60	12½	410	.007	Blade usable after test.
992	9260-4RCS	15	100	1,650	25½	M8094	50	10½	350	.007	Blade chipped and worn.
992a	"	16	100	1,650	22	B9079	50	12	350	.008	Blade still usable.
9P	PR2-4RCS	18	210	3,470	29	K9109(26-18-50)	45	8½	310	.0075	Blade chipped but usable.
11	1030-4RCS	21	1,216	20,060	11	L9066	110	24½	750	.009	Waterloo production stock.
12	1030-5RD	23	847	16,940	14	M8094	100	24	700	.008	Used blade - Waterloo Prod. stock.
12a	"	24	537	10,740	13	K9109	115	24½	800	.0085	Waterloo production stock.
12b	"	25	969	19,380	16½	L9067	95	19	650	.008	Waterloo production stock.

* The values in parentheses describe each blade. (26-18-50) means the blade was 26 inches in diameter, 18 degree negative ground and 50 toothed. This description was omitted for any repetitive listing of a blade.

6.3 The amperage drawn by the spindle motor and the time-to-saw for each cut were recorded on real-time charting tape. Graphs showing motor load versus number of cuts (or square inches of sawed steel) for each individual test are compiled in Appendix B. The sequence of graphs follows Table III grouping with respect to grade of steel. A typical graph (Test No. 7) is shown on the following page.

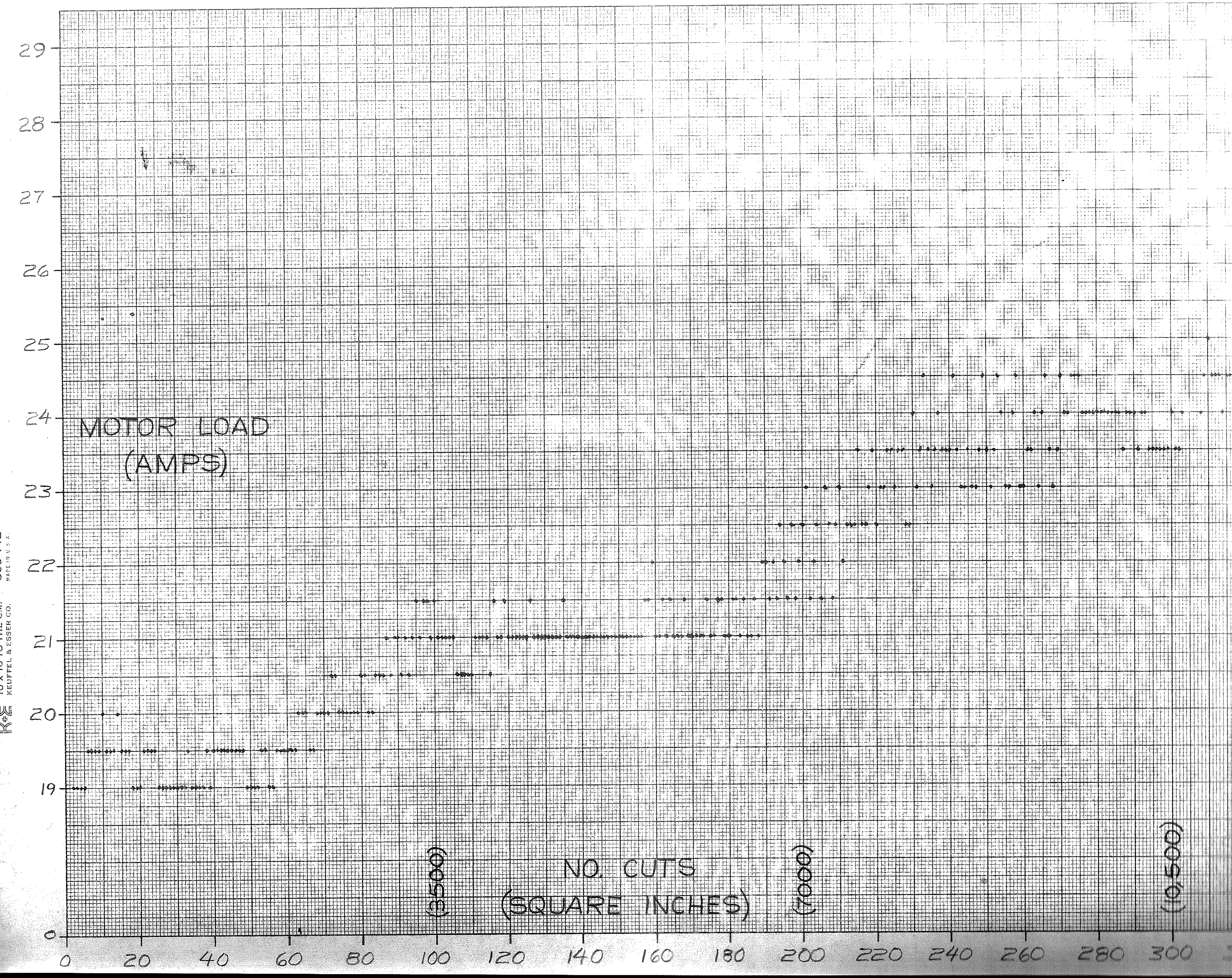
6.4 Table IV, "Blade Teeth Data," summarizes the data on blade teeth inspections before and after individual tests. Values cited represent changes in the overall tooth dimensions, first as a result of wear, and then as a result of the sharpening to restore the cutting edges. Each test blade with its successive sharpenings is listed separately. Referenced are blade description, test number, test material and square inches of material sawed. Typical appearances of the carbide teeth are depicted on Photograph 8942 on Page 29, both before and after testing.

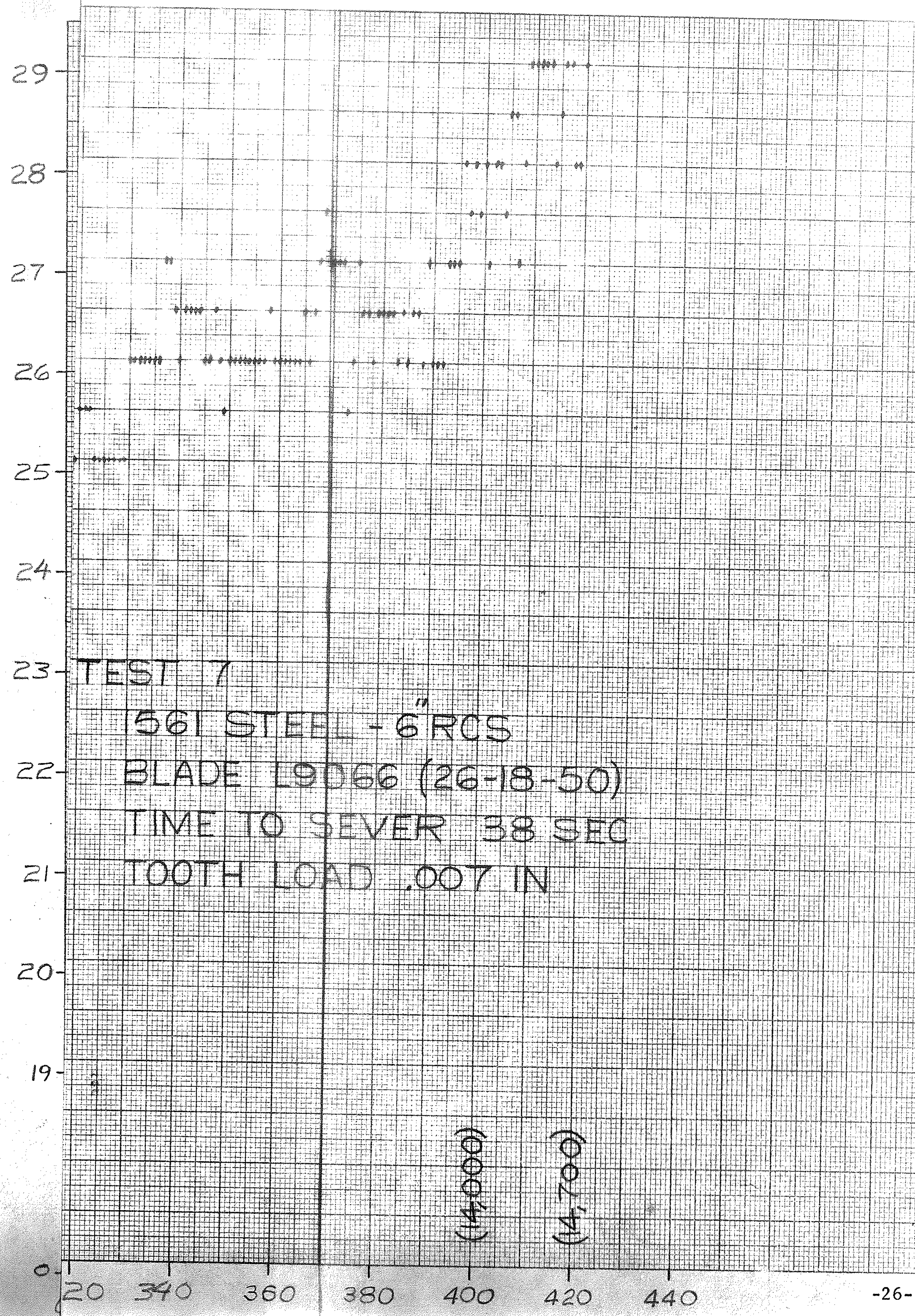
6.5 Table V, "Wafer Thickness Data," summarizes data derived from the measurement of thicknesses on 110 wafers. These samples were selected as every tenth wafer from tests representative of each of three materials: 4340, 1561 and 1340 steels. Actual readings are compiled in Appendix C.

6.6 Tables VI and VII reflect workpiece hardness measurements on wafers representative of the test steels. Table VI summarizes those readings taken to determine work-hardening of the cut surface as a result of the frictional heat generated by the cutting saw blade. Table VII gives the actual readings taken across the cut surface to show the inherent hardness deviation through transverse sections of the bar stock. Hardness data denoting the inherent variation along the steel bar (longitudinal) used in each test may be referenced in Appendix D. Each reading was taken after the cut surface was ground down approximately .010-inch to remove any possible work-hardening.

6.7 Table VIII, "Surface Finish," lists the determinations of surface finish on representative wafers. These wafers are the same as those depicted in Photograph C1452.

(Text continued on Page 34)


MOTOR LOAD (AMPS)
NO. CUTS (SQUARE INCHES)
(3500)
(7000)
(10,500)
29
28
27
26
25
24
23
22
21
20
19
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
10 X 10 TO THE CM. 359-14L
KEUFFEL & ESSER CO. MADE IN U.S.A.



TEST 7
1561 STEEL - 6" RCS
BLADE L9066 (26-18-50)
TIME TO SEVER 38 SEC
TOOTH LOAD .007 IN
(14,000)
(14,700)
29
28
27
26
25
24
23
22
21
20
19
0
20
340
360
380
400
420
440

Table IV. - BLADE TEETH DATA

BLADE NO.	NO. TEETH AND GRIND	TEST NO.	TEST MAT'L	SAWED AREA (In.^{2})	TOOTH DIMENSIONAL CHANGE (In.)* FROM WEAR PRIMARY WIDTH	FROM WEAR PRIMARY RADIAL	FROM WEAR SECONDARY WIDTH	FROM WEAR SECONDARY RADIAL	FROM SHARPENING PRIMARY WIDTH	FROM SHARPENING PRIMARY RADIAL	FROM SHARPENING SECONDARY WIDTH	FROM SHARPENING SECONDARY RADIAL
L9066C7C4	50/18N	1	4340	7,250	.0002	.0010	.0008	0	.0032	.0175	.0034	.0165
(2)**		3	4340	1,890	0	.0007	0	.0003	.0043	.0409	.0042	.0420
(3)		7	1561	14,700	.0002	.0017	.0005	.0007	.0027	.0354	.0031	.0354
(4)		11	1030	20,060	.0003	.0083	.0005	.0002	--	.0495	.0101	--
L9067C7C4	50/18N	2	4340	7,250	.0001	.0013	.0005	.0005	.0017	.0252	.0020	.0245
(2)		4	4340	2,770	0	.0007	.0002	0	.0030	.0361	.0033	.0362
(3)		21	4340	4,730	.0002	.0013	.0001	0	.0061	.0564	.0060	.0548
(4)		12B	1030	19,380	.0005	.0018	.0007	.0007	--	.0417	.0039	--
K9107C7C4	50/18N	2A	4340	9,140	.0002	.0003	.0006	0	.0063	.0423	.0059	.0427
(2)		4A	4340	12,320	0	.0017	.0003	.0004	--	.0388	.0086	--
K9108C7C4	50/18N	1A	4340	8,820	.0003	.0010	.0008	.0008	.0052	.0495	.0053	.0505
(2)		3A	4340	12,920	0	.0027	.0008	0	.0059	.0451	.0063	.0456
(3)		6	4340	14,050	0	.0013	.0003	.0004	--	.0207	.0065	--
K9109C7C4	50/18N	9P	PR2	3,470	0	.0001	0	0	.0036	.0371	.0041	.0356
(2)		12A	1030	10,740	.0002	.0003	.0004	0	--	.0343	.0040	--
K9110C7C4	50/18N	5B	1561	12,250	.0001	.0008	.0003	.0008	.0065	.0452	.0061	.0453
(2)		30	1561	19,600	.0005	.0038	.0002	.0003	--	.0354	.0045	--

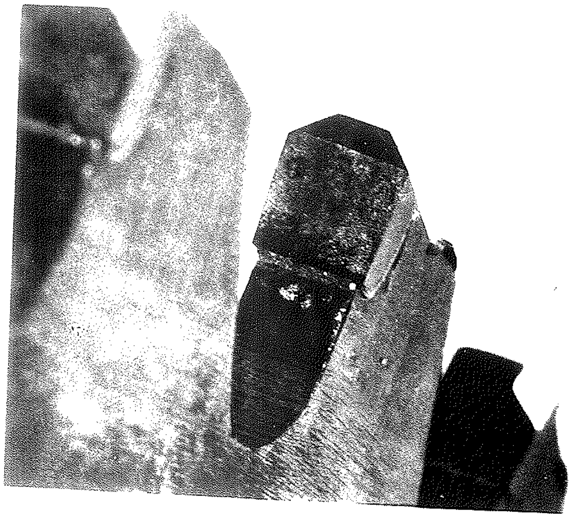
* Each value represents an average change determined from readings taken on 3 teeth located equally about each blade. The values under (wear) derive from readings taken on sharpened teeth before the test and the same worn teeth after the test. Those under (sharpening) derive from readings taken on the same sharpened teeth before the test and the same teeth sharpened after the test.

** Successive sharpenings and subsequent reuse of the same blade are denoted as (2), (3) and (4).

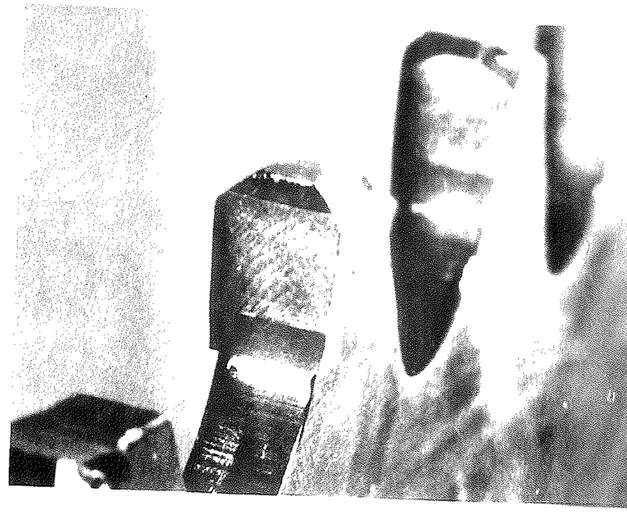
-- Final readings unavailable.

Table IV. - BLADE TEETH DATA (Continued)

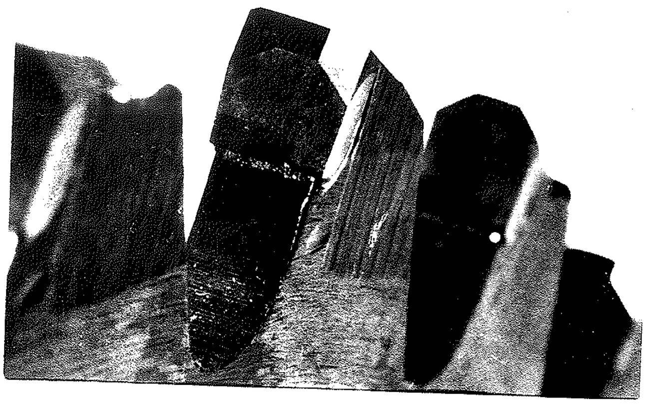
BLADE NO.	NO. TEETH AND GRIND	TEST NO.	TEST MAT'L	SAWED AREA ($In.^2$)	TOOTH DIMENSIONAL CHANGE (In.)							
					FROM WEAR				FROM SHARPENING			
					PRIMARY		SECONDARY		PRIMARY		SECONDARY	
					WIDTH	RADIAL	WIDTH	RADIAL	WIDTH	RADIAL	WIDTH	RADIAL
B9079C7C4	60/15N	20	4340	6,740	.0001	.0010	.0002	.0005	.0050	.0563	.0051	.0568
(2)		992A	9260	1,650	0	.0014	0	.0007	--	--	--	--
M8096C7C	60/18N	5A	1561	950	No Readings After Test				.0043	.0280	.0042	.0270
(2)		10	1561	4,830	No Readings After Test				--	.0104	.0050	--
M8094C7C4	60/18N	5	1561	3,850	.0003	.0017	.0002	.0012	.0079	.0558	.0078	.0543
(2)		992	9260	1,650	0	0	0	0	.0024	.0290	.0047	.0291
(3)		10	1561	7,980	0	0	.0002	0	Sharpened After Test 12			
(3)		12	1030	16,940	.0010	.0024	.0006	.0003	--	.0232	.0041	--
B9108C7C	60/18N	913	1340	5,610	0	.0017	.0003	.0007	Sharpened After Test 10			
"		10	1561	10,010	.0007	.0012	.0006	.0006	--	.0267	.0065	--



PRIMARY TOOTH – NEWLY SHARPENED



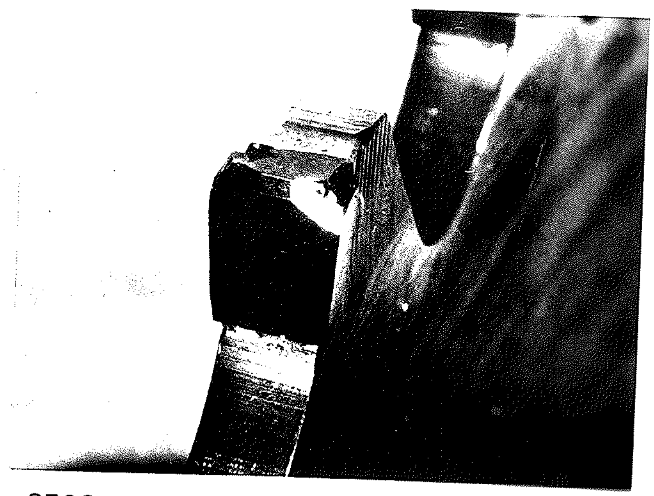
PRIMARY TOOTH – SHOWING WEAR



SECONDARY TOOTH – NEWLY SHARPENED

SECONDARY TOOTH – EROSIVE WEAR

SECONDARY TOOTH – EROSIVE WEAR
PLUS FATIGUE CHIP (TIP REAR)



SECONDARY TOOTH – EROSIVE WEAR
PLUS FATIGUE CHIP (OPP. REAR)

PHOTOGRAPH NO. 8942

CARBIDE TEETH (BEFORE AND AFTER)

CHAMBERLAIN MANUFACTURING CORPORATION

Table V.- WAFER THICKNESS DATA

TEST NO.	TEST MATERIAL	NO. SAMPLES	AVERAGE THICKNESS READING (In.)				MEAN DEVIATION (In.)**
			TOP*	BOTTOM	ENTRANCE	EXIT	
3A	4340	41	.526	.528	.513	.540	.011
5B	1561	35	.485	.484	.483	.486	.007
913	1340	34	.513	.529	.529	.529	.006

* Each location references the saw cut as wafer cutting occurred. Each measurement was made 1/2 inch in from the peripheral edge of the cut face.

** An average value of the maximum deviation readings, one reading from each sample wafer.

Table VI. - WORK-HARDENING

TEST STEEL	SAMPLE NO.*		READING LOCATION**			ROCKWELL SCALE
	TEST	WAFER	CUT SURFACE	< .010 INCH UNDER SURFACE	> .050 INCH UNDER SURFACE	
4340	3A	409	98.2	96.6	96.0	R"B"
1561	30	519	100.0	96.0	97.8	R"B"
1340	913	329	96.3	95.0	94.5	R"B"
9260	992	82	33	29	28	R"C"
PR2	9P	209	32	29.5	28	R"C"

* Each sample was one of the last wafers sawed per respective test.

** Cited values are average of eight readings for 4340 and 1561 steels; 6 readings for others.

Table VII. – HARDNESS VARIATION (TRANSVERSE SECTION)

SAMPLE NO. TEST	SAMPLE NO. WAFER	HARDNESS READINGS* 0°	90°	180°	270°	CENTER	DEVIATION ACROSS WAFER
3A	409	96/96	95/95	93/93	92/94	94/96	4
3A	319	95/96	95/97	93/94	94/94	96/94	3
3A	219	94/95	95/95	94/94	93/93	94/94	2
3A	119	92/92	93/94	93/94	94/94	94/91	3
5B	179	96/98	96/96	97/97	96/96	98/97	2
5B	119	97/98	97/97	98/97	98/99	97/96	3
5B	319	97/99	97/95	99/99	96/96	99/99	4
5B	219	99/98	98/97	97/99	95/96	99/98	4
913	329	96/94	91/92	92/95	93/94	94/94	5
913	219	92/92	96/96	95/96	93/96	95/95	4
913	158	94/95	97/97	98/98	95/97	99/98	4
913	19	94/95	95/95	94/96	93/93	97/95	3
9P	199	34/33	33/33	33/32	34/33	34/33	2
9P	99	33/32	34/35	33/33	33/32	33/32	2
992	19	33/31	32/32	30/30	30/31	33/33	3
992	99	31/31	31/32	32/31	32/31	37/36	6
992A	99	30/29	32/32	32/33	31/31	34/35	6

* Readings were taken at the four quadrants plus the center of each sample. Except for the center, measurements were taken 1/2 inch from the peripheral edge on the cut face. Each spot was surface ground approximately .010 inch before hardness checked. Readings for Tests 3A, 5B and 913 are Rockwell "B" scale; Tests 9P, 992 and 992A are Rockwell "C".

Table VIII - SURFACE FINISH

TEST MATERIAL	SAMPLE NO.* TEST	SAMPLE NO.* WAFER	PROFILOMETER READING	VISUAL COMPARISON
4340	3A	38	70-100 μ inches, rms	500 μ inches, rms
	3A	399	80-100	500
1561	7	19	40-50	500
	7	399	70-100	500
1340	913	17	40-60	500
	913	329	60-70	500
PR2	9P	38	40-55	250
	9P	208	85-100	500
9260	992	38	65-100	500
	992A	38	50-65	500
1030	11	1000	50-60	500
	12B	500	30-40	500

* Sample wafers are the same as those on Photograph C1452.

6.8 Tables IX through XVI appear later in this report under Discussion of Results. These tabulations accumulate similar raw data and analysis for two distinct sub-studies. This section discusses the efforts of a time-study evaluation relating to an eventual production application of the Goellner saw. Following this discussion there is an evaluation of the 1561 steel production stock cut for Chamberlain's Scranton Army Ammunition Plant. Included is a generalized economic comparison between the Goellner saw and the nick and break method of bar separation.

7. DISCUSSION OF RESULTS

7.1 This section discusses the documented results of the preceding section. To better correlate with the objectives of this study, the discussion will follow these objectives in order as listed in Section 2.

7.2 Reference Objective 2.1.1a - Saw Endurance

7.2.1 Blade life with respect to number of cuts (or square inches) per sharpening is summarized for each test steel in Table II. Selecting the best data for validity results in 10,000 to 17,000 square inches obtainable per blade dependent upon the steel grade. The test results improved as the program progressed as shown on Table III. Though Test 21 is an exception, it was believed the unusually hard bar stock was responsible for the poor blade life. Reference to Appendix D reveals that stock cut in this test was significantly harder than in other tests. Optimum operation of the saw was not known when testing commenced; however, knowledge increased with each test experience. The evidence of this statement is shown in Section 7.3 which discusses blade life in conjunction with "load increase factors" used to define blade life. Besides the variables of spindle speed and saw feed, selections of 50 or 60 tooth blades had to be verified. And though like blades referenced like grinds, it is to be noted that they differed in quality of grind. The width across the cutting face varied from .225-inch on Blade K9107 to .242-inch on Blade L9066, both measurements taken before their respective first tests. Subsequent sharpenings could widen this typical difference even more, depending on blade use and resulting wear.

7.2.2 Side-dubbing was an important feature of the blade grind which also varied from blade to blade as well as from one side of a given blade to the other side. Side-dubbing refers to the intentional dulling of the sharp cutting edge of the secondary tooth. The result is a very light chamfer which serves to alleviate tooth chipping and hence increase blade life. Photograph 8942 on Page 29 illustrates the side dub on the view of the sharpened secondary tooth. Shown also are typical before and after shots of both the primary and secondary teeth. It is noted that chipping, when it occurred, was not always restricted in location to the leading cutting edges as was the obvious erosional wear. Chipping often resulted at the rear of the carbide insert at the brazed interface. This would indicate that the impact loading of the tooth was transmitted through the tooth without failure until the shock impulse doubled back on itself at the rear of the tooth in a pseudo-spalling action. Then too, the brazing operation may have raised minor stress cracks at the base of the insert which propagated under load. With the exception of two blades (Refer to Table IV on Pages 27 and 28) all blades possessed carbide teeth of the same grade designated as C7C4. This grade was selected best by the blade manufacturer prior to testing because of its resistance to impact chipping yet possessing sufficient hardness to yield reasonable life performance. However, current test results are not conclusive because a slightly harder or perhaps a slightly softer carbide may produce even better performance than thus far attained.

7.2.3 Table IV tabulates for each test the reduction in dimensional size of the measured teeth due to both actual wear and subsequent resharpening. Though the current evaluation program was time-limited, it was possible to wear down two blades through four sharpenings each. An average dimensional change per sharpening of .036-inch on the primary teeth (radial height) and .0051-inch on the secondary teeth (width) resulted from all test blades in the program. Based on these data, which include poor results from some non-optimum saw operations, an estimated six to eight sharpenings per blade may be expected. Assuming 10,000 to 17,000 square inches per blade use, depending on material grade and condition, this corresponds to 60,000 to 135,000 square inches of sawed steel from a given blade before complete retipping with new carbide inserts becomes necessary. The blade then is ready for another six to eight sharpenings. As expected, it was noted that tooth wear was predominant on the leading edges on the width of the secondary teeth and on the height of the primary teeth.

7.3 Reference Objectives 2.1.1b and 2.1.1c - Saw Endurance

7.3.1 Another measure of tool wear involves operation of the blade on the saw. On-the-saw measurements and subsequent predictability of wear would enable optimum timing of tool changes for greatest economy. A worn blade thus can be replaced before excessive and expensive tooth chipping occurs. Because the feed rate on the movement of the saw head remains at a set constant throughout the operation (power screw system), blade dulling or wear is reflected in the increased amperage drawn by the spindle motor. Therefore, monitoring the motor loading enables the saw operator to determine blade condition. After some general comments below, motor loading regarding blade performance will be discussed in detail for each grade of steel cut in the test program.

7.3.2 As previously stated, amperage load versus number of cuts was recorded and plotted for each test and the graphs compiled are in Appendix B. A review of these plots shows that the load increased almost immediately and followed an ascending slope generally through a series of plateaus. Refer again to sample graph, Test No. 7, Page 26. It should be noted here that the initial load on any given test is a function of the machine control settings, the condition of blade grind and, of course, the workpiece itself. Generally, the no-load amperage (blade not in cut) ran about 10 to 12 amps depending only on the rpm setting for the spindle motor.

7.3.3 The sample chips shown in Photograph C1454 on Page 23, are characteristic of each grade of steel with respect to shape, size and color. As each test blade became dull and more heat went into the workpiece, the chips lost their curling and appeared more ribbon-shaped, and because of work-hardening, broke up more readily. The actual period of transformation varied from steel to steel but was observed to occur gradually about midway during the life of each blade. It definitely was noted though that this change did not signify the end of blade life. Nor chould this change be determined via inspection of the motor loading graph.

7.3.4 A "load increase factor," expressed as a percent increase over initial motor load, can be used to define the limit of blade wear at which time blade removal for resharpening is required. Factors determined from this initial study varied from 30% to 55% depending on the steel grade and size. Cutting beyond this limit accelerated tooth wear and chipping as characterized by the erratic and/or rapidly increasing amperage loads depicted on some graphs. Chipping on one tooth usually leads to chipping on the successive tooth; i.e., one primary tooth to the next primary tooth or secondary to next secondary. Because the broken tooth cannot make a full cut, the next tooth has an extra heavy cut. Thus, this added tooth load works to accelerate wear and eventual chipping. If the worn or chipped blade is removed before excessive chipping occurs, only a minimum of the tooth carbide need be removed to effect a newly-sharpened tool. Consequently, overall blade life is lengthened because of the increased number of sharpenings possible on a given set of carbide teeth.

7.3.5 6-Inch Rd 4340 Steel

Good results with regard to blade life did not occur until Tests 1a and 2a in the test program. Sequential results follow according to individual tests.

Tests 1 and 2 - Mediocre results were obtained (7,250 square inches per blade). The .008-inch tooth load, as determined later, was too high. Load increase factors were 15% and 21% respectively on these two tests.

Tests 3 and 4 - Poor results due to poor regrinding. These blades were the same as those used on the first two tests, but the chipped teeth had not been ground properly.

Test 20 - Poor results because of excessive drift in the cut which, in turn, caused rapid tooth wear. Drift was attributed to unbalanced side-dubbing. The test blade was the only 15° negative ground blade employed in the test program. This blade was used again in Test 992a on 9260 steel and also was the only 60-tooth blade used on 4340 stock. All others had 50 teeth.

Tests 1a and 2a - Good life (about 9,000 square inches) was obtained with tooth load maintained at .008-inch but decreasing both speed and feed. Load increase factors were 23% and 27% respectively.

Tests 3a and 4a - This was a repeat of Tests 1a and 2a with the same respective blades. The tooth load was decreased to .007-inch which resulted in over 30% increase in blade life (12,900 square inches on Test 3a). Approximately one-quarter way through Test 4a the load was increased to .0085-inch, which may have attributed to its decreased life (12,300 square inches). Load increase factors were 27% and 32% respectively.

Test 21 - Poor life resulted. It was suspected that the increased wear rate could be caused by a harder-than-usual piece of bar stock. The normal hardness on the 4340 steel ranges from Rockwell "B" 92 to 96 (Refer to Table I) whereas several sample wafers from Test 21 tested as high as Rockwell "B" 107 (Refer to Appendix D).

Test 6 - A repeat of Test 3a with the same blade resharpened a second time yielded the best blade life (14,000 square inches). The load increase factor was 33%.

Based on the above tests, it would appear that tooling change becomes necessary at about a 30% to 33% increase in motor load for cutting 6-1/4 inch Rd 4340 steel in the hardness range of Rockwell "B" 92 to 96. Saw operation settings would be as shown for Test 6, Table III on Page 24.

7.3.6 <u>6-Inch RCS 1561 Steel</u>

Test 5 - The blade life in this first test on 1561 steel was rather inadequate. It was determined later that the .008-inch tooth load was too high.

Test 5a - This test actually never got going. A .009-inch tooth load for the initial cut in this test proved to be too great for the 25 horsepower spindle motor. The blade stalled while in the cut and was damaged sufficiently for subsequent cutting to finish the blade quickly.

Test 5b - The test blade had 50 teeth (previous two were 60). The load was lowered to .007-inch and good blade life resulted (12,200 square inches). It was determined later that this blade was removed too soon. The percent load increase was only 26%. It also was determined during this test that a light hand-dubbing of the blade with a dressing stone while on the machine would correct a tendency of the blade to drift to one side or the other.

Tests 7 and 30 - Excellent blade life was obtained. A .007-inch tooth load was decided to be best. Both tests used 50-tooth blades. Load increase factors were 53% and 55% respectively.

Test 10 - Production billets weighing 170 pounds each were cut for the Scranton Army Ammunition Plant. Results regarding shell fabrication were discussed in Section 6. Three 60-tooth blades were used to cut the 702 billets. Results from the first were poor inasmuch as the blade was out-of-round due to the initial inadequate grinding. The second blade was a used, unsharpened blade from Test 913. Still this blade cut 10,000 square inches of 1561 plus 5,600 of 1340 steel from Test 913 for a total of nearly 16,000 square inches before resharpening. The last blade finished the Scranton stock (8,000 square inches) and was used to cut another 17,000 square inches of 1030 steel in Test 12 for a total of nearly 25,000 square inches before resharpening. Overall load factors for the last two blades of Test 10 were 97% and 71% respectively. These values should not be considered valid, however, since different steels were cut with the same blade and different steels (and sizes) directly affect the motor load readings.

Based on the limited good data above, it would appear that tooling change becomes necessary at about a 50% to 5[illegible] increase in motor load for 6-inch RCS 1561 steel in the hardness range of Rockwell "B" 95 to 99. Saw settings would be as shown for Test 10, Table III on Page 24, for a 60-tooth blade or for Test 30 for a 50-tooth blade.

7.3.7 <u>4-Inch RCS and 5-Inch Rd 1030 Steel</u>

All cutting of 1030 steel was on production stock. The workpieces were 30-pound billets which were later fabricated into 105-mm, M314 Projectiles currently being produced at Chamberlain's Waterloo plant. Test 11 involved cutting 4-inch RCS stock; all other tests, 5-inch round. It was observed that blade life on 1030 was more a function of erosive wear on the blade teeth rather than chipping as was characteristic of other steels tested.

Test 11 - Good blade life was obtained on the second blade used (20,000 square inches) with a tooth load of .009-inch. The first blade employed was damaged early in the test when the bar stock shifted because of an overlooked piece of slag collapsing under the clamp-down jaw. The blade used had 50 teeth. The load increase factor was 41%.

Test 12 - Good results were achieved from the unsharpened 60-tooth blade used in Test 10 (Refer to Section 7.3.6). Both surface feed and tooth load were reduced from Test 11. The overall load increase factor was 71% but is not considered valid because two different steels were cut with the same blade.

Test 12a - Mediocre life was obtained from another 50-tooth blade with saw operation changed slightly from Test 11. Spindle rpm was raised from 110 to 115 and the tooth load reduced to .0085-inch. The load increase factor was 30%.

Test 12b - Both speed and feed were reduced to give an .008-inch tooth load on another 50-tooth blade. The results were good with 19,000 square inches obtained at a load factor of 30%.

Based on the above limited data, a 30% to 40% increase in motor load would necessitate a tooling change for cutting 1030 steel in the hardness range Rockwell "B" 80 to 83. The 10-point range results from the two sizes of steel tested. Both the 50-tooth and 60-tooth blades yield good life on this relatively soft bar steel.

7.3.8 4-Inch RCS Special Steels (1340, 9260 and PR2)

No determination on attainable blade life resulted from cutting these special steels. The limited quantity of bar stock did permit sufficient testing to prove the feasibility of cutting these steels on the Goellner saw.

Test 913 - 1340 steel was easily cut with a 60-tooth blade operated with a .007-inch load, a choice based on all previous testing. This same blade (still good after consuming all the 1340 stock) was used to cut 10,000 square inches of 1561 stock for a total of nearly 16,000 square inches before resharpening became necessary. The load increase after cutting the 1340 was only 18%.

Tests 992 and 992a - Poor life was obtained on these tests using 60-tooth blades operated at different speeds and feeds. The 9260 steel proved difficult to cut basically because of its high hardness, Rockwell "C" 30 to 35.

Test 9p - Again, insufficient bar stock did not allow the complete dulling of one blade. The 50-tooth blade did exhibit significant chipping, however, attributed mainly to the high hardness, Rockwell "C" 30 to 35.

7.4 Reference Objective 2.1.2a - Saw Performance

7.4.1 The precise time required to effect a cut through a given steel bar depends directly upon the feed rate operation of the traversing saw head. As previously stated, blade dullness results not in a slower cutting time but in higher spindle motor loading. Table III on Page 24 summarizes the average time-to-saw data for each test. These values were determined using a hand-held stopwatch and, unfortunately, reflect human error. This error was further influenced by a limit switch on the saw which often was changed to effect a cleaner break just as the saw blade cut through the test bar. Detailed data regarding time-to-saw originally were documented on the individual test monitor sheets (Refer to Appendix A). Nominal values of cutting speed expressed in square inches of steel per minute were determined for the six grades of steel and are listed on Table IX on Page 43.

7.5 Reference Objective 2.1.2b - Saw Performance

7.5.1 Table X on Page 43 lists the cycle time per cut for all six test steels. Values cited are averages determined by dividing total elapsed time by the number of consecutive cycles monitored. Each cycle period includes both indexing of the bar stock into position and moving the saw head into and out of the cut. Except dur'ng Tests 10, 11 and 12b, all bar indexing consisted of 3/4-inch movements (wafer cutting). Bar indexing for full length billets necessarily requires a slightly longer total cycle time. Also, except for the time-study observation, the stated cycle time includes an excessive retraction time for the saw head. Operation of the saw under the laboratory conditions of this program required a retraction space of about two inches between the blade and the bar stock. A nominal distance of 1/2-inch would suffice for production operations and was assumed for the time-study observations.

Table IX - CUTTING RATES

	NOMINAL TIME TO SAW (Sec.)	AREA PER CUT (Sq. In.)	NOMINAL SQUARE INCHES PER MINUTE
4340	36.0 (10½)	31.5	52.5
1561	37.8 (9½)	35.0	55.6
1030	15.8 (19)	20.0	75.9
1340	19.2 (12½)	16.5	51.6
9260	20.0 (12)	16.5	49.5
PR2	28.2 (8½)	16.5	35.1

( ) Blade Feed Rate (ipm) From Table III

Table X - CUTTING CYCLE TIMES

TEST STEEL	TEST REF.	CYCLE TIME (Sec.)	SOURCE OF DATA
6¼ Rd. 4340	1	40.5/10*	Test Monitor Sheet, Stop Watch
6¼ Rd. 4340	2	41.1/20	Test Monitor Sheet, Stop Watch
6¼ Rd. 4340	2	41.3/20	Test Monitor Sheet, Stop Watch
6¼ Rd. 4340	2	41.9/20	Test Monitor Sheet, Stop Watch
6¼ Rd. 4340	1A	49.8/20	Test Monitor Sheet, Stop Watch
6¼ Rd. 4340	1A	49.9/18	Test Monitor Sheet, Stop Watch
6¼ Rd. 4340	6	49/20	Recording Ammeter Chart
6 RCS 1561	5	41.3/20	Test Monitor Sheet, Stop Watch
6 RCS 1561	7	56.5/19	Recording Ammeter Chart
4 RCS 1340	913	34.7/18	Recording Ammeter Chart
4 RCS 9260	992A	35.5/35	Recording Ammeter Chart
4 RCS PR2	9P	43.5/30	Recording Ammeter Chart
5 Rd. 1030	12B	29.1/28	Recording Ammeter Chart
6¼ Rd. 4340	6	48.9	Time-Study Observations
6 RCS 1561	10	46.5	Time-Study Observations
5 Rd. 1030	12B	21.6	Time-Study Observations
4 RCS 1030	11	18.6	Time-Study Observations

* Number of consecutive cycles monitored.

7.6 Reference Objective 2.1.2c - Saw Performance

7.6.1 The wafer thickness data in Appendix C were recorded on three tests to determine accuracy of cutting billet lengths under fully automatic bar indexing operation. In these tests, however, 3/4-inch indexing movements were used. Cut-to-cut accuracy, therefore, was not the same as that obtained in Tests 11, 12, 12a and 12b where actual billets were sawed. Appendix C data show deviations from .042-inch minimum (Test 3a) to .187-inch maximum (Test 913). This is relatively good as compared to the nick and break method of bar separation, where billet length variations range from .250-inch to 2.0-inches. Accuracy in the above mentioned billet cutting tests was much better than the wafer cutting in that billet weights were easily held between 29.5 and 30.0 pounds corresponding to .090-inch maximum deviation. No billet indexing data were acquired from the cutting of the 1561 Scranton steel. This steel bar was too heavy to index automatically with the lightweight indexing mechanism on the prototype saw.

7.6.2 Perpendicularity of the cut surface is indicated by the mean deviation values on Table V on Page 30 as derived from Appendix C data. More meaningful determinations of squareness are tabulated on the individual monitor sheets (Appendix A) because the parent bar was used as a reference for measurement. It is noted that squareness resulted as long as the test blade was sharp or was worn evenly on both sides of the teeth. If, for some reason, the blade became worn more on one side than the other, the blade would drift in the cut in the direction of the sharper cutting side. Drift tended to increase blade wear and, as wear increased, drift increased more. Hand-dubbing of the saw blade with a dressing stone was employed occasionally in the test program to straighten the resulting cutting action and accordingly increase blade life. It was found that a drifting blade is very sensitive or responsive to the most minimal hand-dubbing.

7.6.3 Kerf widths were a direct result of the actual widths of the teeth on any given saw blade. The measured widths of the secondary teeth (wider than the primary teeth) ranged from .2218-inch on Blade K9107 before Test 2a to .2605-inch on Blade M8094 before Test 5. Kerfs on successive tests grew less as a result of wear and subsequent teeth sharpenings (Refer to Table IV, Pages 27 and 28).

7.6.4 Hardness determinations to detect work-hardening revealed that this condition does exist. Hardness readings on samples from each of five test steels (Refer to Table VI on Page 31) show that cold-working caused nominal surface hardening but that the actual point range was within the normal deviation of the raw stock. Depth of hardening was less than .010-inch below the surface and is deemed negligible with regard to subsequent forging or cold-working applications. The samples on which the checks were made purposely were chosen from near the end of each respective test as it was assumed greater work-hardening would result from a nearly dull saw blade than from a sharp one.

7.6.5 Table VIII on Page 33 lists the determinations of surface finish on the cut surfaces of representative wafers. In general, the finishes were considered very good as compared to the interfaces of broken billets (nick and break method). Two distinct finish readings prevailed on all samples as reflected in the two columns in the table. The first column consists of readings using a profilometer. Readings tabulated in the second column were determined by visual comparison of the sample finish to a standard set of representative finishes. The wide difference between the two readings resulted from the fact that the sensing stylus on the profilometer could not detect the gross waviness in the cutting pattern. This waviness was caused by the saw blade as it passed through the bar stock and characteristically was prevalent on all wafers cut in the program. This cutting pattern is depicted in Photograph C1452 on Page 22 which shows those sample wafers on which the finish readings were made. As expected, the profilometer detected less smoothness on wafers cut near the end of each respective test. This was assumed to be caused by the dulling saw blade with its eroded or chipped cutting edges. The wafer roughness easily was discernible by visual inspection and by touch.

7.7 Reference Objectives 2.1.2d and 2.1.2e - Saw Performance

7.7.1 A time-study analysis revealed that a single saw operator should be able to oversee the operation of four Goellner machines in a production-oriented installation. This conclusion resulted from the detailed observations of billet cutting in Test Nos. 10, 11 and 12b by an experienced methods analyst. However, the observations were of the saw operating under what was considered laboratory conditions; therefore, all conclusions must be qualified to this extent. Billets from the above tests were subsequently made into 105-mm, M314 and 175-mm, M437 Projectiles.

7.7.2 Table XI on Page 47 describes the elements involved by one man operating four saws cutting 1030 stock (Test 12b reference) and the "normal time" ascertained to be associated with each element. Actual data recorded for determination of total machine time on each of the three observed tests are listed in Table XII on Page 47. Inverting the machine time per cyc. yields the machine rate from which the standard piece-rate can be figured.

7.7.3 Using the machine time of .360 minute per cut (.230 for actual cut time plus .130 for index time) with the preceding element data plus appropriate efficiency standards, a piece-rate of 461 per hour was computed for cutting M314 billets (5-inch Rd 1030 steel). Again, this assumes one man operating four saws. Standard piece-rates for other stocks on the Goellner saw and on other bar separation devices are compared in Table XIII on Page 48. The values represent analysis similar to that used to evaluate the 1030 steel. Included are actual production data on Chamberlain-operated band saws (DoAll Model C-70), segmental-blade cold-saws (Heller Model SSH630-A) and nick and break presses. All resulting piece-rates were figured such that each actual machine rate is approximately 145% of standard.

7.7.4 Note the direct comparisons. On 5-inch Rd 1030 steel, one man running four Goellner saws can out-produce by three times one man operating six DoAll saws or one man operating five Heller saws. On the 4-inch RCS 1030, he can also out-produce by three times one man operating six DoAll saws. On 6-1/4 inch Rd 4340 steel he can out-produce by three times one man operating five Hellers. On 6-inch RCS 1561 steel he can out-produce by 19% the 2-1/2 men required to operate one nick and break press. A more detailed evaluation on 1561 billet separation is discussed in Section 7.8. Comparing actual machine time per billet reveals the Goellner saw to be much faster, ranging up to five times faster than the DoAll cutting the relatively soft 1030 steel.

7.7.5 All of the computed production rates for the Goellner saw are based on one man operating four machines. An assumption made, in order to arrive at this labor per machine ratio, was that the operator would oversee saw operation only. The raw bars would be made available to the saw without interruption. Proper feeding of the stock would enable the operator to use the bar indexing mechanism on the saw to grasp each new bar after the final cut

(Text continued on Page 49)

TABLE XI - ELEMENT OF OPERATION

ELEMENT	NORMAL TIME (Minutes)
Lower Stop-Position Bar to Stop-Start Cycle	.4500
Lift Stop	.0250
Aside to Scale, Weigh	.2000
Aside to Receiving Tub from Scale	.0500
Lower Stop-Position Last Piece-Start Cycle	.4500
Position Bar to Clamp	.5000
Aside Scrap End	.1390
Walk Between Machines	.1800
Clean Machines and Area	20.0000
Change Blade (Tooling)	6.0000

TABLE XII - MACHINE TIME

STEP	TIME (Min per cycle) 5" RD 1030 (Test 12b)	4" RCS 1030 (Test 11)	6" RCS 1561 (Test 10)
Clamp In	.01	.01	.01
Up Vise	.025	.01	.02
Move Bar	.015	.035	.105
Down Vise	.02	.01	.02
Blade In *	.03	.03	.05
Cut Time	.23	.185	.54
Blade Return	.03	.03	.03
TOTAL MACHINE TIME	.360	.310	.775

* Assumes .5 inch blade-to-workpiece distance. Stated value was scaled from the actual time measured for a 2.5-inch travel distance. The longer distance was employed throughout laboratory testing to enable closer monitoring of blade performance.

TABLE XIII - STANDARD PIECE-RATE COMPARISONS

SEPARATION DEVICE	STEEL STOCK	REFERENCE PROJECTILE	LABOR-MACHINE RATIO	ACTUAL MACHINE TIME (Min./Cycle)	STANDARD PIECE RATE (Pcs./Hr.)
Goellner Saw	5" RD 1030	105-mm, M314	1 man/4 saws	.360	461
Goellner Saw	4" RCS 1030	105-mm, M314	1 man/4 saws	.310	524
Goellner Saw	6" RCS 1561	175-mm, M437	1 man/4 saws	.775	215
Goellner Saw	6¼" RD 4340	152-mm, XM657	1 man/4 saws	.815	205
DoAll Saw	5" RD 1030	105-mm, M314	1 man/6 saws	1.800	140
DoAll Saw	4" RCS 1030	105-mm, M314	1 man/6 saws	1.375	177
Heller Saw	5" RD 1030	105-mm, M314	1 man/5 saws	1.345	146
Heller Saw	6¼" RD 4340	152-mm, XM657	1 man/5 saws	3.324	63
Nick-and-Break Press	6" RCS 1561	175-mm, M437	2½ men/1 press	Not Available	180

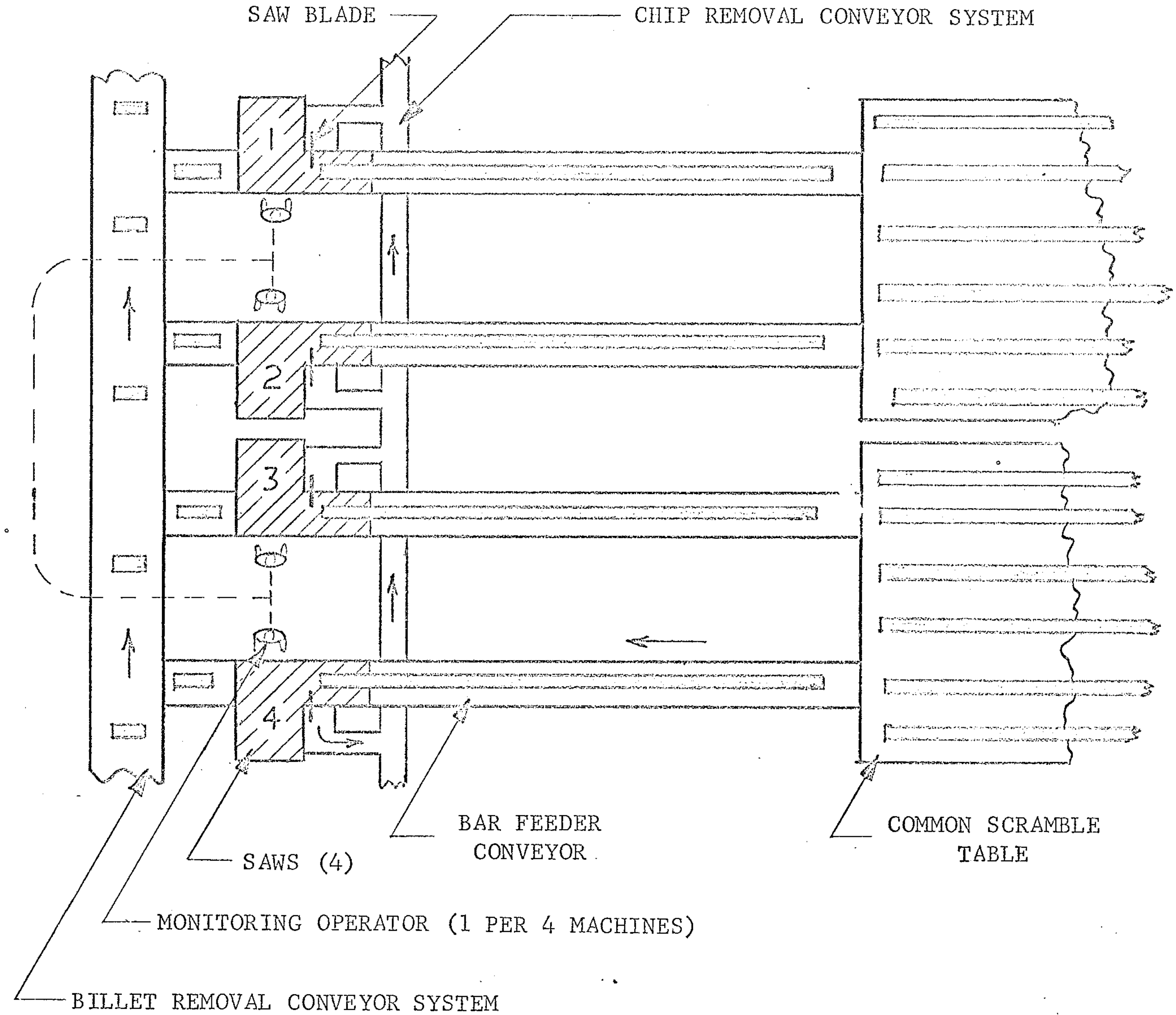
was made on the preceding bar. After each billet is cut, it would be pushed automatically via machine indexing onto a power conveyor to be carried on to subsequent furnacing. Scrap removal also was assumed to be handled automatically, most probably by conveyor or wash system. The primary responsibility of the operator, therefore, is to simply monitor the near-automatic operation of his machines. The only manual control involved is the grasping of each new bar plus routine machine maintenance including tooling change due to wear. Even catastrophic blade failure can be handled adequately by the machine itself. Since spindle motor load (amperage) i' gauged to monitor blade wear, it is a simple matter to arrange a feedback system to the machine controls whereby the machine automatically can shut itself off should the motor load reach a dangerous level. This situation could result from the loss of one or more teeth. The production model of the Goellner saw will be built with such tooling protection.

7.7.6 A suggested arrangement of the four saws per operator also resulted from the time-study analysis. If possible, the machines would be lined up side-by-side in the layout on the following page. Note that two machines would be "left-handed" and thus arranged to facilitate bar feeding, scrap removal and shorten the required steps for the operator to walk from machine to machine. Though left-handed machines were not assumed in the aforementioned one man per four machines ratio, it was felt that such machine availability could result in increasing the production output of each saw operator.

7.8 Reference Objective 2.2 - Comparison with Nick and Break Method

7.8.1 The 702 billets sawed from 1561 steel in Test 10 for the 175-mm, M437 Projectile were processed as production shell at Chamberlain's Scranton facility. The processing was monitored for the purpose of determining, on a very limited test sample, the effect of end-squareness and saw finish on shell fabrication. In addition, it was endeavored to make an economic comparison between the Goellner saw and the nick and break method of bar separation.

7.8.2 In general, the most marked improvement resulting from the sawed billet as compared to the broken billet was in the cavity condition of the forged can. Less rejects because of porosity,



LAYOUT OF SUGGESTED SAW ARRANGEMENT FOR PRODUCTION

CHAMBERLAIN MANUFACTURING CORPORATION

WATERLOO, IOWA

laminations, and scale were found in the can (third draw forging) forged from the sawed billets. The broken surface of the nick and break billet is rough and irregular giving rise to high porosity areas particularly in the base and near the open end of the forging. Small pieces of metal or shards are commonplace on the broken billet and usually result in wall laminations or at best deeply scarred and scaled surfaces within the cavity. Most are reclaimable through special but expensive grinding to remove the tight scaling and the prevalent sharp edges. The clean surfaces on the sawed billets reduced reclaim via grinding by nearly one-half. A breakdown of rejects after the shot-blasting operation on the test sample compared with recent representative daily runs of broken billets was as follows:

TABLE XIV - INSPECTION AFTER SHOT BLAST

BILLET END	SAMPLE SIZE	NUMBER OF REJECTS				NO. OF REWORKS (GRINDING)	SCRAP FORGINGS
		SHORT	LAMINATIONS	POROSITY	SCALE		
Sawed	625[1]	4(.64)[3]	0(0)	1(.16)	55(.88)	47(7.5)	13(2.1)
Broken[2]	638	0	3	3	100	100	6
	396	1	24	1	33	57	2
	640	2	6	9	60	66	11
	674	0	7	7	120	127	7
	701	2	2	4	51	53	6
TOTAL BROKEN	3,049	5(.16)	42(1.4)	24(.78)	344(11.3)	403(13.2)	32(1.0)

[1] Sample size reduced from original 702 count because of a furnace problem which invalidated the results of one batch of 77 billets.

[2] Sample groups of broken billets representing individual heats run on the same forge line.

[3] Figures in parentheses denote percent of total sample count.

Nose-forming the shell accents any previously obscure cavity defect which may have been present near the open end of the forged can. Successive inspections, after nosing, and after subsequent process stations up to and including shell painting, yielded the following rejection data. Note the significant reduction in rejects due to laminations and burrs.

TABLE XV - INSPECTIONS AFTER NOSING

BILLET END	SAMPLE SIZE	NUMBER OF REJECTS LAMINATIONS	SCALE HOLES	BURRS	RECLAIMS (GRINDING)
Sawed	612[1]	4 (.65)[2]	6 (.98)	17 (2.8)	All
Broken	Continuous	(4.99)	(1.3)	(11.6)	Usually All

[1] Sample size is reduced by 13 scrap pieces from prior inspection (refer to previous tabulation).

[2] Figures in parentheses denote percent of total sample. Data for broken billets represent a continuous production operation.

Eccentricities on the cans forged from the sawed billets nominally ran at .040-inch. This was the same as normally obtained from broken billets forged on the same presses. Though differences, if any, appear negligible it is realized that the sample size was relatively small for significant evaluation. The same conclusion applies to speculations regarding material savings. Thirteen (13) billets were sawed per mill bar (with no end piece left over) as compared with 13 broken billets per bar. Only over an extended period of production operation can these potential advantages for sawed billet separation be evaluated adequately.

7.8.3 A generalized comparison of cost of operation between the Goellner saw and the nick and break method of billet separation was made. It is emphasized that the results are indicative only. Data pertaining to the Goellner saw were obtained from saw operation under laboratory conditions, quite dissimilar from operation in a production environment. Also, it is most difficult to attach a realistic value to the improvement of forging quality and its obviously favorable effect on subsequent shell fabrication processes. For example, it was found from the limited sample of sawed billets processed through production that labor currently assigned to simply grinding cavity defects could be reduced significantly. More meaningful data can be derived from a more comprehensive investigation as recommended in Section 3.2.

The tabulation below represents an estimated comparison of both tooling and direct labor costs only. No dollar estimate relating to cost reduction because of improvement in forging quality was considered. These data are, in general, highly qualified and so to forestall any misinterpretation, the sources of information and the assumptions that were made are explained in the notes following.

TABLE XVI - COST OF 175-MM BILLET SEPARATION (PER BILLET)

	NICK AND BREAK[1]	GOELLNER SAW
Labor Cost[2]	$.0956	$.0141
Tooling Cost[3]	.0428 (.0128)[4] (.03)	.1313 (.0887)[5] (.0426)
TOTAL COST	$.1384	$.1454
Relevant Information		
Daily Rates (Pieces Per Shift)	2,720 (2 Presses)[6]	2,760 (6 Saws)[7]
Manpower Required (One Shift)	5	2[7]

1 All data listed under the nick and break method were derived from actual production operations at Chamberlain's Scranton plant. Tooling costs, however, represent best estimates because plant records document only major expendable tooling. Also, some tooling expenses are not normally correlated to production rates.

2 This implies direct labor only. No indirect labor such as material handlers (yardmen, crane operators, etc.) or inspection are included. An average rate of $3.25 per hour was assumed as the labor rate for all jobs. To operate one nick and break operation requires one press operator, one nicker and one marker, the latter being used only 1/2 time. Operation of one saw requires one man part time. The listed labor cost for the saw assumes one operator running four machines. This results from the time-study analysis of the one-man operation of a prototype saw under laboratory conditions (Reference previous section).

3 Tooling cost refers to expendable items and regular tool maintenance only. No major capital equipment was included.

4 The first figure in parentheses represents cost of electrodes used to effect the nicks along the raw bar. This figure reflects yearly costs divided by yearly shell output. The second number represents other tooling and its maintenance estimated at 1-1/2 to 2-1/2 cents per billet for welder repair plus about 1 cent for press tooling and maintenance (anvil, ram, etc.)

5 The first figure in parentheses represents blade resharpening and remedial retipping (one to ten carbide inserts) as required. The quoted cost was based on an average cost of $35.84 per blade and 404 cuts per blade, both values derived from actual costs incurred in the test program. It is anticipated that production operation will reduce the blade sharpening cost to approximately $30.00 per blade, a reduction of 1.4 cents per billet. Blade maintenance is assumed in each case to be performed by an outside blade vendor.

The second figure represents an estimated original blade cost ($250.00) plus four complete retipping jobs ($110.00 each) prorated over 16,200 cuts. This number of cuts was again based on test results; i.e., 404 cuts per blade times an estimated eight sharpenings per blade tipping times five complete tippings per blade life. Freight charges were not assumed in these cost estimates because it is anticipated that the resharpening cost per blade in production will be sufficiently reduced to compensate for same.

6 Two complete nick and break setups were quoted because the barmarking process is approximately twice as fast as the nicking or breaking operations. That is, one marker can keep pace with two separate but side-by-side nick and break lines.

7 Six saws are estimated to be required to equal the output of two nick and break presses. Two operators would be necessary to man these six production machines although eight machines could be handled as stated in Note 2.

APPENDIX A

TEST MONITOR SHEETS

DATE 12/19/69 and 12/22/69 TEST NO. 1 BLADEL9066 C7C4(26-18-50) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	70	13.5	480	.0077	28.0	---	---	---	
10					"	28.9	.0015 1	.003 r	
15					"	29.1	---	---	
20					"	29.0	---	---	
30					28.5	29.0	.060 r	.040 1	
40					28.0	30.0	---	---	
42					---	28.0	---	---	
48	70	14.0	480	.008	---	28.0	.000	.060 1	
50					28.5	28.0	---	---	
56					---	---	---	---	
57 (12/22)	70	14.0	480	.008	---	---	---	---	
60					29.5	28.4	---	---	
70					28.0	28.0	---	---	
79					"	"	---	---	
80					"	"	.020 r	.060 1	
85					---	"	---	---	
90					29.0	"	---	---	
99					"	"	---	---	
100					"	"	---	---	
110					29.5	6-45 (10 Cycles)	---	---	
120					"	28.0	.0015 r	.003 1	
130					30.0	"	---	---	
140					"	"	.000	.003 1	
150					"	"	---	---	
160					"	"	.000	.003 1	
170					"	"	---	---	
180					30.5	"	.000	.006 1	
190					31.0	"	---	---	
200					"	"	.050 r	.110 1	Stopped to Measure Blade
203					"	"	---	---	
210					"	"	---	---	
220					32.0	"	---	---	
230					"	"	.000	.040 1	Stopped, Chipping Evident

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
1 denotes leaning or drifting to the left.

DATE 12/22/69 and 12/23/69 TEST NO. 2 BLADE L9067 C7C4 (26-18-50) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	--	--	--	--	--	--			
5	70	14.0	480	.008	27.0	28.0			
10					"	"			
20					"	"	.000	.000	
30					"	"			
40					27.5	"			
50					28.0	--			
60					28.5	13-42 (20 Cuts)	.000	.000	
70					"	--			
80					"	13-47 (20 Cuts)	.0015 1	.000	
90					29.0	28.0			
100					29.5	"	.000	.000	
110					"	"			
120					"	"	.0015 1	.000	
122					--	--			Recorder Started
130					30.0	28.0			
140					--	--			
155					29.5	28.0			
160					30.0	"	.000	.070 1	
170					"	"			
180					"	"	.000	.070 1	
190					"	--			
200					"	13-59 (20 Cuts)	.000	.040 1	Stopped to Measure Blade
201(12/23)	--	--	--	--	--	--			
205	70	14.0	480	.008	31.0	28.0			
210					"	"			
215					"	"			
220					30.0	"			
225					31.0	"			
230					32.0	"	.000	.020 r	Stopped, Chipping Evident

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.

DATE 12/23/69 and 1/5/70 TEST NO. 5 BLADE M8094 C7C4 (26-18-60) MATERIAL 6-1561

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	--	--	--	--	--	--			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.
5	60	14½	410	.008	29.5	27.0			
10					"	"			
15					"	"	.000	.010 1	
20					30.0	"	.000	.005 1	
25					30.5	--			
30					"	--			
35					"	--			
40					31.0	13-47 (20 Cuts)			
42					"	--			
43 (1/5)	--	--	--	--	--	--			
50	60	14½	410	.008	32.0	27.0			
55					--	"			
60					32.5	"	.000	.000	
70					"	"			
75					33.0	"			
80					33.0	"	.000	.000	
90					32.5	"			
95					33.0	"			
100					"	"	.000	.060 r	
105					34.0	"			
110					35.5	"	.000	.120 r	Stopped, Bladed Started Walking Badly.

DATE 1/6/70 TEST NO. 3 BLADE L9066 C7C4 (26-18-50) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	PERPENDICULARITY DEVIATION (in.) * SIDE (90°)	REMARKS
1	--	--	--	--	--	--			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the <u>right</u> as it cut. l denotes leaning or drifting to the <u>left</u>.
20	70	.14	480	.008	30.0	27.5			
25					29.5	28.0			
30					"	27.5			
40					"	"			
45					30.0	27.0			
50					31.0	"			
60					31.5	"	.002 r	.050 l	Stopped, Badly Chipped. Suspect Blade Still Chipped From Test 1 When Test 3 Commenced.

DATE 1/6/70 TEST NO. 4 BLADE L9067 C7C4 (26-18-50) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	70	14	480	.008	--	--			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. l denotes leaning or drifting to the left.
5					30.0	27.0			
10					"	"			
15					"	"			
20					"	"	.000	.000	
30					"	"			
40					31.0	"	.010 r	.060 l	
50					32.0	"			(20) Chipping More Evident
55					"	"			
60					"	"	.000	.000	
65					32.5	"			
70					33.0	"			
75					"	"			
80					"	"	.000	.000	
85					34.0	"			
88					38.0	"	.000	.100 l	Stopped, Badly Chipped.

Visual inspection Before Test 4 Revealed Several Chipped Teeth Not Ground Out After Test 2.

DATE 1/6/70 and 1/7/70 TEST NO. 20 BLADE B9079 C7C4 (26-15-60) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	--	--	--	--	--	--			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.
15	70	.14	480	.008	32.0	--			
20					30.0	27.5			
25					"	"			
30					"	"			
35					"	"	.000	.010 1	
40					"	"			
50					30.5	"	.020 r	.060 1	
60					30.0	"			
70					30.5	"	.000	.020 1	
80					--	"			
90					32.0	"	.002 1	.100 r	
95					33.0	"			
100					33.5	"			
105					34.0	"			
110					"	"	.040 1	.100 r	Stopped, Blade Was Drifting.
115 (1/7)	70	.14	480	.008	34.5	"			Test Resumed in Hopes of Blade Correcting Itself.
120					35.0	"			
125					"	"			
130					"	"	.001 r	.000	
140					34.5	"			
150					36.0	"	.000	.000	
160					35.5	"			
168					34.5	"			
170					"	"			
180					35.5	"			
190					--	"			
205					38.0	"			
210					39.5	"	.050 1	.120 r	
214					--	"			Stopped, Blade Drifting Excessively.

DATE 1/7 & 1/8/70 TEST NO. 1A BLADE K9108-C7C4 (26-18-50) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	--	--	--	--	--	--			
5	60	.12	410	.008	22.0	--			
15					23.0	33.0			
20					"	"	.005 r	.040 l	(20) Indexing Vertical Slide Was Shimmed From This Point On.
30					"	"			
40					24.0	"	.000	.020 l	
50					23.5	"			
60					24.0	"	.000	.040 l	
70					"	"			
80					"	"			
90					"	"	.000	.020 l	
100					"	"			
110					"	"	.000	.040 l	
120					"	"			
130					"	"	.000	.050 l	
140					24.5	--			
150					"	16-37 (20 Cuts) 33.0	.010 r	.050 l	
160					"				
170					"	"			
180					25.0	"	.000	.040 l	
190					"	--			
200					24.5	--			
210					"	14-59 (18 Cuts) 33.0	.000	.040 l	
215					"				
216					--	--			
220					25.0	33.0			
230					"	"	.000	.040 l	Visual Inspection - No Chipping.
240					25.5	"			
243					"	"			
244(1/8)					--	--			Stopped For Night, 7:00 p.m.
280					28.0	33.0			Stopped Due To Excessive Chipping; Some Chipping Noted When Inspected At Approximately Cut No. 260.

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
l denotes leaning or drifting to the left.

DATE 1/8 & 1/9/70 TEST NO. 2A BLADE K9107 C7C4 (26-18-50) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	PERPENDICULARITY DEVIATION (in.) * SIDE (90°)	REMARKS
1	60	12	410	.008	--	--			
5					22.0	33.0			
10					"	"			
15					"	"			
20					"	"	.000	.020 r	
30					"	"			
40					22.5	"	.000	.030 r	
50					"	"			
60					23.0	"	.000	.030 r	
70					"	"			
80					"	"			
90					"	"	.000	.050 r	
100					23.5	"			
110					"	"			
111					--	--			Last Of First 5 Bars Of Stock.
120					24.0	33.0	.020 l	.050 r	
135					"	"			
140					24.5	"	.020 l		
150					25.0	"			
160					24.5	"			
170					--	--			
180					24.5	33.0			
190					"	"			
191					--	--			
192 (1/9)	60	12	410	.008	--	--			
195					25.0	34.0			
200					26.5	32.8	.000	.020 r	
210					--	--			
220					25.5	32.8	.000	.040 l	
230					26.0	"			
240					"	"	.000	.040 r	
250					26.5	"			
260					"	"	.000	.020 r	
270					"	"			
280					"	32.0	.000	.060 r	

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
l denotes leaning or drifting to the left.

DATE 1/8 & 1/9/70 TEST NO. 2A (Continued) BLADE K9107 C7C4 (26-18-50) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	PERPENDICULARITY DEVIATION (in.) * SIDE (90°)	REMARKS
285	60	12	410	.008	27.5	32.0			(285) Chipping Sound Noted.
290					"	"	.020 r	.050 l	(290) Stopped, Badly Chipp

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
l denotes leaning or drifting to the left.

DATE 1/12/70 TEST NO. 5A BLADE M8096 C7C (26-18-60) MATERIAL 6-1561

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)
1	55	15	380	.009	--	--		
10	60	.13	410	.00725	30.0	29.0		
15					"	"		
20					31.5	"	.000	.050 r
27					--	--		

REMARKS

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the <u>right</u> as it cut.
1 denotes leaning or drifting to the <u>left</u>.

(27) Stopped; Chipping Evident. Further Testing Unnecessary; Blade Damaged Too Much From Binding In Cut No. 1

Blade Bound Up In First Cut - .009 Chip Apparently Too Much For Machine With 25 hp Motor.

DATE 1/12 - 1/14/70 TEST NO. 5B BLADE K9110 C7C4 (26-18-50) MATERIAL 6-1561

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	--	--	--	--	--	--			
10	55	9½	380	.007	20.0	41.0			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.
20					21.0	"	.000	.060 r	
25					"	"			
30					"	"			
40					"	"	.000	.100 r	
45					21.5	"	.000	.125 r	
50					"	"			
60					22.0	40.0			Limit Switch Adjusted.
65					"	"			
70					"	"	.000	.060 r	
71(1/13)	55	9½	380	.007	--	--			
78					--	--			Recorder Started
80					22.0	39.0			
92					"	"	.000	.020 r	
100					23.0	"	.000	.040 1	
110					"	--			
120					"	39.0	.000	.030 1	
130					"	"			Hand-Dubbing (Stone Dressing The Blade) Was Tried Successfully Around Cut 85 And Periodically Thereafter To Improve Perpendicularity Of Cut.
131					"	"	.000	.030 1	
132(1/14)	55	9½	380	.007	--	--			
140					23.0	39.0			
150					22.0	"	.000	.020 1	
160					23.0	"			
170					"	"	.000	.020 1	
180					23.5	"			
190					"	"			
200					"	"	.000	.020 1	
210					24.0	"			
220					23.5	"	.000	.015 r	
221					24.0	"			
230					23.5	"			
240					24.0	"	.000	.040 r	
250					"	"			
251					--	--			

DATE 1/12 - 1/14/70 TEST NO. 5B (Continued) BLADE K9110 C7C4 (26-18-50) MATERIAL 6-1561

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	PERPENDICULARITY DEVIATION (in.) * SIDE (90°)	REMARKS
260	55	9½	380	.007	24.0	39.0	.000	.040 r	* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.
270					"	"			
280					"	"	.000	.060 r	
290					--	--			
300					--	--			
310					26.0	39.0	.000	.040 r	
320					25.5	"			
330					"	"	.000	.020 r	
340					"	"			
350					"	"	.000	.130 r	Stopped; Minor Chipping But Tooth Erosion Sufficient To Deem Blade Worn.

DATE 1/14, 1/15, 1/20/70 TEST NO. 9-13 BLADE B9108-C7C (26-18-60) MATERIAL 4-1340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	PERPENDICULARITY DEVIATION (in.) * SIDE (90°)	REMARKS
1	50	10½	345	.007	--	--			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.
17	55	11½	380	.007	--	23.0			
18 (1/15)	55	11½	380	.007	--	"			
39					18.5	"			
40					"	"	.020 1	.020 1	
41	60	12½	410	.007	--	--			
50					19.5	21.5			
60					20.0	"	.000	.020 1	
90					"	"			(17) Recorder Started
115					"	"			
120					"	"	.000	.020 1	
160					"	"			Removed Blade For Inspection Omitted Erroneously Prior To Commencing Test.
161	60	12½	410	.007	--	--			
170					20.0	22.5			
190					"	"			(161) Test Resumed.
260					20.5	"			
270					"	"			Blade Removed, Inspected, And Saved For Demonstration.
271(1/20)	60	12½	410	.007	--	--			
280					20.0	21.0			(271) Test Resumed.
290					"	"			
300					"	21.5			
310					21.0	"			
320					"	"			
330					"	"			
340					"	"			Stopped; Test Material Consumed Before Blade Became Worn.

DATE 1/15/70 TEST NO. 3A BLADE K9108-C7C4 (26-18-50) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) ✳ TOP OF CUT	PERPENDICULARITY DEVIATION (in.) ✳ SIDE (90°)	REMARKS
1	--	--	--	--	--	--			✳ r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.
6	60	.10½	420	.007	22.0	38.0			
35					23.0	"			
40					"	"	.000	.000	
60					"	"	.000	.000	
70					"	"			
80					"	"	.000	.000	
90					"	"			(6) Recorded Started.
100					"	"	.000	.010 1	
110					23.5	"			
170					24.0	"			
190					--	"	.020 r	.050 1	
230					26.0	"	.020 r	.060 1	
260					25.5	"	.000	.030 1	
280					26.0	"	.000	.000	
290					"	"			
320					"	"	.020 r	.050 1	
340					"	"	.000	.040 1	
350					"	"			
360					"	"	.000	.040 1	Visual Inspection Revealed Some Minor Chipping.
370					26.5	"			
390					28.0	"			
400					"	"			
410					"	"	.000	.060 r	Stopped; Blade Worn With Excessive Chipping.

DATE 1/19 & 1/20/70 TEST NO. 7 BLADE L9066-C7C4 (26-18-50) MATERIAL 6-1561

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)		REMARKS
1	55	9½	380	.007	--	--				* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.
10					20.0	39.0				
20					"	"	.000	.000		
30					"	"				
40					"	"	.000	.000		
50					"	39.5				
60					"	40.0	.000	.020	1	
70					21.0	39.0				Limit Switch Adjusted.
80					"	"	.000	.025	1	
90					22.0	38.5				
100					"	38.0	.000	.000		
110					"	37.5				
120					"	"	.000	.020	r	
130					"	38.0				
140					"	"	.000	.000		
150					"	"				
160					"	"	.000	.000		
170					"	"				
180					"	"	.000	.015	1	
190					23.0	"				
200					24.0	"	.000	.000		
210					"	"				
220					"	"	.000	.060	1	
230					25.0	"				
240					"	"	.000	.060	1	
250					26.0	"				
260					"	"	.000	.020	1	
290					25.5	"				
310					"	"	.000	.040	1	
320					26.0	"				
330					"	"	.000	.060	1	Stopped For Night.
331(1/20)	55	9½	380	.007	--	--				
340					28.0	37.5				
350					27.0	37.0	.000	.000		
360					"	"				

DATE 1/19 & 1/20/70 TEST NO. 7 (Continued) BLADE L9066-C7C4 (26-18-50) MATERIAL 6-1561

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	PERPENDICULARITY DEVIATION (in.) * SIDE (90°)
370	55	9½	380	.007	28.0	37.0	.000	.080 l
380					"	"		
390					"	"	.000	.030 l
400					29.0	"		
410					"	"	.000	.090 l
420					30.0	"	.015 r	.125 l

REMARKS

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
l denotes leaning or drifting to the left.

(420) Stopped; Blade Drifted And Hit Hold-Down Jaw. Blade Bound In Cut; Retraction Revealed An Entire Tooth Broken Off.

DATE 1/20 & 1/21/70 TEST NO. 4A BLADE K9107 C7C4 (26-18-50) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	60	10½	410	.007	--	--			
10					23.0	31.5			
20					24.0	"	.000	.020 1	
30					23.0	"			
40					"	"	.000	.040 1	
50					"	"			
60					24.0	"	.000	.020 1	
70					"	"			
80					"	"	.000	.030 1	
90					"	"			
100					"	"	.015 r	.040 1	
291(1/21)	60	12½	420	.0085	--	--			
300					29.0	30.5			
310					30.0	"	.030 1	.050 1	
320					29.0	"			
330					"	"	.030 1	.100 1	
340					"	"			
350					30.0	"	.050 r	.125 1	
360					"	"			
370					"	"	.030 r	.125 1	
380					"	"			
390					34.0	"			
391					"	"	.020 r	.030 1	Stopped, Badly Chipped.

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
1 denotes leaning or drifting to the left.

DATE 1/21/70 TEST NO. 992 BLADE M8094 C7C4 (26-18-60) MATERIAL 4-9260

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	50	10½	350	.007	18.0	25.0			
10					19.0	25.0			
20					"	25.5			
30					"	"			
40					"	"			
50					"	"			
60					"	"			
70					20.0	"			
80					"	"			
90					"	"			
100					"	"			Stopped, Chipped Teeth.

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
l denotes leaning or drifting to the left.

DATE 1/21/70 TEST NO. 992A BLADE B9079 C7C4 (26-15-60) MATERIAL 4-9260

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	50	12	350	.008	--	--			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.
10					20.0	22.0			
20					"	"			
30					21.0	"			
40					22.0	"			
50					"	"			
60					"	"			
70					"	"			
80					"	"			
90					"	"			
100					"	"			Stopped - All 9260 Material Consumed; Blade Chipped But Could Still Be Used.

DATE 1/22/70 TEST NO. 21 BLADE L9067 C7C4 (26-18-50) MATERIAL 6¼-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	60	10½	410	.007	--	--			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
10					22.0	37.0			
20					23.0	"	.000	.060 1	
30					"	36.0			
40					"	"	.000	.060 1	1 denotes leaning or drifting to the left.
50					"	"			
60					--	--			
70					26.0	36.0			
80					28.0	32.0	.000	.040 1	Corrected Machine Feed Which Had Been Altered Inadvertently.
90					27.0	"			
100					"	"	.000	.000	
110					29.0	"			
120					30.0	"	.000	.030 1	
130					31.0	"			
140					"	"	.000	.040 1	
150					"	"			Stopped, Chipped Teeth. Suspect Harder Than Usual Bar Stock.

DATE 1/22/70 TEST NO. 9P BLADE K9109 C7C4 (26-18-50) MATERIAL 4-PR2

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	45	8½	310	.0075	--	--			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. l denotes leaning or drifting to the left.
10					14.0	29.5			
20					15.0	"			
30					16.0	29.0			
40					15.0	"			
50					"	"			
60					--	--			
70					16.0	29.0			
80					"	"			
90					"	"			
100					"	"			
110					17.0	"			
120					"	"			
130					"	"			
140					--	--			
150					18.0	29.0			
160					"	"			
170					"	"			
180					"	"			
190					"	"			
200					"	"			
210					19.0	"			Stopped, All Test Material Consumed But Teeth Badly Chipped

DATE 1/27/70 TEST NO. 30 BLADE K9110 C7C4 (26-18-50) MATERIAL 6-1561

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	PERPENDICULARITY DEVIATION (in.) * SIDE (90°)	REMARKS
1	--	--	--	--	--	--			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the <u>right</u> as it cut. l denotes leaning or drifting to the <u>left</u>.
10	55	9½	380	.007	22.0	38.0	.000	.120 r	
30					22.5	"	.000	.100 r	
40					23.0	"	.000	.100 r	
50					23.5	"			
60					"	"	.000	.050 r	
120					"	"	.000	.090 r	
140					26.0	"			
150					25.0	"	.000	.100 r	Blade Drifted At The Onset Of Test; Attributed To Unequal Side Grinds; Hand Dubbing Unsuccessful In Achieving Straight Cut.
160					24.5	"			
170					25.5	"	.000	.080 r	
210					26.0	"	.000	.005 r	
240					"	"	.000	.000	
430					28.0	"			
440					"	"	.000	.020 r	Blade Became Worn Enough After About 200 Cuts To Result In Near Perpendicular Cuts.
460					29.0	"	.000	.000	
480(1/28)	55	9½	380	.007	29.0	"	.000	.000	
490					29.5	"			
500					30.0	"	.000	.030 r	
540					--	"	.000	.000	
560					--	"			Stopped; Blade Worn (Tooth Erosion).

M8096-C7C (26-18-60)
B9108-C7C " (Used)

DATE 1/28 - 1/30/70 TEST NO. 10 BLADE M8094-C7C4 " MATERIAL 6-1561 (Scranton)

BAR AND BILLET NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)
1-1	55	11½	380	.007	--	33.0		
11-13					--	"		
12-1(1/29)	55	11½	380	.007	--	"		
12-9					--	"		
18-3					--	--	.000	.040 1
18-4					--	33.0	.000	.040 1
18-5					--	--	.000	.040 1
21-2					--	--	.000	.000
21-3					--	--	.000	.020 r
21-7					--	--	.020 1	.020 r
21-8					--	--	.020 1	.050 r
22-10					--	33.0	.020 1	.040 r
22-11					--	"	.040 1	.020 r
22-12					--	"	.040 1	.020 r
30-12					--	--	.000	.050 1
30-13					--	--	.000	.050 1
32-3					--	--	.000	.050 1
32-4					--	--	.000	.050 1
32-5					--	--	.000	.050 1
32-6					--	--	.000	.020 1
33-2					--	33.0	.000	.000
33-3					--	"	.000	.000
33-4					--	"	.000	.000
35-2					--	--	.000	.040 r
35-3					--	--	.020 1	.040 r
35-4					--	--	.020 1	.020 r
36-4	55	11½	380	.007	--	33.0	--	--
37-6					--	"	.000	.000
37-7					--	"	.000	.000
37-8					--	"	.000	.000
38-1(1/30)	55	11½	380	.007	--	--	.000	.020 r
38-2					--	--	.000	.000
38-3					--	--	.000	.000
43-2					--	33.0	.000	.000
43-3					--	"	.000	.000

REMARKS

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
1 denotes leaning or drifting to the left.

Blade M8096 Badly Out-Of-Round Due To Poor Grind. Replaced With Blade B9108 On Billet 12-9.

WEIGHT SAMPLE (Lbs.)

165.5 (1-1)	168.8
167.5	168.8
169.0	167.3 (2-13)
163.0 (1-13)	169.3
169.0	168.6
169.0	

BAR LENGTHS

18-11½ to 19-1

BILLET LENGTHS

17-1/8 to 17-3/8

← Tooth Badly Chipped On B9108; Replaced With Blade M8094. (at 36-4)

CYCLE TIME

47 Sec. W/½ In. Withdraw
54 Sec. W/2 In. Withdraw

DATE 1/28 - 1/30/70 TEST NO. 10 (Continued) BLADE M8096-C7C (26-18-60) / B9108-C7C " (Used) / M8094-C7C4 " MATERIAL 6-1561 (Scranton)

BAR AND BILLET NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
43-4	55	11½	380	.007	--	33.0	.000	.000	
44-4					--	--	.000	.000	
44-5					--	--	.000	.020 r	
44-6					--	--	.000	.000	
46-2					--	--	.000	.030 1	
46-3					--	--	.000	.000	
46-4					--	--	.000	.000	
52-2					--	33.0	.000	.030 r	
52-3					--	"	.000	.030 r	
52-4					--	"	.000	.030 r	
54-11					--	--	.000	.030 r	
54-12					--	--	.000	.040 r	Last Bar Of Stock; Blade M8094 Still Good.

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
1 denotes leaning or drifting to the left.

DATE 2/2 - 2/4/70 TEST NO. 11 BLADE M8098-C7C4 (26-18-60) L9066-C7C4 (26-18-50) MATERIAL 4-1030

HEAT CODE 79R678

BAR AND BILLET NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)
1-1	--	--	--	--	--	--		
1-5	100	.25½	690	.0085	--	--		
2-1					--	--		
2-2	110	24½	750	.009	--	11.0		
2-31					--	"		
2-32					--	"		
3-1(2/3)	110	24½	750	.009	--	"		
20-32					--	"		
21-1(2/4)	110	24½	750	.009	--	--		
39-32					--	--		

TOTAL CUTS	BLADE
33 (1 Bar)	M8098
1,216 (38 Bars)	L9066

NOTES:

Approximately 18 Seconds May Be Possible With ½ Inch Blade Retraction.

Recorder Inadvertently Disconnected About Noon 2/3 And Reconnected On Bar 19 Or 20.

Broke Piston Rod On Indexing Cylinder On Cut 20-32; Welded To Bolt Head Via Night Maintenance.

REMARKS

* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut.
l denotes leaning or drifting to the left.

Blade Bound In Cut 2-1 And Tooth Broken; Slag On Bar Caused Same To Shift While Being Cut. Blade Replaced With L9066.

SAMPLING

	WT. (Lbs.)	LGTH. (In.)
2/2	30.4	6-7/8
	30.9	6-7/8
	30.1	6-3/4
	30.6	6-7/8
	30.5	6-7/8
	30.4	6-3/4
	30.2	6-3/4
	30.3	6-3/4
	30.1	6-3/4
	30.1	6-3/4
2/4	30.1	6-3/4
	30.1	6-3/4
	30.5	6-13/16
	30.5	6-13/16
	30.5	6-13/16
	30.5	6-13/16
	30.5	6-13/16
	30.5	6-13/16
	30.5	6-13/16

DATE 2/4 & 2/5/70 TEST NO. 6 BLADE K9108-C7C4 (26-18-50) MATERIAL $6\frac{1}{4}$-4340

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1-10	60	$10\frac{1}{2}$	410	.007	--	--	--	--	
20	60	$10\frac{1}{2}$	410	.007	--	--	.000	.030 l	* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. l denotes leaning or drifting to the left.
40					23.0	35.0	.000	.030 l	
80					24.0	"	.000	.050 l	
100					--	--	.000	.050 l	
120					--	--	.000	.030 l	
140					--	--	.010 r	.010 l	
150					--	--	--	--	
151 (2/5)	60	$10\frac{1}{2}$	410	.007	--	34.0	--	--	Limit Switch Adjusted.
160					--	--	.020 r	.030 l	
180					--	--	.000	.040 l	
200					--	--	.000	.010 l	
220					--	--	.000	.000	
240					--	--	.000	.000	
280					27.0	34.0	.000	.040 l	
300					--	--	.000	.060 l	
320					--	--	.000	.000	
340					--	--	.000	.000	
360					29.5	34.0	.030 r	.030 l	
380					--	--	.020 r	.060 l	
400					--	--	.000	.060 l	
430					30.0	34.0	.000	.000	
440					--	--	.000	.020 r	
446					--	--	--	--	Stopped; Teeth Chipped And Worn.

DATE 2/5 & 2/6/70 TEST NO. 12 BLADE M8094-C7C4 (26-18-60) MATERIAL 5-1030

BILLET NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	--	--	--	--	--	--			
5	100	.24	700	.008	--	13.8			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.
304					--	13.9			
305 (2/6)	100	24	700	.008	--	13.8			
306					--	"			
307					--	"			
410					--	"			
411					--	"			
412					--	"			
724					--	--			New Heat Code 6320044 Begun; Previous Code Was J83438.
730					--	13.8			
731					--	"			
732					--	"			
847					--	--			Stopped; Blade Eroded Excessively.

INITIAL SAMPLING

WT. (Lbs.)	LENGTH (In.)
29.5	5-3/8
30.2	5-15/32
29.6	5-3/8
29.5	5-3/8
29.4	5-3/8

Periodic Weight Sampling Held Billet Weights Between 29.5 And 30.0.

Recorder Was Not Operating From Cut 305 To Cut 546.

DATE 2/9/70 TEST NO. 12A BLADE K9109-C7C4 (26-18-50) MATERIAL 6-1030

HEAT CODE 6320044

BILLET NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY DEVIATION (in.) * TOP OF CUT	SIDE (90°)	REMARKS
1	--	--	--	--	--	--			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. 1 denotes leaning or drifting to the left.
5	100	.21	700	.0085	--	--			
50	115	24½	800	.0085	--	12.9			
55					--	13.0			
60					--	"			
61					--	"			
200					--	"			
201					--	"			
202					--	"			
203					--	"			
537					--	--			Stopped; Blade Eroded Excessively.
									Weights Monitored Periodically To Hold Between 29.5 And 30.0 Pounds.

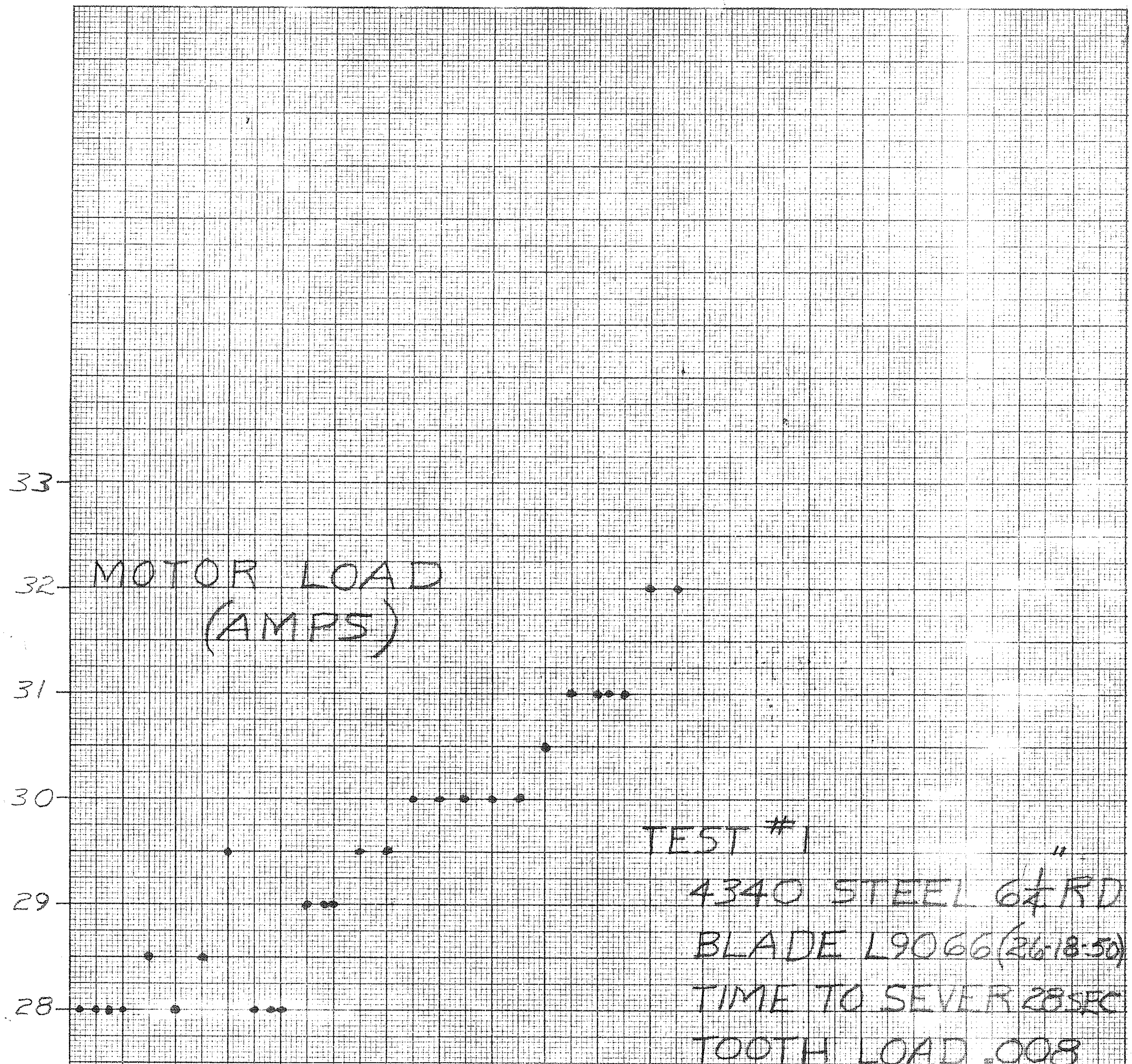
DATE 2/9 & 2/10/70 TEST NO. 12B BLADE L9067 C7C4 (26-18-50) MATERIAL 5-1030
HEAT CODE 6320044

WAFER NO.	BLADE SPEED (rpm)	LATERAL FEED (ipm)	SURFACE FEED (sfm)	TOOTH LOAD (in.)	SPINDLE MOTOR LOAD (amps)	TIME TO SEVER (Sec.)	PERPENDICULARITY * DEVIATION (in.) TOP OF CUT	SIDE (90°)	REMARKS
1	95	19	650	.008	--	16.5			* r denotes that the blade leaned to (TOP) or drifted to (SIDE) the right as it cut. l denotes leaning or drifting to the left.
200					--	"			
201					--	"			
212					--	--			
213(2/10)	95	19	650	.008	--	--			
298					--	16.5			
299					--	"			
300					--	"			
583					--	"			
584					--	"			Noon
969					--	--			Stopped; Blade Worn.
									Weights Periodically Monitored To Hold Between 29.5 And 30.0 Pounds.

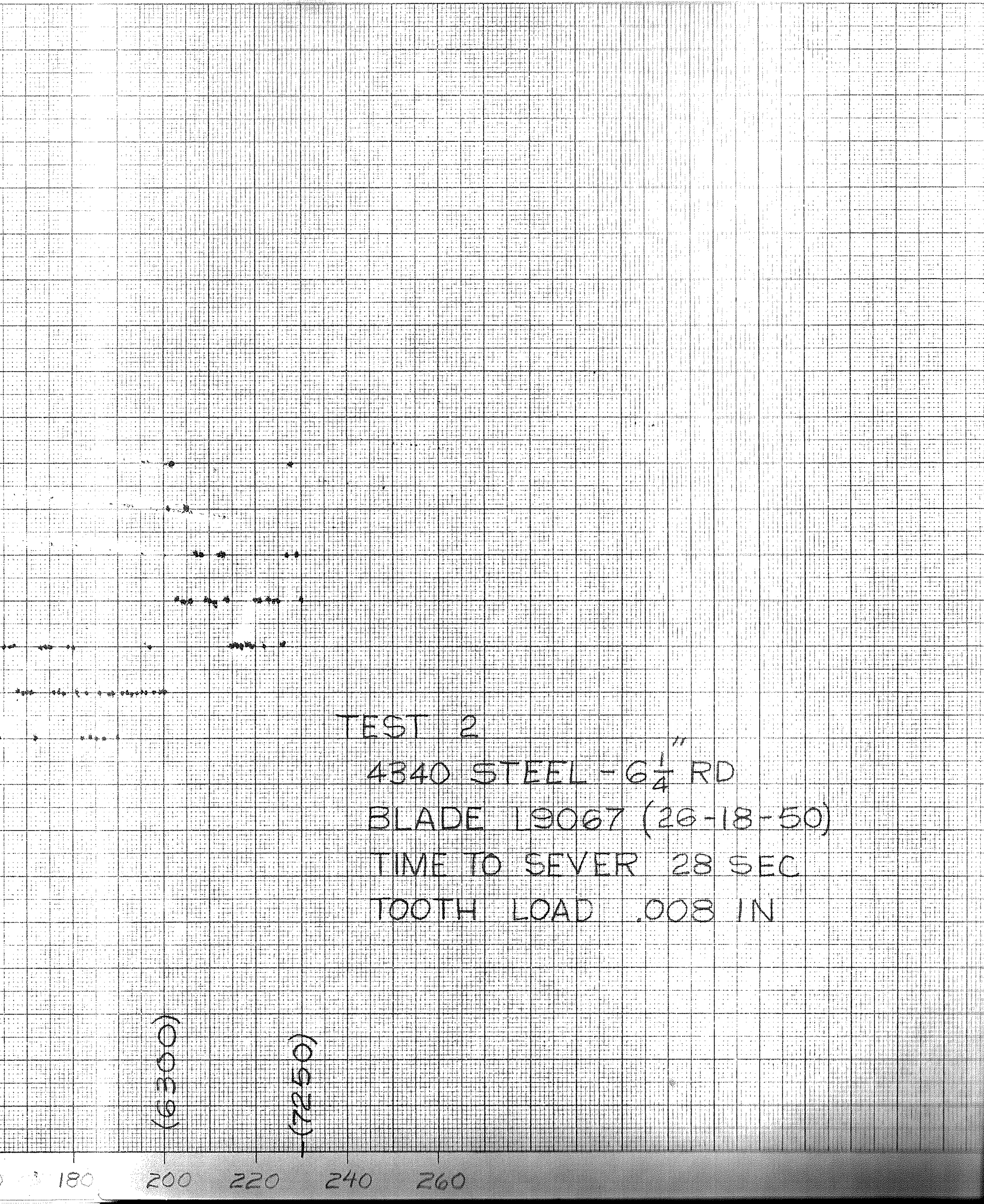
APPENDIX B

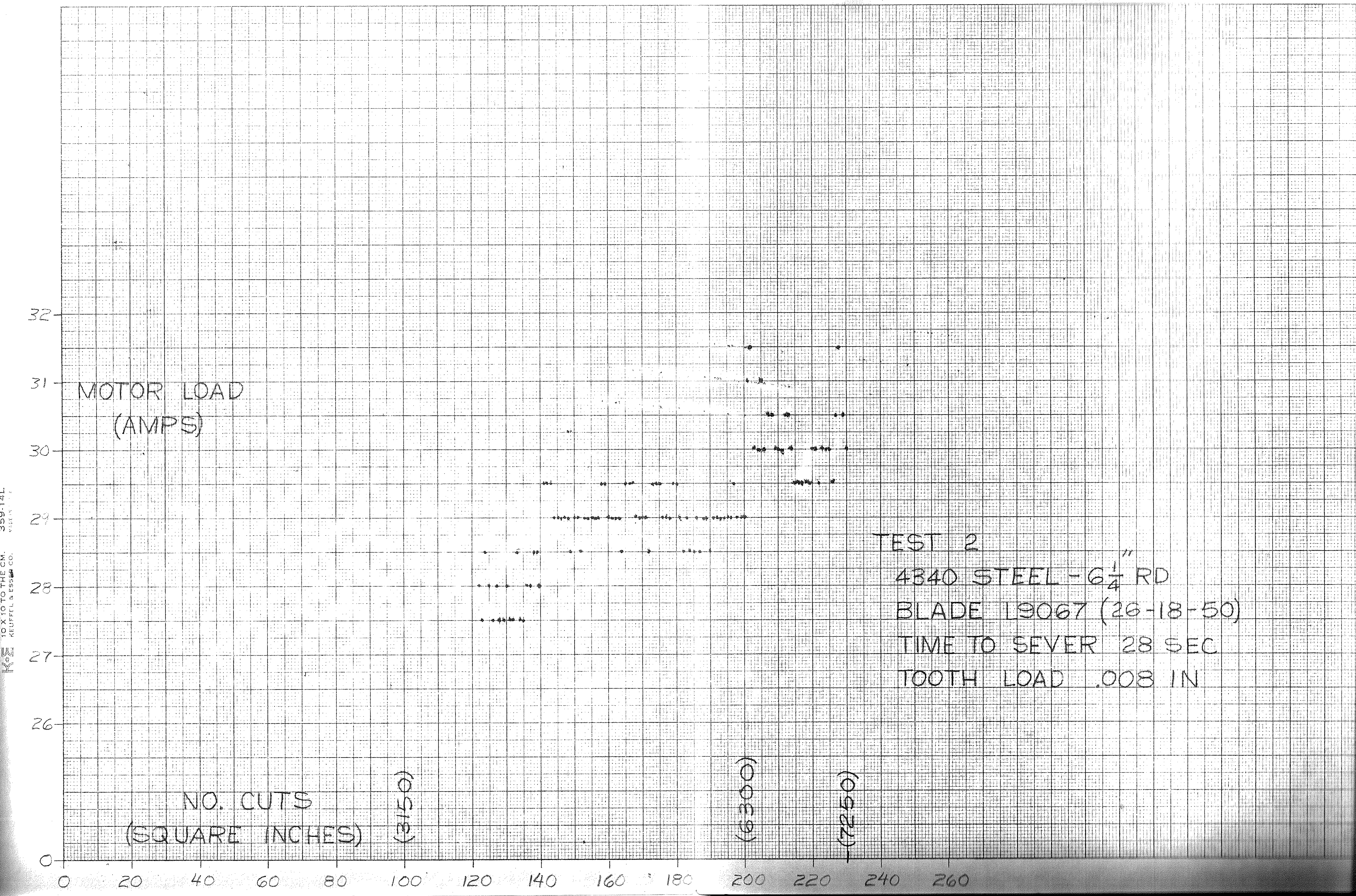
INDIVIDUAL TEST GRAPHS

(MOTOR LOAD *VERSUS* NUMBER OF CUTS)

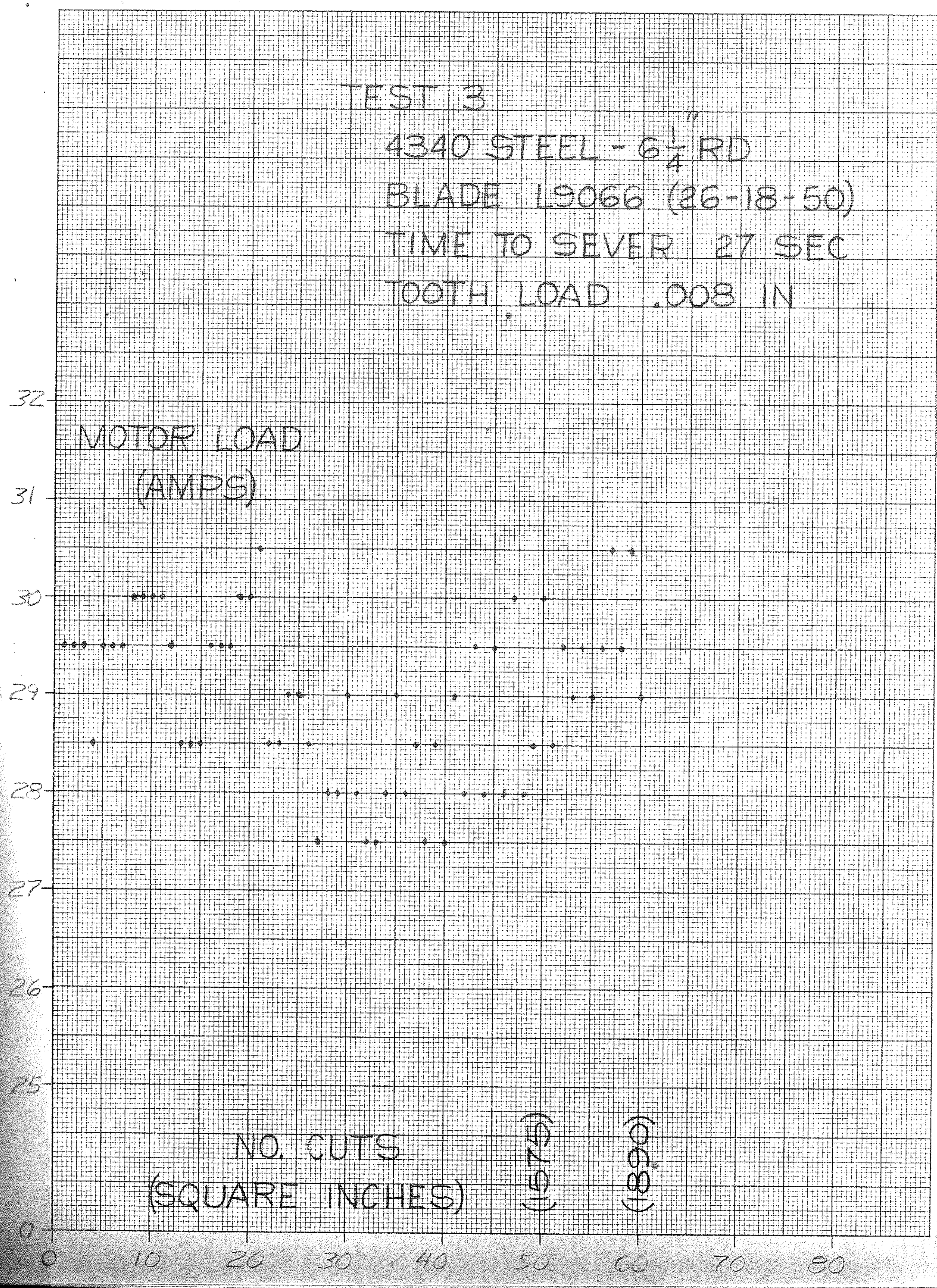


33
32
31
30
29
28
MOTOR LOAD
(AMPS)
TEST #1
4340 STEEL 6¼" RD
BLADE L9066 (26-18:50)
TIME TO SEVER 28 SEC
TOOTH LOAD .008

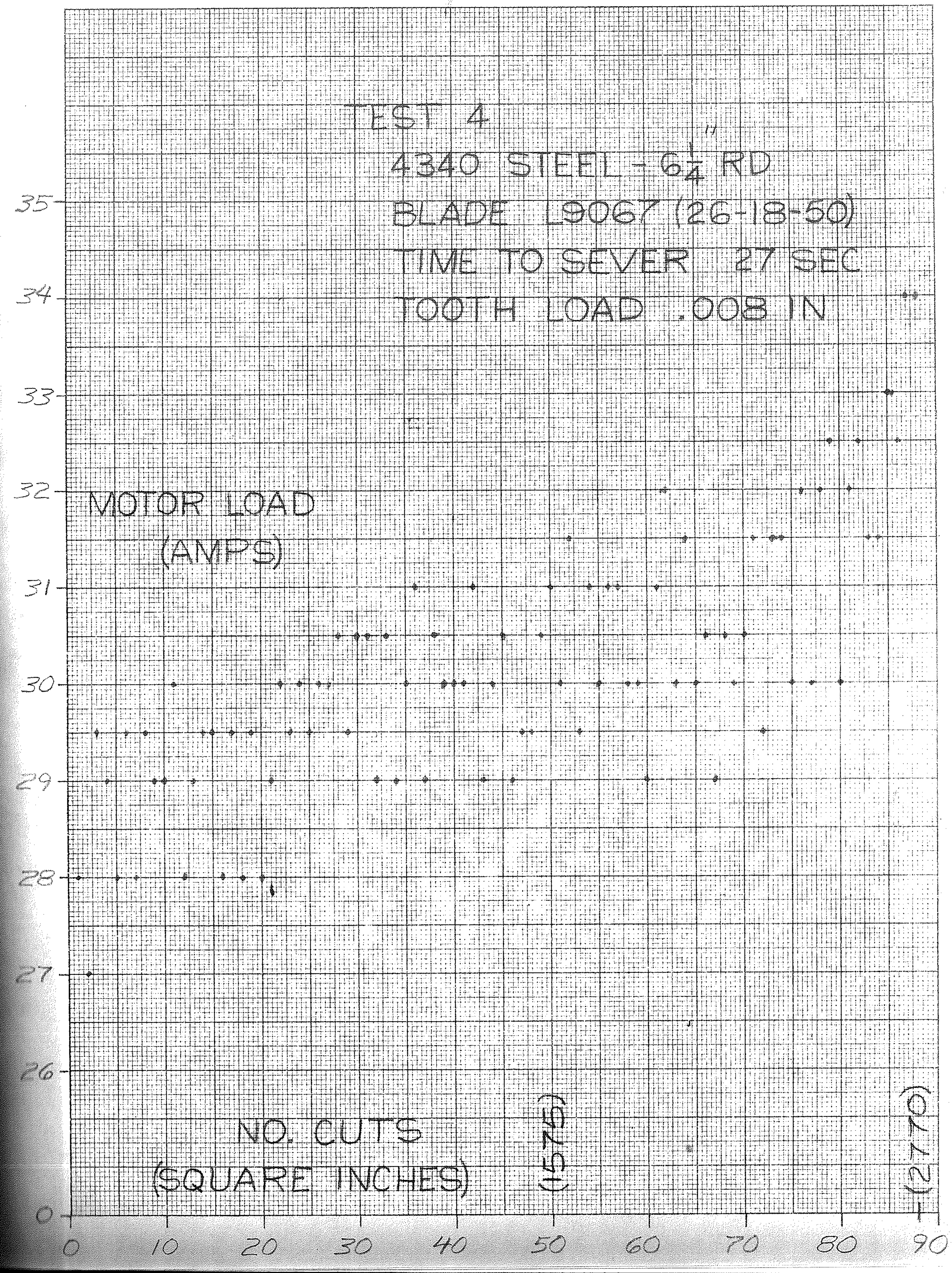

TEST 2
4340 STEEL - 6 1/4" RD
BLADE L9067 (26-18-50)
TIME TO SEVER 28 SEC
TOOTH LOAD .008 IN
(6300)
(7250)
180
200
220
240
260

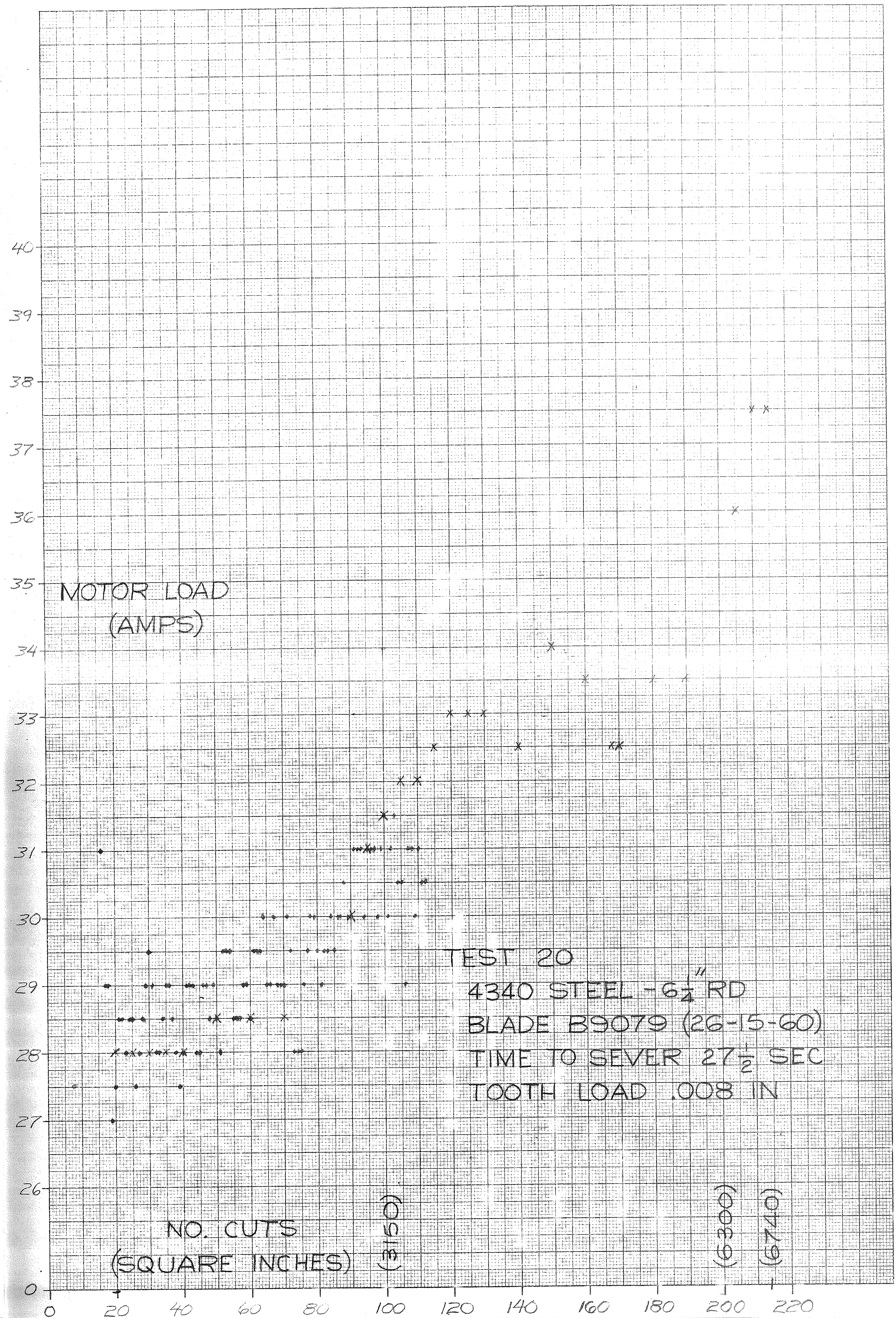


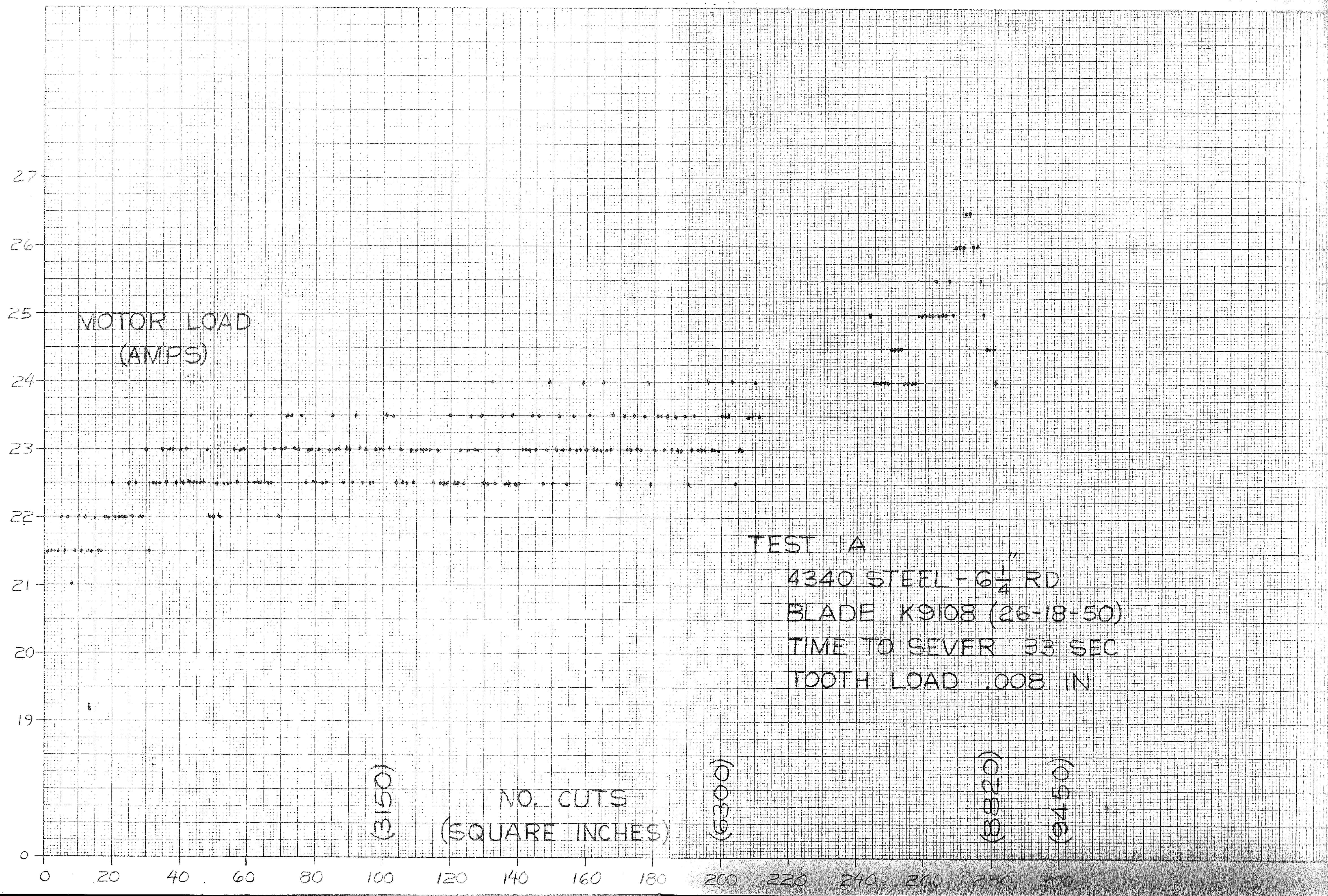
MOTOR LOAD
(AMPS)
32
31
30
29
28
27
26
0
TEST 2
4340 STEEL - 6 1/4" RD
BLADE L9067 (26-18-50)
TIME TO SEVER 28 SEC
TOOTH LOAD .008 IN
NO. CUTS
(SQUARE INCHES)
(3150)
(6300)
(7250)
0
20
40
60
80
100
120
140
160
180
200
220
240
260

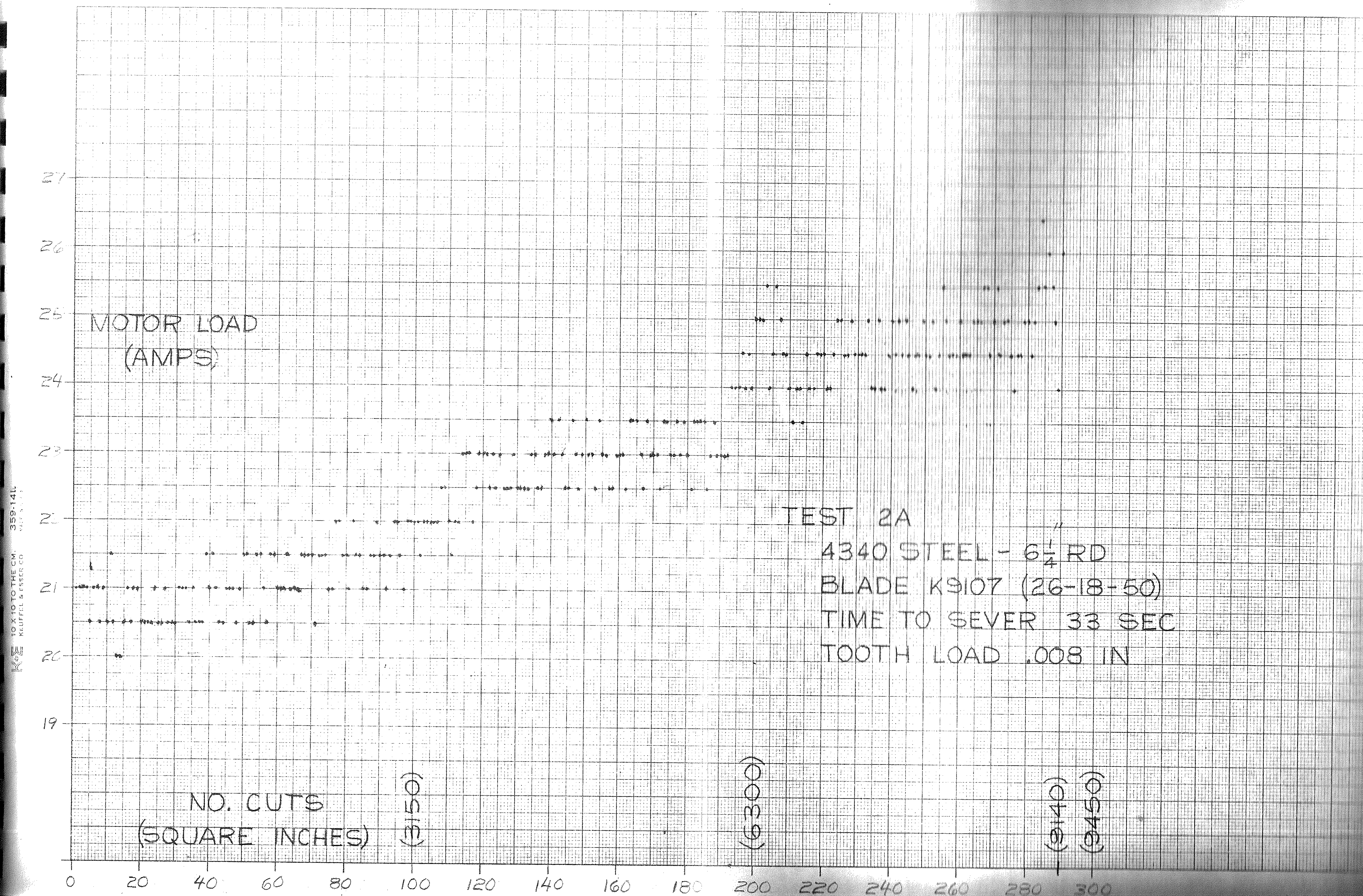


TEST 3
4340 STEEL - 6 1/4" RD
BLADE L9066 (26-18-50)
TIME TO SEVER 27 SEC
TOOTH LOAD .008 IN
MOTOR LOAD
(AMPS)
32
31
30
29
28
27
26
25
0
NO. CUTS
(SQUARE INCHES)
(1575)
(1890)
0
10
20
30
40
50
60
70
80

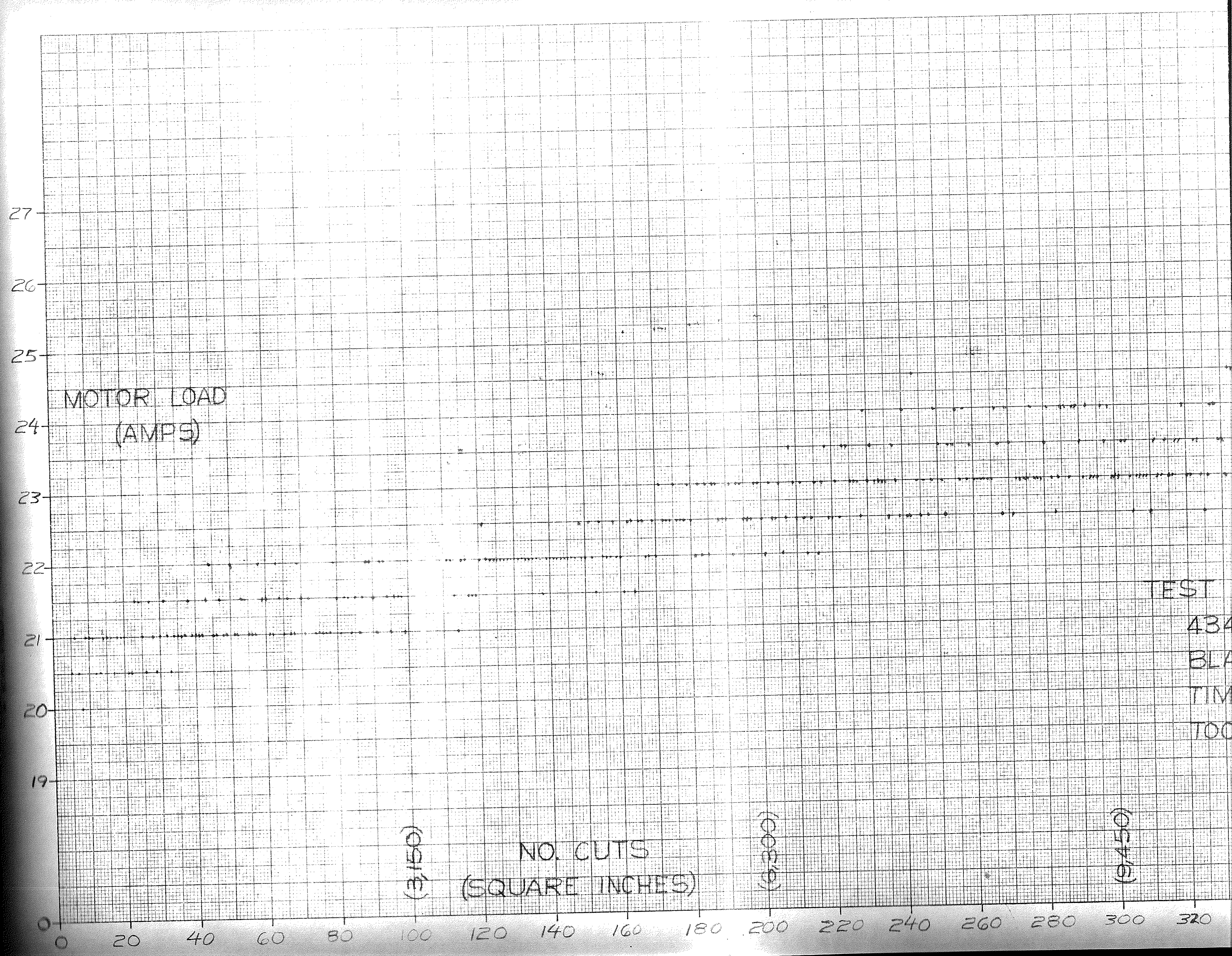

TEST 4
4340 STEEL - 6 1/4" RD
BLADE L9067 (26-18-50)
TIME TO SEVER 27 SEC
TOOTH LOAD .008 IN
MOTOR LOAD
(AMPS)
NO. CUTS
(SQUARE INCHES)
(1575)
(2770)
35
34
33
32
31
30
29
28
27
26
0
0
10
20
30
40
50
60
70
80
90

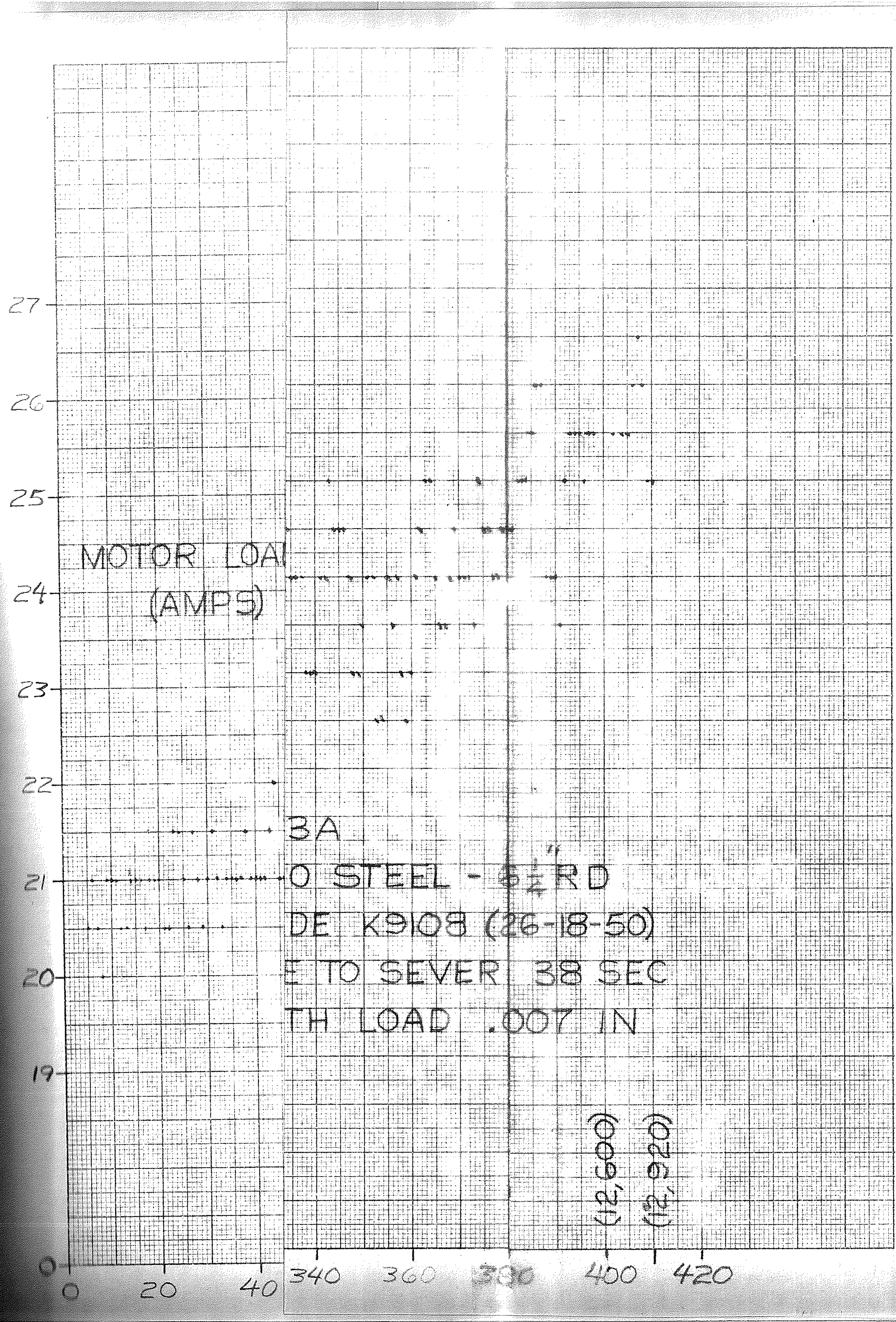

MOTOR LOAD
(AMPS)
TEST 20
4340 STEEL - 6¼" RD
BLADE B9079 (26-15-60)
TIME TO SEVER 27½ SEC
TOOTH LOAD .008 IN
NO. CUTS
(SQUARE INCHES)
(3150)
(6300)
(6740)
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
0
0
20
40
60
80
100
120
140
160
180
200
220


MOTOR LOAD
(AMPS)
27
26
25
24
23
22
21
20
19
0
TEST 1A
4340 STEEL - 6 1/4" RD
BLADE K9108 (26-18-50)
TIME TO SEVER 33 SEC
TOOTH LOAD .008 IN
NO. CUTS
(SQUARE INCHES)
(3150)
(6300)
(8820)
(9450)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300

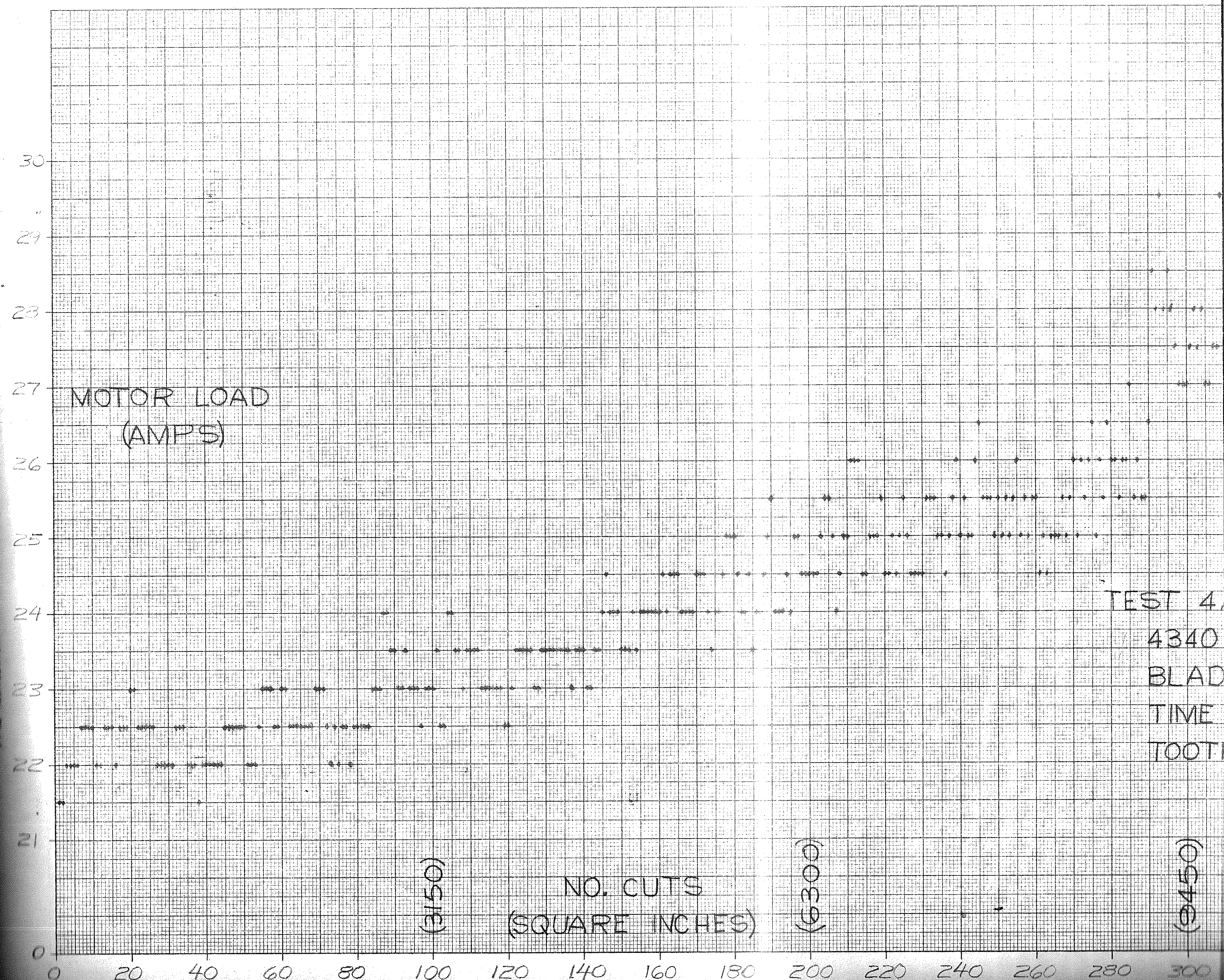


MOTOR LOAD
(AMPS)
27
26
25
24
23
21
20
19
TEST 2A
4340 STEEL - 6 1/4" RD
BLADE K9107 (26-18-50)
TIME TO SEVER 33 SEC
TOOTH LOAD .008 IN
NO. CUTS
(SQUARE INCHES)
(3150)
(6300)
(9140)
(9450)
0
20
40
60
80
100
120
140
160
200
220
240
260
280
300
10 X 10 TO THE CM. 359-14L
KEUFFEL & ESSER CO.

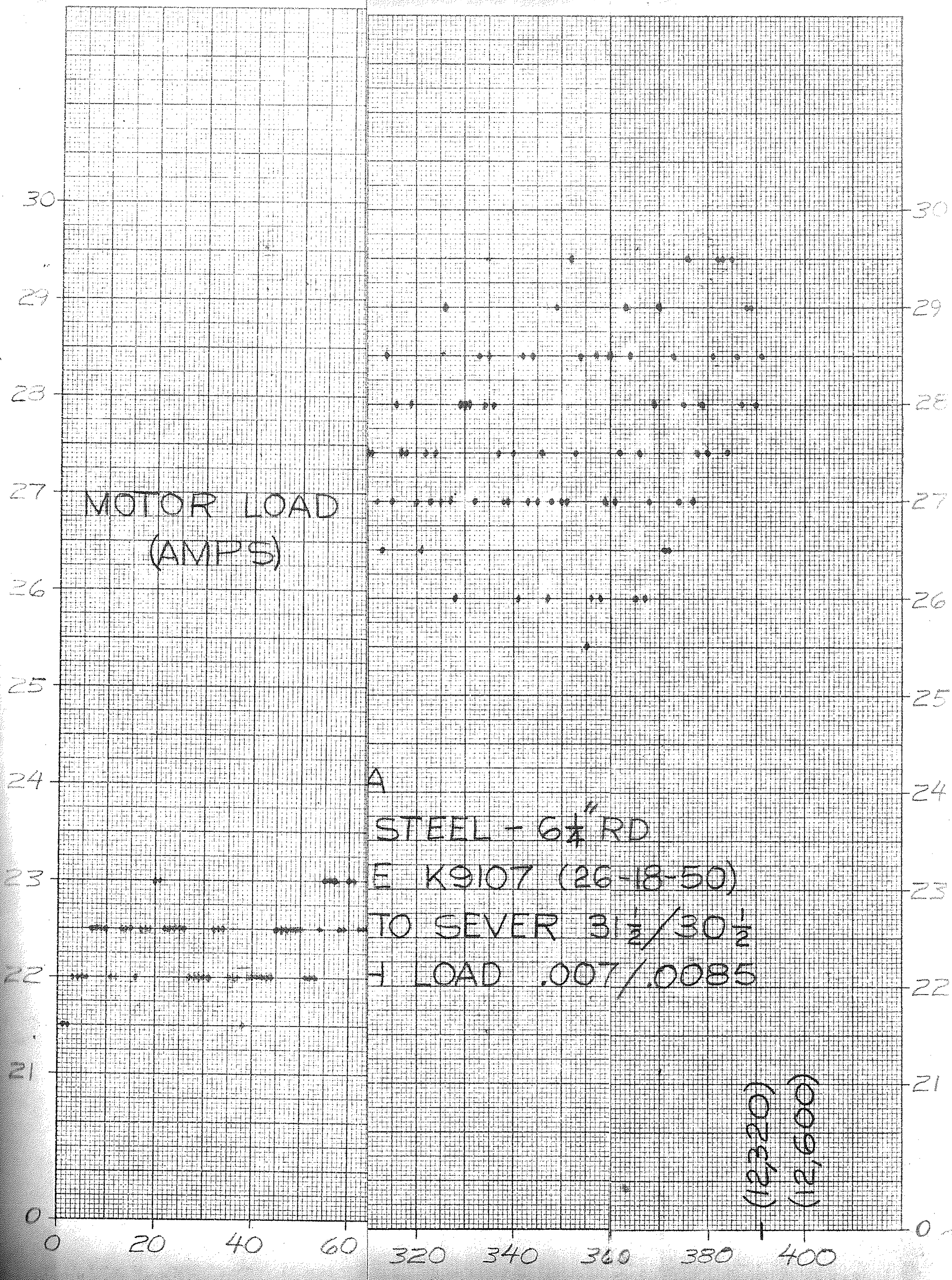

MOTOR LOAD
(AMPS)
27
26
25
24
23
22
21
20
19
0
NO. CUTS
(SQUARE INCHES)
(3150)
(6300)
(9450)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
TEST
434

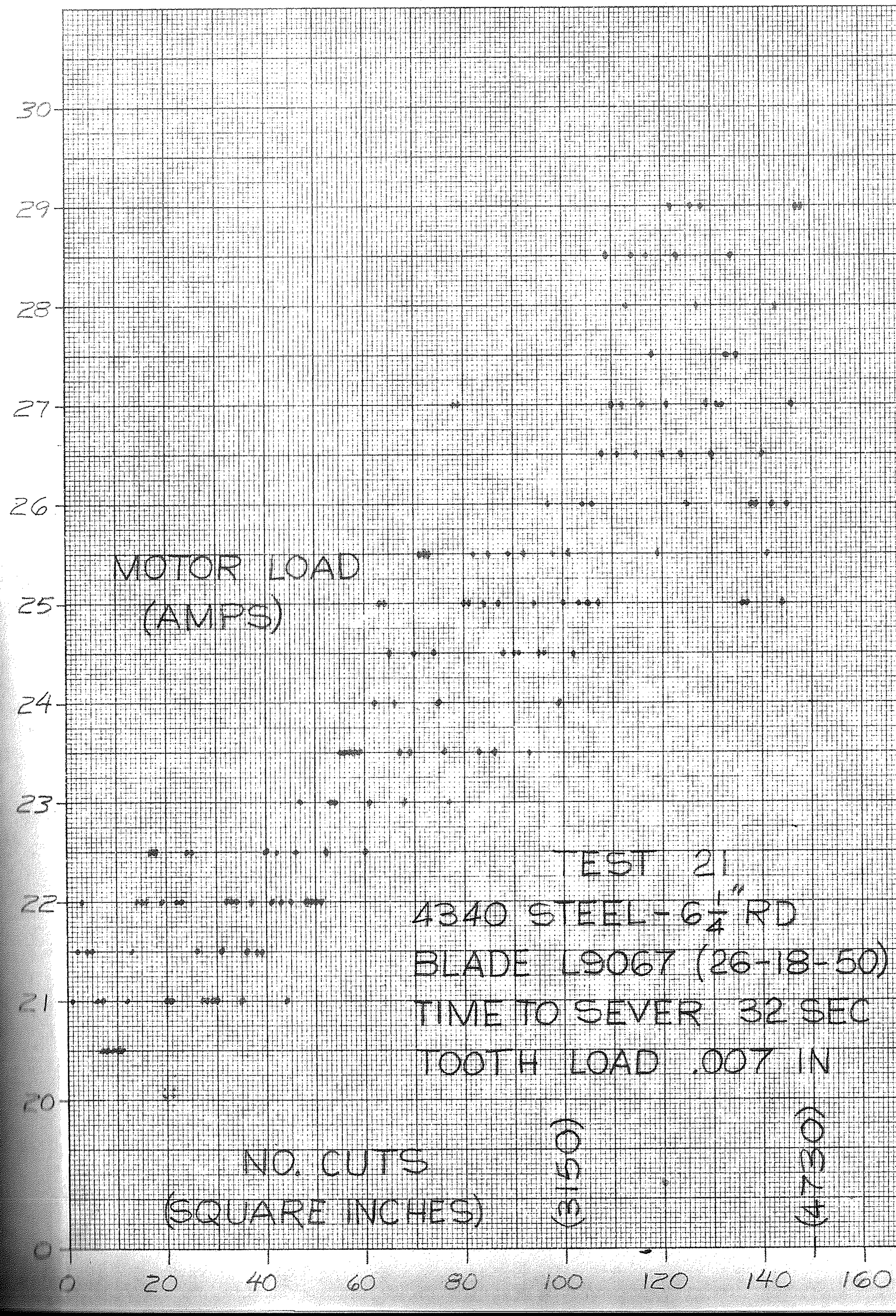


MOTOR LOA
(AMPS)
27
26
25
24
23
22
21
20
19
0
3A
O STEEL - 6 1/4" RD
DE K9108 (26-18-50)
E TO SEVER 38 SEC
TH LOAD .007 IN
(12,600)
(12,920)
0
20
40
340
360
380
400
420

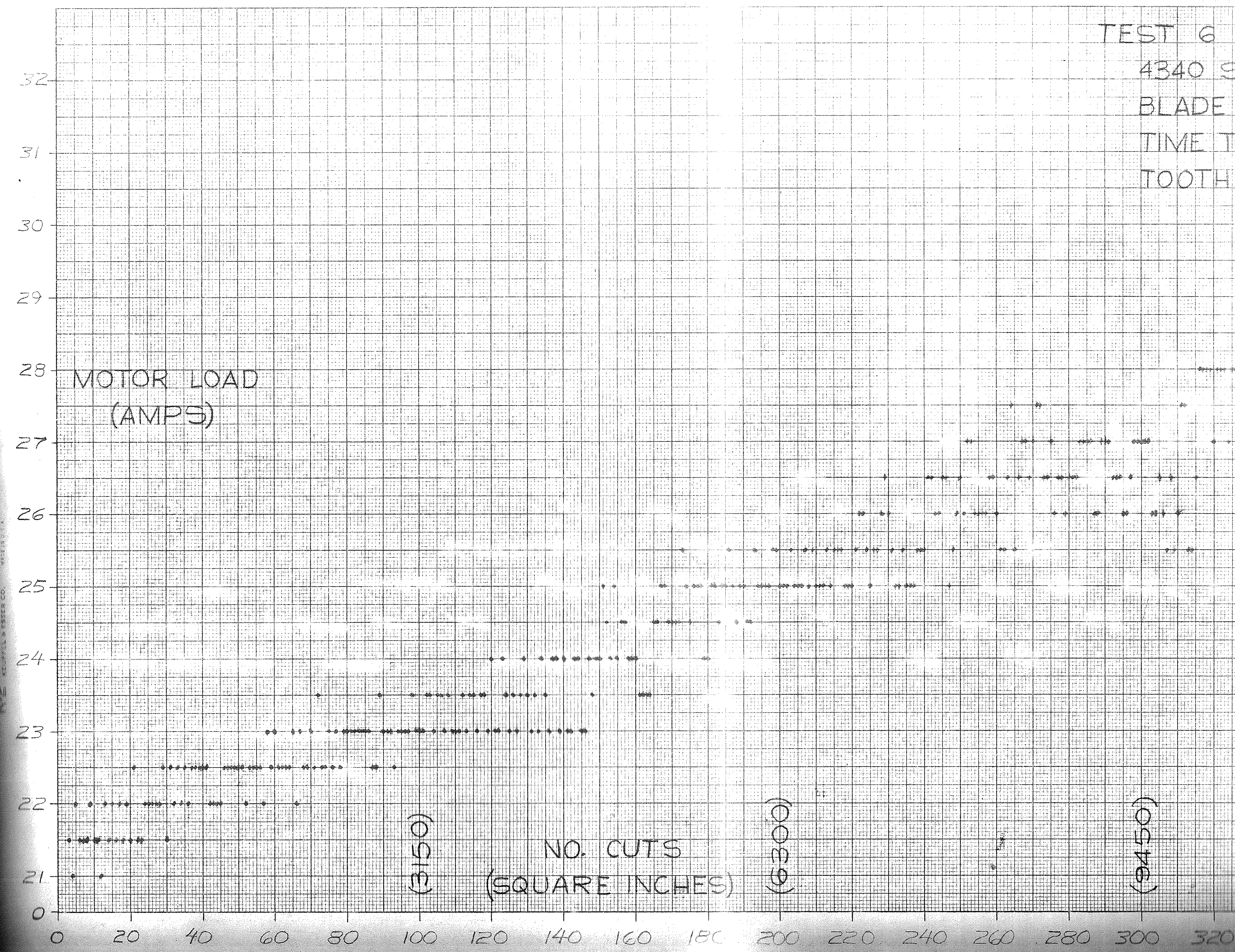


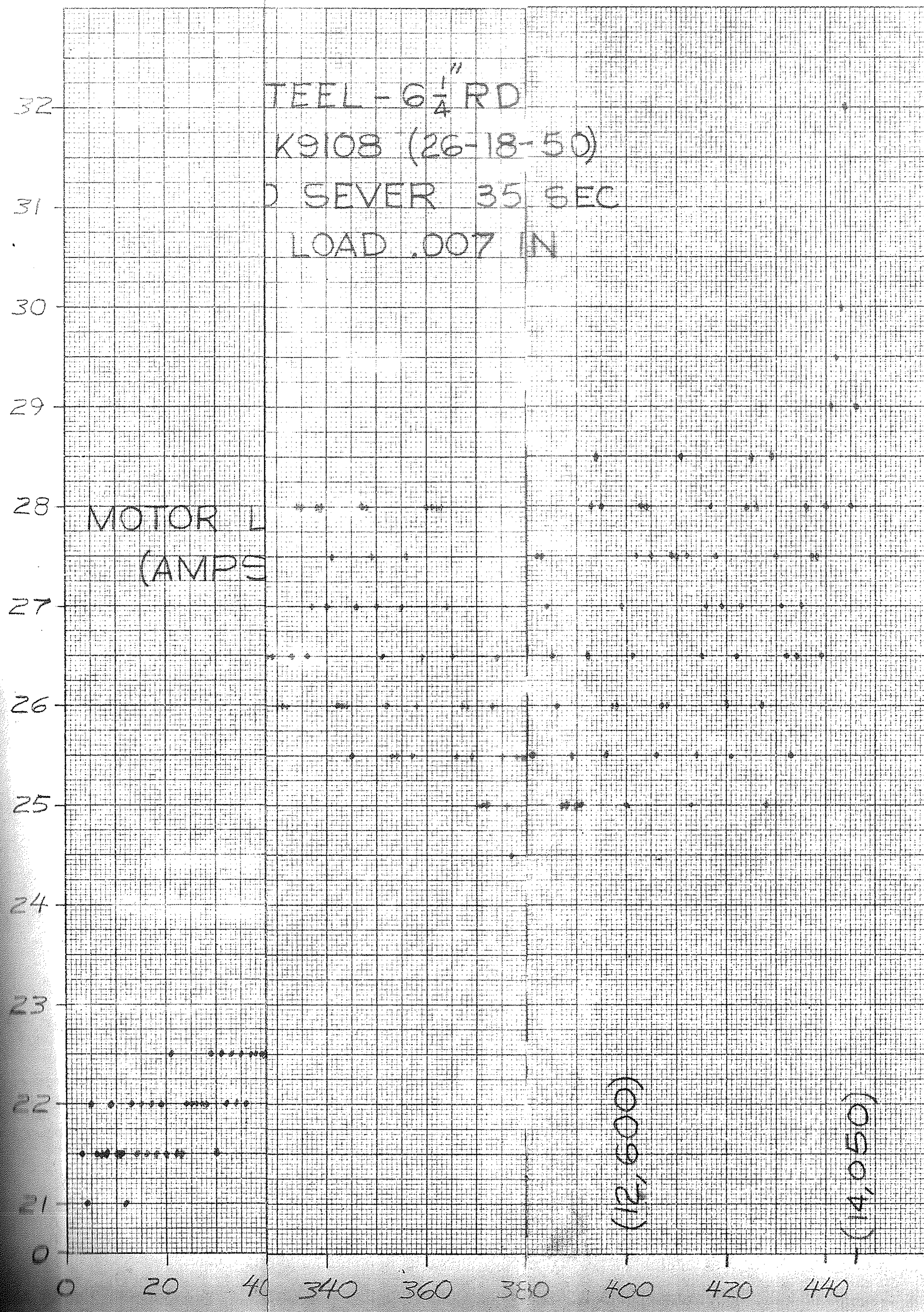
MOTOR LOAD
(AMPS)
NO. CUTS
(SQUARE INCHES)
(3150)
(6300)
(9450)
TEST 4
4340
BLAD
TIME
TOOT
0
21
22
23
24
25
26
27
28
29
30
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300

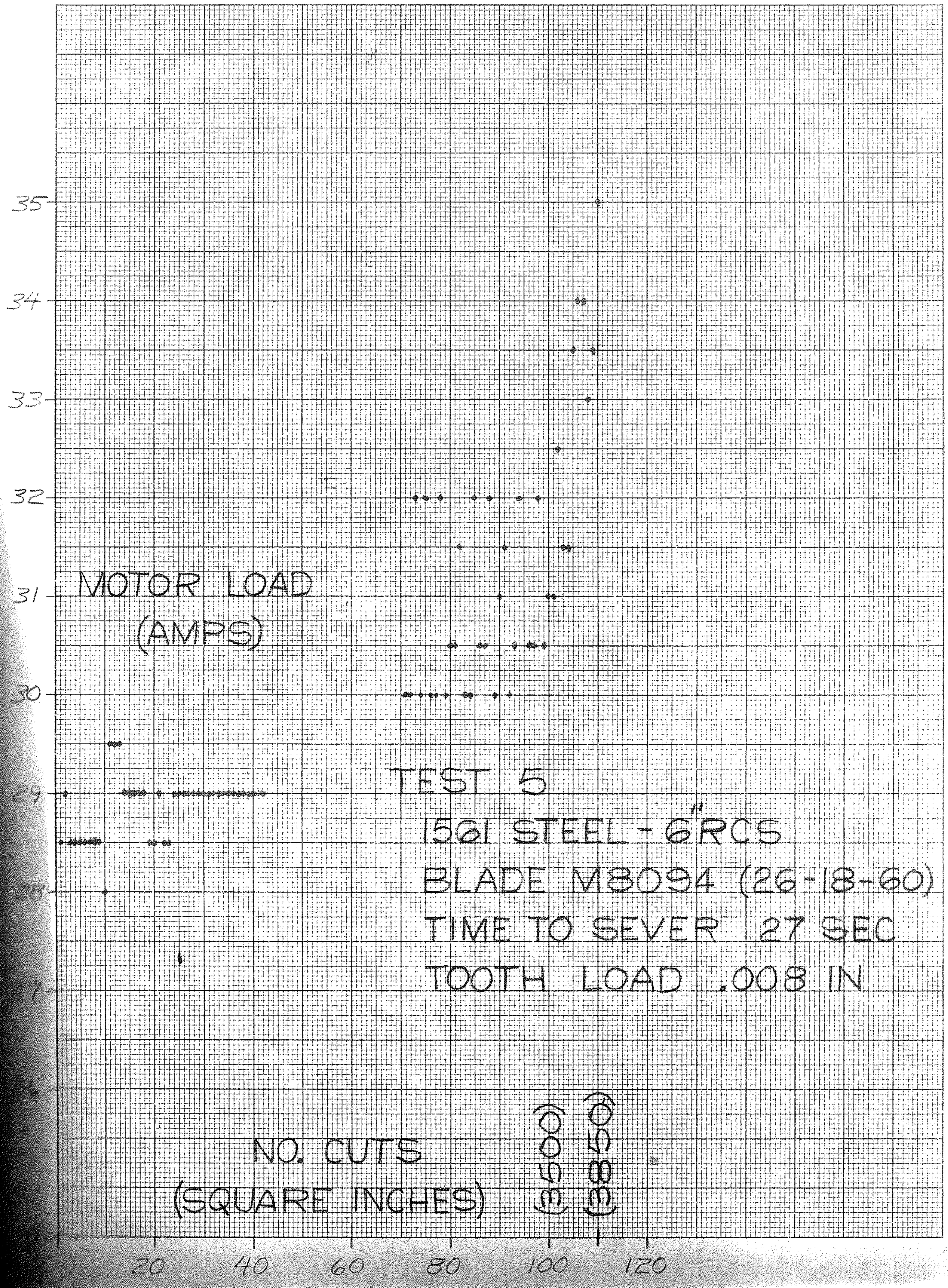

MOTOR LOAD
(AMPS)
A
STEEL - 6¼" RD
E K9107 (26-18-50)
TO SEVER 31½/30½
H LOAD .007/.0085
(12320)
(12,600)
30
29
28
27
26
25
24
23
22
21
0
0
20
40
60
320
340
360
380
400



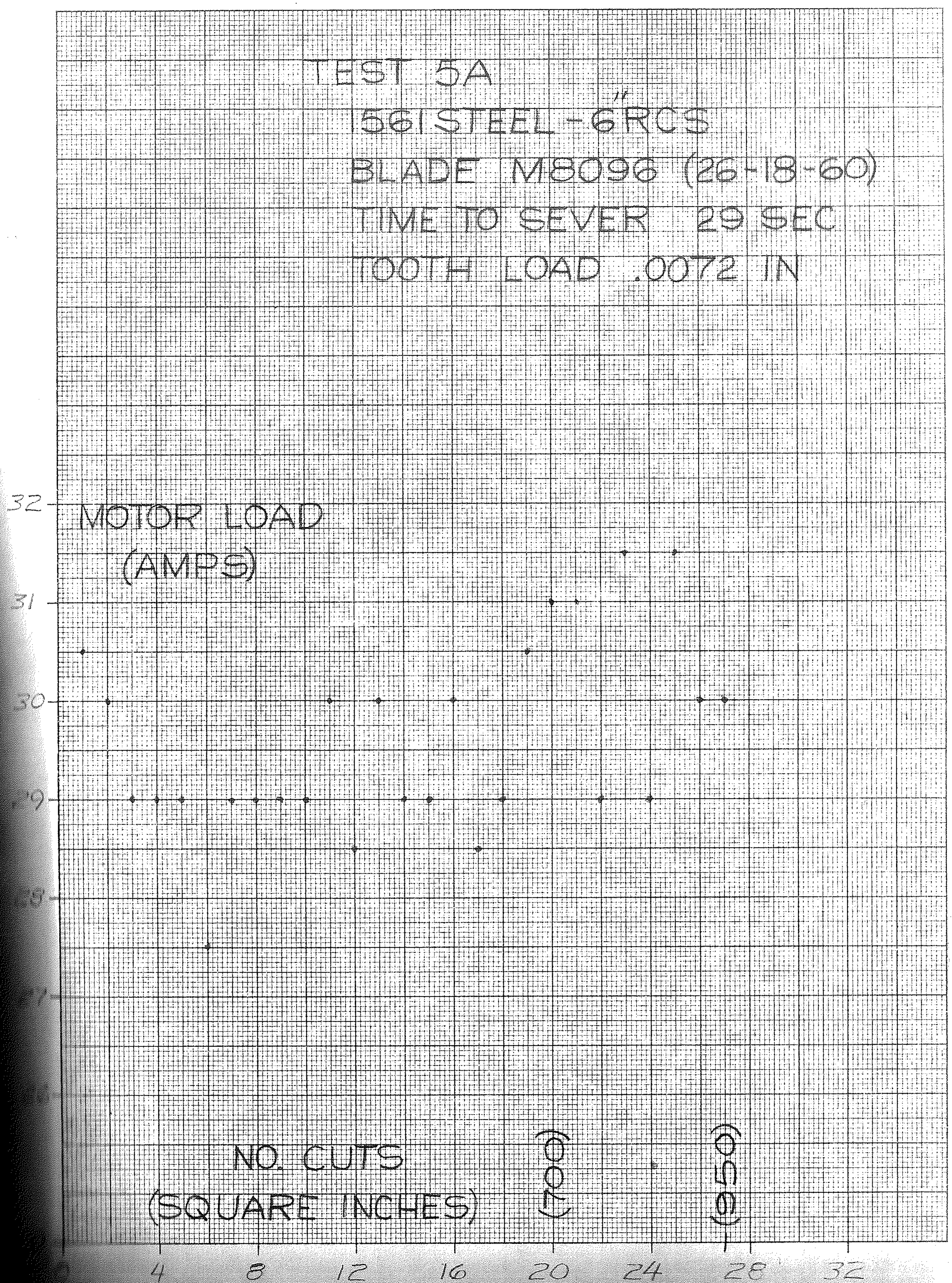
30
29
28
27
26
25
24
23
22
21
20
0
MOTOR LOAD
(AMPS)
TEST 21
4340 STEEL - 6 1/4" RD
BLADE L9067 (26-18-50)
TIME TO SEVER 32 SEC
TOOTH LOAD .007 IN
NO. CUTS
(SQUARE INCHES)
(3150)
(4730)
0
20
40
60
80
100
120
140
160

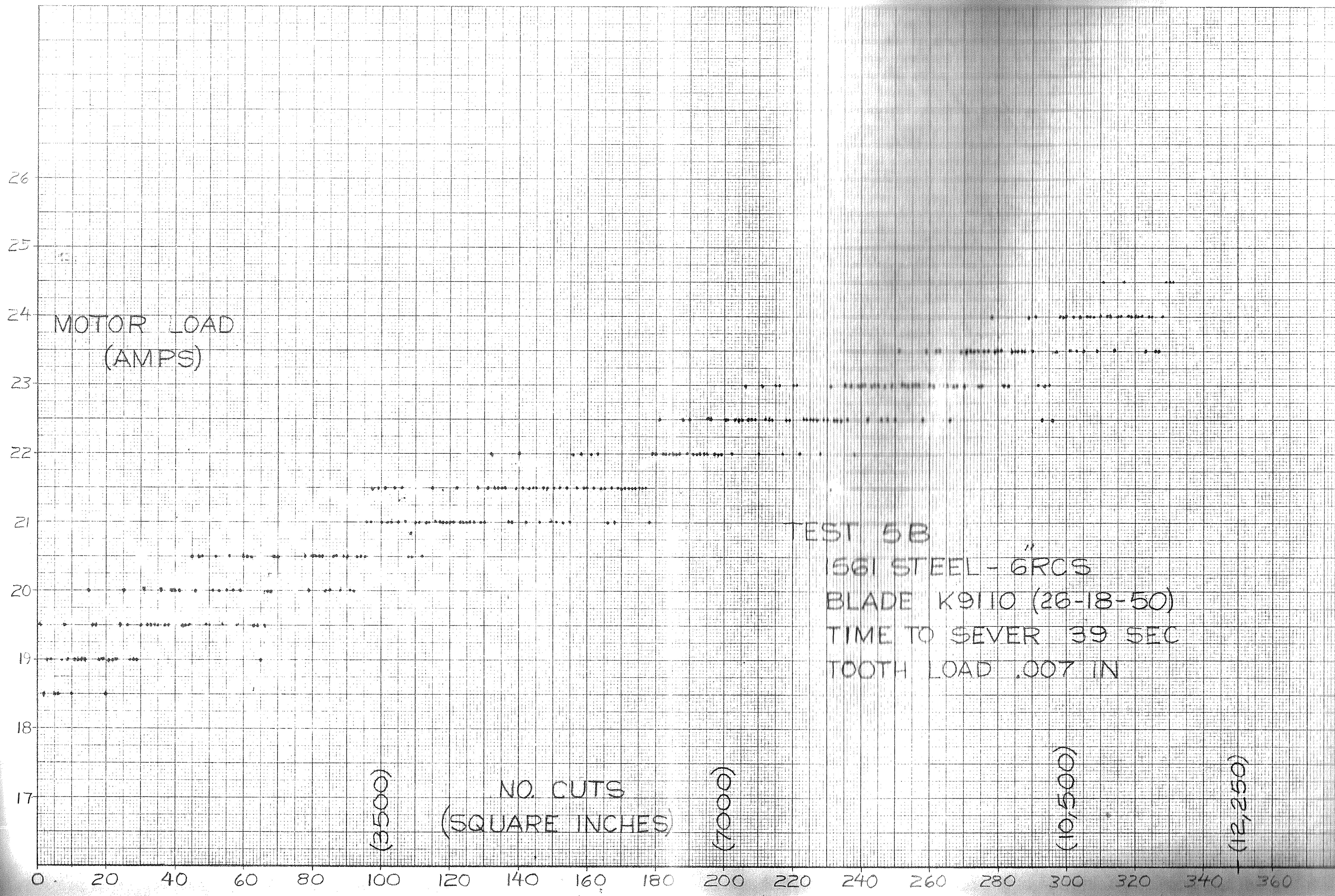

TEST 6
4340 S
BLADE
TIME T
TOOTH
MOTOR LOAD
(AMPS)
NO. CUTS
(SQUARE INCHES)
(3150)
(6300)
(9450)
0
21
22
23
24
25
26
27
28
29
30
31
32
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320

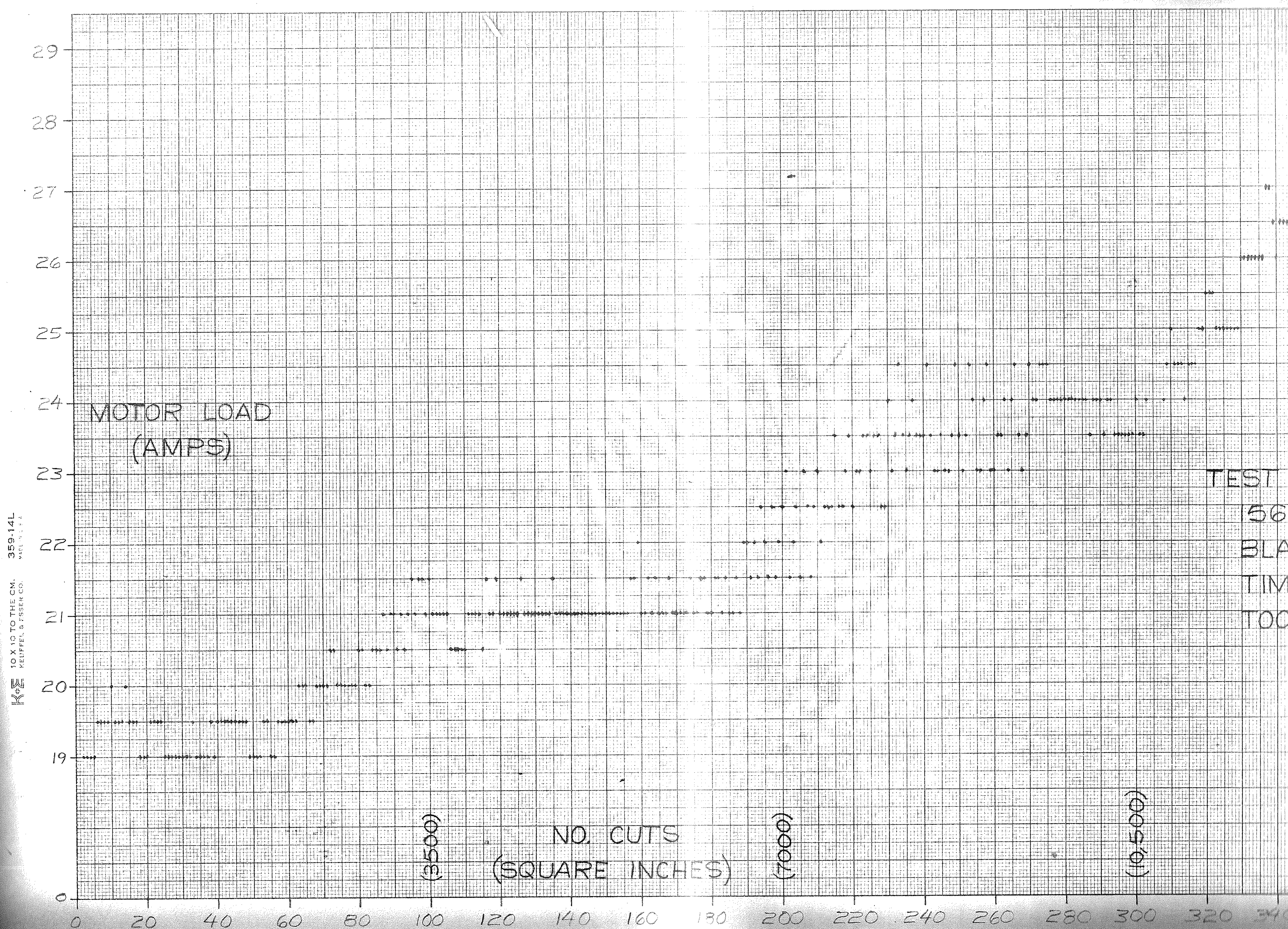

TEEL - 6 1/4" RD
K9108 (26-18-50)
SEVER 35 SEC
LOAD .007 IN
MOTOR L
(AMPS
32
31
30
29
28
27
26
25
24
23
22
21
0
0
20
40
340
360
380
400
420
440
(12,600)
(14,050)



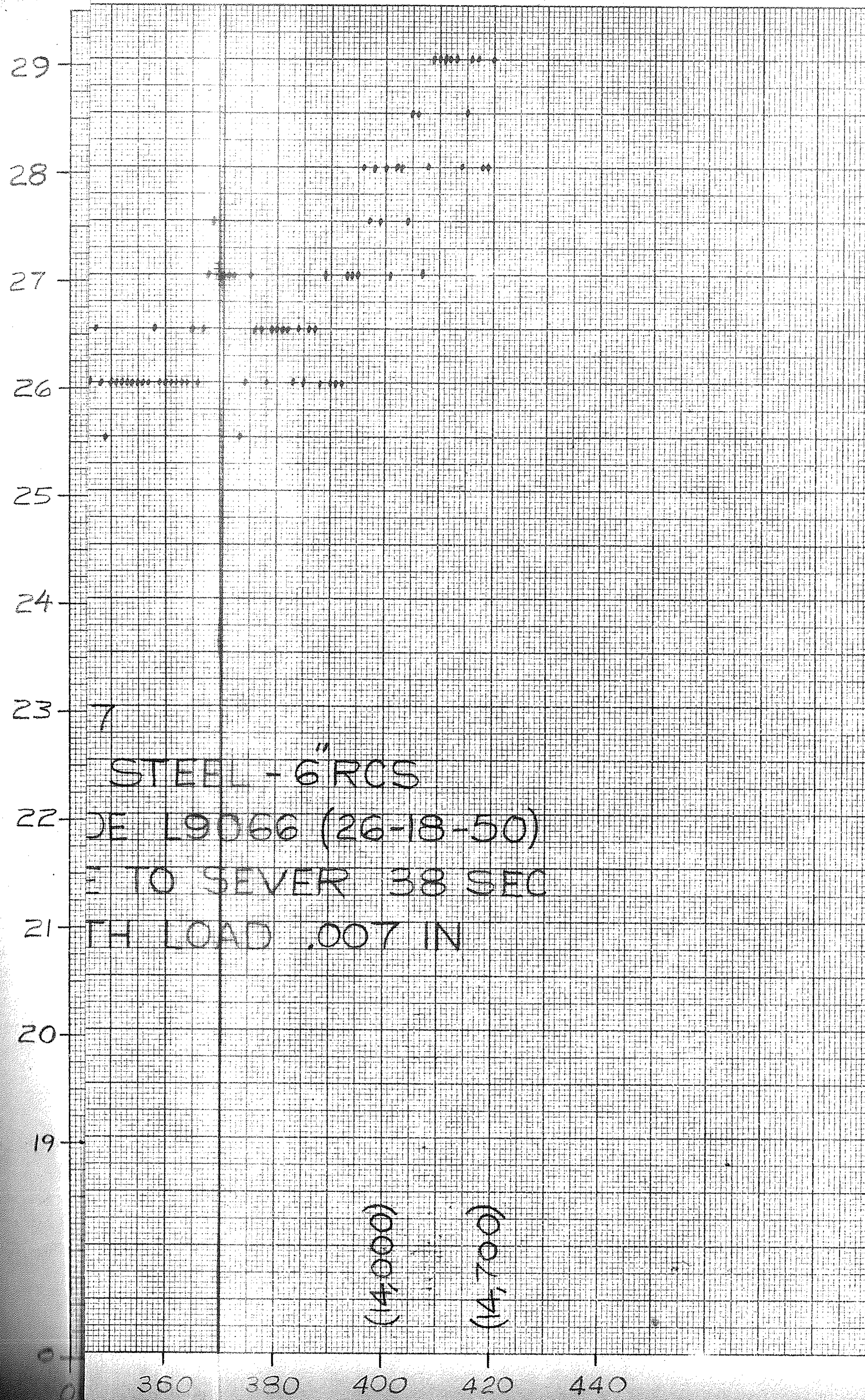
MOTOR LOAD
(AMPS)
35
34
33
32
31
30
29
28
27
TEST 5
1561 STEEL - 6" RCS
BLADE M8094 (26-18-60)
TIME TO SEVER 27 SEC
TOOTH LOAD .008 IN
NO. CUTS
(SQUARE INCHES)
(3500)
(3850)
20
40
60
80
100
120

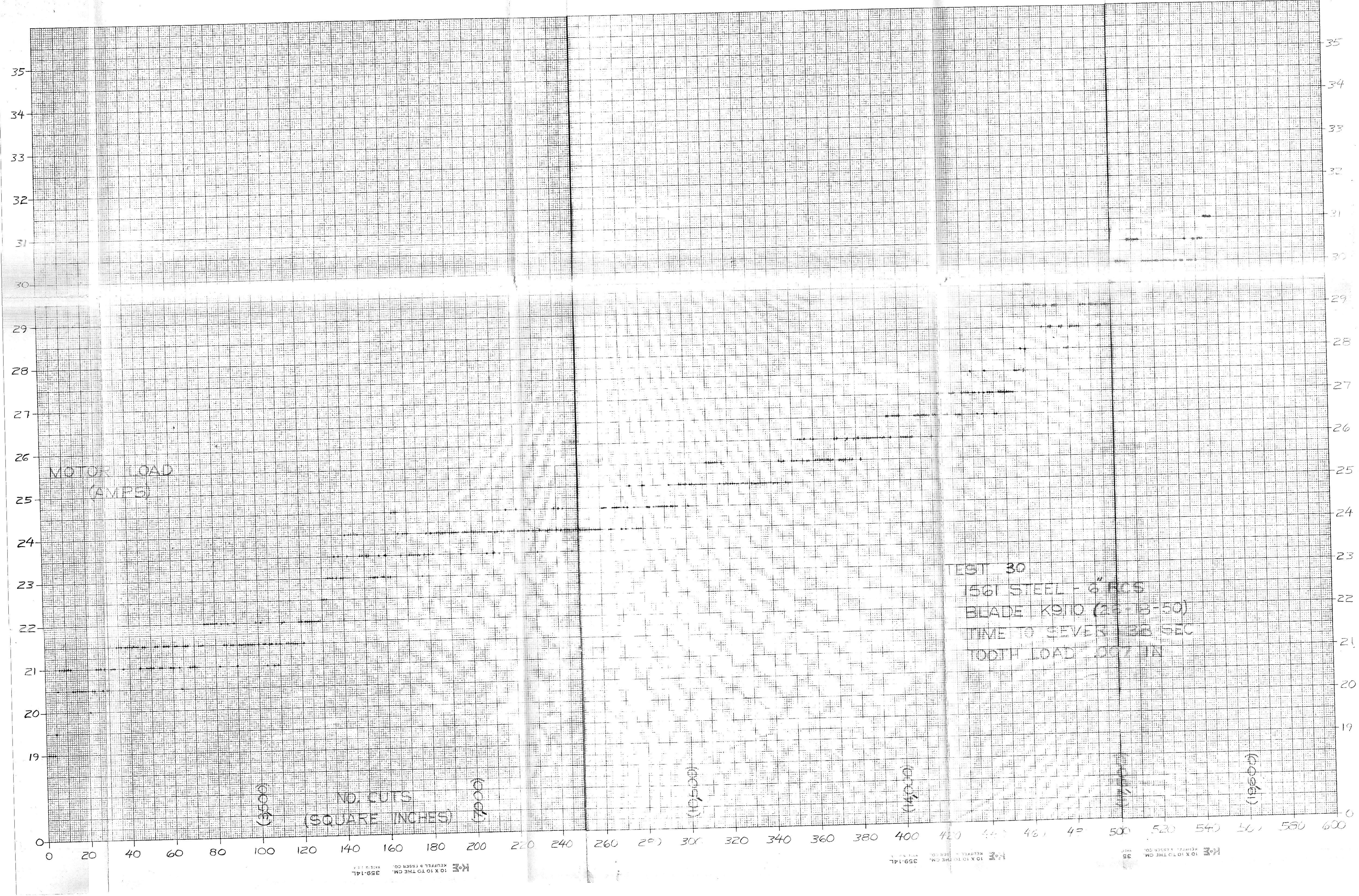

TEST 5A
1561 STEEL - 6" RCS
BLADE M8096 (26-18-60)
TIME TO SEVER 29 SEC
TOOTH LOAD .0072 IN
MOTOR LOAD
(AMPS)
32
31
30
NO. CUTS
(SQUARE INCHES)
(700)
(950)
4
8
12
16
20
24
28
32

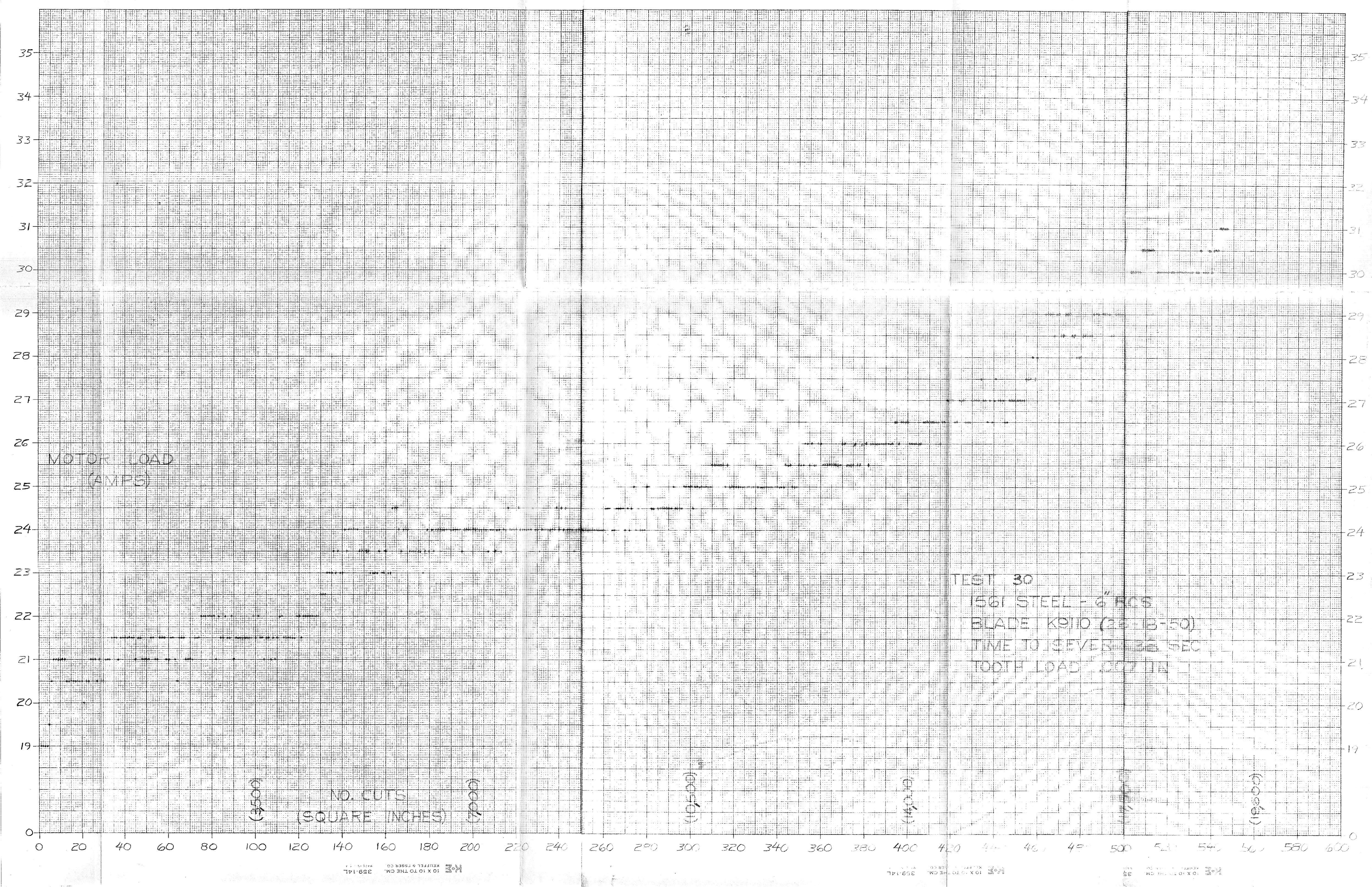

MOTOR LOAD
(AMPS)
26
25
24
23
22
21
20
19
18
17
TEST 5B
1561 STEEL - 6"RCS
BLADE K9110 (26-18-50)
TIME TO SEVER 39 SEC
TOOTH LOAD .007 IN
NO. CUTS
(SQUARE INCHES)
(3500)
(7000)
(10,500)
(12,250)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360

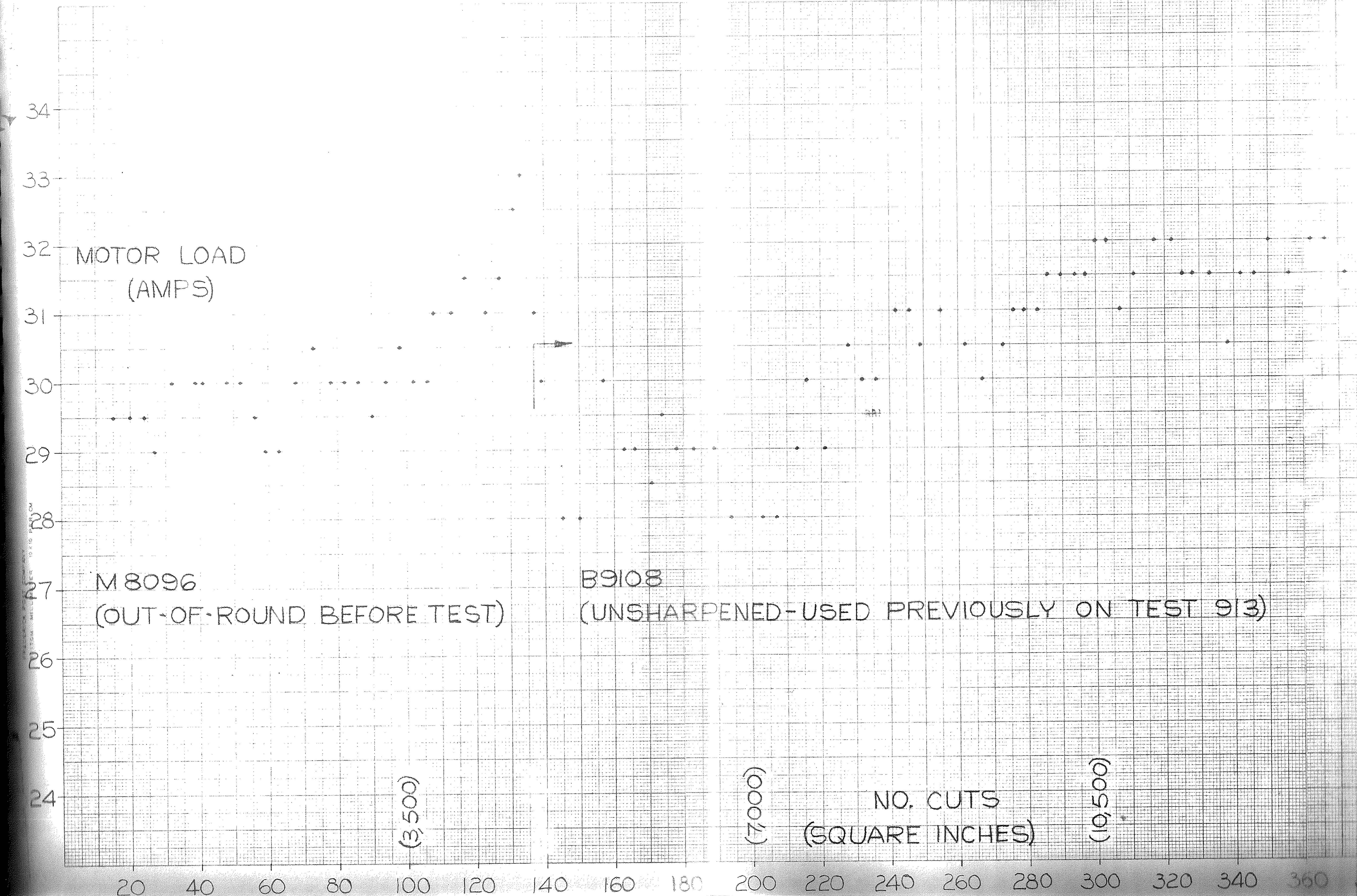


MOTOR LOAD
(AMPS)
29
28
27
26
25
24
23
22
21
20
19
0
NO. CUTS
(SQUARE INCHES)
(3500)
(7000)
(10,500)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
TEST
156
BLA
TIM
TOO
10 X 10 TO THE CM. 359-14L
KEUFFEL & ESSER CO.

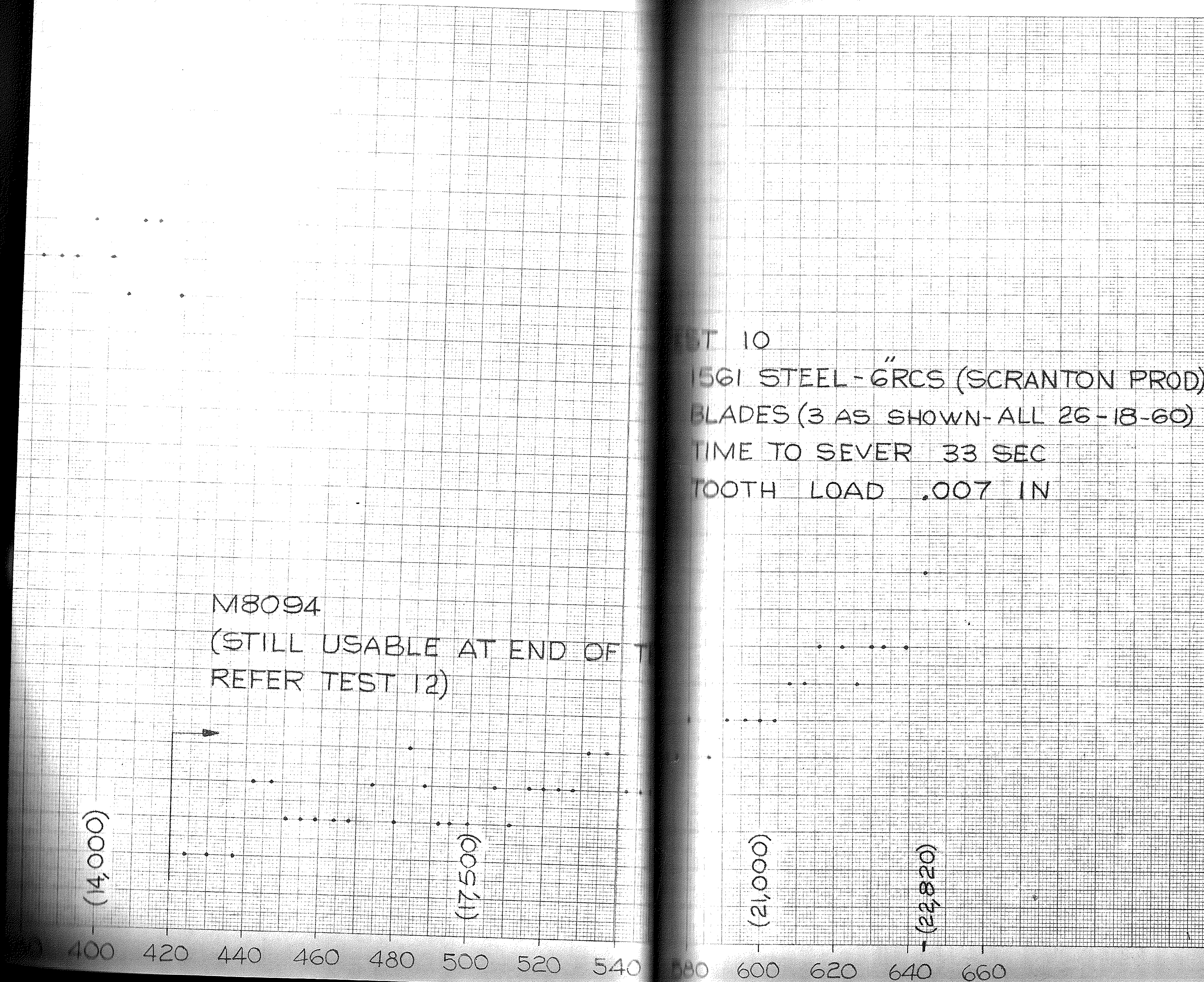

29
28
27
26
25
24
23
22
21
20
19
0
360
380
400
420
440
7
STEEL - 6" RCS
DE L9066 (26-18-50)
E TO SEVER 38 SEC
TH LOAD .007 IN
(14,000)
(14,700)


MOTOR LOAD
(AMPS)
NO. CUTS
(SQUARE INCHES)
(3500)
(7000)
(10,500)
(14,000)
(19,600)
TEST 30
1561 STEEL - 6" RCS
BLADE K910
TIME TO SEVER
TOOTH LOAD

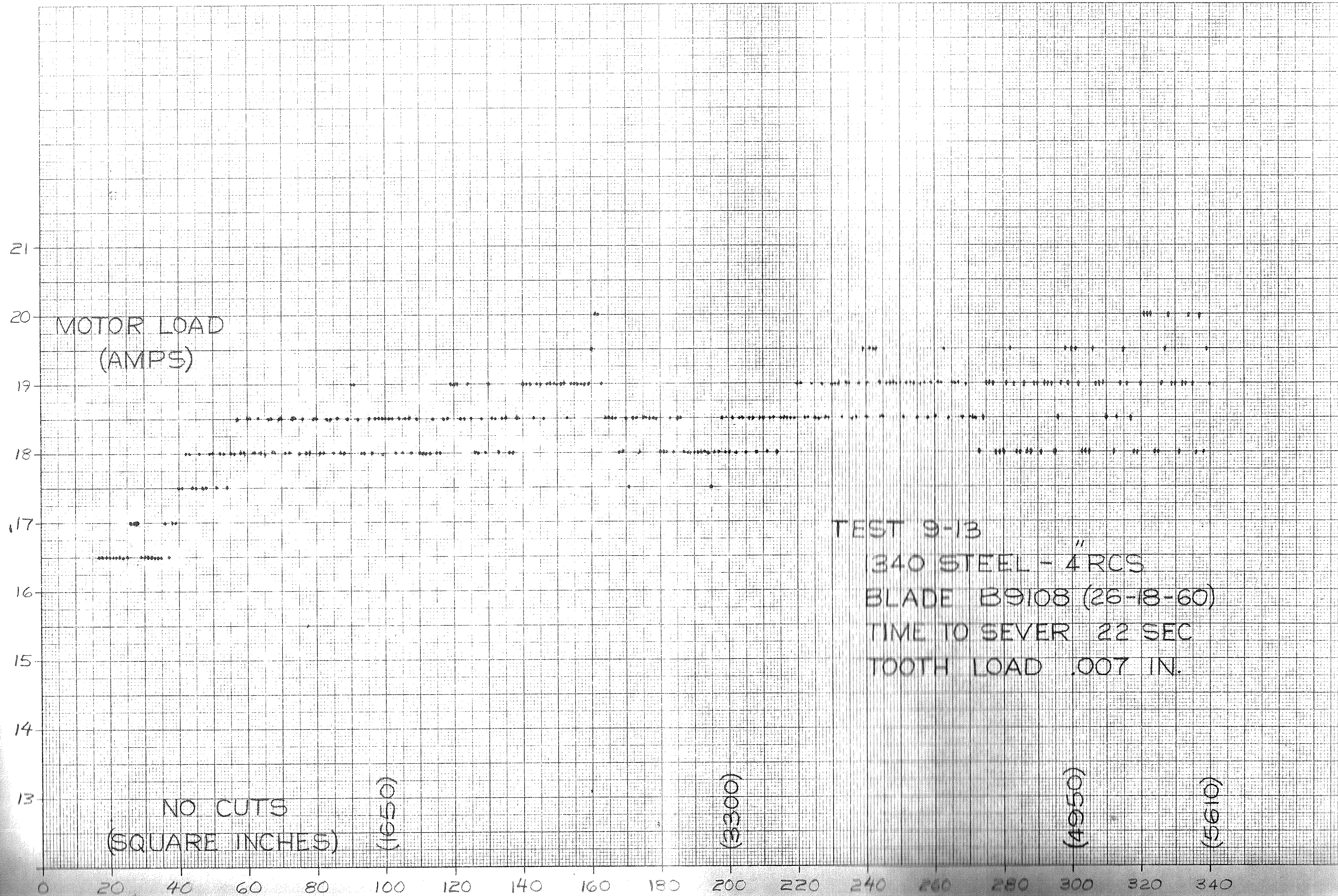

MOTOR LOAD
(AMPS)
NO. CUTS
(SQUARE INCHES)
(3500)
(7000)
(10,500)
(14,000)
(19,600)
TEST 30
1561 STEEL - 6" RCS
BLADE K910
SEC
TOOTH LOAD
IN
0
20
40
60
80
100
120
140
160
180
200
240
260
300
320
340
360
380
400
500
580
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
10 X 10 TO THE CM. 359-14L
KEUFFEL & ESSER CO.

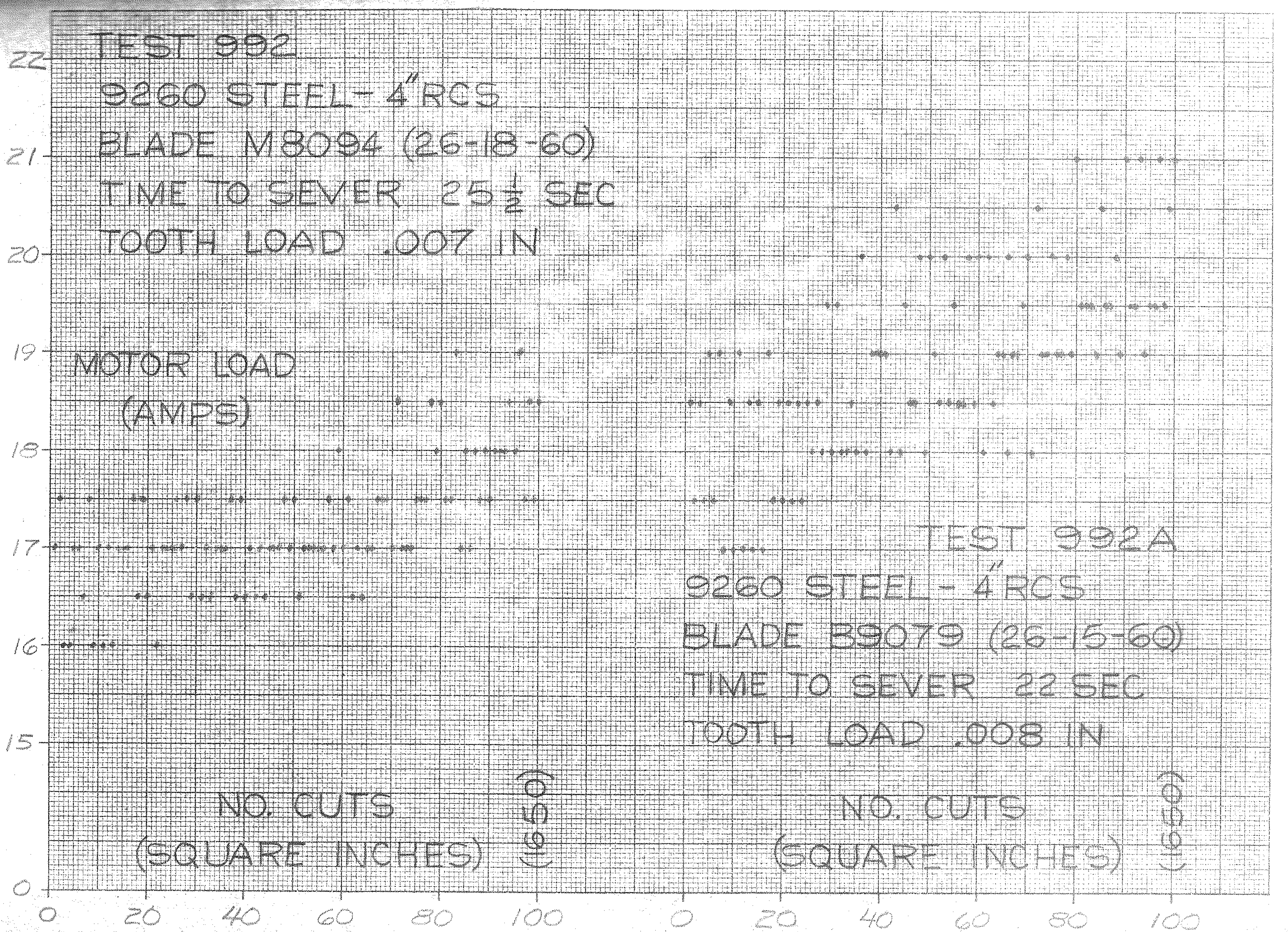


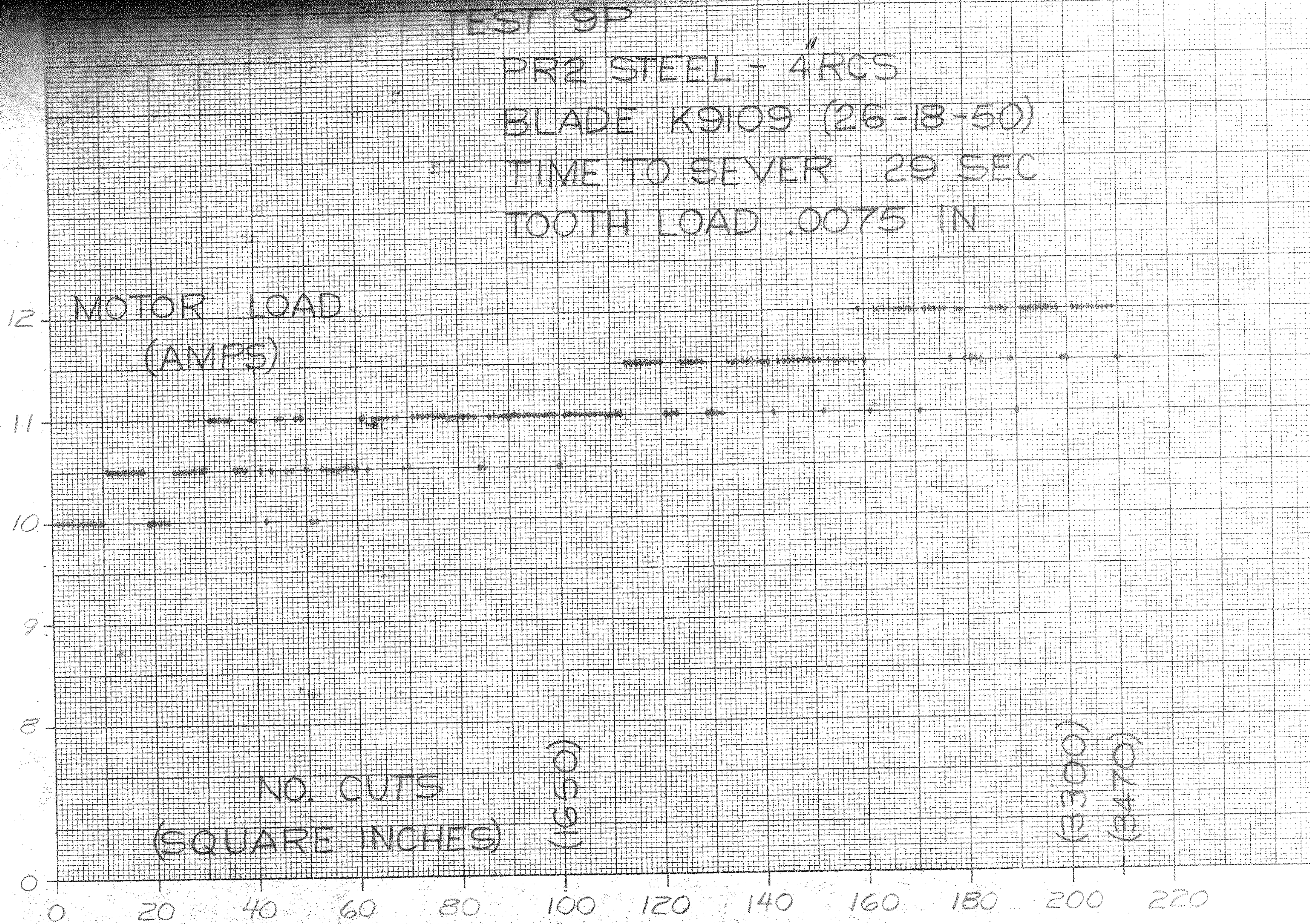
MOTOR LOAD
(AMPS)
M8096
(OUT-OF-ROUND BEFORE TEST)
B9108
(UNSHARPENED-USED PREVIOUSLY ON TEST 913)
NO. CUTS
(SQUARE INCHES)
(3,500)
(7000)
(10,500)
24 25 26 27 28 29 30 31 32 33 34
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360



ST 10
1561 STEEL - 6" RCS (SCRANTON PROD)
BLADES (3 AS SHOWN - ALL 26-18-60)
TIME TO SEVER 33 SEC
TOOTH LOAD .007 IN
M8094
(STILL USABLE AT END OF T
REFER TEST 12)
(14,000)
(17,500)
(21,000)
(22,820)
400
420
440
460
480
500
520
540
600
620
640
660

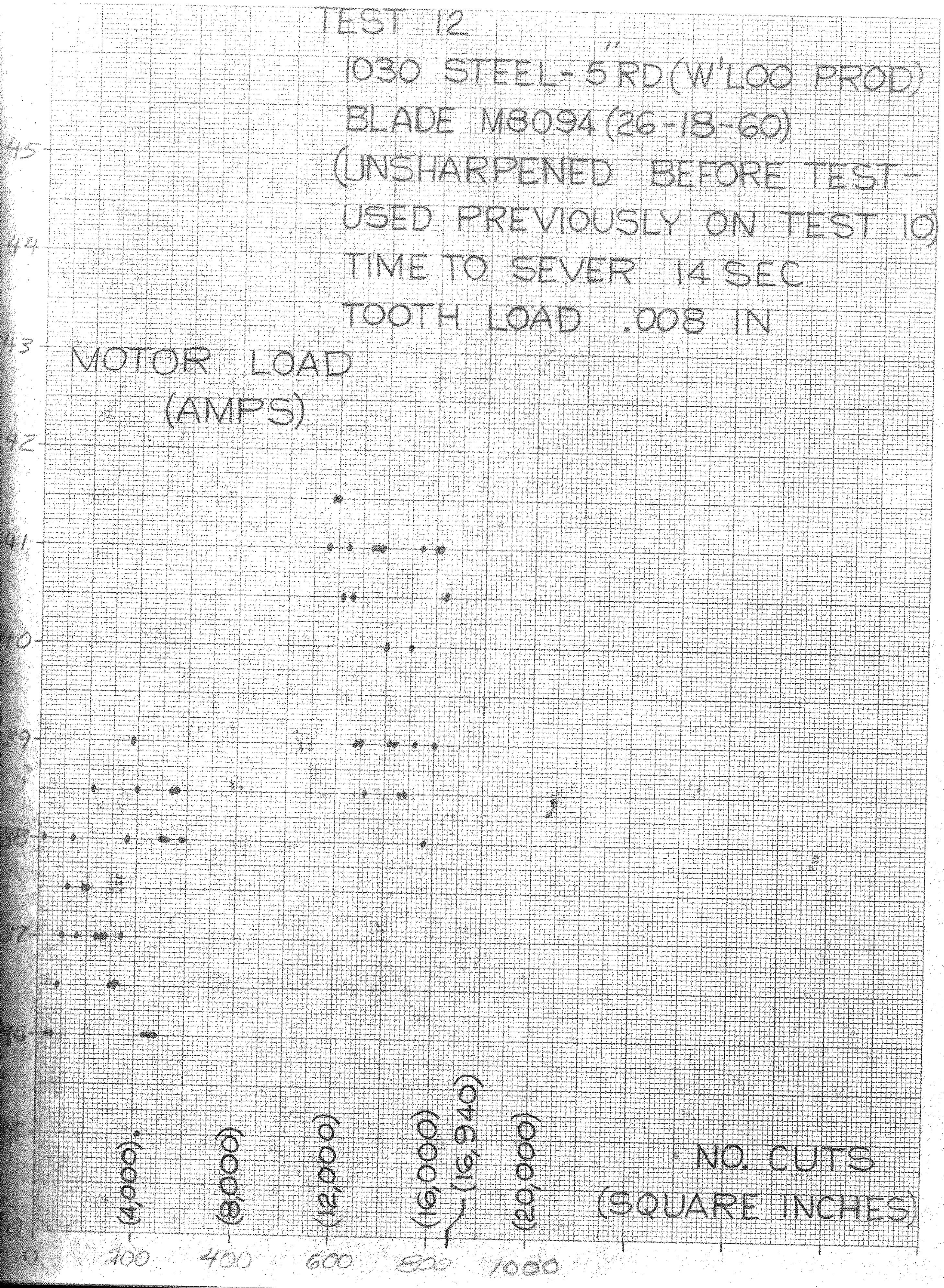

MOTOR LOAD
(AMPS)
21
20
19
18
17
16
15
14
13
TEST 9-13
1340 STEEL - 4" RCS
BLADE B9108 (26-18-60)
TIME TO SEVER 22 SEC
TOOTH LOAD .007 IN.
NO. CUTS
(SQUARE INCHES)
(1650)
(3300)
(4950)
(5610)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
359-14L

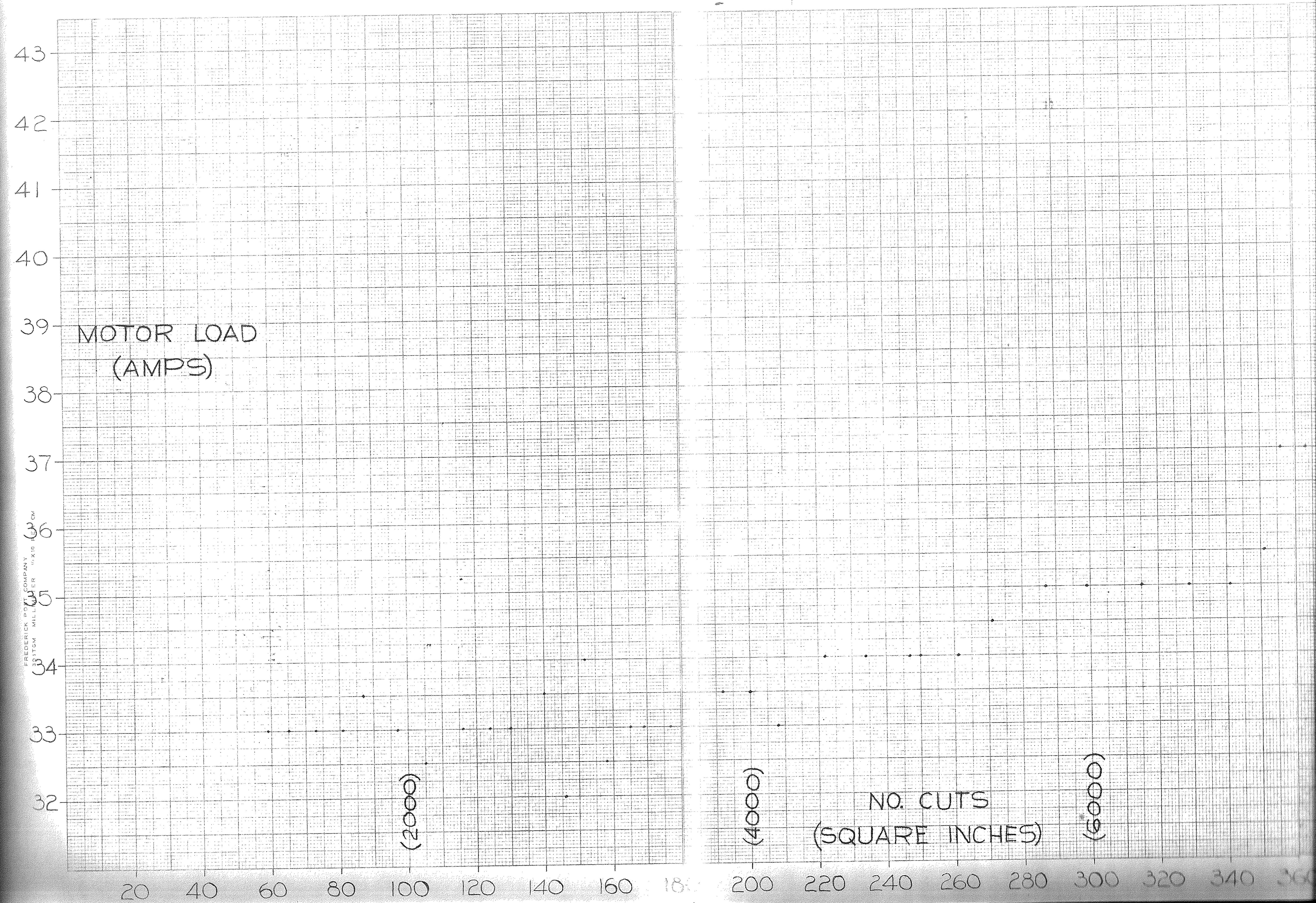

TEST 992
9260 STEEL - 4" RCS
BLADE M8094 (26-18-60)
TIME TO SEVER 25½ SEC
TOOTH LOAD .007 IN
MOTOR LOAD
(AMPS)
22
21
20
19
18
17
16
15
0
NO. CUTS
(SQUARE INCHES)
(650)
0
20
40
60
80
100
TEST 992A
9260 STEEL - 4" RCS
BLADE B9079 (26-15-60)
TIME TO SEVER 22 SEC
TOOTH LOAD .008 IN
NO. CUTS
(SQUARE INCHES)
(1650)
0
20
40
60
80
100

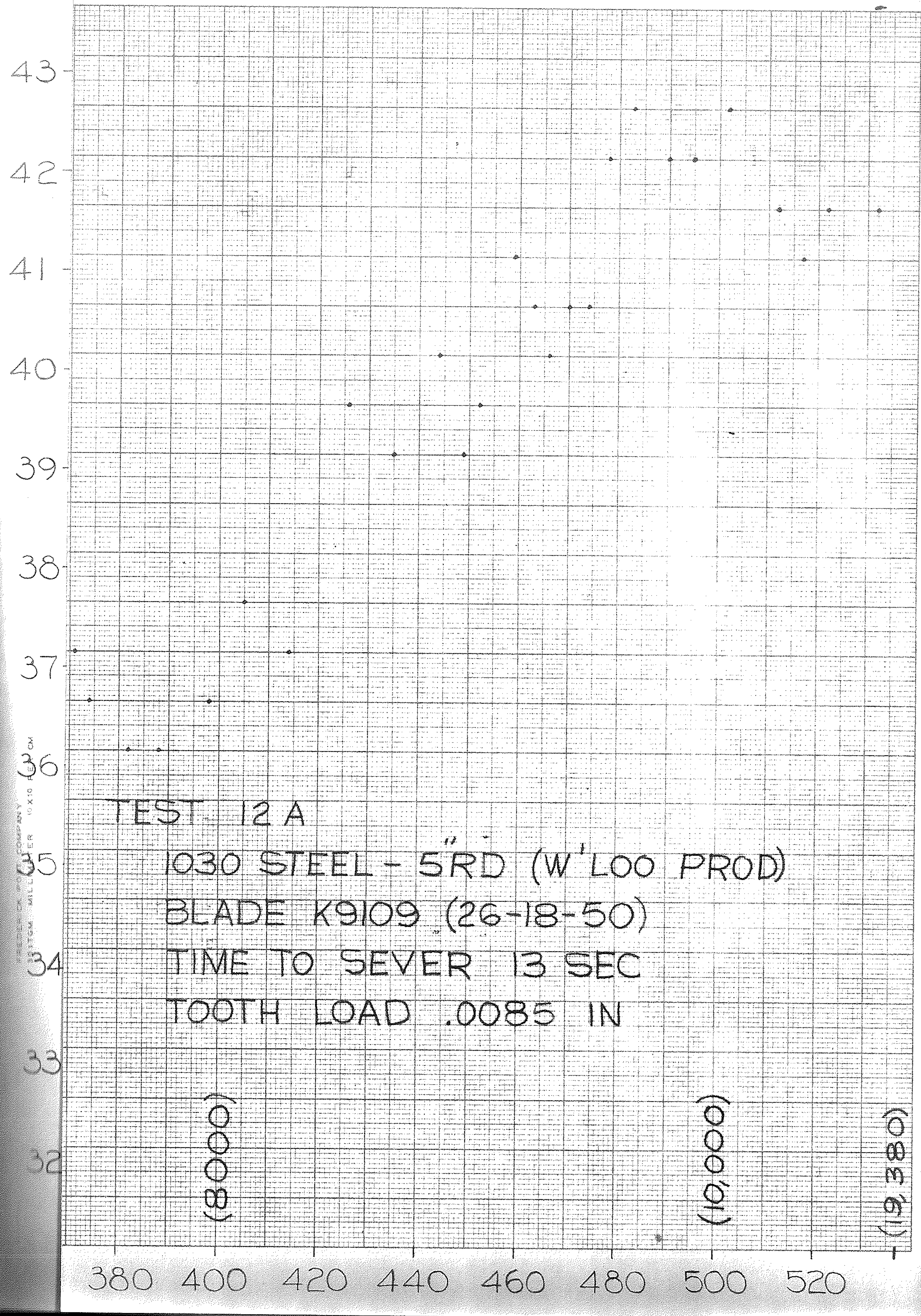


TEST 9P
PR2 STEEL - 4" RCS
BLADE K9109 (26-18-50)
TIME TO SEVER 29 SEC
TOOTH LOAD .0075 IN
MOTOR LOAD
(AMPS)
NO. CUTS
(SQUARE INCHES)
(1650)
(3300)
(3470)
12
11
10
9
8
0
0
20
40
60
80
100
120
140
160
180
200
220

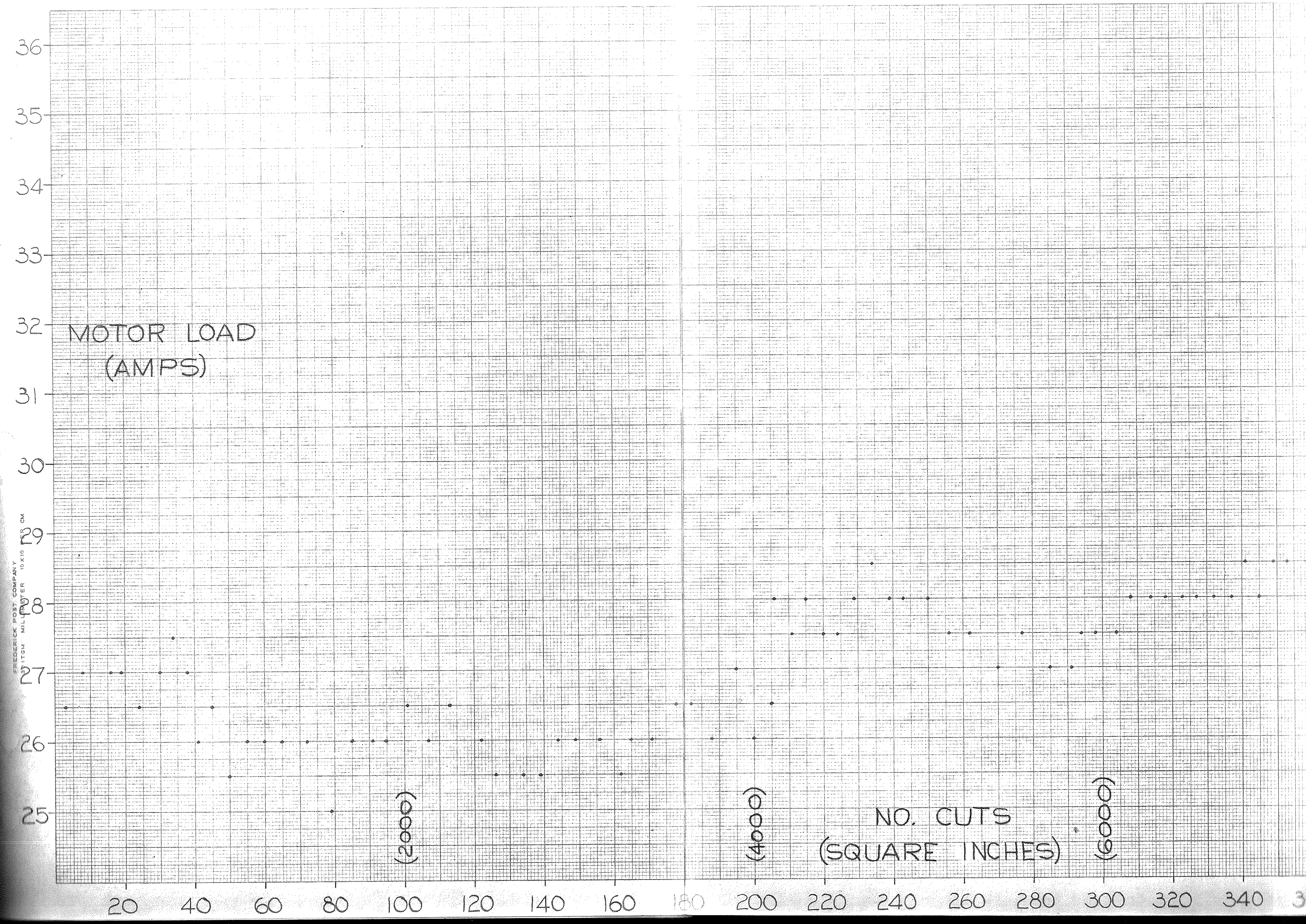

MOTOR LOAD
(AMPS)
NO. CUTS
(SQUARE INCHES)
(1,650)
(3,300)
(4,950)
(6,600)
(9,900)
(11,550)
(13,200)
(14,850)
(16,500)
(18,150)
(19,800)
(20,060)
TEST 11
1030 STEEL-4" RCS
BLADE L9066 (26-18-50)
TIME TO SEVER 11 SEC
TOOTH LOAD .009 IN

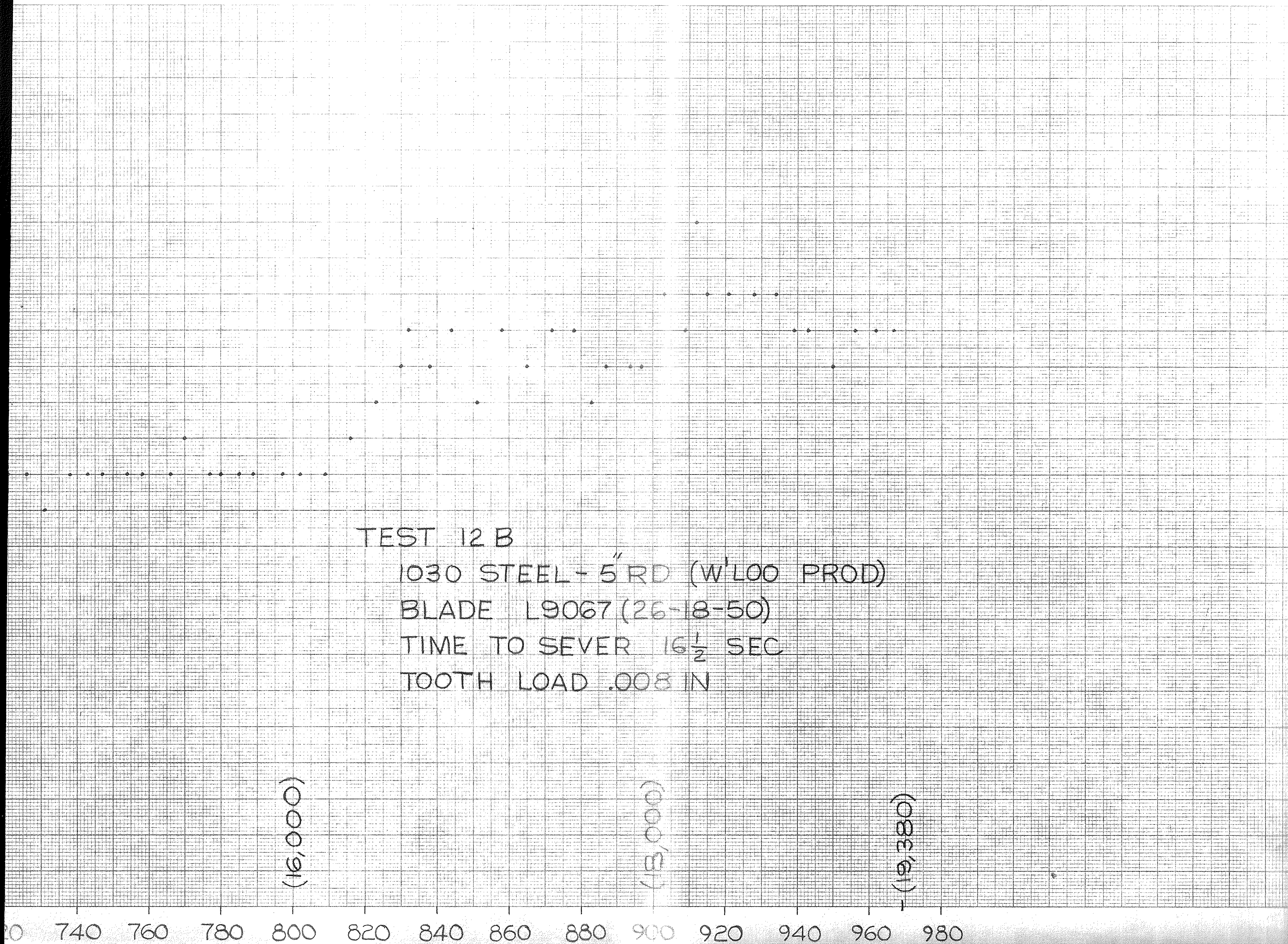

TEST 12
1030 STEEL - 5" RD (W'LOO PROD)
BLADE M8094 (26-18-60)
(UNSHARPENED BEFORE TEST - USED PREVIOUSLY ON TEST 10)
TIME TO SEVER 14 SEC
TOOTH LOAD .008 IN
MOTOR LOAD (AMPS)
45
44
43
42
41
40
39
38
37
36
NO. CUTS (SQUARE INCHES)
(4,000)
(8,000)
(12,000)
(16,000)
(16,940)
(20,000)
0
200
400
600
800
1000


MOTOR LOAD
(AMPS)
43
42
41
40
39
38
37
36
35
34
33
32
NO. CUTS
(SQUARE INCHES)
(2000)
(4000)
(6000)
20
40
60
80
100
120
140
160
200
220
240
260
280
300
320
340



43
42
41
40
39
38
37
36
35
34
33
32
TEST 12 A
1030 STEEL - 5"RD (W'LOO PROD)
BLADE K9109 (26-18-50)
TIME TO SEVER 13 SEC
TOOTH LOAD .0085 IN
(8000)
(10,000)
(19,380)
380
400
420
440
460
480
500
520


MOTOR LOAD
(AMPS)
NO. CUTS
(SQUARE INCHES)
(2000)
(4000)
(6000)
36
35
34
33
32
31
30
29
28
27
26
25
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340



TEST 12 B
1030 STEEL - 5" RD (W'LOO PROD)
BLADE L9067 (26-18-50)
TIME TO SEVER 16 1/2 SEC
TOOTH LOAD .008 IN
(16,000)
(18,000)
(19,380)
740 760 780 800 820 840 860 880 900 920 940 960 980

APPENDIX C

WAFER THICKNESS DATA

DATA SHEET

WAFER THICKNESS

INSPECTOR: C. Ham

TEST NO.: 3a DATE: 24 Feb 1970

WAFER NO.	0° (TOP)	180° (BOTTOM)	90° (ENTRANCE)	270° (EXIT)	MAXIMUM DEVIATION	
10	.573	.5745	.570	.572	.0045	
20	.573	.5825	.5715	.5825	.011	
30	.566	.573	.574	.564	.010	
40	.538	.5365	.539	.537	.0025	
50	.557	.556	.5495	.5615	.012	
60	.568	.572	.5735	.5675	.006	
70	.568	.571	.5685	.5745	.0055	
80	.5435	.543	.546	.5445	.003	
90	.536	.5365	.536	.538	.003	
100	.551	.5555	.5465	.555	.009	
110	.517	.522	.506	.527	.021	
120	.463	.461	.466	.465	.005	
130	.5305	.5285	.537	.5305	.0085	
140	.536	.540	.5315	.540	.0085	
150	.543	.546	.535	.5475	.0125	
160	.546	.5495	.5425	.5535	.011	
170	.541	.547	.5415	.543	.006	
180	.540	.538	.538	.541	.003	
190	.541	.539	.546	.542	.007	
200	.5335	.532	.540	.532	.008	
210	.538	.535	.5415	.530	.0115	
220	.5415	.539	.548	.532	.016	
230	.558	.5545	.5325	.5485	.0255	
240	.556	.5555	.551	.5565	.0155	
250	.525	.5335	.531	.534	.009	
260	.546	.5495	.539	.552	.013	
270	.498	.502	.505	.498	.007	
280	.485	.481	.490	.482	.009	
290	.562	.5695	.551	.577	.026	
300	.541	.531	.5405	.532	.010	
310	.464	.465	.460	.4645	.005	
320	.553	.557	.545	.562	.017	
330	.442	.4695	.4405	.475	.0345	
340	.515	.5135	.5135	.517	.0035	
350	.4765	.470	.485	.470	.015	
360	.456	.449	.466	.4495	.017	
370	.4755	.4765	.467	.485	.018	
380	.498	.4915	.4985	.4925	.007	
390	.4725	.474	.480	.4705	.0095	
400	.498	.519	.507	.5235	.0255	
410	.500	.498	.514	.497	.017	
	.52599	.5277	.513	.5403	.01143	Mean
	.04701	.0548	.061	.0422	--	Dev. to Max.
	.08399	.0787	.0725	.0908	--	Dev. to Min.

DATA SHEET

WAFER THICKNESS

INSPECTOR: C. Ham

TEST NO.: 5b DATE: 24 Feb 1970

WAFER NO.	0° (TOP)	180° (BOTTOM)	90° (ENTRANCE)	270° (EXIT)	MAXIMUM DEVIATION	
10	.515	.513	.516	.5125	.0035	
20	.539	.5515	.5285	.550	.023	
30	.4295	.431	.432	.431	.0025	
40	.439	.439	.440	.439	.001	
50	.490	.485	.475	.4835	.015	
60	.5235	.5225	.523	.525	.0025	
70	.521	.5235	.5235	.524	.003	
80	.5355	.5335	.535	.538	.0045	
90	.498	.496	.496	.4945	.0035	
100	.5825	.585	.5525	.620	.0675	
110	.525	.5235	.523	.526	.003	
120	.440	.439	.4375	.441	.0035	
130	.475	.474	.4745	.472	.003	
140	.5515	.5475	.549	.548	.004	
150	.520	.5205	.521	.5205	.001	
160	.4965	.4945	.4945	.497	.0025	
170	.4865	.4835	.489	.479	.010	
180	.5125	.514	.513	.518	.0055	
190	.5035	.5035	.5035	.504	.0005	
200	.5395	.5395	.5385	.5395	.001	
210	.547	.5455	.5465	.545	.002	
220	.493	.490	.501	.482	.019	
230	.497	.4975	.4965	.500	.0035	
240	.510	.5095	.509	.5125	.0035	
250	.4605	.458	.4595	.460	.0025	
260	.426	.4285	.4275	.427	.0025	
270	.4055	.406	.406	.408	.0025	
280	.436	.4355	.434	.442	.008	
290	.4755	.4755	.4715	.4835	.012	
300	.4455	.4445	.449	.441	.008	
310	.412	.413	.413	.4115	.003	
320	.427	.4265	.425	.437	.012	
330	.4295	.430	.4295	.430	.0005	
340	.4495	.4525	.451	.4565	.007	
350	.4255	.424	.4265	.424	.0025	
	.48464	.48445	.48315	.48635	.0071	Mean
	.09786	.10055	.06935	.13365	--	Dev. to Max.
	.07914	.07845	.07715	.07835	--	Dev. to Min.

DATA SHEET

WAFER THICKNESS

INSPECTOR: C. Ham

TEST NO.: 9-13 DATE: 24 Feb 1970

WAFER NO.	0° (TOP)	180° (BOTTOM)	90° (ENTRANCE)	270° (EXIT)	MAXIMUM DEVIATION	
10	.445	.443	.4425	.4435	.0025	
20	.5865	.588	.588	.587	.0015	
30	.5925	.589	.595	.5875	.0175	
40	.547	.5465	.550	.544	.006	
50	.534	.5315	.532	.535	.0035	
60	.5325	.532	.530	.532	.0025	
70	.557	.557	.558	.5575	.001	
80	.550	.5505	.551	.549	.002	
90	.575	.578	.572	.578	.006	
100	.5695	.568	.568	.5705	.0025	
110	.551	.550	.548	.551	.003	
120	.560	.5605	.559	.5605	.0015	
130	.5655	.5655	.5605	.567	.0065	
140	.5445	.5435	.549	.539	.010	
150	.570	.573	.570	.5745	.0045	
160	.4655	.480	.4735	.471	.0145	
170	.402	.402	.4015	.4005	.0015	
180	.558	.558	.559	.557	.002	
190	.341	.343	.343	.342	.002	
200	.511	.513	.512	.5115	.002	
210	.5105	.511	.5125	.5095	.003	
220	.5045	.507	.5075	.505	.003	
230	.530	.5285	.535	.5295	.0055	
240	.529	.528	.529	.529	.001	
250	.4705	.475	.472	.473	.0045	
260	.405	.4025	.4035	.405	.0025	
270	.4175	.419	.420	.4155	.0045	
280	.5365	.541	.541	.537	.0045	
290	.556	.556	.5615	.552	.009	
300	.537	.533	.537	.534	.004	
310	.5945	.605	.5995	.600	.0105	
320	.620	.613	.618	.615	.007	
330	.599	.568	.5735	.5835	.031	
340	.649	.614	.621	.640	.035	
	.51343	.5286	.5292	.529	.00639	Mean
	.13557	.0854	.0918	.111	--	Dev. to Max.
	.17243	.1856	.1862	.187	--	Dev. to Min.

APPENDIX D

HARDNESS DATA SHEETS

(VARIATION ALONG TEST BAR)

HARDNESS DATA SHEET

(Longitudinal Variation Along Bar - Every 20 Wafers)

Sample No. (Test & Wafer)	Scale R "B"	(T & W)	R "B"	(T & W)	R "B"
1 - 20	91/94	1a - 20	91/92	3a - 20	92/92
40	91/95	40	92/93	40	92/95
60	91/93	60	94/95	60	92/95
80	90/93	80	92/93	80	93/94
100	90/92	100	90/93	100	94/94
120	91/92	120	91/91	120	92/92
140	89/90	140	93/93	140	91/93
160	93/95	160	90/91	160	94/92
180	89/90	180	90/91	180	92/92
200	92/93	200	92/93	200	95/95
		220	91/93	220	94/92
2 - 20	90/91	240	91/91	240	95/94
40	90/91	260	94/94	260	96/94
60	94/94	280	91/92	280	94/92
80	90/91			300	94/93
100	92/93	2a - 20	92/95	320	93/92
120	92/95	40	90/91	340	91/91
140	91/96	60	94/94	360	95/93
160	91/95	80	90/91	380	95/95
180	90/93	100	92/93	400	94/93
200	92/93	120	94/95	420	94/94
		140	93/94		
3 - 20	91/92	160	95/95	4a - 20	91/92
40	90/91	180	93/95	40	94/92
60	92/95	200	93/94	60	93/93
		220	92/95	80	94/92
4 - 20	95/95	240	92/95	100	92/92
40	95/97	260	92/92	120	94/93
60	96/97	280	93/95	140	94/94
80	96/96			160	91/91
				180	95/95
				200	92/91

CALCULATION SHEET

Cont. (T & W)	R "B"	(T & W)	R "B"	Cont. (T & W)	R "B"	
220	92/95	20 - 20	92/92	180	99/97	
240	93/91	40	91/93	200	95/95	
260	92/92	60	90/91	220	97/98	
280	94/94	80	90/91	240	99/99	
300	94/93	100	92/95	260	98/97	
320	94/93	120	94/95	280	98/98	
340	95/95	140	92/93	300	97/96	
360	95/93	160	93/93	320	98/96	
380	93/92	180	93/94	340	97/95	
		200	92/93			
6 - 20	94/95			7 - 20	98/97	
40	94/94	21 - 20	96/96	40	99/99	
60	94/95	40	96/94	60	99/98	
80	94/95	60	98/94	80	99/98	
100	94/95	80	105/103	100	98/97	
120	94/95	100	94/94	120	97/96	
140	93/93	120	107/107	140	93/96	
160	92/94	140	94/93	160	99/96	
180	93/93			180	97/97	
200	92/92	5 - 20	100/98	200	97/94	
220	94/94	40	100/99	220	97/95	
240	93/94	60	100/99	240	97/94	
260	93/95	80	99/99	260	98/97	
280	91/92	100	100/99	280	98/95	
300	94/94			300	97/93	
320	94/95	5b - 20	94/95	320	96/96	
340	92/95	40	98/99	340	99/97	
360	95/96	60	98/95	360	97/97	
380	92/92	80	99/98	380	98/98	
400	90/91	100	99/97	400	97/97	
420	89/92	120	99/98	420	98/97	
440	93/95	140	99/98			
		160	97/97			

CALCULATION SHEET

0344

(T & W)	R "B"	(T & W)	R "C"	(T & W)	R "B"	
30 - 20	99/99	9P - 20	30/29	913 - 20	96/97	
40	99/99	40	31/31	40	94/97	
60	99/99	60	30/31	60	96/97	
80	98/97	80	30/31	80	94/96	
100	99/98	100	33/32	100	95/97	
120	99/99	120	30/30	120	95/95	
140	98/97	140	31/31	140	96/96	
160	103/103	160	31/31	160	97/99	
180	98/97	180	30/30	180	98/99	
200	99/99	200	30/32	200	95/97	
220	99/96			220	94/97	
240	102/99	992 - 20	31/32	240	95/99	
260	99/99	40	33/34	260	94/98	
280	99/98	60	34/34	280	92/95	
300	98/97	80	33/32	300	95/95	
320	100/99	100	32/32	320	95/97	
340	99/96			340	94/96	
360	96/95	992a - 20	33/35			
380	96/95	40	32/33			
400	100/99	60	35/36			
420	99/98	80	32/32			
440		100	33/35			
460	99/96					
480	98/97					
500	98/97					
520	99/98					
540	100/99					

CALCULATION SHEET

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