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NO. 13010

FATIGUE MEASUREMENT

FOR

REMAINING LIFE

SEPTEMBER 1984

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Work reported was for the eight-month period of Apr 1983 thru Nov 1983. The objective was to follow track pin surface residual stress as a function of fatigue test cycles. Twenty pins were selected from a group of 250 new T-142 track pins for this test. They were selected on the basis of being representative of pins having median values of surface residual stress as received from the shot peening operation in manufacturing. Residual stress measurements were made in both the longitudinal direction and hoop/transverse direction at three spots on each pin. The spots were at areas most likely to develop cracking and

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eventual failure. The equipment used for residual stress measurement was automated X-ray diffraction equipment. Surface residual stress was found to remain virtually unchanged throughout the entire two million cycles of fatigue testing. Pins failing prior to the two million cycle test limit displayed no residual stress indication that failure was eminent.

PREFACE

This work was funded under the FY83 Materials Testing Technology (MTT) Program as received from Army Materials and Mechanics Research Center (AMMRC).

Appreciation is offered for the opportunity of working on this challenging project. Acknowledgements are extended to Mr. C.E. Lynn, Process Engineer at the Goodyear Tire & Rubber Company, St. Marys, OH for expeditious and careful selection and shot peening of test track pins used in this study.
Mr. Sylvester T. Allen is to be especially thanked for his diligent help with X-ray diffraction measurement of residual stresses. Mr. John Zolling is to be thanked for his expeditious performance of fatigue testing project track pins.

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1.0. INTRODUCTION

Residual stresses are induced in components during manufacturing processes (e.g., heat treatment, machining, welding, casting and other metal working processes) and during in-service fatiguing. These stresses can be of an undesirable nature, concentration, or level adversely affecting functional performance and durability. Cumulative high dynamic and residual stresses may exceed design load limits of the parts. X-ray diffraction is capable of measuring residual stresses nondestructively. With automated X-ray diffraction equipment, measurements can be made with exposure times as short as a half minute.

The work reported herein was motivated by the desire to establish a nondestructive means of measurement of degree of fatigue/remaining life of component parts, thus establishing part replacement based on cause rather than by procedural schedule. These measurements were expected to aid in streamlining rebuild procedures by determining worthiness of used components. Components found to have adequate remaining fatigue life were to be reused while others were discarded.

2.0. OBJECTIVE

The component selected for this effort was the T-142 track pin used on the M-60 Tank. The objective of this work was to follow track pin fatiguing with measurements of surface residual stress in an attempt to:

- Correlate fatigue life with surface residual stress.
- Estimate remaining useful life of component parts.

3.0. CONCLUSION

On the T-142 track pin (as presently configured and manufactured), surface residual stresses attributable to fatigue remain virtually constant throughout the useable life of the pin, if surface residual stress does change prior to failure, its change occurs too late and is too precipitous to be used as a cost effective indicator of remaining life of the pin.

4.0. RECOMMENDATION

No recommendations are presented in this report.

5.0. DISCUSSION

A total of 20 T-142 track pins (Fig. 4-1) were randomly selected for this project from 180 pins that were in the central cell of a histogram plot, (Fig. 4-2) of longitudinal residual stresses measured on 250 freshly shot peened T-142 track pins. The pins were shot peened at Goodyear Tire and

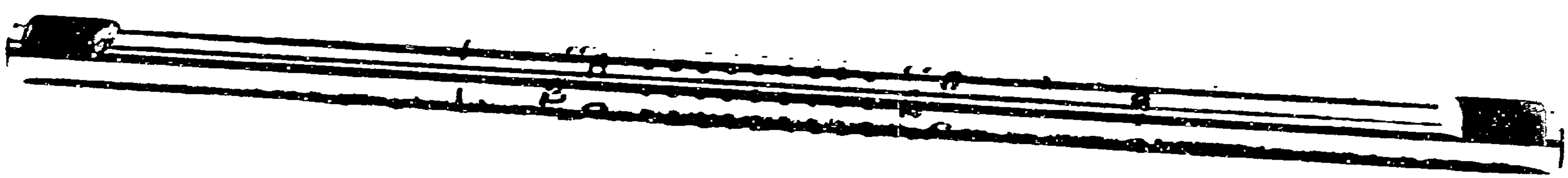


FIGURE 4—1 PHOTOGRAPH OF A T-142 TRACK PIN

250 T-142 TRACK PINS
SHOT PEENED AT GOODYEAR

H I S T O G R A M

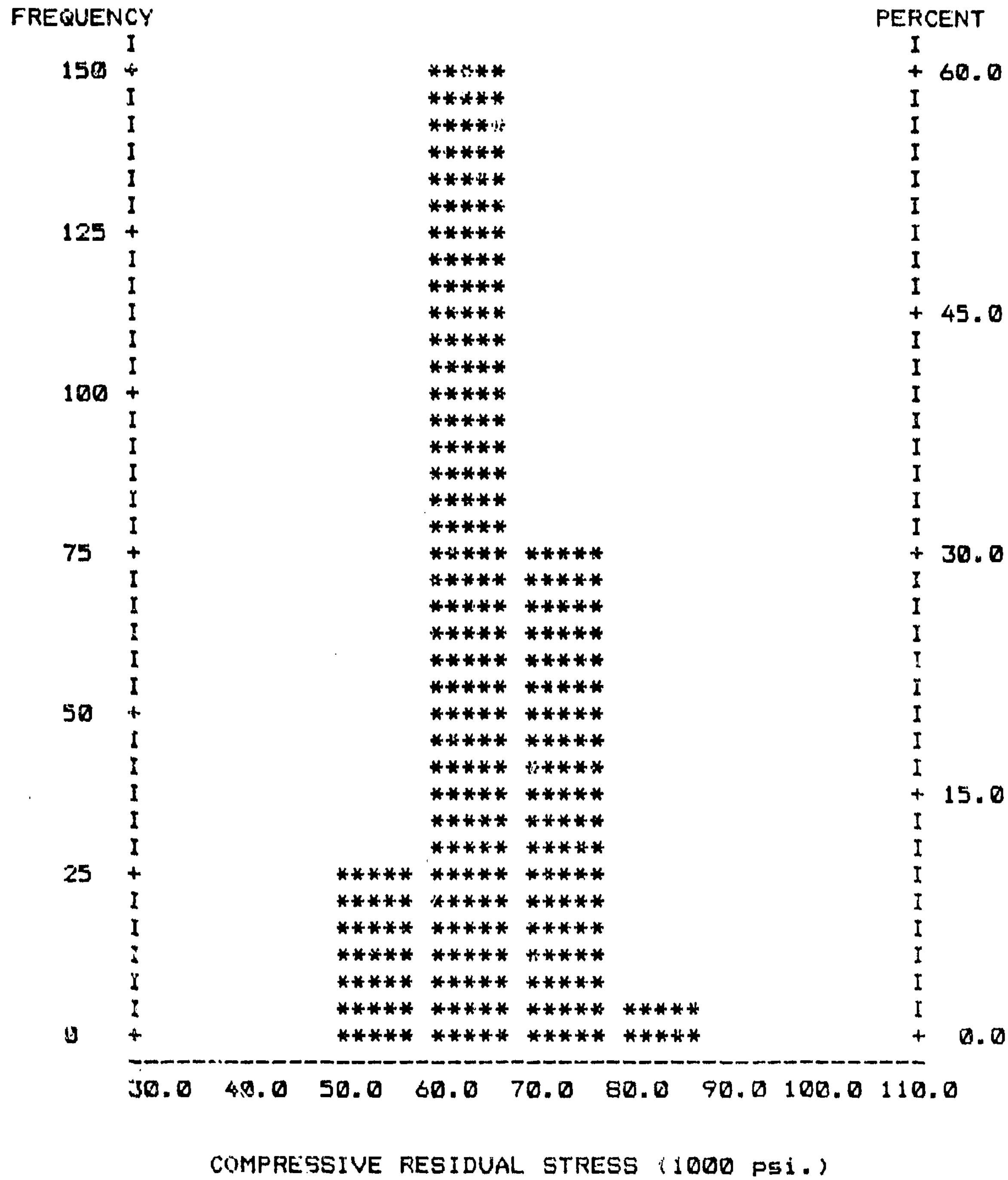


FIGURE 4—2 RESIDUAL STRESS DISTRIBUTION (LONGITUDINAL DIRECTION) OF 250 FRESHLY SHOT-PEENED T-142 TRACK PINS

Rubber Company, St. Marys, OH on equipment manufactured by Wheelabrator. Residual stress measurements were made at TACOM using automated X-ray diffraction (AXRD) equipment manufactured by American Analytical Corporation, Grafton, OH, (Fig. 4-3). The residual stress measurement technique/method used was the X-ray diffraction method as described in SAE Technical Report No. 182.

Fatigue testing was performed at TACOM on a Baldwin Vibration table. Histogram plots were made on Hewlett-Packard computer Model #9830A with #9866A printer and #9862A plotter peripherals.

The approach taken in this effort was to apply the standard two million cycle acceptance fatigue test used by TACOM (AMSTA-RCKT) for T-142 track pins. Testing was performed in quarter-million cycle segments and residual stress measurements were made after each segment of testing. The results were plotted on residual stress vs. fatigue cycle coordinates and are shown in figures 4-4 thru 4-23. Fatigue testing consisted of supporting the pins at two points, 19 inches apart on centers, and centrally loading the pin with a static load of 3,215.4 pounds and a dynamic load of 2900 pounds. These gave a maximum applied tensile stress of 150,000 psi on the bottom surface of the pin.

The work effort was designed to determine whether any relationship/correlation existed between residual stress level (as measured on the surface of the track pin after increments/segments of fatigue testing) and number of fatigue cycles endured, and whether such a relationship was gradual over time. If the relationship was precipitous (i.e., residual stress changes occur rapidly, just prior to failure) then this work effort would not find that relationship. Since residual stress measurements were taken only after each quarter-million cycle increment, only residual stress fluctuations that occur over periods of quarter-million cycles or longer were detected. Fewer test cycles per test segment were not used to follow precipitous failures because this type of information would provide only very short term guarantee of usefulness of tested component. A longer term guarantee of component usefulness (remaining life) was sought in this work since it is more useful and cost effective for the Army.

The spots chosen to X-ray for residual stress level measurement were those most likely to show residual stress fluctuations as a function of cyclical fatigue testing. Spots chosen were on the bottom surface (bottom as defined in fatigue testing orientation) where maximum tensile stresses are applied and where fatigue cracking and failure is known to occur in fatigue testing. Three spots were used per pin. One spot was at the center of the length of the pin; the other two spots were one inch on either side of the central spot.

The largest collimator (.060") available for the AXRD was used in the X-ray exit port. The X-ray beam was slightly divergent; the size of the X-ray spot

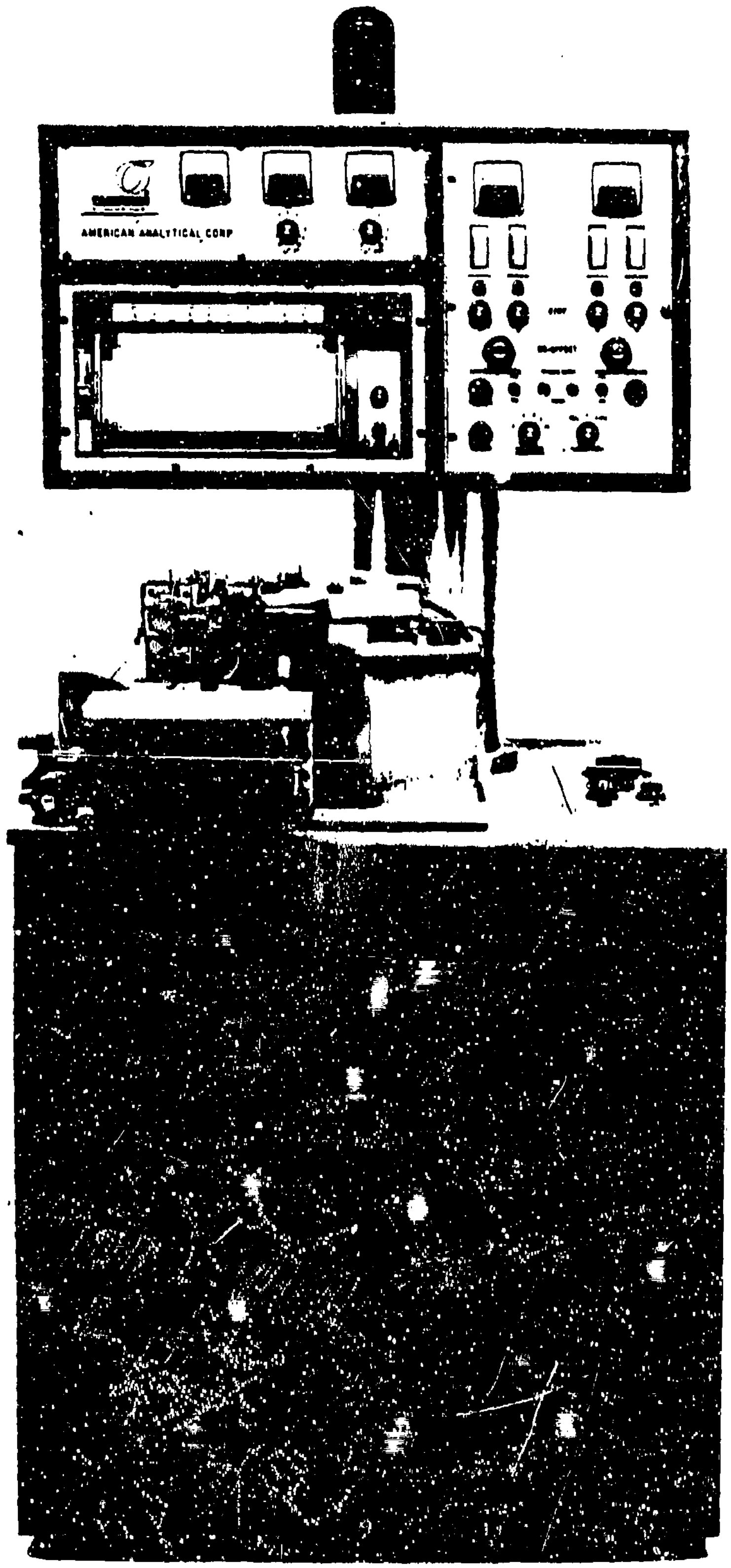


FIGURE 4—3 AUTOMATED X-RAY DIFFRACTION UNIT FOR RAPID MEASUREMENT OF RESIDUAL STRESS

on the track pin was approximately 1/8 - inch. Values of residual stress obtained were valid only for the particular spot X-rayed and only for the surface of the pin including about 0.001" below the surface. There was no surface preparation prior to X-ray. No attempt was made in this effort to follow sub-surface residual stresses by material removal via electro-etching/polishing and subsequent fatigue testing and residual stress measurement. Only nondestructive testing was employed. The X-ray beam did not alter the state of the track pin and was completely nondestructive. The X-ray tube used in this work was a water cooled chromium target tube operated at 30KV and 5mA.

Residual stress has direction as well as magnitude. Measurements were taken in two directions on each track pin at each of the three spots measured: longitudinal direction (i.e., stresses directed along the length of the track pin) and hoop stress direction (i.e., stresses directed circumferentially around the track pin outside diameter).

6.0. RESULTS

Eighteen of the twenty T-142 track pins studied survived the two million cycle fatigue test without fracture or visual indications of cracking. The two remaining pins broke during fatigue testing, failing nearly at the half-way point of the two million cycle test, one breaking after 924,000 cycles and the other after 1,222,000 cycles.

Surface residual stresses (both longitudinal and hoop stresses) remained virtually constant (from beginning of fatigue testing to end) on the eighteen T-142 track pins surviving the two million cycle fatigue test. Likewise, surface residual stresses remained constant on the two pins that broke during fatigue testing from beginning of fatigue testing up to the last measurement taken prior to failure. One pin broke 174,000 cycles after the last residual stress measurement had been taken on it. The other broke 222,000 cycles after the last residual stress measurement had been taken on it. Graphs showing residual stress vs cycles of fatigue testing for each of the twenty test pins are shown in Figures 4-4 thru 4-23.

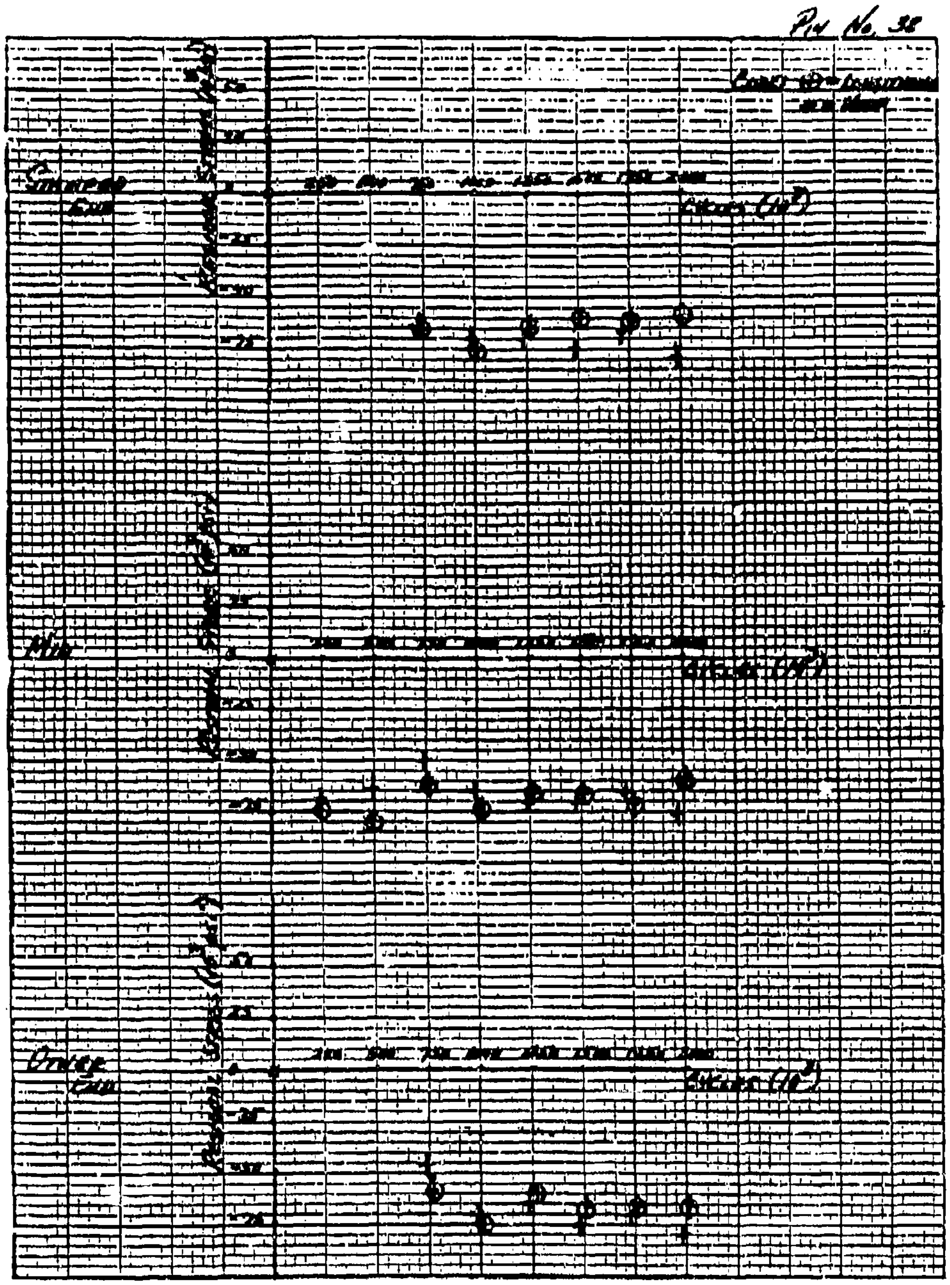
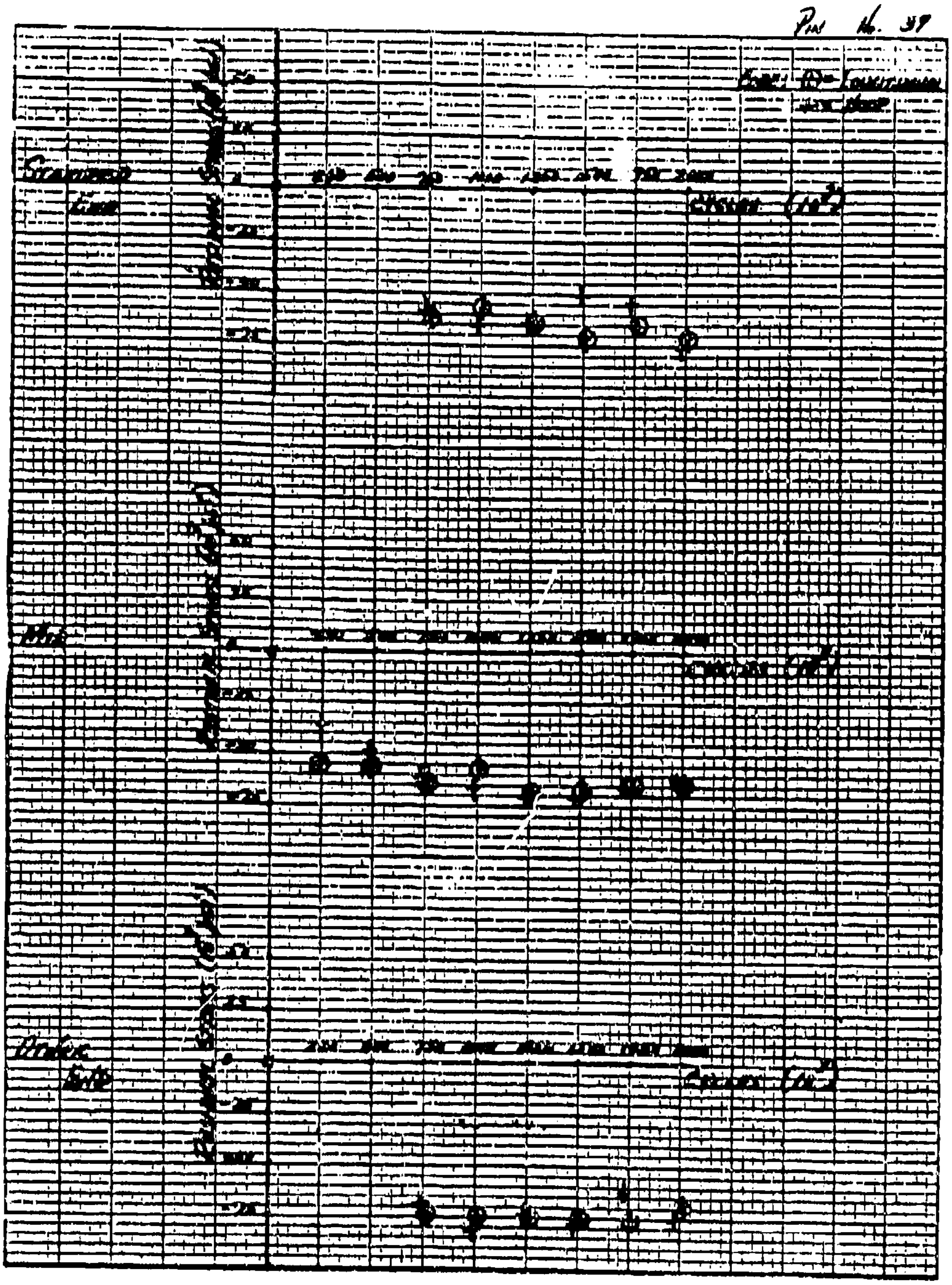


FIGURE 4—4 RESIDUAL STRESS VS. FATIGUE TEST CYCLES (PIN NO. 38).



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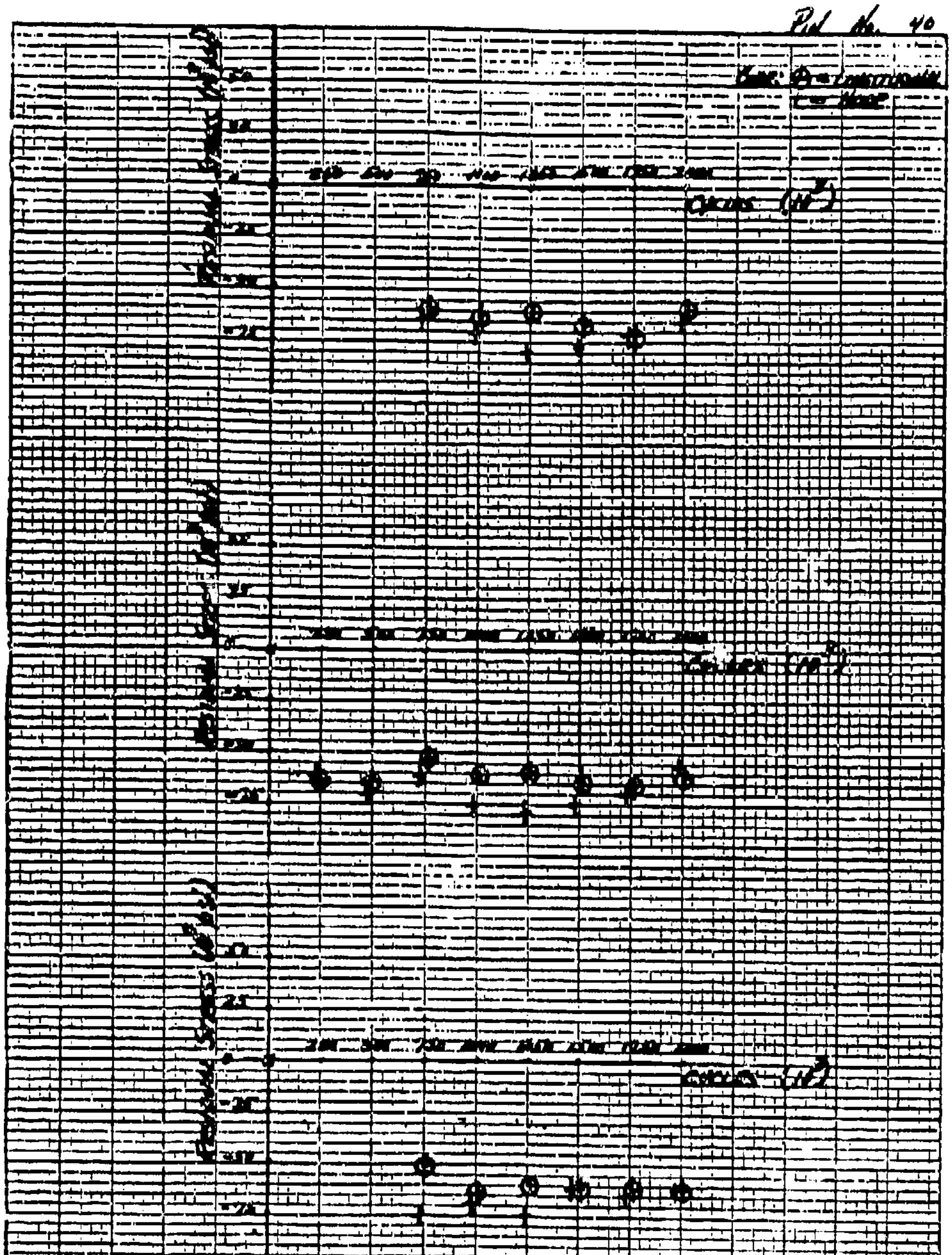

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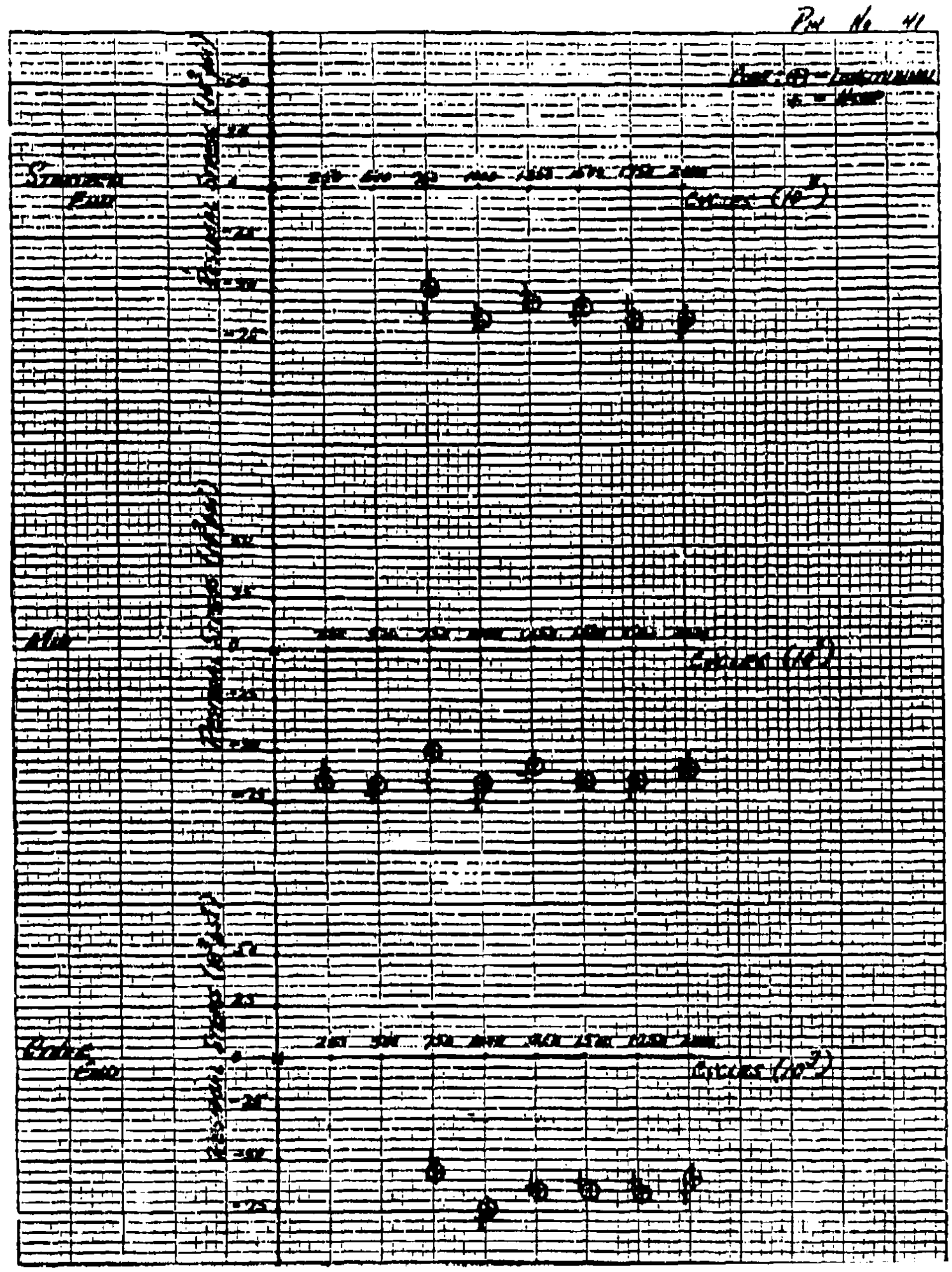

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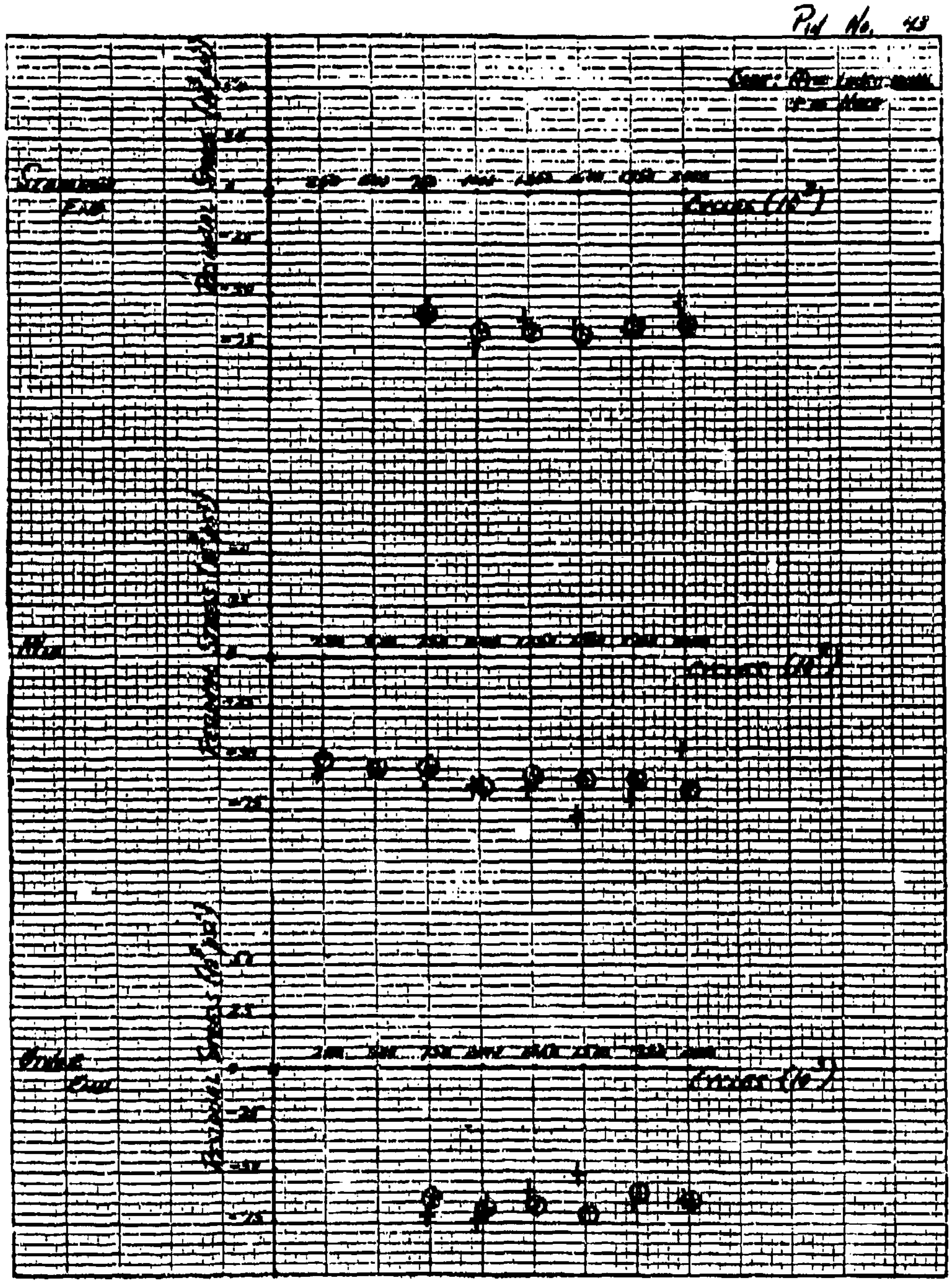

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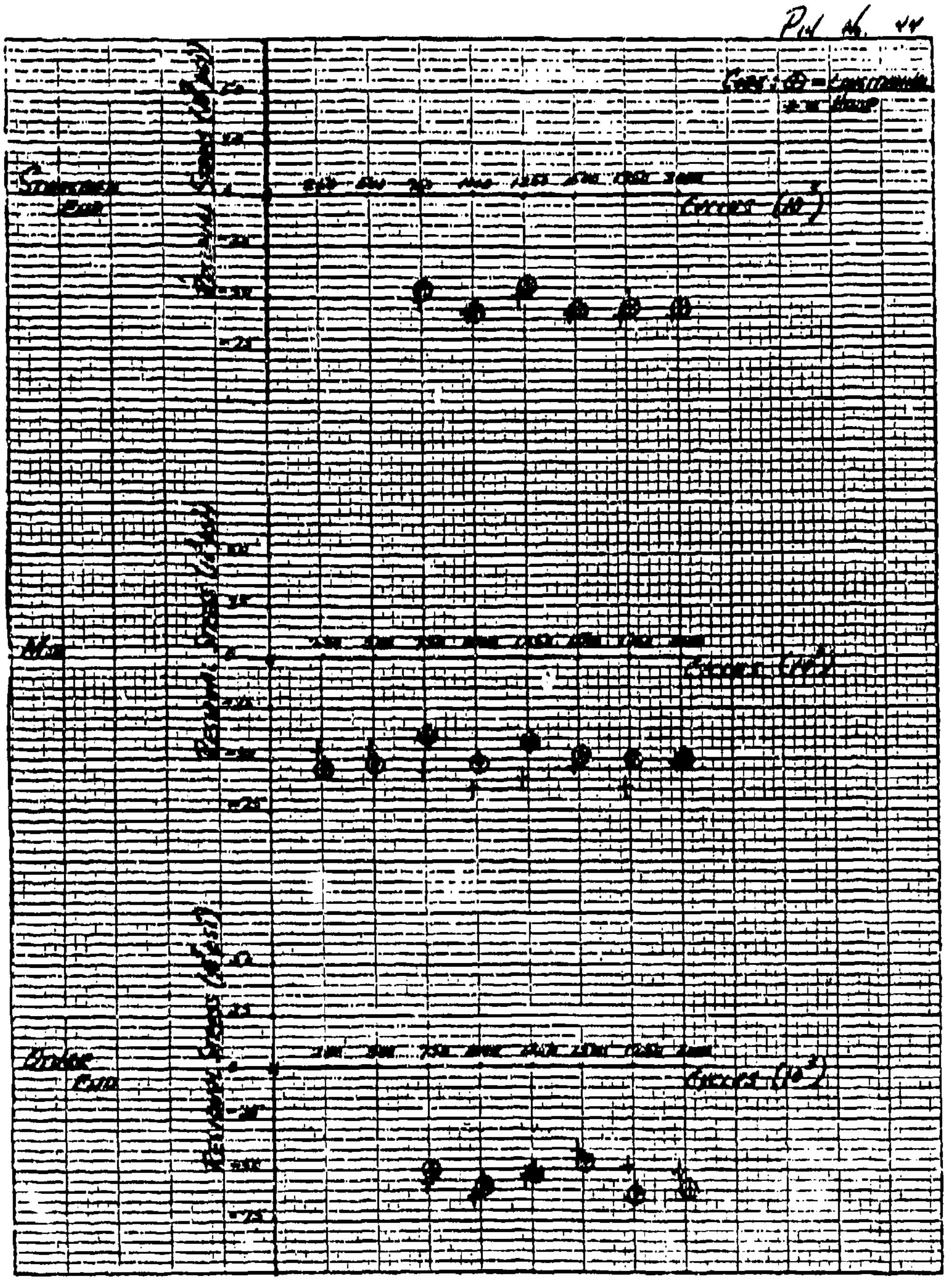

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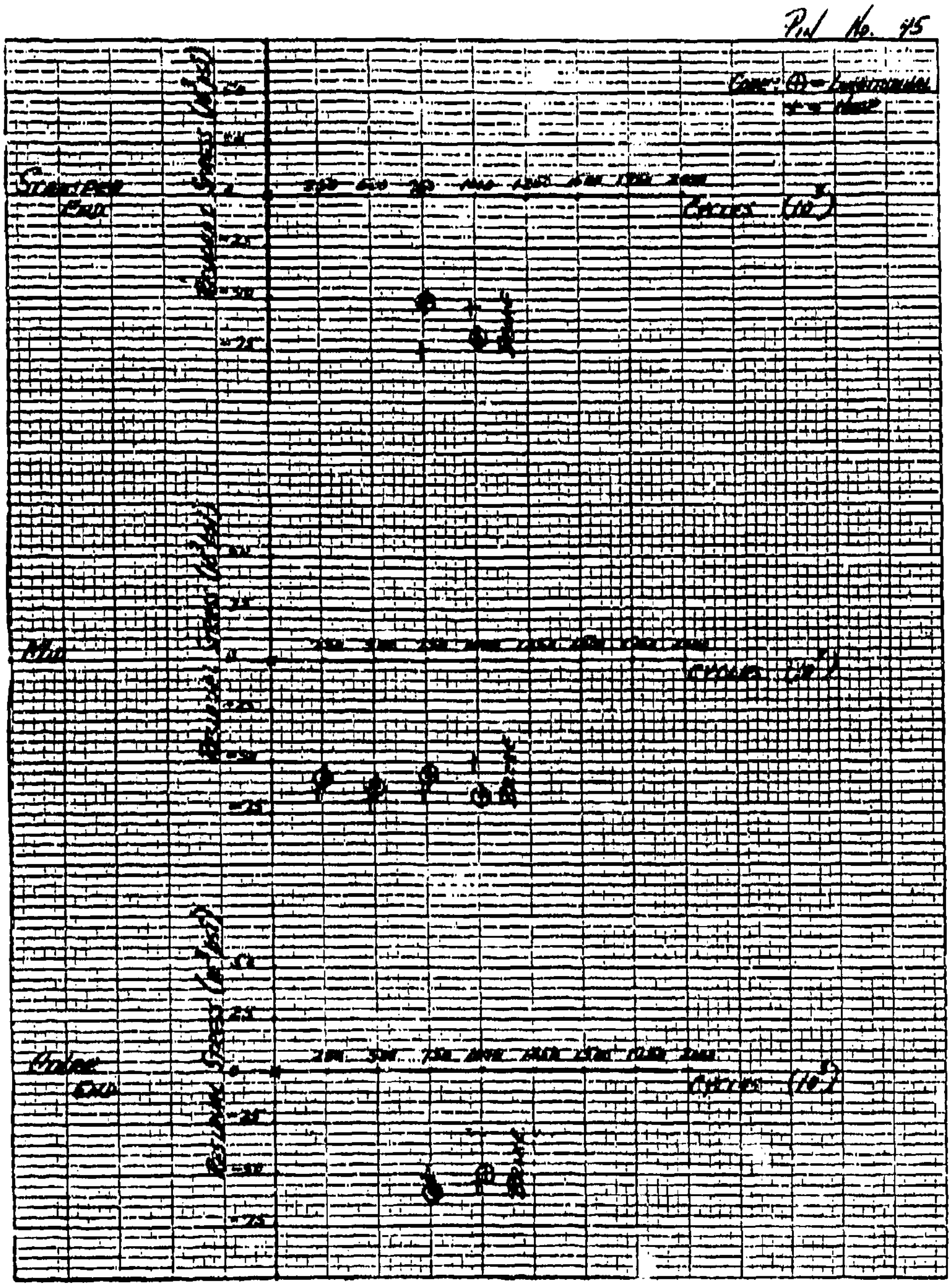

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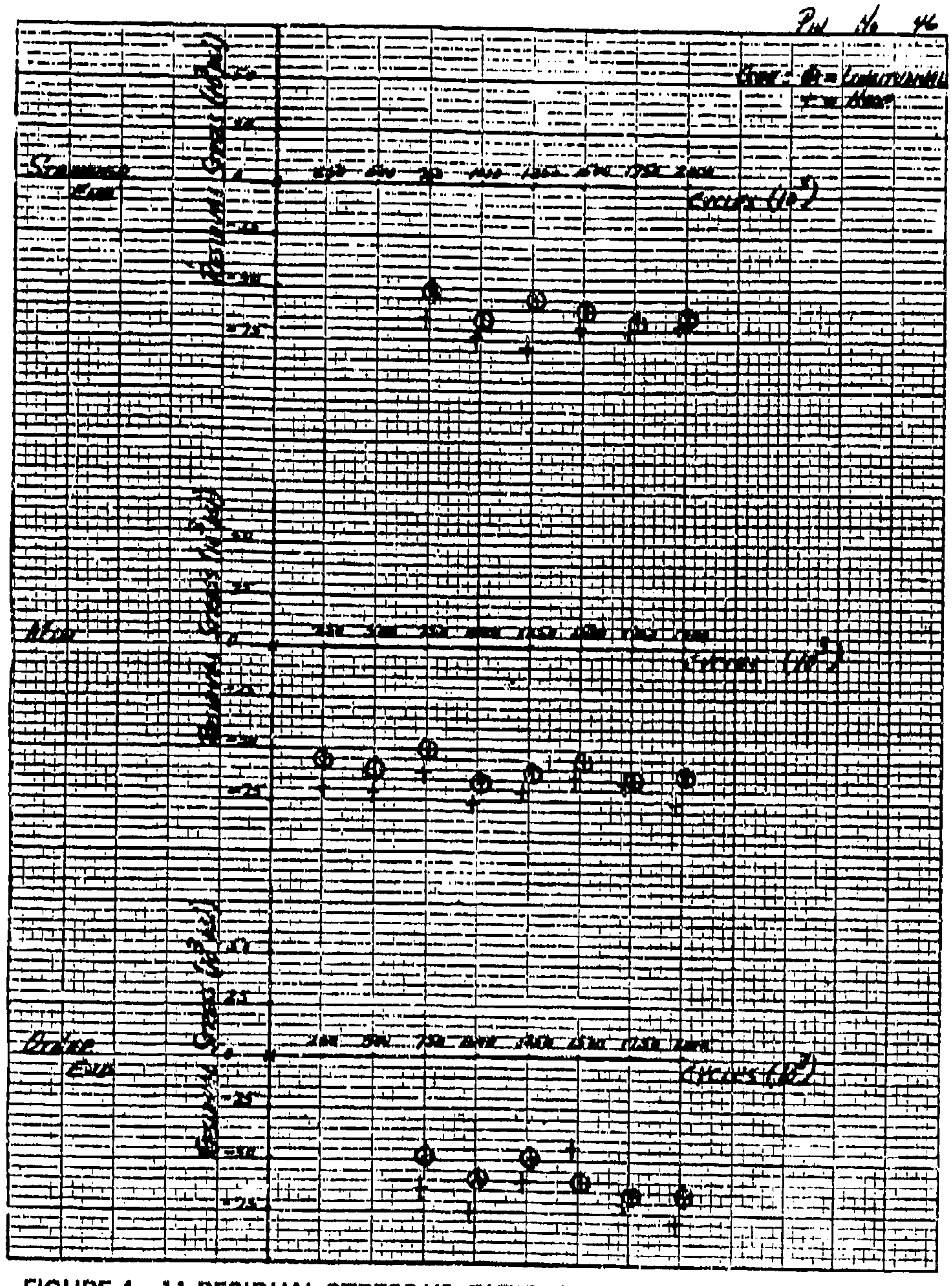

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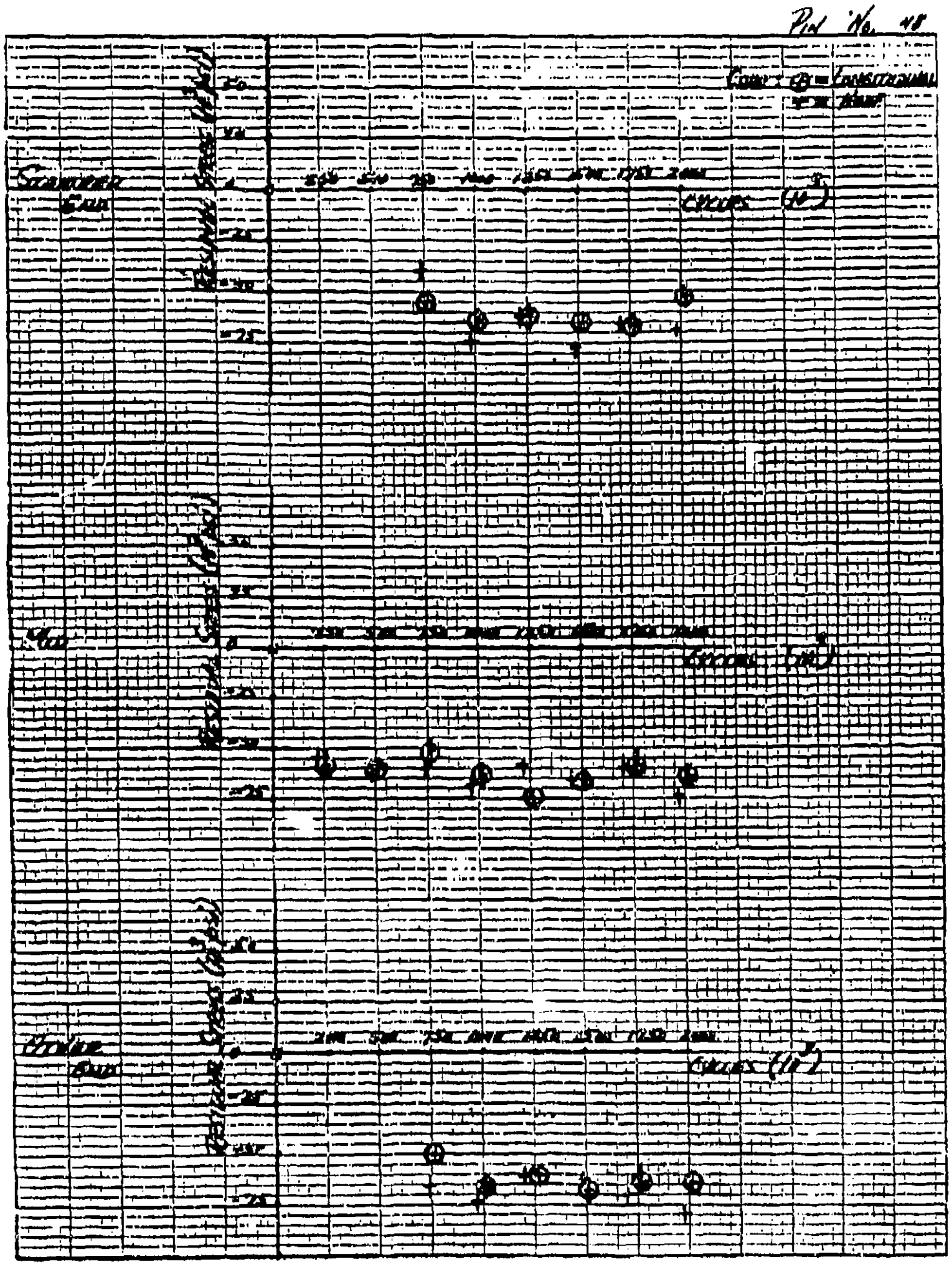

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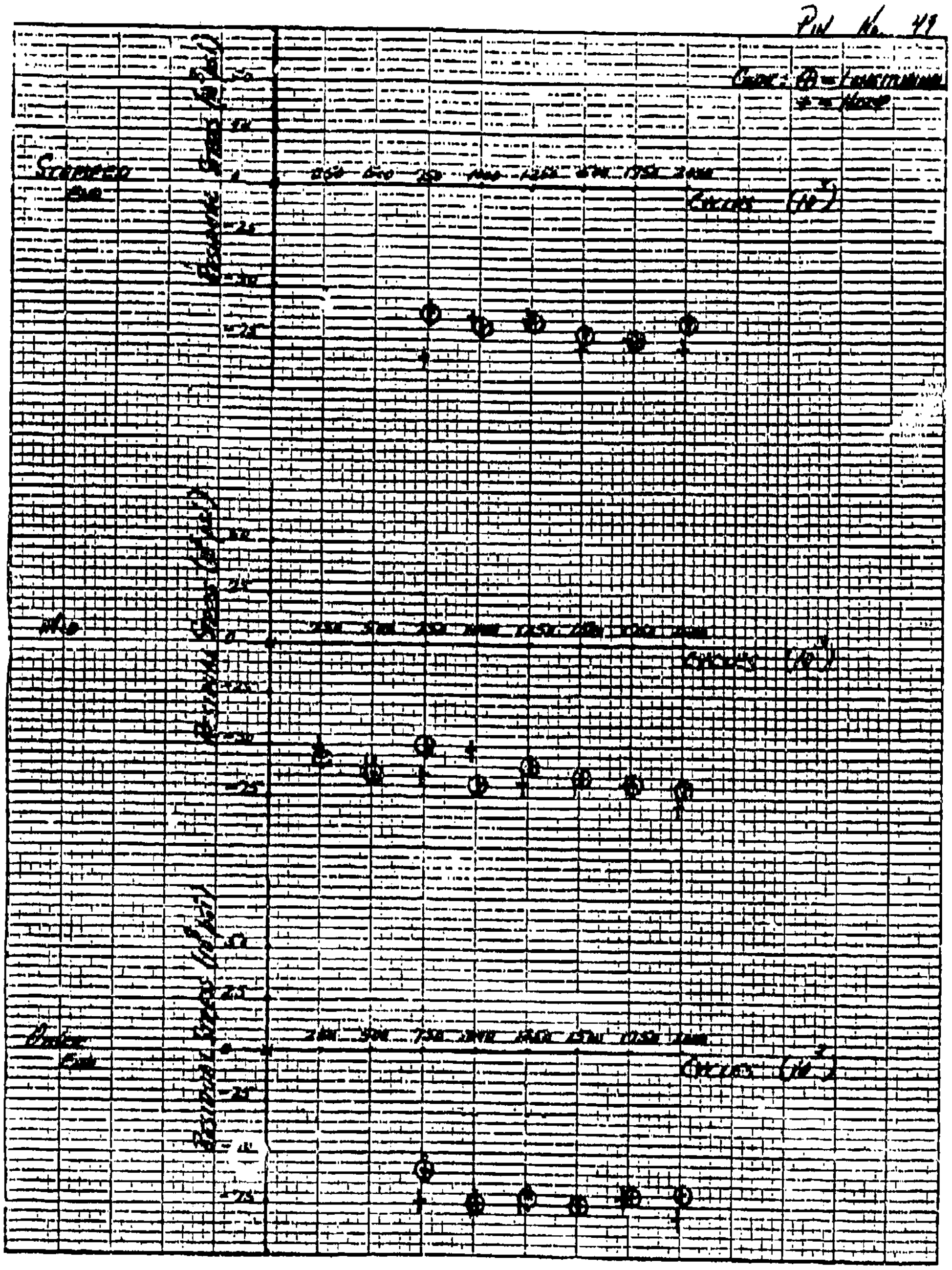

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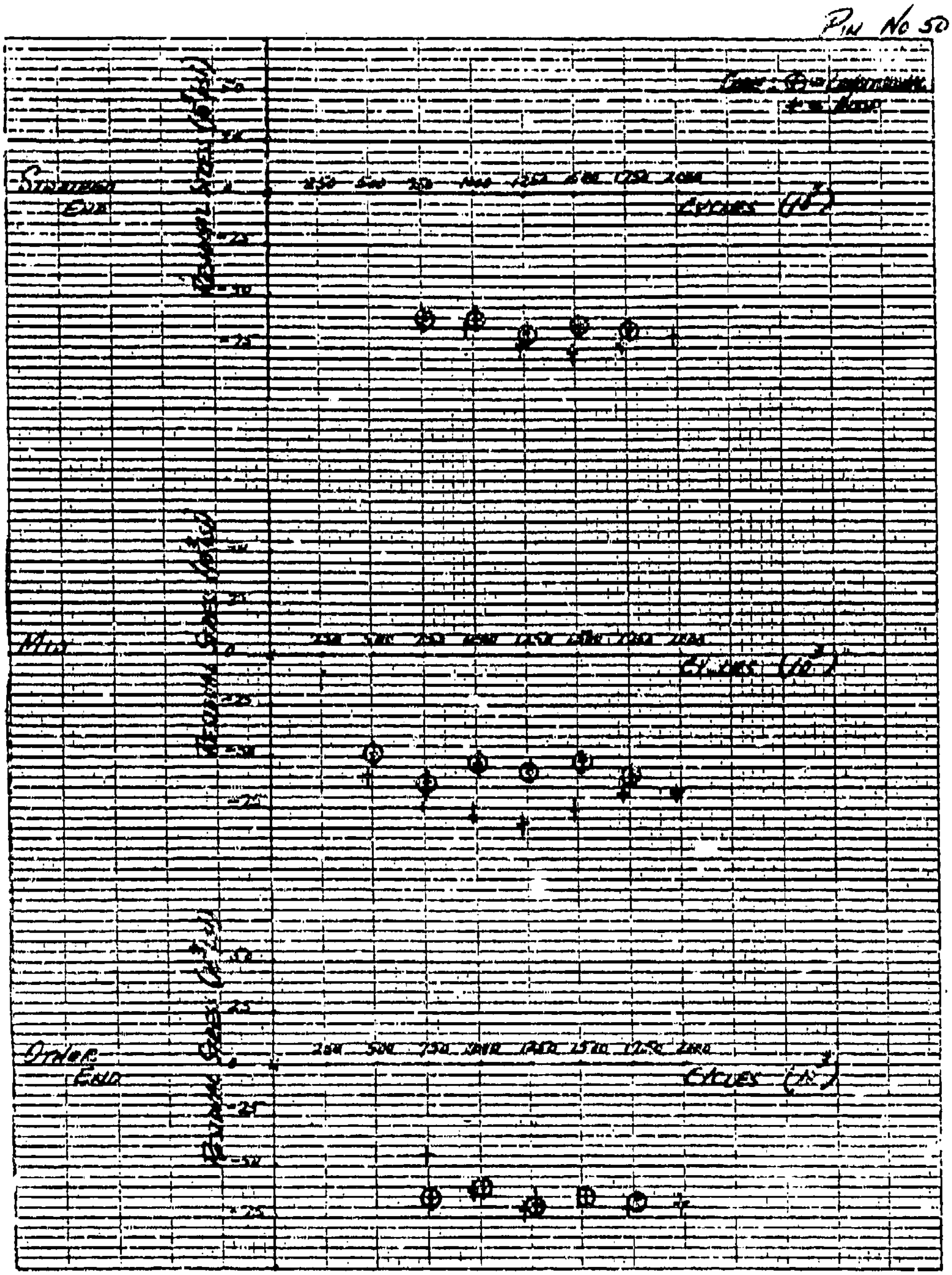

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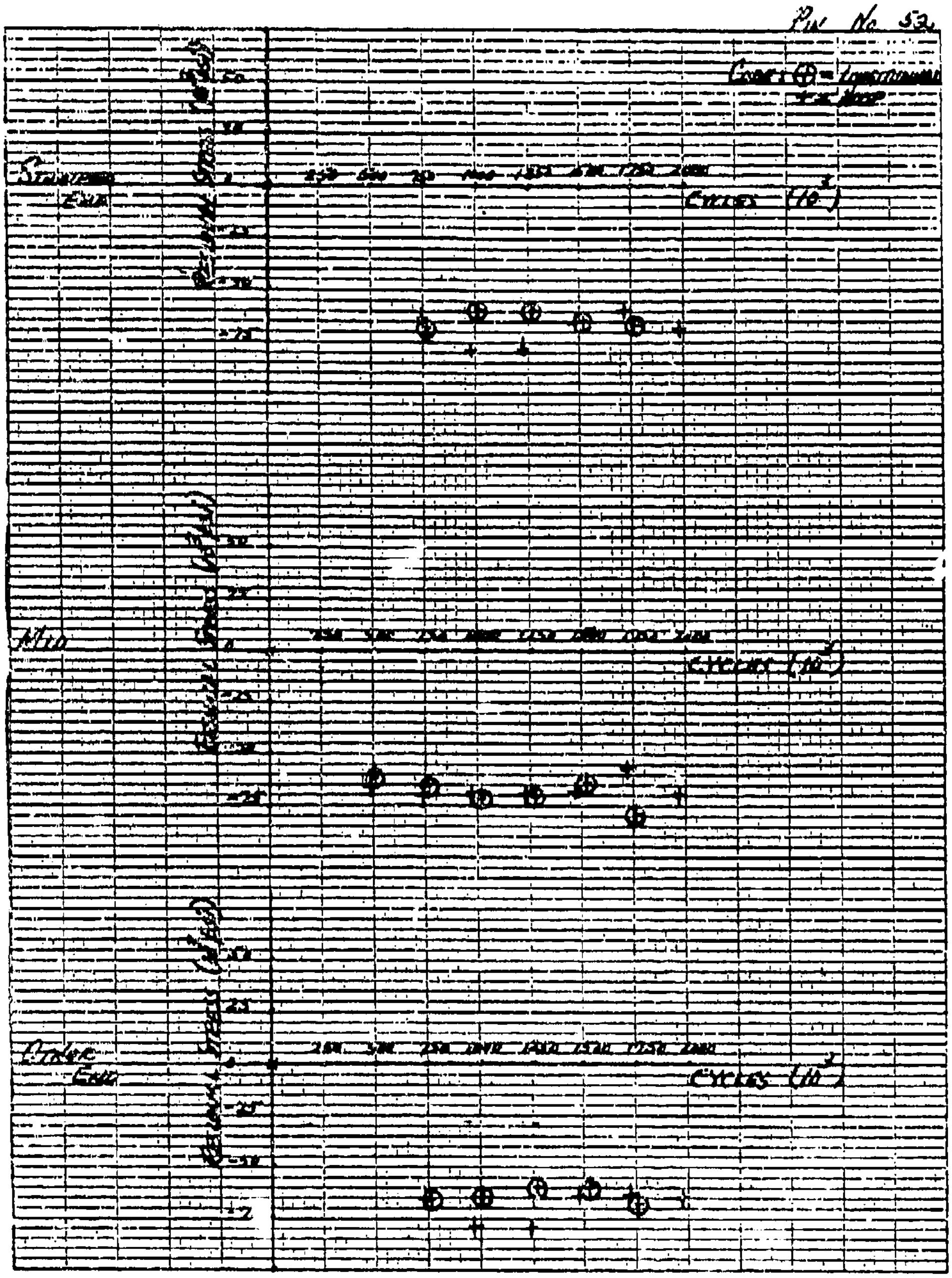

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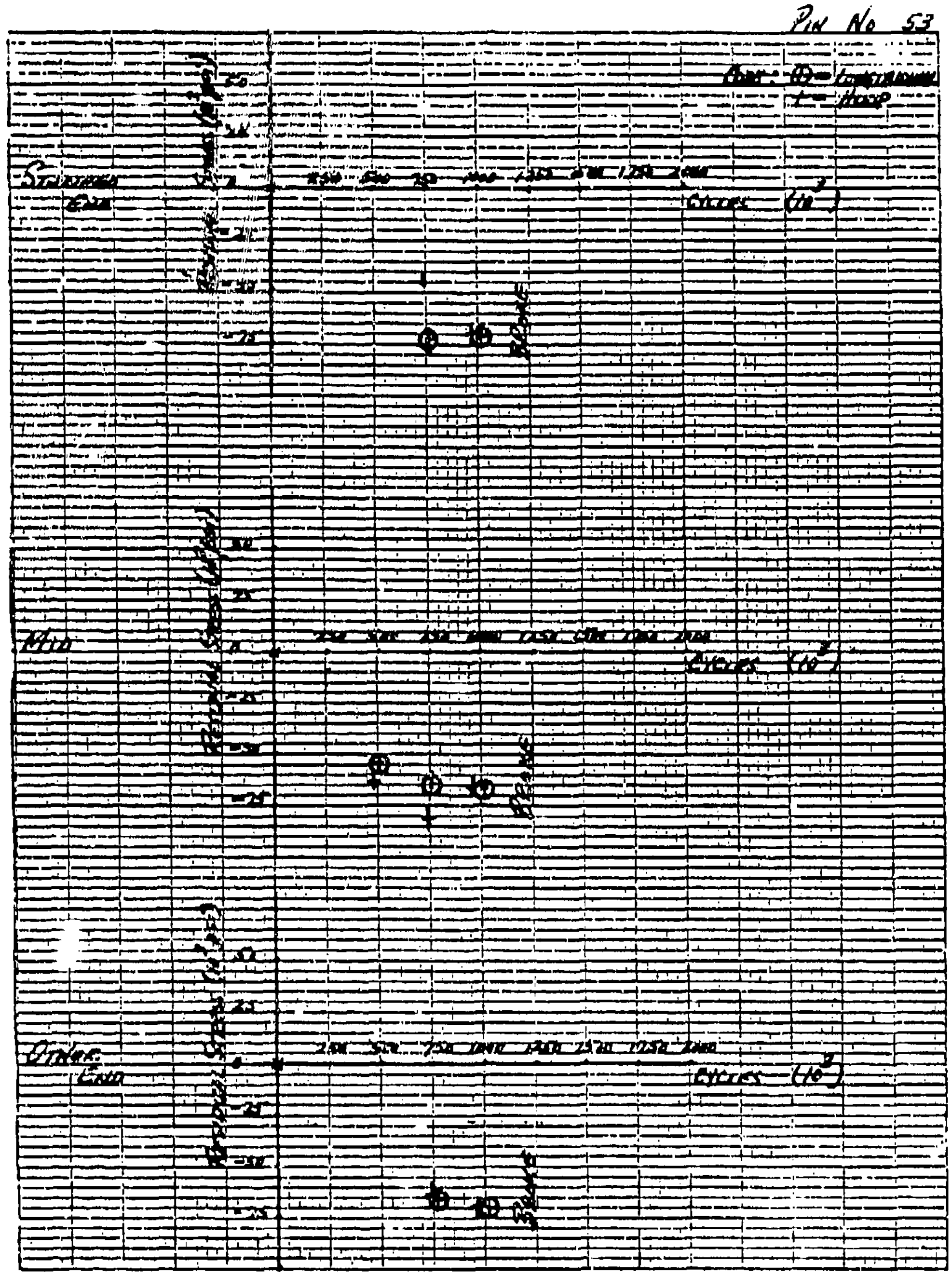
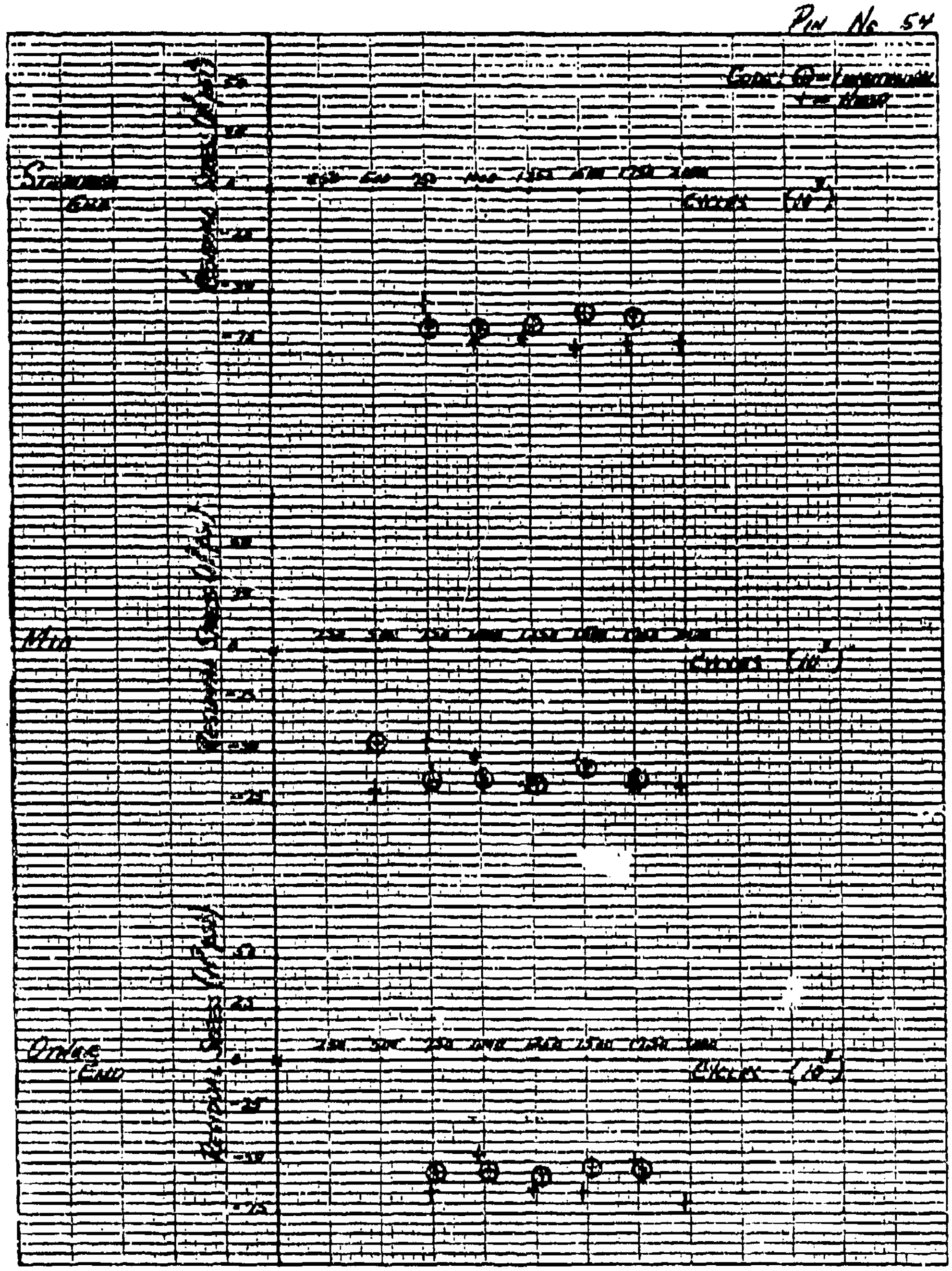


FIGURE 4—16 RESIDUAL STRESS VS. FATIGUE TEST CYCLES (PIN NO. 53).



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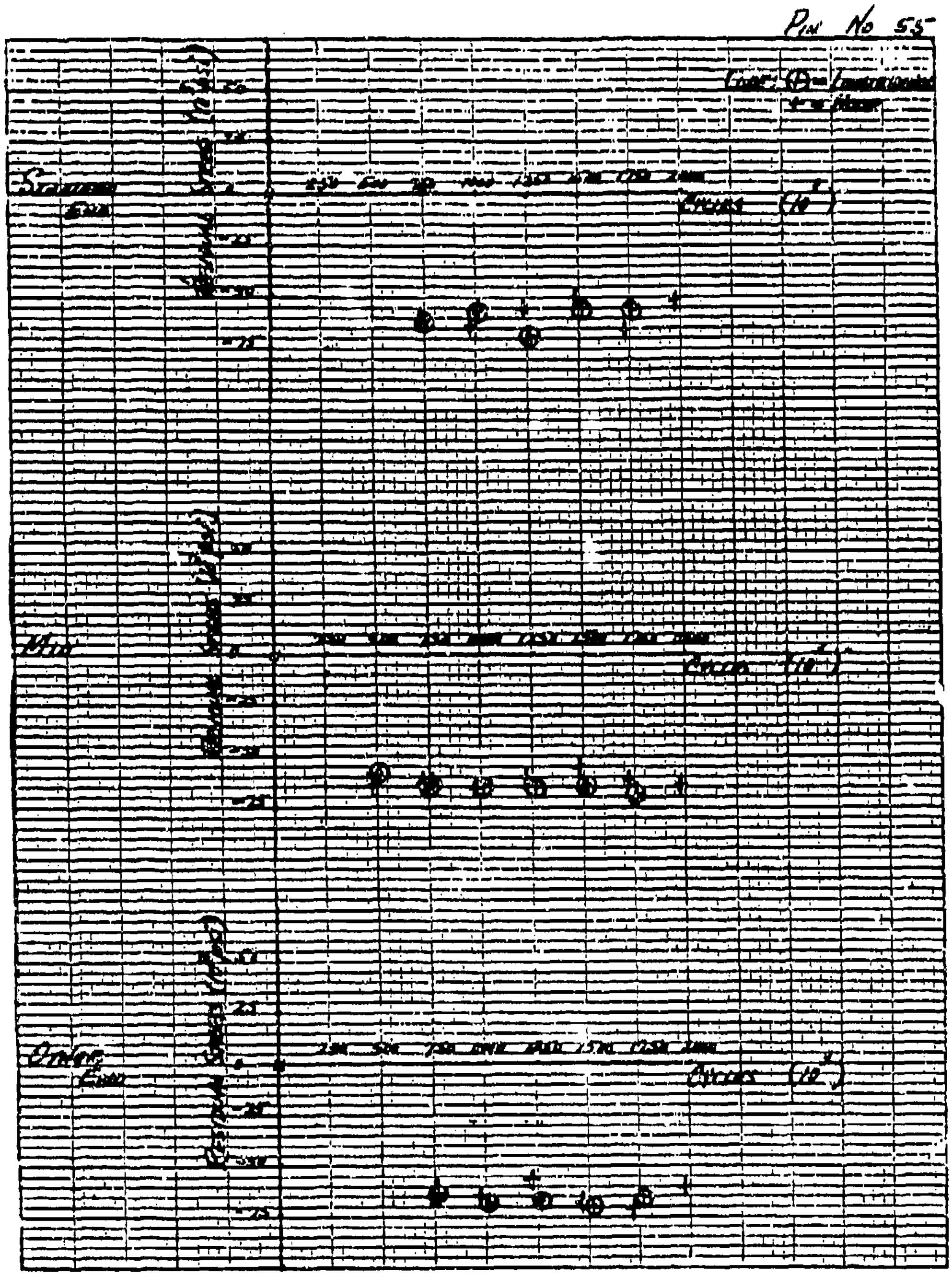

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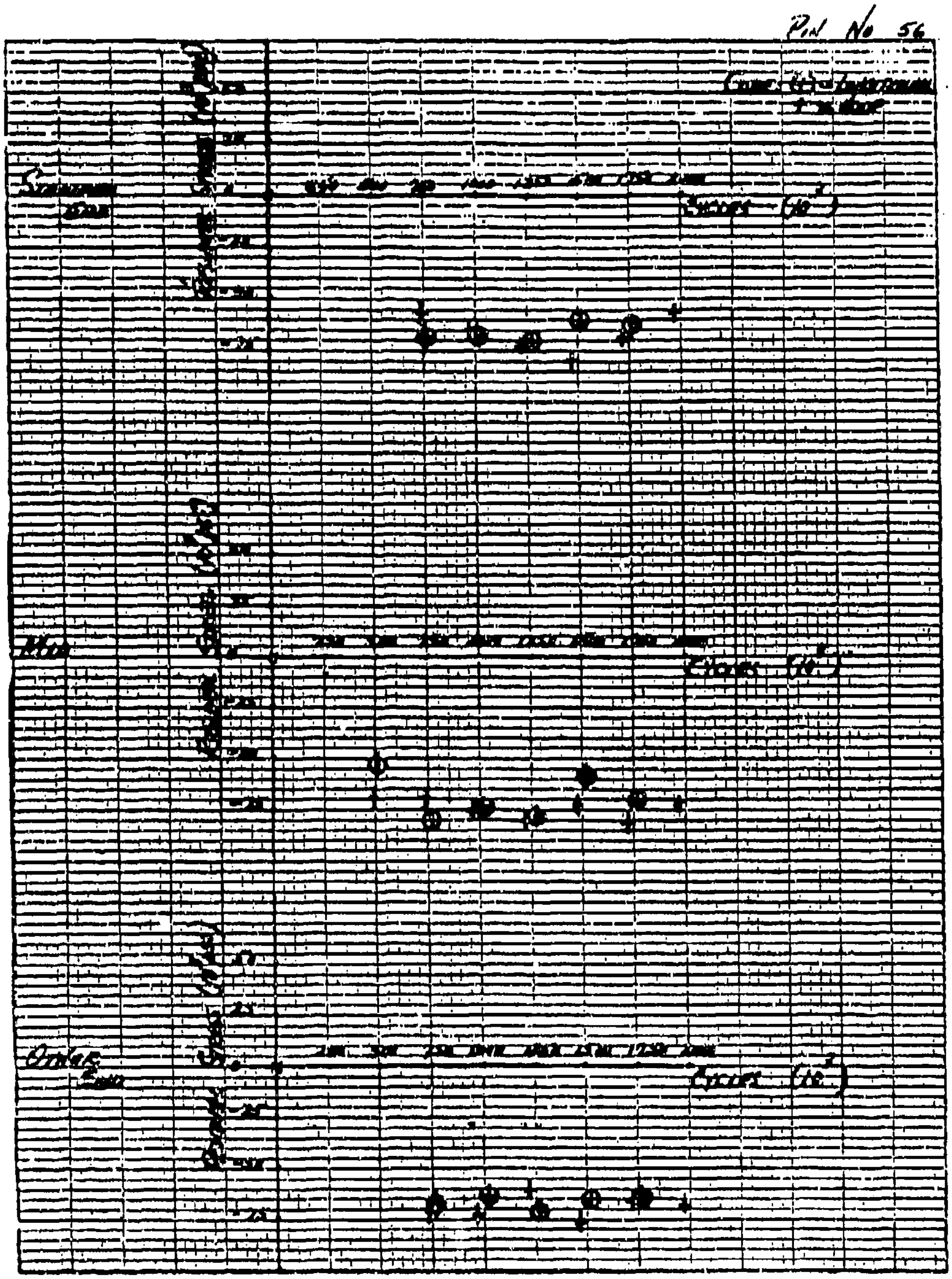

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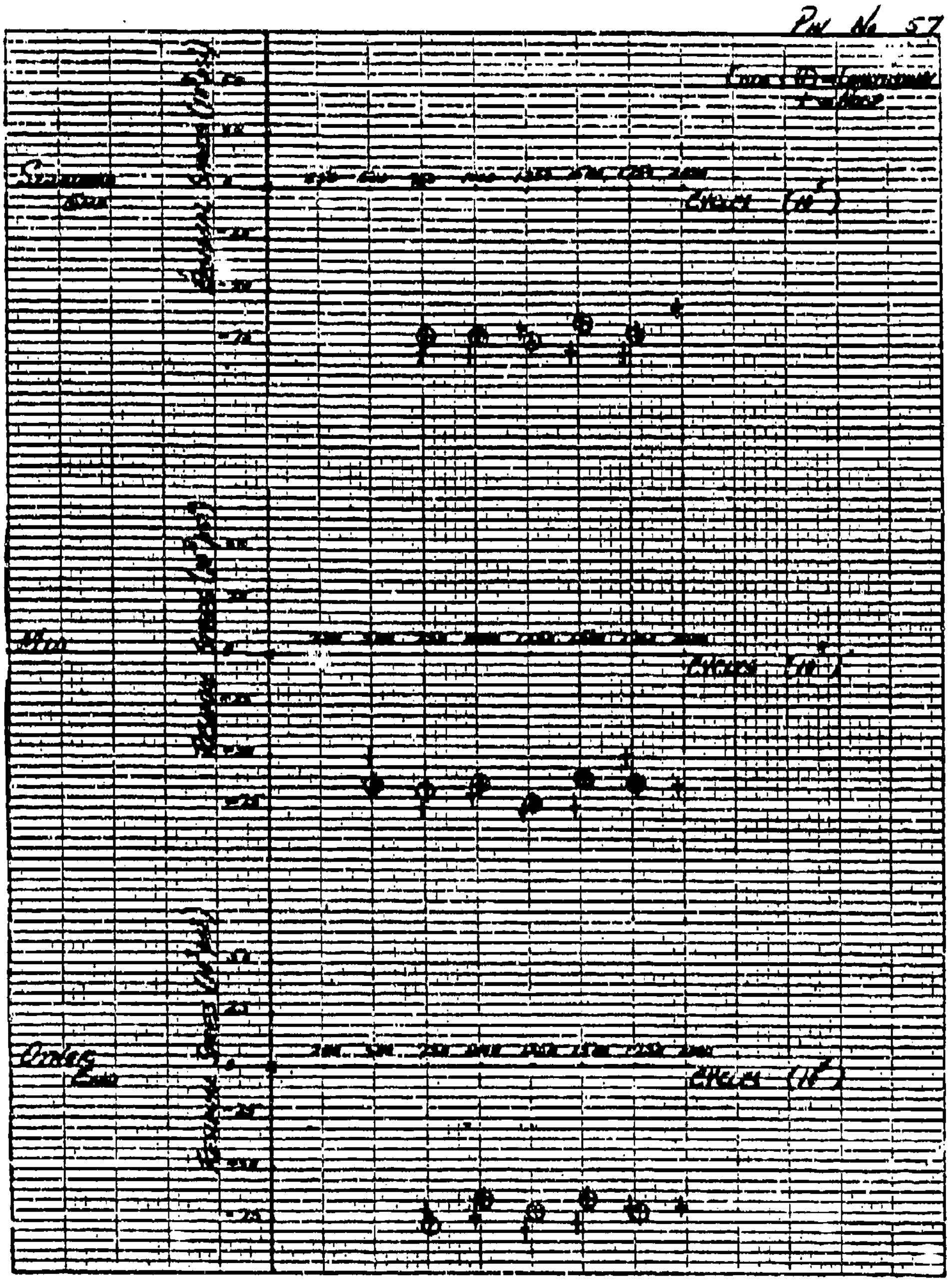

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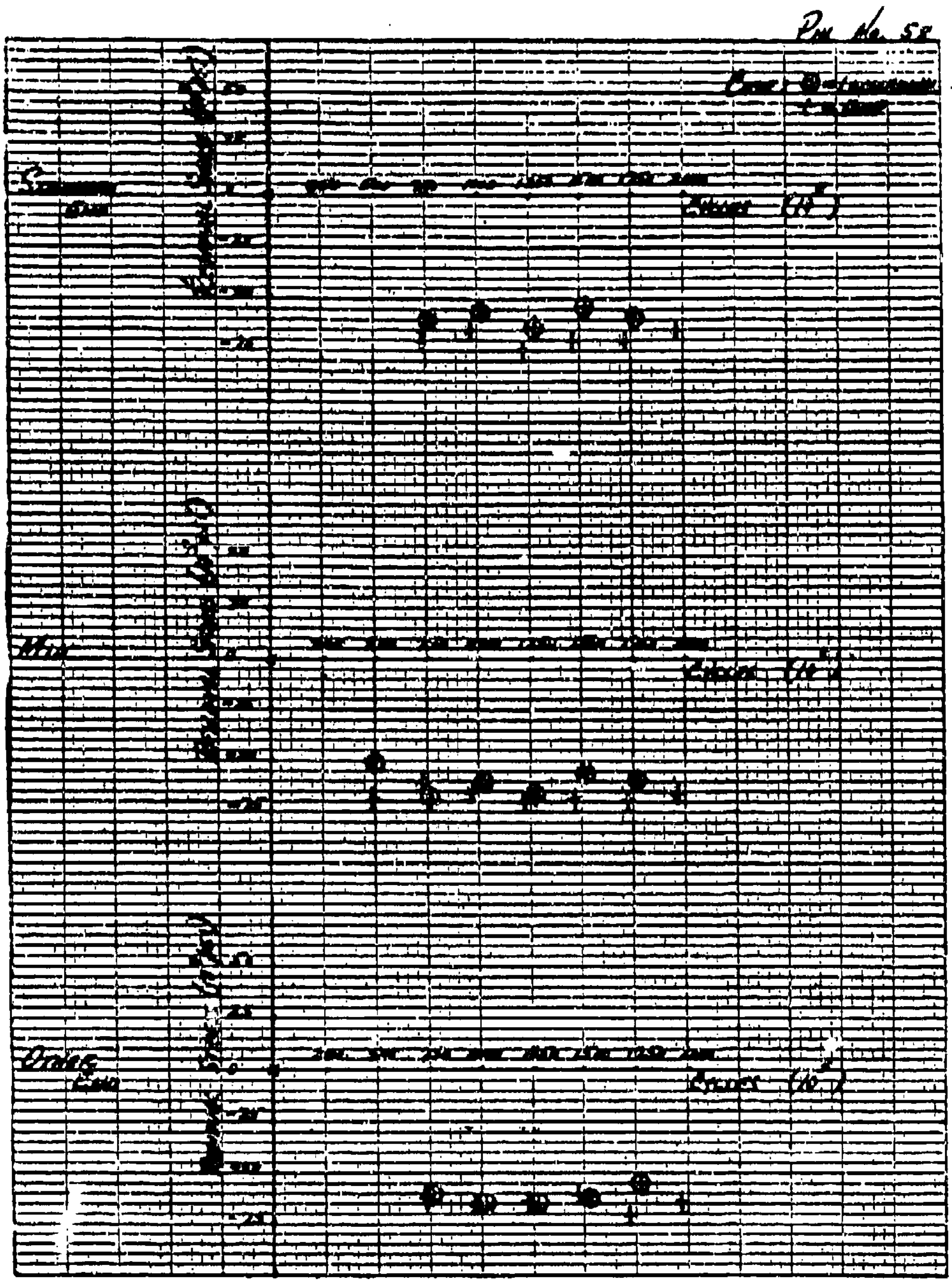

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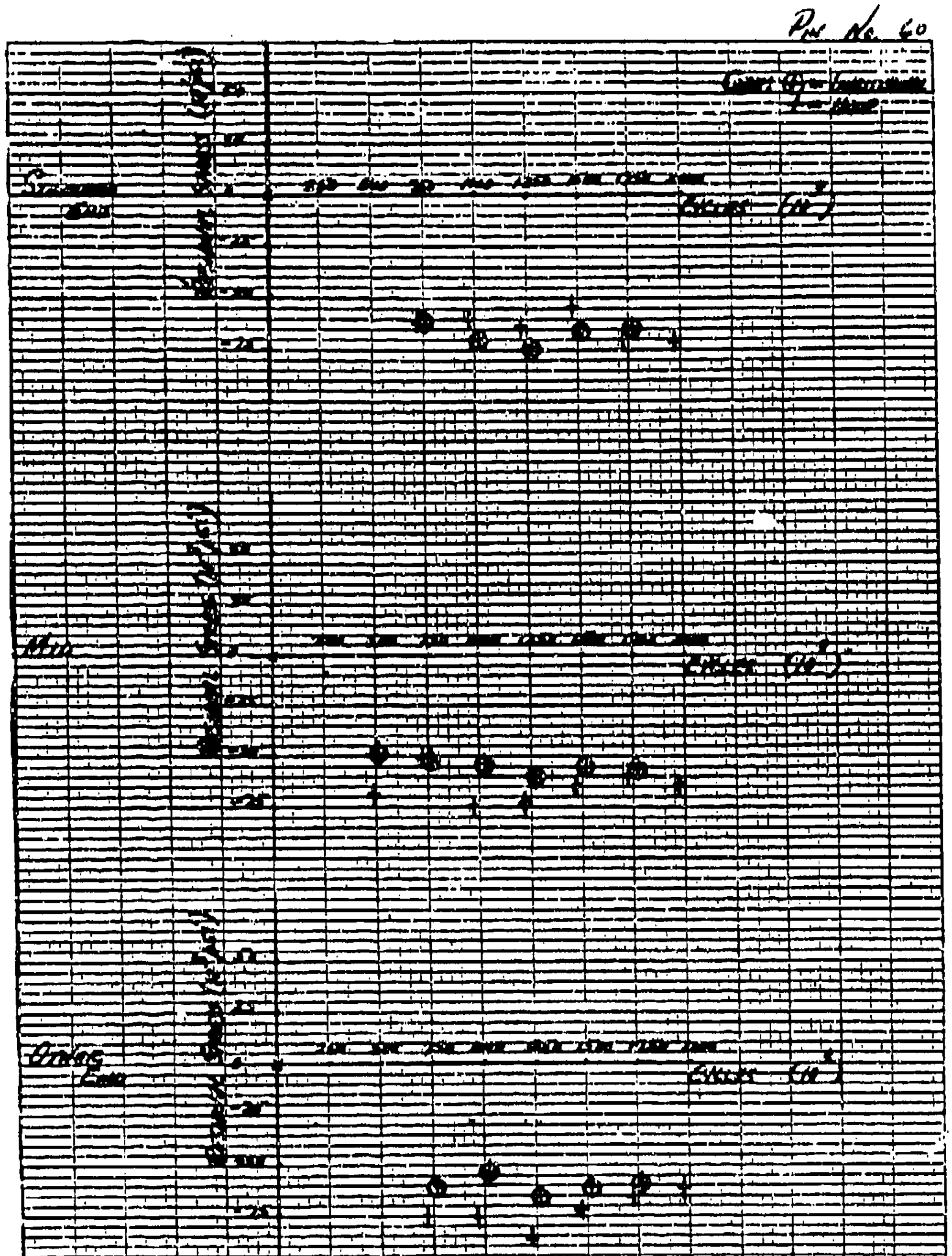

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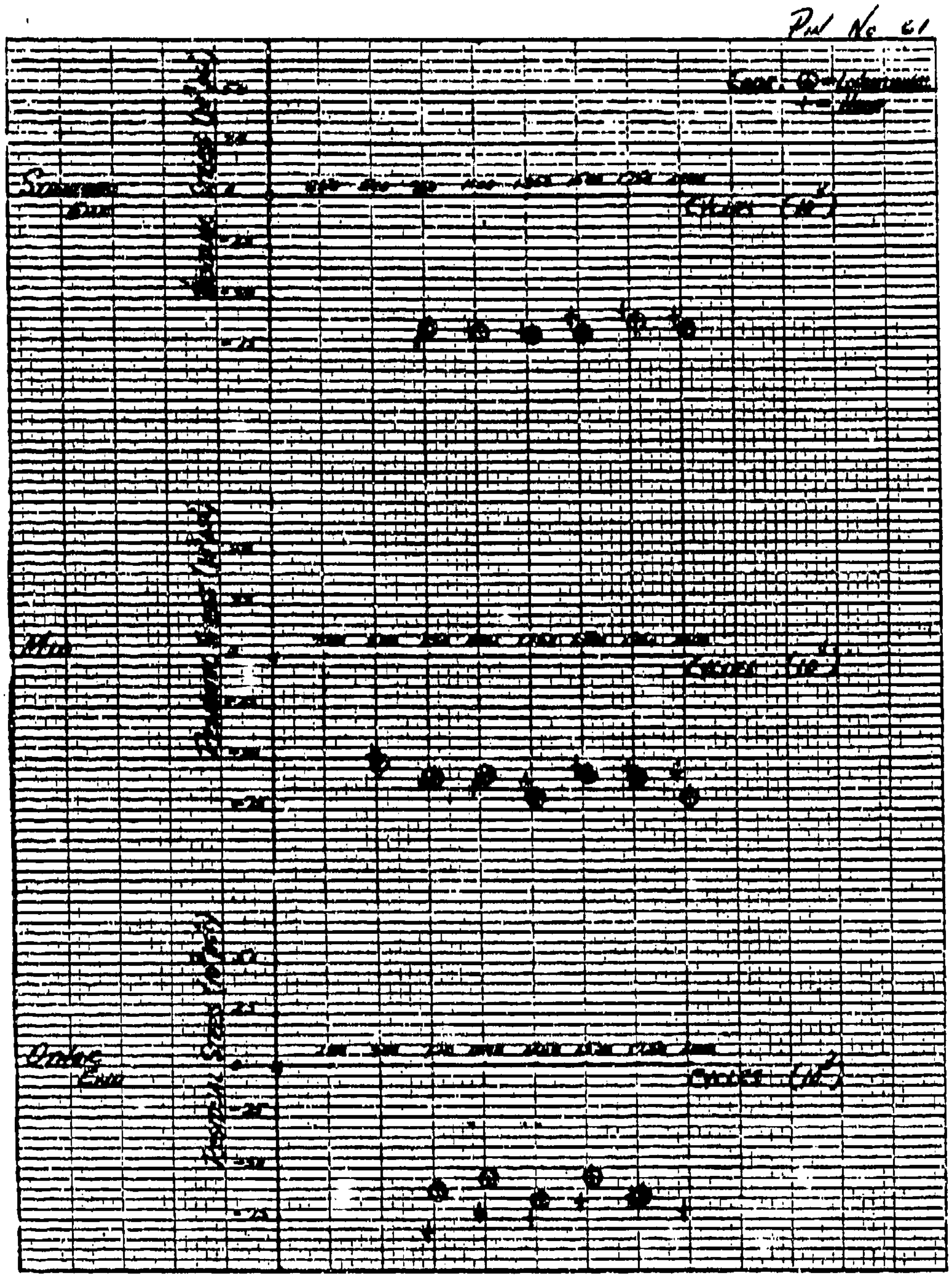

FIGURE 4—23 RESIDUAL STRESS VS. FATIGUE TEST CYCLES (PIN NO. 61).

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