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DSN HUMAN FACTORS PROJECT FINAL REPORT

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TABLE OF CONTENT

		PAGES
	EXECUTIVE SUMMARY	1
1.0	INTRODUCTION	3
2.0	SCOPE	4
3.0	ACKNOWLEDGEMENTS	5
4.0	ISSUES	6
5.0	HYPOTHESES	9
6.0	EXPERIMENTAL DESIGN	11
7.0	EXPERIMENT DESCRIPTION	14
8.0	RESULTS	21
9.0	DISCUSSION	36
10.0	CONCLUSIONS	38
11.0	RECOMMENDATIONS	39
	REFERENCES	i
APPENDICES A.	SIMPLICITY IN COMMAND & CONTROL SYSTEMS	A-1
B.	EXPERIMENT COMPLETION STATISTICS	B-1
C.	COMMAND FORMATS	C-1
D.	SEMANTIC DIFFERENTIAL SCALES	D-1
E.	NUMBER SEQUENCE	E-1
F.	DEMOGRAPHIC QUESTIONNAIRE	F-1
G.	PERFORMANCE PLOTS	G-1
H.	SEMANTIC DIFFERENTIAL QUESTIONNAIRE RESULTS	H-1
I.	FIRST ATTEMPT PERFORMANCE TIMES	I-1
J.	SPECIFIC GUIDELINE RECOMMENDATIONS FOR DSN SOFTWARE DEVELOPMENT	J-1

EXECUTIVE SUMMARY

This experiment is part of a project that was initiated in response to a growing concern about the usability of DSN operational software. The level of complaints that the software was hard to use indicated that some action was necessary to make the software "easier to use". The goal of this project was to increase understanding of the dynamics of the Man Computer Interface (MCI) so that it could be designed to be easier to use.

The project plan was to hold focus groups to identify the factors influencing the "ease of use" characteristics of software and to bound the problem. A questionnaire survey was conducted to evaluate those factors which were more appropriately measured with that method. The performance oriented factors were analyzed and relationships hypothesized. The hypotheses were put to test in the experimental phase of the project.

The specific factors influencing the operation of the MCI were suggested to be: dialogue control, alternative displays, task/command compatibility, task complexity, command stucture and documentation organization. The dialogue control issue is whether the operator controls the MCI dialogue or the computer system controls the dialogue. The alternative display issue is whether the computer system displays the alternatives available to the operator or not. The task/command compatibility is whether the command arguments are in the same order as the task parameters or not. Task complexity is the mental work required to accomplish the task. Command structure relates to the decision tree which the command structure forces the operator to use, i.e., wide and shallow or deep and narrow. The documentation organization issue is whether the command listings are presented in a functional order (that is related to the functioning of the system) or not. In addition the experiment attempts to measure several operator characteristics to be used as mediating variables to reduce the effects of differential operator skills and abilities. Typing skill, spatial ability and analytic ability tests were administered to the experimental operators.

The experiment involved use of a simulated computer system in which system and task oriented variables were controlled. Skills and ability tests were administrated through the same computer system used in the performance tests. The experimental operators were given a sequence of controlled tasks and asked to accomplish those tasks with a command format which was randomly assigned to them. They used the same format through the experiment. Their inputs and performances times were recorded for analysis. One-hundred six experimental operators completed the experiment and provided the data for the following conclusions.

It was hypothesized that a computer controlled dialogue provides better performance for inexperienced operators and operator controlled dialogue provides better performance for experienced operators. The performance data indicate that this relationship varies with the task complexity. For simple tasks there was essentially no differential effect between command formats (i.e., the dialogue control direction was not important). With inexperienced operators the computer controlled dialogue did indeed give somewhat better performance for complex tasks. The experienced operator part of the hypotheses was not supported. It appears that the experiment

did not run long enough to expose this effect. Other research has found that operator preference for operator controlled dialogue develop between 25 to 50 hours on a system.

A strong effect was found in the command structure issue hypothesis. The wide shallow decision tree formats required considerably longer time than the narrow deep decision tree formats.

The data illustrated that the documentation style of the operators manual has a strong effect on the performance time and on the operators attitude. Operation manuals with commands grouped together functionally supported better performance than manuals with commands listed alphabetically.

The experimental operators liked the menu format the most and the short form mnemonic the least. They felt that the menu format was the most friendly. The prompt and menu formats were the easiest to learn with the short form mnemonic the hardest.

A cursory examination of the relationships between the ability variables with the performance time variable indicate that the spatial and analytic ability variables do not have any significant correlations. Possible explanations are that the tasks may not have truly measured the specific abilities, it may be due to an artifact of the analysis, or most likely there is in fact no relationship. Some format differential correlations are expected between the typing skills and the performance. However, the observed correlations are inconclusive and no clear statement can be made about the population relationship. Further data refinement and data analysis may bring out more interesting results.

In summary, the initial analysis indicates that:

1. There is an initial performance effect favoring computer controlled dialogue but the advantage fades fast as operators become experienced.

2. The user documentation style has a significant effect on performance.

3. The menu and prompt command formats are prefered by inexperienced operators.

4. The short form mnemonic is least favored.

5. There is no clear best command format but the short form mnemonic is clearly the worst.

1.0 INTRODUCTION

The consideration of Human Factors in the design of command and control systems is becoming increasingly important. Systems are becoming increasingly more complex, and more functions are being loaded onto systems operators. Both of these factors lead to potential operator difficulties. Human factors is the analysis of the way in which human operator characteristics interact with the system characteristics. An understanding of human characteristics allows the system designer to design the system to match those human characteristics. Neglecting human factors in system design leads to mismatched systems with reduced operator satisfaction and increased turnover, decreased performance, and increased risk of operator errors.

Although desirable, including human factors in system design is difficult for several reasons. The normal engineering curriculum does not train the designer in human factors. Typically, a designer's experience does not prepare him to include human factors in his design. In addition, human factors specialists are in very short supply. There are no recognized academic programs in this area. Although the physiological issues in human factors are well covered by Human Engineering Handbooks, the cognitive issues are not covered very well at all. And it appears that the cognitive issues in the operation of a computer system are more important than the physiological issues. The human factors literature is either in the form of very specific research published in journals not normally available to system designers (nor in language familiar to them) or in the form of generalizations which are difficult to use. It would be very valuable to have a set of guidelines and specific recommendations to aid the system designer in his efforts. Even more important than specific design guidelines is a better understanding of the fundamental issues so that the Man Computer Interface (MCI) design can be generalized.

The Mission Operations Division of the Jet Propulsion Laboratory, recognizing the need for a better understanding of Human factors issues and desiring specific MCI design guidelines, commissioned the DSN Human Factors Project with the University of Southern California. Dr. Thomas H. Martin was the principal investigator and Roy Chafin was the research assistant. The project consisted of a series of focus groups to identify the pertinent human factors issues, a survey to measure operator attitude issues, and an experiment to investigate performance issues. The focus group and survey activity has been or will be reported in separate reports. This report covers primarily the experimental activity.

2.0 SCOPE

This report covers the experimental phase of the DSN Human Factor Project. The intent of this report is to discuss human factor issues, describe the experiment and present the results, conclusions, and recommendations for MCI design. The experimental issues are discussed in Section 4.0, and the experimental hypotheses tested in the experiment are presented in Section 5.0. The experimental design is discussed in detail in Section 6.0 with the description of the experiment presented in Section 7.0. The results of the experiment are presented in Section 9.0 and their implictions discussed in Section 10.0. Conclusions are presented in Section 11.0 and recommendations in Section 12.0. Detailed experimental data is included in the Appendix together with some supporting theoretical material and also some specific design recommendations for the DSN.

3.0 ACKNOWLEDGEMENTS

Early in this project it become clear that station coordinators were required for the successful administration of the experiment. These station coordinators were recruited and they provided very valuable service to the project. Their efforts on behalf of this project were in addition to their regular duties and in the face of difficult station scheduling problems. Their efforts were appreciated. The following individuals are to be commended for their service to the DSN Human Factors Project: Willard Smith (GTS), A. Chamarro (DSS 61/63), M. Urech (DSS 62), Peter Churchill (Australian Complex), Tom Kratz (CTA 21), and Son Dao (CTA 21). John Saxon's (DSS 44) interest and support is also appreciated.

Recruiting and scheduling volunteers for the experiment required a very significant effort. Two individuals in particular were very helpful in this activity, Susan Laprade of the Network Operation's Analysis Group and Bob Hollingsworth of the Network Operations Control Group. Their help in recruiting volunteers is appreciated.

This experiment required extensive software development, and four people gave very valuable assistance to that development. Rich Spear and Phillipe Urquiza gave very valuable assistance in overcoming the lack of documentation in interfacing the Megadata terminal with the Modcomp computers. John Kelly and Tom Greer were invaluable in helping the project investigator/programmer work though an obtuse Modcomp Operating System. The CTA 21 evening crew, Todd Peterson, Ron Logan, and Bob Verish gave many hours of cheerful support which was much appreciated.

The project is also indebted to Joe Goodwin for his support and encouragement, to Max Wyatt for the resources which were made available to the project, and to Dick Mallis for his clear statement that management supported this project.

4.0 ISSUES

The principle issues in man computer interface design (MCI) are: will it work?, and has the best interface been selected?. These issues are much too broad to discuss meaningfully, so more detailed issues are needed which are more ameanable to measurement and analysis. These issues were determined to be: dialogue control, alternative displays, task/command compatibility, task complexity, command structure, and documentation organization.

Dialogue Control

Dialogue control refers to the direction of control of the man computer interface. The computer can control the dialogue or conversely the operator can control the dialogue. Menu and prompt command formats are examples of computer controlled dialogue and the mnemonic command format is an example of an operator controlled format. The computer controlled dialogue is normally associated with "user friendly" MCI designs, that is they are expected to be easier for the user than operator controlled dialogues. However, several authors have observed that after an operator is thoroughly familiar with a menu format he very often becomes very impatient (1). The flexibility of the operator controlled dialogue (mnemonic) allows a knowledgable operator to save time and effort and go right to the command that he knows is needed.

Alternatives Displayed

The MCI can be designed to provide the operator with a list of alternative inputs or it can be designed so that he must know the alternatives himself (or refer to documentation). The menu command format is an example of a format which displays the alternatives that the operator has at each step in the commanding process.

Task/Command Compatibility

The arguments in the command format can be ordered in the same order as the task parameters are presented in a task assignment, or they can be ordered in a manner entirely unrelated to the task parameter order. If the command format is compatible with task structure (that is their parameter/argument orders are the same) then it is expected that the job of the operator is easier, he can map the task parameters directly into the command arguments.

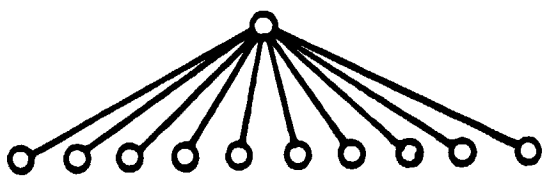
Task Complexity

Task complexity is a measure of the difficulty an individual encounters when accomplishing a given task. This is not a very satisfying concept because it's measurement depends too much on individual abilities. In order to separate the concept of task complexity from individual variations we can go back to a more fundamental concept that is contained entirely within the characteristics of the task itself. The difficulty in the experimental tasks is in selecting commands or command elements which accurately accomplish the task. All potential commands must be evaluated as to their

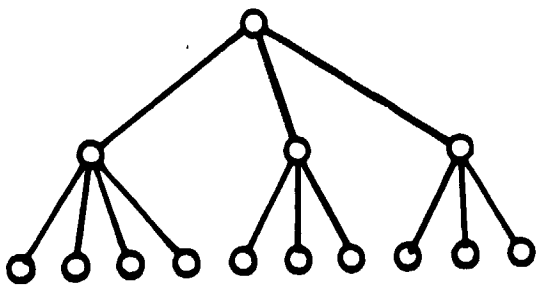
ability to accomplish the task. A measure of the difficulty then is the number of possible tasks (corresponding to the number of commands or command elements). Also the number of decisions required to accomplish the task influences its difficulty. A command that has nine elements requires ten distinct decisions. The first is the decision as to which command to use, the remaining nine are for each of the nine elements. A task with only two elements requires three decisions. A task with nine elements requires more information (and more work from the operator) than a task with only two elements, so therefore, we can consider the nine element task more complex than the two element task. Task complexity is operationalized by counting the number of parameters plus one.

Command Structure

Command formats can be designed to use very shallow and wide decision trees, very deep and narrow decision trees, or something in between. A shallow/wide decision tree (Figure 4-1) allows the operator make the decision in one step but he has to chose from a large number of potential alternatives. A deep/narrow decision tree (Figure 4-2) forces the operator to make many decisions each from a small number of potential alternatives to reach the final decision.



Shallow/Wide
Decision Tree
Figure 4-1



Deep/Narrow
Decision Tree
Figure 4-2

Documentation Organization

The documentation that the operator uses as an aid can be organized so the commands are functionally related or they are not functionally related. Functionally related means that commands associated with a specific function are grouped together, titled with that function and appropriately indexed. In this experiment, the short form mnemomic command format was divided into two treatments, one for each of the manual variable states. Short Form one provided a manual in which the command descriptions where organized functionally. That is all the ship control commands were grouped together, the radar commands together, etc.. The operator could find the specific desired command by matching the system title with the task (ship control with ship control) then scanning only that group listing for the appropriate command to accomplish the task. The short form two format listed all the individual commands alphabetically. Therefore, the operator had to scan the entire list of commands to find the one that he wanted.

Operator Experience

The concept of operator experience is operationalized by the number of times that the operator has accomplished a task using a specific system. For example, it might be the number of times that he has issued a ship control command. It is assumed that experience reinforces and solidifies the operator's internal model which allows him to accomplish the task easier (i.e., better performance).

Cognitive Simplicity

Cognitive Simplicity (see Appendix A) involves those characteristics of a process that make it easy to understand. Typically, it refers to aids built into the system which assist the operator in understanding the process.

Process Simplicity

Process Simplicity involves those characteristics of a process that make it easy to use, that is, make easy to accomplish the process.

5.0 HYPOTHESES

It is easier for the operator when the computer controls the MCI dialogue during of an ordered series of commands (for example, the initialization and the configuration commands of a system). The operator doesn't have to remember the order and he doesn't have to be concerned that he will forget a command or enter one out of order. However, it is easier for an operator to control the MCI dialogue when simple commands are entered. It is easier because he doesn't have to wait for the computer to present it's prompt or menu. Also, it is more satisfying because he has the feeling that he is in charge.

H1: Operator performance is greater when the computer controls the dialogue for a series of commands and when the operator controls the dialogue for individual commands.

We would expect that the performance of an inexperienced operator would be better when the computer controlled the MCI dialogue and it would be better for an experienced operator when he controls the MCI dialogue. When the operator's knowledge is low (lacks experience), he must look the command up in the documentation. Time is saved when the computer leads him through the process, and he doesn't have to look up the command. When he is experienced, he knows what to do so he doesn't have to look up the command (1).

H2: Inexperienced operator performance is better when the computer controls the MCI dialogue. Experienced operator performance is better when the operator controls the MCI dialogue.

The performance of an inexperienced operator is greater when the alternative actions available to him are displayed on the CRT and he does not have to refer to the documentation. He selects the next action from the list on the display thus saving the time required to search the documentation. When he has developed sufficient experience, he knows what to do so he does not have to refer to the documentation nor does he need the display. The time required to display the list of alternatives increase the operator's response time. Also, the extraneous information is an annoyance to him (1).

H3: The performance of an inexperienced operator is greater when alternative actions are available to him on the CRT display. And the performance of an experienced operator is greater when the alternative actions available to him are not displayed.

We would expect that operators performance would be inversely related to the command complexity. Command complexity is the range of choices that the operator has to make in order to complete the command. Also, when the command is less complex, the operator can more easily enter the command into the system. More importantly, a lower complexity level reduces the operator's mental load and reduces the interactions between decisions, reducing both errors and completion time.

H4: Operator's performance is inversely related to command complexity.

One of the processes required of an operator is to map the parameters of a task into the arguments of the command. We would expect that the operator's job would be easier when the command arguments are in the same order as the task parameters. That is, this order is compatible. When they are not compatible extra effort is required to reorder the task parameters.

H5: Operator performance is directly related to the compatability of the task parameter order and the command argument order.

When an operator has to look up the command in the documentation, that look up time is a part of the performance time. So, the easier it is to look up the command the less time is required and the better is the operator performance. We would expect that it is easier to look up a command when the decision range is low, that is there are fewer choices. However, the number of commands required to implement a system depends on both the number of function's required to be specified and the structure of the command decision tree. A shallow/wide decision tree has a wide decision range, the operator has to pick out the command from a list of all the commands. A narrow/deep decision tree makes each decision easier (i.e., smaller decision range) but more decisions are required. When a shallow/wide decision tree is used, then an operator can be aided by grouping the commands into recognizable groups. The operator searches by group then by command reducing the number of discriminations required. A functional grouping provides compatibility between the search process and the task, and we would expect to increase operator performance. Of course, this applies only to inexperienced operators because we would expect experienced operators to have little need for the documentation.

H6: Inexperienced operator performance is better when the documentation is organized so that the commands are in functional groups and is poorer than when it is organized non-functionally.

6.0 EXPERIMENTAL DESIGN

The purpose of the experiment is to test the hypotheses. The experimental design includes the subject selection, treatment, and observation or measurement.

Subjects were recruited from the operating DSN station's, DSN organizations at JPL and non DSN organizations at JPL. The subjects were recruited from a very broad spectrum of job catagories, ranging from dedicated computer system operators, to secretaries, and to engineers. There was no attempt to select subjects according to "ability", all volunteers were accepted. The randomness of the subject selection process was jeoparidized by the self selection of the volunteers. The subject base was made up of those who were agreeable to going through the experiment. Those that did not want to participate were not forced to go through the experiment. Although examination of the data suggests that there were a few subjects who unwillingly went through the experiment and did little more than skip through the tests without entering any meaningful responses. This data was not included in the analysis. This self selection is unavoidable and is important only if there is a significant difference in the population of agreeable subjects versus the non-agreeable subjects. Obviously there is an attitude or a personality difference, however, there is no indication that there is any difference in their performance in accomplishing the experiment tasks.

The treatments for this experiments are the five specific command formats used to accomplish the assigned tasks. The treatment selection was random. Each subject was assigned one of the command formats (treatments) according to the output of a random number generator in the program.

Measurements were taken by the experiment program and were consistent between subjects. This allows direct comparisons between the aggregated performance measurements for each command format.

The quality of the experimental design is directly related to the internal and external validatities of the design. Internal validity is concerned with the question: did the experiment measure what we had expected it to measure, or are there other influences which we did not anticipate? External validity is concerned with the question: over what population can we assume that the conclusions taken from this experiment apply?

Internal Validity

Campbell and Stanley (2) suggest eight classes of extraneous variables which might produce confounding effects on an experiment.

1. History is concerned with specific events which occur between first and second measurement of experimental designs that have first and second measurements. History is not directly applicable to this experiment because only one measurement is taken. However, there are potential secondary history effects due to specific events changing the character-

istics of of the subject population. The data collection was approximately four months long. During this period there were no specific identifiable events which would be expected to vary the subject population characteristics. There were station equipment upgrades and preparations for Voyager encounter but these should not have had a significant effect on the operators ability to perform the experiment.

2. Maturation is the changing of subject characteristics over time due to subjects growing older, growing tired, or growing more skillful. Again, this is potentially a problem for multiple measurement experimental designs but is not appropriate for this one time measurement design. The four months data collection span would not be expected to produce significant secondary maturation effects.

3. Testing effects are the impacts of a subject taking an initial test upon subsequent test scores. Since each subject took the test only once, this effect is not applicable. There is a possibility that cross referencing between subject might influence the later tests. That is, one subject giving the answers to a later subject would invalidate the second subject's scores. Because this was a field experiment, as compared to a controlled environment experiment, this possibility cannot be controlled. However, there is no indication that this happened to any significant extent. The coordinators monitored the testing to some extent to avoid passing on of answers. Also, except for two of the small mediating variables tests, the experiment did not lend itself to the sharing of answers.

4. Instrumentation effects are those changes in the calibration of the measuring instrument over the period of data collection. We would not expect any calibration changes because the measurements are taken by by the program and the program was not changed during data collection.

5. Statistical regression is an artifact of the sampling process when groups are selected on the basis of their extreme scores. Since the subject selection was random, this effect is not applicable.

6. Biases are due to differential selection of comparison groups. Because the assignment of subjects to groups was random, we can ignore this effect.

7. Experimental mortality is considered by Stanley and Campbell to be subject dropouts between the first and second measurements. This consideration is inapplicable for this experiment because there is only one measurement period. However, there is a mortality factor for subjects who start the experiment but do not finish. Since comparison data between command formats is primarily on data from completed performance tests this mortality factor is minimized. The effect of test mortality on the characteristics of the subject population is similar to the effect of unwilling subjects and is essentially unknown. Of the subjects who started the experiment (161), 130 or 80% started the performance test and 106 or 66% completed the entire test (Appendix B). The possible reasons for the

non-completion can be subject related such as fatique, lack of motivation, etc., or it can be non-subject related such as running out of station time for the experiment (equipment was required for a spacecraft track), or equipment failing.

8. Selection maturation interaction is not of concern in this experimental design because maturation itself is not an issue.

External Validity

External validity is concerned with the issue of generalizability. That is, can the results of this experiment be inferred to a larger population.

In the strictest sense, the conclusions drawn from this experiment can only be applied to those individuals that participated completely in the tests. However, generalizability is based on the assumption that if every member of a population has an equal opportunity to be in the test sample, then the test results may be inferred to the entire population under the rules of inferential statistics. The greatest threat to the external validity of this experiment is the unavoidable lack of a truly random subject sample. In order to obtain enough samples for statistical power it was necessary to accept every volunteer. And of course, those that did not volunteer or refused to participate potentially biased the sample. Also, when the recruiting was done through specific organizations, there was a tendency to recruit those people who could most be spared in the organization's operation. The "busiest" people tended to be excluded from the sampling. Because the experiment had to be conducted within a volunteer context this potential bias must be accepted. However, there is no indication nor reason to believe that the results are adversely affected by this potential bias.

Another aspect of the external validity issue is that the results of this experiment are expected to be applied to future systems. And, of course, future operators cannot be included in the present sampling. Again, this issue can be viewed in terms of the stability of the characteristics of the operator population. If the characteristics of future operators do not change, then we can readily apply the results of this experiment. But we must be careful in the future to scrutized the overall operator population characteristics for significant changes which would possibly invalidate these results.

7.0 EXPERIMENT DESCRIPTION

This is a simulation experiment in which man computer interface (MCI) designs are studied using a Simulated Computer System. The experiment consists of 55 separate tasks making up a naval warfare scenerio. The test subject acts as the computer operator of a computer controlled ship. He is provided with orders on his CRT screen to control the ship. He translates these orders (or tasks) into computer commands using the command format assigned to him. The experiment program records his response, times the response, and in some cases provides feedback to him. Two times are recorded, the total time required to enter the response and the think time required for the operator to decide which command to use.

Typically, the performance time for different individuals in greater than the difference for different treatments. In order to remove some of the variance due to individuals, mediating variables were included in the experimental design. They were intended to provide more precision in the analysis.

The anticipated mediating variables are typing skill, short term memory, spatial ability, and reasoning ability. Typing skill is operationalized using a series of typing tests, short term memory ability with a short memory test. Spatial ability is operationalized using a maze traversal test. Reasoning skill is operationalized in two ways, using a number sequence test and a reasoning game (DUDZAP game).

Scope

This section will describe the experiment and it's elements. Each test will be described separately. The test design and rationale will be covered. The specific formats will be covered. The data record and the data scoring will be presented.

Performance Test

The performance test is the principle element in the experiment. The operator is assigned to one of five possible treatments. The exercise is explained in a series of displays. A four task training session is provided. Then 55 tasks are presented sequentially. The operator response time and think time are recorded for each task.

The four available formats are: short form mnemonic, long form mnemonic, prompt and menu.

Short Form Mnemonic

The short form mnemonic consisted of a three character mnemonic with a slash delimiter, and a single following parameter. (For example, HDR/276.)

The parameter may be either numeric or alphanumeric. The short form mnemonic format respresents a very broad and shallow selection tree. There are 45 separate mnemonics in this format (see Appendix C). Each task requires a sequence of mnemonics to accomplish the complete task. This format represents an operator controlled dialogue format. The operator originates the operation by selecting a mnemonic command and enters a parameter value without any help from the program.

The short form mnemonic operating sequence is: the task is displayed on the CRT in green. A line is drawn under the task. The operator selects the first mnemonic/parameter pair and enters it into the keyboard. It is displayed in yellow on the CRT. A carriage return terminates each mnemonic command. Subsequent commands are entered until the task has been completed. The operator hits the TAB bar to indicate that he is finished with this task, the next task is then presented. The total time is measured from the presentation of the task to the last carriage return. The think time is the accumulated time between the presentation of the task and typing the first character of the first command and also the time between each carriage return and the next typed character.

Long Form Mnemonic

The long form mnemonic also represents that class of commands which are operator controlled dialogues and do not present the operator with available alternatives. It is different from the short form mnemonic in that there is a smaller mnemonic list from which to choose. And each mnemonic format contains multiple arguments (For example SHIP/276,10).

This format represents a deeper more narrow decision tree than the short form mnemonic. One long form mnemonic command contains all the arguments necessary to accomplish a given task.

The long form mnemonic operating sequence is the same as the short form sequence except that only one command is entered. The task is displayed in green with a separating line, the operator enters the appropriate command with arguments and terminates it with a carriage return. He hits the TAB bar to go to the next task.

All keystrokes are recorded. The total time is the time between when the task is displayed and when the carriage return key is hit. The think time is the time between the task display and the first typed character.

Prompt

The prompt command format represents the class of commands in which the computer controls the dialogue without giving the operator a list of alternative inputs. The task is accomplished by the program asking the operator questions.

The scenario starts the same for all formats. The task is displayed in green with a separating line. The prompt format presents the operator with the first question. It asks for the operator to select and enter the ship's system needed to accomplish the task. The first character of the input is

unique for each ship's system. It is used to select the subsequent prompts. The remaining prompts in a selected system are fixed in sequence. See Appendix C for the list of prompts. Each input is terminated with a carriage return.

The program records the operators response, the total time and the think time. The total time is the time between the task display and the last carriage return. The think time is recorded for each input. It is the time between the prompt display and the first entered character. The scoring routine accumulates the individual prompt think time and calculates a total think time for the task.

Menu

The menu command format represents that class of formats for which the computer not only controls the dialogue but also provides the operator a list of alternatives from which to select.

The scenario starts the same. The task is displayed then the first menu. The first menu is the system menu. Each menu selection in the sequence determines the next menu to be displayed.

Numerical data (such as ship heading) falls back to the prompt mode, with the program asking for specific data. The operator has the option at each level, except with the prompted requests, to go back to the previous menu or back to the first (system) menu. Each input is terminated with carriage return, and the operator hits the TAB bar to go to the next task.

Each menu identifier code is recorded along with the operators response. The time and the think time is recorded for each menu. The total time for the task is also recorded. The task total time is from the time the task is displayed until the last carriage return. The think time for each menu is the time between the display of the menu and the time the first character of the respone is entered. The scoring routine aggregates the individual think times into a total task think time.

Treatment Selection

The experiment program randomly assigns a specific command format (or treatment) to each experimental operator. The random assignment was obtained from a random number generator. The random number generator is a 17 bit pseudo random shift register generator giving a sequence length of $2^{17}-1$ words. The starting seed is obtained from the time of day at the initialization of the program. Subsequent calls to the random number generator advance the shift register once. The output of the random number generator is a 16 bit word, with a numerical value from -16,383 to 16,383.

The 16 bit word is converted to a modulo 8 number (1-8). "1" selects the short form mnemonic format (SF1), with the functionally organized manual. "2" selects the short form mnemonic format (SF2), with the alphabetically organized manual. "3" and "4" select the long form mnemonic form (LF). "5" and "6" select the prompted format. And "7" and "8" select the menu format.

Semantic Differential

At the end of the performance test the operator is given a set of semantic differential scales to measure his attitude towards the command format used in the performance test. (See Appendix D). The semantic differential measures the operator's attitude on a specific concept by asking him to rate that concept on a scale anchored on the extremes by bipolar adjectives. For example,

Did you like the command format?

LIKED 1:2:3:4:5:6:7 DISLIKED

Task Description

The 55 tasks of this experiment are presented within the context of a naval warfare scenario. The experimental operator is the ship's computer operator. His task is to translate the captain's command (i.e., tasks) into the correct computer commands and enter them into the simulated system through the keyboard.

There are five basic ship's systems: 1) ship control system that provides heading and speed commands for manual control, 2) navigation system that establishes the destination for automatic control, 3) propulsion system to control the ship's boilers, 4) the radar system to control the ship's radar equipment, 5) the fire control system to control the ship's weapons systems. The fire control system is further subdivided into cannon, machine gun, torpedo, and depth charge control weapons systems.

Training

Before the operator is presented with the 55 tasks he is given a training session which consists of an explanation of the naval warfare scenario, and the command format which was assigned to him. These are displayed on the CRT. He is given an example of a typical task and the proper response on the CRT. All format tests use the same task example with the response appropriate to the assigned command format. He is then given a series of four training tasks. He enters his response to the task terminating his response by depressing the TAB bar. The program displays the correct responses in blue below his response, except for the prompt mode which displays the direct response for each prompt after that prompt response.

Manual

Each operator is given an operator's manual by the test coordinator at the beginning of the experiment. Each command format has its own manual. At the beginning of the performance test, the operator is asked to enter a number contained within a box on a specific page. If the entered number does not match the expected number for the assigned command format the program pauses until the coordinator supplies the operator with the correct manual and the correct number is entered. The manual describes the ship's five systems identically in all format manuals. Each command in the format is described with its arguments, their ranges and all limitations.

There are two different short form mnemonic manuals in order to provide a treatment for the for the experiment. The short form one (SF1) manual organizes the list of mnemonics in a functional manner. That is they are grouped by the ship's system with which they are associated. The short form two (SF2) manual organizes the mnemonics alphabetically.

Complexity

The amount of complexity in the tasks is varied in order to observe the effect of complexity on performance. The complexity is measured by the number of decisions an operator has to make to accomplish a task. There is three levels of task complexity, low as examplified by the ship control system task (3), medium as in the propulsion control system (5), and high as in the radar control system (9).

Compatibility

The tasks are displayed with the task parameters either in the same order as expected in the command argument list or out of order.

Descriptiveness

The descriptiveness of the task wording was varied to observe any effect on the performance. High descriptiveness provides wording establishing the context for the numerical task parameter, (for example, "Set the boiler pressure to 100 PSI"). Low descriptiveness leaves out the verbal context and provides only the parameter value with identifying units (for example, "100 PSI").

Completeness

A few of the tasks ask for only a single parameter instead of the set of parameters normally associated with the command. For example, a partial task will ask for only a change in ship's heading rather changes in both the heading and speed. Or, only the radar power level is adjusted instead of all the radar parameters.

Ability Tests

It is characteristic of this kind of experiment that differences between individuals are greater than differences between treatments. It is desirable to measure individual characteristics which may be used as mediating variables in the multivariate regression analysis. The variance due to these mediating variables is removed in the analysis leaving the remaining variance due to the treatment difference. The specific skills chosen as potentially influencing the operator performance are: typing skill, spatial ability, analytic ability, and short term memory.

Typing Skill

Typing skill is measured by giving the operator a page of text and measuring the time required by him to enter it into the keyboard. Also, separately each keystroke is recorded in order to obtain an error count. The typing test for this experiment was divided into four parts each emphasizing different typing characteristics. The first part was a page of practice characters. Every keyboard character was presented to the operator for practice. So that in the following typing tests, the character locations would not be completely new. This was felt to be required because of the wide range of typing skills and experiences. Some operators were accustomed to other keyboards with some different character locations, and some were not familiar with any keyboard. The second part of the typing test was one page of text taken from a standard typing test. It was English text telling a short story. The story required 6 pages of display. This was much too long for the expected operator typing skills, so only the first page was typed. The remaining pages were presented to the operator so that he could finish the story. These remaining five pages were the third part of the test. It is not a typing test but a reading test. Randomly, the five pages were displayed in either all caps or mixed mode lower case with appropriate capitalization (normal English test). The reading time is measured to provide a comparison between the two display modes.

The fourth typing test is a random character test. Three lines of random characters are displayed in groups of 3 characters for first page, 5 characters for the second, 7 for the next and 9 for the next. The preceding character groups consist exclusively of upper case alphabetic characters. The last page consists of 5 random characters per group taken from the entire range of printable ASCII characters. This test was to study the relation between group length and performance.

Spatial Ability

Spatial ability hopefully is measured with a series of mazes. The maze is displayed on the screen and the operator manuevers the cursor through the maze using the cursor control keys. He is looking at the maze from a position above so he can visualize the entire maze. The path taken through the maze is selected by the operator. His success in traversing the maze is expected to be related to his spatial ability. The total time to traverse the maze is recorded. Also each step and the time taken to make that step is recorded. The scoring routine scores the total time for one variable and the first step time for a second variable. The rationale for the first step time variable is that it was observed in the pilot testing that often the operator would traverse the maze visually before moving the cursor for the first time. The maze test consisted of seven mazes presented in order of increasing difficulty. The first five mazes were adapted from the Porteus Maze tests.(3) These first five mazes were intended for ages up to 10, so two more difficult mazes were created to hopefully increase the test variance.

Analytic Skills

Two analytic games are used in the experiment. The first is a mathematical sequence game. A sequence of five numbers is presented and the operator determine the next number in sequence. There were ten sequences generally ordered in terms of increasing difficulty. The sequences are shown in Appendix E together with their weighting scale. The scoring routine assigned greater weight to the sequences which are deemed to be more difficult. After the operator entered his estimate of the next number in sequence, the program either output "OK" for a correct input or output the correct answer in blue for an incorrect input.

The second game is called DUDZAP. It is included in the experiment as an attempt to tie this research data with previous research (4,5). The operator was presented with a series of six bit words. After the 6 bit words the program adds the word "ZAP" if the 6 bit word corresponds to a rule that the program knows but the operator doesn't. The rule is restricted to the logical OR combination of two of the six bits. If the word does not correspond to the rule, DUD is added to the word. The object of the game is for the operator to guess the rule from the given sequence of six bit words. The scores are obtained from the number of words displayed before the operator determines the correct rule and from the number of guesses made before the correct rule is determined. Four games were played with the final score aggregated from the separate games.

Short Term Memory

The short term memory test was modified for the computer experiment from standard short term memory tests (6,7,8). A series of five groups of randomly selected characters are displayed to the operator for 2 seconds. He is distracted for 5 seconds so that he does not rehearse the characters. Then he is asked to type in the characters. The number of characters in the group is increased from 3, to 5, to 7, and to 9. In order to distract the operator during the 5 seconds in the standard tests the subject is asked to count backwards by 3's The computer cannot monitor that activity so another approach was taken. A witty saying was displayed for the 5 seconds, hoping to distract the operator.

Demographic Questionnaire

Each operator is asked for his birth date. This information is intended to be used to tie the experimental data with the previous survey data. Age is derived from the year of birth. It is available as a mediating variable. Three questions cover the operator's job catagory and specific experience (see Appendix F). These questions provide a basis for stratifying the sample for specific analyses. The first question establishes the operator environment. The catagories are: station operating crew, station staff, net control operations, other DSN personnel and other non DSN personnel. The second question establishes the operators individual job catagory. The options are: operator, clerical, technician, engineer, programmer, supervisor, manager, and other. The third question establishes the operator's experience level for megadata terminals and for terminals in general. Another series of three questions attempt to measure characteristics relating to cognitive style (9). Preference for complexity is measured along with preference for structure and preference for variety.

8.0 RESULTS

The experimental results will be explored in this section. First the individual random format assignments will be considered, then the individual mediating variables, the performance test and finally the interrelationships will be considered.

Format Assignment

The command format used by each subject was selected by a random number generator. It is of interested to see if the random assignment was consistent throughout the experiment. The data records indicate that the experiment program was loaded 381 times. One hundred ninty four (194) starts of the experiment were recorded. Therefore, there were 193 loads which did not result in an experiment start. This can be due to several reasons. The subject number is incremented at each program load but the load is only recorded when the station ID is entered. So, a program load to check the equipment would not register if the station ID is not entered. Also, the station coordinator has the option of starting the program in the TEST mode which is recorded but is not reflected in the 194 experiment starts. The reasons for one half of the program starts failing to produce an experiment start is due to equipment checks and test mode runs, neither of which should affect the statistical frequency of formal selections.

The first meaningful measure of the frequencies of the random format selection is for program starts in the experiment mode and with the station ID entered. There were 194 of these program starts with frequencies listed in Table 8-1.

FORMAT	PROGRAM STARTS IN IN EXPERIMENT MODE	EXPERIMENT STARTS	EXPERIMENT COMPLETIONS	EXPECTED FREQUENCIES
Short form mnemonic #1	17 (8.8%)	16 (10.0%)	13 (12.2%)	12.5%
Short form mnemonic #2	20 (10.3%)	17 (10.5%)	7 (6.6%)	12.5%
Long form mnemonic	56 (28.8%)	43 (26.7%)	30 (28.3%)	25.0%
Prompt	60 (31.0%)	49 (30.4%)	34 (32.0%)	25.0%
Menu	41 (21.1%)	36 (22.3%)	22 (20.7%)	25.0%
Totals	194(100.0%)	161(100.0%)	106(100.0%)	100.0%

Table 8-1

Each percentage value is the percentage for that format of the total remaining at that stage of the experiment. The experiment starts when the questionaire has been completed. There is a fallout of 33 cases between the program start in the experiment mode and the actual experiment start. Again, these are expected to be equipment tests and are not legitimate experiments. The legitmate experiment starts are 161 cases. The frequencies (percentages) indicate that the short form mnemonic frequencies are close to the expected frequencies (10.0% vs. 12.5% and 10.5% vs. 12.5%). The discrepancy from the expected random frequency (12.5%) appears to be nominal. The long form mnemonic frequency is close to expectation (26.7% vs. 25%). The prompt format frequency is overrepresented (30.4% vs. 25%) but there is no reasonable

format related explanation so it should be accepted. The menu format frequnecy is slightly underrepresented (22.3% vs. 25%).

The column labeled as Experiment Completion contains frequencies of the experiment session which were carried to completion by the individual subjects. The total of 106 completed cases indicates that 55 subjects started the experiment but did not finish. The dropouts could be related to format effects, subject effects and/or external effects. Subject effects were not investigated and would be a good candidate for further investigations. The external effects are such things as termination of the session due to station demands for the equipment. The frequencies of all the formats except short form mnemonic 2 are reasonable and can be assumed to be random. The frequency for short form mnemonic 2 format is consideriable underrepresented. This is most likely a format effect and is discussed in detail in the section on document organization.

Mediating Variables

The mediating variables were scored individually. They are presented by specific test in this section.

Demographics

The first series of questions that are presented to the operator deal mainly with factors which may influence the results. The first variable is the operator's age. The average age is 34.5 for 89 experimental operators. The 1 sigma value was 10.3 years. The histogram of the age variable indicates that this is a good spread in age (range from 18 to 69). All ages are reasonably represented and the distribution is reasonable for a population of computer system operators.

The second demographic variable concerns the operator's organizational position. The choices were:

1. Station operating crew
2. Station staff (non operations)
3. Net control operations
4. Other non station DSN personnel
5. Other non DSN personnel

Forty-three percent reported that they were on the station operating crew with 37% reporting that they were non station DSN personnel. The remaining 20% were fairly equally distributed between the remaining catagories.

The next demographic variable is concerned with the operator's job classification. The choices were:

1. Operations
2. Clerical
3. Technician
4. Engineer
5. Programmer
6. Supervisor
7. Manager
8. Other

Thirty percent reported that they are in operations, 17% technician, 13% each for engineers and programmers.

The last demographic variable attempts to obtain a general experience level by measuring the operator's computer terminal usage. The catagories are:

1. Use Megadata terminal routinely
2. Use Megadata terminal occasionally
3. Use other computer terminals routinely
4. Use other computer terminals occasionally
5. Use word processor primarily
6. Do not use any computer terminals
7. None of the catagories fit

The variable values were fairly evenly distributed except for the word processor catagory and the none catagory. We can expect that most of the 23% who reported using the Megadata terminals routine are station operators. Twenty percent reported that they used other computer terminals regularly, and 13% used them occasionally. These are either operators in other systems (i.e., NOC Ops) or people are knowledgeable because they use interactive terminals. Twenty percent reported that they did not use any computer terminals.

Cognitive Style Variables

The next three questions relate to cognitve style. Cognitive Style is a method separating people into a limited set of groups based on their information processing habits. Knowledge of cognitive style allows prediction of some characteristics. The Driver-Mock cognitive style model (9) is used in this analysis. The Driver-Mock model is a two dimensional model in which one dimension is related to preference for structure and the other is related to preference for complexity. One style question asks the experiment operator for his preference for structure. The other two are related, one asks for preference for complexity and the other preference for variety. Each use a seven point scale with end points of highly structured/ highly unstructured, very simple/very complex, variety of tasks/consistent tasks.

The preference for structure has a mean of 4.55 on scale of 1 to 7 with "1" meaning a preference for structure. The histogram for this variable is bimodel, that is, there are two groups, one with a large preference for moderate to little structure and a small group prefering much structure.

The mean for the complex preference measure is 5.02, which is distinctly baised towards the preference for complexity, although there is a small indication of a second group which prefers simplicity.

The mean for the variety preference is 2.07 which is strongly baised towards the preference for a variety of tasks. It does not indicate any bimodal tendency. This variable reinforces the indicated preference for complexity.

These variables indicate that this population would not feel comfortable and would not care for a very structured procedurally oriented operating environment.

However, it should be recognized that these three variable are potentially affected by some strong cultural effects. For example, preference for complexity has some cultural connotation of intelligence, and therefore is more desirable. Preference for structure and variety have some similar connotations, therefore these variables are somewhat suspect.

Typing Skills

Individual typing skills were measured by a series of tests. The experimental operators training and skills self assessment were measured with a questionnaire. General text typing skill was measured. Random character code typing skill was measured. Thirty-five percent (35%) of the experimental operators reported that they used the touch typing method, that is, they use all ten fingers. Thirty-four percent (34%) reported that they used the two finger hunt and peck system, and 18% reported that they used the one finger hunt and peck system. This data appears reasonable for the experiment population. Fifty-nine percent (59%) reported that they had no formal typing training, 40% report that they did have formal training. The experimental operators self assesment of their typing skill was measured with the question "Can you type without looking at the keyboard or do you have to look for the characters?". It was measured on a seven point scale with the end points "never look" and "always look". Thirty-two percent (32%) reported that they always look. The remaining data is fairly evenly distributed. The mean is 4.99 reflecting the heavy response on the alway look extreme. This data suggests that the majority of the experimental operators were not skilled typists. This is expected and is supported by the experimenter's experience in administering the experiment. The most frequent complaint about the experiment from the station crews was the large amount of typing involved.

The text typing test data had a wide range of from .2 to 1.9 seconds per character. The mean was .67 second per character with a standard deviation of .30 seconds. The text was one page containing approximately 800 characters. The text was taken from a standard typing test and was normal English text. There were no numbers or special characters used.

The random character tests consisted of five pages of groups of approximatly 100 random characters. The first page grouped the characters in groups of three alphabetic characters. The next page used groups of 5, the next 7, and the fourth page was grouped in groups of 9 characters. The fifth page grouped 5 characters together but expanded the character set to the entire ASCII set instead of just alphabetic characters. The 3 character page typing speed mean was .84 sec per characters with a standard deviation of .36 sec. There appear to be two distinct groups from the histogram. The first one, centering on .40 sec per character, is assumed to represent the trained typist. The typing speeds are presented in Table 8-2. The speed is in seconds per character typed (including spaces).

TYPING TEST	MEAN	STANDARD DEVIATION	1st GROUP	2nd GROUP
Text	.67	.36	.36	.80
3 Random Char. Group	.84	.36	.40	.90
5 Random Char. Group	.94	.41	.40	1.05
7 Random Char. Group	1.03	.45	.40	1.10
9 Random Char. Group	1.09	.62	.50	1.20
5 Random ASCII Char Group	2.21	1.05	--	--

Typing Speed in Seconds per Character

Table 8-2

We can make some interesting observations from Table 2.

1. As we might expect, there are distinct differences in typing speeds between trained and untrained typists, differences of 1:2 to 1:3. The .40 sec per character corresponds to about 25 words per minute. This is fairly slow for a good typist, but a trained typist is not necessarily a good typist and the keyboard was unfamiliar to even the good typists. So an average of 25 words per minute is not unreasonable for trained typists in this experiment.

2. Random characters are more difficult to type than English text. This supports other findings in the field (10). The difference appears to be about a 10% speed penalty for the simplest random character groups over English text.

3. The trained typists' speed for different number of random characters in a group is quite constant. But, it is clear that the untrained typist has an adverse reaction to increasing the number of characters in a random group. This is most likely an interaction with short term memory. The trained typist does not use his short term memory. He keeps his eyes on the text and types without having to move them to the keyboard. The untrained typist (hunt and peck system) must look at the text, use his short term memory to store the characters, transfer his attention to the keyboard, recall the characters, and type them. The data supports the theory that short term memory is inversely related to the length of the character groups.

4. The random ASCII character set required more than twice the typing time as the equivalent (5 char. group) alphabetic only character set. We would expect longer typing time for characters with which the typist (trained or untrained) is not familiar. It is interesting to note that apparently training is not an asset for arbitrary characters. We should also note that the less used characters in the ASCII set are not in consistent locations on all keyboards. In fact, two of the ASCII characters were not even on the keyboard used in this experiment.

Spatial Ability

Spatial ability is measured by a series of mazes. It is assumed that spatial ability is related to the experimental operators ability to "see" the path through the maze. The time required to traverse the maze is measured as spatial ability. There are seven mazes starting with a simple one and progressing to more difficult ones. Table 3 gives the maze traverse times in seconds.

MAZE	MEAN	STANDARD DEVIATION
1	31.4	16.7
2	33.0	7.9
3	32.5	7.7
4	37.8	16.6
5	56.3	13.6
6	105.5	29.5
7	97.8	43.7

Maze Traverse Times

Table 8-3

The series of increasingly difficult mazes were used in order to give the operator practice and so that he could learn the mechanics before he tried difficult mazes. The first maze was very simple, its standard deviation indicative of the learning process. By the second maze the standard deviation indicates that the operators had essentially mastered the mechanics. The fourth maze starts to give an indication of differential effects. The sixth maze is in fact the most difficult as indicated by the mean traverse time and standard deviation. The seventh maze is somewhat easier as indicated by its mean traverse time. The large SD for the seventh maze can perhaps be explained by fatigue. Those individuals with high spatial ability will not be stressed and will perform well. But those with low spatial ability may well be fatigued after the previous hard maze and perform worse than expected.

Analytic Ability

Analytic ability was measured using two tests, the number sequence task and the DUDZAP game. The number sequence test was scored by summing the weighted correct answers over the 10 sequences. The data taken from this test is nominal, that is, it has meaning in relationship to other variables or to other groups but not in an absolute sense. The mean was 14.04 and the standard deviation was 7.28. The histogram indicates a reasonable distribution. So, the variable appears to have sufficient variance and proper distribution for further regression analysis.

The DUDZAP game was scored two ways. First by summing over the four games the number of displayed words required to determine the logic rule and second by summing the number of hypotheses or guesses required to determine the logic rule. The mean and standard deviation for the first is 28.0 and 16.0 and for the second is 17.0 and 10.8. Both variables appear to have sufficent variance and distribution to be useful in further regression analysis.

Performance tests

The results of the performance tests are plotted against specific experience in Appendix G. The performance time and think time are plotted for each format for each task of each system. The specific systems were plotted together to illustrate the change in performance for increased experience in a consistent situation. Three systems, ship control, propulsion control, and radar, will be discussed primarily because they represent low, medium, and high task complexities. Also, they will be discussed because they were exercised more completely than the other systems and provide a more complete picture of the format characteristics. From these plots, the following observations can be made.

Task Complexity

As is expected, more complex tasks require more time. The simplest system was the ship control system. It has a task complexity as defined in the issues section of this report of 3. There are three decisions to be made: which system is being commanded, and the heading and speed. The propulsion control system has a complexity of 5 and the radar control system of 9. The low complexity ship control system performance time appears to approach an asymptote at approximately 20 seconds. The medium complexity propulsion control system appears to approach the asymptote at approximately 30 seconds and the high complexity radar system at 40 seconds.

Attempts to compare the different systems with the same complexity have not been successful. This creates a presumption that the definition for complexity is too simple. Further effort is needed in refining the operationalization for complexity. Most likely, including the span of decision (or number of choices) would be fruitful.

Task Complexity vs. Command Complexity

It is clear that the complexity of the task determines the minimum complexity of the command. However, the command structure can add complexity. This is demonstrated by the performance time of the short form mnemonic format compared to the other formats. In all but the simplest task (ship control system) the short form mnemonic format performance times were significantly greater than the performance times for the remaining formats. This can be explained by examining the decision process. In selecting a command, the short form mnemonic format requires a mnemonic command for each parameter. Therefore, the entire mnemonic range of 45 mnemonics must be scanned for each parameter. The long form mnemonic has fewer mnemonics to scan (8) and they have to be scanned only once per task. Of course, the complete determination of the command from the mnemonic repertoire and the task parameters is more involved. Further research effort would be valuable in developing a more isomorphic model. It appears that a model based on an analysis of the decision processes for each command format may allow numerical complexity values to be derived which can be used for consistent comparisons between formats.

The existing comparisons between command formats is based entirely on the measured performance times. They do not include any assesment of error patterns. The analysis should be continued using the error rates for the individual task responses.

Command Format Comparison

Table 8-4 is a ranking of the command formats in terms of their overall performance times for each of the different experiment systems, with a higher number for the longer performance times.

	Format				
System	SF1	SF2	LF	P	M
Ship	1	1	1	1	1
Propulsion	2	2	1	1	1
Radar	4	3	2	1	1
Navigation	3	3	2	1	1
Cannon	4	5	3	2	1
Machine Gun	2	2	1	1	1
Depth Charge	2	3	1	1	1
Torpedo	3	3	2	1	2

Command Format Performance Ranking

Table 8-4

Those rankings were obtained by observations from the performance time plots in Appendix G.

From Table 8-4 it can be seen that the format differentiation is minimal for low systems complexity. The low complexity ship control system performance is essentially the same for all formats. The medium complexity propulsion control system shows differential effects between the short form formats and the others. The high complexity radar system shows significant differential effects for all but the prompt and menu formats.

Think Time

Think time is plotted on each system performance time plot in Appendix G. The think time is the time taken by the experimental operator to think about the task and decide which command or parameter to use. It is clear from the plots that, except for a very few isolated points, the think time follows the shape of the performance time plots very closely. This leads to the conclusion that the variance in the performance times are principally due to think time not to execution time. Table 8-5 is a ranking of the command formats in terms of the think time for each of the different systems, with higher numbers for longer think times.

	Format				
System	SF1	SF2	LF	P	M
Ship	2	2	1	3	3
Propulsion	4	4	1	2	3
Radar	3	3	1	2	3
Navigation	4	5	1	2	3
Cannon	3	4	1	2	2
Machine Gun	2	2	1	2	2
Depth Charge	2	3	1	2	-

Think Time Ranking

Table 8-5

The consistent ranking of one for the long form mnemonic is an artifact of the scoring routine. It did not take into account the think time for each argument, that is when the operator stopped to think between each argument for a command. Therefore it is somewhat lower that it should be. Patterns for think time rankings are somewhat more difficult to find than for performance times. However, it appears that the prompt and menu think times are in general less than for the short form mnemonics. And where there is a difference between the prompt and the menu, the prompt appears to have lower think times. The interaction between differential think time and system complexity appears to be very weak. This leads to a question about the consistency between the performance times of the long form mnemonic, the prompt, and the menu formats when that consistency doesn't seem to exist in the think time. This may be an artifact of the specific format design, that is the think time and execution times may cancel out for some unknown reason. More analysis and possibly more research is suggested in this area.

Compatibility

Compatibility is the similarily of the ordering of the task parameters and the command arguments. It would be expected that incompatibility would be seen in the increased times for performance. The variations for low complexity ship control performance are so small that compatibility difference are difficult to detect. The variations for high complexity radar performance are quite large and are consistent over the long form mnemonic, prompt, and menu plots, so it will be used to investigate the effect of incompatibility. The individual tasks plots Figure 8-1 are labeled either "C" for compatible or "C" for not compatible. Three out of five longer performance times (positive deviations) were associated with incompatible task presentations. All four shorter performance times (negative deviations) were associated with compatible task presentations. This lends support to the hypothesis that compatibility between the task presentation and the command format improves performance time, at least for the more complex tasks. Additional analysis may provide more insight into this process. Another way to analyze this issue is that 3 of the 4 incompatible tasks have positive deviations and 4 of the 6 compatible tasks have negative deviations, again providing some support for the hypotheses.

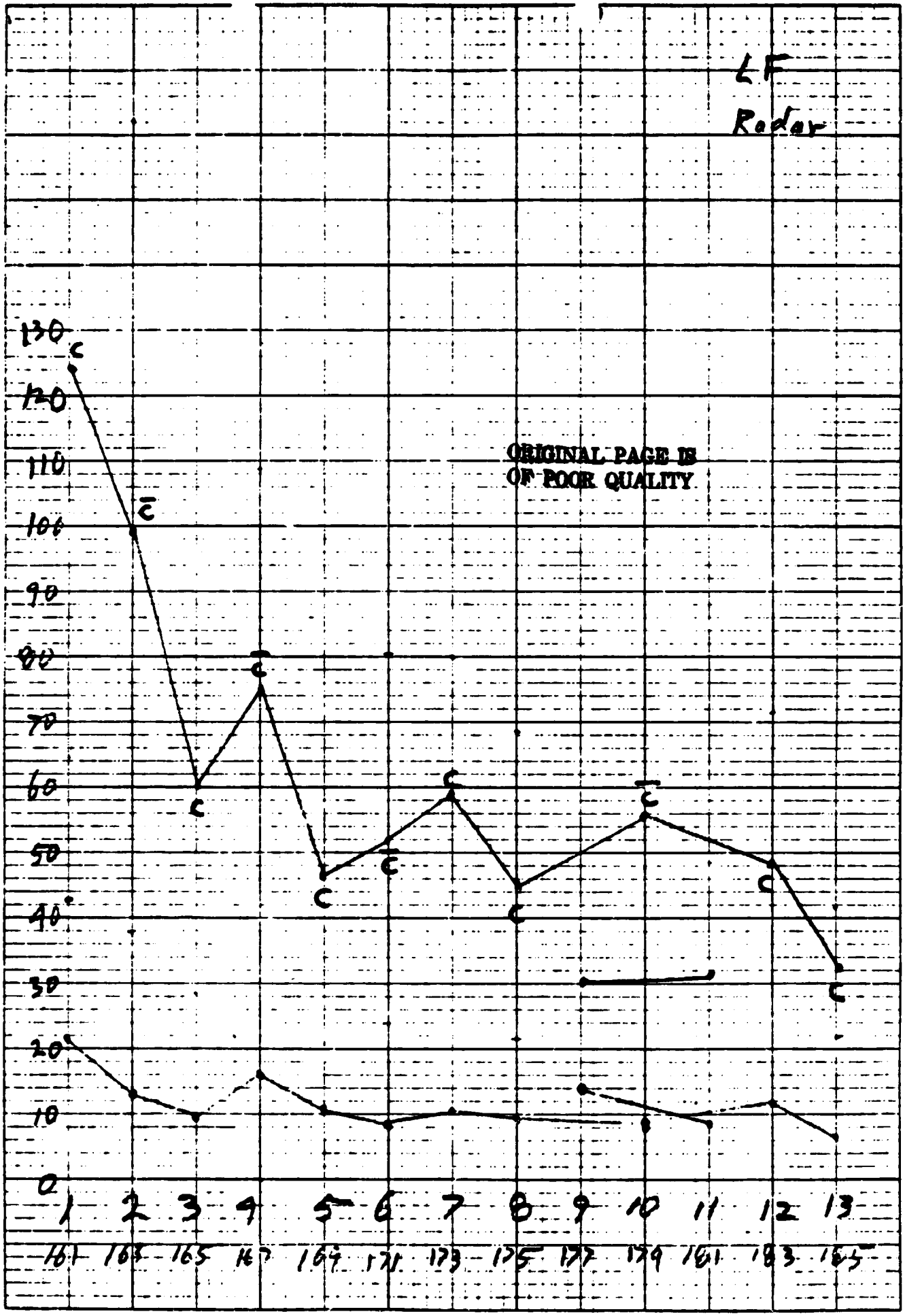

LF
Radar
ORIGINAL PAGE IS
OF POOR QUALITY
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13
161 163 165 167 169 171 173 175 177 179 181 183 185

Figure 8-1

Partial Tasks

At times a task requires only a partial system input. For example, in this experiment there were two tasks that required only the ship's speed to be changed instead of both speed and heading, or only the radar system power level was changed rather than all eight parameters. It is interesting to look at how the performance time is affected by these partial tasks for the different command formats. Table 8-6 lists the ranking of performance time improvement for the different formats for partial tasks.

	Format				
System	SF1	SF2	LF	P	M
Ship Control (low complexity)	1	1	3	3	2
Radar (high complexity)	1	1	3	3	2

Ranking of performance time improvement for partial tasks

Table 8-6

As might be expected the short form mnemonic formats show the most improvement for a partial task. In fact they show the best performance for a partial task. The short form mnemonic allows a one parameter task to be carried out with one mnemonic command. The other formats must identify which parameters are being changed and which one are not being changed.

Context Time

An interesting phenomenom can be observed in the ship control performance time plots (Appendix G) which is important for procedure design and for man computer interface dialog design. The ship control system performance time decreases with experience as expected. However, the last two points show a distinct performance time increase of about 25%. The difference between these two points and the preceding points is that these last two points are isolated tasks, that is they are inserted between tasks for other systems. The first series of ship control system data points are consecutive tasks. Reflection on this observation leads to the definition of another concept. This concept can be labelled "context". Context is the process an operator goes through when he approaches a different part of the system. He must identify that part of the system, determine what parameters are associated with it, and any limitations on the parameters. It takes time to do this, which we can call context time. Therefore a task accomplished within a series of similar tasks already has the context developed. A task embedded within dissimilar tasks requires restablishing the context and requires more time, even for the same operator experience level. This phenomenom is not observed in the other system plots because their data points were either all within one sequence or were all isolated events.

Documentation Style

Documentation style is concerned with the effects that different ways of presenting the user operating manual has on the performance time. This variable applied only to the short form mnemonic command format. The experimental operators who were assigned the short form mnemonic were randomly assigned either the manual organized functionally (SF1) or the manual organized alphabetially (SF2).

Differential effects are illustrated in three areas; the performance times, the attitude survey, and the differential completion rates for different formats. The performance time profiles for the SF1 and SF2 formats were very similiar. However, in all but one system (navigation) the first attempt to use the short form format took longer if the alphabetically organized manual was being used. Table 8-7 lists the percentage increase of SF2 over SF1 for each of the experimental systems from the performance time plots of Appendix B.

System	Percentage
Naviagation	0
Propulsion	11%
Ship control	20%
Radar	7%
Cannon	32%
Machine Gun	24%
Depth Charge	80%
Torpedo	8%

Increase of SF2 performance time
Over SF1 performance for
First system attempt

Table 8-7

Table 8-7 indicates that the alphabetic organized command list takes longer to use at first. The plots indicate that for the second and subsequent uses the user adjusts to the alphabetic order and the performance times are essentially the same.

The results of the post experiment semantic differential survey are presented in Appendix H. From this data we can see that:

1. SF1 commands were liked better than SF2 commands.

2. SF2 commands were felt to be slower than SF1 commands.

3. Both SF1 & SF2 were more uncomfortable than the other formats and SF2 was more uncomfortable than SF1.

4. SF2 commands were considered to be more complex than SF1 commands.

5. SF2 commands were felt to be harder to use than SF1 commands.

6. SF2 commands were significantly harder to learn than SF1 commands.

7. The SF1 command format was felt to be more useful than the SF2 command format.

8. The operators using SF2 had to look up the command more often than those using SF1

9. It was felt that the SF1 SOM was easier to use than the SF2 manual.

The survey shows a clear preference for the functionally ordered manual over the alphabetically ordered manual.

Table 8-8 lists the completion rate for the performance tests for the different formats.

Format	Completion Rate
Short Form Mnemonic one (SF1)	81%
Short Form Mnemonic two (SF2)	70%
Long Form Mnemonic	88%
Prompted	81%
Menu	85%

Format Completion Rates
Table 8-8

Noncompletion of the performance tests can be operator related or due to external causes. The equipment may have failed or have been required for higher priority activities (spacecraft track). Or the operator may have become fatigued or unmotivated. The completion rates for all the formats except for SF2 are quite consistent. We can assume that the lower completion rate of the SF2 format indicates either increased operator fatigue or loss of motivation. This interpretation is consistent with the previous analysis.

Low Experience Performance

The performance time for the first attempt at each system is listed in Appendix I. It shows the impact of the different formats on performance time for the first attempt to use each of the different systems. These patterns are summarized in Table 8-9 as performance rankings for each system.

System Format	SF1	SF2	LF	P	M
Navaigation	4	4	3	2	1
Propulsion	4	5	3	1	2
Ship Control	2	3	1	1	1
Radar	4	5	3	2	1
Cannon	4	5	3	2	1
Machine Gun	4	5	1	3	2
Depth Charge	4	5	3	1	2
Torpedo	3	4	2	1	2
Totals	29	36	19	13	12

First attempt performance Ranking
Table 8-9

In all systems, the two short form mnemonic formats take longer than the other three formats. In all but one the functionally oriented manual produced better performance than the alphabetically oriented manual. The rankings of the long form mnemonic, prompt, and menu formats are not as distinctive. The low complexity system (ship control) indicates essentially no format differential effect. The high complexity systems (Navigation, Radar and Cannon) indicate a consistent format differential effect with the menu format providing the best performance followed by the prompt format and then the long form mnemonic format. The medium complexity systems show mixed results. Summing the rankings in Table 8-9 for each format supports the observation that the first attempt performance difference between prompt and menu is very slight, that the long form mnemonic format requires somewhat longer time, and the short form mnemonic format requires siqnificantly longer times. Summing the raw performance times from Appendix I supports these observations. (Table 8-10).

SF1	SF2	LF	P	M
785	925	542	457	447

Performance times of first attempt
Summed over all system

Table 8-10

It is interesting to look at the format differentials of the performance times for the second attempts Table 8-11.

SF1	SF2	LF	P	M
624	620	449	400	401

Performance times of second attempts
Summed over systems

Table 8-11

The performance time plots suggest that the impact of the differences between formats are small by the second attempt to use a command except in the case of the short form mnemonic. Table 8-11 supports the difference between the short form mnemonic formats and the other formats. It supports the observation of minimun difference between the prompt and the menu formats but it appears that overall, the long form mnemonic format requires about 10% longer than the prompt and menu.

Semantic Differential Questionnaire

The semantic differential questionnaire at the end of the performance test probed the experimental operator's attitudes towards the format that he used for the performance tests. A seven point scale was used. 1 or 7 are extreme response and 4 is essentially neutral response. The responses for each format and each question are listed in Appendix H.

Some specific results are:

1. The operators liked the menu format the best, and they liked the short form mnemonic two (SF2) the least (Q1). All the other formats were liked about the same.

2. They felt that the SF2 format was slower than the other formats (Q2).

3. They felt that the prompt and menu formats were the most comfortable and the SF2 format the least confortable (Q4).

4. They felt that the prompted format was the simplest and the SF2 format was the most complex (Q6).

5. They felt that the prompt and menu formats were more "friendly" than the mnemonic formats (Q7).

6. They felt that the SF2 commands were harder to use (Q8) than the other formats, even though the SF1 commands were identical to SF2 ones.

7. The operators felt that the SF2 format was harder to learn than the other formats (Q9), which is statistically significant the 5% level.

8. The prompt and menu formats were felt to be the easiest to learn.

9. As might be expected, they indicated the most frustration with the SF2 format (Q10).

10. They indicated that the SF2 command format was the least useful (Q11).

11. Interestingly, the operators indicated that they used the manual for looking up commands most often for the SF1 format (Q14).

9.0 DISCUSSION

The first interesting item suggested by the experimental performance data is that complexity plays a very important role in the man computer interface. The performance difference between tasks of different complexities is greater than the performance difference between formats. And the differential format effects were directly related to the level of complexity. At the lower levels of complexity all formats performed essentially equally. At the higher levels of complexity the differential format effects became observable.

The commands which implement more complex tasks do require more time. This relationship is hardly unexpected. What is interesting is the performance levels associated with the various levels of complexity. Hypothesis four is supported. It appears that the average performance times once experience has been acquired are essentially equivalent for the long form mnemonic, prompt, and menu formats, and are:

Low complexity - 20 sec

Medium complexity - 30 sec

High complexity - 40 sec

The experimental data does not support hypothesis one, that operator performance is greater when the computer controls the dialogue for a series of commands and when the operator controls the dialogue for individual commands. In retrospect, it becomes clear that the task statements did not adequately expose this series/individual command condition. This hypothesis predicts better performance for the short form mnemonic format for individual (or short) commands and the prompt or menu formats for a series (or long) commands. The short form mnemonic does not show any advantage for the short commands, but the prompt and menu formats do show an advantage for the long commands. However, this may be more concerned with the issue of complexity rather than individual/series commands. We cannot make a statement about hypothesis one from the existing analysis. This issue may be more related to the error performance than the time performance and as such may show up in later analysis.

Hypothesis two states that for inexperienced operators system performance is better when the computer controls the dialogue and for experienced operators when the operator controls the dialogue. The data supports hypothesis two for inexperienced operators. However, it seems to be strongly related to task complexity. The low complexity tasks do not show a differential effect, the high complexity tasks do show a small differential effect. As the attitude survey indicates, there was a preference for computer controlled dialogue (prompt and menu formats). Starr Roxanne Hiltz* indicates that for a computer conferencing system which she examined, user preference was for a menu format until some time between 25 and 50 hours of operation. Then their preference switched to a command format. Apparently the naval senario experiment was not sufficiently long to expose a perference for mnemonic commands. The rather small differential effects may well indicate that the issue is not one of performance but of attitude.

*Comments during panel discussion at the ASIS 80 meeting, Anaheim, 7 Oct. 1980.

The experiment supported hypothesis three about the same level as hypothesis two. Hypothesis three states that the performance of inexperienced operators is greater when they have alternative actions displayed. There is some support for this conclusion from the very first attempts to carry out the complex tasks. The effect was small and the operators appeared to learn rapidly. There were no observable differences for low complexity tasks. The other aspect of hypothesis three is that experienced operator performance is greater when the alternatives are not displayed. This relates to the added time required to display the alternatives. This hypothesis was not supported by the data. We would expect the performance of the mnemonic format to be better after the experimental operators has become experienced. The performance time curves leveled off at essentially the same performance time for the long form mnemonic, prompt, and menu formats. Possibly more detailed analysis might expose some difference but this would not be a large difference.

Hypothesis five states that performance time is greater when the command argument order is compatible with the task parameter order. The experimental data provided some support for this hypothesis for complex task. The tasks which were less complex only had two parameters and the effect was minimal. Again, this effect may be related more to error performance then to time performance, and a difference may show up when error analysis is done.

The experimental data provides strong support for hypothesis six. Operator's manuals or documentation which are organized so the command lists are functionally organized rather than alphabetically organized leads to faster and more satisfying system performance. The performance times with functionally organized manuals were better, operator attitudes about the command format were better, and the completion rate was greater.

10.0 CONCLUSIONS

The following comments summarize the conclusions from this experiment:

1. There is no one best command format.

2. There is one worst format, it is the short form mnemonic. All other formats (long form mnemonic, prompt, and menu) start with some small differential effects and settle to essentially the same performance levels.

3. Complexity is a major issue, it produces most of the observed variance in the experiment. The other effects appear to be related to the level of complexity of the tasks.

4. Think time appears to predominate in performance times and in the variance of performance times.

5. Documentaton is important to acceptance and performance using mnemonic format. The prompt and menu formats are less susceptible to degradation due to poor documentation.

6. This experiment adequately explored short term effects but not long term effects. Techniques other than experiments must be used to explore long term, saturation, or overlearned effects.

11.0 RECOMMENDATIONS

There are three areas about which recommendation can be made based on this experiment.

First of all, the following recommendations can be made for design of man-computer interface (MCI) systems:

1. The MCI should be designed in relation to systems usage. MCI's which are going to be used by inexperienced operators, or used infrequently by even experienced operators should be designed for cognitive simplicity (Appendix A). MCI's which are used frequently, (i.e., everyday) by experienced operators should be designed for process simplicty.

2. The complexity of a MCI task should be kept within cognitive limitations. If a basic task requires a great number of decisions then it should be partitioned into a hierarchic format with a small number of decisions at each stage. Specifically the short form mnemonic command structure should not be used except for relatively simple systems.

3. The structure and organization of a MCI should be related to the functional process being controlled. The operator should be able to relate his input to the process that he is trying to control.

4. In the operator's manual, the list of commands should be organized functionally. That is commands should be presented in functional groups that simplify finding the desired one.

The second set of recommendations involves additional activity on this experimental data set:

1. The data samples taken after the initial closing date should be gathered from the stations and included in the data set. This will increase the sample size.

2. The data quality should be improved by finding and removing extraneous data. This is data which is not representative of the operator's response. For example, data from tests that were aborted should be removed.

3. Variables which were not scored for lack of time should be scored and analyzed. This relates primarily to the short term memory variable and the error profiles on other variables.

4. More sophisticated curve fitting should be attempted on the performance data.

5. The data should be analyzed by separating out different groups (for example, operators/non-operators) in order to examine population homogeneity.

6. Refine the operational definitions for task complexity.

Finally, the follow areas should be considered for future research:

1. Investigations into the long term effects of the different formats, most likely requiring field studys of existing systems.

2. Investigation of command structures with the goal of developing criteria for optimizing the decision tree structure for MCI dialogue design.

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APPENDIX A

Simplicity in Command and Control Systems: A Human Factors Consideration

SIMPLICITY IN COMMAND AND CONTROL SYSTEMS:

A HUMAN FACTORS CONSIDERATION

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ABSTRACT

Simplicity in the Man Computer Interface (MCI) is a desirable feature. Hopefully, it makes the system containing the MCI "easier to use". This paper uses results from a MCI study at the Jet Propulsion Laboratory (JPL) to identify an area where the system MCIs can be simplified. It identifies the circumstances where these simplifications are appropriate. The concepts of Cognitive simplicity and Process simplicity are presented as MCI design alternatives. The concepts of Understandability, Operation, Learnability, Level of learning, and Useability are presented as tools for the system designer. The use of these concepts to provide a systematic MCI design is discussed.

INTRODUCTION

The first thought many system designers have, when considering how to make the system easy to use, is to keep it simple. Unfortunately, what is simple to one, may not be simple to another. Very often, simplicity to the system designer means expressing the system in terms not at all simple to the user. It is not simple to the user because he does not understand the system to the same depth as the designer. In order then, to design a "simple" MCI, the designer needs to know the user's characteristics. Very few systems designers are prepared by training, experience, or even by basic nature to evaluate the systems user population in human terms. The system designers often cannot rely on Human Factors Specialists because of their short supply. Typically, the system designer will have to carry the responsibility for human factors. Hopefully, this paper will be useful to the system designer in this capacity. This is a conceptual paper exploring MCI simplicity to the level below the over-simplistic "keep it simple" idea.

It was recognized at JPL, a National Aeronautics and Space Administration facility, that a need existed to improve the MCI in the command and telemetry systems at the Deep Space Network(DSN), a spacecraft tracking station network. A project was initiated to gain a better understanding of the MCI dynamics. The project consisted of a series of focus groups, a survey, and an experiment (1). The focus groups and the survey explored the operator's perception of the system. The experiment provided comparative measurements between different MCI characteristics in simulated system configurations. The concepts in this paper were distilled from the focus group results. It was observed that the effectiveness of the operator depends upon the operator understanding how to operate the system. The effectiveness also depends upon the operator being able to operate the system. These then are two of many dimensions which affect the system ease of use. The first is labeled Cognitive simplicity. It is characteristic of a system which is easy to use because the system is easy to understand. The designer can improve Cognitive simplicity by providing system features which aid the operator in understanding the system. The second concept is labeled Process simplicity. It is characterized by minimum physical or mental effort being required to operate the system. The concept that humans prefer operations with the least effort is attributed to Zipf(2). It has face validity and it was also supported by the DSN MCI study. The system designer can control the Cognitive and Process simplicities and thereby hopefully he can improve the effectiveness of the MCI design. These two concepts are by no means the only ones affecting the MCI design, but we are limited by boundaries of this paper to these two concepts.

The concepts of Understandability, Operation, Learnability, Level of learning, and Useability are presented in order to provide a conceptual framework for the use of the concepts of Cognitive and Process simplicities by system designers. They are used by the system designer to analyze the system environments and to develop the rationale to select either Cognitive or Process simplicity for a specific MCI design.

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COGNITIVE SIMPLICITY

A process which has Cognitive simplicity is one which is easy to understand. The process may have Cognitive simplicity because it is basically simple. It may have Cognitive simplicity because it is compatible with the operators prior experience or knowledge. Cognitive simplicity may be due to cognitive aides being included in the design of the interface format. That is, aids which facilitate the operator's understanding of the MCI. They are typically structured aids such as menus or prompts which lead the operator through the MCI dialogue. They can also be structural elements in the MCI command formats which allow the operator to more easily separate the elements of the command format. Delimiters can be used in a command format to set off parameters and identify types of parameters.

For example:

MPC/36,2(10),18 (1)

the slash ("/") separates the mnemonic command name (MPC) from the argument parameters (36,2(10),18). The commas separate the parameters and the parenthesis identify an optional parameter. Conversely, command formats which are separated by only spaces are more cognitively complex because they do not provide the cognitive aids which help the operator understand the command structure.

Cognitive simplicity can be enhanced in a system by providing complete and fully explanatory error and status messages, on-screen instructions, or on-call help instructions. Complete and fully explanatory means that the messages contain all the information necessary to understand the command process. It also means that the context is well established. English language characteristics can be used to enhance the understanding. Subject, verb, object forms can be used together with redundancy to increase understanding. This is the natural language concept suggested by many.

PROCESS SIMPLICITY

Process simplicity relates to the relative ease which tasks can be accomplished. This may deal primarily with anthropological characteristics of the computer system operators. For example, with typing tasks, issues such as finger reach, keystroke pressure, key cap size, key spacing, etc. (3) are important. The obstacles to Process simplicity are then physiological limitations, such as finger reach, arm movements, etc.

Process simplicity may also deal with the mental effort required to operate a system. The actions may be basically cognitive activities such as selecting an item out of a population of items. The obstacles to Process simplicity then are psychological limitations such as short term memory, motivations, etc. Note that this concept is different than Cognitive simplicity in which we are concerned with the mental effort required to understand the process. The difference between the concepts is the difference between the effort required to understand the process versus the effort required to accomplish the process.

UNDERSTANDABILITY

Understandability (Figure 1-A) is the ease of which the system can be understood by the population of operators. Understanding a system is the process of an individual developing a model of the system(4,5) within the his own mind. On one end of this dimension, the parts of the system and their interrelationships fit together well in the individuals mind. On the other end of the dimension, the individual cannot identify parts of the system ("it is a black box") or cannot determine the relationship between parts ("beats me how it works"). System Understandability then is an aggregate measure over the operator population of the state of individuals minds or their attitudes about the system's ease of understanding. It can be measured with a self-reporting questionnaire. This measure can provide a relative measure for comparing different systems, but does not provide an absolute measure.

OPERATION

The concept of Operation (Figure 1-B) can be described by considering the two en... of the dimension. On one end, the operator can operate a system based on his good understanding of that system. That is, he has a good internal model of the system. On the other end, he may not understand the system, but operates it by rote, or by previously established procedures. Either method is reasonable and can lead to effective system operation depending upon the existing environment. Again, the system can be characterized by the aggregate of measures taken over the operator population.

Understandability

(A) Low — Hard to Understand ——— High — Easy to Understand

Operation

(B) By Rote — Uses Procedures Strictly ——— By Functional Understanding — Does not Use Procedures

Learnability

(C) Low — Hard to Learn ——— High — Easy to Learn

Level of Learning

(D) Low — Under Learned — Must Use Documentation — Normally Uses Documentation — Seldom Uses Documentation — Has to Think About Operating ——— High — Over Learned

Useability

(E) Low — Hard to Use ——— High — Easy to Use

Figure 1. Concept Dimensions

LEARNABILITY

Learnability is one of those concepts which is easy to inadequately define. The difficulty is: learning what? In this paper, system Learnability is limited to learning how to operate the system. Note that Learnability and Understandability are separate concepts. An operator can learn to operate a system without understanding the system. He can operate from procedures (by rote). The dimension (Figure 1-C) varies from hard to learn to easy to learn. Easy to learn can apply to the idea that it is easy to learn the operating procedures or that it is easy to learn to operate the system by functional understanding. Learnability can be measured by the time required for an operator to attain some proficiency level. The system Learnability is an aggregate of the individual measures over the operator population.

LEVEL OF LEARNING

Level of learning (Figure 1-D) progresses from "underlearned" in which the operator essentially does not know how to operate the system to "overlearned" in which the operator can operate the system without having to think through each step (i.e. automatically). The concept can also be considered in terms of the mental effort required to operate the system. When an individual is "underlearned", extreme mental effort (6) is required. Increased Level of learning brings the individual to where he can operate the system with the help of documentation or assistance from other people. As his Level of learning increases, he required less help from the documentation or other sources. Until he reaches an overlearned condition in which he needs no external assistance and furthermore he does not even have to think about the process in order to operate the system. An example is touch typing, a trained typist does not have to think about which finger is going to type a particular character, it is automatic.

Level of learning is a characteristic of the operator population and thus is an environmental factor to system design. However, the Level of learning measure of the operator population is influenced by the Learnability concept which is a system factor. When the Learnability of a system is high, we can expect that the Level of learning will be higher for that system with any given operator population than for a system with low Learnability.

ORIGINAL PAGE IS
OF POOR QUALITY

USEABILITY

Useability (Figure 1-E) is concerned with the ease of operating the system. It varies from hard-to-use to easy-to-use. The measure of useability for system is an aggregate measure of the operator population's perception of how easy it is to operate the system. It is obtained through a self-reporting questionnaire. Useability is related to both cognitive effort required (i.e. mental effort) and to physical effort required. When the system is being operated at a relatively low Level of learning, Useability is primarily a cognitive issue. That is, the operator must think through each step of the process and he has to exert extreme effort to understand what he is attempting to accomplish. When the system is being operated at a relatively high Level of learning, it is principally a minimum effort issue. The operator does not have to expend effort to learn the system. He wants to expend the least physical effort in accomplishing the task, i.e. keying in data, etc. And also wants to expend the least mental effort in evaluating conditions and making decisions.

COGNITIVE SIMPLICITY VERSUS PROCESS SIMPLICITY

Cognitive simplicity or Process simplicity within the man-computer interface design are alternates available to the system designer. The interface can be designed to aid the understanding of the process or it can be designed to aid accomplishing the process. The choice of using a menu interface versus a mnemonic interface is an example of these choices. Several authors have suggested that menu interface designs are useful when the user is learning the system, but he tends to become impatient when he knows the system and what he has to do (4,7). Menu interfaces usually are examples of Cognitive simplicity. They tend to be easy to understand and easy to learn. They tend to not have Process simplicity, because it often requires more effort to traverse through a series of menus than to enter a single mnemonic command to accomplish a task. Also, waiting for the menu to be displayed tends to destroy the operator's mental pacing.

Process simplicity in a MCI design is related to the effort required to accomplish the task. For example, Process simplicity is obtained by minimizing the number of key strokes or the effort required to accomplish the keystrokes. Mnemonics with single characters provide Process simplicity because of the minimum keystrokes. But a longer mnemonic (when properly designed) may have Cognitive simplicity, that is, it is easier to understand. For example, "D" for display request can be keyed with only one keystroke, but "DISPLAY" for display request is easier to understand. Which is better? It depends on the complexity of the task and the Level of learning associated with the operator population. A simple system task should allow a man-computer interface design which is both cognitive and process simple. Martin (8) describes an airline reservation system which uses single character mnemonics and each mnemonic is clearly related to its subject (ie, "E" for End). However, for a system MCI which is more complex, that is, it has a greater repertoire of commands, the single character loses its Cognitive simplicity because of the large discrimination space in which the operator has to work. He has more things to scan in deciding which command to use. And also, chances of ambiquity increase. For example, does "D" mean Display or Delete? In the DSN tracking station system man-computer interface study, the operators felt that three character mnemonics were about right. This was influenced by the fact that the system that they were normally use has three character mnemonics. What was interesting was that they did feel comfortable with the mnemonics. Three character mnemonics were appropriate for the command complexity of that specific system.

The system, which the operators in the DSN study normally use, is a mnemonic design. A mnemonic MCI design uses a command identifier, the mnemonic, and a list of arguments to apply to the commanded action. The operator has the option of using commas, slashes, colons, etc., or spaces for delimiters.

For example:

XYY/26,15:46:24 (2)

XYZ 26 154624 (3)

The first example has Cognitive simplicity, the second has Process simplicity. The delimiters in the first example provide Cognitive simplicity because they clearly delineate the mnemonic from its arguments (/), the arguments themselves (,), and the subparts of the time word (:) for hours, minutes, and seconds. The spaces used as delimiters in the second example provide Process simplicity in that they are considerably easier to use than the other deliminters. The space key is larger than the other keys. Fitts law (9) indicates better accuracy will be attained with a larger key, because the operator is less likely to miss the key. For operators who touch type, the space bar is hit with the thumb which has no other responsibilities. And the space bar does not require a shift key. Keystrokes which require shifting

are particularly bothersome. They greatly reduce the Process simplicity. The Level of learning for the DSN system indicated better effectiveness for the Process simplicity alternative (space delimiter option). A different system with a lower Level of learning would suggest that the delimiter option with greater Cognitive simplicity would be more effective.

Error and status messages are another area in which the system designer can exercise his design prerogatives. He can design the system error and status messages to be either short and concise or long and explanatory. They can be in the operators terminology or the designers terminology. The messages can explain the system fault only or they can additionally suggest recovery actions. The previous concepts can be used to help the designer choose the error and status messages characteristics.

Systems operating in a low Level of learning environment call for Cognitive simplicity. The system messages should be easy to understand. They should be long enough to be self-explanatory. Systems operating in a high Level of learning environment can be designed with Process simplicity. The frequency in which the message appears generally determines the Level of learning for that message. When a message appears very often, the operator recognizes the message immediately. Often, he recognizes it by its form rather then its content. That is, he recognizes the pattern, say the number of words or the size of words. This condition calls for a message with Process simplicity. It should be short so that it does not tie up the Input/Output terminal and it does not make the operator wait for its completion. Messages which are infrequent, call for Cognitive simplicity. They should be complete in their content, because the operator requires the content, in order to understand the message. These messages tend to be longer. A special case is a message which warns of a high risk system condition. When the risk associated with misunderstanding a system message is high, that message should be cognitively simple. It should be complete and self-explanatory even though it may be long and may appear often.

Cognitive simplicity and Process simplicity are not mutually exclusive. A system message may have both Cognitive and Process simplicity, i.e. it can be high in both dimensions. It can be short and completely understandable. Of course that is preferable, but not always obtainable. The opposite can also be true. The message may be low in both dimensions. It may be long and difficult to understand.

Whether the message is cognitively simple or complex is determined largely by whether it is presented in the operators terminology or the designer's terminology. That is, whether it fits the operator's internal model or the designer's internal model. Consider for example the following messages:

"The telemetry data rate is exceeding the system capacity."

"Step 26a is aborted."

"TLM buffer overflow."

The first message is appropriate to an operator's internal model when operating by functional understanding. It refers to the functional process of the system. The second message is appropriate to an operator's model when operating by procedures. It refers to a procedure step rather than the system itself. The third message is inappropriate because it is presented in terms of the systems internal design. It represents the designer's internal model not the operator's.

Error, warning, or fault messages can enhance cognitive simplicity by suggesting recovery action. The first message might also say "Reduce spacecraft telemetry data rate." The second message might go on to tell the operator to "Go to Anomoly Procedure M54." Again, the action suggested is in terms of the operating method expected. When operating by functional understanding (Figure 1-B), the recovery action should be given in terms of the system functions (i.e. reduce telemetry data rate). When operating by procedures (Figure 1-B), the recovery action should be given in terms of the procedures being used.

DISCUSSION

Concepts such as have been presented in this paper are only good when they can be used. This discussion will address the issue of how these concepts can be used in system design. Initially, the system designer must analyze the system goals. In addition, to the functional, cost, and schedule requirements, human factor goals should be analyzed. Usually, this is fairly simple. We want to maximize useability and hopefully thereby gain the most from the operator staff. However, other goals may be important, possibly political goals for example. This analysis will affect later design efforts.

The environment factors which influence the system design can be analyzed in terms of the previous concepts. The Operation concept is influenced by management desires. The military very often operates by rote or procedure ("Don't try to understand it, just do what you are told.") The Operation concept is influenced by such factors as personal turnover rates. For operations with low turnover, operation by functional understanding is appropriate; especially when the operators are well trained, experienced, and the operations task is somewhat unstructured. The JPL DSN has a relatively low operator turnover and the operators are well trained and are experienced. However, the high risk of failure in spacecraft operations make a combination of operating by procedures and by functional understanding appropriate.

The Level of learning is determined by the interaction of the operator population skill levels and the Learnability of the system. The type of user influences the expected Level of learning. Novice user will probably operate the system in an underlearned state. Casual users would operate the system with a higher Level of learning. They would have a basic understanding, but would require relearning details every time that they operate the system. Dedicated and experienced operators would probably operate the system at an overlearned level.

Cognitive simplicity and Process simplicity are used to tailor the operation of the system to match the environment as analyzed with the preceeding concepts. For example, the tracking stations of the JPL DSN operate at close to an overlearned condition. Some procedures are available for operations, but the operators normally work by functional understanding. The tracking station operational systems that are used everyday to track spacecraft, mostly have Process simplicity. The initial surveys conducted by the Human Factors Project indicated that the MCI design was appropriate for the existing Level of learning and the type of Operations except for one area. The initialization of the systems require a sequence of inputs to set up the system configuration. Some operators felt uncomfortable because the sequence required a higher level of understanding than existed and the process was prone to operator errors. The recommendation was to change the initialization from a mnemonic design to a prompted design in order to gain Cognitive simplicity. Another area that requires greater Cognitive simplicity is the systems which are used infrequently, such as the utility programs, dump programs, test programs, etc. The users must relearn them each time they are used. It is not cost effective to develop procedures for their use, they are used infrequently and very often are used on rather unstructured tasks (i.e., troubleshooting). An MCI design with greater Cognitive simplicity is more appropriate, such as a menu or prompted design.

CONCLUSIONS

This paper has presented a series of concepts which hopefully provide a theoretic foundation for one small area of man-computer interface design. The concepts provide an analytic tool for specific MCI design projects. Admittedly, this design approach may present difficulty to the MCI designer. Concepts are much harder to use than guidelines. Theoretical analysis places a greater burden on the designer to understand and properly use the concepts. Assuming that the concepts and their relationship are realistic and that the added analytic complexity is mastered, the benefit is a more systematic MCI design which will hopefully lead to a better MCI design.

The concepts of Cognitive and Process simplicity provide the MCI designers with specific design alternatives. The concepts of Operation and Level of learning provide the framework for selecting either Cognitive or Process simplicity for the MCI design. The concepts of Understandability and Learnability provide tools for the evaluation and comparison of different MCI designs. And the Useability concept provides an analysis and evaluation tool for the MCI design in terms of the system objectives.

RECOMMENDATIONS

The concepts of Understandability, Learnability, Operation Level of learning, and Useability are presented in this paper to support system analysis in developing the rationale for selecting either Cognitive or Process simplicity. The depth of this paper predicated limited discussion of these concepts. Further conceptual refinement is recommended. And in order to provide working tools for the system designer, it is recommended that guidelines be developed for specific application areas and measuring instruments be developed for each concept.

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APPENDIX B

Experiment completion statistics

Format Frequencies

FORMAT	MACHINE STARTS	TEST STARTS	TEST COMPLETIONS	EXPECTED FREQUENCIES
Short form mnemonic one	17(8.8%)	16(10.0%)	13(12.2%)	12.5%
Short form mnemonic two	20(10.3%)	17(10.5%)	7(6.6%)	12.5%
Long form mnemonic	56(28.8%)	43(26.7%)	30(28.3%)	25.0%
Prompted	60(31.0%)	49(30.4%)	34(32.0%)	25.0%
Menu	41(21.1%)	36(22.3%)	22(20.7%)	25.0%
Totals	194 (100%)	161 (100%)	106 (100%)	100.0%

Performance test completion by format

FORMAT	PERF TEST STARTED	SIG PERF TEST	PERF TEST COMPLETED
Short form mnemonic one	16(100%)	14(87%)	13(81%)
Short form mnemonic two	10(100%)	8(80%)	7(70%)
Long form menmonic	34(100%)	31(91%)	30(88%)
Prompted	42(100%)	36(86%)	34(81%)
Menu	26(100%)	24(92%)	22(85%)
Totals	130(100%)	113(87%)	106(82%)

APPENDIX C

Command Formats

Short Form Mnemonic One Command Format

Software Operators Manual

The following commands are used in the command directive test.

Navigation System

Longitude: lon/AAA BB CC D

AAA is the longitude degrees (0 - 359).
BB is the longitude minutes (0 - 59).
CC is the longitude seconds (0 - 59).
D is east or west longitude (E/W).

example: lon/89 50 12 E

Latitude: lat/AAA BB CC D

AAA is the latitude degrees (0 - 359).
BB is the latitude minutes (0 - 59).
CC is the latitude seconds (0 - 59).
D is north or south latitude (N/S).

example: lat/218 45 1 N

Day of year for the arrival: doa/AAA

AAA is the day of year for the ship's arrival (1 - 366).

example: doa/256

Time of day for the arrival: toa/AAAA

AAAA is the time of day for the ship's arrival in GMT (0 - 2400).

example: toa/1800

Status: nav/status

Navigation system status request.

Ship Control System

Heading: hed/AAA

AAA is the commanded ship's heading in degrees (0 - 360).

example: hed/270

Speed: spd/AA

AA is the commanded ship's speed in knots.

example: spd/18

Status: shp/status

Propulsion Control System

Select type of fuel: ftp/A

A is either bunker fuel 1, 2, or 3

example: ftp/1

Note: When the fuel type is selected, the fuel flow rate and the boiler pressure must also be changed.

Fuel Flow Rate: frt/AAA

AAA is the fuel flow rate in KG per hr. (100 - 600 KG per hr.).

example: frt/200

Boiler pressure: bpr/AAA

AAA is the commanded boiler pressure in PSI (50 - 250 PSI).

example: bpr/100

Status: prp/status

Radar Control System

Mode control: mde/AAA

AAA is either scan for the scan mode, or track for the track mode.

example: mde/scan

Note: The mode command must be entered first for scan or track mode changes.

For the scan mode, the following commands must be entered.

Moving Target Indicator: mti/AA

AA selects the moving target indicator either on or off (on/off).

example: mti/on

Note: The MTI command must be set in the scan mode but must not be set in the track mode.

Beam width: bwd/AAAAAA

AAAAAAA selects the beam wide to narrow, medium, or wide.

example: bwd/medium

Note: The beam width must be set in the scan mode but must not be set in the track mode.

For the track mode, the following command must be issued.

Target direction: rdr/AAA

AAA is the direction to the target in degrees (0 - 360).

example: rdr/289

Note: The direction command must be issued in the track mode but must not be issued in the scan mode.

Range: rng/AAA

AAA is the range scale for the scan mode and the target acquisition scale for the track mode. The range of values is 5,10,15,25,50,100 KM

example: rng/15

Note: The range command must be set in both the scan and the track modes.

Pulse rate: prt/AAA

AAA is the pulse rate in PPS (50,100,150,250,500,1000 PPS).

example: prt/100

Note: The pulse rate must be set for scan or track mode. It can be changed without changing the modes, in which case it is entered without the mode command. The power level must be set whenever the pulse rate is changed.

Power level: plv/AA

AA sets the transmitter power level in KW's (1,5,10 KW).

example: plv/10

Note: The power level can be changed for the last configuration. If the pulse rate is changed, it must be entered before the power level command.

Status: rds/status

Fire Control System

Torpedo system

Torpedo Tube select: tbn/A

A is the selected torpedo tube number (1 - 4).

example: tbn/3

Torpedo warhead select: twh/AA

AA selected the warhead for the torpedo . The chose is between high explosive (HE) or armor piercing (AP).

example: twh/AP

Target range: trg/AAAAAAA

AAAAAAA is the range to the target in meters.

example: trg/13000

Torpedo running speed: tsp/AA

AA is the torpedo running speed in knots.

example: tsp/25

Torpedo running depth: tdp/AA

AA is the torpedo running depth in meters.

example. tdp/10

Status: tpd/status

Cannon system

Platform number: pno/A

A is the number of the gun platform containing the selected cannon (1 - 6).

example: pno/3

Gun size: gsz/AA

AA selects either the 20 mm cannon (20) or the 125 mm cannon (125).

example: gsz/125

Target altitude: cal/AAAA (20 mm cannon only)

AAAA is the altitude in meters of the aircraft target for the 20 mm cannon in the anti-aircraft mode.

example: cal/500

Target direction: cdr/AAA

AAA is the direction of the target in degrees (0 - 360).

example: cdr/245

Target range: crg/AAAAAA

AAAAAAA is the range to the target in meters.

example: crg/200000

Number of rounds: nrd/AA

AA is the number of rounds to be fired.

example: nrd/200

Warhead select: cwh/AA

AA is either HE for high explosive, AP for armor piercing, or SP for shrapnel.

example: cwh/SP

Status: cst/status

Machine gun system

Machine gun number: mgn/A

A is the machine gun number (1 - 20, or all)

example: mgn/15

Machine gun size: msz/AA

AA is 30 for .30 caliber machine guns and 50 for .50 caliber ones.

example: msz/50

Target direction: mtd/AAA

AAA is the direction to the target in degrees (0 - 360).

example: mtd/145

Target range: mtr/AAAAAA

AAAAAA is the range to the target in meters.

example: mtr/12000

Cease Fire: cfr/

This commands the previously selected machine guns to cease firing.

Status: mgs/status

Depth charge system

Number of depth charges: dcn/A

A is the number of depth charges to be dropped.

example: dcn/5

Depth charge size: dsz/AAA

AAA is either 100, 250, or 500 KG's to select the size of the depth charges to be dropped.

example: dsz/250

Interval: int/AA

AA is the number of seconds interval between dropping the individual depth charges.

example: int/15

Firing depth: dpt/AA

AA is the firing depth in meters set into the depth charges.

example: dpt/60

Status: dcs/status

Short Form Mnemonic Two Command Format

Software Operators Manual

The following commands are used in the command directive test.

bpr/AAA — Boiler pressure, propulsion control system.

AAA is the commanded boiler pressure in PSI (50 - 250 PSI).

example: bpr/100

bwd/AAAAAA — Beam width, scan mode, radar control system.

AAAAAA selects the beam width to narrow, medium, or wide.

example: bwd/medium

Note: The beam width must be set in the scan mode but must not be set in the track mode.

cal/AAAA — Target altitude, cannon system (20 mm cannon only).

AAAA is the altitude in meters of the aircraft target for the 20 mm cannon in the anti-aircraft mode.

example: cal/500

cdr/AAA — Target direction, cannon system.

AAA is the direction of the target in degrees (0 - 360).

example: cdr/245

cfr/ — Cease fire, machine gun system.

This commands the previously selected machine guns to cease firing.

crg/AAAAAA — Target range, cannon system.

AAAAAA is the range to the target in meters.

example: crg/20000

cst/status — Status, cannon system.

cwh/AA — Warhead select, cannon system

AA is either HE for high explosive, AP for armor piercing, or SP for shrapnel.

example: cwh/SP

dcn/A — Number of depth charges, depth charge system

A is the number of depth charges to be dropped.

example: dcn/5

dcs/status — Status, depth charge system

doa/AAA — Day of year for the arrival, navigation system.

AAA is the day of year for the ship's arrival (1 - 366).

example: doa/256

dpt/AA — Firing depth, depth charge system.

AA is the firing depth in meters set into the depth charges.

example: dpt/60

dsz/AAA — Depth charge size, depth charge system.

AAA is either 100, 250, or 500 KG's to select the size of the depth charges to be dropped.

example: dsz/250

frt/AAA — Fuel flow rate, propulsion control system.

AAA is the fuel flow rate in KG per hr. (100 - 600 KG per hr.).

example: frt/200

ftp/A — Select type of fuel, propulsion control system.

A is either bunker fuel 1, 2, or 3

example: ftp/1
Note: When the fuel type is selected, the fuel flow rate and the boiler pressure must also be changed.

gsz/AA Gun size, cannon sytem.

AA selects either the 20 mm cannon (20) or the 125 mm cannon (125).

example: gsz/125

hed/AAA Heading, ship control system.

AAA is the commanded ship's heading in degrees (0 - 360).

example: hed/270

int/AA Interval, depth charge system.

AA is the number of seconds interval between dropping the individual depth charges.

example: int/15

lat/AAA BB CC D Latitude, navigation system.

AAA is the latitude degrees (0 - 359).
BB is the latitude minutes (0 - 59).
CC is the latitude seconds (0 - 59).
D is north or south latitude (N/S).

example: lat/218 45 1 N

lon/AAA BB CC D longitude, navigation system.

AAA is the longitude degrees (0 - 359).
BB is the longitude minutes (0 - 59).
CC is the longitude seconds (0 - 59).
D is east or west longitude (E/W).

example: lon/89 50 12 E

mde/AAA Mode control, radar control system.

AAA is either scan for the scan mode, or track for the track mode.

example: mde/scan

Note: The mode command must be entered first for scan or track mode changes.

mgn/A — Machine gun number, machine gun system.

A is the machine gun number (1 - 20, or all).

example: mgn/15

mgs/status — Status, machine gun system.

msz/AA — Machine gun size, machine gun system.

AA is 30 for .30 caliber machine guns and 50 for .50 caliber ones.

example: msz/50

mtd/AAA — Target direction, machine gun system.

AAA is the direction to the target in degrees (0 - 360).

example: mtd/145

mti/AA — Moving target indicator, scan mode, radar system.

AA selects the moving target indictor either on or off (on/off).

example: mti/on

Note: The MTI command must be set in the scan mode but must not be set in the track mode.

mtr/AAAAAA — Target range, machine gun system.

AAAAAA is the range to the target in meters.

example: mtr/12000

nav/status — Status, navigation system.

nrd/AA — Number of rounds, cannon system.

AA is the number of rounds to be fired.

example: nrd/200

plv/AA — Power level, radar control system.

AA sets the transmitter power level in KW's (1, 5, or 10 KW).

example: plv/10

Note: The power level can be changed for the last configuration. If the pulse rate is changed, it must be entered before the power level command.

pno/A — Platform number, cannon system.

A is the number of the gun platform containing the selected cannon(1 - 6).

example: pno/3

prp/status — Status, propulsion control system.

prt/AAA — Pulse rate, radar control system.

AAA is the pulse rate in PPS (50,100,150,250,500,1000 PPS).

example: prt/100

Note: The pulse rate must be set for scan or track mode. It can be changed without changing the modes, in which case it is entered without the mode command. The power level must be set whenever the pulse rate is changed.

rds/status — Status, radar control system.

rdr/AAA — Target direction, track mode, radar control system.

AAA is the direction to the target in degrees (0 - 360).

example: rdr/289

Note: The direction command must be issued in the track mode but must not be issued in the scan mode.

rng/AAA — Range, radar control system.

AAA is the range scale for the scan mode and the target acquisition scale for the track mode. The range of values is 5,10,15,25,50,100 KM.

example: rng/15

Note: The range command must be set in both the scan and the track modes.

shp/status — Status, ship control system.

spd/AA — Speed, ship control system.

AA is the commanded ship's speed in knots.

example: spd/18

tbn/A — Torpedo tube select, torpedo system.

A is the selected torpedo tube number (1 - 4).

example: tbn/3

tdp/AA — Torpedo running depth, torpedo system.

AA is the torpedo running depth in meters.

example: tdp/10

toa/AAAA — Time of day for the arrival, navigation system.

AAAA is the time of day for the ship's arrival in GMT (0 - 2400).

example: toa/1800

tpd/status — Status, torpedo system.

trg/AAAAAA — Target range, torpedo system.

AAAAAA is the range to the target in meters.

example: trg/13000

tsp/AA — Torpedo running speed, torpedo system.

AA is the torpedo running speed in knots.

example: tsp/25

twh/AA — Torpedo warhead select, torpedo system.

AA selects the warhead for the torpedo. The chose is between high explosive (HE) or armor piercing (AP).

example: twh/AP

Long Form Memonic Command Format

Software Operators Manual

The following commands are used to control the ship in this exercise. The delimiters between the parameters of these commands can be either spaces or commas. Except where parameters are skipped and commas are required to identify missing parameters.

Navigation system

nav/AAA,BB,CC,D,EEE,FF,GG,H,III,JJJJ

where:
AAA is the longitude degrees (0-359).
BB is the longitude minutes (0-59).
CC is the longitude seconds (0-59).
D is the east or west longitude (E/W).
EEE is the latitude degrees (0 - 359).
FF is the latitude minutes (0 - 59).
GG is the latitude seconds (0 - 59).
H is north or south latitude (N/S).
III is the arrival day of year (1 - 366).
JJJJ is the arrival time of day (0 - 2400)GMT.

example: nav/186,57,32,E,97,3,16,S,226,1800

To request status: nav/status

Ship control system

ship/AAA,BB

Where:
AAA is the ship's heading in degrees (0 - 360).
BB is the ship's speed in knots.

example: ship/180 15

Note: The ship's heading and speed can be commanded separately.

example: ship/127
ship/,21

To request status: ship/status

Propulsion system

prop/A,BBB,CCC

Where:
A is the type of fuel selected (1, 2, or 3).
BBB is the commanded fuel flow rate in KG per hr (100 - 600 KG per hr.).
CCC is the commanded boiler pressure in PSI (50 to 250 PSI).

example: prop/1 200 100

Note: The fuel flow rate and boiler pressure can be changed without changing the fuel type.

example: prop/,300,250

To request status: prop/status

Radar system

radr/scan,AAA,BB,DD,EEE,FF

for the scan mode and

radr/track,CCC,DD,EEE,FF

for the track mode

Where:
scan selects the scan mode.
track selects the track mode.
AAA is the scanning beam width (narrow, medium, or wide).
BB is the MTI control (on/off) for scan mode only.
CCC is the target direction in degrees for acquisition (0 - 360), for track mode only.
DD is the range selector in KM (5 - 100 KM) for the scan mode.
DD is the target acquisition range in KM (5 - 100 KM) for the track mode.
EEE is the pulse rate in PPS (50 - 1000 PPS).
FF is the transmitter power level select in KW (1, 5, or 10 KW).

examples: radr/scan,medium,off,10,150,5

radr/track,256,100,500,10

To change pulse rate and power level only for scan mode:

radr/scan,,,250,10

To change pulse rate and power level only for track mode:

radr/track,,250,10

Note: For abbreviated commands the mode must be consistent with the previously selected mode.

To change the power level only:

radr/scan,,,,5

radr/track,,,,5

To request status: radr/status

Fire Control System

The following commands control the firing systems, torpedo, cannon, machine gun, and depth charge.

Torpedo

firet/A,BB,CCC,DD,EE

Where:

- A is the torpedo tube number (1 - 4).
- BB is the warhead select
  - HE for high explosive
  - AP for armor piercing.
- CCC is the range to the target in meters.
- DD is the torpedo running speed in knots.
- EE is the torpedo running depth in meters.

example: firet/4,AP,15000,35,15

To request status: firet/status

Cannon

firec/A,BB,CCCC,DDDD,EEEE,FFF,GG

Where:

A is the gun platform number (1 - 6).
BB is the size of the gun selected (20 for 20 mm, 125 for 125 mm).
CCCC is the target altitude in meters (20 mm gun only).
DDDD is the target direction in degrees (0 - 360).
EEEE is the target range in meters.
FFF is the number of rounds to be fired.
GG is the warhead select,
HE for high explosive,
AP for armor piercing,
SP for shrapnel.

examples: firec/4,20,850,135,1800,10,HE

firec/3,125,,45,18000,2,SP

To request status: firec/status

Machine Gun system

firemg/A,BB,CCC,DDDD

Where:

A is the machine gun number (1 - 20, or all).
BB is the machine gun size,
30 for .30 caliber, or
50 for .50 caliber.
CCC is the target direction in degrees (0 - 360).
DDDD is the target range in meters.

example: firemg/3 30 105 800

To cease firing:

firec/cease fire

To request status:

firec/status

Depth Charge system

firedc/A,BBB,CC,DD

Where:

A is the number of depth charges to be dropped.
BBB is the size of the depth charges (100, 250, or 500 KG).
CC is the interval in seconds between depth charge drops.
DD is the fire depth in meters set into the depth charges.

example: firedc/4 100 20 25

Status:

firedc/status

Prompt Command Format

Software Operators Manual

The following prompts will be issued with the corresponding responses expected. Underlining indicates specific response options. Each response is terminated with a carriage return. A prompt can be bypassed with a carriage return response.

Prompt	Response	Explanation
System		
SYSTEM?	navigation	Selects the navigation system.
	ship	Selects the ship control system.
	propulsion	Selects the propulsion system.
	radar	Selects the radar system.
	fire control	Selects the fire control system.
Navigation System		
STATUS?	yes	requests navigation system status
	no	no or CR selects next prompt
LONGITUDE?	Enter longitude in degrees, minutes, seconds, and east or west	
LATITUDE?	Enter latitude in degrees, minutes, seconds, and north or south	
ARRIVAL DAY OF YEAR?	Enter arrival day of year (1 - 366)	
ARRIVAL TIME OF DAY?	Enter arrival time of day (0 - 2400)	
Ship Control System		
STATUS?	yes	requests ship control system status
	no	no or CR selects next prompt
HEADING?	Enter ship's heading in degrees (0 - 360)	
SPEED?	Enter ship's speed in knots	
Propulsion System		
STATUS?	yes	requests propulsion system status
	no	no or CR selects next prompt
FUEL TYPE?	1,2,3	Selects the fuel type

Propulsion System (cont.)

FUEL RATE?	Enter fuel flow rate in KG per hr. (100 - 600)	
BOILER PRESSURE?	Enter boiler pressure in PSI (50 - 250)	

Radar System

STATUS?	yes no	requests radar system status no or CR selects the next prompt
MODE?	scan track	Selects operating mode
BEAM WIDTH?	narrow medium wide	Selects scan beam width (scan mode only) Bypass for track mode.
DIRECTION?	Enter target direction	in degrees (0 - 360) (track mode only) Bypass for scan mode.
MTI?	on off	Controls moving target indicator (scan mode only) bypass for track mode.
RANGE?	Enter range in KM (5 - 100)	Range scale for scan mode. Acquisition range for track mode.
PULSE RATE?	Enter pulse rate in PPS (50 - 1000)	
POWER LEVEL?	Enter power level in KW (1,5,10)	Transmitter output power level.

Fire Control System

WEAPONS?	torpedo	Selects the torpedo system
	cannon	Selects the cannon system
	machine gun	Selects the machine gun system
	depth charge	Selects the depth charge system

* Torpedo system

STATUS?	yes no	requests the torpedo system status. no or CR selects the next prompt.
TUBE NO.?	Enter the tube number	Selects the torpedo tube number to be used (1 - 4).
WARHEAD?	HE AP	Selects either the high explosive or armor piercing warhead.

Torpedo system (cont.)

RANGE?	Enter range to target in meters.	
SPEED?	Enter torpedo running speed in knots.	
DEPTH?	Enter torpedo running depth in meters.	

* Cannon system

STATUS?	yes no	requests cannon system status. no or CR selects next prompt.
GUN NO.?	Enter gun platform number (1 - 6).	
SIZE?	20 125	gun size selected either 20 mm or 125 mm.
TARGET ALTITUDE?	Enter target altitude in meters (20 mm gun only).	
TARGET DIRECTION?	Enter target direction in degrees (0 - 360).	
RANGE?	Enter target range in meters.	
NUMBER OF ROUNDS?	Enter number of rounds to be fired.	
WARHEAD?	HE AP SP	Select warhead, eith high explosive, armor piercing, or shrapnel.

* Machine gun system

STATUS?	yes no or CR	requests machine gun status selects next prompt.
CEASE FIRE?	yes no	cease firing on all machine guns selects next prompt.
MACHINE GUN PLATFORM?	Enter machine gun number (1-20 or all)	
SIZE?	30 50	.30 caliber .50 caliber
DIRECTION?	Enter target direction in degrees (0-360)	

* Depth Charge system

STATUS?	yes	requests machine gun system status.
	no	no or CR selects the next prompt.

NUMBER OF DEPTH CHARGES? Enter the number of depth charges to be dropped in the pattern.

SIZE?	100	Size of the depth charges to be
	250	dropped in KG.
	500	

INTERVAL? Enter the interval between depth charge drops in seconds.

DEPTH? Enter the firing depth in meters.

Menu Command Format

```
"SYSTEM SELECT",
"1.  NAV SYSTEM",
"2.  SHIP CONTROL SYSTEM",
"3.  PROPULSION CONTROL SYSTEM"
"4.  RADAR CONTROL SYSTEM"
"5.  FIRE CONTROL SYSTEM"
"6.  TERMINATE REQUESTS"

        "NAV REQUEST",
        "1.  NEW REQUEST"
        "2.  STATUS",
        "3.  LAST MENU",
        "4.  SYSTEM MENU",

                "ENTER LONGITUDE "
                "ENTER LATITUDE "
                "ENTER ARRIVAL DAY OF YEAR ",
                "ENTER ARRIVAL TIME OF DAY ",
                "THE NAVIGATION SYSTEM IS GREEN",

        "SHIP CONTROL",
        "1.  HEADING & SPEED"
        "2.  HEADING ONLY",
        "3.  SPEED ONLY",
        "4.  STATUS",
        "5.  LAST MENU",
        "6.  SYSTEM MENU"

                "ENTER HEADING"
                "ENTER SPEED ",
                "THE SHIP CONTROL SYSTEM IS GREEN"

    "PROPULSION CONTROL",
    "1.  PROPULSION SYSTEM SET UP",
    "2.  FUEL RATE & BOILER PRESSURE ONLY"
    "3.  STATUS",
    "4.  LAST MENU",
    "5.  SYSTEM MENU",
                "THE PROPULSION SYSTEM STATUS IS GREEN"

                "FUEL TYPE",
                "1.  BUNKER FUEL #1"
                "2.  BUNKER FUEL #2"
                "3.  BUNKER FUEL #3"
                "4.  LAST MENU",
                "5.  SYSTEM MENU"

                "FUEL RATE"
                "1.  100 KG PER HR"
                "2.  200 KG PER HR"
                "3.  300 KG PER HR"
                "4.  400 KG PER HR"
                "5.  500 KG PER HR"
                "6.  600 KG PER HR"
                "7.  LAST MENU"
                "8.  SYSTEM MENU",

                "BOILER PRESSURE"
                "1.  50 PSI"
                "2.  100 PSI"
                "3.  150 PSI"
                "4.  200 PSI"
                "5.  250 PSI"
                "6.  LAST MENU"
                "7.  SYSTEM MENU"
```

```
"RADAR CONTROL"
"1.  SET UP NEW RADAR MODE"
"2.  POWER LEVEL ONLY"
"3.  PULSE RATE AND POWER LEVEL ONLY"
"4.  STATUS"
"5.  LAST MENU"
"6.  SYSTEM MENU"

        "RADAR SYSTEM IS GREEN"

        "RADAR MODE CONTROL"
        "1.  SCAN",
        "2.  TRACK",
        "3.  LAST MENU",
        "4.  SYSTEM MENU",

        "RADAR BEAM WIDTH CONTROL"
        "1.  NARROW",
        "2.  MEDIUM"
        "3.  WIDE",
        "4.  LAST MENU",
        "5.  SYSTEM MENU"

        "ENTER RADAR POINTING DIRECTION"

        "MTI CONTROL"
        "1.  ON",
        "2.  OFF",
        "3.  LAST MENU",
        "4.  SYSTEM MENU",

        "RADAR RANGE SELECTON"
        "1.  5  KM"
        "2.  10 KM"
        "3.  15 KM"
        "4.  25 KM"
        "5.  50 KM",
        "6.  100 KM",
        "7.  SYSTEM MENU"

        "RADAR PULSE RATE"
        "1.  50 PPS"
        "2.  100 PPS"
        "3.  150 PPS"
        "4.  250 PPS"
        "5.  500 PPS"
        "6.  1000 PPS",
        "7.  LAST MENU",
        "8.  SYSTEM MENU"

        "RADAR POWER LEVEL"
        "1.  1 KW",
        "2.  5 KW",
        "3.  10 KW",
        "4.  LAST MENU"
```

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```
"FIRE CONTROL".
"SELECT WEAPONS SYSTEM"
"1.  TORPEDO".
"2.  CANNON".
"3.  MACHINE GUN"
"4.  DEPTH CHARGE"
"5.  LAST MENU".
"6.  SYSTEM MENU"

        "TORPEDO CONTROL"
        "1.  FIRE TORPEDO"
        "2.  STATUS",
        "3.  LAST MENU"
        "4.  SYSTEM MENU"

                "TORPEDO SYSTEM IS GREEN"

                "SELECT TORPEDO TUBE".
                "1.  TUBE NO.1"
                "2.  TUBE NO.2"
                "3.  TUBE NO.3"
                "4.  TUBE NO.4"
                "5.  LAST MENU"
                "6.  SYSTEM MENU"

                "TORPEDO WARHEAD SELECT"
                "1.  HIGH EXPLOSIVE"
                "2.  ARMOR PIERCING"
                "3.  LAST MENU"
                "4.  SYSTEM MENU"

                "ENTER TARGET RANGE IN METERS-"

                "ENTER TORPEDO RUNNING SPEED IN KNOTS  "

                "ENTER TORPEDO RUNNING DEPTH IN METERS-"

"CANNON CONTROL",
"1.  FIRE CANNON"
"2.  CHANGE WARHEAD ONLY"
"3.  CHANGE TARGET ONLY"
"4.  STATUS",
"5.  LAST MENU",
"6.  SYSTEM MENU",

                "GUN PLATFORM SELECT".
                "1.  GUN NO. 1"
                "2.  GUN NO. 2"
                "3.  GUN NO. 3"
                "4.  GUN NO. 4"
                "5.  GUN NO. 5"
                "6.  GUN NO. 6"
                "7.  ALL GUNS",
                "8.  LAST MENU"
                "9.  SYSTEM MENU"

                "GUN SIZE",
                "1.  20 MM"
                "2.  125 MM"
                "3.  LAST MENU",
                "4.  SYSTEM MENU"

                "ENTER TARGET ALTITUDE "

                "ENTER TARGET DIRECTION-"

                "ENTER TARGET RANGE IN METERS-"

                "ENTER NUMBER OF ROUNDS
                "WARHEAD SELECT",
                "1.  HIGH EXPLOSIVE"
                "2.  ARMOR PIERCING"
                "3.  SHRAPNEL"
                "4.  LAST MENU"
                "5.  SYSTEM MENU".

                "ALL CANNONS ARE GREEN"
```

```
"MACHINE GUN CONTROL"
"1.  FIRE MACHINE GUN"
"2.  CHANGE TARGET"
"3.  CEASE FIRING"
"4.  STATUS"
"5.  LAST MENU"
"6.  SYSTEM MENU"

        "MACHINE GUN STATUS"
        "GUNS NO. 3(.30 CAL) AND NO.12 (.50 CAL)"
        " ARE JAMMED"
        "ALL OTHER GUNS ARE GREEN"

        "SELECT MACHINE GUNS (NO. 1 TO NO. 20 OR ALL)-"

        "SELECT MACHINE GUN SIZE(CALIBER)"
        "1.  .30 CAL"
        "2.  .50 CAL"
        "3.  LAST MENU"
        "4.  SYSTEM MENU".

        "ENTER TARGET DIRECTION-"

        "ENTER TARGET RANGE IN METERS-".



"DEPTH CHARGE CONTROL"
"1.  DROP DEPTH CHARGES"
"2.  DEPTH CHARGE SYSTEM STATUS"
"3.  LAST MENU"
"4.  SYSTEM MENU"

        "THE DEPTH CHARGE SYSTEM IS GREEN"

        "ENTER NUMBER OF DEPTH CHARGES "

        "SELECT DEPTH CHARGE SIZE"
        "1.  100 KG"
        "2.  250 KG"
        "3.  500 KG"

        "SET TIME SEQUENCE (SECS)-"

        "SET DEPTH CHARGE DEPTH (METERS)-".
```

APPENDIX D

Semantic Differential Scales

```
1         PGM QUES10
2   *
3   *     10 FEB 80  RLC
4   *
5   *     CATALOG AS Q10
6   *
7   *
8         DFC           10
9         DFC           1
10        DFC           "*Q",1,1,7
11        DFC           $A,"DID YOU LIKE THE COMMAND FORMAT?",$A0A
12        DFC           "      LIKED 1:2:3:4:5:6:7 DISLIKED",$A0A,"%%"
13  *
14        DFC           "*Q",2,1,7
15        DFC           $A,"THE COMMANDING WAS:",$A0A
16        DFC           "       FAST 1:2:3:4:5:6:7 SLOW",$A0A,"%%"
17  *
18        DFC           "*Q",3,1,7
19        DFC           $A,"THE COMMANDING WAS:",$A0A
20        DFC           "    PRECISE 1:2:3:4:5:6:7 IMPRECISE",$A0A,"%%"
21  *
22        DFC           "*Q",4,1,7
23        DFC           $A,"THE COMMANDING WAS:",$A0A
24        DFC           "COMFORTABLE 1:2:3:4:5:6:7 UNCOMFORTABLE",$A0A,"%%"
25  *
26        DFC           "*Q",5,1,7
27        DFC           $A,"THE COMMANDS WERE:",$A0A
28        DFC           "    TOO                    TOO",$A
29        DFC           "ABBREVIATED 1:2:3:4:5:6:7 WORDY",$A0A,"%%"
30  *
31        DFC           "*Q",6,1,7
32        DFC           $A,"THE COMMANDING WAS:",$A0A
33        DFC           "    COMPLEX 1:2:3:4:5:6:7 SIMPLE",$A0A,"%%"
34  *
35        DFC           "*Q",7,1,7
36        DFC           $A,"THE COMMANDING WAS:",$A0A
37        DFC           "   FRIENDLY 1:2:3:4:5:6:7 UNFRIENDLY",$A0A,"%%"
38  *
39        DFC           "*Q",8,1,7
40        DFC           $A,"THE COMMANDS WERE:",$A0A
41        DFC           "EASY TO USE 1:2:3:4:5:6:7 HARD TO USE",$A0A,"%%"
42  *
43        DFC           "*Q",9,1,7
44        DFC           $A,"THE COMMANDS WERE:",$A0A
45        DFC           "    EASY TO                HARD TO",$A
46        DFC           "    LEARN 1:2:3:4:5:6:7 LEARN",$A0A,"%%"
47  *
48        DFC           "*Q",10,1,7
49        DFC           $A,"THE COMMANDING WAS:",$A0A
50        DFC           "FRUSTRATING 1:2:3:4:5:6:7 SOOTHING",$A0A,"%%"
51  *
52        DFC           "*Q",11,1,7
53        DFC           $A,"THE COMMAND FORMAT IS:",$A0A
54        DFC           "      USEFUL 1:2:3:4:5:6:7 NOT USEFUL",$A0A,"%%"
55  *
56        DFC           "*Q",12,1,7
57        DFC           $A,"THE COMMAND FORMAT IS:",$A0A
58        DFC           "INTERESTING 1:2:3:4:5:6:7 DULL",$A0A,"%%"
```

```
* REVISED !   CE EDITOR (C)  DATE  09/10/80  22:42:24        PA    1

        PGM QUES11
*
*       22 JAN 80  RLC
*
*       CATALOG AS Q11
*
*
        DFC             11
        DFC             1
        DFC             "*Q",1,1,7
        DFC             $A,"COMMANDING WAS:",$A0A
        DFC             "       USUAL 1:2:3:4:5:6:7 UNUSUAL",$A0A,"%%"
*
        DFC             "*Q",2,1,7
        DFC             $A0A
        DFC             "DURING THIS EXERCISE,",$A
        DFC             "I USED THE SOM FOR LOOKING UP COMMANDS:",$A0A
        DFC             "OFTEN 1:2:3:4:5:6:7 NONE",$A0A,"%%"
*
        DFC             "*Q",3,1,7,$A0A
        DFC             "!THE SOM WAS:",$A
        DFC             "EASY TO USE 1:2:3:4:5:6:7 HARD TO USE",$A0A,"%%"
*
        DFC             "*S",4,15000
        DFC             $A0A,$A0A
        DFC             "THIS IS THE END OF THE EXPERIMENT",$A0A
        DFC             "THANK YOU FOR YOUR PARTICIPATION.","%%"
*
        DFC             "*E",5,1
        END
POS TASK01
LIST
```

APPENDIX E

Number Sequence

The following number sequences were used in the number sequence test.

SEQUENCE NUMBER	SEQUENCE	NEXT NUMBER	RULE
1.	2, 4, 6, 8, 10,	12	(N+2)
2.	32, 16, 8, 4, 2,	1	(N/2)
3.	1, 3, 5, 7, 11,	13	(Next Prime number)
4.	2, 4, 7, 11, 16,	22	(N+(n+1)) n is the position)
5.	2, 5, 10, 17, 26,	37	(N+(2n+1))
6.	180, 175, 165, 150, 130,	105	(N-(5n))
7.	254, 252, 248, 240, 224,	192	(N-2n)
8.	2, 4, 12, 48, 240,	1440	(N*(n+1))
9.	3, 8, 27, 112, 565,	3396	((N*m)+n)
10.	3, 8, 25, 100, 499,	2992	((N*m)+(3-n))

Sequence Numbers 2, 4, 5, 6, 7, &8 are taken from Lamb, S, Mathematical Games, Puzzles, & Fallacies, Anco Publishing Company, Inc., 219 Park Ave., South, N.Y., N.Y. 10003, 1977.

APPENDIX F

Demographic Questionnarie

```
"*Q",1,1,12,#A
#12,"TERMINATE ENTRY WITH CARRIAGE RETURN",#1UUA
"PLEASE INDICATE THE MONTH OF YOUR",#A
"BIRTHDAY",#AUA
"1   JANUARY",#A
"2   FEBRUARY",#A
"3   MARCH",#A
"4   APRIL",#A
"5   MAY",#A
"6   JUNE",#A
"7   JULY",#A
"8   AUGUST",#A
"9   SEPTEMBER",#A
"10  OCTOBER",#A
"11  NOVEMBER",#A
"12  DECEMBER",#AUA,"%%"

"*Q",2,0,0,#A
"WHAT DAY IN THAT MONTH WERE YOU BORN?",#AUA,"%%"

"*Q",3,0,0,#A
"IN WHAT YEAR WERE YOU BORN?",#AUA,"%%"


"*Q",5,1,5,#A
"WHICH OF THE FOLLOWING CATAGORIES",#A
"DO YOU BEST FIT?",#AUA
"1   STATION OPERATING CREW",#A
"2   STATION STAFF (NON OPERATIONS)",#A
"3   NET CONTROL OPERATIONS",#A
"4   OTHER NON STATION DSN PERSONNEL",#A
"5   OTHER NON DSN PERSONNEL",#AUA,"%%"


"*Q",6,1,8,#A
"PLEASE SELECT THE JOB CATAGORY",#A
"WHICH IS MOST APPROPRIATE TO YOU.",#AUA
"1   OPERATIONS",#A
"2   CLERICAL",#A
"3   TECHNICIAN",#A
"4   ENGINEER",#A
"5   PROGRAMMER",#A
"6   SUPERVISOR",#A
"7   MANAGER",#A
"8   OTHER",#AUA,"%%"
```

```
"*0",2,1,7,#A
"PLEASE INDICATE YOUR EXPERIENCE USING ",#A
"COMPUTER TERMINALS. SELECT THE ",#A
"CATAGORY THAT IS MOST APPLICABLE TO  ",#A
"YOUR EXPERIENCE.",#AOA
"1  USE MEGADATA TERMINAL ROUTINELY",#AOA
"2  USE MEGADATA TERMINAL OCCASIONALLY",#AOA
"3  USE OTHER COMPUTER TERMINALS ",#A
"     ROUTINELY",#AOA
"4  USE OTHER COMPUTER TERMINALS ",#A
"     OCCASIONALLY",#AOA
"5  USE WORD PROCESSORS PRIMARILY",#AOA
"6  DO NOT USE ANY COMPUTER TERMINALS",#AOA
"7  NONE OF THE CATAGORIES FIT",#A
".    MY EXPERIENCE WELL",#AOA,"%%"
```

```
"*0",1,1,7,#A
"DO YOU PREFER JOB TASKS WHICH ARE",#A
"STRUCTURED OR UNSTRUCTURED?",#A
"THAT IS, STRUCTURED JOBS",#12,"(WHICH HAVE",#A
"FIXED PROCEDURES)",#12," OR UNSTRUCTURED ",#A
"JOBS",#12,"(IN WHICH YOU HAVE TO DETERMINE  ",#A
"HOW TO ACCOMPLISH THE TASK YOURSELF)",#12,".",#AOA
"HIGHLY                    HIGHLY",#A
"STRUCTURED 1:2:3:4:5:6:7 UNSTRUCTURED",#AOA
#12,"IF YOU PREFER =",#A
"HIGHLY STRUCTURED TASKS, ENTER 1",#A
"HIGHLY UNSTRUCTURED TASKS, ENTER 7",#A
"IF YOU DO NOT PREFER AN EXTREME",#A
"PICK A NUMBER BETWEEN THE EXTREMES  ",#A
"WHICH REPRESENTS YOUR POSITION",#AOA
#11,"%%"
```

```
"*0",3,1,7,#A
"DO YOU PREFER JOB TASKS WHICH ARE",#A
"SIMPLE IN NATURE OR COMPLEX?",#AOA
"VERY                      VERY",#A
"SIMPLE 1:2:3:4:5:6:7 COMPLEX",#AOA,"%%"
```

```
"*0",3,1,7,#A
"IN YOUR JOB, DO YOU PREFER A VARIETY",#A
"OF TASKS OR DO YOU PREFER CONSISTENT",#A
"TASKS?",#AOA
"VARIETY OF                CONSISTENT",#A
"TASKS   1:2:3:4:5:6:7 TASKS",#AOA,"%%"
```

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APPENDIX G

Performance Plots

The following are plots of the performance time (seconds on the vertical ordinate) against specific experience (horizontal ordinate) specific experience is the number of times that specific command was need.

There is a plot for each experimental system by format. The upper curve is the ploted performance time and the lower curve is the think time.

The formats are identified in the upper right of the plot. They are:

SF1 - short form mnemonic one format (with functionally listed manual)

SF2 - short form mnemonic two format (with alphabetic listed manual)

LF - long form mnemonic format

P - prompted gormat

M - menu format

The specific task or experimental system is listed in the upper right corner as follows:

Ship - ship control system

Prop - propulsion contrcl system

Radar - radar control system

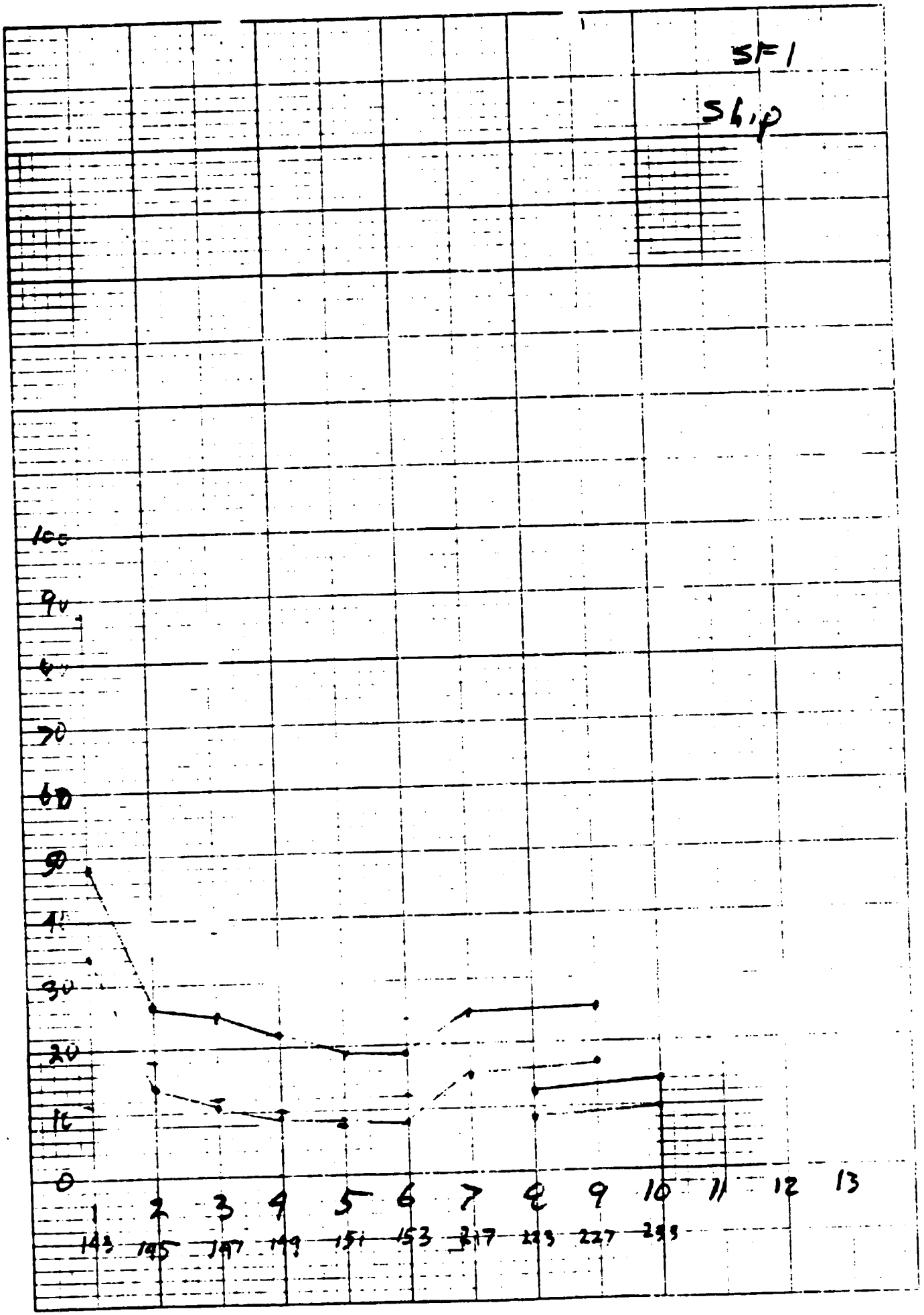
Nan - navigation system

Cannon - cannon fire control system

MG - machine gun fire control system

DC - depht charge fire control system

Tpd - torpedo fire control system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SL,P
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90
80
70
60
50
40
30
20
10
0
1
2
3
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7
8
9
10
11
12
13
143
145
147
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153
217
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227
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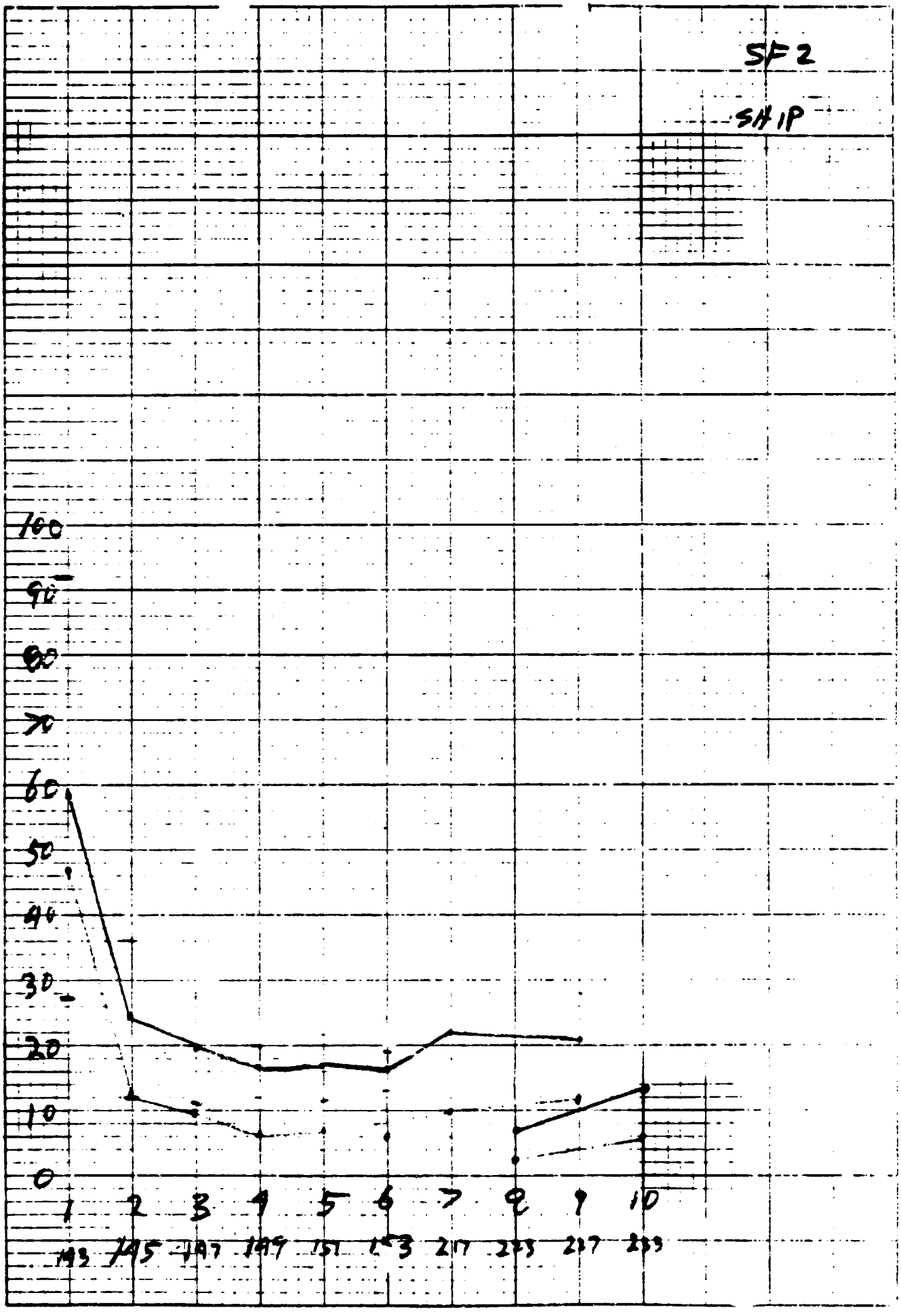
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SHIP
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80
70
60
50
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30
20
10
0
1
2
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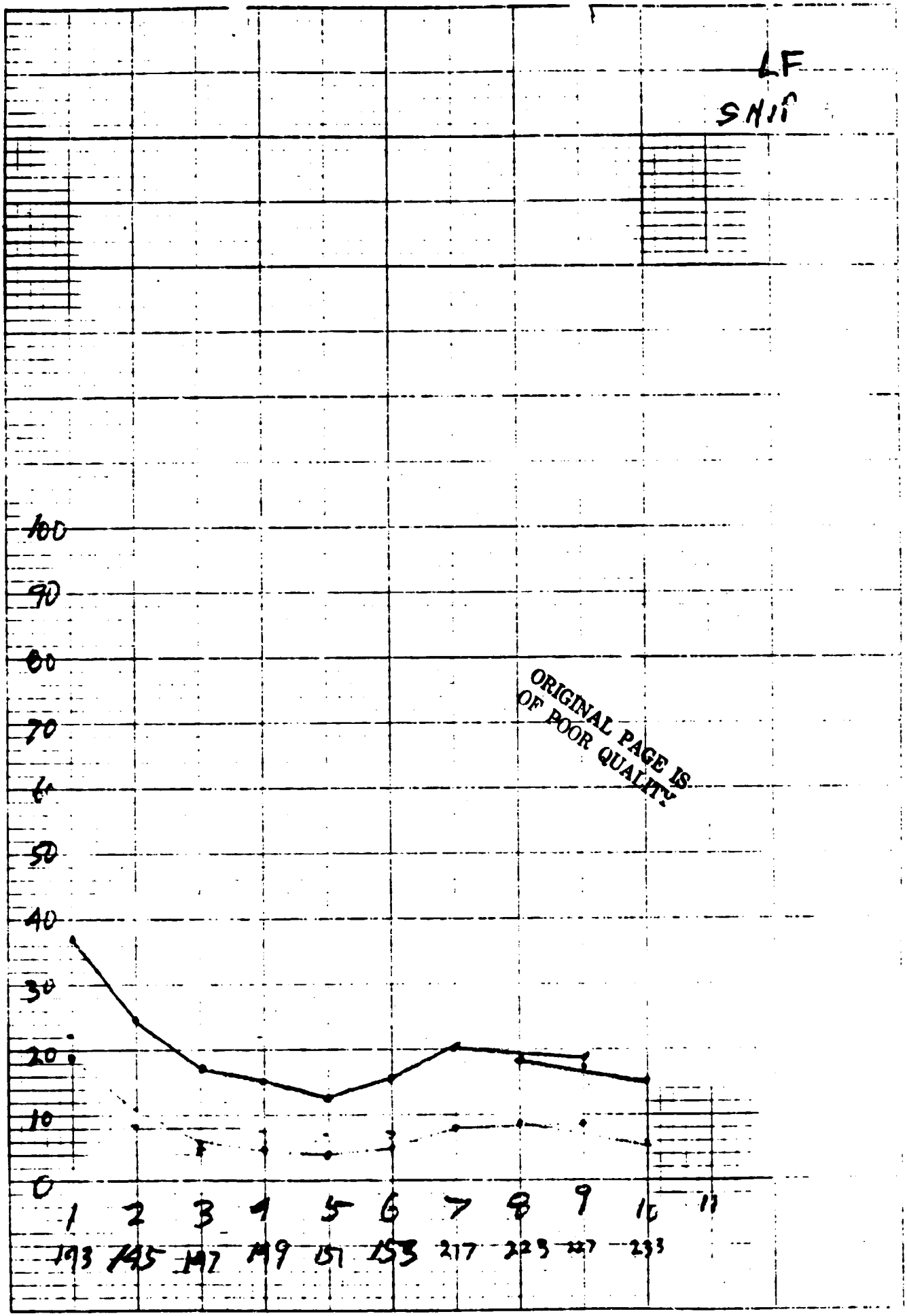
9
10
193
195
197
199
151
153
217
233
217
233



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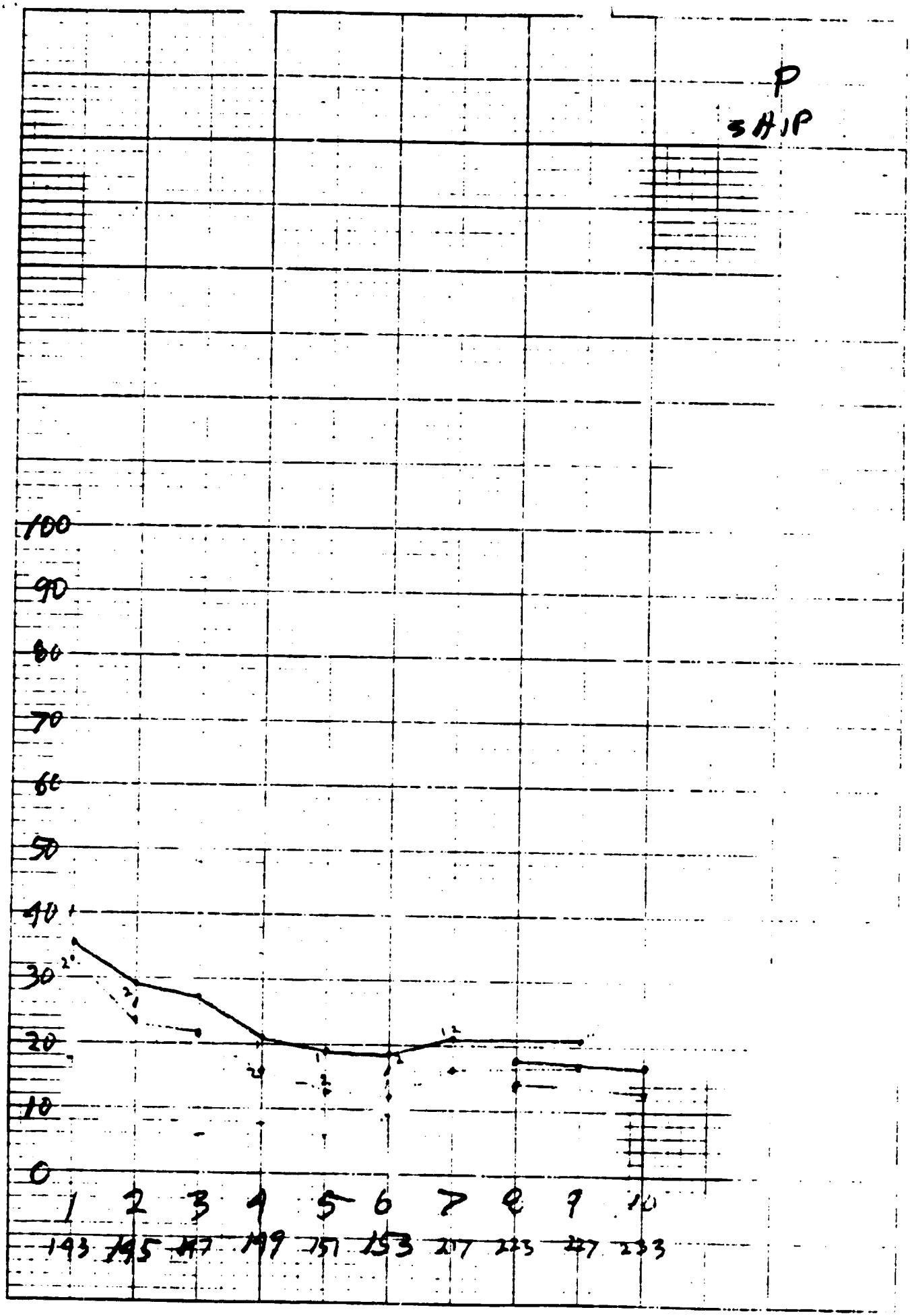
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SHP
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1 2 3 4 5 6 7 8 9 10
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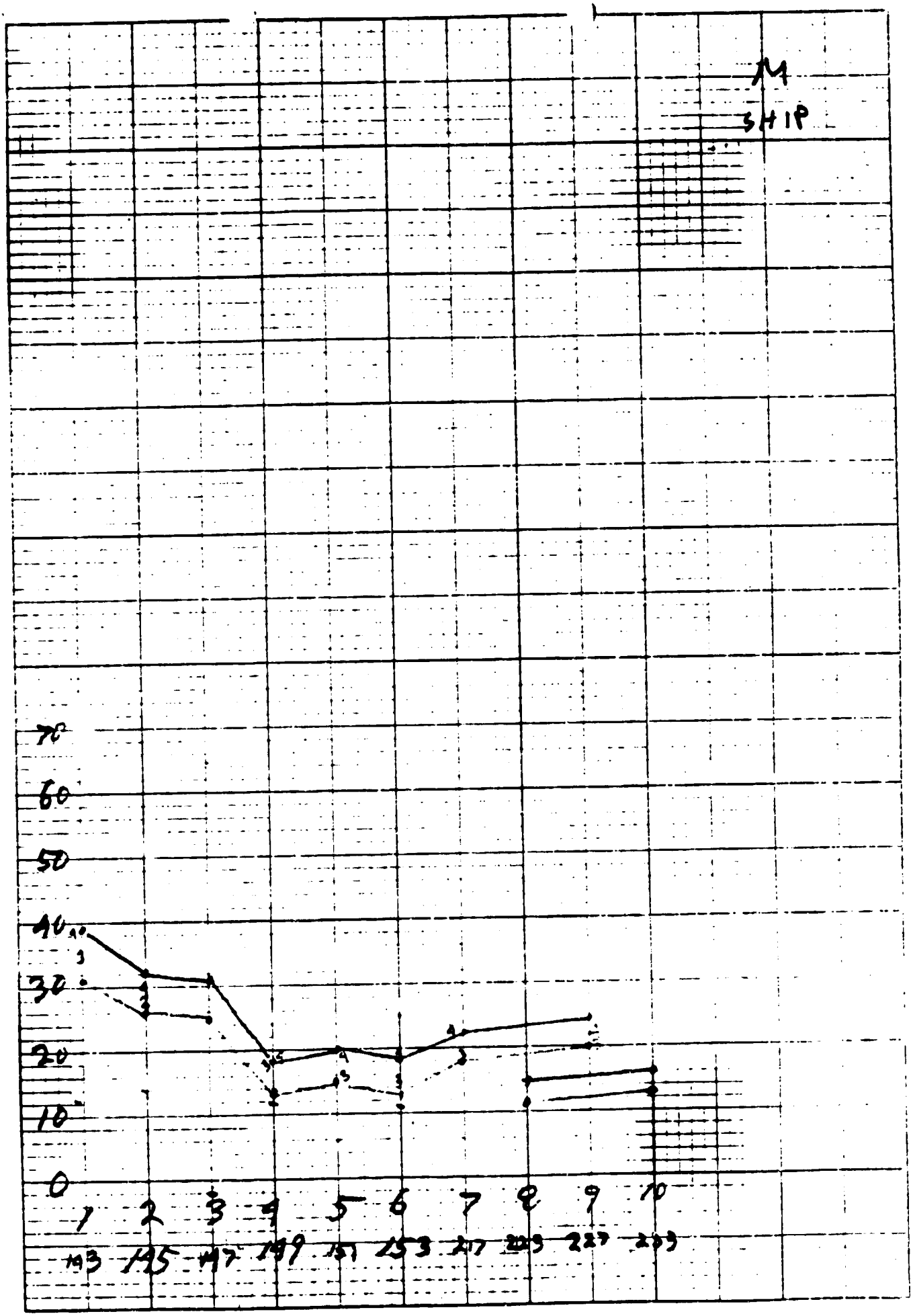
SHIP
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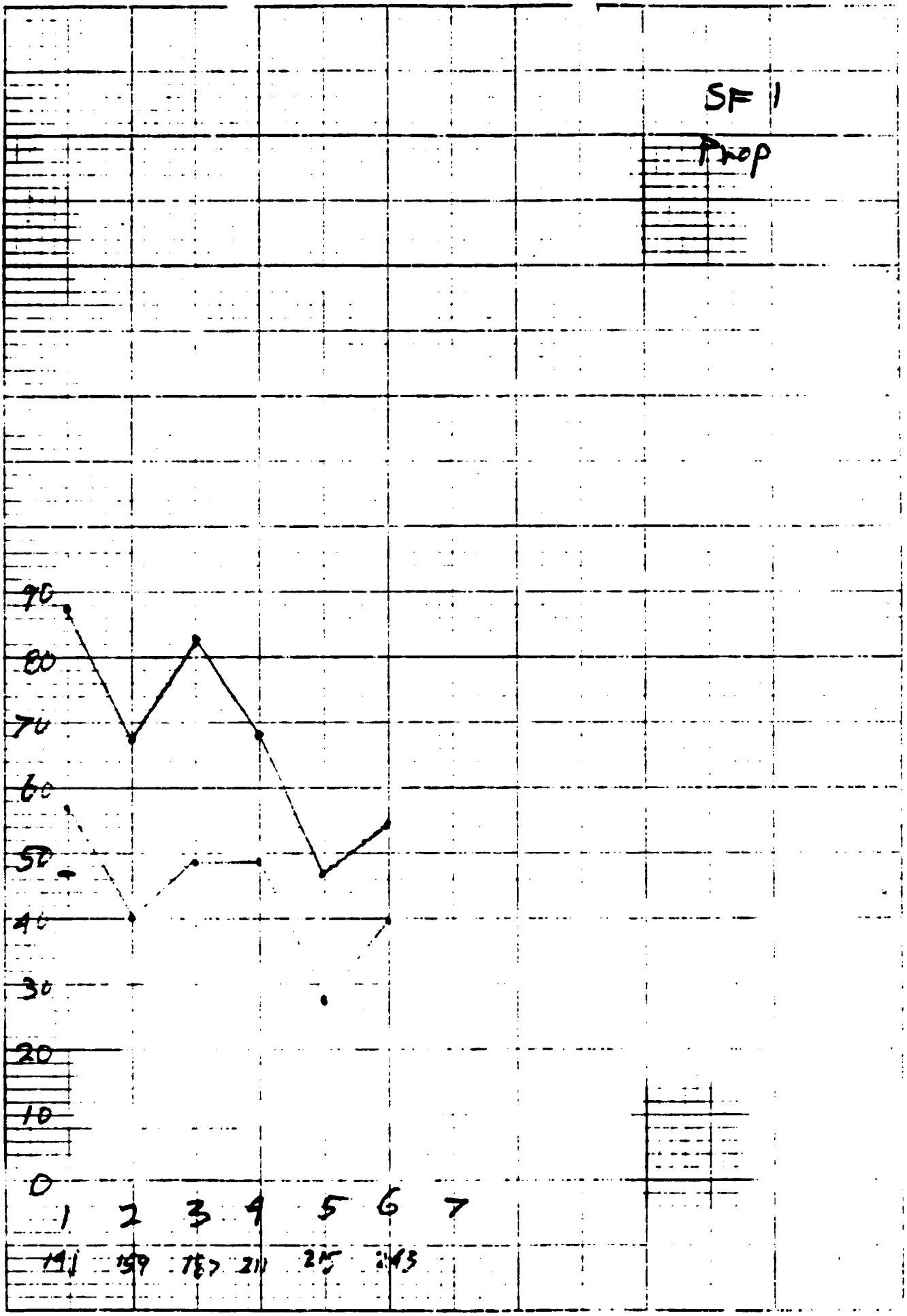
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Prop
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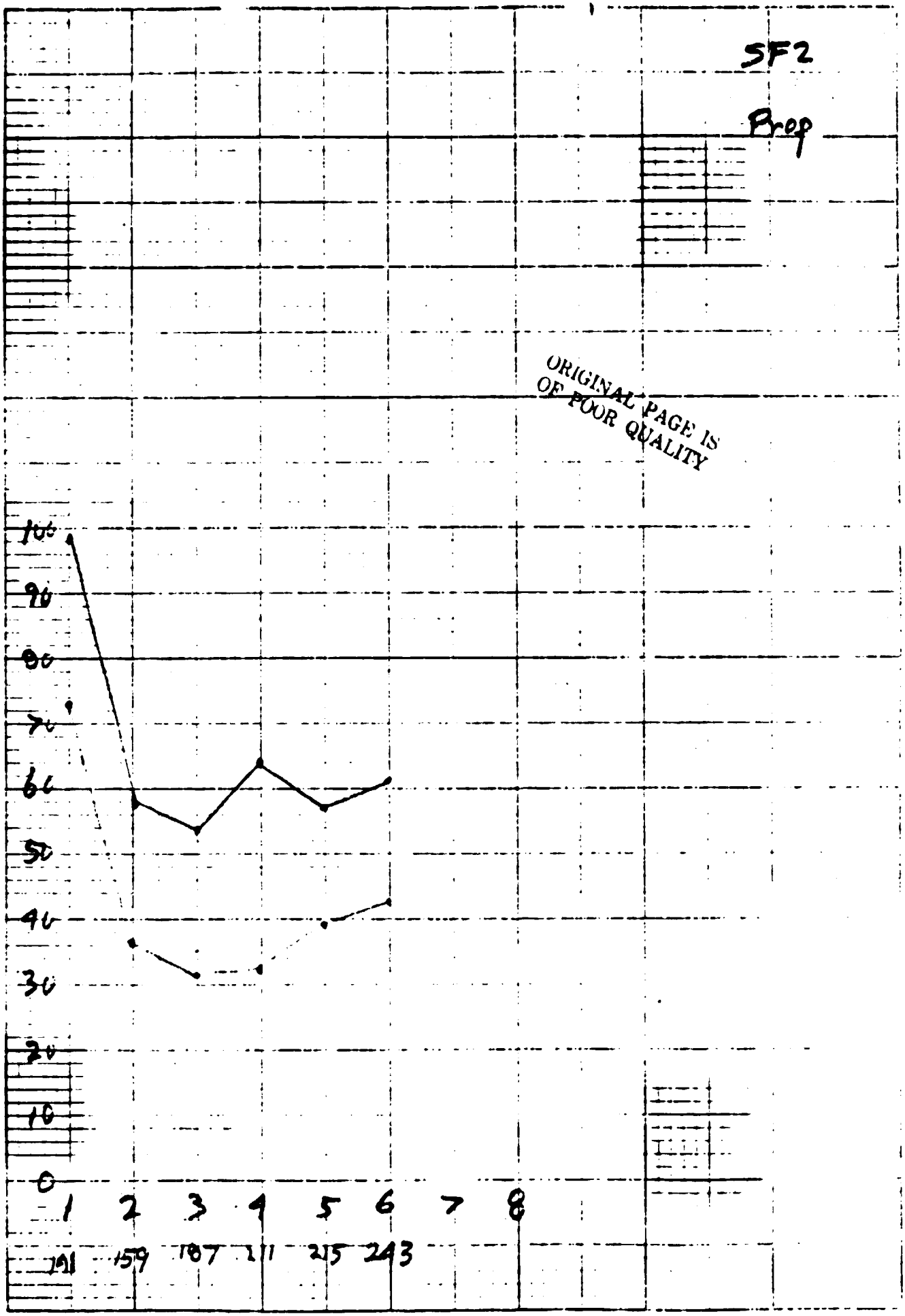
5
6
7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Brep
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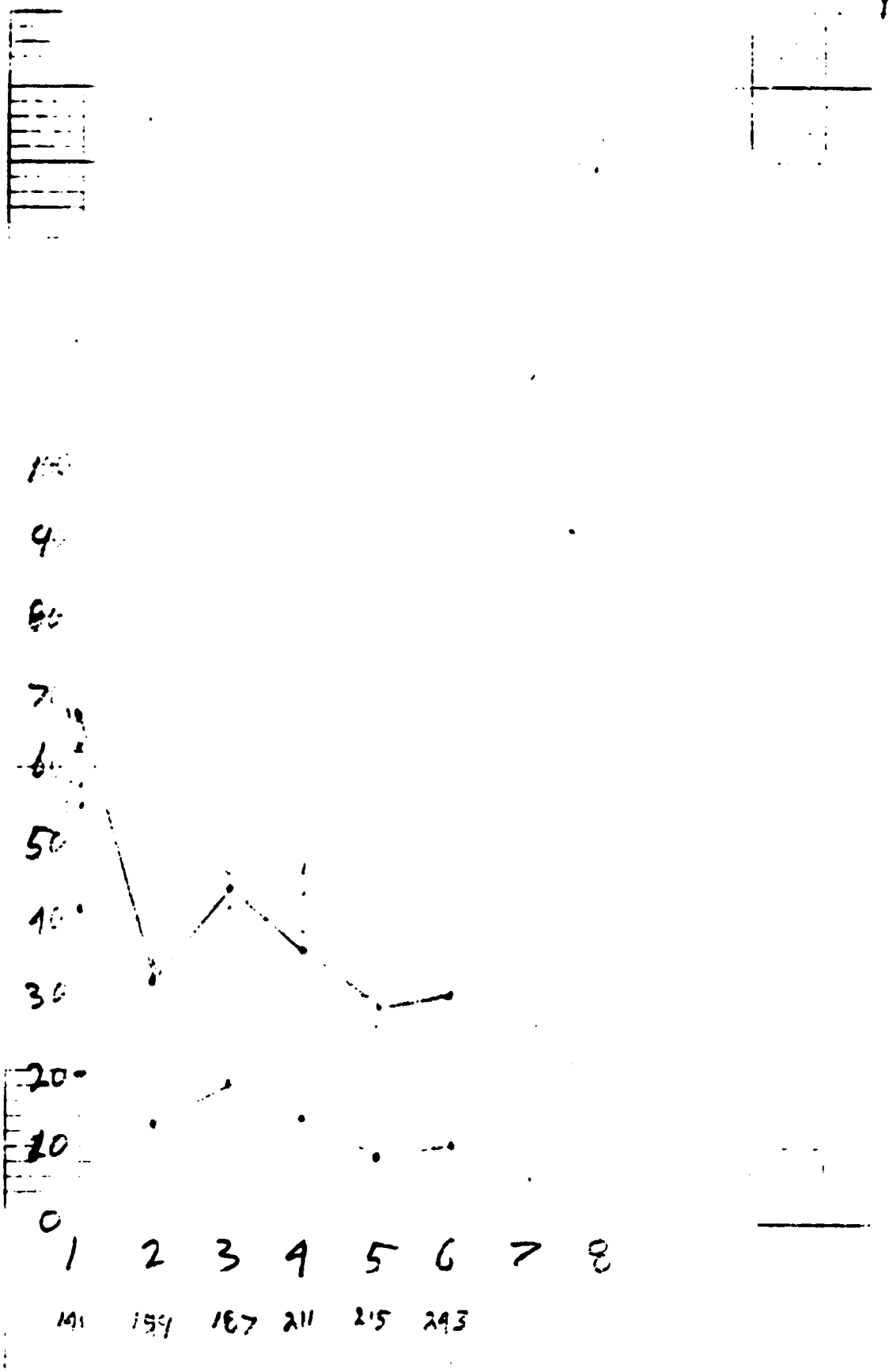
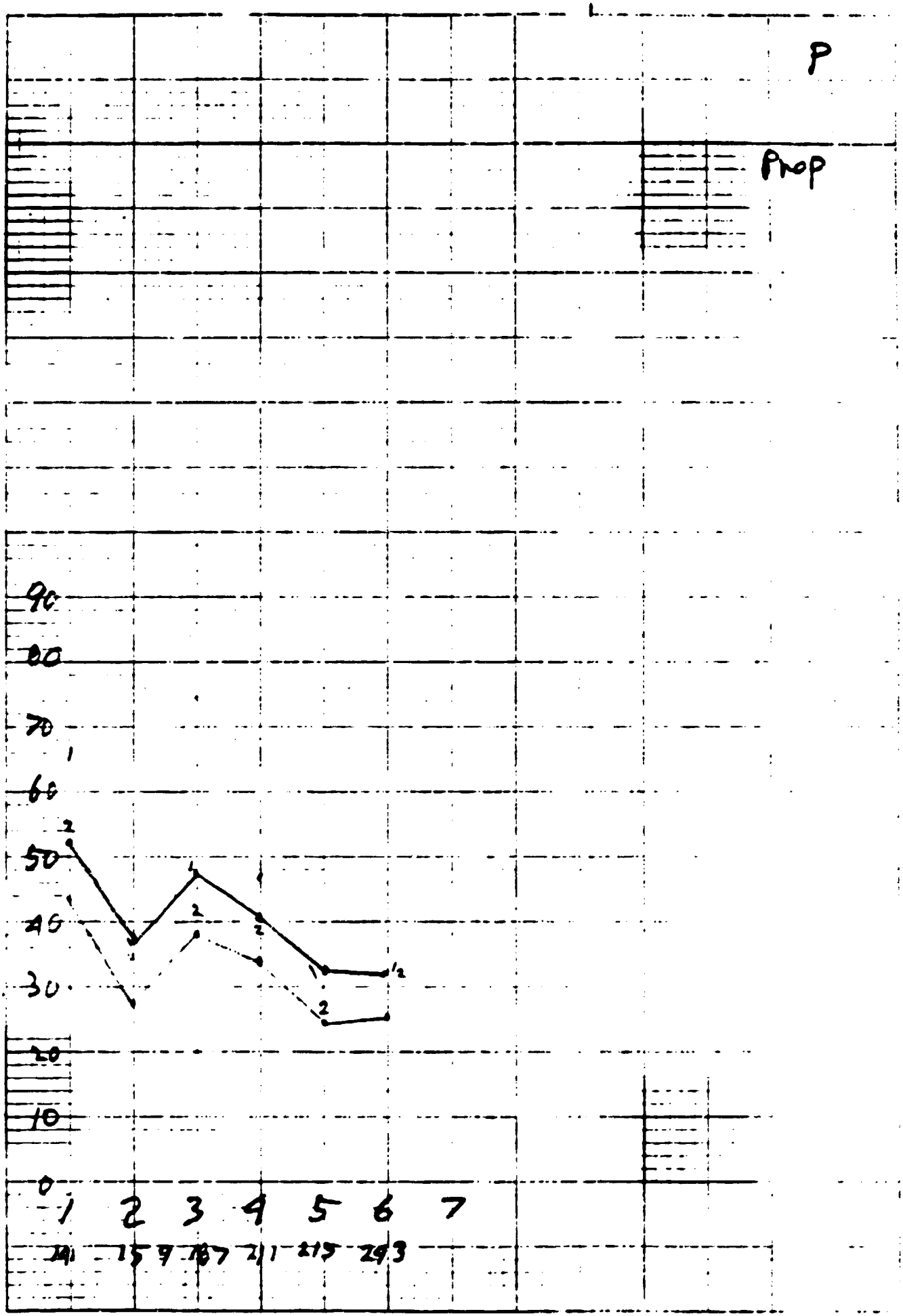
7
8
191
159
187
211
215
243

LF

Prop

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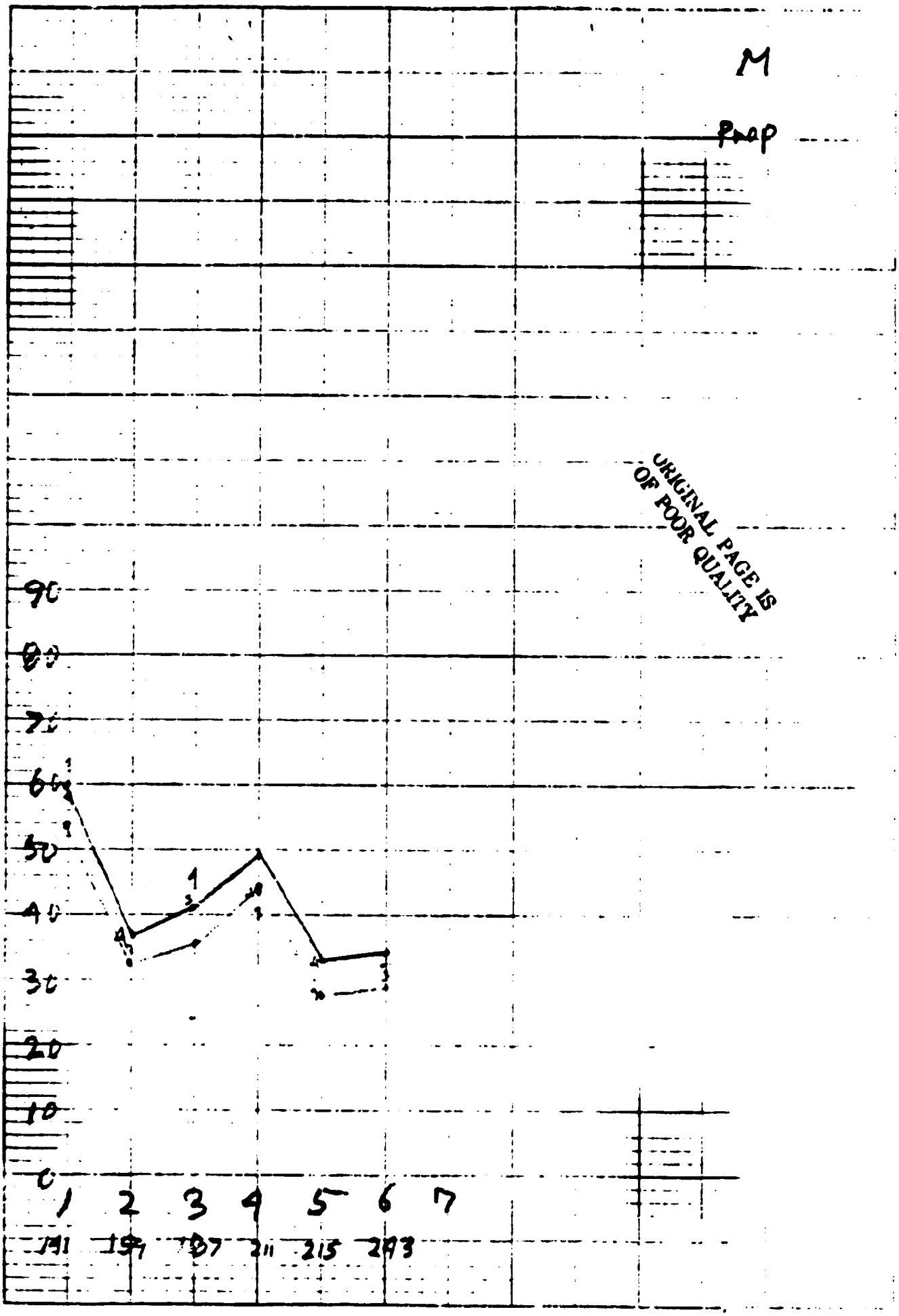
0
1 2 3 4 5 6 7



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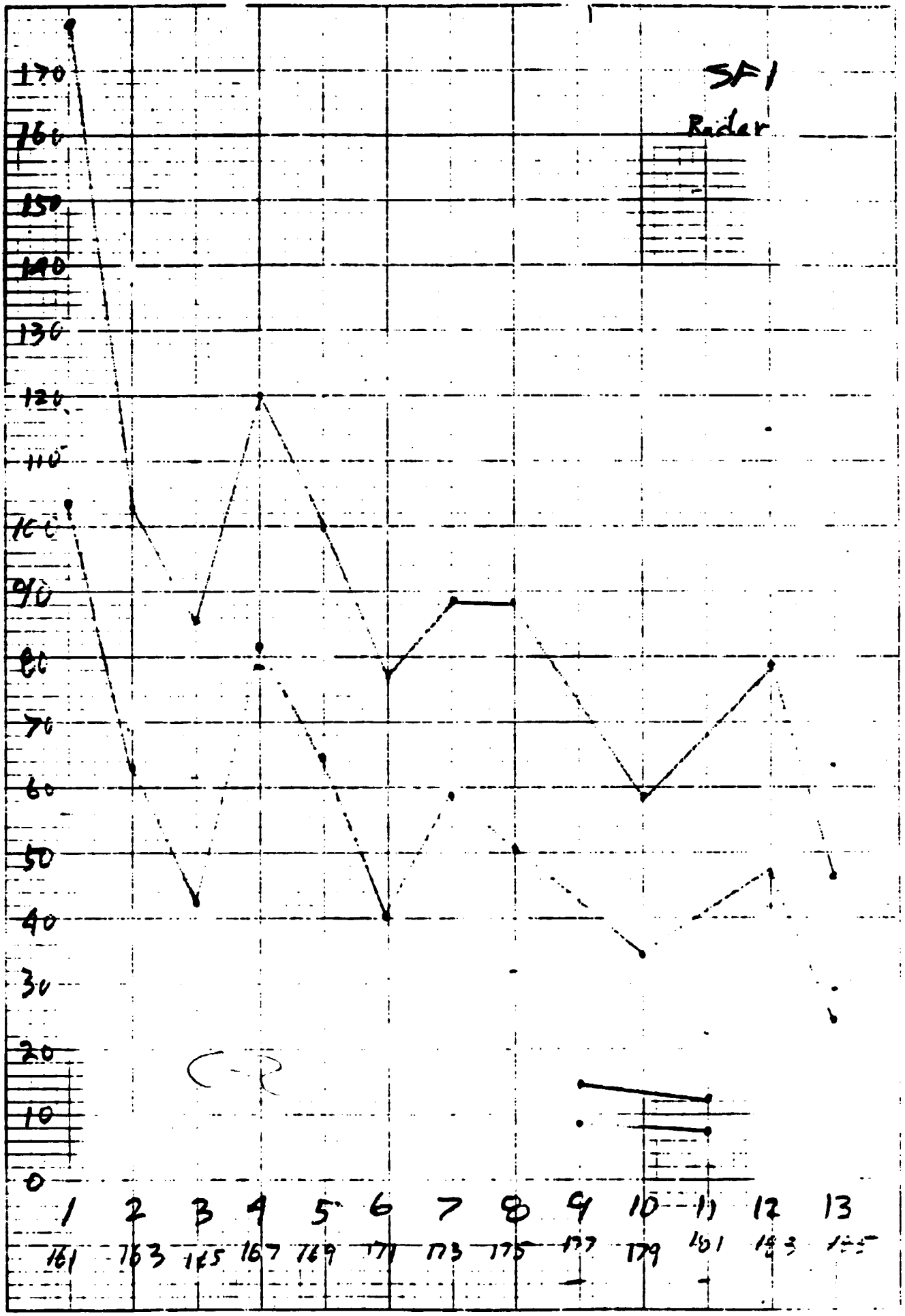
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Rader
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160
150
140
130
120
110
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40
30
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0
1
2
3
4
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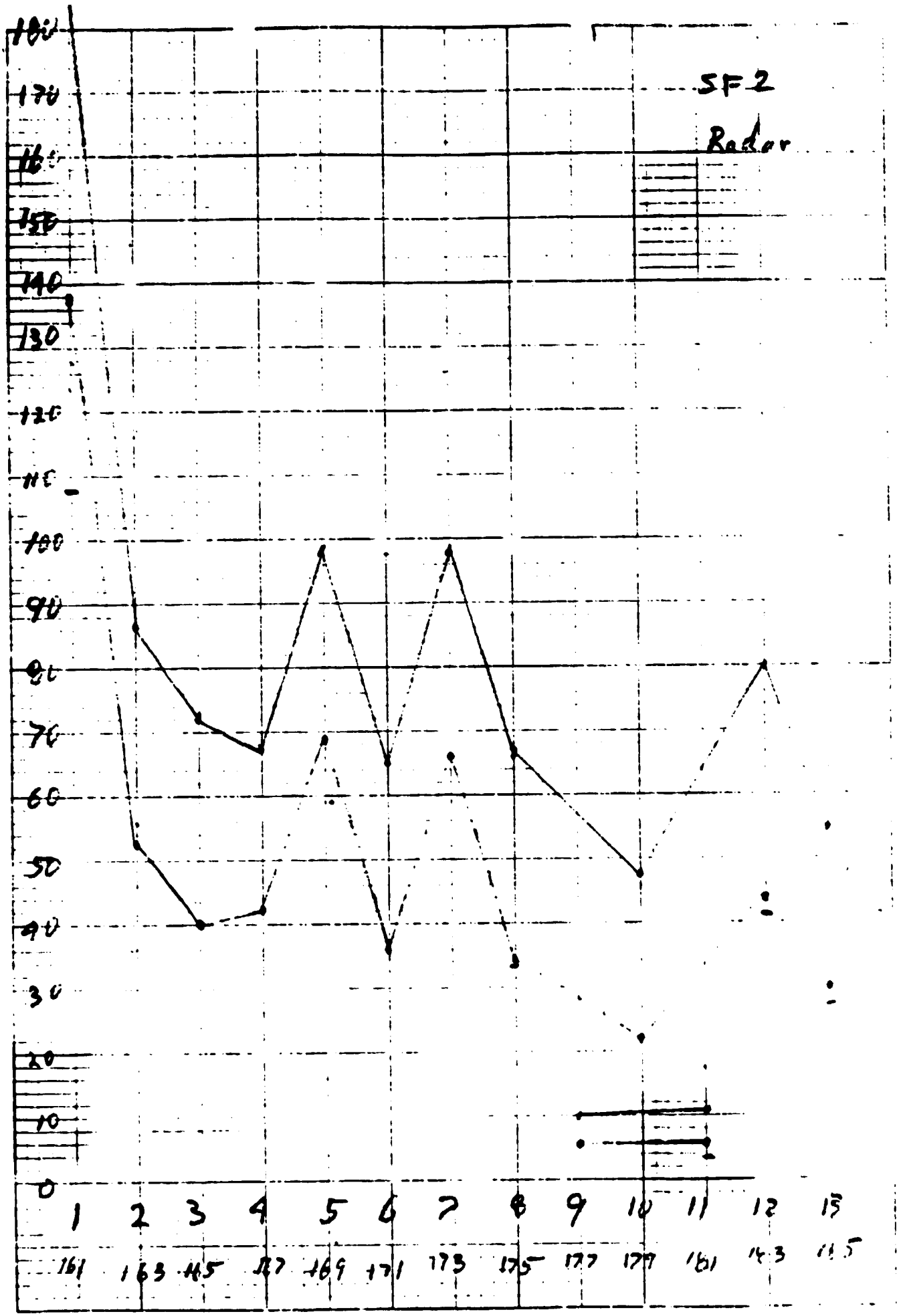
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Radar
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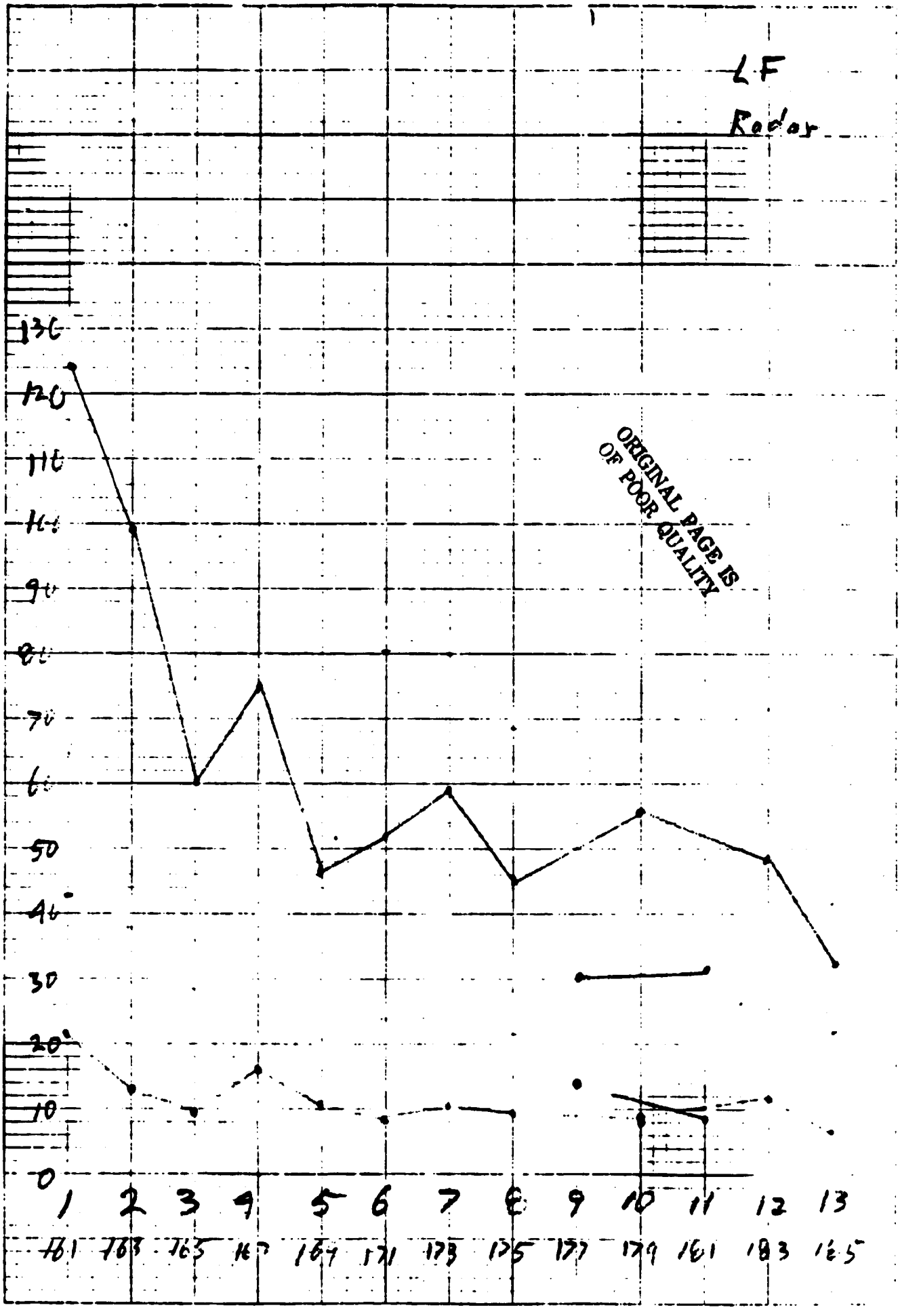
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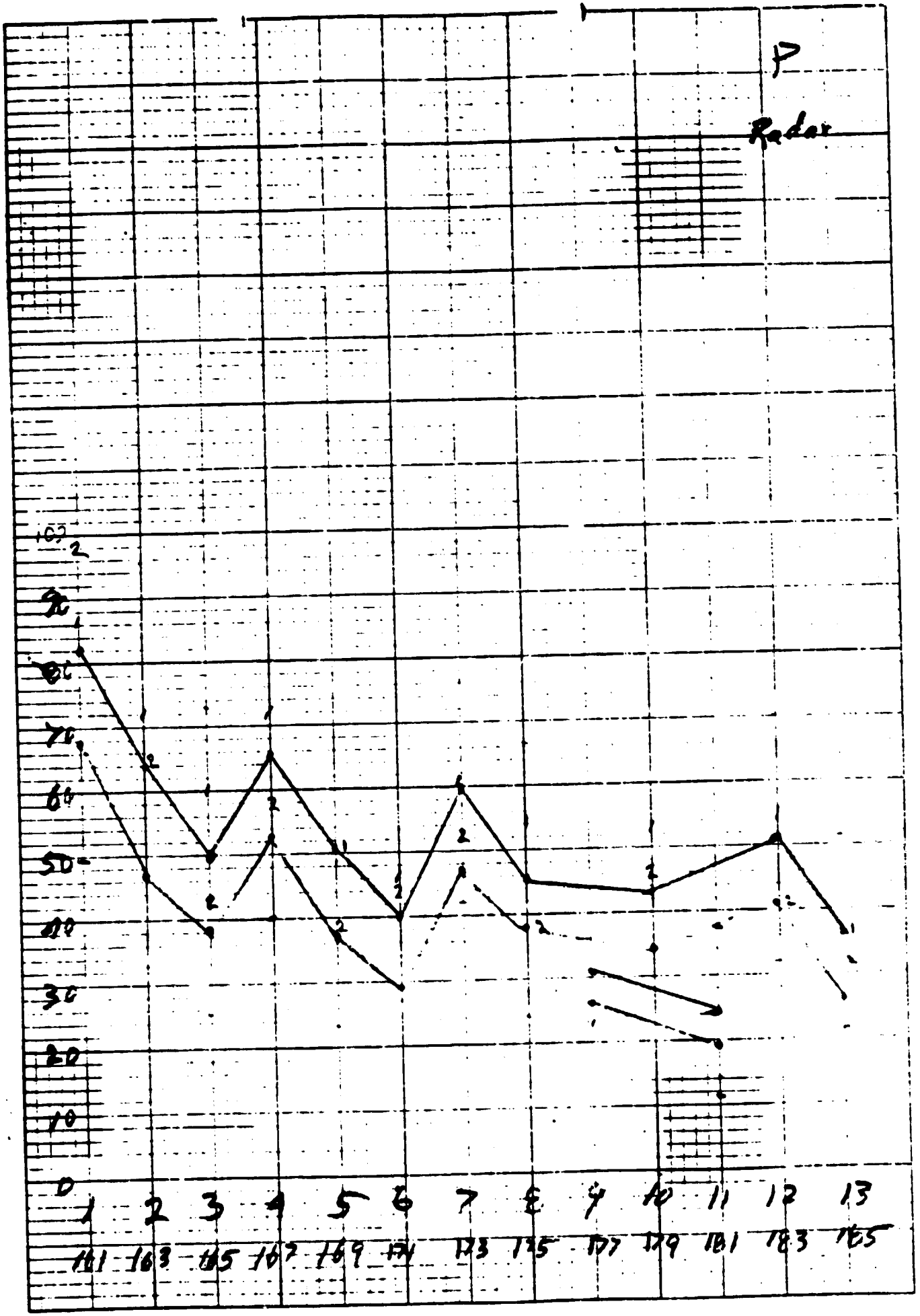
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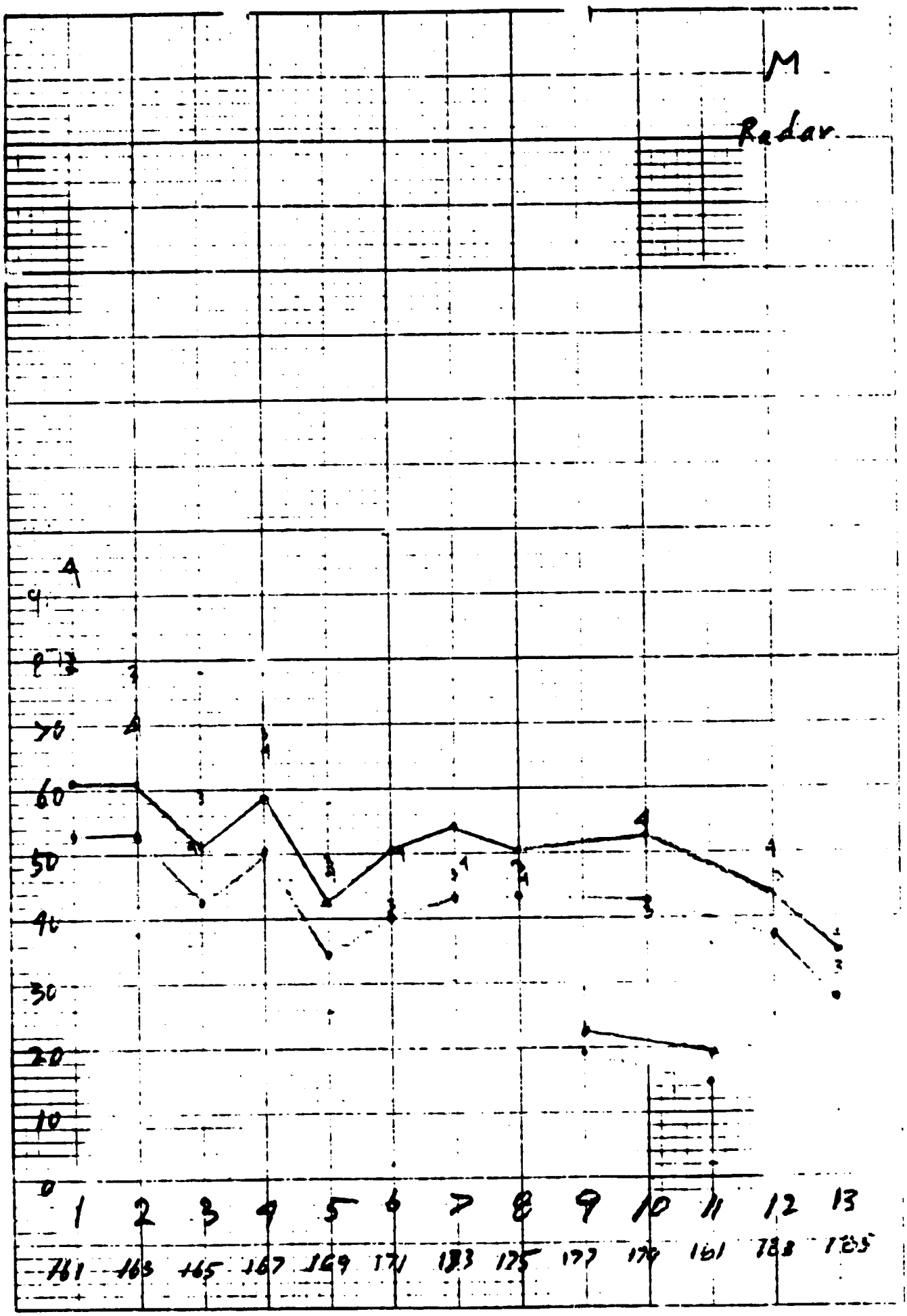
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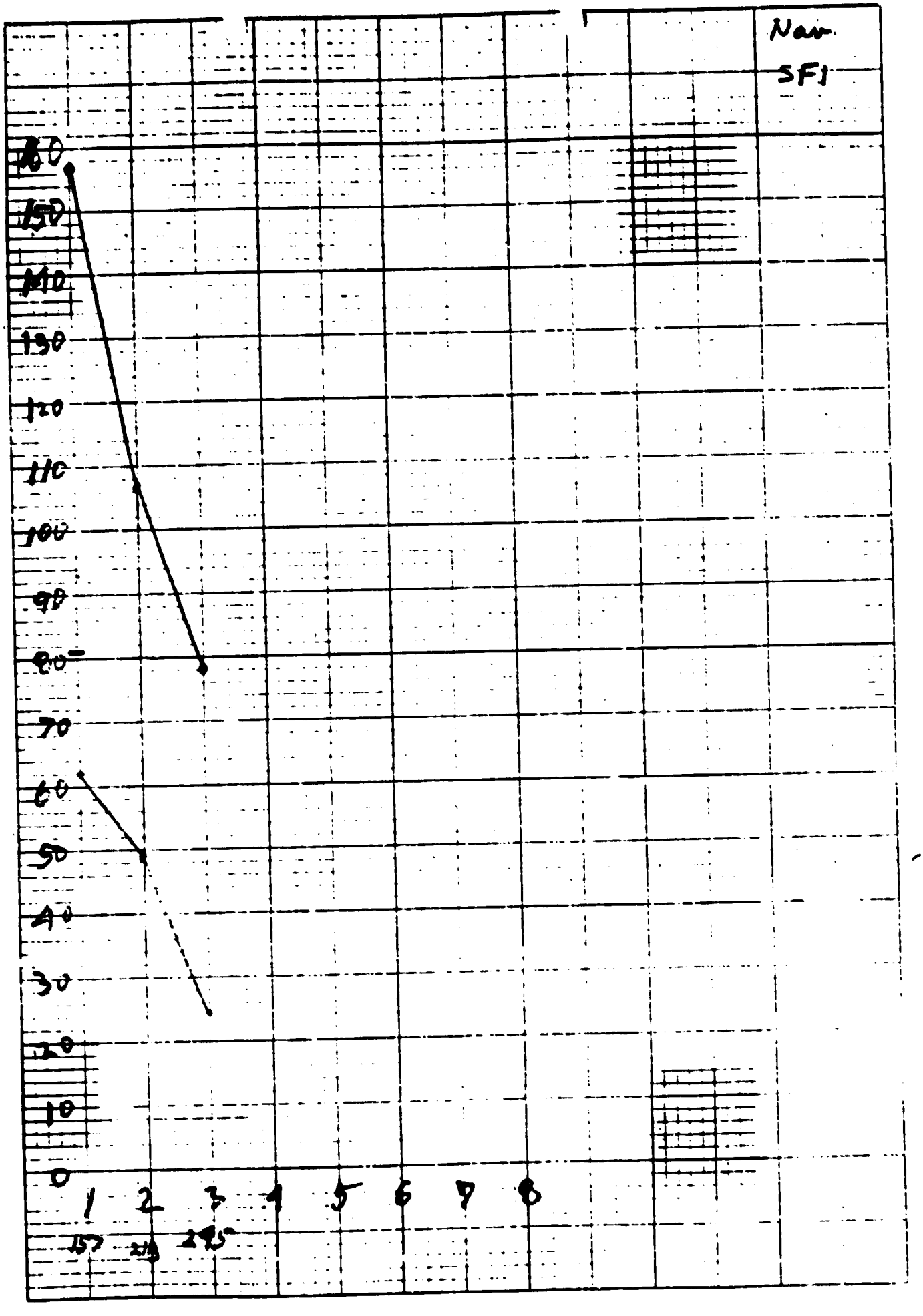
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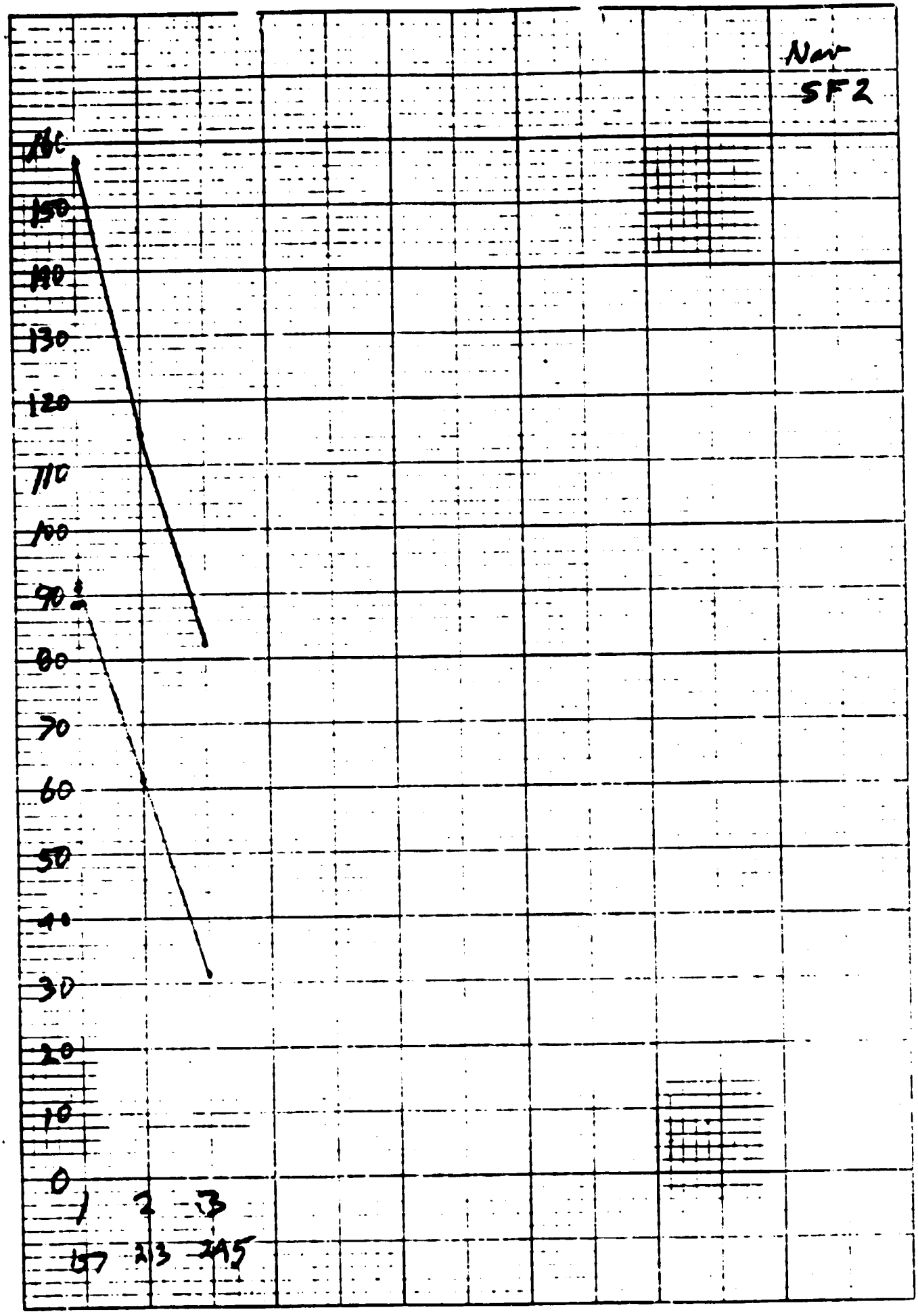
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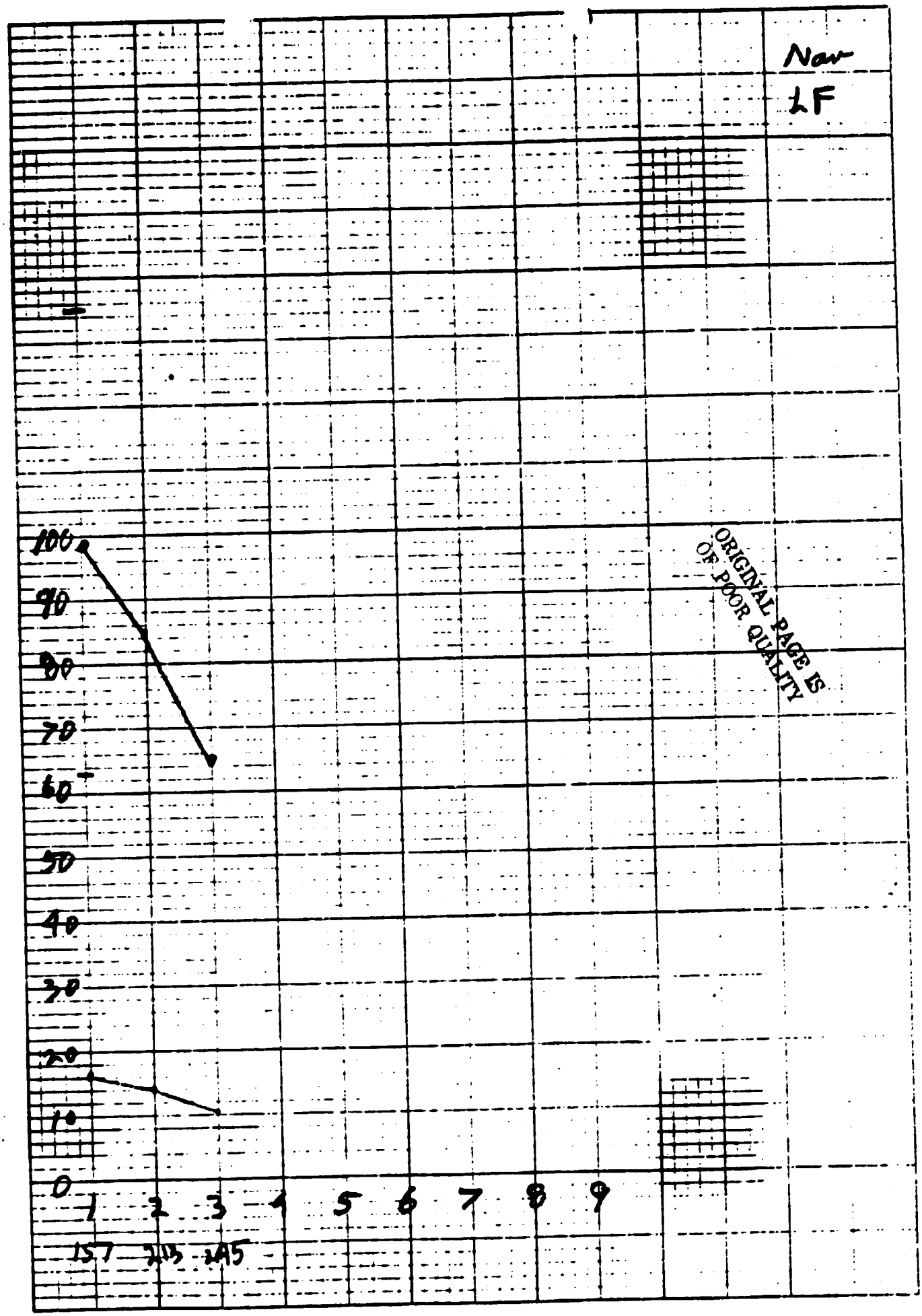

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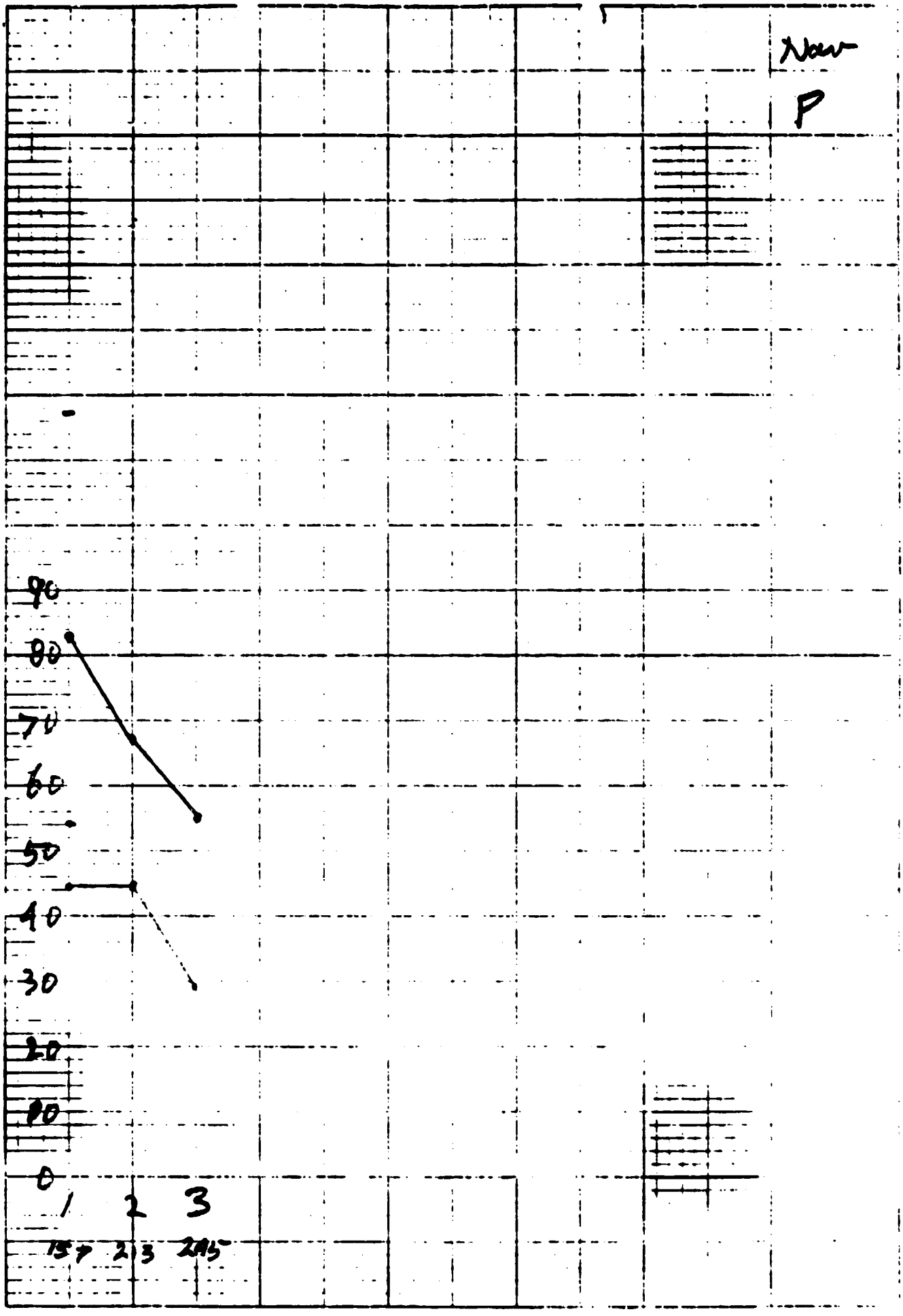
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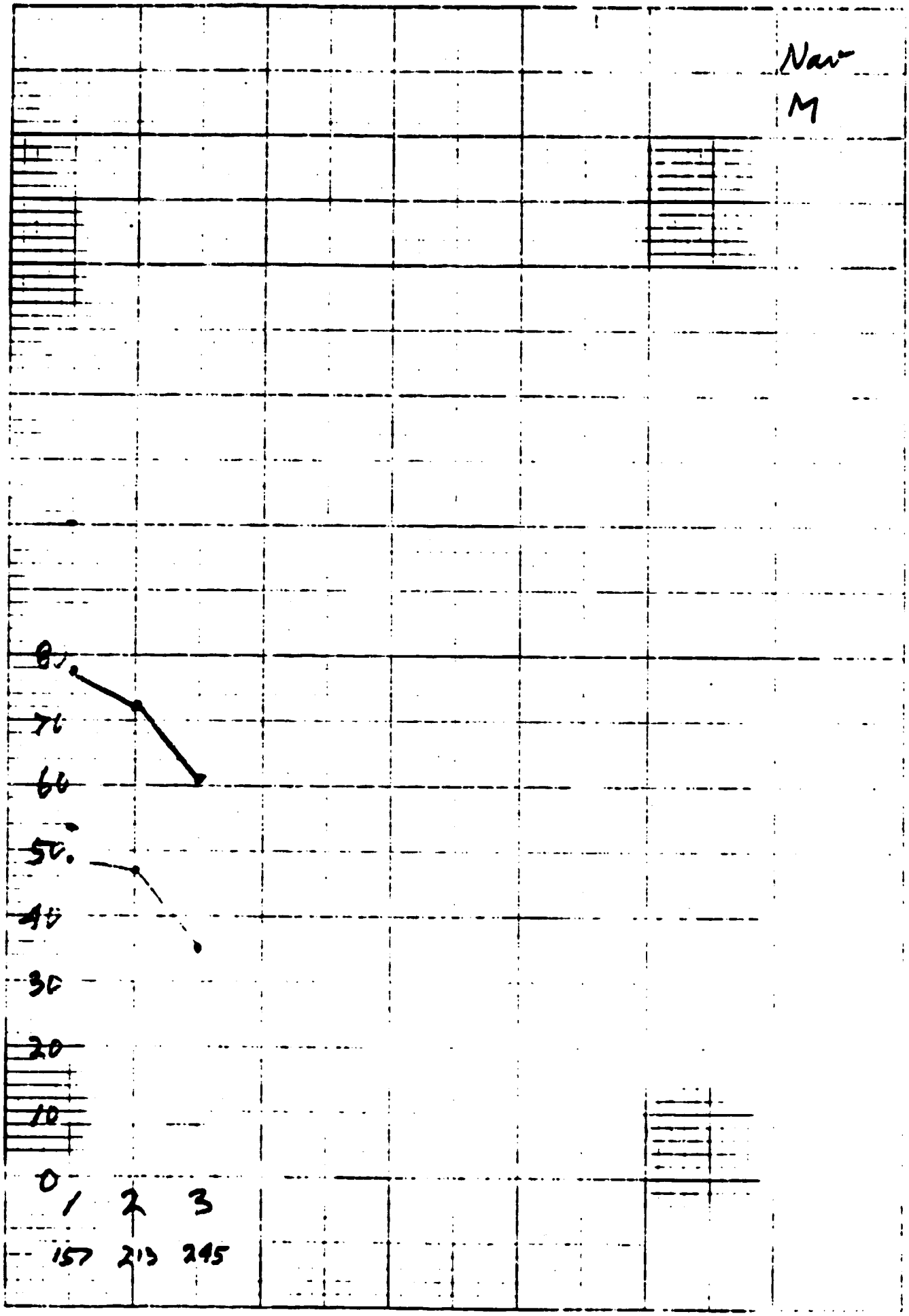
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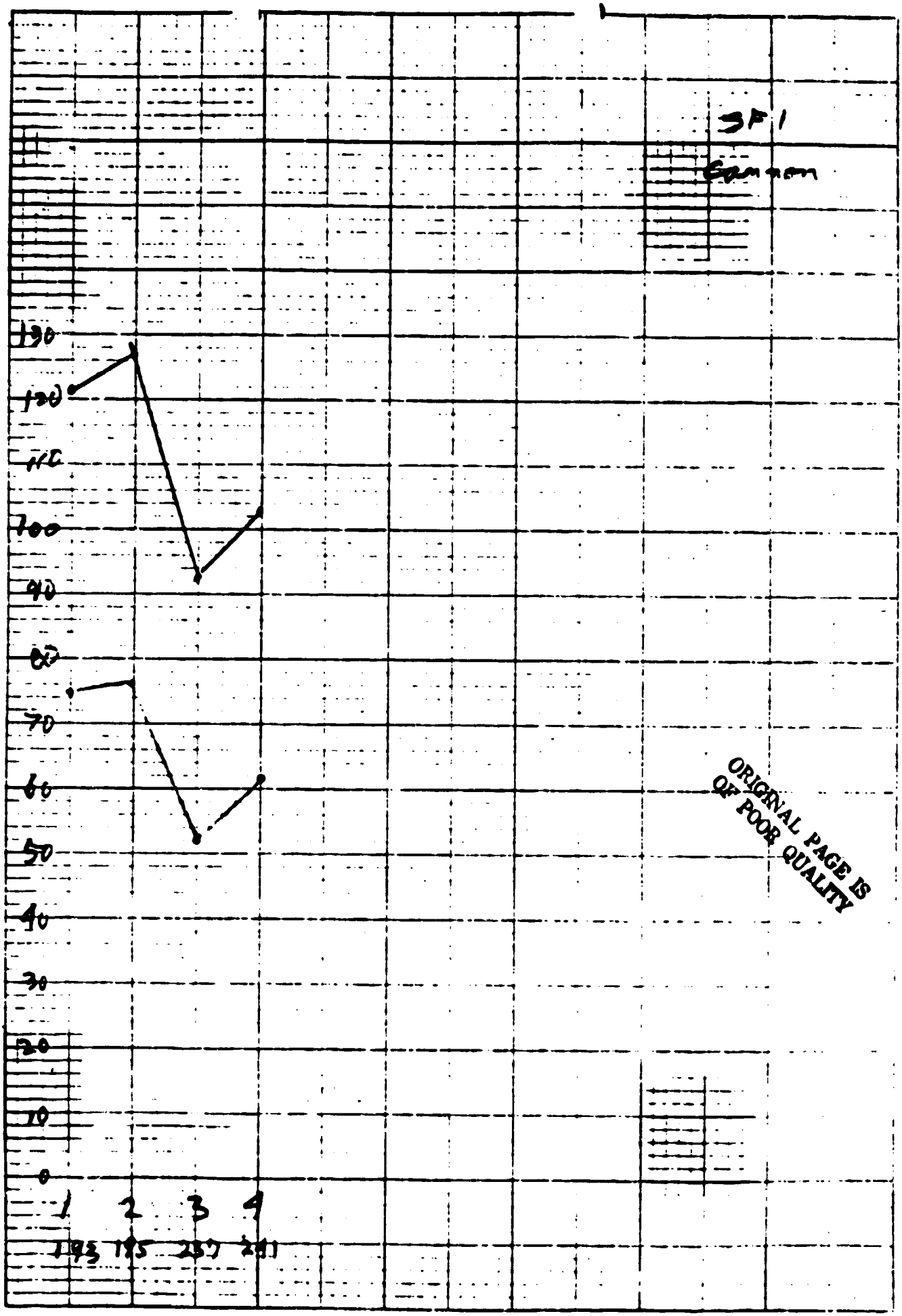
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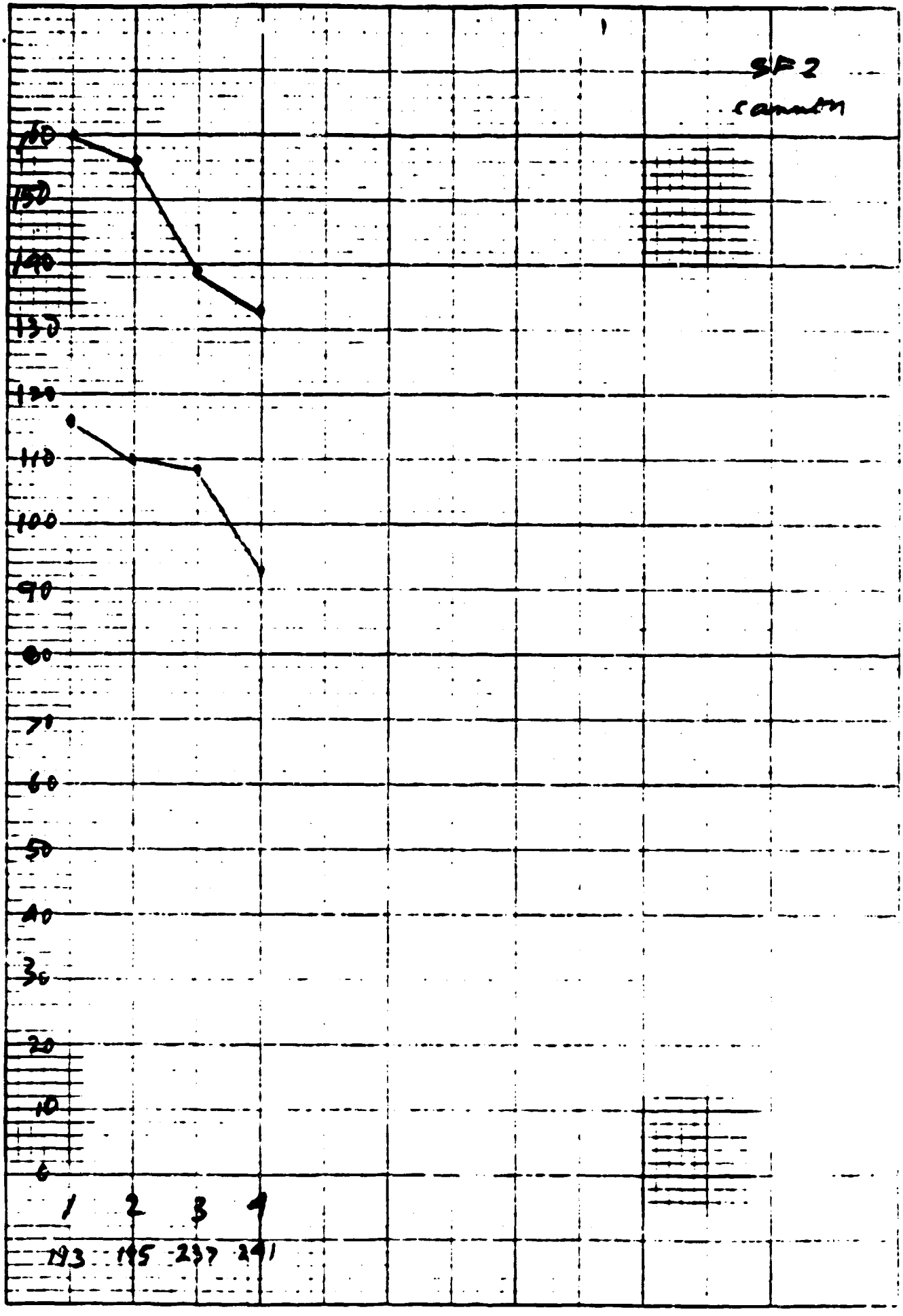
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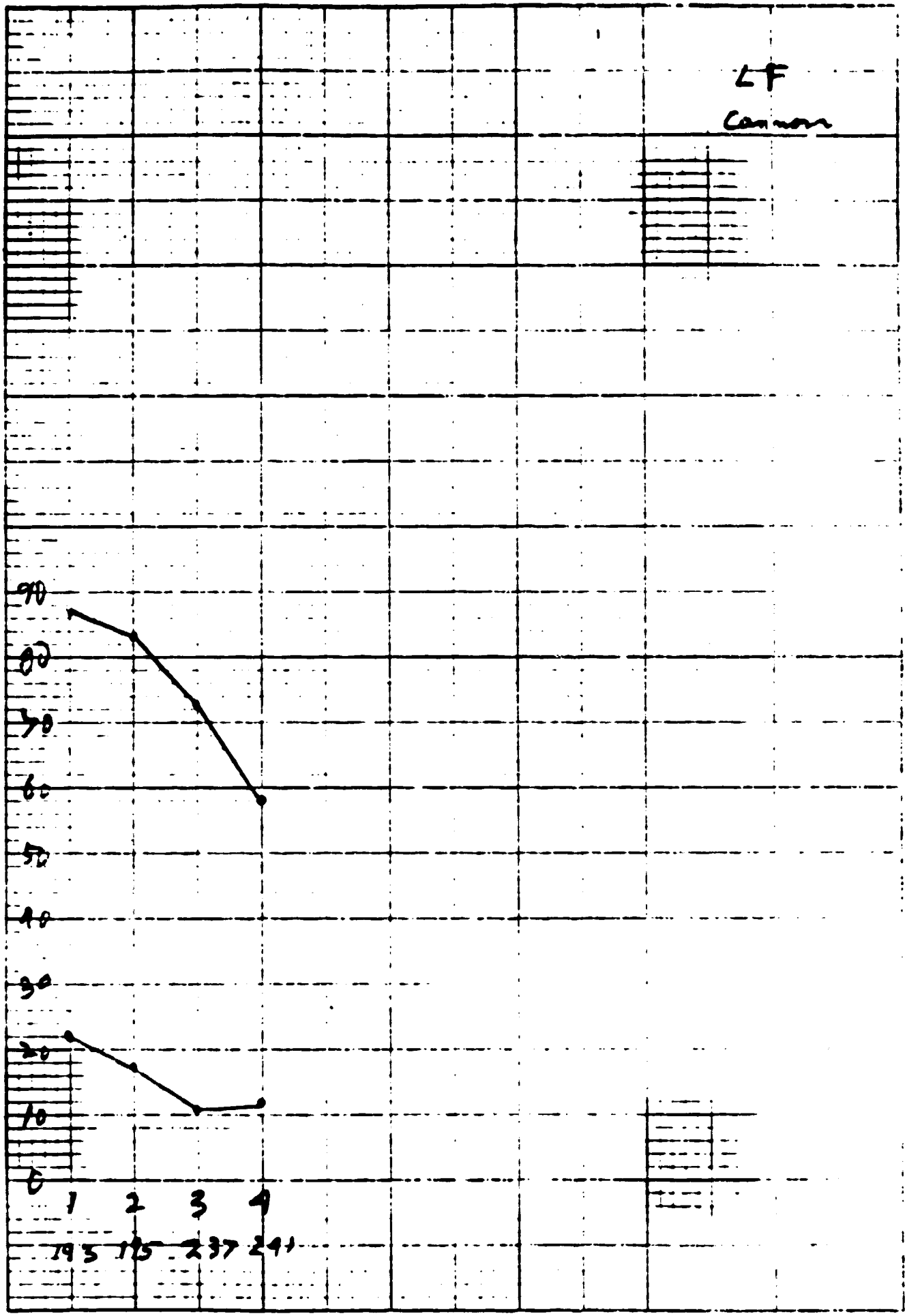
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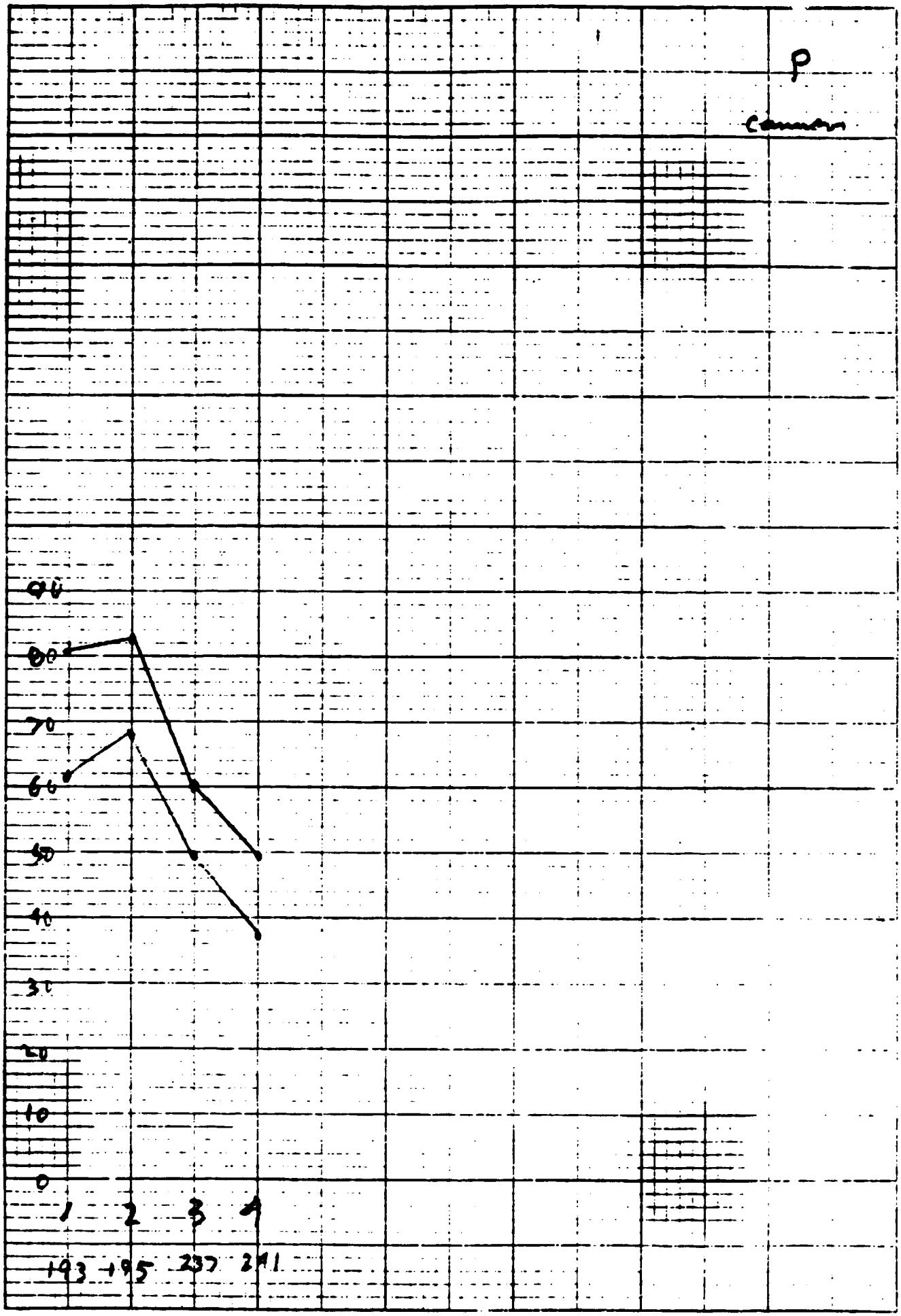
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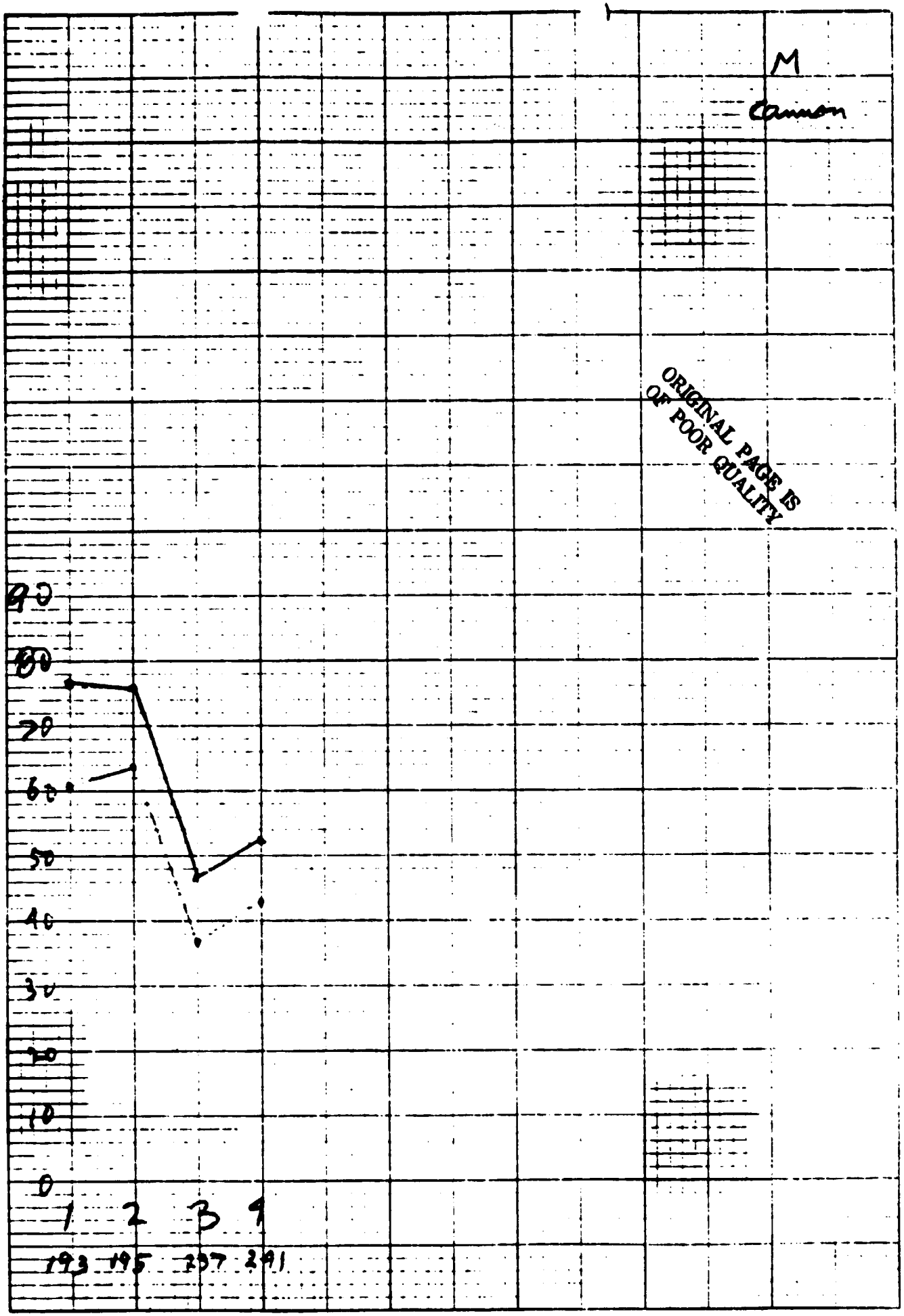
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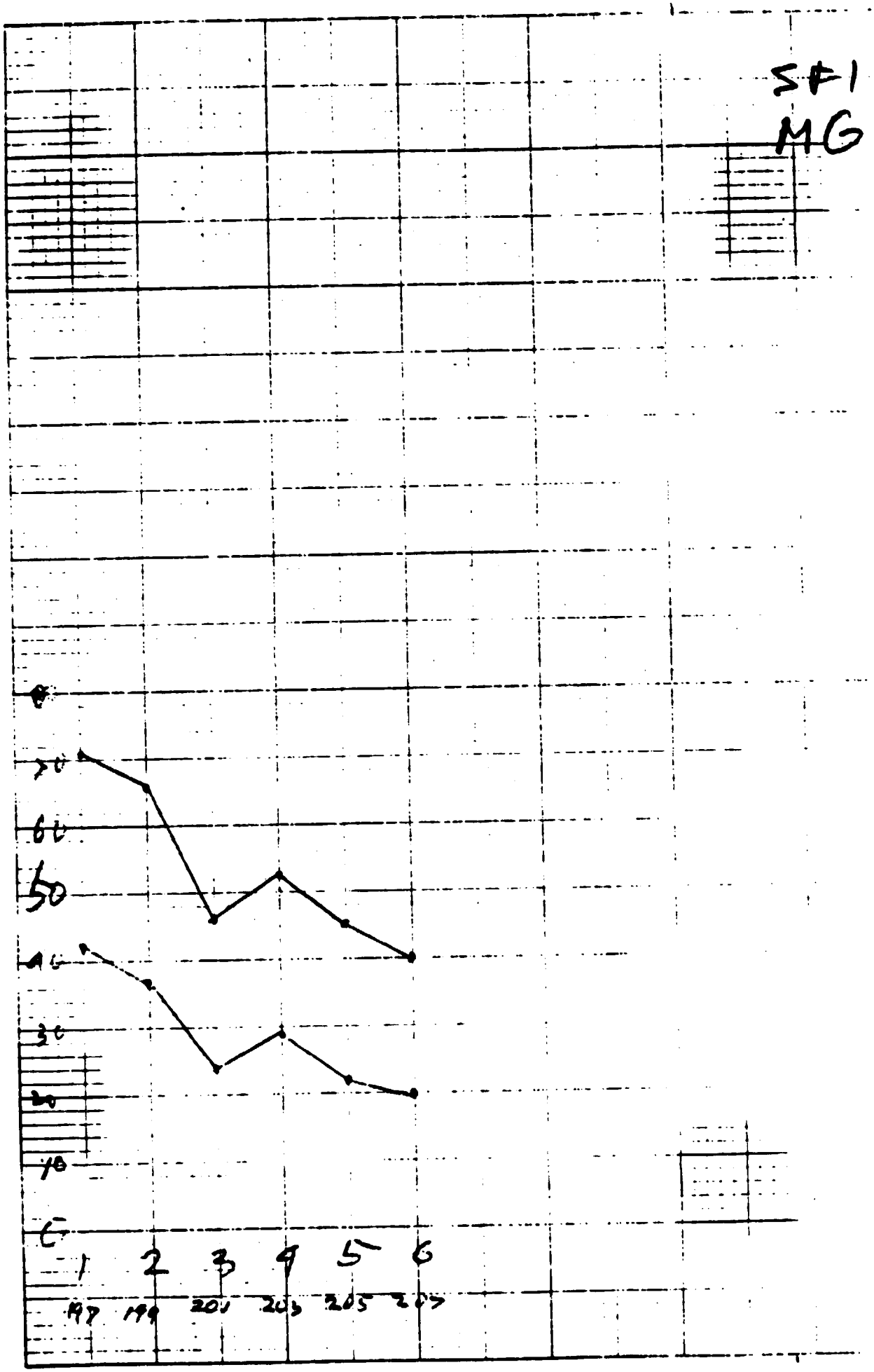
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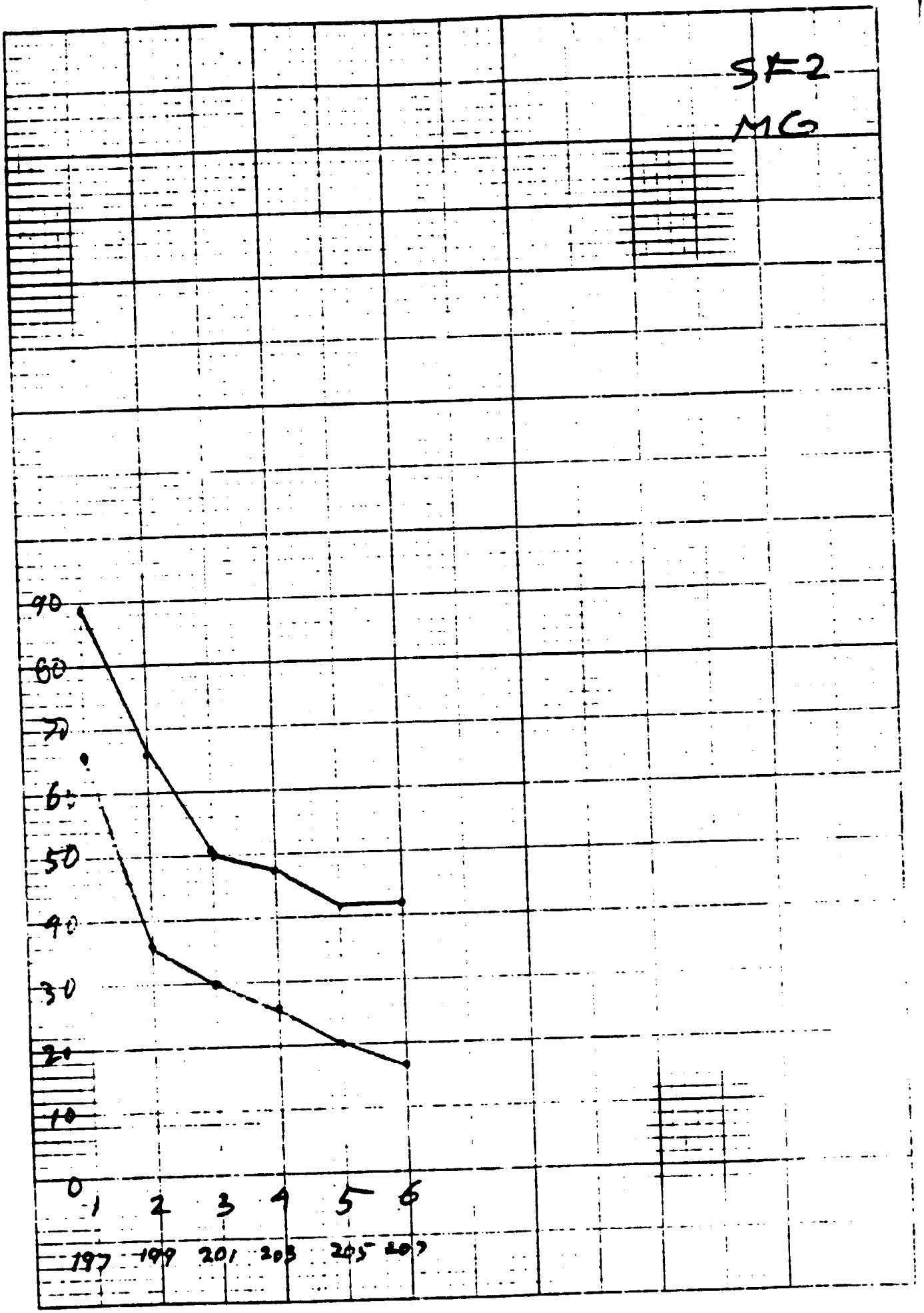
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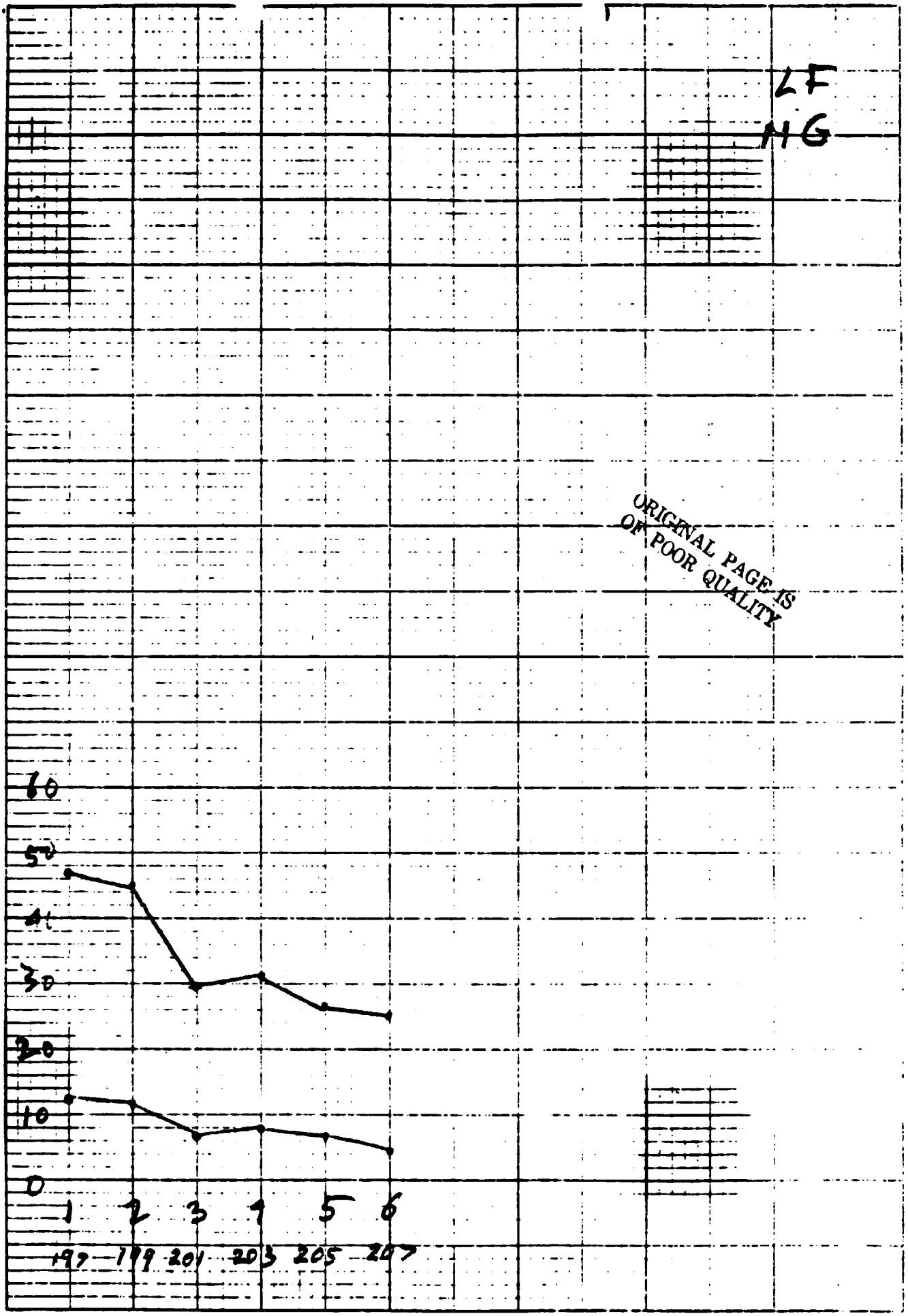
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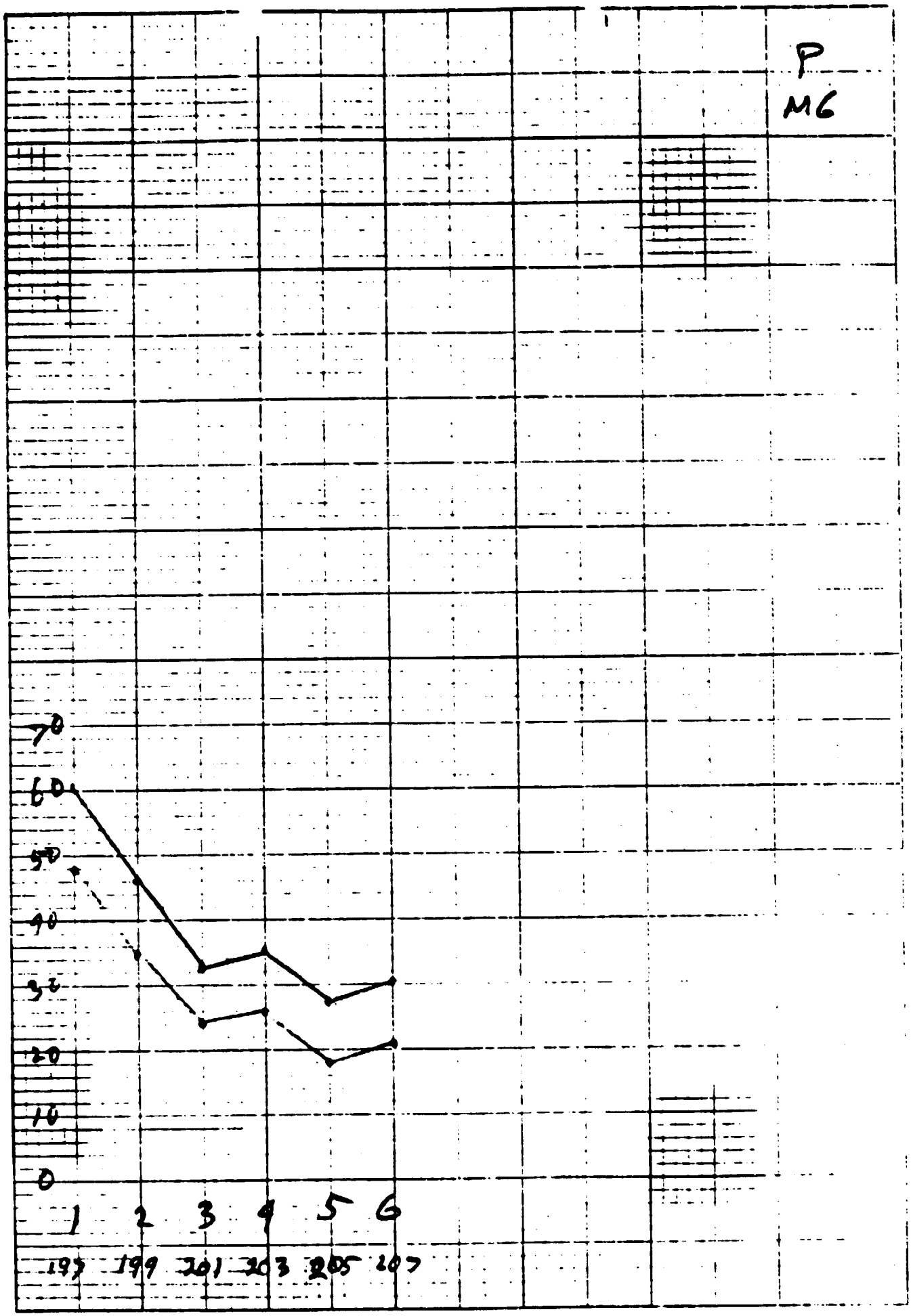

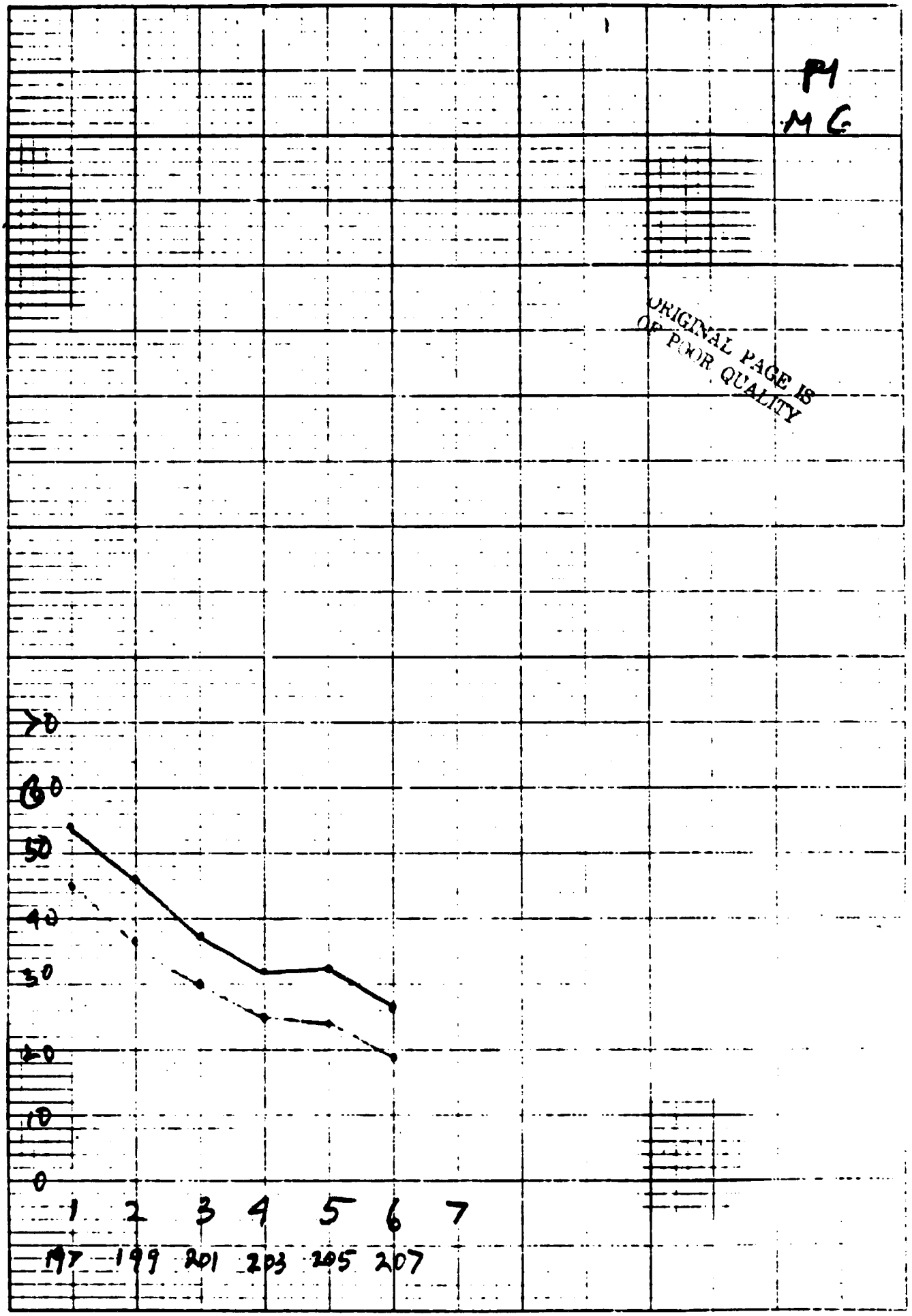
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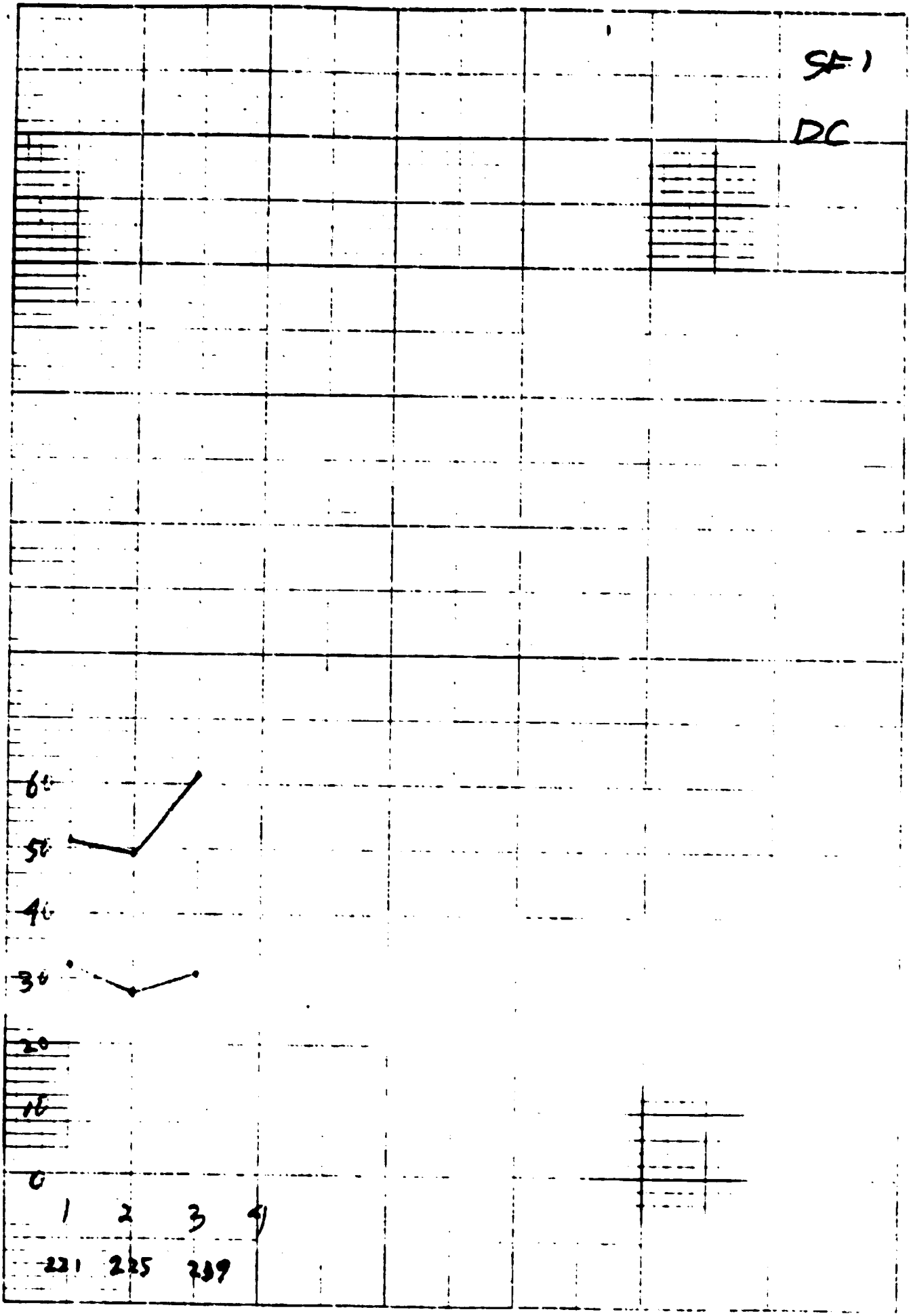
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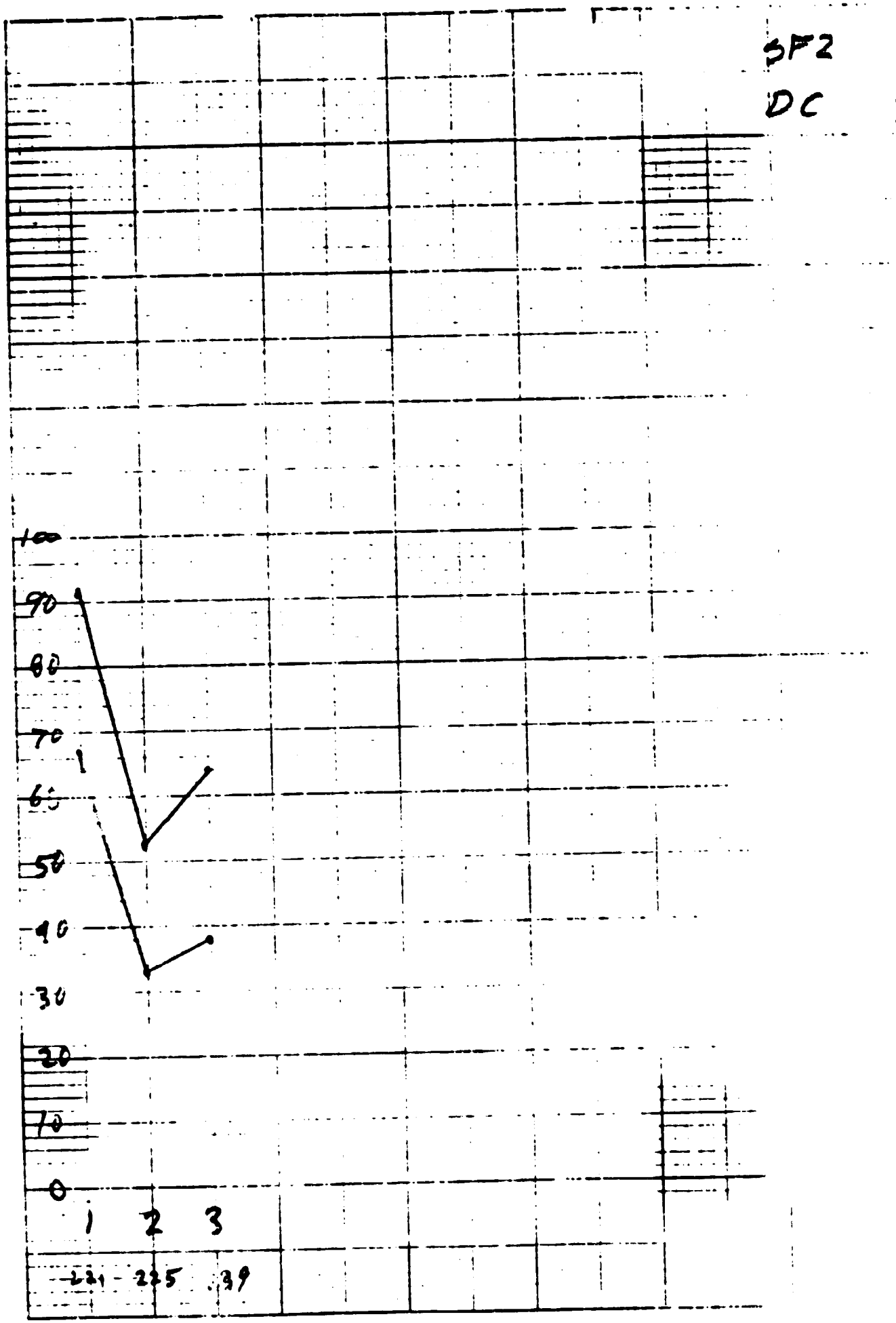
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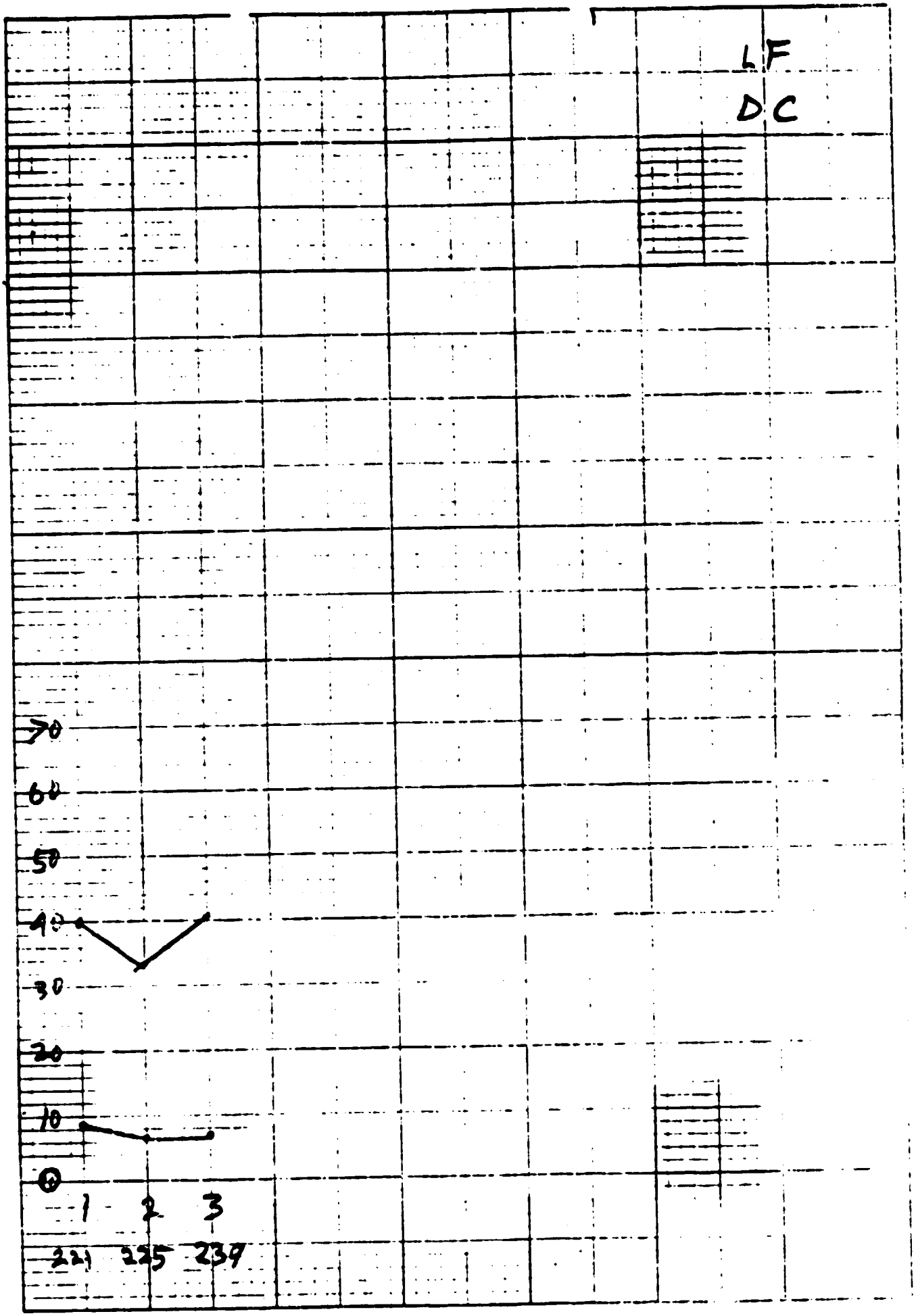
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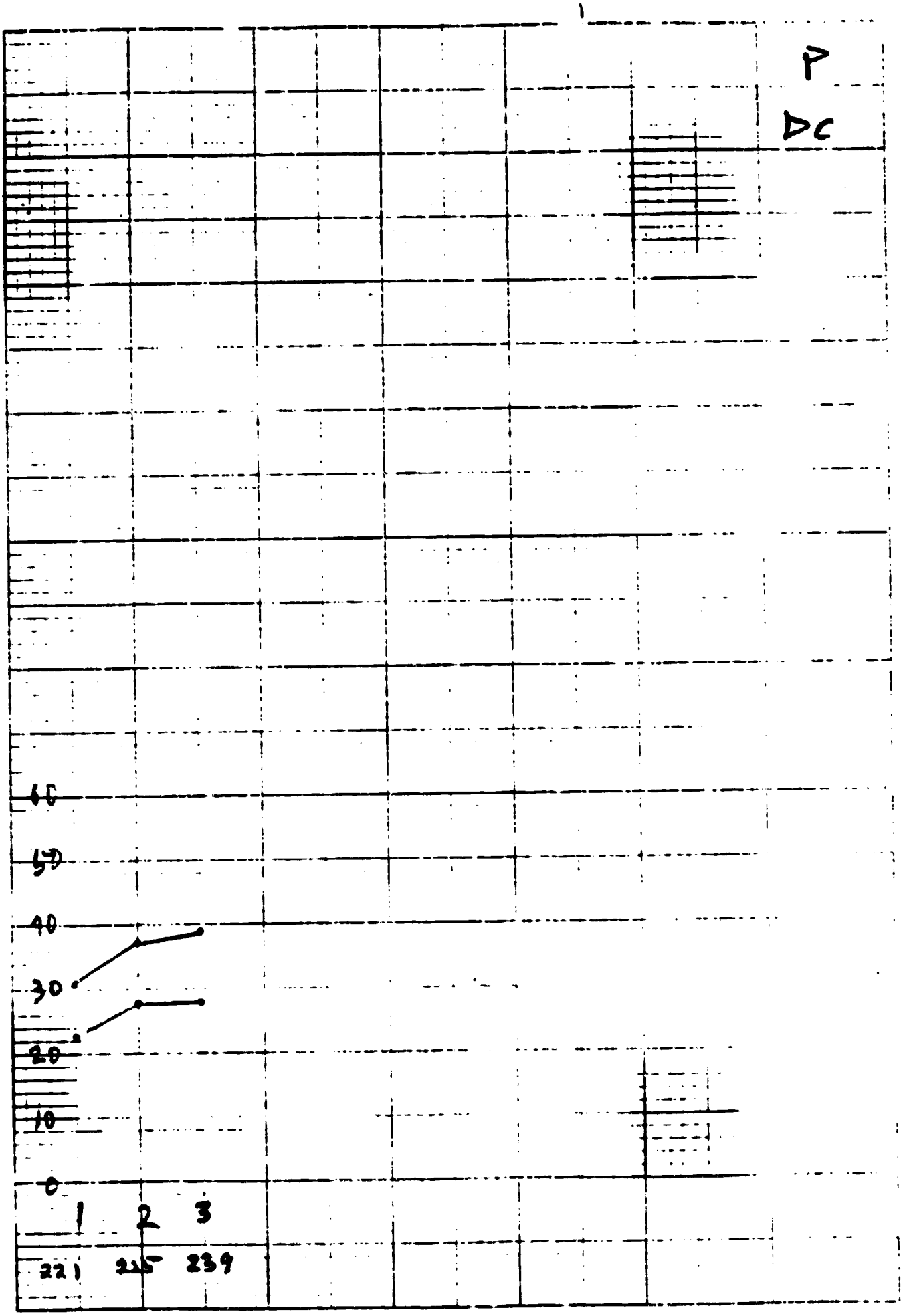
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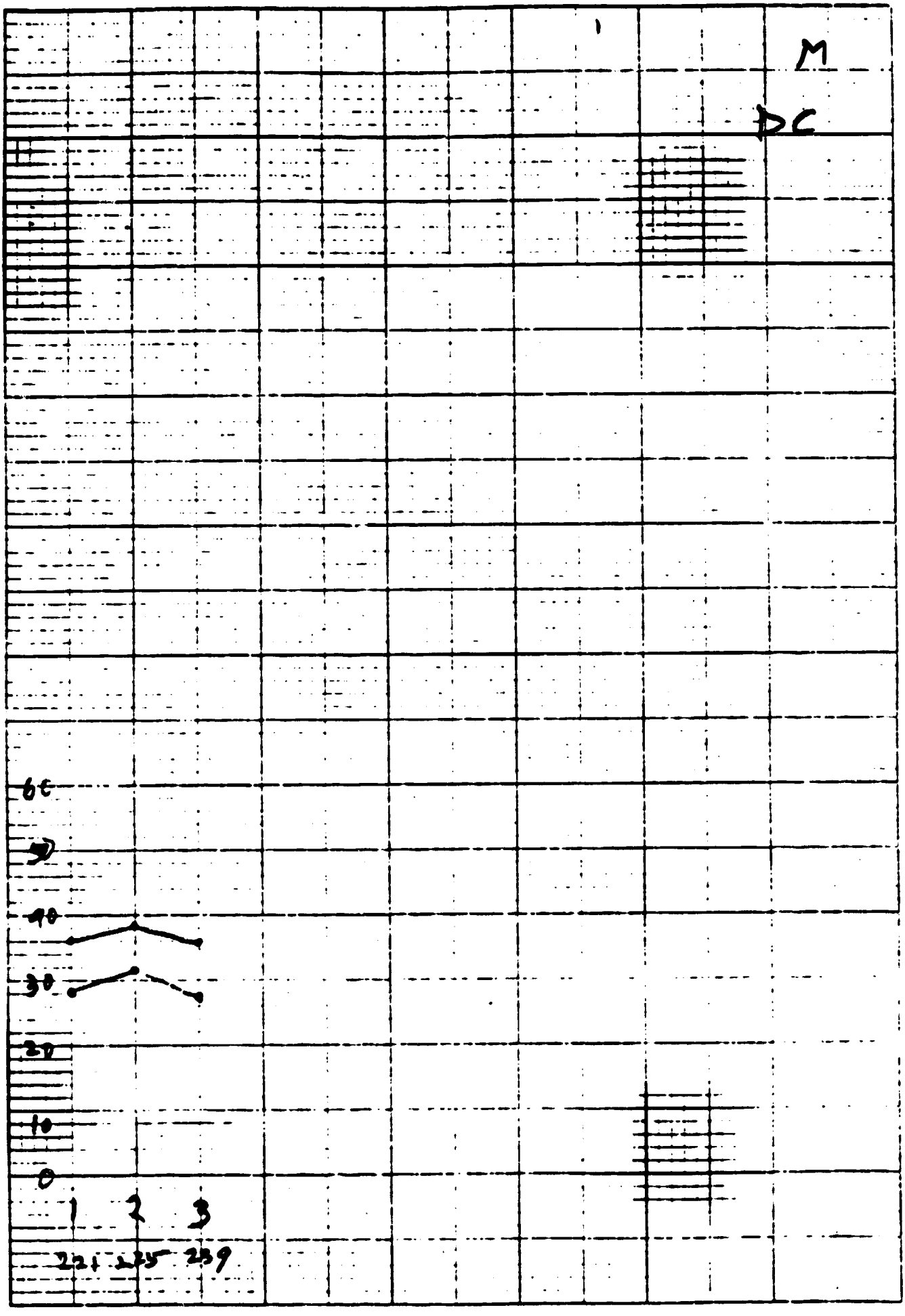
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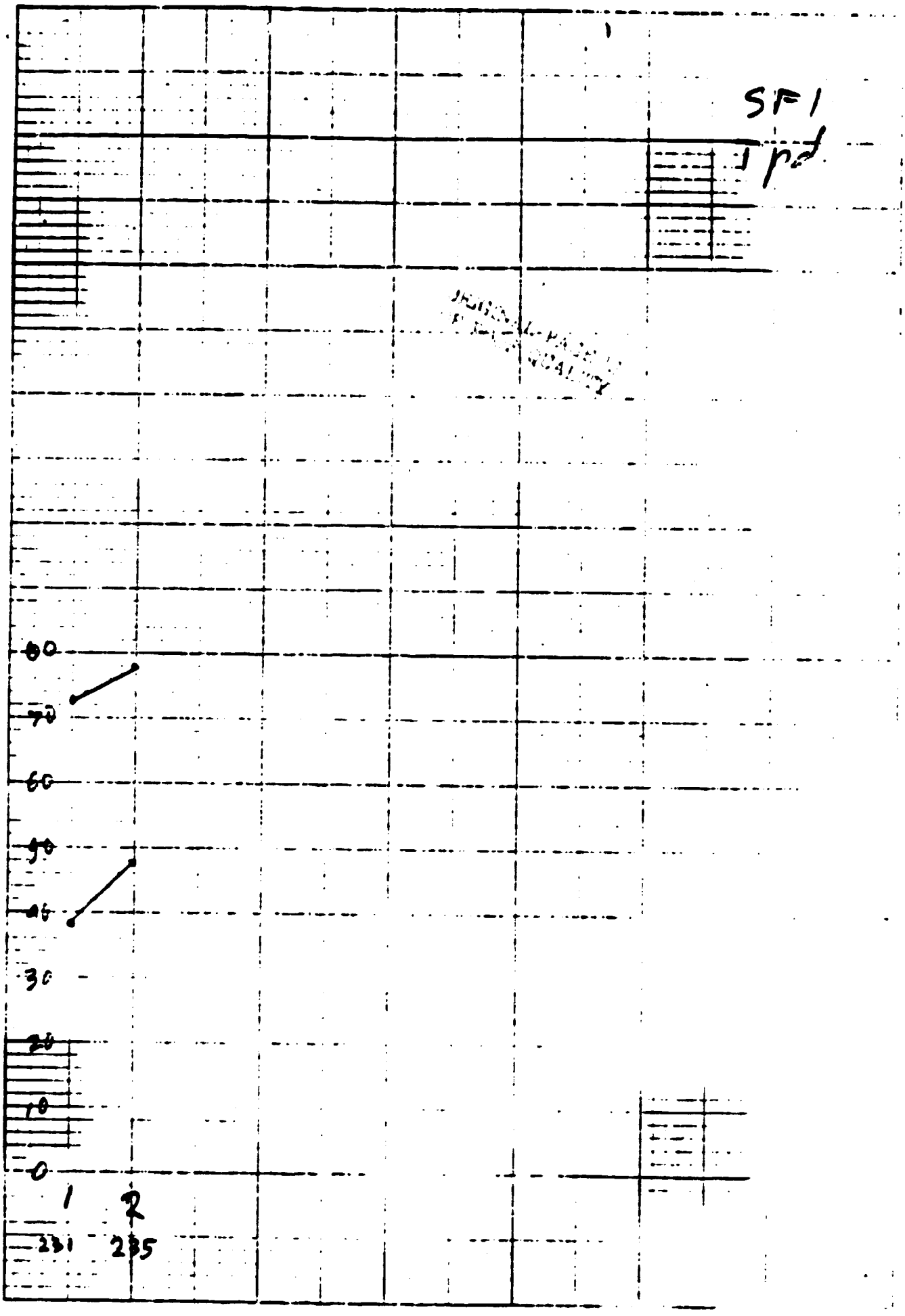
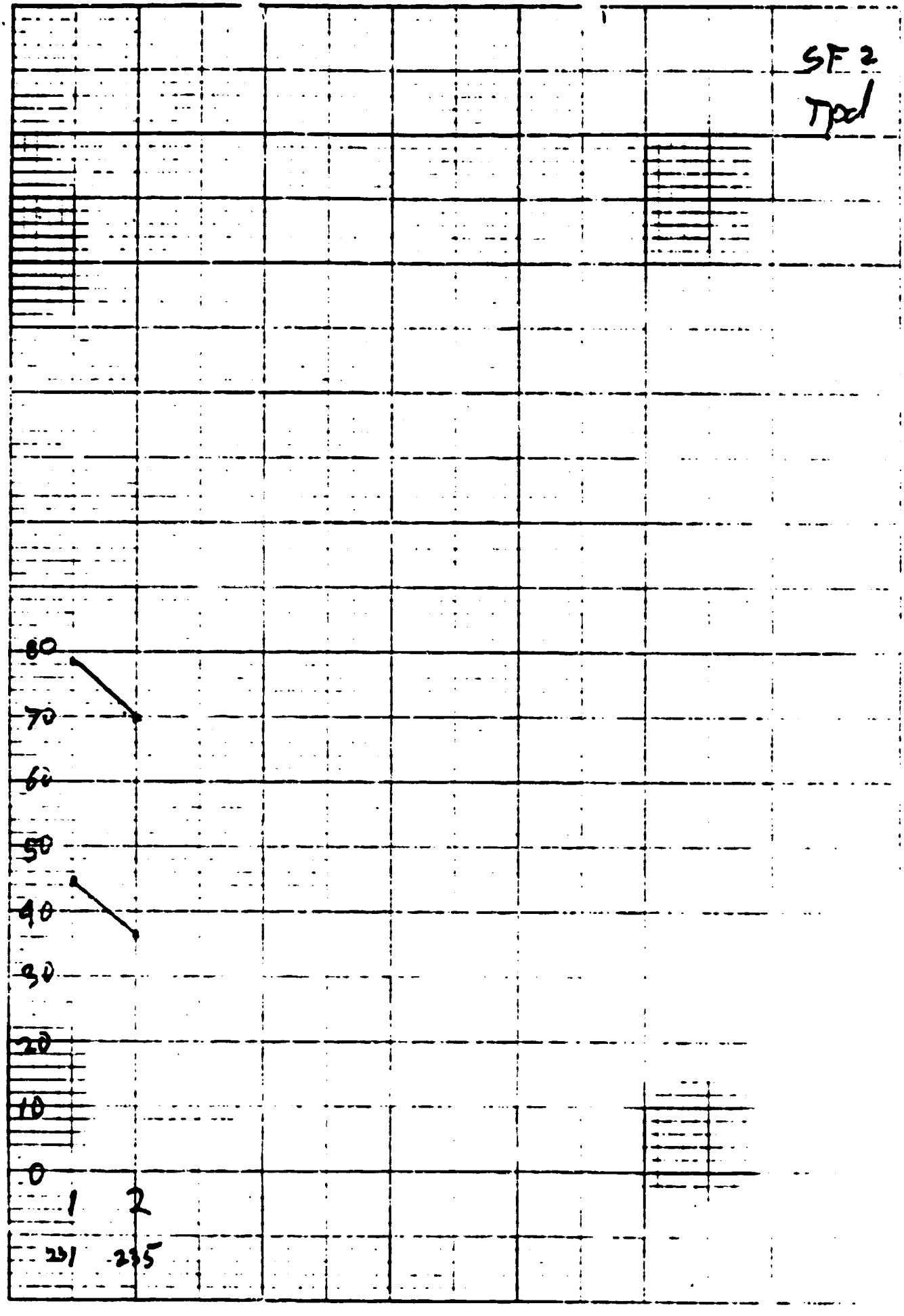
SF 1



SF2



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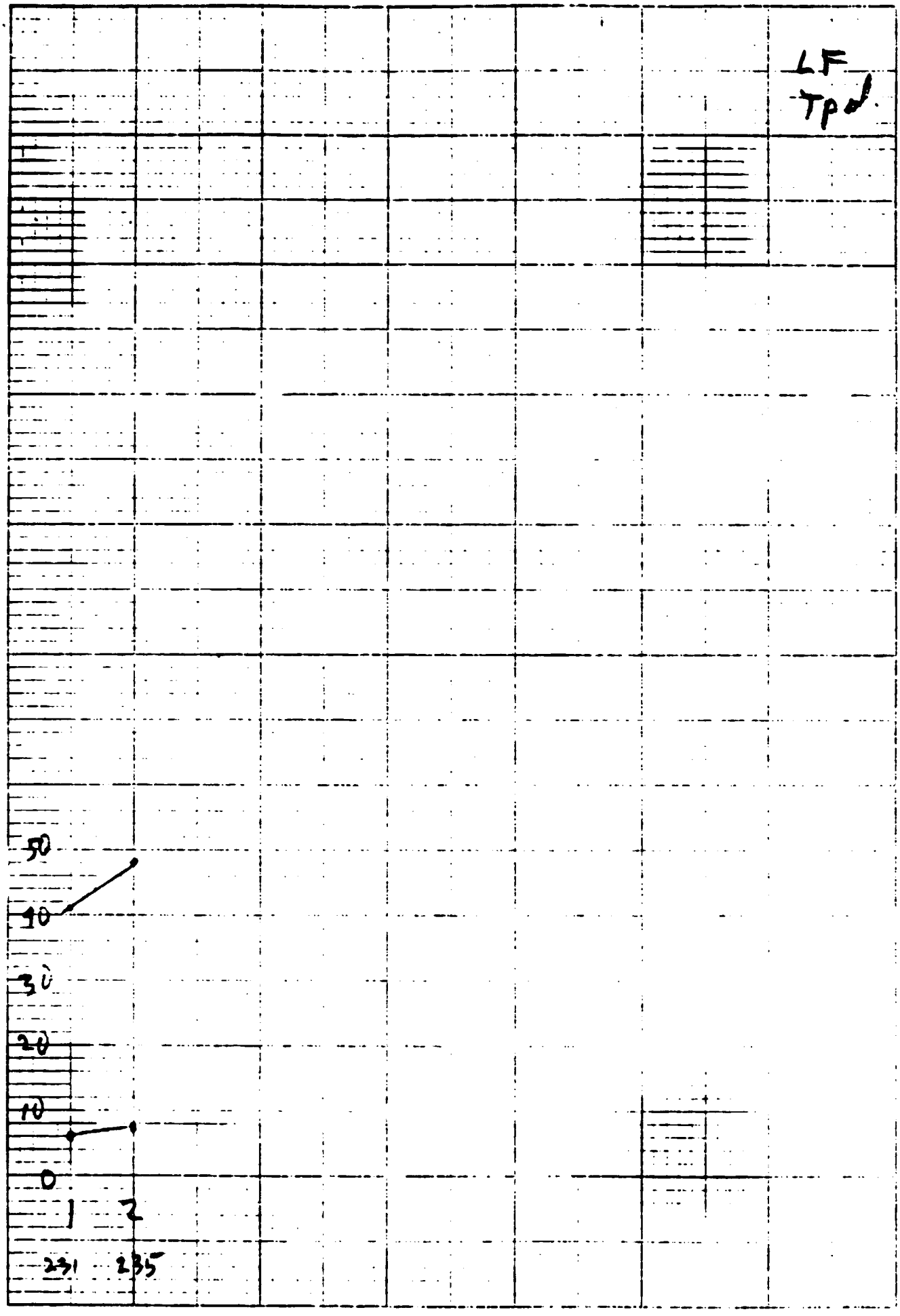

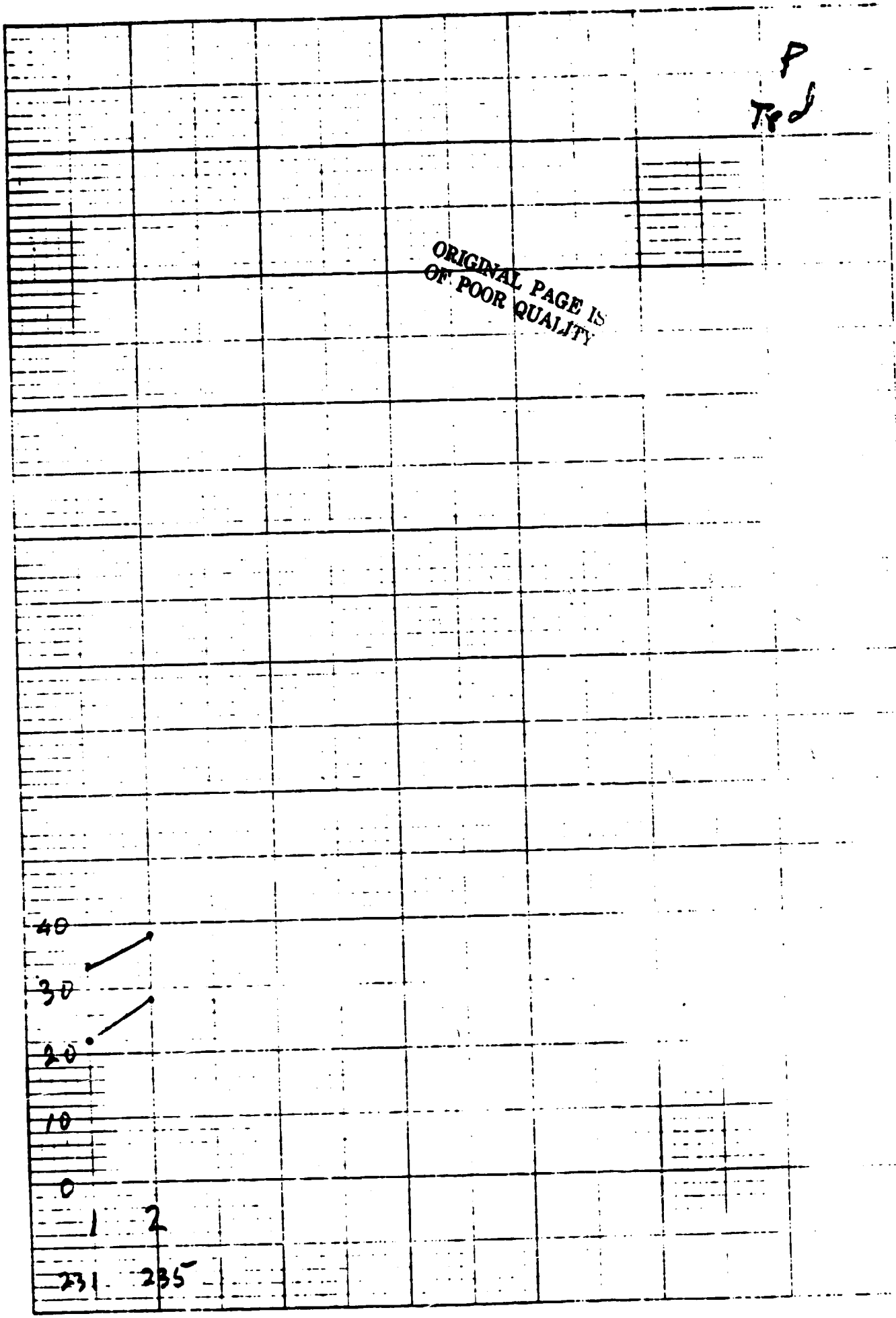
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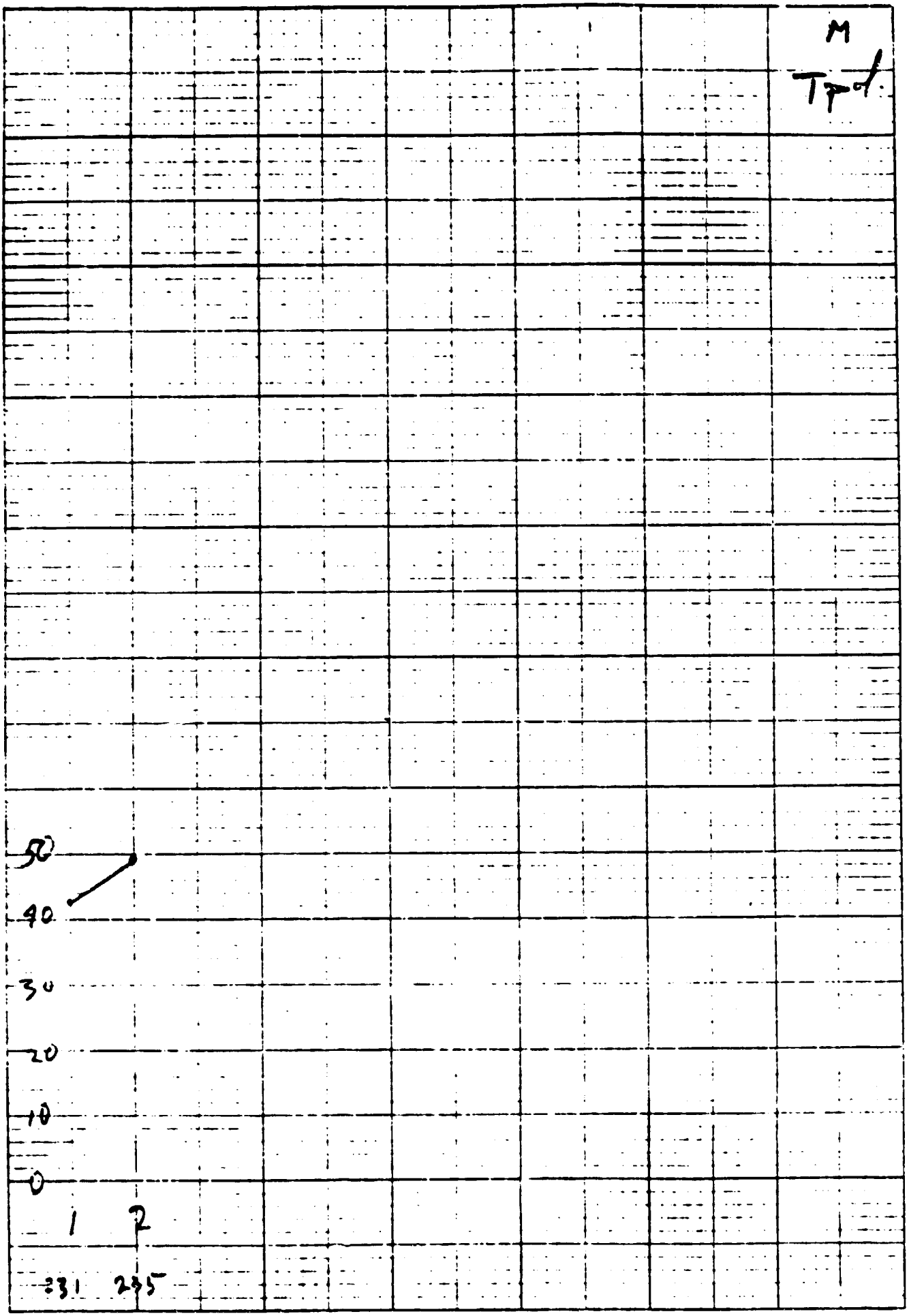
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235

APPENDIX H

Semantic Differential Questionnarie Results

Following are the means for each format response for each semantic differential question.

* indicates significant to the 5% level.

SF1 - short form mnemonic one (functional manual)

SF2 - short form mnemonic two (alphabetic manual)

LF - long form mnemonic

P - Prompted

M - Menu

Comb - the aggreate mean for all formats

```
      PGM QUES10
*
*     10 FEB 80  RLC
*
*     CATALOG AS Q10
*
*
      DFC         10
      DFC         1
      DFC         "*Q",1,1,7
      DFC         $A,"DID YOU LIKE THE COMMAND FORMAT?",$A0A
      DFC         "      LIKED 1:2:3:4:5:6:7 DISLIKED",$A0A,"%%"
*
      DFC         "*Q",2,1,7
      DFC         $A,"THE COMMANDING WAS:",$A0A
      DFC         "       FAST 1:2:3:4:5:6:7 SLOW",$A0A,"%%"
*
      DFC         "*Q",3,1,7
      DFC         $A,"THE COMMANDING WAS:",$A0A
      DFC         "    PRECISE 1:2:3:4:5:6:7 IMPRECISE",$A0A,"%%"
*
      DFC         "*Q",4,1,7
      DFC         $A,"THE COMMANDING WAS:",$A0A
      DFC         "COMFORTABLE 1:2:3:4:5:6:7 UNCOMFORTABLE",$A0A,"%%"
*
      DFC         "*Q",5,1,7
      DFC         $A,"THE COMMANDS WERE:",$A0A
      DFC         "    TOO                    TOO",$A
      DFC         "ABBREVIATED 1:2:3:4:5:6:7 WORDY",$A0A,"%%"
*
      DFC         "*Q",6,1,7
      DFC         $A,"THE COMMANDING WAS:",$A0A
      DFC         "    COMPLEX 1:2:3:4:5:6:7 SIMPLE",$A0A,"%%"
*
      DFC         "*Q",7,1,7
      DFC         $A,"THE COMMANDING WAS:",$A0A
      DFC         "   FRIENDLY 1:2:3:4:5:6:7 UNFRIENDLY",$A0A,"%%"
*
      DFC         "*Q",8,1,7
      DFC         $A,"THE COMMANDS WERE:",$A0A
      DFC         "EASY TO USE 1:2:3:4:5:6:7 HARD TO USE",$A0A,"%%"
*
      DFC         "*Q",9,1,7
      DFC         $A,"THE COMMANDS WERE:",$A0A
      DFC         "    EASY TO                HARD TO",$A
      DFC         "    LEARN 1:2:3:4:5:6:7 LEARN",$A0A,"%%"
*
      DFC         "*Q",10,1,7
      DFC         $A,"THE COMMANDING WAS:",$A0A
      DFC         "FRUSTRATING 1:2:3:4:5:6:7 SOOTHING",$A0A,"%%"
*
      DFC         "*Q",11,1,7
      DFC         $A,"THE COMMAND FORMAT IS:",$A0A
      DFC         "     USEFUL 1:2:3:4:5:6:7 NOT USEFUL",$A0A,"%%"
*
      DFC         "*Q",12,1,7
      DFC         $A,"THE COMMAND FORMAT IS:",$A0A
      DFC         "INTERESTING 1:2:3:4:5:6:7 DULL",$A0A,"%%"
```

SF1	SF2	Lf	P	M	COMB.
3.69	4.57	3.46	3.48	2.96	3.46
3.69	4.43	-	3.30	3.91	[illegible]
2.38	2.71	2.57	2.30	2.43	2.44
4.58	5.14	4.00	2.82	3.00	3.54
3.08	4.29	4.32	3.73	4.39	4.00
4.69	3.86	4.43	5.45	4.83	4.83
3.31	3.57	3.68	2.22	2.43	2.89
2.62	3.86	2.86	2.03	2.83	2.62
2.92	4.71*	3.11	2.12	2.04	2.64
3.69	3.29	4.25	4.28	4.09	4.09
2.62	4.00	3.00	2.21	2.83	2.72
3.00	3.00	3.39	2.82	3.13	3.08

```
* REVISED SOURCE EDITOR (C)  DATE  09/10/80  22:42:24        PAGE   1

      PGM QUES11
*
*     22 JAN 80  RLC
*
*     CATALOG AS Q11
*
*
      DFC         11
      DFC         1
      DFC         "*Q",1,1,7
      DFC         $A,"COMMANDING WAS:",$A0A
      DFC         "       USUAL 1:2:3:4:5:6:7 UNUSUAL",$A0A,"%%"
*
      DFC         "*Q",2,1,7
      DFC         $A0A
      DFC         "DURING THIS EXERCISE,",$A
      DFC         "I USED THE SOM FOR LOOKING UP COMMANDS:",$A0A
      DFC         "OFTEN 1:2:3:4:5:6:7 NONE",$A0A,"%%"
*
      DFC         "*Q",3,1,7,$A0A
      DFC         "!THE SOM WAS:",$A
      DFC         "EASY TO USE 1:2:3:4:5:6:7 HARD TO USE",$A0A,"%%"
*
      DFC         "*S",4,15000
      DFC         $A0A,$A0A
      DFC         "THIS IS THE END OF THE EXPERIMENT",$A0A
      DFC         "THANK YOU FOR YOUR PARTICIPATION.","%%"
*
      DFC         "*E",5,1
      END
POS TASK01
LIST
```

SF1	SF2	LF	P	M	COMB
3.46	3.43	3.57	3.36	-	3.34
1.69*	2.14	2.39	3.39	5.91*	3.38
2.85	3.43	2.50	2.76	2.57	2.70

APPENDIX I

First Attempt Performance Times

Following are comparisons of the First attempt performance times (seconds) for each format and each experimental system.

SYSTEM/FORMAT	SF1	SF2	LF	P	M
Navigation	157	157	99	83	77
Propulsion	88	99	67	52	60
Ship Control	48	59	37	35	39
Radar	177	190	124	82	61
Cannon	121	160	87	81	77
Machine Gun	71	89	47	60	54
Depth Charge	51	92	40	31	36
Torpedo	72	79	41	33	43
Totals	785	925	542	457	447

Following are comparisons of the second attempt performance times (seconds)

System/Format	SF1	SF2	LF	P	M
Navigation	107	105	85	67	72
Propulsion	68	58	32	37	37
Ship Control	26	24	24	29	32
Radar	103	86	99	64	61
Cannon	127	158	83	82	76
Machine Gun	66	66	45	46	46
Depth Charge	49	53	33	37	38
Torpedo	78	70	48	38	39
Totals	624	620	449	400	401

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APPENDIX J

Specific Guideline Recommendations for DSN Software Development

The following guidelines are offered for DSN Software Development. They attempt to accomodate the DSN operations enviroment and to offer specific recommendations for station software man computer interface designs. These guidelines are presented with the fervent hope that they are not slavishly followed without understanding the underlying rationale. They are a good place to start the MCI design, but with adaptations to fit local requirements.

1. Primary Command Format - the aggregate level of learning of the DSN Station Operations is relatively high. They use the operations software everyday as an internal part of their job. The mnemonic command structure is appropriate for these operators.

2. Secondary Command Formats - prompt command format should be used for the stations initialization and configuration activity. This activity typically requires multiple inputs which must be entered in a specific sequence. A prompt format insures that no command will be overlooked and that the sequence is correct. Command sequences which control high risk activities such as manual spacecraft commanding should use the prompt format. Again, this reduces the potential for missing a command or entering a command out of sequence. Programs which are used infrequently by the operators should use the prompt format. The prompt format is appropriate here because of the operator's lower level of learning.

3. Decision Span - this research indicates that decision span is one of the more important parameters in MCI design. It is recommended that the decision span at any one level of activity be limited to ten or less. If the inherent decision span is larger than ten some form of hierarchical structure or grouping identifier such as first character codes (for example, TXX for a telemetry command) be used.

4. Command Arguments - the number of command arguments should be limited to four or less.

5. Character Lengths - the number of characters in either the mnemonic code or the arguments should be four or less. If an argument requires more that four characters, it should be broken up into 4 or less character groups with some logical delimiter (for example, time - 10:34:48).

6. Delimiters - the delimiters between arguments and between the mnemonic code and the first argument should be a spare. Because the space is the easiest character to type.

7. Command Structure - the command structure should be functionally related to the activity that it is controlling. For example, the order of the command arguments should be in the same order in which the operator thinks of the system parameters.

8. Manual - the operator's manual should list the commands in functional groupings to aid the operator's search activity.

9. Standard Names - similar commands in different systems should have similar names. The same function should have the same names (for example, HALT for program termination).

Summary

1. Use Mnemonic Command Format for operational software.

2. Use Prompt Command for:

   a. Initialization
   b. High risk commands
   c. Low useage programs

3. The Decision Span should be 10 or less.

4. The Argument List should be 4 or less.

5. The number of characters should be 4 or less in any mnemonic or argument.

6. Use the spare character as a delimiter.

7. The Command Structure should be functionally related to the controlled activity.

8. The Operator's Manual should be organized in a manner functionally consistent with the system.

9. Standardize