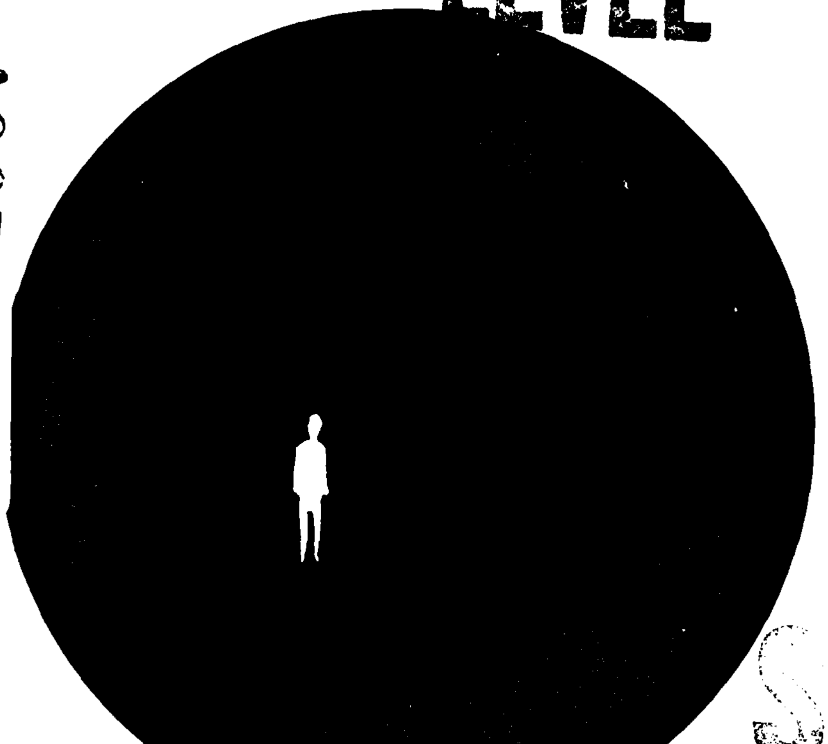
TAEG

TRAINING
ANALYSIS
AND
EVALUATION
GROUP

(12) SC

TAEG REPORT NO. 84

LEARNING OF PROCEDURES IN NAVY TECHNICAL TRAINING: AN EVALUATION OF STRATEGIES AND FORMATS



FOCUS ON THE TRAINED MAN

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION IS UNLIMITED.

MARCH 1980

TRAINING ANALYSIS AND EVALUATION GROUP

ORLANDO, FLORIDA 32813

TAEG Report No. 84

LEARNING OF PROCEDURES IN NAVY TECHNICAL TRAINING: AN EVALUATION OF STRATEGIES AND FORMATS

Anne M. Polino
Richard Braby

Training Analysis and Evaluation Group

Sponsored by

Chief of Naval Education and Training

and the

David W. Taylor Naval Ship Research and Development Center,
Naval Technical Information Presentation Program

March 1980

ALFRED F. SMODE, Ph.D., Director,
Training Analysis and Evaluation Group

WORTH SCANLAND, Ph.D.
Assistant Chief of Staff for
Research and Instructional Systems
Development
Chief of Naval Education and Training

ACKNOWLEDGMENTS

The support provided by the Basic Electricity and Electronics School, Orlando, is gratefully acknowledged. Special thanks is extended to CEC T. Sheehy who served as liaison between the military personnel and the Training Analysis and Evaluation Group (TAEG) and helped to maintain an efficient working relationship. SMCM E. J. Chambless, Director of the Signalman "A" School, Orlando, is also acknowledged for support provided in the conduct of the study.

Appreciation is also extended to Dr. J. Peter Kincaid and Dr. Myron Zajkowski of TAEG who provided technical assistance in defining the study plan and in editing the report.

We are pleased to acknowledge the counsel of Dr. Alfred Smode and his efforts in refining the presentation of the material.

(14) TAEG-84

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

Field	Entry
1. REPORT NUMBER	TAEG Report No. 84
2. GOVT ACCESSION NO.	AD-A084 067
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle)	(6) LEARNING OF PROCEDURES IN NAVY TECHNICAL TRAINING: AN EVALUATION OF STRATEGIES AND FORMATS
5. TYPE OF REPORT & PERIOD COVERED	
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s)	(10) Anne M. Polino [redacted] Richard Braby
8. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	Training Analysis and Evaluation Group Orlando, FL 32813
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	(12) 1.1
11. CONTROLLING OFFICE NAME AND ADDRESS	
12. REPORT DATE	(11) Mar[redacted]980
13. NUMBER OF PAGES	114
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	
15. SECURITY CLASS. (of this report)	Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Procedure Learning
Job Performance Aids
Learning Aids
Design of Instructional Materials
Instructional System Development
Learning Strategies
Computer-Aided Authoring
Automated Authoring
Visual Imagery

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

This study compared the effectiveness of three types of handbooks utilized by students in learning to perform procedural tasks. The handbooks are the traditional narrative presentation, the job performance aid, and the learning aid.

The study is the second in a series for the Naval Technical Information Presentation Program (NTIPP) conducted by the Training Analysis and Evalua-

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601 |

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

410 626

20. tion Group (TAEG) in the design of machine producible instructional formats compatible with the learning guidelines in the Interservice Procedures for Instructional Systems Development. These formats were conceived to provide effective support for learning and were designed to be constructed by computer routines from basic task information stored in a digital data base. In this study, the Job Performance Aid and Learning Aid were the machine producible formats.

The experimental task was a 21 step equipment procedure that involved calibrating the probe of a Tektronix 545B oscilloscope. The study design employed six groups. Groups were established for each combination of the three types of instructional material and two aptitude levels. Following the use of the instructional materials, job performance and job knowledge were measured.

The main conclusion was that the learning aid format was superior to the other formats tested when the goal was to have students accurately perform the procedure from memory. However, if the goal was to teach verbal information about the procedure, such as nomenclature or system theory, none of the formats appeared to be adequate.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION I

INTRODUCTION

The Naval Technical Information Presentation Program (NTIPP) of the David W. Taylor Naval Ship Research and Development Center is a large-scale effort to improve the Navy's efficiency in publishing technical information supporting Navy equipment. This program is concerned with the generation, distribution, and control of technical information needed for training, maintenance, equipment operation, and logistic support. The goal of the program is to define a full set of hardware support documents, including job performance aids and learning aids, and to design a state-of-the-art system for authoring, composing, illustrating, printing, distributing, and updating these documents. Several Navy organizations are participating in this effort. The Chief of Naval Education and Training (CNET) has a special interest in this program since the resulting technical manuals will be used in the CNET-managed "C" schools, and contractor-prepared training handbooks will be used as student and instructor guides in these schools and in onboard training.

Under the sponsorship of CNET and NTIPP, the Training Analysis and Evaluation Group (TAEG) is designing a series of machine producible instructional formats for use in training documents (Braby, 1979; Ainsworth, 1979; Braby, Parrish, Guitard and Aagard, 1978) which are compatible with the learning guidelines in the Interservice Procedures for Instructional Systems Development (NAVEDTRA 106A, 1975). These are conceived to provide effective supports for learning and are designed to be constructed by computer routines from basic task information stored in a digital data base.

The present study is concerned with the learning of equipment operation and maintenance procedures in the context of technical training. Procedural activities constitute the largest percentage of involvement in most tasks. As used here, procedure learning involves executing from memory, or with simple published aids, a standard sequence of steps for the assembly, inspection, calibration, operation or service of a piece of equipment. This type of task requires relatively little judgment or analysis and a minimum of alternative behaviors. Manipulating controls is generally within the response repertoire of the students; therefore, the emphasis is placed on the correct sequencing of steps, locating components to be acted upon, positioning of knobs and switches, and judging whether equipment response to these actions is within desired or published norms.

This report provides an evaluation of traditional and innovative ways to present information on the learning of procedures that are adaptable for use in schools and in onboard training. It compares a type of lesson material used in Navy schools with a type of job aid being called for in some recent Department of Defense contracts, and an innovative type lesson material based on learning guidelines in the Interservice Procedures for Instructional Systems Development. It is the second in a series of studies concerned with machine producible formats for low cost training materials. A previously cited study dealt with machine producible formats for symbol learning (Ainsworth, 1979).

PURPOSE

The purpose of this study is to compare the effectiveness of three types of handbooks utilized by students in learning to perform procedural tasks. The handbooks are the traditional narrative presentation, the job performance aid, and the learning aid. The job performance aid and learning aid represent machine producible formats while the narrative presentation does not.

SECTION II

METHOD

This section describes the technical approach used to compare the effects of three types of learning materials differing in format and learning strategies on the ability of students to perform a procedure following task from memory. The task was a 21-step equipment calibration procedure that involved calibrating the probe of a Tektronix 545B oscilloscope. This included sequences for initiating power and obtaining a waveform and for probe adjustments to obtain the waveform shape for correct calibration.

Information which follows describes the subjects employed, the instructional materials, and the procedures used in training and testing subjects. The study design employed two basic classes of students in terms of aptitude. Within this, six groups were established to account for all combinations of the types of learning material and aptitude levels.

All groups completed the three phases of the study. In the initial phase, students read through their assigned study materials. This was immediately followed by a performance test and a job knowledge test. In the practice phase, students continued to study the assigned materials until the study time in phases 1 and 2 totaled 90 minutes. The retention phase began after a pause of 7 days, at which time the performance test was again administered to all students. This 3 x 2 x 3 factorial design is shown in figure 1.

SUBJECTS

The subjects were 90 male enlisted students who were undergoing or had just completed training in the basic electricity and electronics (BE&E) course at the Naval Training Center, Orlando, Florida. They were assigned to two groups of 45 each in terms of above average and below average aptitude scores. Above average aptitude was defined as a composite standard score between 184 and 210 on the arithmetic reasoning (AR), word knowledge (WK), and spatial perception (SP) subtests of the Armed Services Vocational Aptitude Battery (ASVAB). This is approximately the upper one-third of the student distribution. Below average aptitude was defined as a composite standard score between 115 and 147 on the same subtests. This is approximately the bottom one-third of the student distribution.

As these students reported, they were assigned randomly to one of the three types of instructional material groups in such a way as to keep the numbers in the groups as nearly balanced as possible, until each subgroup contained 15 students. None of the students had received formal training in the operation of the oscilloscope or other complex test equipment.

MATERIALS

Three types of handbooks presented information on the task procedure. The handbooks differed in three ways. First, the amount of pictorial information presented varied. This ranged from few illustrations (written words described the steps in the procedure) to highly illustrated material where the pictorials defined the procedure (written words were used only to clarify).

INSTRUCTIONAL MATERIAL

APTITUDE	Traditional			Job Performance Aid			Learning Aid		
	Initial Study	Practice	Retention	Initial Study	Practice	Retention	Initial Study	Practice	Retention
Below Average Students	PT JKT	PT	PT	PT JKT	PT	PT	PT JKT	PT	PT
Above Average Students	PT JKT	PT	PT	PT JKT	PT	PT	PT JKT	PT	PT

PT = Performance Test

JKT = Job Knowledge Test

Figure 1 Experimental Design and Testing Plan

Second, the handbooks differed in the extent to which operational equipment was called for in the learning process. This varied from equipment being used only in testing to equipment being used in each phase of learning and in testing. Finally, the handbooks differed in the extent to which they provided guidance and support to the student in applying efficient learning principles. This ranged from no guidance to extensive coaching and support in the use of learning principles. The three handbook types are described below.

TRADITIONAL NARRATIVE HANDBOOK. This 21-page handbook has the same format as the Basic Electricity and Electronics Student's Guide (1978) currently in use at the BE&E School, Orlando, Florida. It presents a narrative discussion of basic oscilloscope controls and functions and enumerates the steps of the probe calibration procedure. This text is used in conjunction with the actual equipment so that a student can set up the equipment as he reads through the steps. A multiple-choice job knowledge test is provided for the student to measure his own understanding of oscilloscope operations and control functions. (This handbook format is shown in appendix A.)

JOB PERFORMANCE AID. This 20-page handbook presents the probe calibration procedure using photographs and printed directions. The primary means of communicating the procedure is through the illustrations, and the words are used to clarify the specific acts the technician must perform. The material does not contain practice exercises or self-tests. An operational oscilloscope is used only in formal testing. (This handbook format is shown in appendix B.)

LEARNING AID. This 116-page handbook presents the probe calibration procedure with photographs and printed directions and contains practice exercises and self-tests. It implements seven guidelines for procedure learning outlined in Aagard and Braby (1976) and in the Interservice Procedures for Instructional Systems Development, Phase III, Develop (NAVEDTRA 106A, 1975).

The 21-step probe calibration procedure is divided into four sections with three to seven steps in each section. Exercises which help students chain the individual steps into a smooth sequence of events and self-tests with performance feedback were incorporated in each section. A final criterion test with answers is also included to provide feedback to the students about their achievement in learning the sequence of steps. The calibration procedure used a format in which photographs and printed words are the primary and secondary communication channels, respectively. The printed words serve to clarify the specific acts the technician must perform. The operational oscilloscope is used only in formal testing. (This handbook format is shown in appendix C.)

The learning principles and an explanation of their usage are presented in table 1. A learning algorithm showing how these seven guidelines are combined and sequenced in the Learning Aid format is diagramed in figure 2.

TABLE 1. PROCEDURE LEARNING GUIDELINES CARRIED OUT IN THE LEARNING AID

Learning Guidelines	How/Where Implemented in Handbook
1. State behavioral objectives so that they are relevant to student's future real-world assignments. Describe how the learning materials are organized to achieve the desired behavior.	Presented in "Introduction" under headings of "Learning Objectives," "Why Learn This Procedure," "Organization of Training Materials." (See page 74.)
2. Divide the procedural steps into small parts if students are of low ability, the procedures are complex, or the entire procedure is lengthy.	The procedure is divided into four sections: "Turn Power On," "Get a Trace," "Center the Trace," and "Tune the Probe." Each section contains three to seven individual steps.
3. Present a demonstration of each task performance on an observable model.	A visual demonstration of control positioning is presented for each step in the "Training" exercises and for all the steps combined in the "Demonstration" exercise. The "Step Sequence Drill" also serves as a demonstration. (See pages 77 to 92 and 93 to 95.)
4. Direct the student to practice the following:	
a. When presented with each checklist item (step), explain or perform its corresponding procedural action.	"Check Your Memory" exercises presented after each step carry out this guideline. These exercises present the step name and require the student to recall the action, equipment responses, and any special notes or cautions and to act out the procedural action on a large overview photo of the equipment control panel. (See page 90 and 101/102.)
b. When presented with a group of checklist items, explain or perform their corresponding procedural actions. The first item of each group should overlap the last item of the previously studied group of steps.	At the end of each "Training" section, the "Self-Test" provides a list of steps and requires the student to recall the action, equipment responses, etc., and to carry out the series of steps on the large overview control panel. In the "Step Sequence Drill," the first item of each group overlaps the last item of the previous group. (See pages 93 to 95 and 101/102.)

TABLE 1. PROCEDURE LEARNING GUIDELINES CARRIED OUT IN THE LEARNING AID (continued)

Learning Guidelines	How/Where Implemented in Handbook
c. When presented with a single list of all the checklist items (entire procedure), explain or perform their corresponding procedural actions.	The "Final Test" presents all checklist items and requires students to perform the same recall and act-out exercises as the "Self Tests" mentioned for the previous guideline. A final "Step Sequence Drill" is included to insure practice of the entire procedure. (See pages 96 to 101/102.)
5. Early in training use:	
a. Immediate and frequent knowledge of results (KOR).	An opportunity for KOR is provided after each step via the "Check Your Memory" exercises. After completing the exercise students are directed to immediately turn back to the page the step was presented on in order to check their answers. Answer pages and directions of how and when to use them are also provided for the "Self-Tests," "Final Test," and "Step Sequence Drills." (See pages 90, 95, and 97.)
b. Immediate and frequent reinforcement.	No overt reinforcement techniques are used. It is intended that reinforcement will occur when students receive knowledge of correct answers.
c. Little or no operational distractors.	This is accomplished by training with paper and pencil instead of the actual equipment. The learning exercises are highly controlled and present isolated information. The training is removed from the operational setting.
d. Guiding and prompting student responses.	Guides and prompts are provided in the "Check Your Memory" exercises, "Self-Tests" and "Final Test" in the form of key words like "action," "response." Visual prompts are provided in the form of arrows in the "Step Sequence Drill" to aid in recall of step locations. (See pages 90, 96, and 94.)

TABLE 1. PROCEDURE LEARNING GUIDELINES CARRIED OUT IN THE LEARNING AID (continued)

6. Identify features of the operational environment which could be used as mediators to trigger the student's recall of checklist items.	Critical equipment responses are identified for relevant steps in the "Training" sections. Photographs of the control dials serve as visual cues to aid in recall of control settings. (See page 91.)
7. Arrange for extensive repetition (overlearning) by the student to take advantage of the internal feedback properties generated by performing positioning movements accompanied by external feedback.	Acting-out on the overview used in the "Check Your Memory," "Step Sequence Drill," "Step-Tests," and "Final Test" provide extensive repetition and an initial level of proprioceptive cues that are intensified and transferred to the actual equipment in later stages of training. (See page 90.)

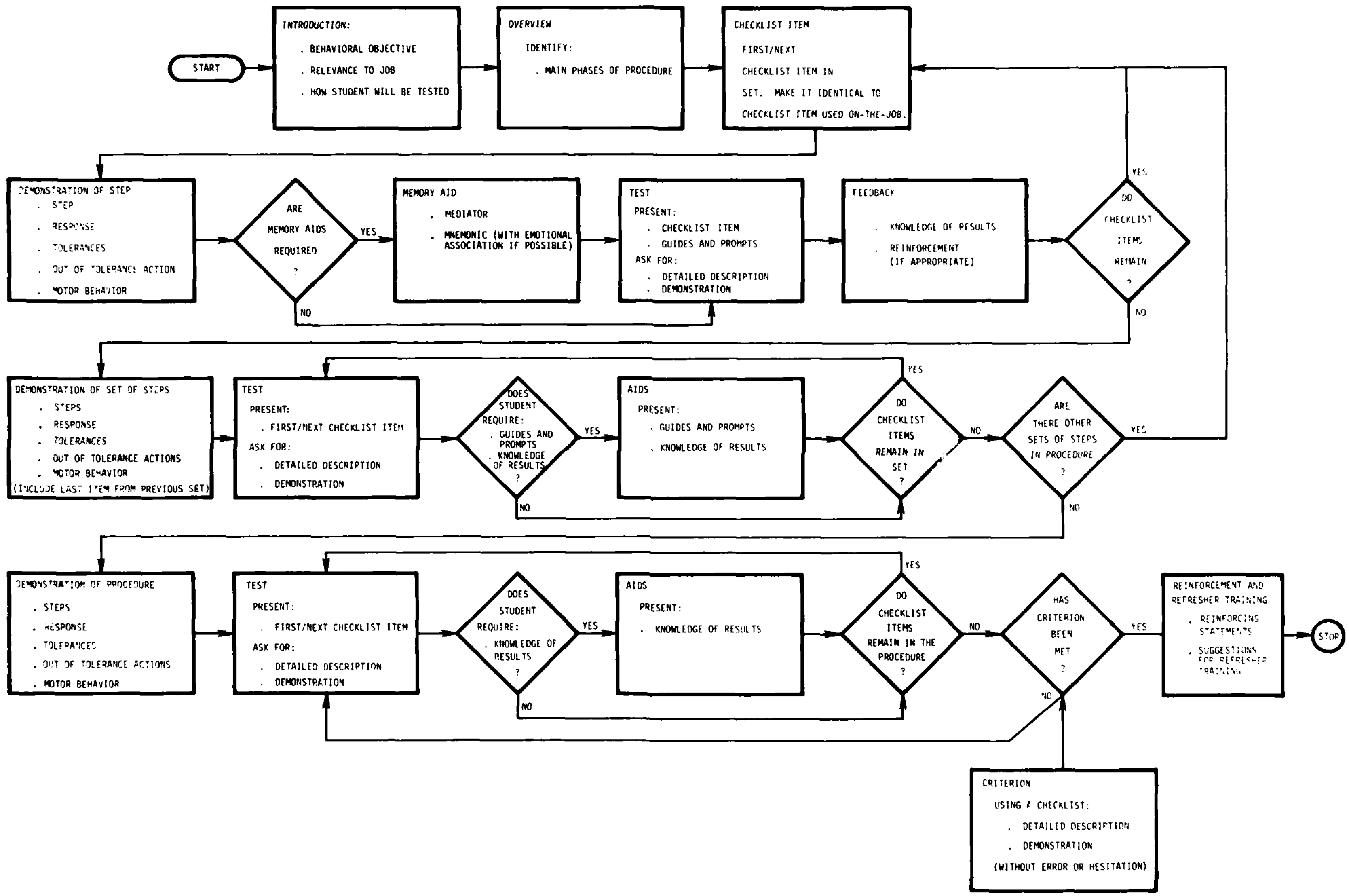


Figure 2. Learning Algorithm for Learning Aid

PROCEDURE

Students were individually scheduled for training and testing. As each arrived, he was told he would be participating in an evaluation of alternative instructional materials. (Instructions to the students are presented in appendix D.)

INITIAL STUDY PHASE. At the beginning of the first study session, students in each of the three training groups were told to study carefully their respective handbooks one time through. The amount of time it took each student to complete this task was recorded. At the end of this session, students were given a performance test which required that they carry out from memory on an actual oscilloscope the calibration procedure just studied. Measures of performance were: time to complete the task, accuracy of control settings, and correctness of step sequencing.

A multiple choice Job Knowledge Test was also administered to collect data on the amount of job related information the students learned from their respective study material. (Appendix E provides a copy of the Job Knowledge Test.)

PRACTICE PHASE. After the Initial Study Phase, each student was given a practice session. The amount of time a student was allowed during this phase was that which remained after subtracting the amount of time required to complete the initial study phase from the 90 minutes allotted for total training. In this session, subjects were told to re-study their training materials, paying particular attention to the steps they missed on the performance test. In both the initial study and practice sessions, the experimenter closely monitored the subjects--providing assistance if they had any problems and ensuring that the textbooks were used correctly. At the end of this phase, subjects were again required to perform the calibration procedure on the oscilloscope. Time to complete the task, control setting errors, and step sequence errors were again recorded.

RETENTION PHASE. When training was completed, the students were told that they would return in 1 week to take a short performance test. They were reminded not to mentally rehearse the procedure. Since the particular oscilloscope model used in the study was not available at the BE&E School, the students had no opportunity to practice on the equipment or study related technical manuals. At the beginning of the retention testing session, the students were given 2 minutes to look at the oscilloscope and familiarize themselves with the control panel. They were then asked to perform the calibration procedure. The same performance measures, time to complete task, control setting, and sequence errors, were again recorded.

SECTION III

RESULTS

The relative effectiveness of the three types of instructional material is discussed in this section. The outcomes are described in terms of performance errors, performance time, and scores on a job knowledge test.

PERFORMANCE ERRORS

The results clearly indicate the superiority of the Learning Aid format for teaching an equipment calibration procedure. Summaries of the statistical analyses employed are provided in appendix F. The groups using the Learning Aid performed the calibration procedure with significantly fewer errors than did the groups that used the Job Performance Aid or the Traditional Narrative Handbook. The use of the Traditional Narrative Handbook resulted in the poorest performance. Figure 3 shows the average errors for all trials made by students assigned to each training method.

Both lower and higher aptitude students performed best using the Learning Aid, and each aptitude group was least effective when using the Traditional Narrative Handbook. These relative performance levels were maintained during the three calibration trials; i.e., initial learning, after practice, and the retention test. The average number of errors on the three trials for each combination of aptitude level and training method is presented in figure 4.

The higher aptitude groups did better than lower aptitude groups with each type of instructional material. However, format influenced the lower aptitude students' performance to the extent that after they studied the Learning Aid they made fewer errors than did the higher aptitude students who studied the Traditional Narrative Handbook. Figure 4 graphically presents the differences in student performance, as a function of the formats, on the three calibration tests.

TIME TO PERFORM

Student aptitude and amount of practice significantly affected the amount of time it took to perform the calibration procedure. On the average, higher aptitude students performed the task faster than lower aptitude students. In addition, the amount of time it took students to perform the procedure decreased from the first performance test to the second and increased from the second performance test to the retention test. A summary of the statistical analysis of performance time is contained in appendix F.

JOB KNOWLEDGE TEST

Both student aptitude and instructional material signficantly affected performance on the Job Knowledge Test. As expected, students who used the Traditional Narrative Handbook made fewer errors than students who studied either the Learning Aid or Job Performance Aid. The latter effect is most likely due to the relationship between the method of presenting information to be learned and the form of testing the students' knowledge of that information. The Learning Aid and Job Performance Aid formats made extensive use

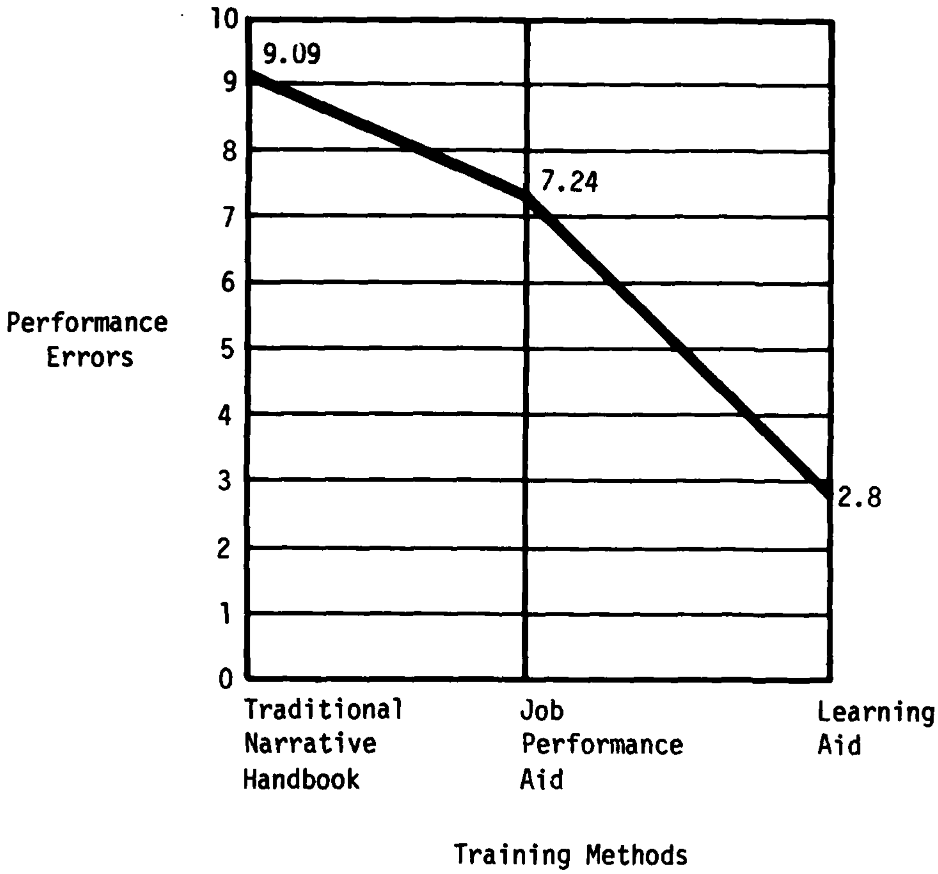
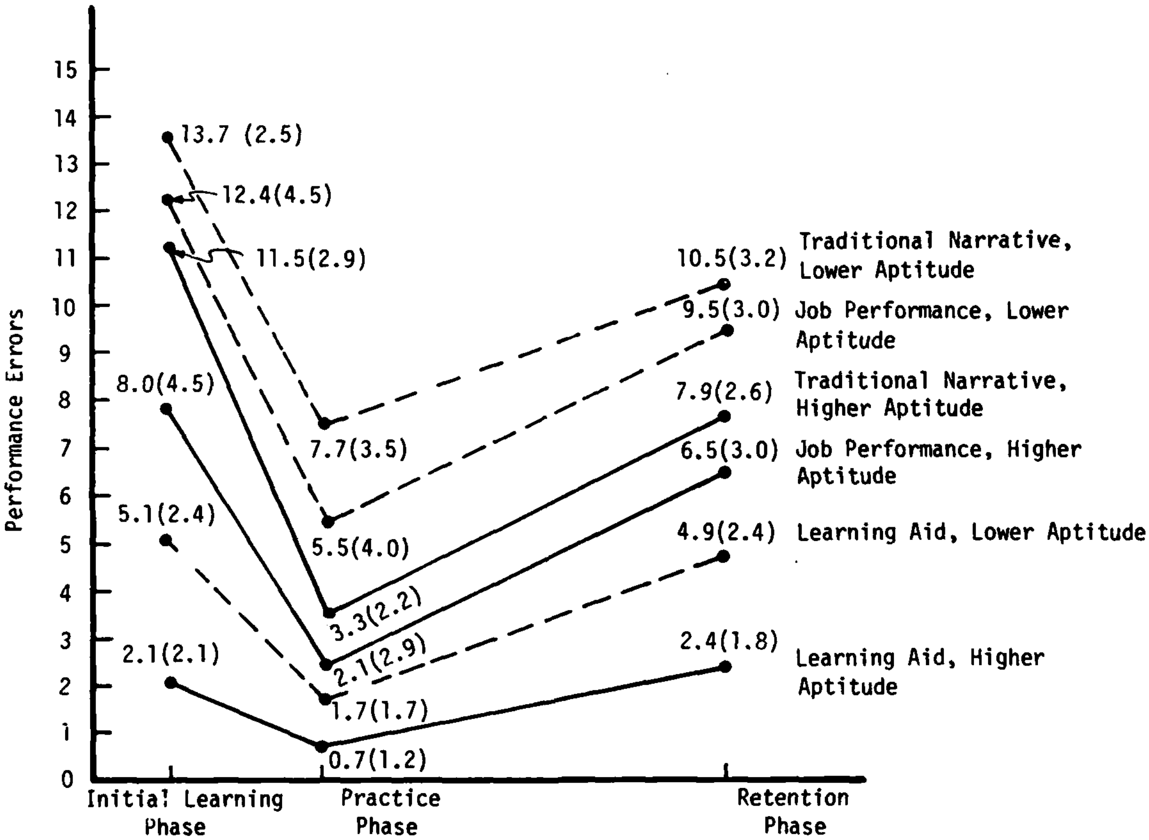


Figure 3. Average Number of Performance Errors on All Trials as a Function of Training Method



*Standard deviation is shown in parenthesis

Figure 4. Mean Errors per Phase as a Function of Training Method and Aptitude Level

of visual information while the Traditional Narrative Handbook relied heavily on verbal information. The Job Knowledge Test, of course, is oriented toward verbal information. Similarly, students of above average aptitude made fewer errors on the Job Knowledge Test than the below average aptitude students.

Table 2 presents the average Job Knowledge Test scores for each combination of aptitude level and type of instructional material. Lower aptitude groups averaged 61 percent correct items on the Traditional Narrative Handbook and the Learning Aid and 55 percent on the Job Performance Aid. Scores in this range are usually considered unsatisfactory. Even the average performance of higher aptitude students might be considered marginal in a criterion referenced test.

TABLE 2. PERCENT OF ITEMS CORRECT ON THE JOB KNOWLEDGE TEST

	Traditional Narrative Handbook	Job Performance Aid	Learning Aid
Higher Aptitude Students	86%	72%	74%
Lower Aptitude Students	61%	55%	61%
Average Scores	74%	64%	68%

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The Learning Aid format is superior to the Traditional Narrative Handbook and the Job Performance Aid for teaching procedures when the goal is to have students learn to accurately perform a procedure from memory. The Learning Aid format:

- is suited for use with students of either above average or below average aptitude
- results in superior learning and retention compared to the traditional methods after 1 week
- requires less hands-on equipment time than traditional methods to accomplish this type training task.

However, if the goal is to teach verbal information about a procedure, such as nomenclature and system theory as measured in classroom paper and pencil tests, none of the formats appear to be adequate.

RECOMMENDATIONS

Training materials designed to teach students to perform equipment operating and maintenance procedures from memory should be constructed according to the Learning Aid format. It is specifically recommended that:

- The CNET Instructional Program Development Centers should use Learning Aid type formats when the goal is to train beginning students to perform procedures from memory. These learning aids support the initial phase of learning and their use should be followed by hands-on practice.
- Training exercises in the Learning Aid should teach verbal information about the procedure if this information must be recalled by the students.
- The Naval Technical Information Presentation Program (NTIPP) should adopt the Learning Aid format as a standard for presenting proceduralized instructions when the goal of training is to have beginning students perform a procedure from memory. This format with its training exercises may be especially useful for onboard training materials.

Current success being experienced in using the learning guidelines in the <u>Interservice Procedures for Instructional Systems Development</u> as a guide in formatting information to teach procedures and symbols points to the desirability of continuing this effort for still other common types of job tasks. Immediate attention should be given to presenting information on systems theory and nomenclature, rule learning, classifying patterns, and tactical decision making.

REFERENCES

Aagard, J. and Braby, R. Learning Guidelines and Algorithms for Types of Training Objectives. TAEG Report No. 23. 1976. Training Analysis and Evaluation Group, Orlando, FL. (AD A023066)

Ainsworth, J. Symbol Learning in Navy Technical Training: An Evaluation of Strategies and Mnemonics. TAEG Report No. 66. 1979. Training Analysis and Evaluation Group, Orlando, FL. (AD A068041)

Booher, H. "Relative Comprehensibility of Pictorial Information and Printed Words in Proceduralized Instruction." Human Factors. 1975, 17(3), 266-277.

Braby, R. Computer-Aided Authoring of Instructional Materials. TAEG Technical Note 2-79. 1979. Training Analysis and Evaluation Group, Orlando, FL.

Braby, R., Parrish, W. P., Guitard, C. R., and Aagard, J. Computer-Aided Authoring of Programmed Instruction for Teaching Symbol Recognition. TAEG Report No. 58. 1978. Training Analysis and Evaluation Group, Orlando, FL. (AD A060143)

Guitard, C. R. Computer-Aided Authoring System (AUTHOR) User's Guide. TAEG Report No. 59. 1978. Training Analysis and Evaluation Group, Orlando, FL. (AD A059572)

Interservice Procedures for Instructional Systems Development, Phase III, Develop. NAVEDTRA 106A. 1 August 1975.

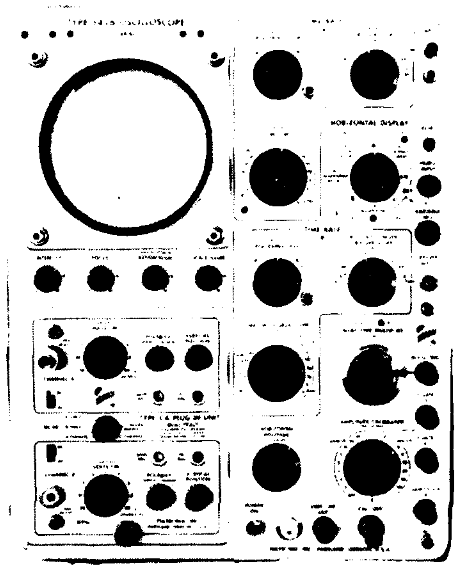
Study Booklet Student's Guide. Prepared for Basic Electricity and Electronics CANTRAC A-100-0010. July 1978. Prepared by Individualized Learning Development Group, Service School Command, NTC, San Diego, CA 92133, pp. 113-140.

APPENDIX A

TRADITIONAL NARRATIVE HANDBOOK

PROBE CALIBRATION PROCEDURE

Tektronix 545B Oscilloscope



TRADITIONAL

Anne M. Polino

Training Analysis and Evaluation Group

March 1979

OVERVIEW
LESSON I

Operation

In this lesson, you will study and learn about the names of the oscilloscope control knobs and what they do. You will also learn how to calibrate a 10X test probe used in conjunction with the oscilloscope.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

1. IDENTIFY the function and effect of the ON-OFF, Focus, Intensity, Scale Illumination, Astigmatism, Horizontal Position, Volts/Cm, Variable Volts/Cm, Vertical Position, AC/DC coupling, Amplitude Calibrator, Trigger Slope, Triggering Mode and Mode controls with respect to an oscilloscope presentation by matching the front panel controls to their functions and to their effects.

2. CALIBRATE a 10X probe, given an uncalibrated 10X probe and an oscilloscope.

3. IDENTIFY the steps in the procedure used to calibrate a 10X probe.

SUMMARY
LESSON I

Operation

The most versatile piece of test equipment available to the technician is the oscilloscope. The oscilloscope enables the technician to see what is actually taking place in a circuit by graphically displaying voltage amplitude, wave shape, phase, and frequency.

The basic controls and their functions are the same for most oscilloscopes, the only difference is the way they are named.

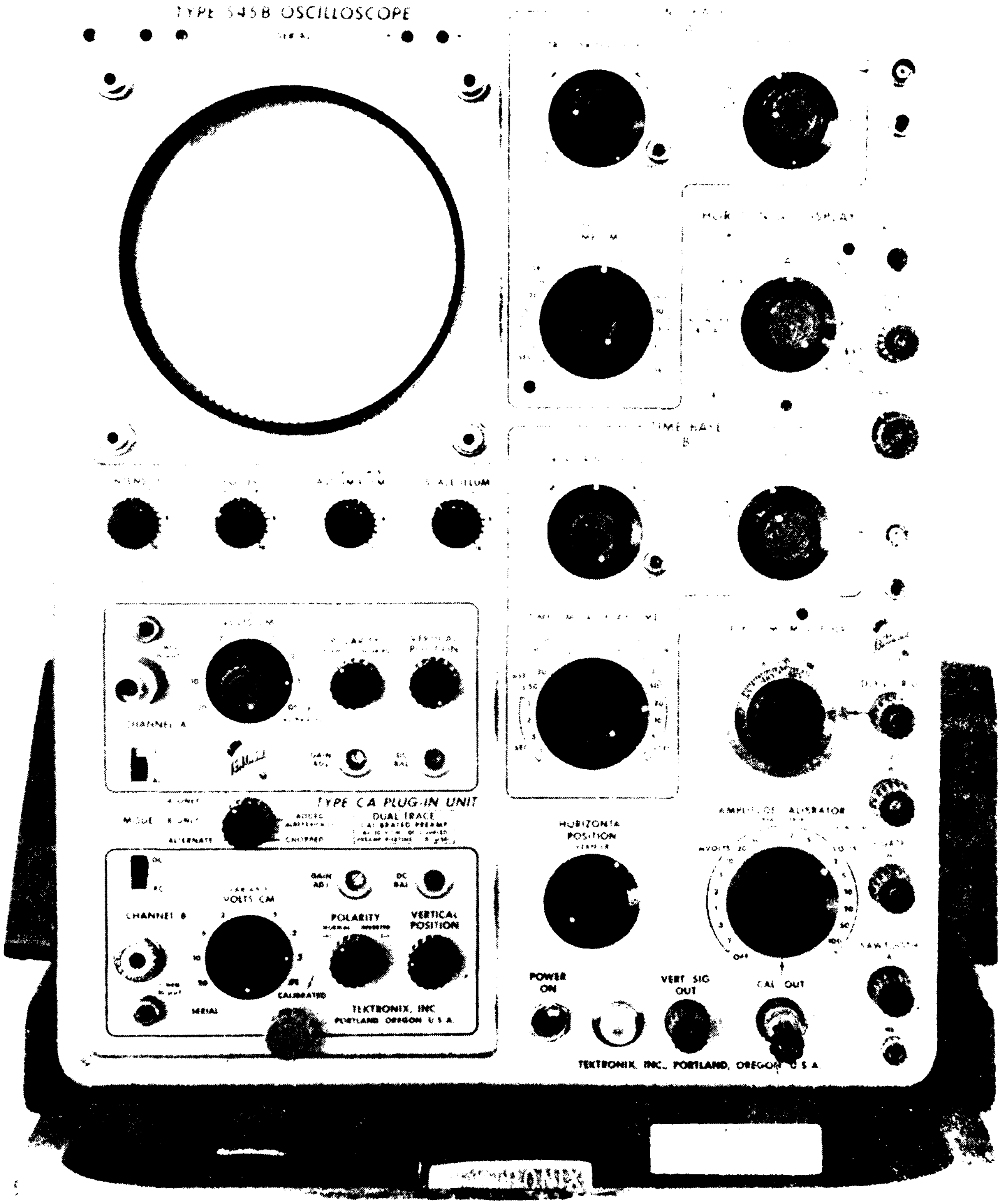

TYPE 545B OSCILLOSCOPE
TYPE CA PLUG-IN UNIT
DUAL TRACE
CHANNEL A
ALTERNATE
CHOPPED
CHANNEL B
VOLTS/CM
GAIN ADJ
POLARITY
VERTICAL POSITION
SERIAL
CALIBRATED
TEKTRONIX, INC
PORTLAND OREGON U.S.A.
HORIZONTAL POSITION
POWER ON
VERT SIG OUT
CAL OUT
TEKTRONIX, INC., PORTLAND, OREGON U.S.A.

Figure 1

The following is a brief list of the controls for the oscilloscope shown in Figure 1 and their functions.

On/Off (power) switch energizes the oscilloscope and controls all functions of the oscilloscope by controlling the power.

INTENSITY control varies the intensity of the line trace from very bright to so dim it can't be seen.

If you have a blurred or fuzzy line trace the FOCUS and ASTIGMATISM controls will remedy the problem. The FOCUS control varies the concentration of the electron beam to give a sharply defined trace. The ASTIGMATISM control varies the point at which the electron beam converges to improve trace definition.

The brightness of the graticule or scale on an oscilloscope is controlled by the SCALE ILLUMINATION control.

The horizontal controls consist of the HORIZONTAL DISPLAY, 5X MAGNIFIER, TIME/CM, VARIABLE TIME/CM, and the HORIZONTAL POSITION controls.

The HORIZONTAL DISPLAY selector determines what time base (A or B) will be used. It also determines what modes the time base will be used in.

The 5X MAGNIFIER switch, when set to the ON position, causes the horizontal portion of the display to be magnified five times wider than normal.

The TIME/CM control essentially govern the speed at which the sweep moves across the CRT scale.

The VARIABLE TIME/CM switch, when at "calibrated," serves to hold the value set by the TIME/CM selector constant so that the speed at which the sweep moves across the screen does not fluctuate.

The HORIZONTAL POSITION control does nothing more than move the sweep from left to right. It also has a course and fine tuning feature.

The vertical section is comprised of the VOLTS/CM, VARIABLE VOLTS/CM, AMPLITUDE CALIBRATOR, and the VERTICAL POSITION controls.

The VOLTS/CM selector states how many volts are represented by each centimeter on the vertical portion of the CRT scale. It essentially governs the size of the displayed waveform.

The VARIABLE VOLTS/CM, when set at "calibrated," keeps the value set by the VOLTS/CM selector constant so that the size of the displayed waveform does not fluctuate.

The AMPLITUDE CALIBRATOR determines the peak-to-peak voltage of the square wave available at the CAL OUT connector.

The VERTICAL POSITION control moves the presentation up and down on the screen.

In order to have a stable sweep the oscilloscope must be synchronized with a trigger.

The TRIGGER SLOPE control provides triggers from these places:

The INT position gives an internal trigger from the oscilloscope itself.

The EXT position makes provisions for connecting an external signal of your choice to the oscilloscope.

The LINE position provides a 60 Hz trigger to the oscilloscope.

The +/- for each source determines if the waveform will trigger on the positive or negative portion of a signal.

The TRIGGERING MODE determines what part of the triggering signal will start the sweep.

The MODE selector determines in what form the waveform will be displayed on the CRT.

The AC/DC coupling switch can be used to block out the DC portion of the input signal.

A method of connecting the signal being measured to the oscilloscope is needed. For this purpose a test probe is used, more notably a 10X probe. See Figure 2.

The 10X probe attenuates (decreases) the signal by a factor of 10; therefore, you must multiply by 10 to get a true voltage measurement. The 10X probe has an internal adjustable capacitor for impedance matching the probe to the oscilloscope. This matching is called calibration and must be checked daily.

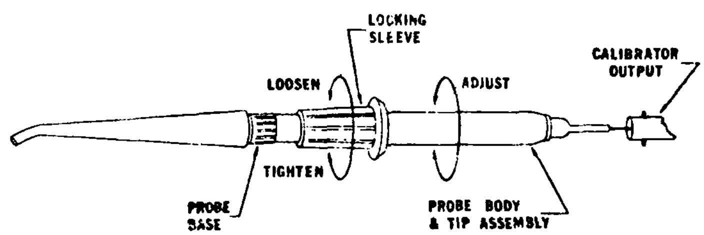


Figure 2

NARRATIVE
LESSON I

Operation

The most versatile piece of test equipment available to the technician is the oscilloscope. The oscilloscope enables the technician to graphically display voltage amplitude, shape, phase, and frequency of a waveform. All this means is, that you can see a picture of what is actually taking place in the circuit that is being checked. The oscilloscope, with the addition of various accessories, can do a number of other more advanced operations.

Let's find out how the oscilloscope does all of this.

The display screen is the front or "face" of a cathode ray tube, commonly abbreviated as CRT. In operation, there is a spot of light on this screen called the "trace spot." This trace spot is moved from left to right across the screen by electronic circuits in the oscilloscope called the "horizontal sweep circuits." The time it takes the trace spot to move from left to right across the screen can be varied. These changes are precisely calibrated so that the speed of horizontal movement represents an exact amount of time. If the trace spot is moved across the screen fast enough, it will appear to become a solid line. This line is commonly called a "line trace" or "sweep." The length of this line trace (maximum left to right movement) is pre-determined by internal circuitry. This line trace or sweep is the heart of the oscilloscope. Without the trace, it would be impossible to display anything on the oscilloscope.

The trace spot can also be deflected vertically. This deflection is created by the signal being measured. The size of the signal being displayed can be amplified or reduced so the signal may be more clearly observed and accurately measured. The capability to amplify or reduce the size of the signal is precisely calibrated so that a specific signal voltage will cause the trace spot to be deflected a specific distance on the face of the CRT.

Combining the vertical movement of the trace spot, caused by the signal being measured, with the left to right movement of the trace spot, caused by the internal horizontal sweep circuitry, will produce a graphic display. This display is commonly called the "waveform" of the signal. This graphic waveform is plotted against time in the horizontal axis, and amplitude in the vertical axis.

This is a very basic explanation of how an oscilloscope does what it does.

The oscilloscope you will be using is a "Tektronix 545B." With the exception of the physical placement of controls and control names, the information contained in this lesson can be applied to virtually any general oscilloscope.

Now let's discuss the basic controls of the oscilloscope. Each control on the oscilloscope has a definite affect on the waveform presented on the CRT. As the basic controls are discussed in this lesson, the control name used in this lesson will be on the oscilloscope you will be using, with other common names for the same control in parenthesis. In the job program following this lesson, you will get "hands on" experience operating the various controls.

ON/OFF

The most important control on the oscilloscope is the ON/OFF (POWER) switch. This switch is used to energize or turn the oscilloscope on. It controls every function of the oscilloscope, either directly or indirectly by virtue of controlling whether or not any power is applied to the oscilloscope.

INTENSITY

The INTENSITY control of the oscilloscope varies the intensity or brightness of the line trace. Normally turning the INTENSITY control in a clockwise direction will increase the intensity of the line trace and turning it counterclockwise will decrease the intensity. If turned completely counterclockwise often a point will be reached where the trace can no longer be seen. If you are using an oscilloscope and can't get a line trace, there is a good possibility that the INTENSITY control has been turned down.

FOCUS AND ASTIGMATISM

After the intensity is set to the desired level, you are going to want a sharp, clear, well defined line trace. If the line trace is blurred or fuzzy, there are two controls that remedy this problem. The FOCUS control varies the concentration of the electron beam to give a sharply defined trace, and the ASTIGMATISM control varies the point at which the electron beam converges to improve trace definition (clarity). Usually, the trace will be set at its clearest point with the FOCUS and ASTIGMATISM controls around a mid-range setting. The FOCUS, and ASTIGMATISM controls interact when being adjusted. This means that when you adjust one it might affect the other control, necessitating the re-adjustment of the other.

SCALE ILLUMINATION

Most oscilloscopes have a scale or graticule on the face of the CRT. The waveforms are plotted against this graticule to make voltage and frequency measurements. In order to see this graticule clearly it must be illuminated. The scale ILLUM. control varies the amount of light on the scale. Turning it counterclockwise will decrease the illumination and turning it clockwise will increase the illumination.

There are 5 basic horizontal controls consisting of the HORIZONTAL DISPLAY, 5X MAGNIFIER, TIME/CM, VARIABLE TIME/CM, and the HORIZONTAL POSITION controls.

HORIZONTAL DISPLAY

The HORIZONTAL DISPLAY selector determines how the time bases will be displayed on the CRT. In the "A" position it allows only TIME BASE A to appear on the CRT. In the "B" position only TIME BASE B will appear on the CRT. The other positions are delayed functions and single sweep functions.

5X MAGNIFIER

The 5X MAGNIFIER control, when activated, will multiply the horizontal sweep by a preset factor. On the oscilloscope you will be using this factor is 5 times. On other oscilloscopes this factor could be anywhere from 5-100 times. This function allows a waveform viewed on the oscilloscope to be magnified to a point that only a very small portion of the original signal covers the entire horizontal axis of the CRT.

TIME/CM

The TIME/CM switch will determine the frequency (speed) that the trace spot moves across the CRT. As you decrease the time per centimeter with the TIME/CM switch, the trace spot moves faster and becomes a solid line or line trace. If you increase the time per centimeter with the TIME/CM switch, the trace spot moves across the face of the CRT more slowly. The TIME/CM switch is usually calibrated in seconds, milliseconds, and microseconds. Each position will represent a preset amount of time it takes the line trace to move one division of the graticule from left to right. A crowded presentation can be spread out by decreasing the TIME/CM. A presentation that expands beyond the limits of the CRT can be contracted for easier viewing by increasing the TIME/CM.

VARIABLE TIME/CM

The VARIABLE TIME/CM, when in the "calibrated" position, serves to keep the sweep rate value set by the TIME/CM selector constant. If the switch is in the "uncalibrated" position, the sweep rate specified by the TIME/CM switch can be slowed by a factor of at least 2.5X. When the switch is in the "uncalibrated" position a lamp comes on to let you know.

HORIZONTAL POSITION

Suppose, that while using the oscilloscope, you find the presentation is positioned to the left of the center of the CRT. The position can be changed by simply adjusting the HORIZONTAL POSITION control in a clockwise direction until the presentation is centered on the CRT. Counterclockwise movement of the HORIZONTAL POSITION control moves the trace to the left. The HORIZONTAL POSITION control governs only the horizontal movement of the line trace. This particular control also has a course tuning (outer black knob) and a fine tuning (inner red knob) feature.

VOLTS/CM

Now that the horizontal controls have been covered, let's discuss the vertical controls. The VOLTS/CM control adjusts the vertical amplitude of the signal viewed on the CRT. The VOLTS/CM switch is a rotary switch with preset volts per centimeter divisions. It is usually calibrated in seconds, milliseconds, and microseconds. If your signal is too small vertically to be seen clearly, turning the VOLTS/CM switch clockwise will increase its size. If the vertical signal is too large to see the entire signal on the CRT, turn the VOLTS/CM switch counterclockwise to decrease the size of the signal.

VARIABLE VOLTS/CM

The VARIABLE VOLTS/CM control works much in the same way the VARIABLE TIME/CM switch does. If in the "calibrated" position, the value set by the VOLTS/CM will remain constant. If in the "uncalibrated" position, the vertical amplitude of the displayed waveform can be varied.

VERTICAL POSITION

Suppose the vertical position of the trace were such that you couldn't see the entire signal. To remedy this situation, there is a control called the VERTICAL POSITION control. This control moves the trace position up and down on the CRT. Turning the control clockwise will move the trace up and turning it counter-clockwise will move it down.

AC/DC

The AC/DC switch determines what type of coupling is used on the input to the vertical section. In the DC position, the vertical input is directly coupled allowing a DC signal to be passed to the vertical section. When viewed on the face of the CRT, a DC signal is an upward or downward shift of the trace. An upward shift indicates a positive voltage and a downward shift indicates a negative voltage. In Figure 3, with no signal input, the trace will be at the other line of the graticule. With a +20 volt DC signal input, the trace will shift upward to a point equivalent to +20 volts.

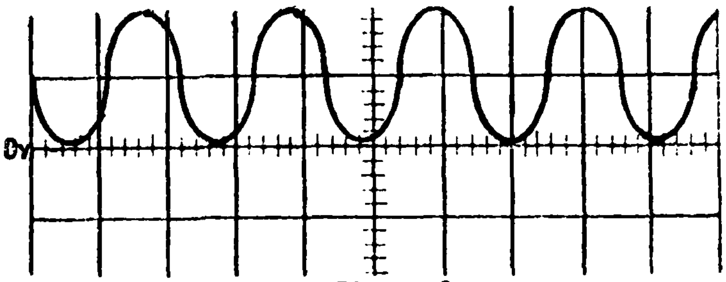


Figure 3

If you have an AC signal superimposed on a DC signal, the whole signal will shift along with the DC voltage as shown in Figure 4.

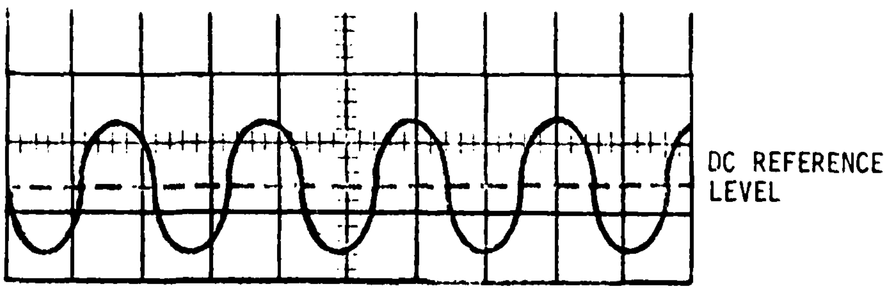


Figure 4

In the AC position, the input is capacitively coupled blocking all DC to the vertical section. With the AC switch in this position, there is no shift in the trace even with a DC signal present. The signal viewed will remain on the center line of the scale.

TRIGGER SLOPE

Normally, there are 3 sources available for use as synchronizing signals. The TRIGGER SLOPE control determines which of these signals is being used.

INT

Selecting the INT position applies an internally generated signal to the sweep to be used to synchronize the waveform.

EXT

The EXT position allows an external signal to be applied to the sweep. This external signal can be from whatever source provides the correct frequency and type of signal necessary to synchronize the sweep. Normally this external signal comes from the equipment being tested.

LINE

The LINE position provides a synchronizing signal of 60 Hz. This signal is used with input signals of 60 Hz or any harmonic (multiple) of 60 Hz (120 Hz, 240 Hz).

The + and - for each source determines on which portion of the signal, + or -, the waveform will begin.

TRIGGERING MODE

The TRIGGERING MODE control determines what part of the triggering signal will start the waveform display.

AUTO

Permits normal triggering on simple waveforms with repetition rates higher than about 50 Hz with no trigger signal. At a lower repetition rate the trigger circuit free runs at approximately 40 Hz and triggers the time base at this rate, providing a reference trace.

AC LF REF (Time Base A only) attenuates trigger signal frequencies below about 30 kHz, decreasing their effect upon the trigger circuit.

AC

Blocks the DC component of the triggering signal and allows triggering to take place only on the changing portion of the signal. For best triggering at high frequencies use an AC coupling position.

DC

Permits triggering on both high and low frequency signals. For signals below 30 Hz use the DC position.

AMPLITUDE CALIBRATOR

The AMPLITUDE CALIBRATOR sets-up the peak-to-peak voltage of the square wave that is available at the oscilloscope CAL OUT connector.

MODE

The MODE selector switch determines how the signal will be displayed on the CRT. For instance, by selecting A ONLY it tells the equipment to only display the waveform set-up from TIME BASE A.

JOB PROGRAM
LESSON I

Operation

Introduction

The oscilloscope is a rugged piece of equipment. Aside from mechanical damage (dropping, forcing controls and other abuses) an oscilloscope is subject to "burning" the screen (explained in the text). The oscilloscope will accept input voltage to a maximum of 600 volts peak without damage.

This job program is designed to give you "hands on" experience in using the oscilloscope. Don't be afraid to experiment with the controls, just keep in mind to experiment carefully.

Very high voltages exist inside the case of oscilloscopes. DO NOT REMOVE THE COVERS.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

1. CALIBRATE a 10X probe, given an uncalibrated 10X probe and oscilloscope.

2. IDENTIFY the steps in the procedure used to calibrate a 10X probe.

EQUIPMENT AND MATERIAL

1. Oscilloscope
2. BNC cable
3. Probe

PROCEDURE

In the first part of this section, you will learn how to energize the oscilloscope and what the CRT controls do. In Lesson 1, you learned the basic controls associated with an oscilloscope. In this job program you will encounter controls found in a more complex oscilloscope. These new controls will be discussed as they are encountered in the job program. Perform the following steps on the Tektronix 545B oscilloscope.

1. Make sure power is OFF by pushing switch down. The power must be off so that the oscilloscope is not damaged when it is plugged-in.

2. Attach power cords in the back of the oscilloscope and to the wall outlet.

3. Set the CRT controls (the horizontal row of four knobs located beneath the CRT).

    a. INTENSITY midrange
    b. FOCUS midrange
    c. SCALE ILLUM. midrange

CAUTION: The screen can be "burned" producing a dark, dead spot on the screen. "Burning" is a result of having the trace spot in the same position for a period of time with the INTENSITY turned up.

To prevent "burning" the screen, follow these rules:

a. Ensure the INTENSITY control is not beyond the midrange.
b. Turn the INTENSITY control clockwise only enough so that the trace can be easily seen.

4. Energize the oscilloscope by pushing the POWER switch up. When this is done the light to the right of the switch, and the ventilation fan comes on.

5. Set the MODE selector switch (located at the center of the Type CA Plug-in Unit) to A ONLY.

The next group of controls you will set are the Time Base A TRIGGERING MODE and TRIGGER SLOPE. These controls determine when the trace will begin to sweep across the screen. This action is accomplished by "holding" the trace spot at the left side of the screen until it is told to "go" by a starting signal called a trigger.

6. Set the Time Base A TRIGGERING MODE switch (inner red knob) to AUTO by turning the knob completely counterclockwise until it stops. The AUTO mode electronically sets the trigger level near zero, eliminating the need to set the TRIGGER LEVEL control that is located just left of the TRIGGERING MODE and TRIGGER SLOPE knobs.

7. Set TRIGGER SLOPE switch (outer black knob) to +INT. This control determines the source of the starting trigger. It tells the oscilloscope that the signal will be generated from its own circuitry (INT means internal). The "+" tells the oscilloscope to start the trace on the positive going portion of the triggering signal.

The next group of knobs you will set are horizontal sweep controls.

8. Set the HORIZONTAL DISPLAY switch (outer black knob) to A. When you do this a trace should be visible on the CRT.

9. Set the 5X MAGNIFIER switch (inner red knob on the Horizontal Display control) to OFF by turning it completely counterclockwise.

10. Set the Time Base A TIME/CM switch (outer black knob) located to the left of the Horizontal Display control, to .5 mSEC.

Now let's do some figuring. The time per centimeter switch (TIME/CM) is in the .5 mSEC position. How long will it take the trace spot to move one centimeter on the screen?

(Ans.) .5 milliseconds

How long will it take to sweep from the left to the right side of the scale?

(Ans.) .5 mSEC x 10 centimeters = 5 milliseconds

If you set the TIME/CM switch to 50 mSEC how long would it take the trace spot to sweep from the left side to the right side of the scale?

(Ans.) 50 milliseconds x 10 centimeters = 500 milliseconds or .5 seconds

11. Set the VARIABLE TIME/CM switch (inner red knob) to CALIBRATED by turning it clockwise until it clicks and the light goes out. The VARIABLE control allows you to slow the sweep speed set by the TIME/CM selector by a factor of 2.5X. However, when it is in the CALIBRATED position the sweep rate set by the TIME/CM knob will remain constant.

12. Illuminate scale on display surface by turning the SCALE ILLUM. Knob, located just below the CRT, fully clockwise. Note the change in the scale brightness as you turn the control.

13. Adjust the HORIZONTAL POSITION knob located above the POWER ON switch until the edge of the trace touches the left graticule of the screen scale.

14. Adjust the VERTICAL POSITION knob, located on the CHANNEL A portion of the Type CA Plug-in Unit, until the trace line is centered on the CRT scale.

15. Adjust the FOCUS and ASTIGMATISM controls. If you rotate the FOCUS control fully counterclockwise and then fully clockwise the trace will become larger and "fuzzier" as you move the control away from its center position. Leave the FOCUS control at its fully clockwise position. If you rotate the ASTIGMATISM control fully counterclockwise and then fully clockwise controls "interact" which means when you turn the FOCUS control the thickness of the trace may be affected, and when the ASTIGMATISM control is turned the sharpness may be affected. To compensate for this action, it may be necessary to adjust one control and then the other several times to get the trace set up properly.

16. Lock the probe line onto the CHANNEL A INPUT connector located below the INTENSITY knob.

17. Set CHANNEL A AC/DC switch (located just below the CHANNEL A INPUT connector) to AC. When this switch is in the AC position the input signal goes through a capacitor which will block any DC voltage present on the signal. If you are not specifically concerned with DC voltage, it is usually better to use the AC position.

Next you will set the various vertical controls.

18. Set the CHANNEL A VOLTS/CM switch to .1 volts and its VARIABLE control to "CALIBRATED" (fully clockwise).

Multiply the number of centimeters by the VOLTS/CM selector setting. Your answer is the peak-to-peak voltage of the waveform.

19. Set the AMPLITUDE CALIBRATOR (located to the right of the HORIZONTAL POSITION control) to 2 volts.

20. Insert the probe tip into the CAL OUT connector located just below the

AMPLITUDE CALIBRATOR and look at the waveform displayed on the CRT. The waveform will have a negative and a positive peak exactly 2 centimeters apart, and, if the probe is calibrated, the peaks will be absolutely flat. See Figure 5.

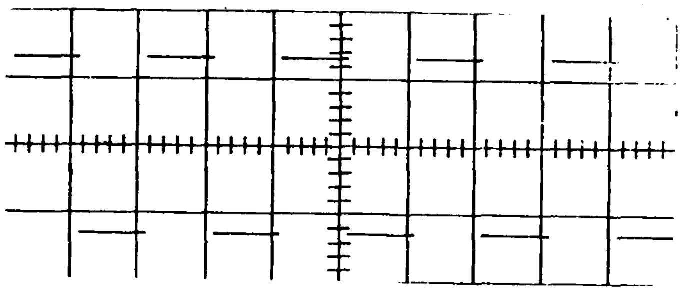


Figure 5

If the probe is over-corrected the sweep will have peaks on the leading edge. See Figure 6.

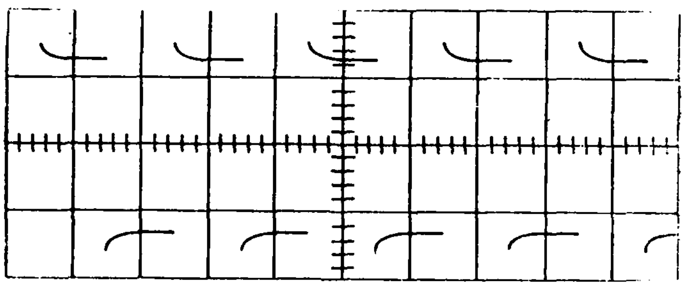


Figure 6

If the probe is under-corrected the leading will be rounded. See Figure 7.

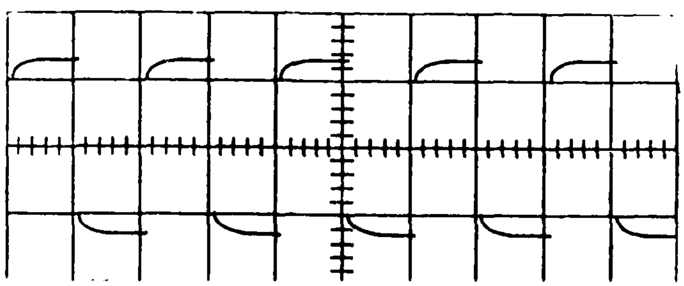


Figure 7

To calibrate the probe, hold the adjusting collar with the right hand, loosen the locking sleeve about one quarter turn with the left hand. While watching the trace on the CRT, turn the adjusting collar until the peaks are absolutely flat. Now, slowly turn the locking sleeve until it is "finger-tight". Look at the waveform to ensure the trace on the CRT hasn't changed while locking the probe. See Figure 8.

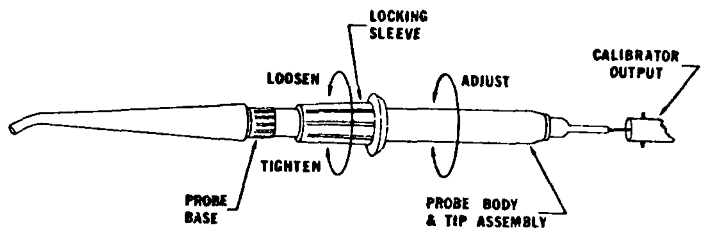


Figure 8

PROGRESS CHECK
LESSON I

Answer all the questions in this section and check your responses with the answer sheet on page 42. If you incorrectly answered a few of the progress check questions, the correct answer page will refer you to the appropriate pages so you can restudy the parts of this lesson you are having difficulty with.

1. An oscilloscope lets you see what is taking place in a circuit by

   a. x-raying the circuit under test and producing a photographic display of the signal.
   b. graphically displaying voltage amplitude, wave shape, phase and frequency of a waveform.
   c. graphically displaying circuit current and resistance.
   d. analyzing the input and output of the circuit and producing a photograph of the circuit action.

2. The ON/OFF switch

   a. varies the brightness of the sweep.
   b. turns power on or off.
   c. varies the illumination of the graph on the CRT face.
   d. horizontally positions the trace.

3. The FOCUS control

   a. varies the point where the electron beam converges.
   b. varies the brightness of the sweep.
   c. varies the concentration of the electron beam.
   d. moves the sweep up and down.

4. The INTENSITY control

   a. varies the brightness of the sweep
   b. turns the power on or off.
   c. illuminates the graph on the CRT face.
   d. varies the concentration of the electron beam.

5. The SCALE ILLUM. control

   a. turns the power on or off.
   b. varies the brightness of the sweep.
   c. adjusts the oscilloscope for a stable presentation.
   d. varies the illumination on the graph on the CRT face.

6. The ASTIGMATISM control

   a. varies the concentration of the electron beam.
   b. turns the power on or off.
   c. varies the point where the electron beam converges.
   d. magnifies the horizontal sweep by a preset factor.

7. The HORIZONTAL DISPLAY control

   a. magnifies the horizontal sweep by a preset factor.
   b. determines how the time bases will be displayed on the CRT.
   c. lengthens or shortens the sweep with respect to time.
   d. determines the point at which the sweep triggers.

8. The 5X MAGNIFIER control

   a. magnifies the horizontal sweep by a preset factor
   b. moves the entire sweep horizontally.
   c. varies the amplitude of the vertical signal displayed.
   d. changes the coupling of the vertical input signal.

9. The TIME/CM control

   a. moves the entire sweep horizontally.
   b. magnifies the horizontal sweep by a preset factor.
   c. picks the source of the trigger signal for synchronization.
   d. lengthens or shortens the sweep with respect to time.

10. The HORIZONTAL POSITION control

    a. moves the entire sweep up or down.
    b. moves the entire sweep horizontally.
    c. determines the point at which the sweep is triggered.
    d. magnifies the sweep by a preset factor.

11. The VOLTS/CM control

    a. moves the entire sweep up or down.
    b. varies the amplitude of the vertical signal displayed.
    c. lengthens or shortens the sweep with respect to time.
    d. moves the entire sweep horizontally.

12. The VERTICAL POSITION control

    a. moves the entire sweep horizontally.
    b. varies the amplitude of the vertical signal displayed.
    c. moves the entire sweep up or down.
    d. magnifies the horizontal sweep by a preset factor.

13. The AMPLITUDE CALIBRATOR control

    a. varies the amplitude of the vertical signal displayed.
    b. determines the amplitude of the square wave at the CAL OUT connector.
    c. determines the amplitude of the triggering signal.
    d. moves the entire sweep up or down.

14. The AC/DC control

    a. changes the coupling of the vertical input signal.
    b. adjusts the oscilloscope for a stable presentation.
    c. determines at what point the sweep triggers.
    d. picks the source of the trigger signal for synchronization.

Progress Check | Lesson I

15. THE TRIGGER SLOPE control

 a. determines the point at which the sweep is triggered.
 b. adjusts the oscilloscope for a stable presentation.
 c. determines at what point the sweep triggers.
 d. picks the source of the trigger signal for synchronization.

16. The TRIGGERING MODE control

 a. picks the source of the trigger signal.
 b. determines the point at which the sweep triggers.
 c. changes the coupling of the vertical signal.
 d. lengthens or shortens the sweep with respect to time.

17. The VARIABLE TIME/CM control

 a. adjusts the oscilloscope for a stable presentation.
 b. picks the source of the trigger signal for synchronization.
 c. when calibrated, holds the sweep speed constant.
 d. lengthens or shortens the sweep with respect to time.

THE FOLLOWING LIST IS TO BE USED TO ANSWER QUESTIONS 18-22

1. ON/OFF
2. FOCUS
3. INTENSITY
4. SCALE ILLUMINATION
5. ASTIGMATISM
6. HORIZONTAL DISPLAY
7. TIME/CM
8. VARIABLE TIME/CM
9. HORIZONTAL POSITION
10. VOLTS/CM
11. VARIABLE VOLTS/CM
12. VERTICAL POSITION
13. AMPLITUDE CALIBRATOR
14. AC/DC
15. MODE
16. TRIGGER SLOPE
17. TRIGGERING MODE
18. 5X MAGNIFIER

18. If you have an oscilloscope with a blank screen, the problem could be caused by which controls?

 a. 1, 3, 9, 12
 b. 1, 4, 8, 10
 c. 1, 3, 7, 10
 d. 1, 3, 5, 11

19. What controls will cause a blurred presentation on the CRT?

a. 2, 3
b. 2, 5
c. 2, 7
d. 1, 5

20. If the grid on the CRT is not illuminated, the misadjusted control is

a. 2
b. 8
c. 4
d. 3

21. A vertical signal that extends beyond the limits of the CRT can be corrected by using the ______________control.

a. 12
b. 15
c. 9
d. 10

22. A 10:1 probe attenuates the voltage of a measured signal by a factor of:

a. 5
b. 1
c. 100
d. 10

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON I

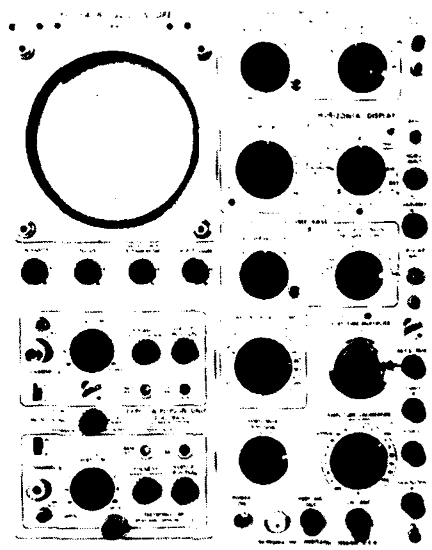
QUESTION NO.	CORRECT ANSWER	REFERENCE PAGES
1.	b	6
2.	b	7
3.	c	7
4.	a	7
5.	d	7
6.	c	7
7.	b	7
8.	a	8
9.	d	8
10.	b	8
11.	b	8
12.	c	9
13.	b	11
14.	a	9
15.	d	10
16.	b	10
17.	c	9
18.	a	7, 8, 9
19.	b	7
20.	c	7
21.	d	8
22.	d	5

APPENDIX B

JOB PERFORMANCE AID

PROBE CALIBRATION PROCEDURE

Tektronix 545B Oscilloscope



JOB AID

Anne M. Polino

Training Analysis and Evaluation Group

March 1979

INTRODUCTION

Learning Objectives	When you complete this lesson you will be able to: 1. Set-up a square wave on an oscilloscope 2. Calibrate a 10X probe
Testing	A test will be given on a Tektronix 545B oscilloscope to see if you know how to calibrate a probe.
Why learn This Procedure	The oscilloscope is used to test circuits, study waveforms, measure voltage and current, and test amplifier responses. A properly calibrated probe is necessary for accurate measurement.
Additional Resources Required	Tektronix 545B oscilloscope and power supply, BNC cable, and a 10X probe.

OVERVIEW

Directions: 1. Look at the large overview photo on the next page. Notice that the oscilloscope is divided into 5 functional sections. Listed below are the sections and the general functions each is responsible for.

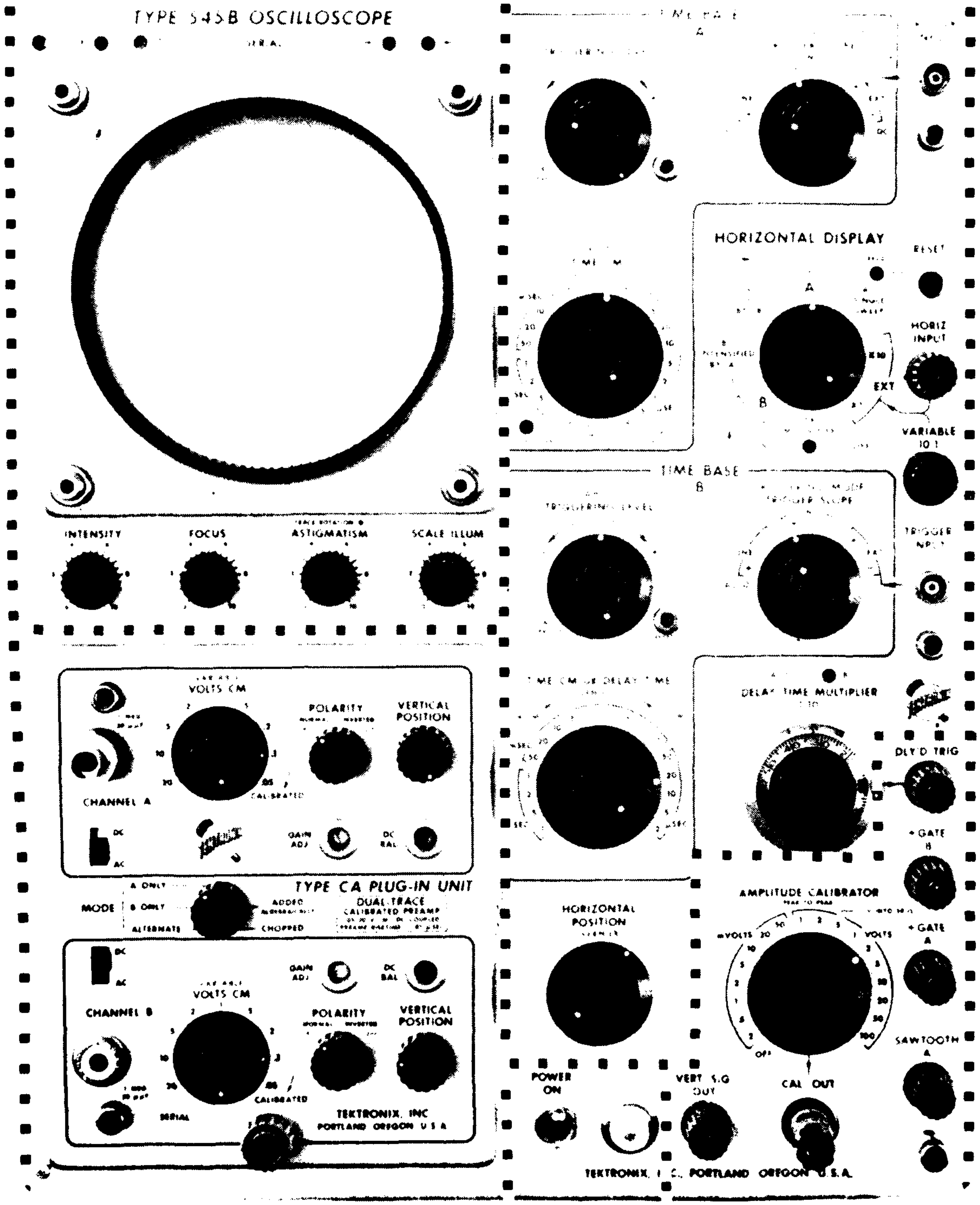
Sections	Functions
Power	on/off power controls
Horizontal controls	determines the width and horizontal positioning of a displayed signal.
Vertical controls	determines the height and vertical positioning of a displayed signal.
Calibration and Output	has output jacks which can be used to drive and synchronize other equipment
Display	presents a picture of the test signal

2. The probe calibration procedure requires that the controls in these sections be set in a certain way. The following pages will show you how to do this.

3. Carefully study each step and remember the setting and sequence for all the steps.

DISPLAY

HORIZONTAL CONTROLS

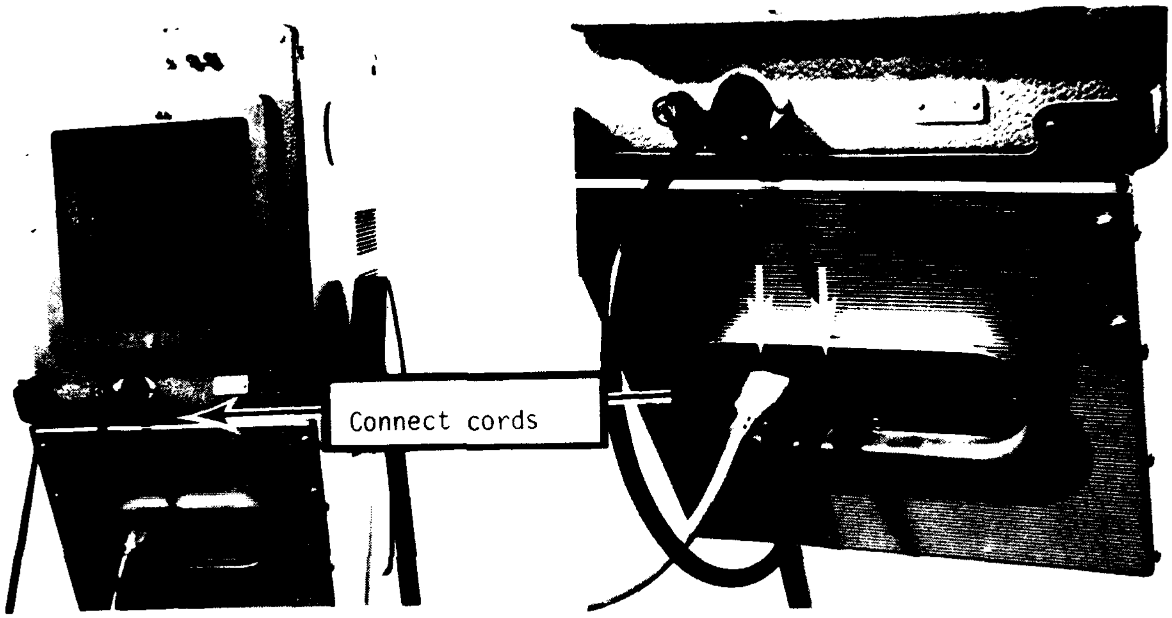


VERTICAL CONTROLS

POWER

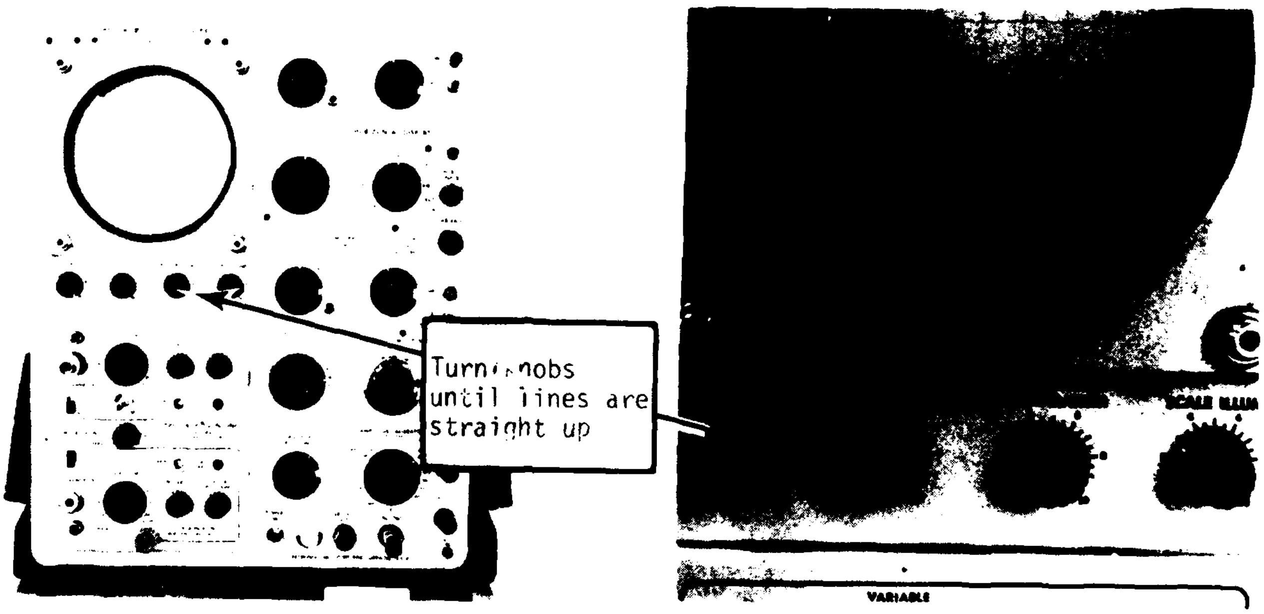
CALIBRATION and OUTPUT

Step 1: Attach power cords

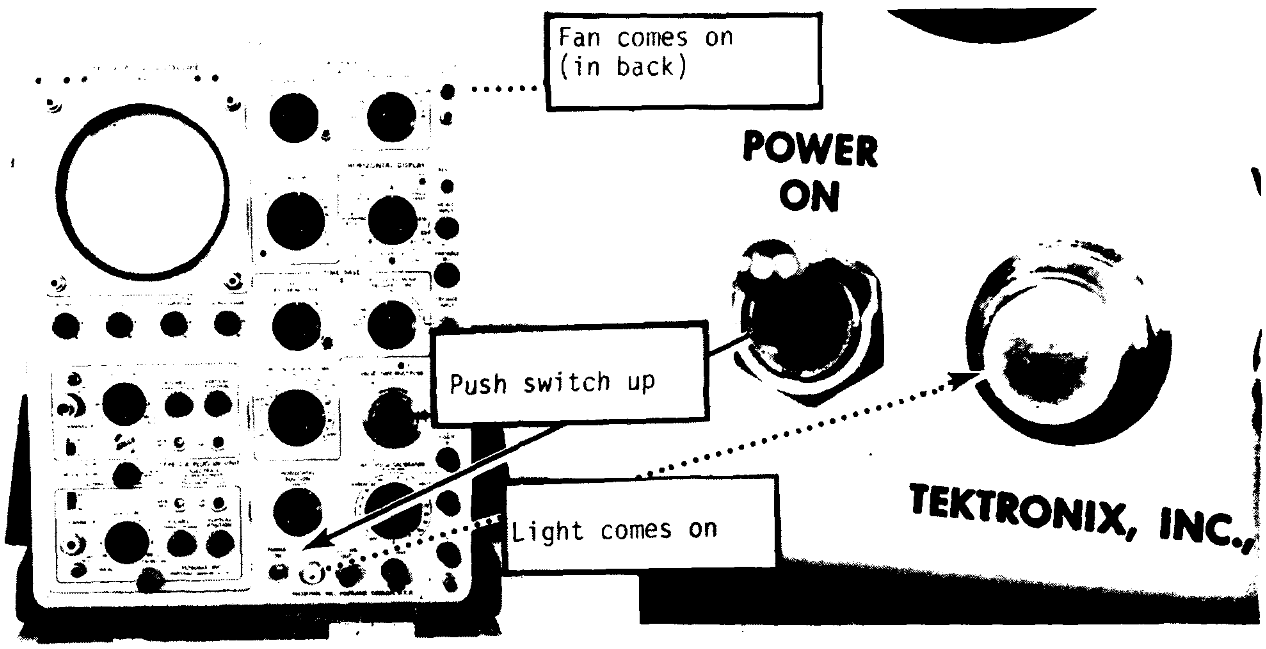


DEMONSTRATION

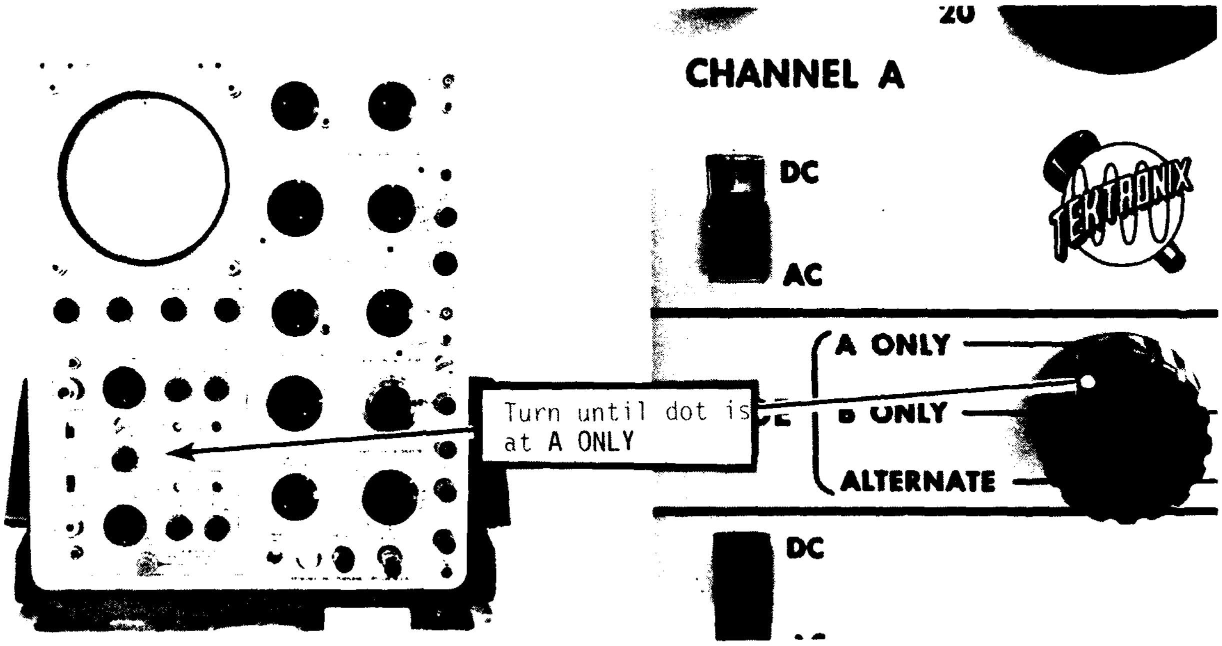
Step 2: Set INTENSITY, FOCUS, and SCALE ILLUM. knobs to midrange.



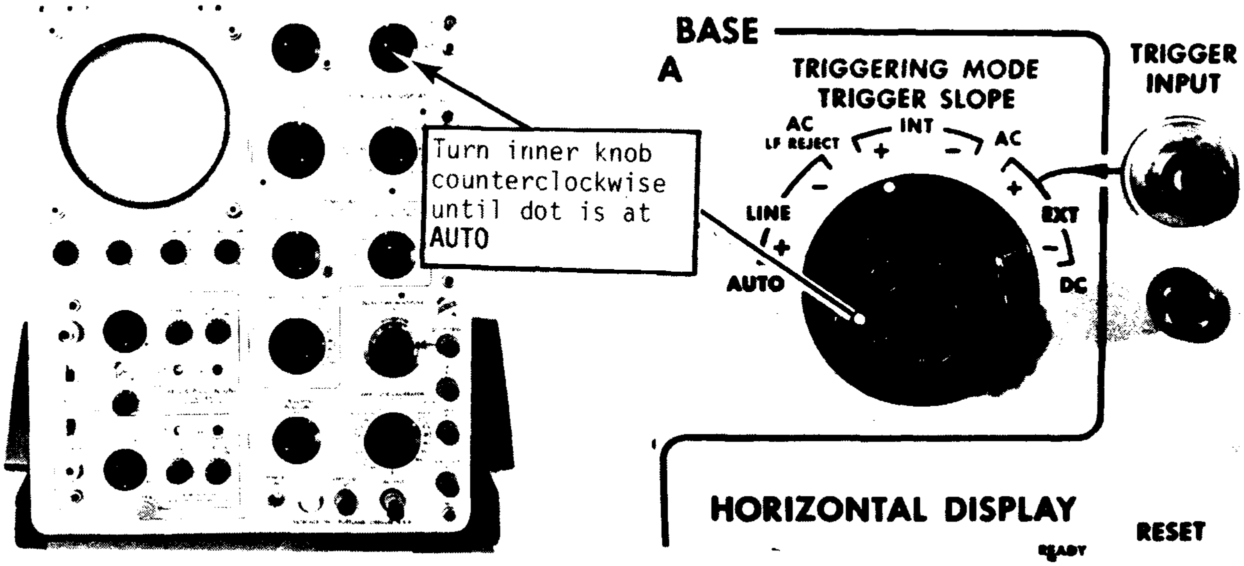
Step 3: Turn power ON.



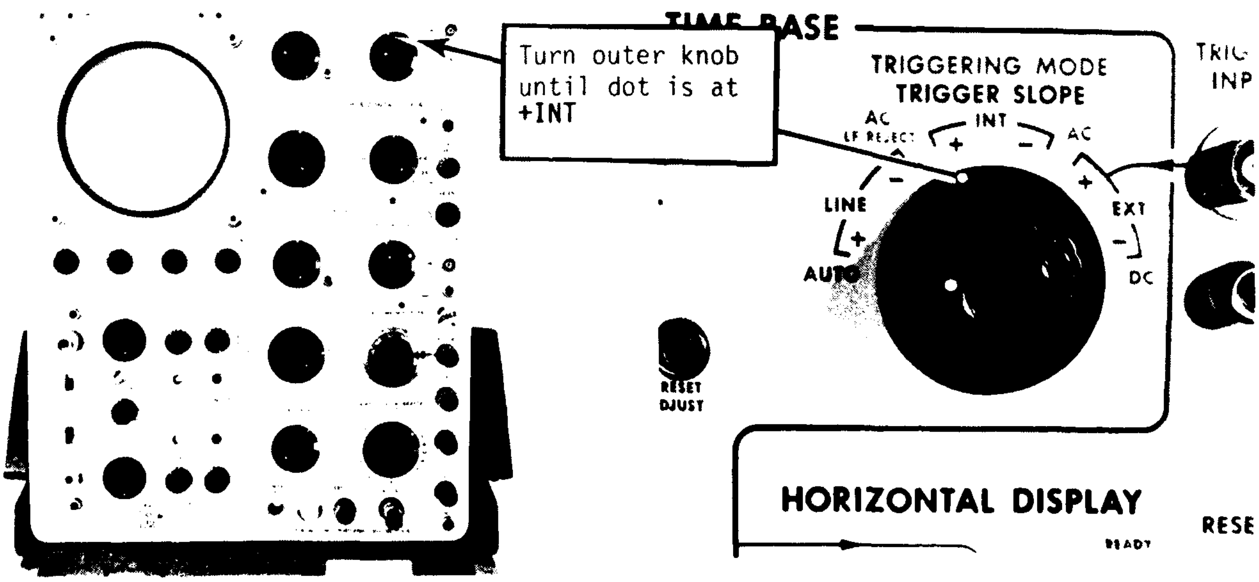
Step 4: Set MODE selector switch to A ONLY



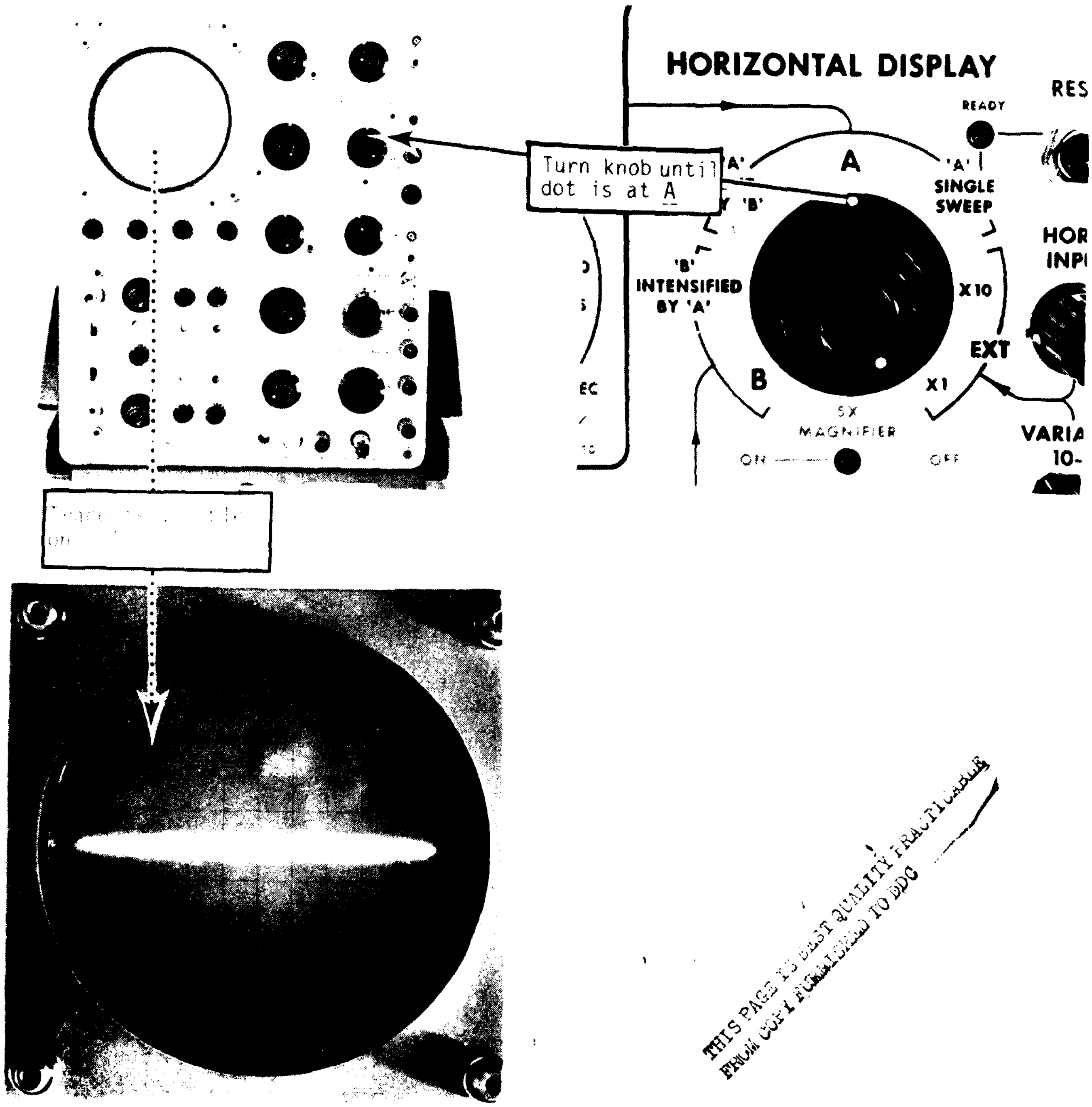
Step 5: Set time base A TRIGGERING MODE to AUTO



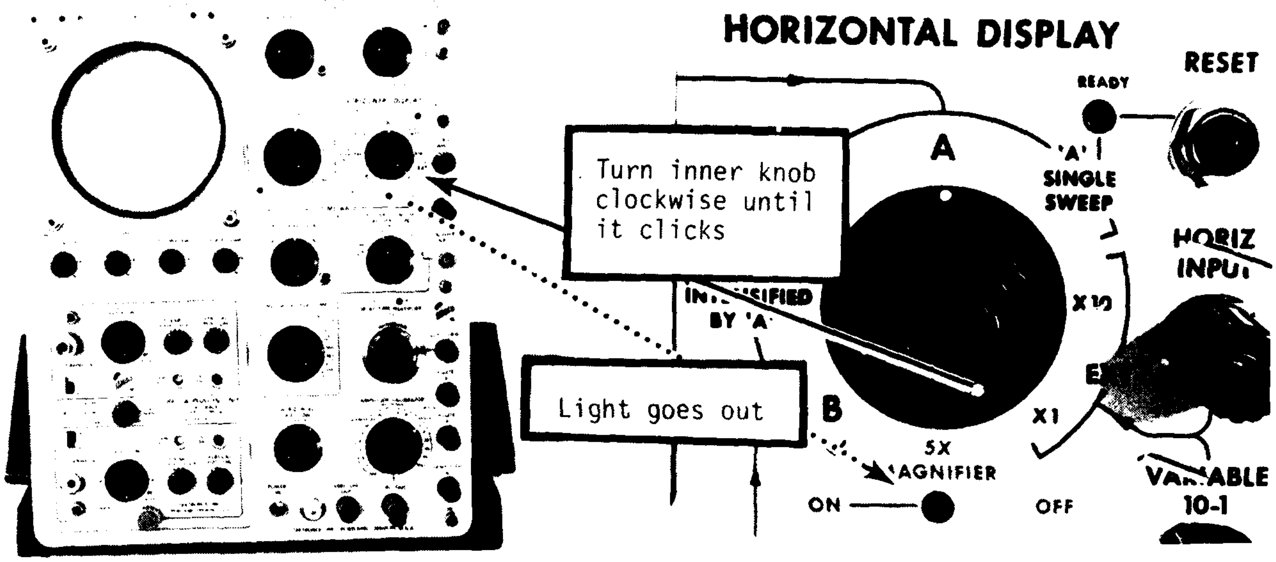
Step 6: Set TRIGGERING SLOPE switch to +INT



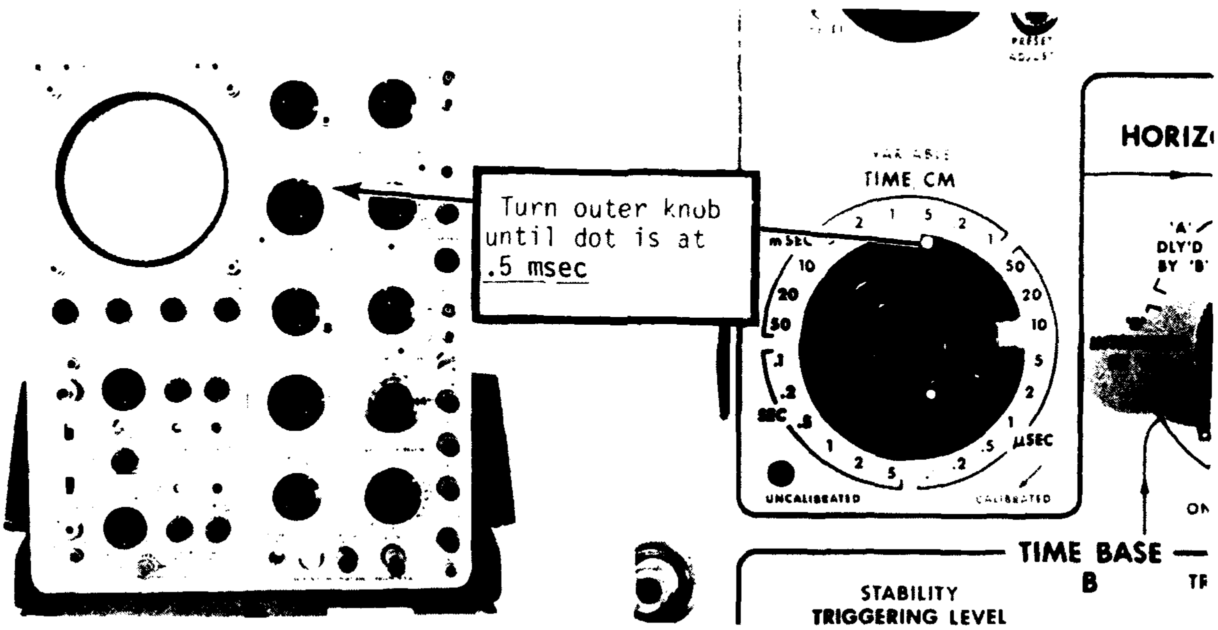
Step 7: Set HORIZONTAL DISPLAY switch to A



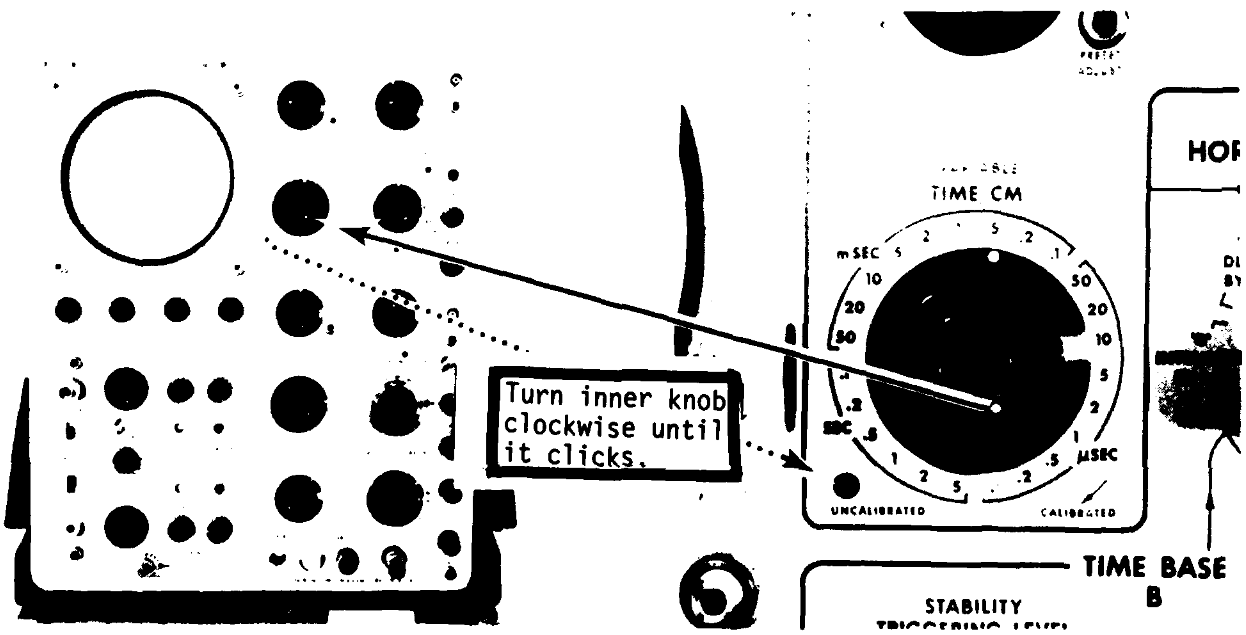
Step 8: Set 5X MAGNIFIER switch to OFF



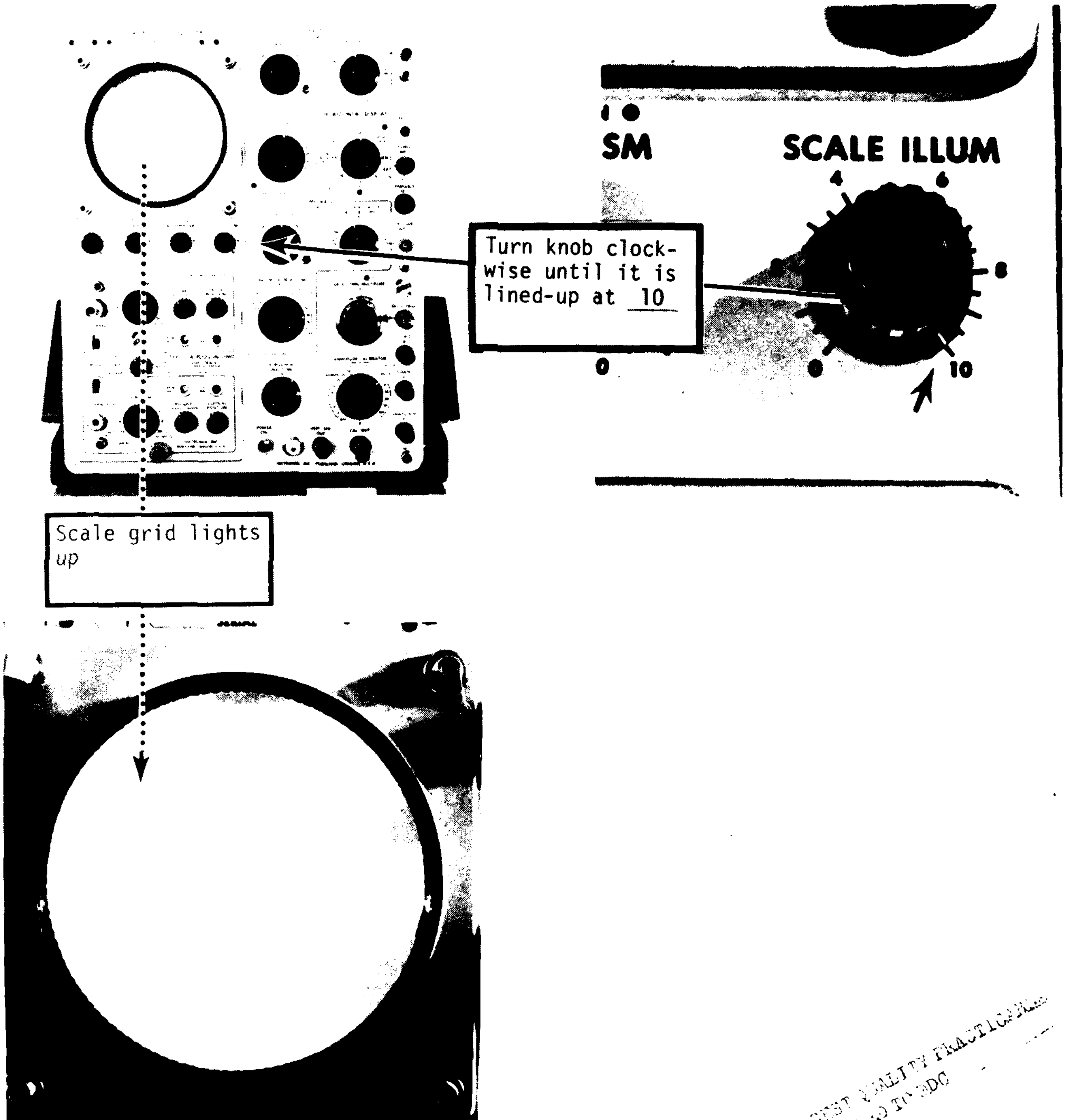
Step 9 : Set time base A TIME/CM selector switch to .5 mSEC



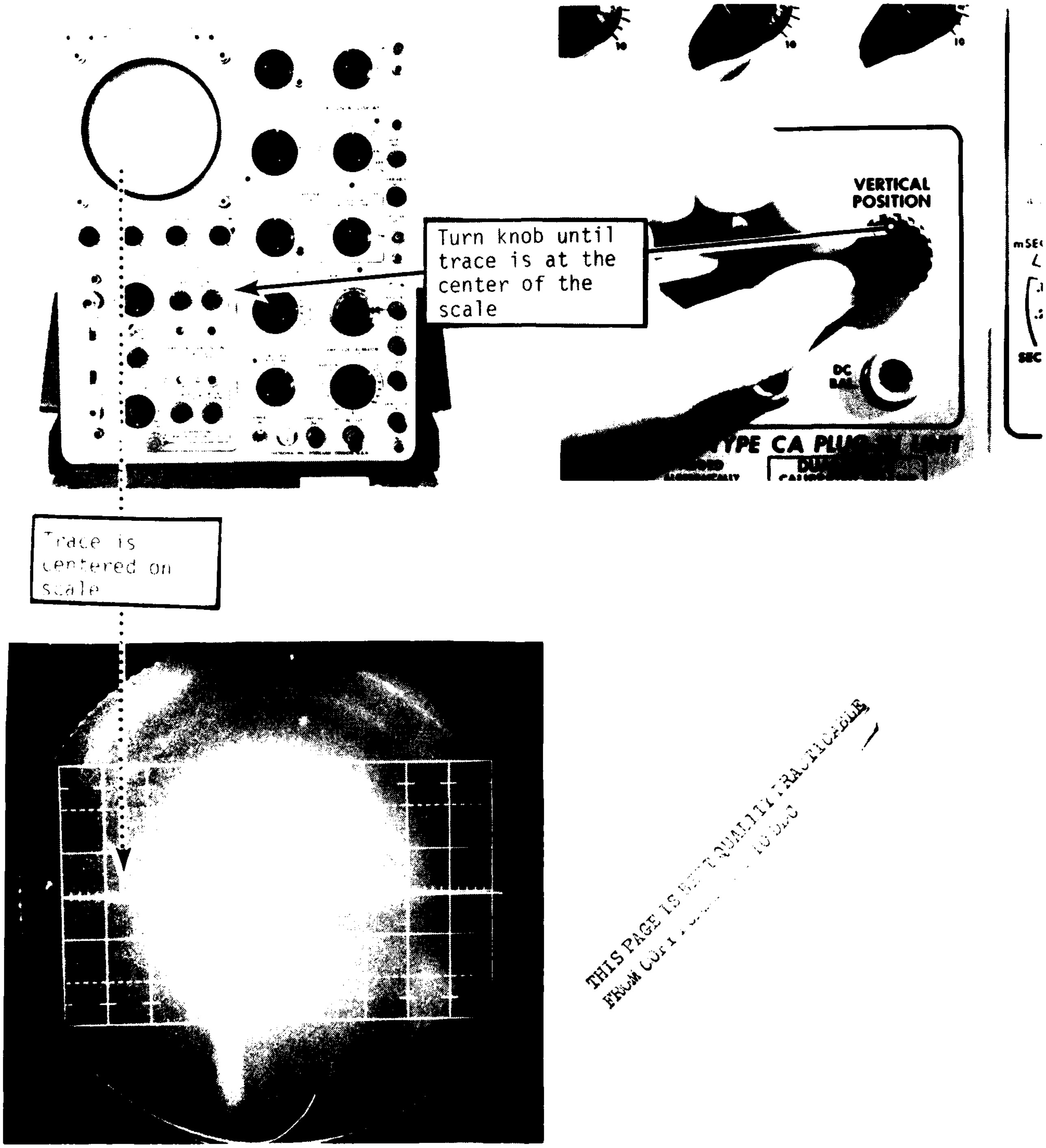
Step 10: Set VARIABLE TIME/CM switch to CALIBRATED



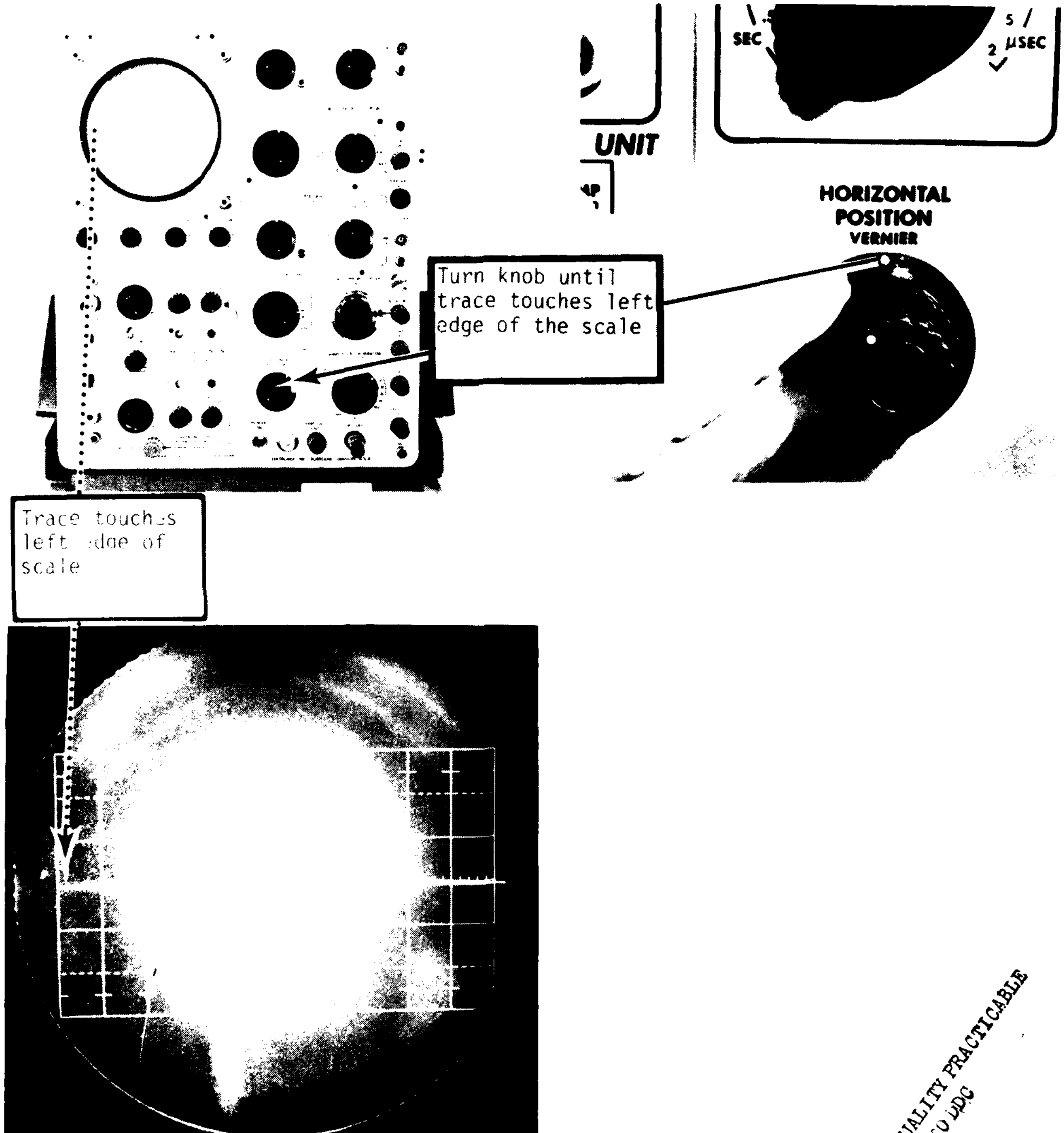
Step 11: Illuminate scale on the display surface.



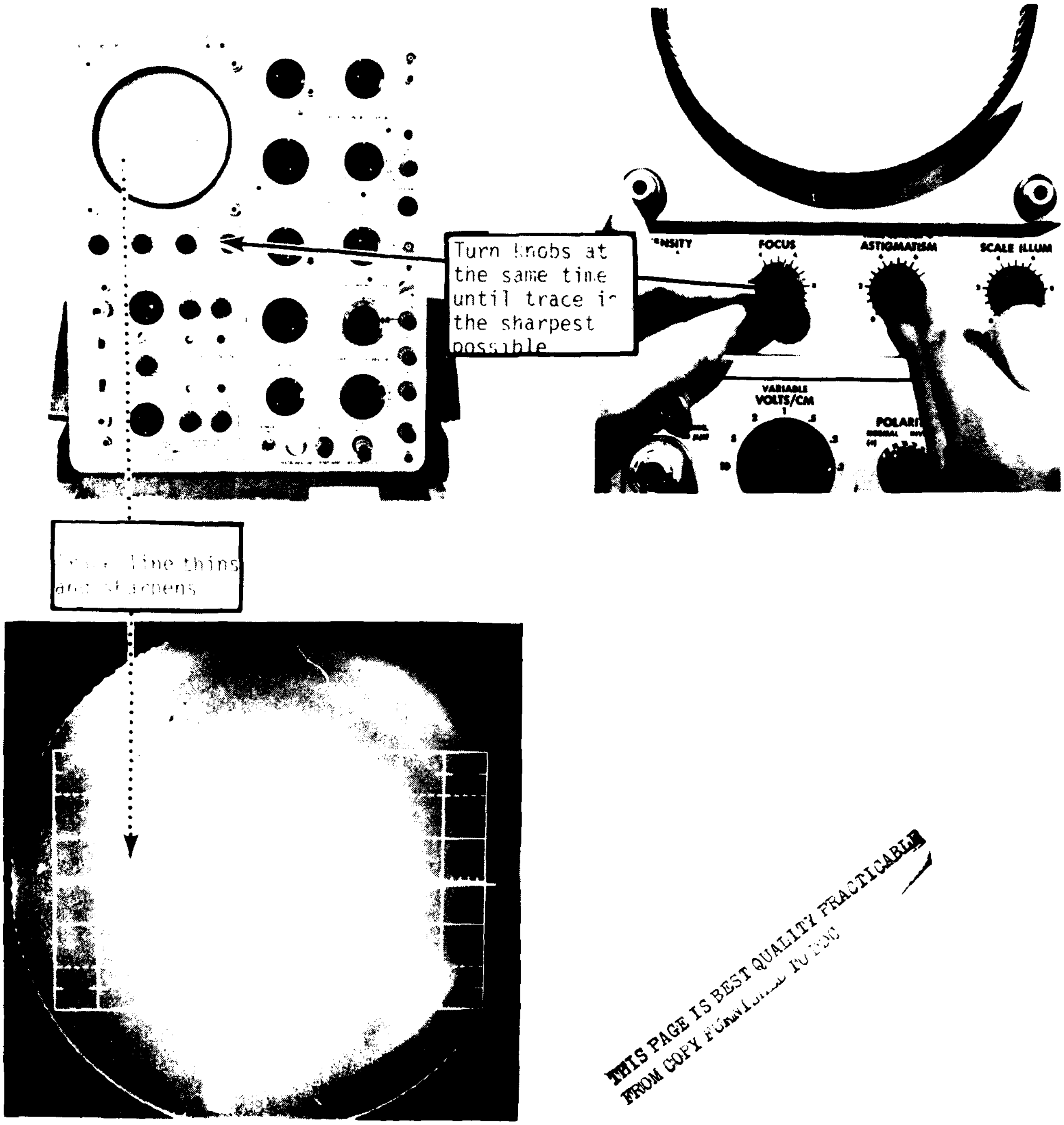
Step 12: Adjust VERTICAL POSITION of the trace.



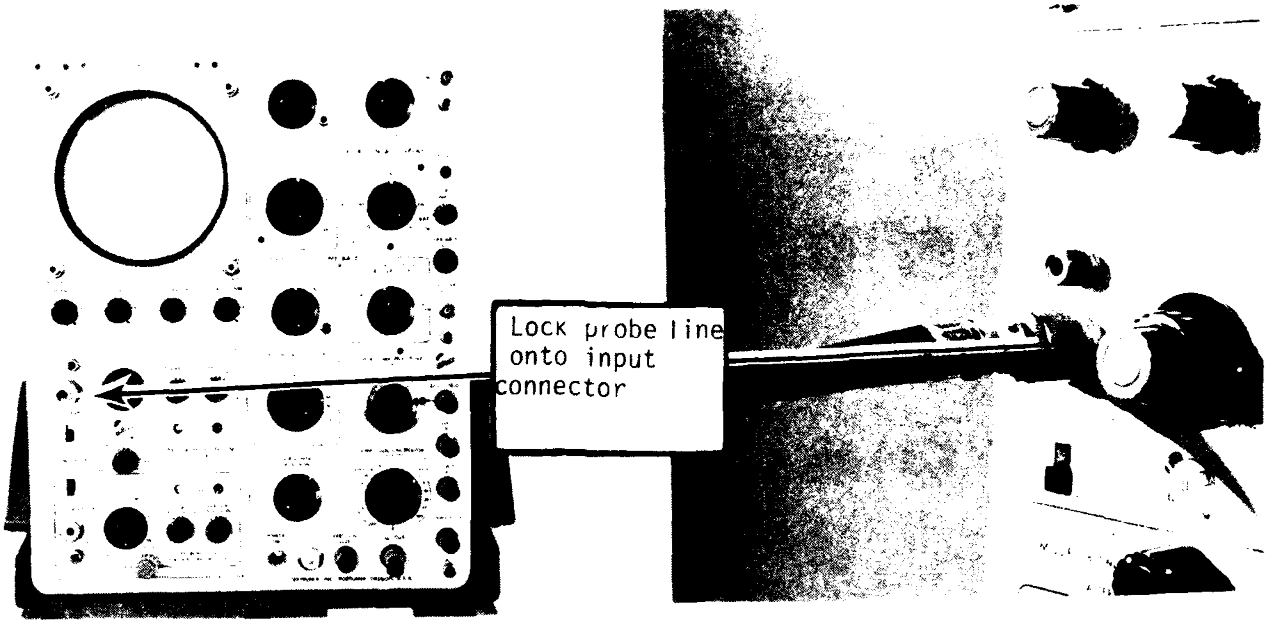
Step 13: Adjust horizontal position of trace



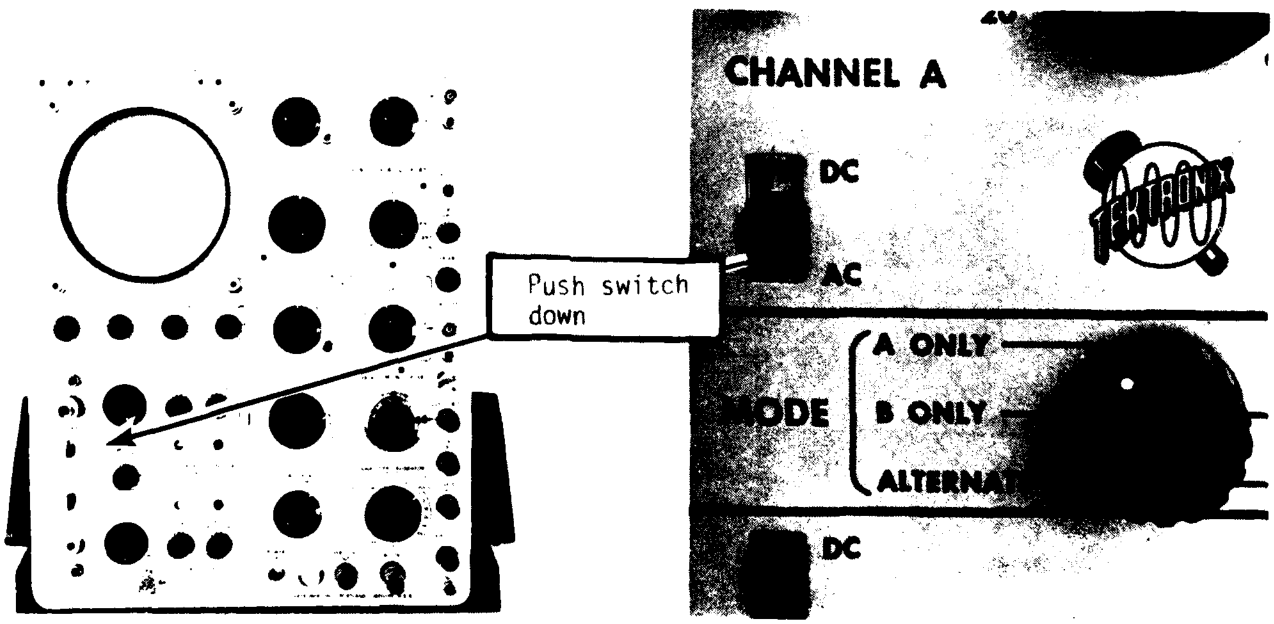
Step 14: Adjust FOCUS and ASTIGMATISM controls



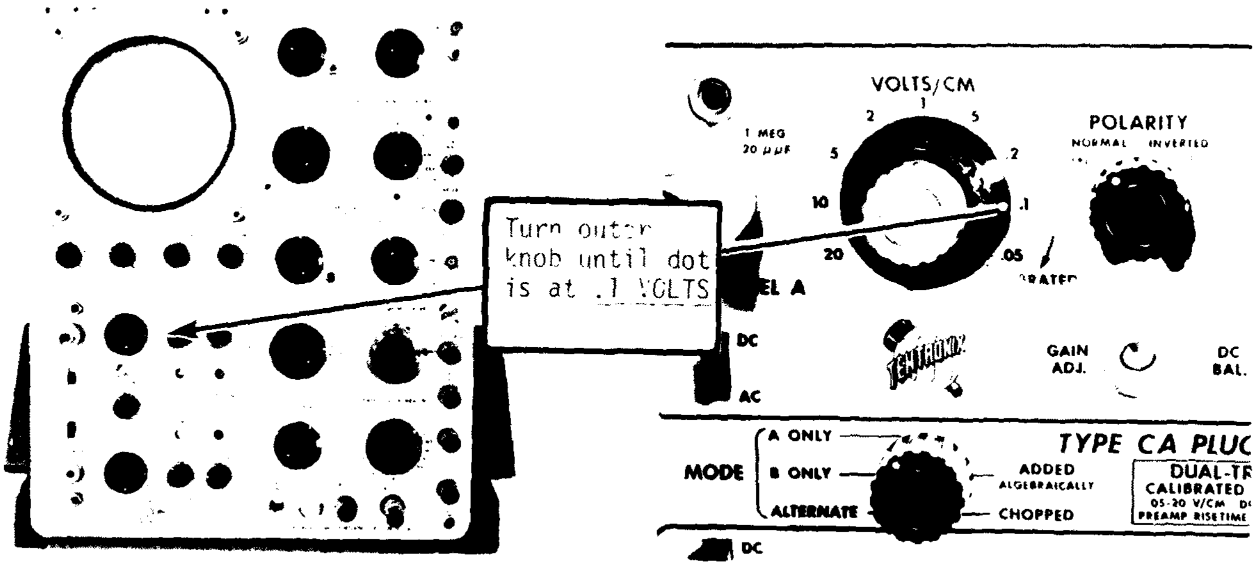
Step 15: Connect probe line to CHANNEL A input connector



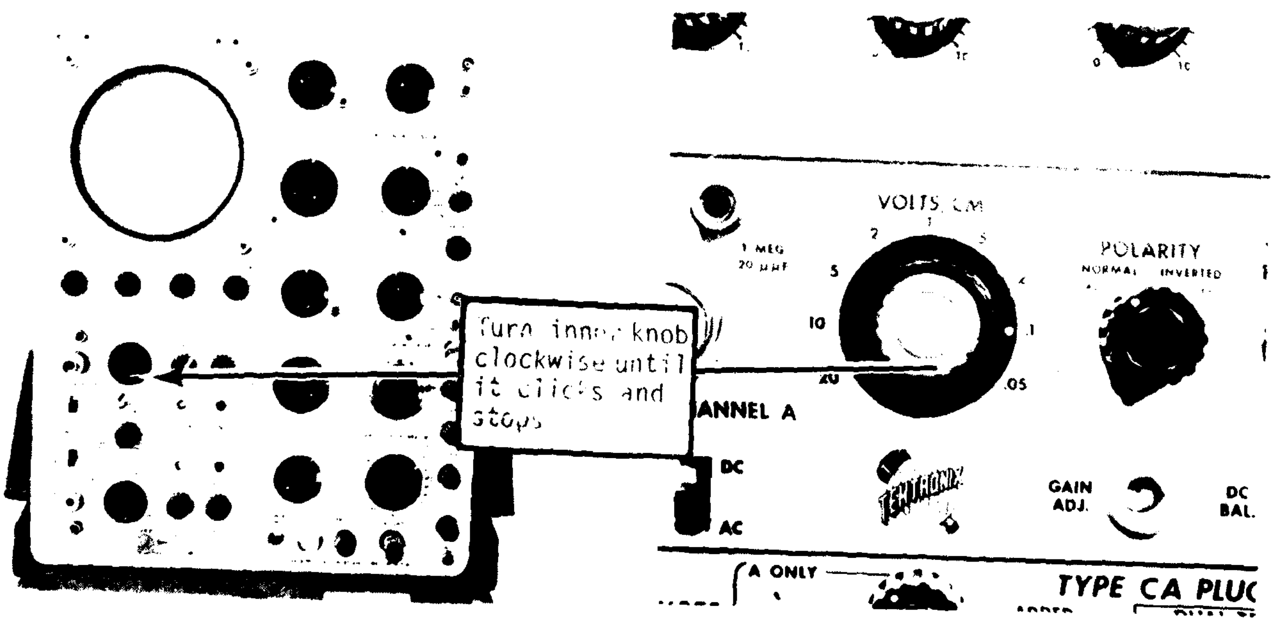
Step 16: Set CHANNEL A coupling switch to AC



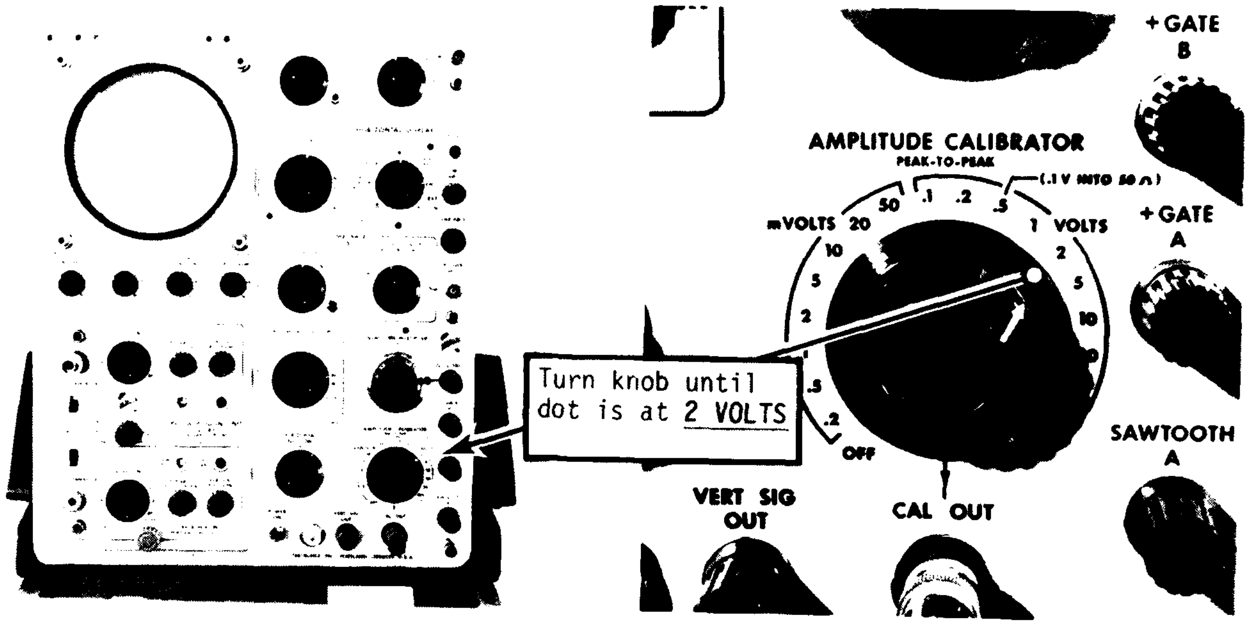
Step 17: Set CHANNEL A VOLTS/CM to .1 volts



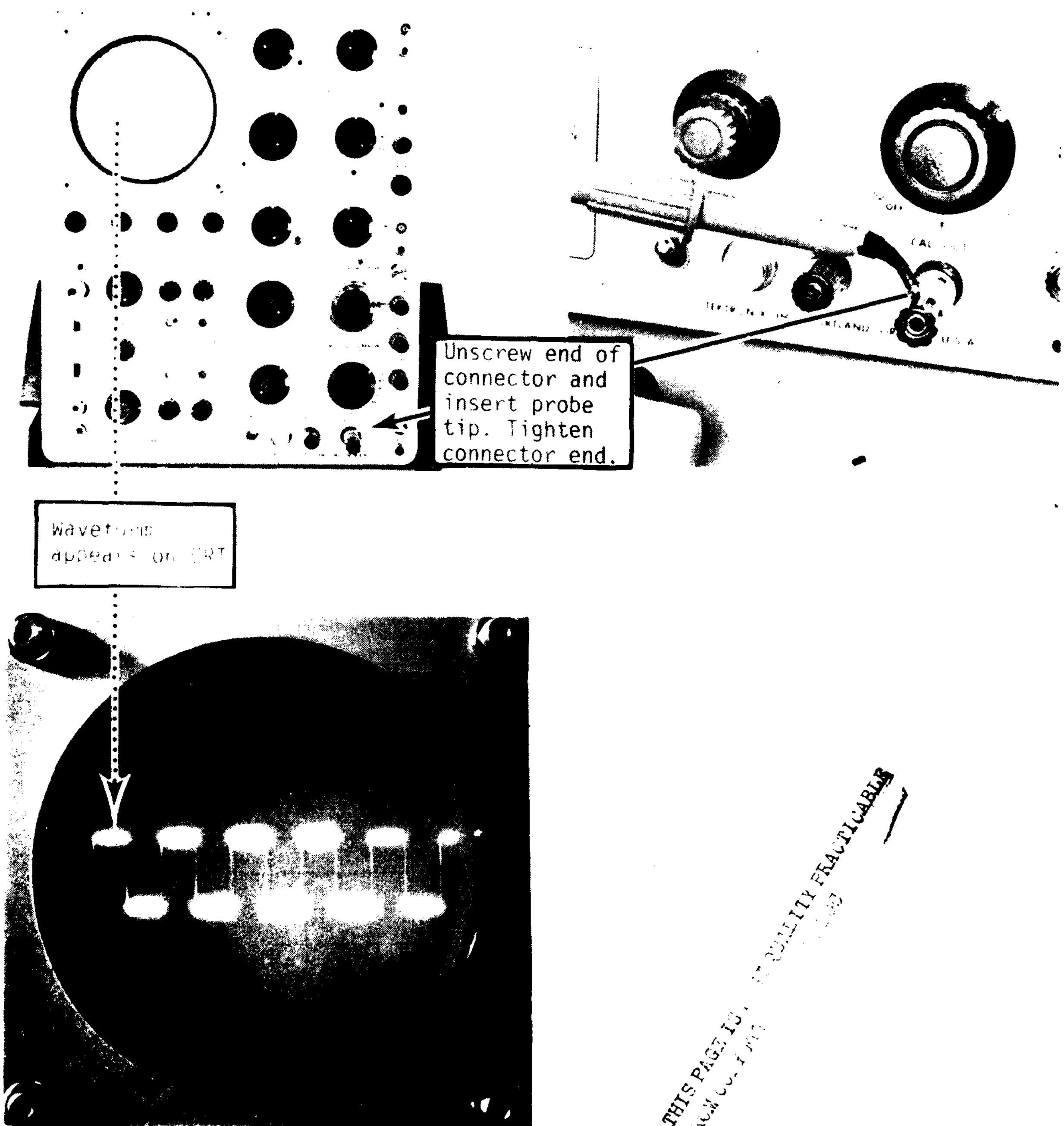
Step 18: Set VARIABLE VOLTS/CM switch to CALIBRATED.



Step 19: Set AMPLITUDE CALIBRATOR to 2 volts.



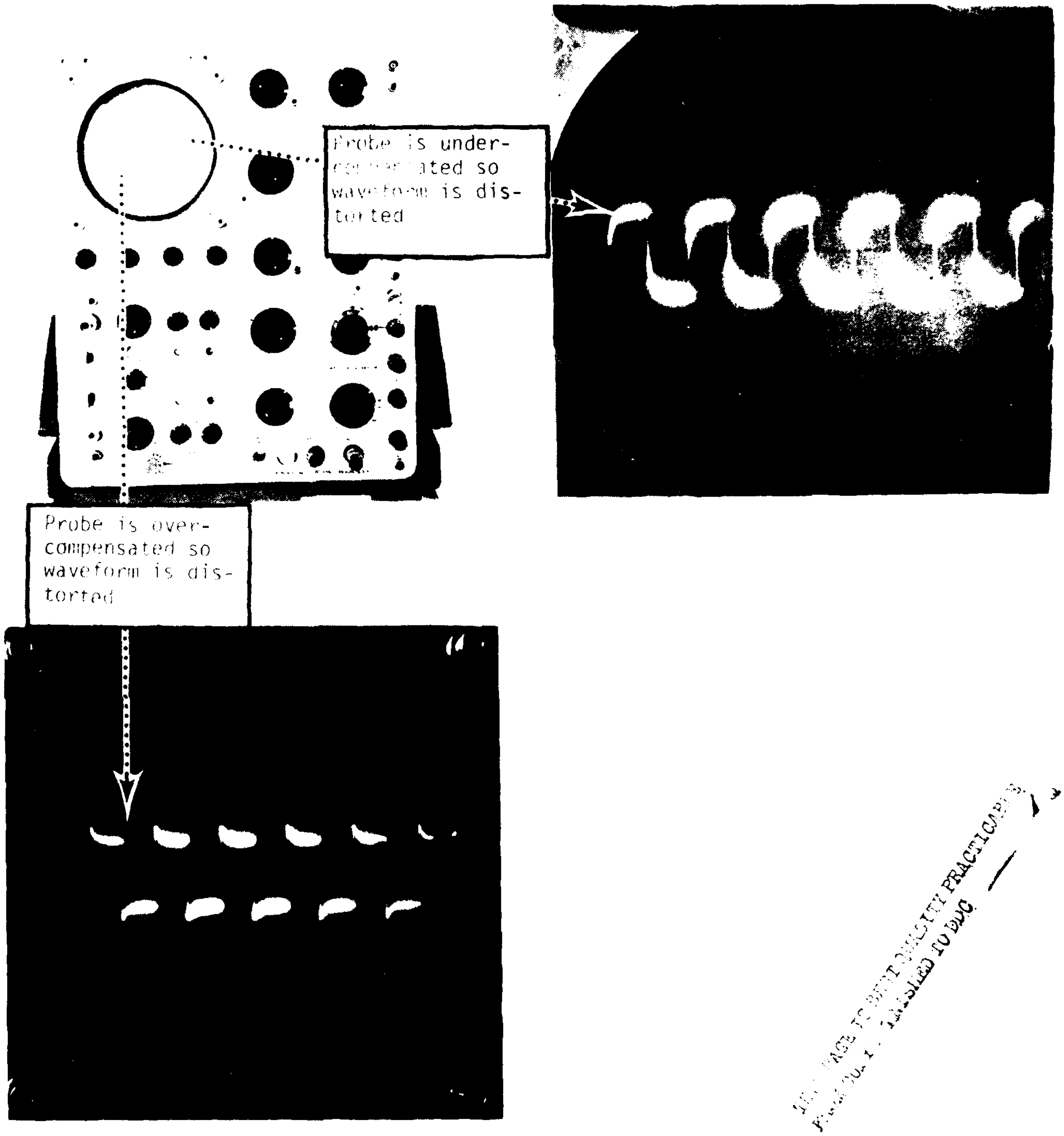
Step 20: Insert probe tip in the CAL OUT connector



DEMONSTRATION

Step 20: Insert probe tip into CAL OUT connector (continued)

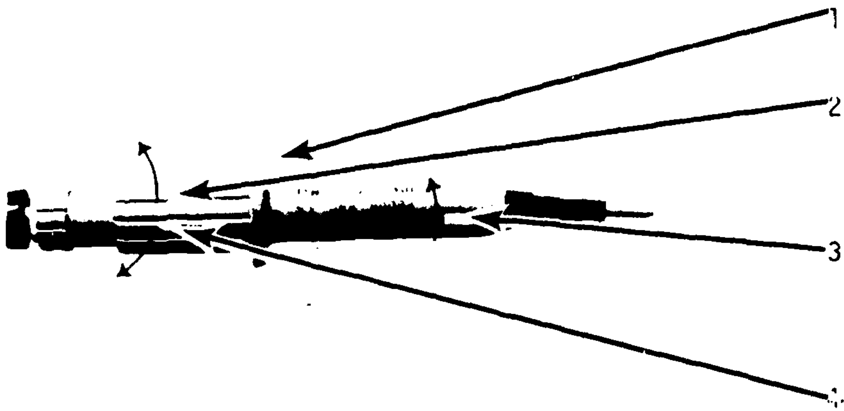
What can go wrong?



Step 20: Insert probe tip into CAL OUT connector (continued)

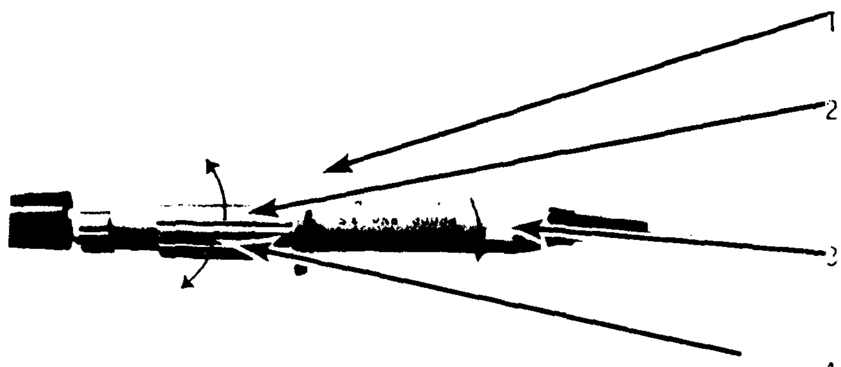
How to correct it

Under compensated probe



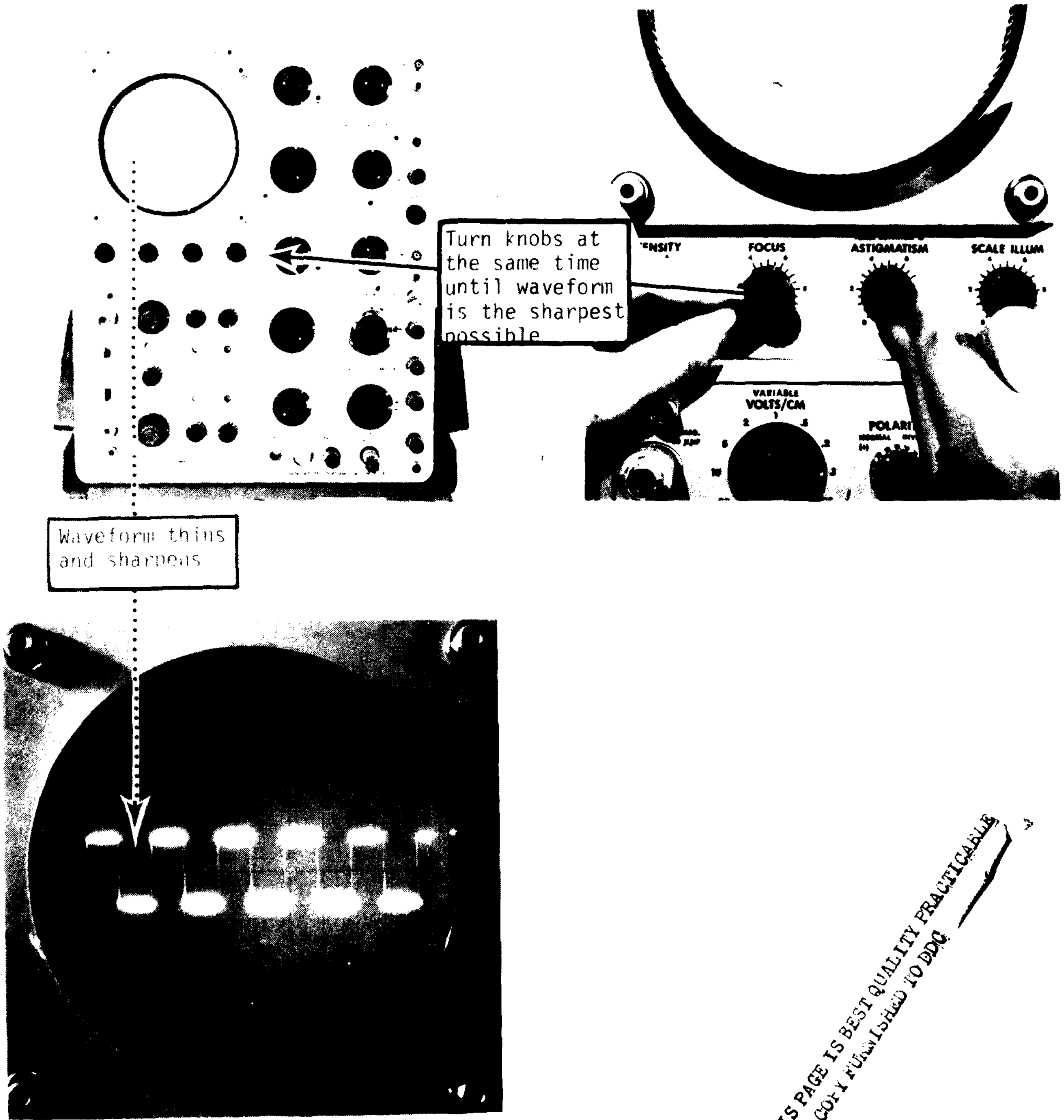
1. Hold center ring of probe.
2. With free hand, turn locking ring counterclockwise until it moves freely.
3. Rotate tuning barrel counter-clockwise until waveform is square.
4. Turn locking ring clockwise until secure.

Over compensated probe



1. Hold center ring of probe.
2. With free hand, turn locking ring counterclockwise until it moves freely.
3. Rotate tuning barrel clockwise until waveform is square.
4. Turn locking ring clockwise until secure.

Step 21: Adjust FOCUS and ASTIGMATISM controls

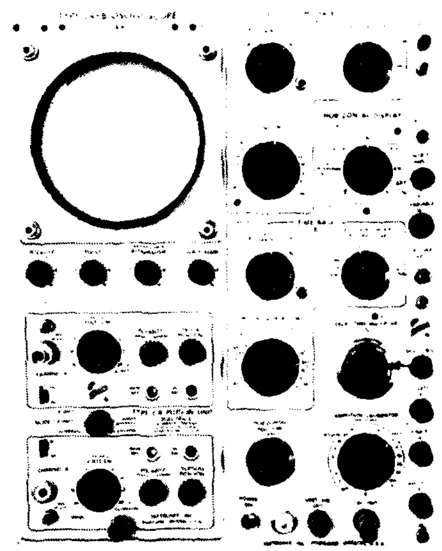


APPENDIX C

SAMPLE PAGES FROM LEARNING AID

PROBE CALIBRATION PROCEDURE

Tektronix 545B Oscilloscope



LEARNING AID

Anne M. Polino

Training Analysis and Evaluation Group

March 1979

INTRODUCTION

Learning Objectives	When you complete this lesson you will be able to: 1. Set-up a square wave on an oscilloscope 2. Calibrate a 10X probe
Testing	A test will be given on a Tektronix 545B oscilloscope to see if you know how to calibrate a probe.
Why Learn This Procedure	The oscilloscope is used to test circuits, study waveforms, measure voltage and current, and test amplifier response. It does this by graphically displaying voltage amplitude, wave shape, phase, and frequency of waveforms on the CRT. A properly calibrated probe is necessary for an accurate graphic display.
Orgainzation Of Training Materials	For easier learning, the procedure is divided into 4 sections: Section I — Turn Power ON Section II — Get a Trace Section III — Center the Trace Section IV — Tune the Probe You will learn the steps in each section separately, then you will practice all the sections together.
Additional Resources Required	Tektronix 545B oscilloscope and power source, BNC cable, and a 10X probe.

OVERVIEW

NOTE

Fold out page 101. Leave it out for the entire lesson.

Directions: 1. Look at the foldout. Notice that the oscilloscope is divided into 5 functional sections. Listed below are the sections and the general functions each is responsible for.

Sections	Functions
Power	on/off power controls
Horizontal controls	determines the width and horizontal positioning of a displayed signal
Vertical controls	determines the height and vertical positioning of a displayed signal
Calibration and Output	has output jacks which can be used to drive or synchronize other equipment
Display	presents a picture of the test signal

2. The probe calibration procedure requires that the controls on these sections be set in a certain way. The rest of this lesson will show you how to do it.

HOW TO USE TRAINING MATERIALS

Directions:

1. This lesson will be presented in a way that might be new to you. The following information will help.

    a. Each step is presented in terms of the ACTION you will perform on the oscilloscope.

    b. If the ACTION of a certain step makes the oscilloscope do something (display a trace line on the CRT) it will be presented under the heading of a RESPONSE.

    c. If in a certain step there is a possibility that something can go wrong and would need troubleshooting, it will be presented under the headings of WHAT CAN GO WRONG and HOW TO CORRECT IT.

2. Take your time and learn each step correctly.

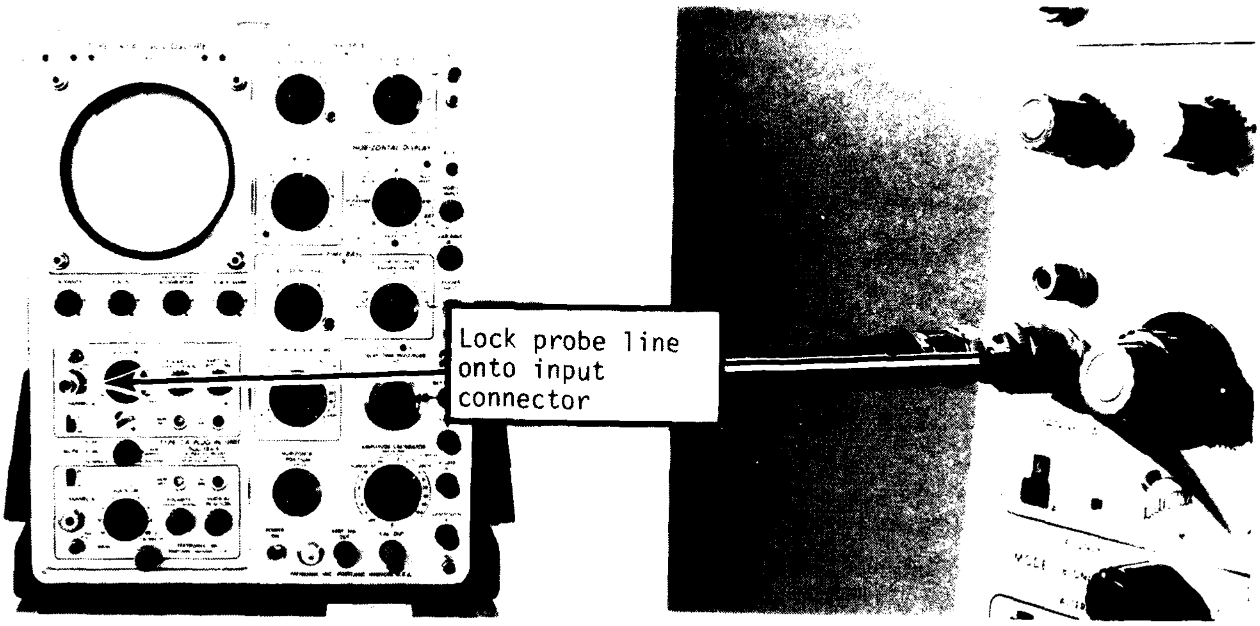
3. After each step you will be required to recall the ACTION and RESPONSE, and WHAT CAN GO WRONG and HOW TO CORRECT IT when necessary.

4. For best results, follow all instructions.

Step 15: Connect probe line to CHANNEL A input connector

<u>Purpose</u>: So that the signal picked-up by the probe can be input to the oscilloscope

Action



CHECK YOUR MEMORY

Step 15: Connect probe line to CHANNEL A input connector

Directions

1. Point through the action on the foldout.

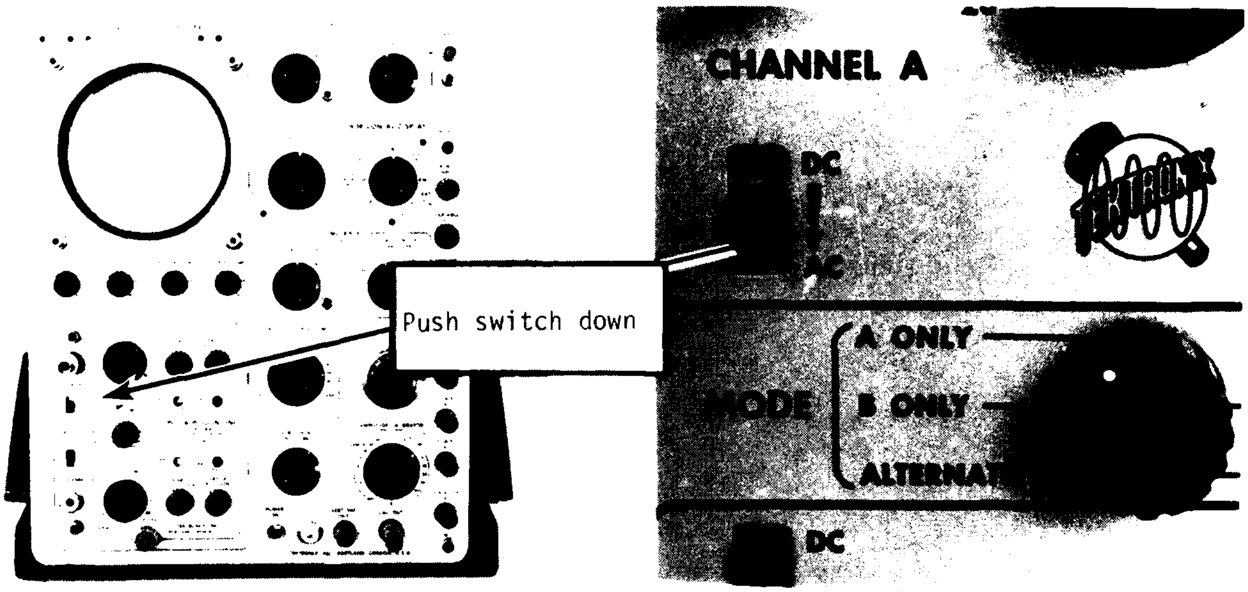
   Action - - - -

2. To check your answers turn back to page 77

Step 16: Set CHANNEL A coupling switch to AC

Purpose: In this procedure only AC signals need to be displayed

Action



CHECK YOUR MEMORY

Step 16: Set CHANNEL A DC/AC coupling switch to AC

Directions

1. Point through the action and response(s) on the foldout and recall the note for this step.

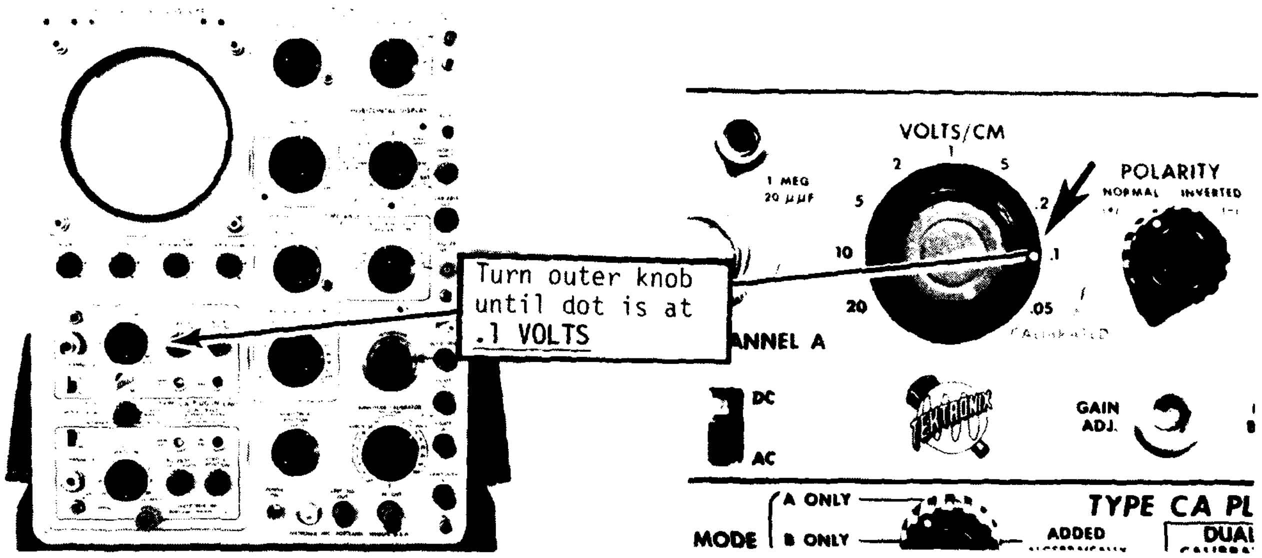
   Action - - - -

2. To check your answers turn to page 79

Step 17: Set CHANNEL A VOLTS/CM to .1 volts

Purpose: With this switch you can set the value of each square on the vertical axis of the CRT scale.

Action



CHECK YOUR MEMORY

Step 17: Set CHANNEL A VOLTS/CM switch to .1 VOLTS

Directions

1. Point through the action on the foldout and recall the note for this step.

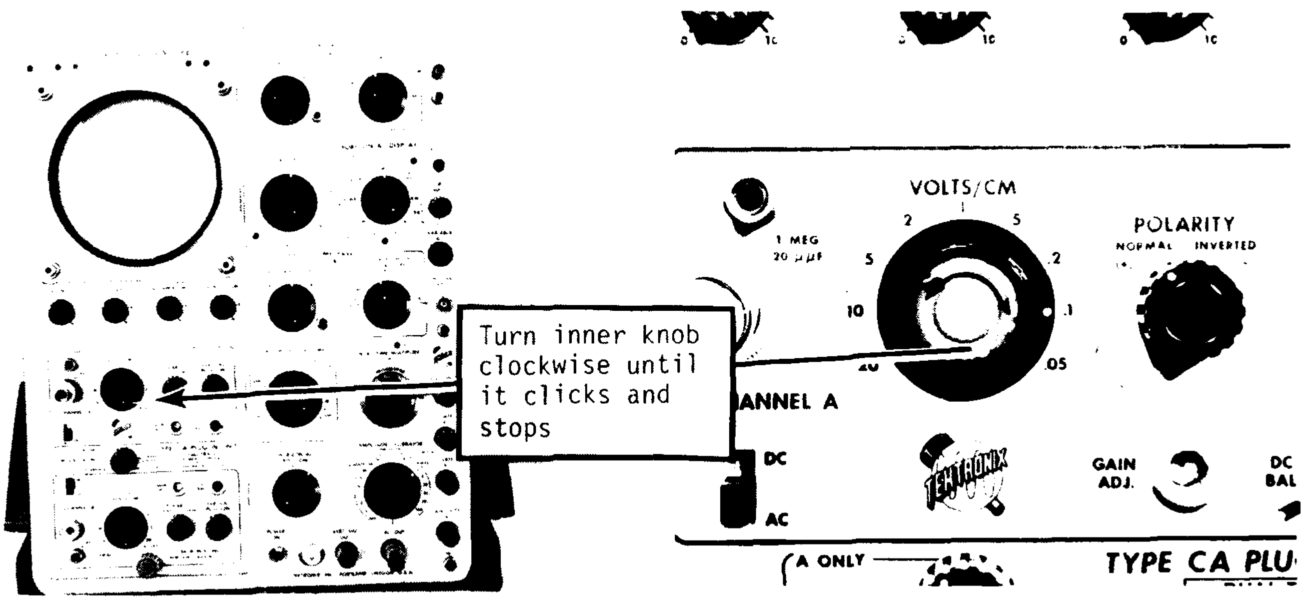
   Action - - - -

2. To check your answers turn back to page 81

Step 18: Set VARIABLE VOLTS/CM switch to CALIBRATED.

Purpose: Ensure that values set in step 17 do not fluctuate

Action



CHECK YOUR MEMORY

Step 18: Set VARIABLE VOLTS/CM switch to CALIBRATED

Directions

1. **Point through the action on the foldout.**

   Action - - - -

2. **To check your answers turn back to page** 83

- -

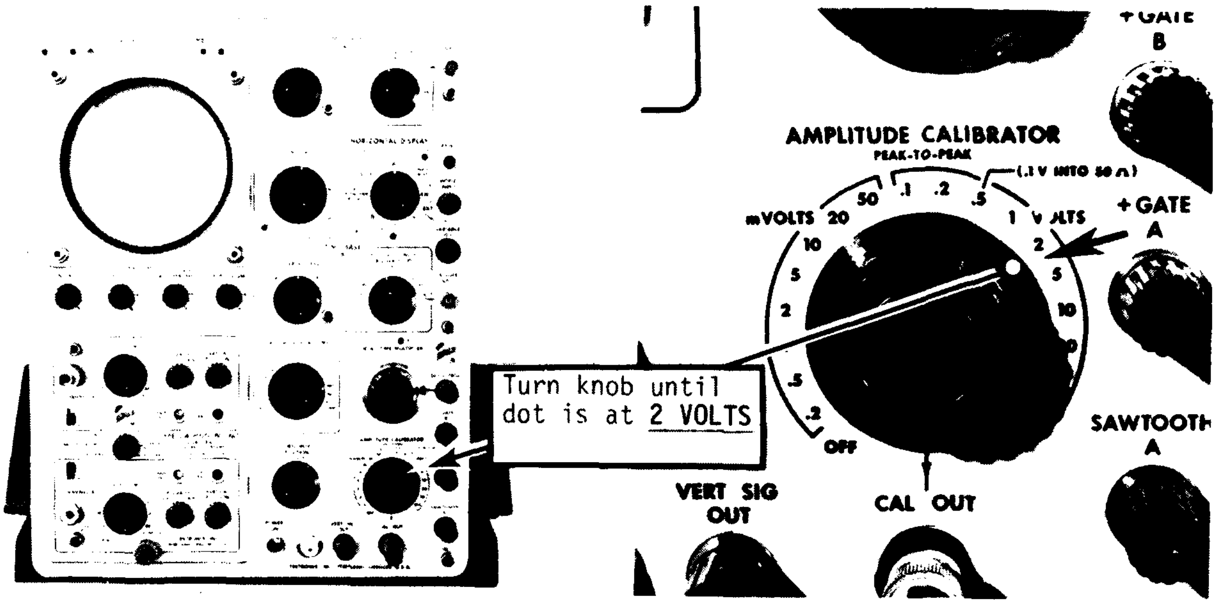
ARE YOU REMEMBERING TO POINT THROUGH THE STEPS?

- -

Step 19: Set AMPLITUDE CALIBRATOR to 2 volts.

Purpose: Defines the height of the square wave that will be displayed in the next step.

Action



NOTE

There are two scales on this knob. One for 1/1000 VOLTS (m volts) and one for VOLTS. Be sure to use the correct one.

CHECK YOUR MEMORY

Step 19: Set AMPLITUDE CALIBRATOR to 2 VOLTS

Directions:

1. Point through the action on the foldout and recall the note for this step.

   Action - - - -

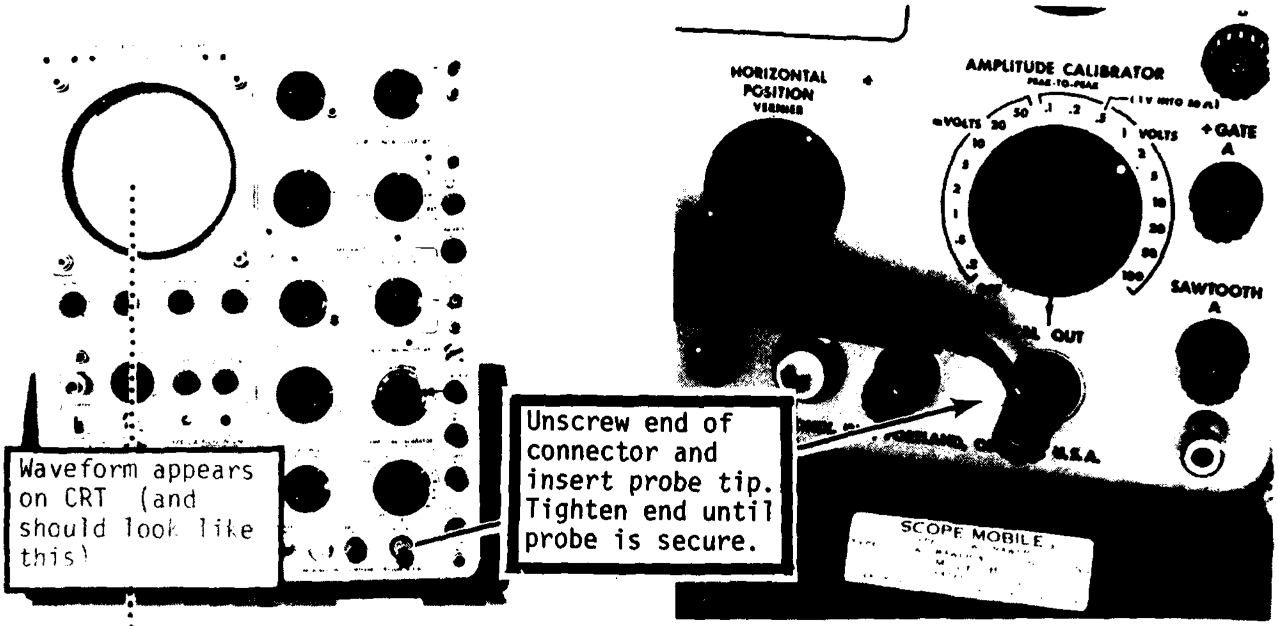
   Note - - - - -

2. To check your answers turn back to page 85.

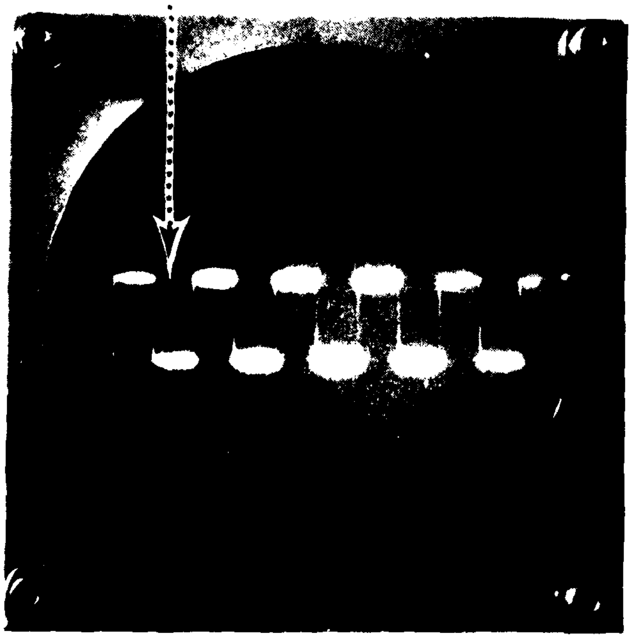
Step 20: Insert probe tip into CAL OUT connector

Purpose: So the signal generated at the CAL OUT connector can be displayed on CRT.

Action



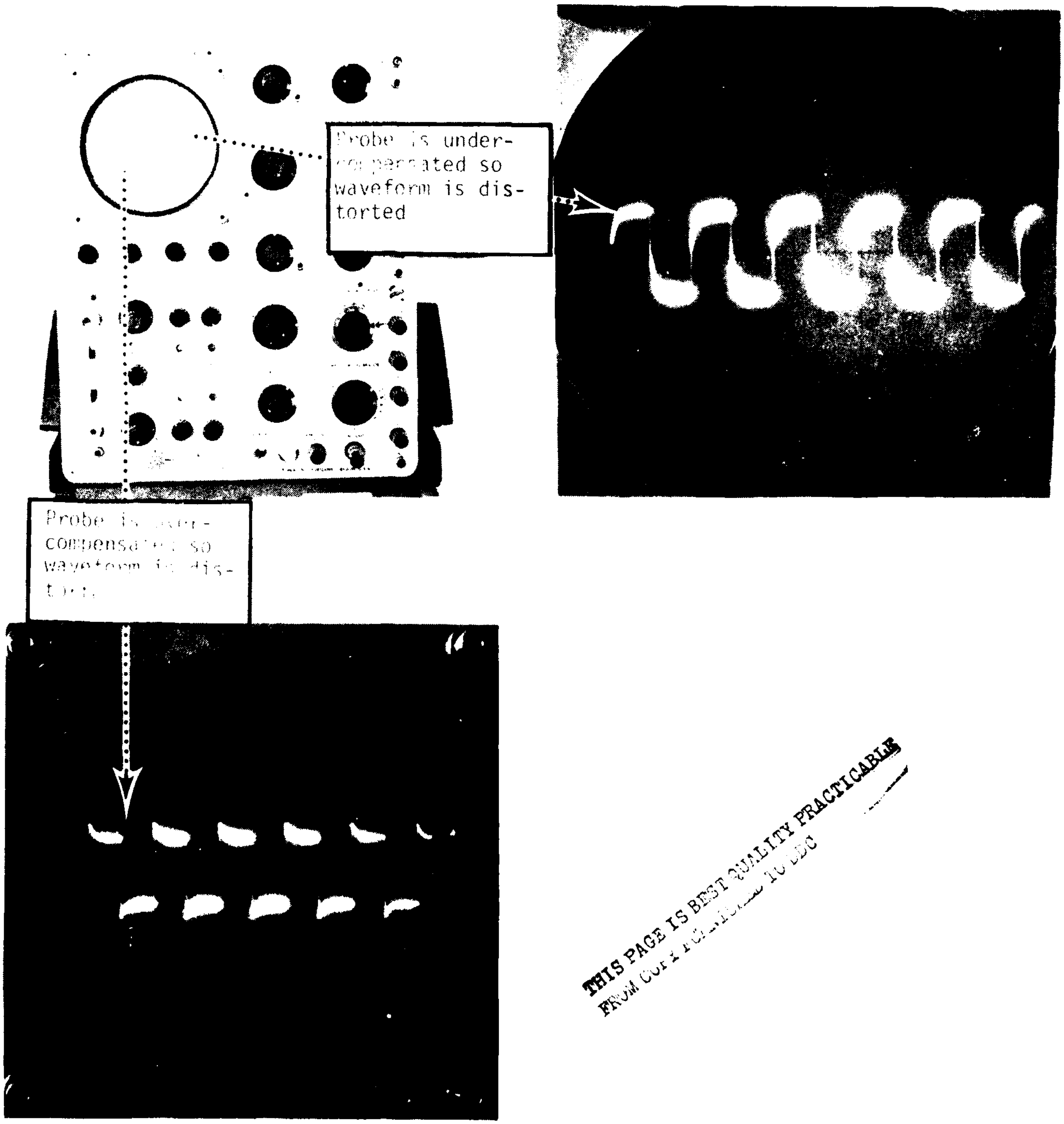
Response



> **NOTE**
>
> The displayed waveform is called a square wave. A square wave is flat on the top and bottom, and all its angles are 90°.

Step 20: Insert probe tip into CAL OUT connector (continued)

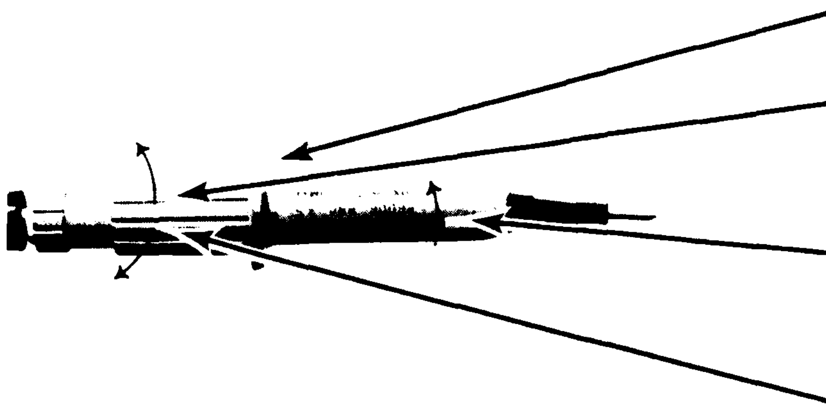
What can go wrong?



Step 20: Insert probe tip into CAL OUT connector (continued)

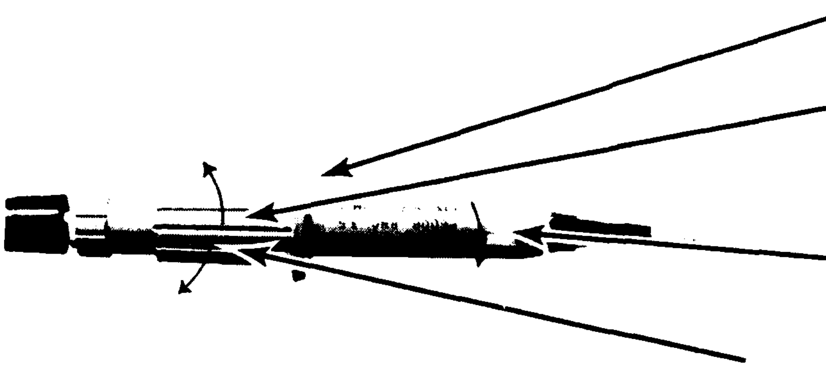
How to correct it

Under compensated probe



1. Hold center ring of probe.
2. With free hand, turn locking ring counterclockwise until it moves freely.
3. Rotate tuning barrel counter-clockwise until waveform is square.
4. Turn locking ring clockwise until secure.

Over compensated probe



1. Hold center ring of probe.
2. With free hand, turn locking ring counterclockwise until it moves freely.
3. Rotate tuning barrel clockwise until waveform is square.
4. Turn locking ring clockwise until secure.

NOTE

It is important to tune the probe correctly, so that you can get an accurate picture of the input signal.

CHECK YOUR MEMORY

Step 20: Insert probe tip into CAL OUT connector

Directions

1. Point through the action and response(s) on the foldout and recall what can go wrong, how to correct it, and the note for this step.

   Action - - - -

   Response(s) - - - -

   What can go wrong (1) - - - -

   (2) - - - -

   How to correct it (1) - - - -

   (2) - - - -

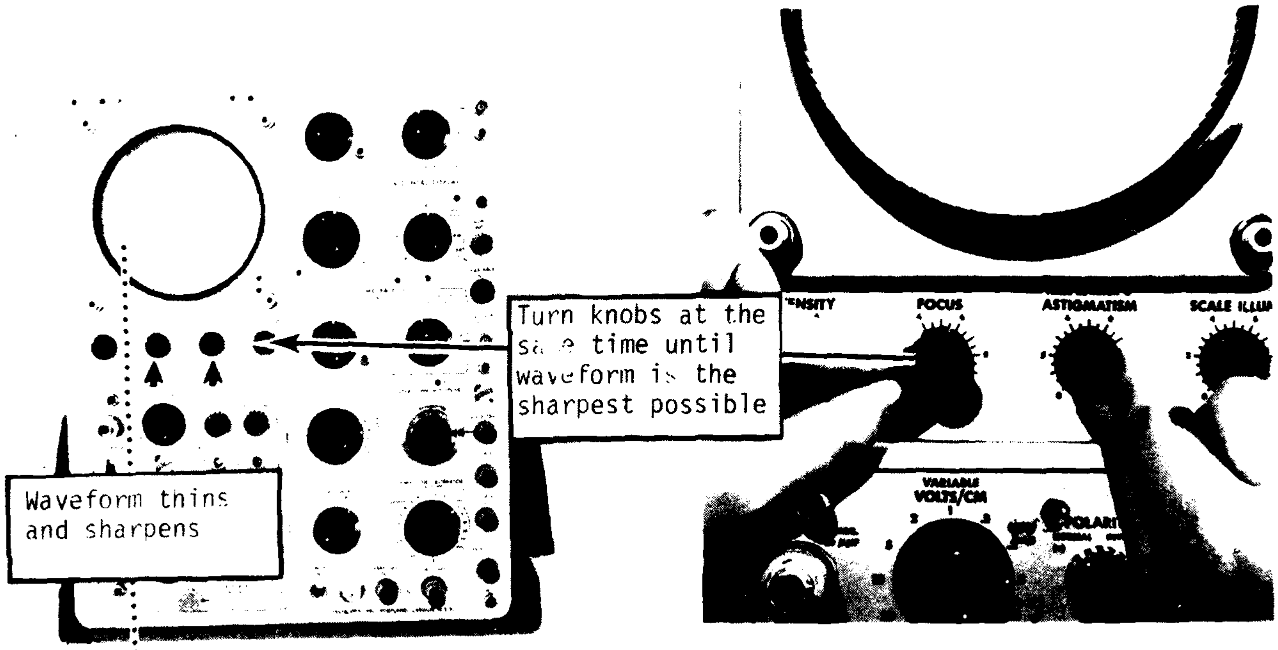
   Note - - - -

2. To check your answers turn to page 87-89

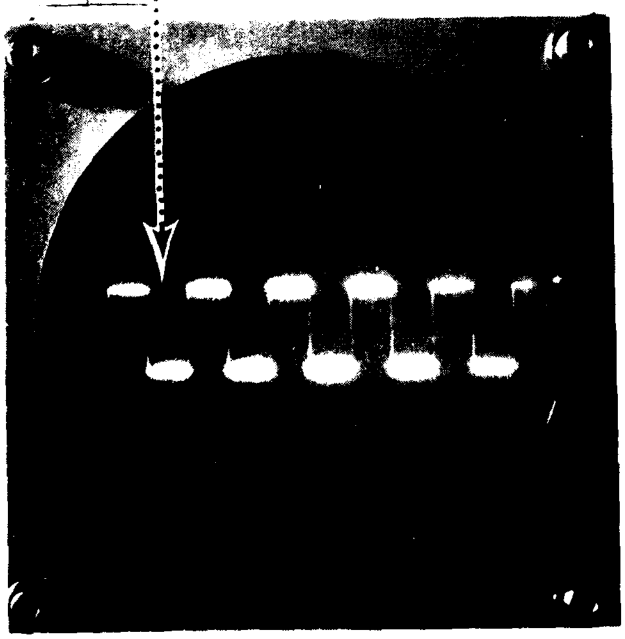
Step 21: Adjust FOCUS and ASTIGMATISM controls

Purpose: To sharpen the display

Action



Response



CHECK YOUR MEMORY

Step 21: Adjust FOCUS and ASTIGMATISM controls

Directions

1. Point through the action and the response(s) on the foldout.

   Action - - - -

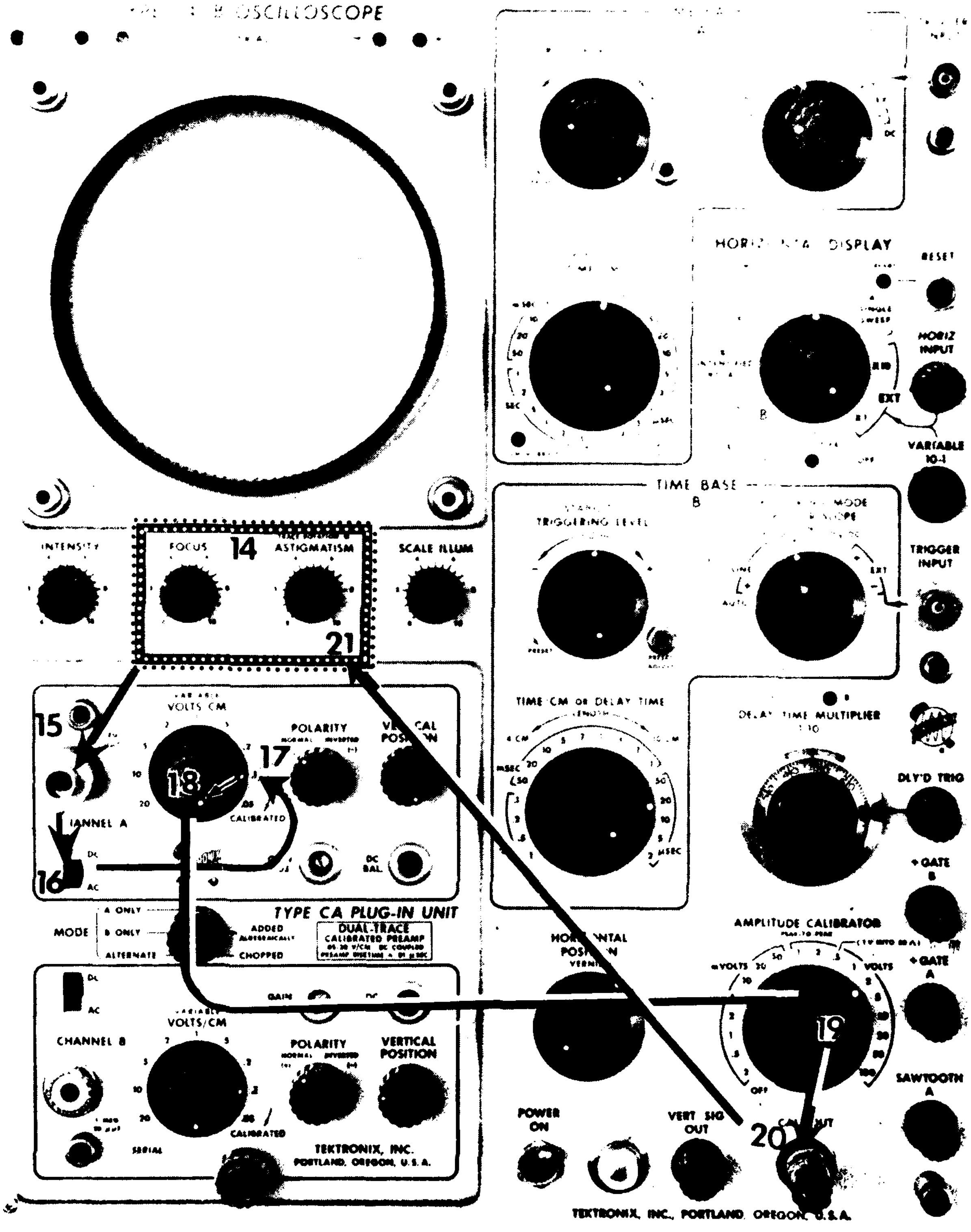
   Response(s) - - - -

2. To check your answers turn to page 91

STEP SEQUENCE DRILL

Directions:

1. Follow the "roadmap" on the next page and trace the sequence of steps with your finger.
2. Remember the location and sequence of each control used.



14
15
16
17
18
19
20
21
INTENSITY
FOCUS
ASTIGMATISM
SCALE ILLUM
HORIZONTAL DISPLAY
RESET
HORIZ INPUT
VARIABLE 10-1
TIME BASE B
TRIGGERING LEVEL
TRIGGER INPUT
TIME/CM OR DELAY TIME
DELAY TIME MULTIPLIER
DLY'D TRIG
+GATE B
AMPLITUDE CALIBRATOR
+GATE A
SAWTOOTH A
VOLTS/CM
POLARITY
CHANNEL A
CALIBRATED
DC BAL
MODE
A ONLY
B ONLY
ALTERNATE
ADDED
CHOPPED
TYPE CA PLUG-IN UNIT
DUAL-TRACE CALIBRATED PREAMP
CHANNEL B
VARIABLE VOLTS/CM
POLARITY
VERTICAL POSITION
SERIAL
TEKTRONIX, INC. PORTLAND, OREGON, U.S.A.
POWER ON
VERT SIG OUT
TEKTRONIX, INC., PORTLAND, OREGON, U.S.A.

STEP SEQUENCE DRILL (cont.)

Directions:

1. Use your finger and trace the step sequence you just learned, *on the foldout* (page 101).
2. *To check your performance* look back at the "roadmap" on page 94.
3. Keep practicing until you can trace the step sequence without looking back or making any mistakes.

TEST

Directions

1. Describe in your own words the activities for each step listed below, and point on the foldout to the controls used in each step.
2. If you need to check your answers:
   - look on page 97-99.
3. If you make mistakes:
   - pracitce the steps you missed
   - keep taking this test until you make no errors

Step 15: Connect probe line to CHANNEL A input connector

Action: ______

Step 16: Set CHANNEL A DC/AC coupling switch to AC

Action: _______

Step 17: Set CHANNEL A VOLTS/CM switch to .1 VOLTS

Action: _______

Step 18: Set VARIABLE VOLTS/CM switch to CALIBRATED

Action: _______

Step 19: Set AMPLITUDE CALIBRATOR switch to 2 VOLTS

Action: ______

Note: ___________

Step 20: Insert probe tip into CAL OUT connector

Action: _______

Response: ______

What can go wrong: (1) ___
(2) ___

How to correct it: (1) ___
(2) ___

Note: ______

Step 21: Adjust FOCUS and ASTIGMATISM controls

Action: ______

Response: ______

PAY SPECIAL ATTENTION TO THE STEP LOCATION AND SETTINGS.

YOU WILL HAVE TO KNOW THEM ALL ON THE FINAL TEST.

TEST:

Answers:

Step 15: Connect probe line to CHANNEL A input connector.

<u>Purpose</u>: So that the signal picked-up by the probe can be input to the oscilloscope.

Step 16: Set CHANNEL A DC/AC coupling switch to AC

<u>Purpose</u>: In this procedure only AC signals need to be displayed.

Step 17: Set CHANNEL A VOLTS/CM to .1 volts

<u>Purpose</u>: *With this switch you can set the value of each* square on the vertical axis of the CRT scale.

Note: The VOLTS/CM selector determines how many volts is represented by each square of the vertical portion of the display.

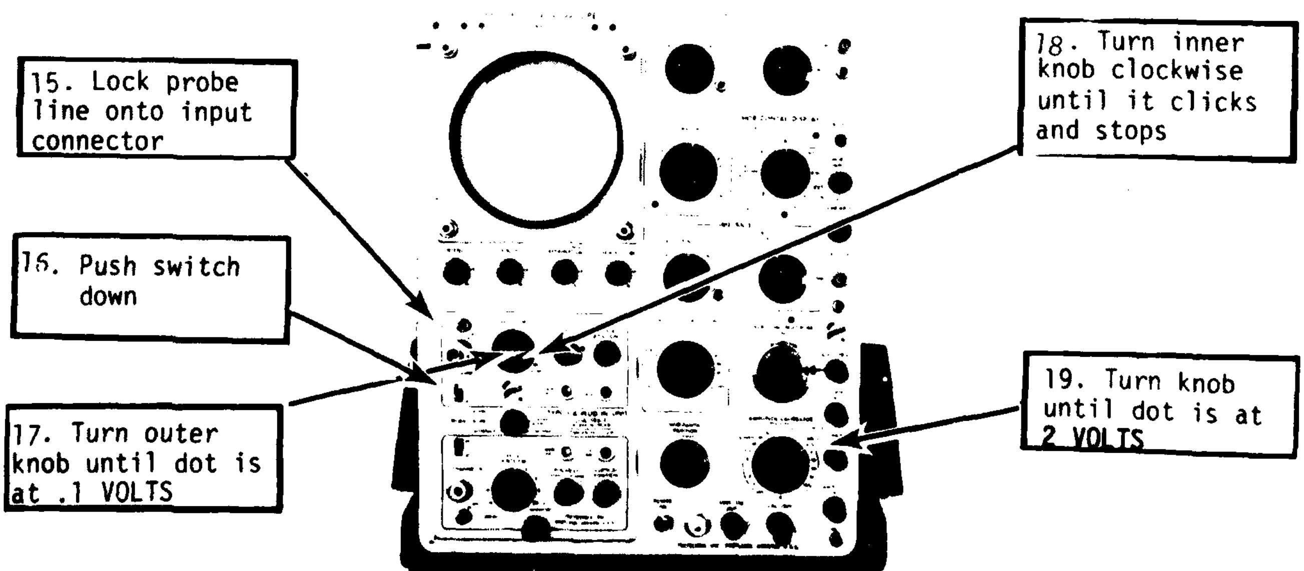
Step 18: Set VARIABLE VOLTS/CM switch to CALIBRATED.

<u>Purpose</u>: Ensure that values set in step 18 do not fluctuate.

Step 19: Set AMPLITUDE CALIBRATOR to <u>2 volts</u>.

<u>Purpose</u>: Defines the height of the square wave that will be displayed in the next step.

Caution: There are two scales on this knob, sec for 1/1000 volts (mVolts) and one for VOLTS. Be sure to use the correct one.



TEST:

Answers:

Step 20: Insert probe tip into CAL OUT connector

Purpose: So the signal generated at the CAL OUT connector can be displayed on CRT.

Response: Waveform appears on CRT.

What can go wrong: 1. Probe is under tuned so waveform is disturbed.

2. Probe is over tuned so waveform is disturbed.

How to correct it: 1. (a) hold center ring of probe

(b) with free hand, turn locking ring counterclockwise until it moves freely.

(c) rotate tuning barrel counterclockwise until waveform is square

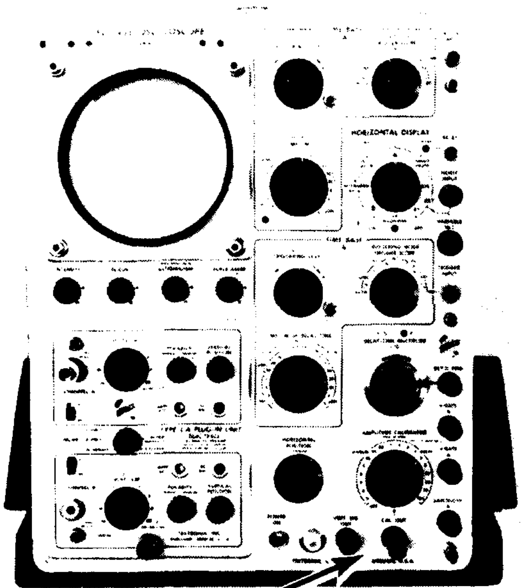
(d) turn locking ring clockwise until secure

2. (a) hold center ring of probe

(b) with free handk turn locking ring counterclockwise until it moves freely

(c) rotate tuning barrel clockwise until waveform is square.

(d) turn locking ring clockwise until square.



20.Unscrew end of connector and insert probe tip. Tighten end until probe is secure.

Notes #1 The desired waveform is called a square wave. A square wave is flat on the top and bottom, and all its angles are 90°.

#2 It is important to tune the probe correctly so that you get an accurate picture of the input signal.

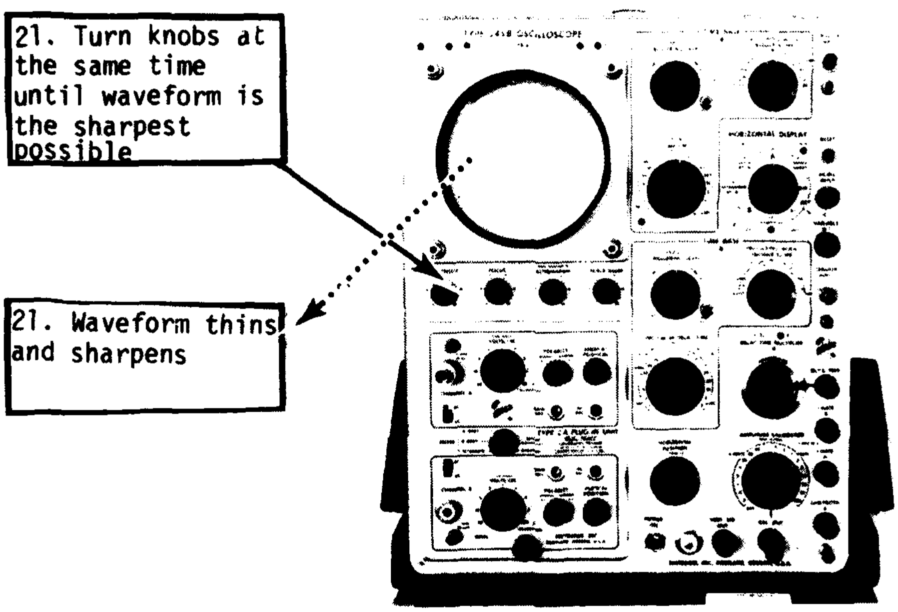
TEST:

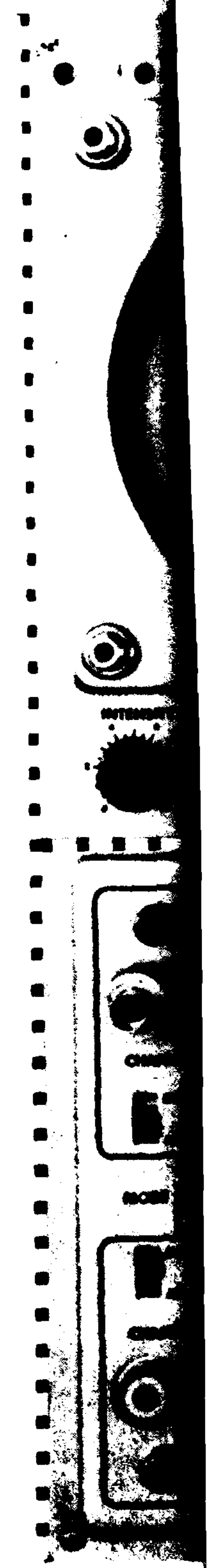
Answers:

Step 21: Adjust FOCUS and ASTIGMATISM controls

<u>Purpose</u>: To sharpen display

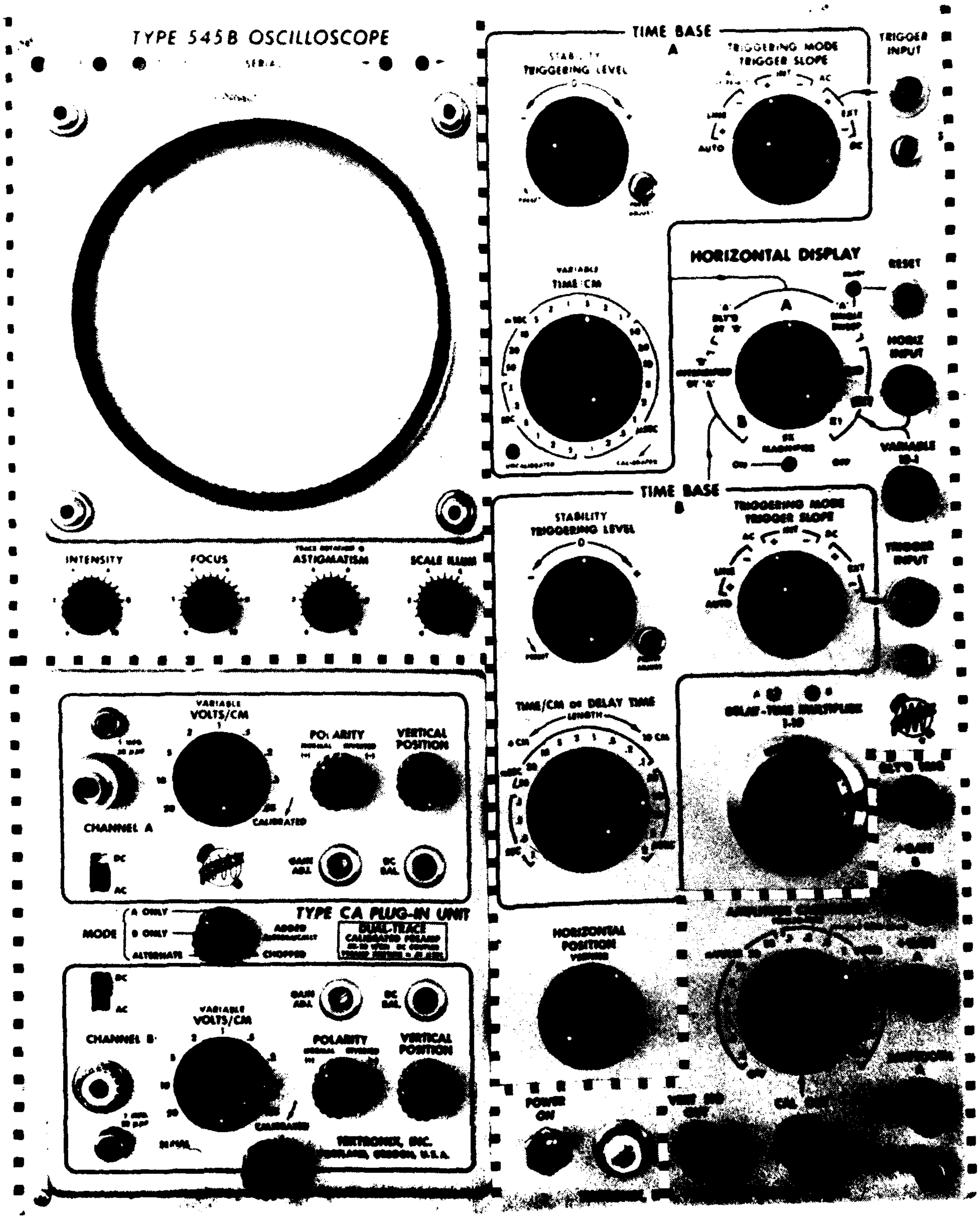
<u>Response</u>: Waveform thins and sharpens.





DISPLAY

HORIZONTAL CONTROL



VERTICAL CONTROL

POWER

CALIBRATION and OUTPUT

APPENDIX D

SCRIPT FOR BRIEFING STUDENTS

SCRIPT FOR BRIEFING STUDENTS

INTRODUCTION

The study in which you are participating is an evaluation of three different methods for learning a procedural task; more specifically, learning how to calibrate an oscilloscope probe.

The Navy spends millions of dollars each year training seamen, like yourself, how to operate and maintain expensive and complex equipment. The Chief of Naval Education and Training sponsors studies like this one to find ways to improve and enhance existing Navy training programs.

The purpose of this evaluation is to determine which of these three training materials results in the best performance and recall of how to calibrate an oscilloscope probe.

For the next 2 hours you will be involved in a series of study sessions and short tests. You will be limited to 1½ hours of total study time. I will give you the necessary instructions for each step as we come to them.

INITIAL STUDY PHASE

The first thing I would like you to do is to read this handbook just one time through. Pay special attention to any instructions given in the handbook and carefully study all parts of it. If you need any assistance, feel free to ask me. When you are finished, close the book, you will then be given a short performance test on the oscilloscope and a 22-question multiple-choice test. You may open the book and begin.

PERFORMANCE TEST

When I tell you to begin, try to calibrate the probe on this oscilloscope in the same way it was presented to you in the study material. Try to remember the same sequence of steps and control settings. You are not expected to get the entire procedure correct this time, but do the best you can. I will be recording errors and keeping track of the time it takes you to perform the task. You may begin.

JOB KNOWLEDGE TEST

The purpose of this test is to get an indication of how well you understand the concepts and job knowledge information presented in your handbook. Read each question carefully and blacken in your answer on the attached answer sheet. You may begin.

PRACTICE PHASE

For the next _______ minutes (1.5 hrs. minus the time in initial study trial for each S) you will be required to re-read and study our training handbook. Pay special attention to those steps and control settings you had problems with during the performance test. I will tell you when your allotted time is up; then you will once again go to the equipment and perform the calibration procedure. You may open the book and begin.

PRACTICE PHASE

When I tell you to begin, calibrate the oscilloscope probe using the same sequence of steps and control settings that you just finished studying. I will once again record errors and keep track of the time it takes you to perform the task. You may begin.

----- after test -----

You have just completed this portion of the evaluation. In 1 week you will return to take one more performance test. In the interim, do not attempt to rehearse the procedure or study any materials about the oscilloscope.

RETENTION PHASE TEST (1 week)

Take 2 minutes to look at the oscilloscope to familiarize yourself with the equipment, and try to recall the steps of the calibration procedure. When I tell you to begin, calibrate the probe--try to remember the exact sequence of steps and control settings that you learned last week. Once again, I will record errors and keep track of the time it takes you to perform the task. You may begin.

APPENDIX E

JOB KNOWLEDGE TEST

JOB KNOWLEDGE TEST

Answer all the questions in this section and check your responses with the Answer Sheet provided.

1. An oscilloscope lets you see what is taking place in a circuit by

   a. X-raying the circuit under test and producing a photographic display of the signal
   b. graphically displaying voltage amplitude, wave shape, phase and frequency of a waveform
   c. graphically displaying circuit current and resistance
   d. analyzing the input and output of the circuit and producing a photograph of the circuit action.

2. The ON/OFF switch

   a. varies the brightness of the sweep
   b. turns power on and off
   c. varies the illumination of the graph on the CRT face
   d. horizontally positions the trace.

3. The FOCUS control

   a. varies the point where the electron beam converges
   b. varies brightness of the sweep
   c. varies the concentration of the electron beam
   d. moves the sweep up and down.

4. The INTENSITY control

   a. varies the brightness of the sweep
   b. turns the power on and off
   c. illuminates the graph on the CRT face
   d. varies the concentration of the electron beam.

5. The SCALE ILLUM. control

   a. turns the power on and off
   b. varies the brightness of the sweep
   c. adjusts the oscilloscope for a stable presentation
   d. varies the illumination of the graph on the CRT face.

6. The ASTIGMATISM control

   a. varies the concentration of the electron beam
   b. turns the power on and off
   c. varies the point where the electron beam converges
   d. magnifies the horizontal sweep by a preset factor.

7. The HORIZONTAL DISPLAY control

   a. magnifies the horizontal sweep by a preset factor
   b. determines how the time bases will be displayed on the CRT
   c. lengthens or shortens the sweep with respect to time
   d. determines the point at which the sweep triggers.

8. The 5X MAGNIFIER control

   a. magnifies the horizontal sweep by a preset factor
   b. moves the entire sweep horizontally
   c. varies the amplitude of the vertical signal displayed
   d. changes the coupling of the vertical input signal.

9. The TIME/CM control

   a. moves the entire sweep horizontally
   b. magnifies the horizontal sweep by a preset factor
   c. picks the source of the trigger signal for synchronization
   d. lengthens or shortens the sweep with respect to time.

10. The HORIZONTAL POSITION control

   a. moves the entire sweep up or down
   b. moves the entire sweep horizontally
   c. determines the point at which the sweep is triggered
   d. magnifies the sweep by a preset factor.

11. The VOLTS/CM control

   a. moves the entire sweep up or down
   b. varies the amplitude of the vertical signal displayed
   c. lengthens or shortens the sweep with respect to time
   d. moves the entire sweep horizontally.

12. The VERTICAL POSITION control

   a. moves the entire sweep horizontally
   b. varies the amplitude of the vertical signal displayed
   c. moves the entire sweep up or down
   d. magnifies the horizontal sweep by a preset factor.

13. The AMPLITUDE CALIBRATOR control

   a. varies the amplitude of the vertical signal displayed
   b. determines the amplitude of the square wave at the CAL OUT connector
   c. determines the amplitude of the triggering signal
   d. moves the entire sweep up or down.

14. The AC/DC control

    a. changes the coupling of the vertical input signal
    b. adjusts the oscilloscope for a stable presentation
    c. determines at what point the sweep triggers
    d. picks the source of the trigger signal for synchronization.

15. The TRIGGER SLOPE control

    a. determines the point at which the sweep is triggered
    b. adjusts the oscilloscope for a stable presentation
    c. determines at what point the sweep triggers
    d. picks the source of the trigger signal for synchronization.

16. The TRIGGERING MODE control

    a. picks the source of the trigger signal
    b. determines the point at which the sweep triggers
    c. changes the coupling of the vertical signal
    d. lengthens or shortens the sweep with respect to time.

17. The VARIABLE TIME/CM control

    a. adjusts the oscilloscope for a stable presentation
    b. picks the source of the trigger signal for synchronization
    c. when calibrated, holds the sweep speed constant
    d. lengthens or shortens the sweep with respect to time.

THE FOLLOWING LIST IS TO BE USED TO ANSWER QUESTIONS 18-22:

1. ON/OFF
2. FOCUS
3. INTENSITY
4. SCALE ILLUMINATION
5. ASTIGMATISM
6. HORIZONTAL DISPLAY
7. TIME/CM
8. VARIABLE TIME/CM
9. HORIZONTAL POSITION
10. VOLTS/CM
11. VARIABLE VOLTS/CM
12. VERTICAL POSITION
13. AMPLITUDE CALIBRATOR
14. AC/DC
15. MODE
16. TRIGGER SLOPE
17. TRIGGERING MODE
18. 5X MAGNIFIER

18. If you have an oscilloscope with a blank screen, the problem could be caused by which controls?

    a. 1, 3, 9, 12
    b. 1, 4, 8, 10
    c. 1, 3, 7, 10
    d. 1, 3, 5, 11

19. What controls will cause a blurred presentation on the CRT?

    a. 2, 3
    b. 2, 5
    c. 2, 7
    d. 1, 5

20. If the grid on the CRT is not illuminated, the misadjusted control is

    a. 2
    b. 8
    c. 4
    d. 3

21. A vertical signal that extends beyond the limits of the CRT can be corrected by using the ______________ control.

    a. 12
    b. 15
    c. 9
    d. 10

22. A 10:1 probe attenuates the voltage of a measured signal by a factor of

    a. 5
    b. 1
    c. 100
    d. 10

APPENDIX F

ANALYSIS OF VARIANCE SOURCE TABLES

TABLE F-1. ANOVA SOURCE TABLE FOR PERFORMANCE ERROR DATA

Source	SS	df	MS	F
Method	1899.23	2	949.61	43.03**
Aptitude	598.53	1	598.53	29.10**
Method X Aptitude	24.80	2	12.40	.60
Trials	1312.14	2	656.07	203.88**
Method X Trials	209.04	4	52.26	16.24**
Aptitude X Trials	2.15	2	1.08	.33
Method X Aptitude X Trials	40.04	4	10.01	3.11*

*$p < .05$
**$p < .01$

TABLE F-2. ANOVA SOURCE TABLE FOR PERFORMANCE TIME DATA

Source	SS	df	MS	F
Method	3687.756	2	1843.87	.18
Aptitude	93409.200	1	93409.20	9.21*
Method X Aptitude	9098.866	2	4549.43	.45
Trials	427089.066	2	213544.53	61.67**
Method X Trials	9362.244	4	2340.56	.62
Aptitude X Trials	13379.288	2	6689.64	.15
Method X Aptitude X Trials	9299.311	4	2323.83	.61

*$p < .05$
**$p < .01$

TABLE F-3. ANOVA SOURCE TABLE FOR JOB KNOWLEDGE TEST DATA

Source	SS	df	MS	F
Method	67.75	2	33.88	5.54**
Aptitude	368.04	1	368.04	60.18**
Method X Aptitude	26.28	2	13.14	.122

**$p < .01$

DISTRIBUTION LIST

Air Force

Headquarters, Air Training Command (XPTD) (Dr. Schufletowski)
Headquarters, Air Training Command (XPTIA, Mr. Goldman)
Air Force Human Resources Laboratory, Brooks Air Force Base
Air Force Human Resources Laboratory (Library), Lowry Air Force Base
Air Force Office of Scientific Research/AR (Dr. A. R. Fregly)
Headquarters Tactical Air Command (DOOS), Langley Air Force Base
AFMTC/XR (Capt. Englebretson), Lackland Air Force Base
Headquarters 34 TATG/TTD (Lt. Col. Lee), Little Rock Air Force Base
Headquarters MAC/DOTF (Capt. Orler), Scott Air Force Base
Defense Language Institute (J. Sisk), Lackland Air Force Base
Technical Training Division (Lydia Hooke), Lowry Air Force Base

Army

Commandant, TRADOC (Technical Library)
ARI (Dr. Ralph R. Canter, 316C; Dr. Edgar Johnson; Mr. James Baker;
Dr. H. F. O'Neil, Jr.; Dr. Beatrice Farr, PERI-OK)
ARI Field Unit - Fort Leavenworth
ARI (Reference Service)
USAMMCS (Mr. Ryder)
USADARCOM (DRXMD, Mr. Ayers)
The Adjutant General Center (Dorothy Nicewarner)

Coast Guard

Commandant, U.S. Coast Guard Headquarters (G-P-1/62; G-RT/81)

Marine Corps

CMC (OT)
CGMCDEC (Mr. Greenup)
Director, Marine Corps Institute
CO MARCORCOMMELECSCOL (ITS) (Mr. D. E. Mueller)

Navy

OASN (R&D, Dr. S. Koslov; MRA&L)
CNO (OP-102X, M. Malehorn; OP-987P10, Dr. R. Smith; OP-987, Mr. H. Stone)
NAVCOMPT (NCD-7)
ONR (458 (2 copies), 455)
CNM (MAT-08T2, Mr. A. L. Rubinstein)
CNET (01, 00A, N-5 (6 copies), N-532 (CDR Corkins))
CNAVRES (02)
COMNAVSEASYSCOM (03, 05L1C, 05L1C2)
COMNAVAIRSYSCOM (03, 340F, 413G)

DISTRIBUTION LIST (continued)

Navy (continued)

CO NAVMEDRSCHDEVCOM (CAPT H. J. Connery)
CNTECHTRA (016, Dr. Kerr (5 copies))
CNATRA (Library)
COMTRALANT
COMTRALANT (Educational Advisor)
NAVAIRREWORKFAC (J. H. Jackson)
COMTRAPAC (2 copies)
CO NAVPERSRANDCEN (Library (4 copies); 309 (Mr. Wisher); Kent Huff)
NAVPERSRANDCEN Liaison (01H)
Superintendent NAVPGSCOL (2124)
Superintendent Naval Academy Annapolis (Chairman, Behavioral Science Dept.)
CO NAVEDTRAPRODEVCEN (AH3; EAT, Dr. Smith)
CO NAVEDTRASUPPCEN NORVA (00 (2 copies); N1111, Joe Fazio)
CO NAVEDTRASUPPCENPAC (5 copies)
CO NAVAEROMEDRSCHLAB (Chief Aviation Psych. Div.)
CO FLTCOMDIRSYSTRACENPAC
CO NAMTRAGRU
CISO, NTTC Corry Station
CO NAVTRAEQUIPCEN (N-424 (2 copies), N-211, N-001, N-002)
Center for Naval Analyses (2 copies)
U.S. Naval Institute (CDR Bowler; Mary Jones)
OIC NODAC (2)
CO TRITRAFAC (2 copies)
CO NAVSUBTRACENPAC (2 copies)
CO FLEASWTRACENPAC
CO FLETRACEN SDIEGO
CISO, SSC (Dr. Flesch)
Executive Director NAVINSTPRODEVDET
CO NAVTECHTRACEN Corry Station (Cryptologic Training Department)
NETSCPAC Field Office Mare Island
Supply Schools Training Officer (Code 730), Meridian
Office of Civilian Personnel, Southern Field Division (Jim Herndon)
VT-10 (Education Specialist)
CO NAVSUBSCOL NLON (Code 0110)
CO NAVTECHTRACEN Treasure Island (Technical Library)
NTIPP (S. Rainey)
NAVSHIPWPNSYSENGSTA (Code 5700, Mr. Radcliff)

Other DOD

Military Assistant for Human Resources, OUSDR&E, Room 3D129, Pentagon (CDR Paul Chatelier)
OASD (MRA&L) (LT COL Grossel)
Program Manager, Office of Cybernetics Technology, Defense Advanced Research Projects Agency (Dr. J. Dexter Fletcher)
Institute for Defense Analyses (Dr. Jesse Orlansky)
COM National Cryptologic School (Code E-2)

DISTRIBUTION LIST (continued)

Information Exchanges

DDC (12 copies)
DLSIE (Mr. James Dowling)
Executive Editor, Psychological Abstracts, American Psychological Association
ERIC Processing and Reference Facility, Bethesda, MD (2 copies)

Non-Government

Westinghouse Electric Corp. (Mr. Kniffin)
Ohio University (Mr. Klare)
NCR Corporation (Mr. Brusaw)
American College Testing Program (Dr. Olivier)

Other Government

Social Security Administration (Linda Smith)
OSI/IPS (Diana M. Tansill)
OSI (Mr. Krumm)