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ABSTRACT

The Lincoln Terminal System is described as a device with the capability to deliver technical information, to monitor student performance, and to assure learning in industrial training. The experimental hardware and the lesson material for the system were tested in two mine maintenance schools and the results show that: (1) student users of the system improved substantially on tests; (2) students found the material and the means of presentation acceptable; and (3) supervisors were favorable to the use of the system. Mine training instructors will proceed to format instructional materials for computer instruction. Field test results and sample lessons are provided. (EMH)

LINCOLN LABORATORY LTS-3S TRAINING SYSTEM: APPLICATION TO TEACHING ESSENTIAL MINING SKILLS

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The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or of the U.S. Government.

FOREWORD

This report was prepared by Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Massachusetts 02173, under USBM Contract Number HO346079. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of PMSRC with Mr. James C. Ault acting as the Technical Project Officer. Mr. Michael W. College was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period 1 July 1974 to 1 August 1975. This report was submitted by the authors on 15 July 1975.

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LINCOLN LABORATORY LTS-3S TRAINING SYSTEM: APPLICATION TO TEACHING ESSENTIAL MINING SKILLS

I. SUMMARY AND RECOMMENDATIONS

The Lincoln Terminal System is described as a device with the capability to deliver technical information, monitor student performance, and assure learning in industrial training. An experimental unit, the LTS-3S, was constructed and delivered to the Bureau of Mines with appropriate lesson material for a test of feasibility and acceptability of this form of training in the mining environment. Operations were conducted at two mine maintenance schools. The overall results were that (1) there was a substantial improvement between tests before and after self-training on the LTS, (2) students found this an acceptable way to learn, and (3) reaction by training personnel and supervisors was favorable toward the feasibility and advantages of using the LTS in the mining environment. Transfer of the LTS to industry depends on availability of reliable units and adequate lesson material.

The requirements for authors of training materials were established based on advice from mine training experts, formal analysis of lesson development procedures, and experience from efforts in lesson development at Lincoln Laboratory. It was concluded that experienced mine training instructors were best qualified to proceed effectively and economically to format instructional material for the LTS, if supported by well-designed facilities and services. Discussion with mining experts confirmed the desirability of generating training materials and delivering instruction at distributed locations to meet local training needs and in direct support of industrial operations.

It is recommended that a phased program to transfer LTS technology to the mining industry be implemented as follows:

(a) Complete the design development and specification of a reliable and economical terminal suitable for commercial production (LTS-5).

(b) Develop and program an extended terminal (LTS-5X) that will give local authors:

  (1) Instruction on LTS lesson design methods and techniques.

  (2) The capability to create a logic file and to run lessons on the machine in a simulated mode.

  (3) The capability to accept and display student performance data recorded at LTS-5 terminals.

(c) Conduct tests of the LTS-5X lesson development support functions at one or more training sites and use the results to perfect the design prior to release.

(d) Complete engineering development of the microfiche production facility with procurement specifications.

II. INTRODUCTION

This is the final report of a one-year effort under a contract with the U. S. Bureau of Mines to determine the feasibility of application of the Lincoln Terminal System (LTS) to training in the mining industry. The major efforts under the contract were:

> Construction, documentation, and delivery of an LTS-3S model instructional unit to the Bureau.
>
> Development of prototypical lesson material on mine safety for the machine.
>
> Demonstrations at various sites and a formal field trial of the concept in mine maintenance training schools.
>
> Site visits, discussions with instructors and training supervisors, and research on the problems of training facing the industry.

This report is the final outcome of these efforts. It attempts an orderly exposition of new findings and specific recommendations to assist in transfer of this new technology to the mining industry.

III. THE LINCOLN TERMINAL SYSTEM (LTS) AS AN INSTRUCTIONAL UNIT FOR TRAINING

The purpose of using the Lincoln Terminal System for training is to provide a degree of automated instruction to enhance the rate and quality of learning. In a typical training situation, students differ widely in learning skills and background. As a result, presentations to groups in the classroom often move too slowly for some students and too rapidly for others. If students are handled on an individual basis or a few at a time by the instructor, those not receiving attention often are not fully occupied. Trainees can learn to some extent on their own, but many times they must have individual help. The help they need depends on the kind of mistakes they make, and in the school the instructor is the only means available to diagnose learning difficulty and give proper remediation. Mine maintenance training instructors report they are overloaded and have trouble giving adequate attention to individual problems if the number in a class exceeds ten. The purpose of the LTS as an instructional unit is to reduce the load on the instructor by using the machine not only to convey information but also to interact with the individual student to help him to solve problems he encounters in learning. If the dependence of the trainee on the instructor can be reduced in this way, two benefits will occur. First, the number of students served by one instructor can be multiplied by two or three times. Second, the instructor's attention can be devoted to the students with the greatest learning difficulty and to the teaching of skills that cannot be delivered by machine. The goal is to extend the number of students an instructor can handle and to improve the overall quality of the results.

Machine-supported learning to be effective must include display of detailed information, diagnosis of student learning difficulties, and branching to proper remediation. More specifically, it must be able to convey technical information such as drawings, photographs, diagrams, data, text, etc., in considerable detail. It must be able to present problems to the student, accept answers, diagnose errors, and branch to remedial material which is appropriate to the kind of error made. A typical strategy for using a machine of this kind is to deal with a new topic in a tightly related set of frames. (A "frame" is a single audio/visual display either of information or of a problem of some kind.) Usually, new information is presented in one frame or a string of several successive ones and on the following frame understanding of this information is tested. The test must be a fairly difficult one in which guessing is unlikely to produce a correct answer by chance. If the answer is correct, learning is assumed to have occurred and the trainee is directed to a new topic. If some failure is detected, he is moved to new remedial information appropriate to the specific kind of mistake. For example, the error may indicate that the student needs to review old material that he was supposed to have already mastered. Or he may need an expanded or alternative explanation of a new topic with which he is having difficulty. When he is done with the remediation, a test is given again, and if successful, the student then goes on to the next topic. If, however, failures are repeated, he is told to "Go find your instructor" or obtain help from an outside source such as reference materials. The Appendix presents an example of this form of training. The training technique of the LTS is extensively illustrated there, and it is suggested that the reader take time at least to scan through it.

It has been demonstrated many times that this method of training is highly effective. With adequate lesson materials, students can progress rapidly on their own. Computer terminals, along with printed or photographic supplementary materials, have proved effective in instruction in computer maintenance, principles of electronics, dentistry, etc. The Lincoln Terminal System (LTS) captures the same training capability in a stand-alone machine which is far more versatile and less costly than one based on conventional computers. Each LTS unit – one per student – has both the data processor and audio/visual information built in. Two of its capabilities, to produce detailed visual images and to deliver a 20-second audio message with each display, are not found in computer systems. Although not always essential to learning, the audio feature enhances lesson delivery in a number of ways. Voice has the overall effect of lending a human quality to the machine. It can be used for emphasis, warnings, and to reinforce learning. It also provides an alternative channel for communicating with the student who has difficulty with reading. And finally, a student listening to audio with earphones is blocked off from noise distractions in his environment. Other media such as sound/slides, motion pictures, and TV have a sound-track capability. These are linear, however, and there is only one path through the material. With the LTS on the other hand there are many paths, one for each student determined by his record of specific successes and failures. The audio as well as the visual presentation is arranged to meet his particular need of the moment. This is called "random access" displays; the presence of random-access audio is unique to the LTS. Students respond very favorably to this feature, and it is our conviction that the presence of random-access audio substantially extends the range of students who will succeed in this form of training.

The LTS realization of automated training has been demonstrated as effective in a large study supported by the U.S. Air Force. These results are summarized in the next section. Under the contract, a field test of training mine mechanics has also been completed. These new results are reported in the following section. The purpose in both studies was to determine (1) if mastery of the material is achieved, (2) if learning proceeds with little dependence on outside help, and (3) if this form of training is acceptable to the students.

IV. FIELD TEST OF THE LTS CONCEPT IN THE U.S. AIR FORCE

An extensive study[1] was conducted at the School for Applied Aerospace Sciences at Keesler Air Force Base in Mississippi. Lessons were prepared for the LTS covering the sixth week of the Basic Electronics Course, normally 30 hours of classroom and laboratory instruction.

The subject matter was series and parallel RCL circuits, and the authors of the lessons were military and civilian personnel at Keesler. The hardware system was one that was very similar in operation to the present stand-alone model, although five terminals shared a minicomputer rather than each having its own processor. (Under the present contract, one of the electronics lessons was converted to the newer machine. The conversion process was not difficult, and the resultant lesson was virtually identical to the original.) The principal findings for the initial experiment on 55 students were as follows:

Mastery of the material was as complete for LTS students as for a matched control group in the regular classroom.

There was a 37 percent savings in learning time when compared to the time (30 hours) allotted for classroom delivery.

Students spent an average of less than 2 percent of their time receiving help from their instructor.

The trainees expressed a very positive set of attitudes toward this form of training.

The students were selected from a group that fell in the 80 to 96 percentile on a test of electronics aptitude and had 12 years of prior education on the average. Twelve of the lessons presented electronic principles, involving problems of circuit analysis, selection of a formula, and algebraic calculations. There were two other lessons that showed the student how to hook up bench equipment to test empirically the operation of the circuits. The lessons covered theory rather than application, they differ, for example, from the material in the Appendix which deals with electrical practice and the Law and very little with principles of electricity. Under these circumstances, the LTS proved to be an efficient, effective, and highly acceptable means of instructional delivery.

A continuing series of experiments provided additional results. Some students were trained in pairs, working through the material together but tested separately, they moved as rapidly and performed as well on the test on the average as singles. High-aptitude students in the 96 to 100 percentile also ran on the LTS and benefited markedly both in terms of reduced training time and improved test scores. A review of findings based on about 200 trainees on the LTS shows that the slowest students seek help from an instructor and take longer on the lessons than might be expected. Apparently as a direct consequence, the number of trainees who failed the final test, leading to a "wash back" in the course, was reduced by about 50 percent. This result suggests that indeed training with the LTS tends to give the most help to students with the greatest need.

V. FIELD TEST OF LTS-3S IN MINE TRAINING SCHOOLS

There was every reason to suppose that the LTS would be equally effective at training mine mechanics as it was for electronic technicians. But the students, the objectives of the schools, and other factors were sufficiently different to warrant a demonstration of its potential, and so a field trial was initiated under a contract for the Bureau of Mines. Four lessons were prepared by Lincoln Laboratory on mine safety, serving a primary mission of the Bureau of Mines. The subjects included the nature of electrical hazard and the meaning of the Mine Safety Act of 1969 as applied to problems of electrical ground. The goal of training in this instance is to impart the knowledge which mine mechanics _must_ have to perform in a safe and proper manner. The purpose of the study was. (1) to prove that learning of such material does occur using the LTS, (2) to assess student acceptance, and (3) to gather opinion and comment from instructors and their supervisors on the potential of this new technology.

The lessons developed for this test included:

(a) _Man as a Conductor of Electricity_: an explanation of shock hazards and their effects on the human body.

(b) _Solid Grounds_: connections to earth, system and frame grounds, resistance grounding.

(c) _The Law and Grounding_: review of Parts 75 and 77 of the Law relative to grounding covering low-, medium-, and high-voltage circuits.

(d) _Problems in Grounding_: electrical connection of a piece of mine equipment to a source of power is made by the student, and violations of the provisions of the Law are detected and corrected. (The Appendix shows in detail part of a problem from this lesson.)

Each trainee was given a test before instruction, worked on his own for about 45 minutes on one or two lessons, was given another test, and filled out a brief questionnaire on the experience. Training was conducted at two sites in Pennsylvania, the mine maintenance training school of the Jones and Laughlin Steel Company near the town of California and the Admiral Peary Vocational and Technical School at Ebensburgh. Students from these two schools, as well as trainees from the Barnes and Tucker Coal Company, participated in the tests. Two LTS-3S experimental delivery units were used, the one delivered to the Bureau under the contract and a second one assigned by Lincoln for the test. . The Bureau machine was transported by truck in an impact-cushioned crate, and the Lincoln unit rode uncrated in a passenger van. Transport in either mode seemed to have no adverse effect and the setup time for a machine was less than one half hour.

Eight students were able to finish only _Man as a Conductor_ in the time allotted, they were younger, less experienced students enrolled at the Admiral Peary Vocational School. Each of the experienced miners, from the Jones and Laughlin and the Barnes and Tucker maintenance training classes, was able to complete one of the other lessons as well, five finished _Problems in Grounding_ and nine _Methods of Grounding_. (The fourth lesson, _Law and Grounding_, was intended as a review for highly experienced mechanics and electricians and thus was not used in this study.) The test beforehand covered all four lessons. The Admiral Peary students scored 43 percent on the average on this test and the experienced miners 58 percent. Tests were scored for questions on material actually taken to measure progress due to learning on the machine. Table I shows scores before and after the lessons for each group. Improvement from 11 to 14 percent over the three groups indicates that substantial learning did occur even in a period of time of less than one hour.

The acceptability of this form of training is reflected in a brief questionnaire given at the end of the learning session. The questions and the frequency of responses are shown in Fig. 1. All students agreed on the first question that the difficulty of learning was "just right," despite the fact that the less experienced students were able to finish only one lesson in about three-fourths of an hour and the more experienced two. This is indicative of how successfully LTS

TABLE I.

SCORES IN PERCENT BEFORE AND AFTER LTS TRAINING

Lessons Taken	Score Before	Score After	Change
Man as a Conductor	50	63	+13
Man as a Conductor Problems in Grounding	72	83	+11
Man as a Conductor Methods of Grounding	55	69	+14

1) How difficult was learning on the machine?

_____ too tough   25 just right   _____ too easy

2) Would you rather learn this material from a book?

_____ yes   2 maybe   23 no

in the classroom?

4 yes   9 maybe   12 no

from a film?

7 yes   8 maybe   10 no

3) Was the voice of the machine helpful?

_____ never   11 sometimes   14 always

4) Did you ever have trouble putting answers in the keyboard?

11 never   14 sometimes   _____ always

Fig. 1. Questions with frequency of answers.

training adapts to individual learning needs, the response to the first question seems to show that trainees recognize and appreciate this feature. In the second question, no students prefer learning from books, but some prefer classroom learning or a film or TV presentation. There is quite a spread of opinion. Perhaps to some students, the phrase "Would you rather learn" means "Would you find it less demanding", in that case, preference for sitting in a class or in front of TV would be expected. The responses to the question on voice are typical – learning without the voice would be entirely possible but students usually say it is very helpful. As to the last question, students always find the LTS easy to use, but some expressed that they had difficulty due to minor equipment problems encountered with the experimental apparatus and to a few flaws in the new lesson material.

Attitude surveys and comments from students who learn on computer training systems and on the LTS have always been very favorable. Here, there was less than an hour of training, but in the Air Force study[1] students responded favorably even after 8 to 30 hours on the system. The longest duration for continuous training in this form seems to be a Navy study[2] involving many weeks of computer-assisted training, six hours per day and five days per week, and it showed no decline in either performance or enthusiasm. A favorable attitude is obtained even after the novelty of this kind of training has worn off.

To summarize, the learning performance on LTS reported here, taken in conjunction with other findings, suggests that this form of training will likely increase the speed of learning and assure mastery of the material for mine mechanics and will be highly acceptable to this kind of trainee. The implication is that trainees can acquire technical knowledge largely on their own and depend much less on instructor support. Some advantages of the LTS that capitalize on this potential as a means of delivery are discussed in the next section.

VI. APPLICATION OF LTS TO MINE TRAINING

As part of the contract, personnel from the coal companies, the unions, MESA, and the Bureau were contacted and surface and underground mining operations were visited in order to gain first-hand knowledge of the problems in mine training as they relate to the LTS. It was pointed out that this is basically a machine for instruction in facts, procedures, principles, and other skill knowledge. It does not, for example, teach eye-hand coordination and as a result is not appropriate for training operation of controls on mining equipment and similar applications. All personnel, however, are responsible for learning safety and must have knowledge about the Mine Safety Act, safe methods, and procedures. Furthermore, the demands for better understanding placed on maintenance, repair, and supervisory personnel is increasing as the number, variety, and complexity of mine machinery grows, new technology is involved and new knowledge is required to cope with it. The general impression was gained that means for increasing skill knowledge of miners, mechanics, electricians, and supervisors is in universal demand, and if it could be met the safety and productivity of coal operations would benefit greatly.

The time-honored method of on-the-job training, the apprentice guided by a journeyman, is no longer feasible because journeymen are not well equipped to instruct, and costly operations cannot be halted while time is taken to indoctrinate a new person. To a considerable extent, industrial training responsibility has shifted to central operations such as VoTech, commercial, and military technical schools. Although the large school is efficient, this kind of training is often incomplete and graduates are by no means fully prepared to perform a job. The job requirements at different sites vary tremendously with respect to equipments, procedures, and the work environment, and a central school cannot tailor each student's program differently in preparation for his specific job circumstances. Another factor is that a broad range of topics is covered in long courses of training, and there is much forgetting between the time of original learning and application in the field. Often in industry training is conducted close by the industrial operations. In mining it is done at the maintenance shop, the portal, the mine office, etc. The LTS has the flexibility and versatility to adapt to an operation close to the mining site where it is possible to structure training as an extension of regular mining operations. There it can be tailored to specific equipments, local procedures, and immediate needs, and what is learned can be applied to the job before it is forgotten.

There are other forms of technical aids to individual instruction that are effective but none have the versatility of the Lincoln terminals. The efficiency of individualized instruction, i.e., managing each student's learning separately, was revealed by training research in the 1960s. It was found that the digital computer was the most effective means to manage the learning process on an individual basis. It proved an expensive and often cumbersome way to train, however, and as a result has been used only on a limited scale. Computer charges are high and the detailed visual displays required for technical subject matter cannot be stored and retrieved economically by electronic means. Access to large mass memories is likely to remain costly, with communication charges to users at distributed locations perhaps even increasing with increasing demand. In the area of processing though, a truly significant new electronics development has occurred. It is the microprocessor which permits each user to have his own computing power instead of being coupled to a large machine and sharing it with others. Microprocessors are becoming cheaper and more powerful every day. As a consequence, in many cases it is more economical to have a complete data processing capability in each terminal than to pay communication costs to a central machine. In this case the terminal need be tied to nothing but an ordinary source of electric power. Presently available microprocessors have the capability to manage learning but, like computers, do not have the memory to support detailed visual displays. These may be handled "off-line," as they have in several experimental computer-based systems, in the form of text, slides, and other conventional media. The handling of lesson materials separately is unwieldy however, and so the LTS incorporates not only its own microprocessor to manage and monitor student learning, but also its own microfilm store of thousands of visual images. It combines the advantages of computer processing with mass information store on film in a single, integrated unit. Because it operates in stand-alone fashion, it is practical to administer instruction at distributed and isolated sites, such as those in the mining industry.

The present experimental model of the LTS appears to have a more than adequate capacity for mine training on-site or in a school setting. If this new technology is to be made widely available, it will be necessary to develop a commercial source of equipment and facilitate the development of instructional materials. These matters are considered in the following sections.

VII. THE LTS-5 PRODUCTION PROTOTYPE

A production prototype (LTS-5) design is shown in Fig. 2. At the left is an 8-1/2 × 11 black-and-white projection, a photographic image of a very high quality that may appear in a horizontal as well as vertical orientation. With each picture, there is up to 20 seconds of audio available by headphones or loudspeaker. There is capability to accept commands and to interpret answers to questions that are entered on the keyboard shown at the right. Numbers

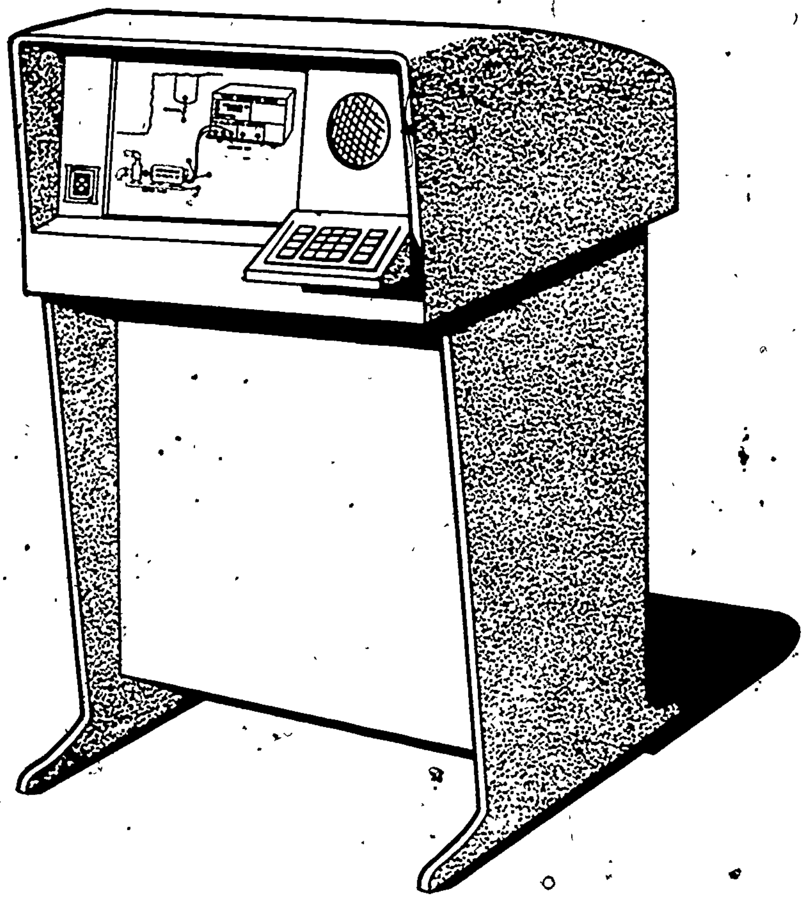


Fig. 2. LTS-5 proposed design.

entered on the keyboard appear on a small display above the keys. Student responses are interpreted by the machine, and appropriate branching to a new audio/visual frame occurs. These capabilities represent a system that should be adequate to serve over a very wide range of skill knowledge training. For reasons of economy and for improved reliability and maintainability, a number of non-critical features were not included in the design.

Some features of media may be used to enhance motivation, thus, color, animation, and the like are used in attempt to sustain interest. They may be important in conventional classroom instruction where the pace is set by the slower learner, but they are much less significant in a system like the LTS where the student is continuously challenged and the pace is always "just right." Self-pacing and the fact that the student is held accountable for learning at regular intervals largely eliminates the need for external, artificial devices to attract and maintain attention. There are a variety of aids to understanding that might be added to a teaching machine, such as motion picture or computer-driven displays, recognition of words as inputs, simulations and games, etc. These add to the cost of the units, complicate maintenance, add to the cost of lesson development, and make the terminal more complicated for the student to use. As motivational aids, they are not required and they are seldom essential for technical training. Therefore, it does not seem cost effective to incorporate them as standard features for a production LTS terminal. Other multi-media and computer devices can be used in conjunction with the LTS, if they are in fact required. Two features appear to be desirable options for later consideration, full-color visual projections and a capability for the student to express his selection of objects on the visual display merely by pointing to them. Each appears feasible but engineering development is required.

The LTS-5 is designed to be an effective unit to deliver instruction within the wider context of a system of training. The basic medium is a 4 × 6-inch film card with 12 audio/visual frames per card. Up to 750 cards are loaded at a time in a carousel in the terminal, 9000 frames in all. This represents at least 100 hours of instruction, and reloading with new material is a simple operation. When a frame on a different card is selected, the carousel rotates to a new card, and it is loaded into a gate. The card is moved in the gate to one of the 12 audio/visual image pairs and the gate is closed. Frame-to-frame time is from two to five seconds. There are two projection lenses, one for the visual and one for audio. The visual image is projected to the screen. The audio image in the form of a width-modulated spiral sound track is projected to an optical scanner and audio sensor, a kind of optical phonograph. The functions of the machine are shown schematically in Fig. 3. The student views the screen and listens to the audio. The onset of the audio is delayed by a few seconds while a small burst of digital data (shown as a dotted line on the spiral) is fed to the processor. When the student reacts to the frame by pressing keys, the digital data are used by the processor to interpret the inputs and to select the next card/frame location. The student enters numbers to answer questions if called for, and they appear right above the keyboard on a display like those in pocket calculators, then he presses GO-ON and the processor interprets the inputs and goes on to the next appropriate frame. He also has options to CLEAR the display, REPEAT the audio, call for HELP or an INDEX, go BACK, and so on. Both interpretation of answers to questions and the other options are controlled by the data at the start of the audio spiral, the "frame logic" specified by the author for each frame in the lesson. Some inputs may not be legitimate on a frame, and a red light is turned on to indicate to the student to try again. Otherwise, a new card is selected if needed and a new frame and the cycle is repeated.

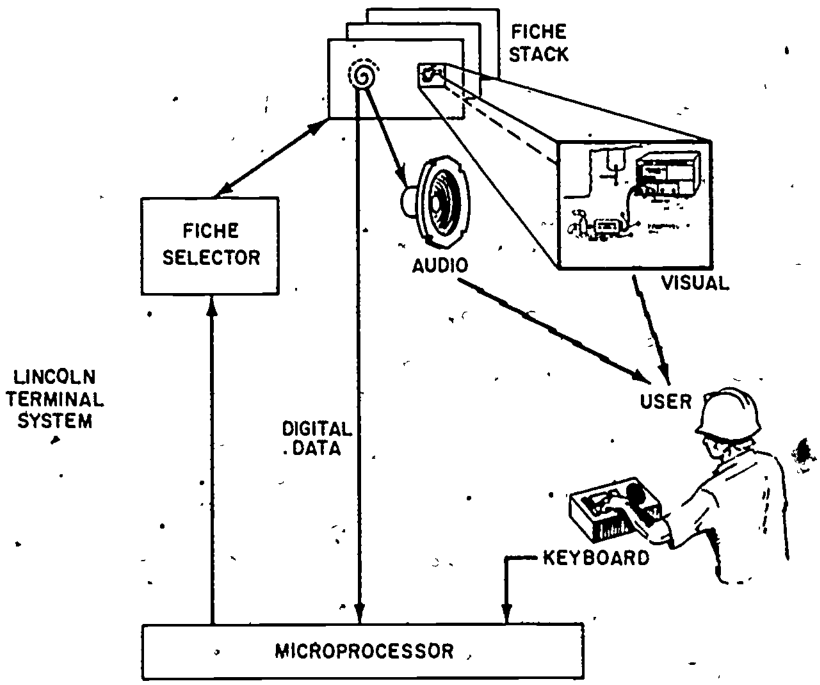


Fig. 3. Schematic drawing of the LTS Instructional Delivery Unit.

A separate contract between Lincoln Laboratory and the Bureau of Mines covers engineering development of the LTS-5 prototype, and procurement specifications are expected to be available in late 1976.

VIII. THE LTS LESSON DEVELOPMENT PROCESS

The effectiveness of LTS instruction depends vitally on the quality of lesson material. Because the whole learning process is managed by the lesson, the materials are more difficult to prepare than conventional text or descriptive matter. In the classroom, the text carries only part of the instructional load. Whatever technical information may be lacking is added by the instructor, and he carries the responsibility to hold each student accountable for learning. On the LTS, the lesson itself must be completely informative and monitor student progress if individual learning is to be sustained. Realizing the full potential of the LTS depends on finding efficient ways to produce such material.

There is first of all the need to find authors. The major qualifications for authoring are to be a subject matter expert, to have relevant job experience, and to have practiced the instruction of individuals or small groups. The preparation of materials for the field test in mine safety training revealed the inefficiency of using authors who are neither expert nor experienced in mining to prepare lessons. More than half the cost of developing the lessons was incurred in educating the authors about mining in general, electrical hazard, grounding circuitry, and the Mine Safety Act. Even so, when the material was reviewed for approval by the Bureau personnel, some misunderstandings in content had to be corrected and certain details were pointed out as unrealistic and possibly misleading. The resultant lessons were entirely satisfactory, but if the authors had had expert knowledge and experience from the start, the process would have been more efficient.

Design of lessons also benefits greatly from the kind of good judgment that is based on experience in teaching. On a quiz frame in a lesson, there are usually many more kinds of errors than it is feasible to deal with, the author must be able to anticipate the likely and significant kinds and remediate just those. The obvious conclusion is that the best candidate for authoring is the training instructor, typically he is an expert in his subject, he has practical experience, and he has proven capability to cope with individual learning problems. Perhaps it is not too great a simplification to say that the function the LTS performs is to capture the expertise of the instructor as well as technical information in a machine and to deliver it later to students at convenient times and locations.

Most efforts to use instructors to prepare materials for automated training systems have faltered badly because they have assumed that authors must learn computer technology, principles of individualized instruction, or some other fairly complex art. In the Air Force study (reported in Sec. IV), a number of factors conspired to force simplification of authoring procedures. LTS was conceived from the start as having very limited data processing capability, although with the advent of microprocessors since that time this constraint no longer holds. There was a limited amount of time to prepare the system and to train the authors. Finally, the authors were located in Mississippi and the system designers in Massachusetts, a separation of 1400 miles. As a consequence, the procedures for using the processor capability of the LTS, the aspect of the LTS these authors were unfamiliar with, were greatly simplified. The instructor-authors were offered five standard methods of fielding student inputs on a frame. They constructed a looseleaf notebook with a page specifying the elements of each frame in a lesson. The visual and audio were specified, and the author chose one of the five standard methods for handling student responses.

He filled out a table for each frame of what has come to be called the "frame logic," showing the kinds of erroneous response that could be expected and identifying a frame to go to for each kind of error. The lesson notebooks were sent to Lincoln Laboratory for editing and conversion to LTS. The lessons developed proved to be effective as the results of the study show. It was a major discovery that experienced instructors require little additional training to produce effective materials, given simplified procedures and adequate author support.

Although Lincoln personnel made no substantive changes in the Air Force lessons, it was troublesome to edit the lessons and to remove minor flaws and logical errors. One source of difficulty was that it was not always easy to determine the author's intent, there are some errors that can only be removed by the author himself. Moreover, errors of this kind were often not apparent until the lesson was converted to film cards and could be run on LTS. To do a complete job of editing, it is necessary to observe how frames relate to each other in operations as experienced by a student. The actual process of converting lesson material to film is not expensive, and the minimum turn-around time is only one or two days. Unfortunately, the real delays in getting a revised card are longer and during busy periods intolerable. The details of a particular lesson design essential to editing are easily forgotten. In response to the difficulty in finding errors, a breadboard checkout facility was implemented that permitted simulated running of a lesson before it is committed to film.

To check out a lesson on this facility, first a lesson logic file is created. The logic is inserted for each frame, in the same manner as entries are made in inventory control and other automated business systems. The user begins the simulated run by opening the lesson notebook to the first frame, looking at the visual, and reading the audio. He responds through a keyboard like the one on LTS as if he were a student taking the lesson. The response is processed according to the frame logic for that frame. However, instead of selecting a new card and frame on film, the page number of the next frame in the notebook is displayed. The user turns to that page and the process is repeated. In this manner he can proceed through the entire lesson much as if he were at a real LTS delivery unit. This facility was first placed in operation in editing the mine safety lessons. It has proven effective not only to remove technical flaws by an editor but also to permit authors themselves to evaluate their lessons as students experience them. Authors at Lincoln have been able to make major improvements in their material with this facility and have come to depend on it as a tool of good lesson design.

The present checkout facility at Lincoln is a breadboard version, adequate when used by technically sophisticated personnel. Our experience suggests that with some development effort it would be possible to engineer and document a practical facility for local checkout of lessons that would not require technical sophistication to run and not impose a very substantial added burden on the author/instructor as a user. Given access to this facility authors would retain firm control of the lesson design and have the capability to evaluate their lessons in operation either by themselves or by trainees and to revise them accordingly. On-site capability of this kind will add substantially to the efficiency of lesson development.

Initial investigation indicates that it would be feasible to extend the LTS-5 to provide the additional capability to create a logic file for a lesson in the machine, to run it in simulated mode, and to display notebook page numbers in place of frame selection on the machine. The LTS-5 has an optional capability to record student performance data, and the extended version of this machine, the LTS-5X, would also have the capability to sort, combine, and display these results in order to evaluate lesson development. Except for a small unit to interface the checkout facility to the LTS-5, the necessary equipment is available as commercial hardware components and would no more than double the cost of a terminal. A single LTS-5X could serve a number of authors, and it would seem attractive to have at least one at even small training schools to enhance training effectiveness. It would serve to generate new material, to speed up the revision and update of existing material to help insure that lesson content is matched to local conditions, procedures, and equipment.

Once a lesson has been developed in notebook form, checked out and revised, it is ready for the materials to be finished in preparation for conversion to film cards. The frame logic file prepared for final lesson checkout is the same one used in the production film cards. The audio is generated by the author himself, first in written form and then on conventional audio tape. Most authors are at first reluctant to record their own voices, but the results are in fact usually very satisfactory. A variety of voices over different lessons lends interest, and the author, unlike a professional talker, always knows exactly where to apply the proper emphasis. Audio can be recorded on any good commercial machine, and a tape is sent along with the notebook for transcription to film. Unlike generation of logic and audio, the drafting and finishing of artwork is a relatively time-consuming and expensive part of lesson development. It is not uncommon for 50 percent of the effort in developing a lesson to go into the visuals. Because the LTS is based on the film medium, it is especially economical to use photographs and to copy existing materials. Otherwise, the cost and methods of preparation of original copy are much the same as for printed materials. Lincoln used commercial artists to produce finished materials for some of the mine safety lessons with considerable success.

The final process of reproducing finished materials on film is straightforward, and relatively inexpensive. In the experimental system at Lincoln Laboratory, cards are produced at an operational cost of about $50 per master and $0.25 per copy. All lesson specific information is contained on the cards, this provides a single, highly economical medium for the production, copying, dissemination, storage, and revision of training material. The components of the film card production system are commercial units with the exception of the machine to produce audio spirals. For this technology to be transferred to industry, there is a need to develop a production-engineered unit to convert audio and logic to film spirals, to make other hardware improvements, and to document the system in detail both with respect to hardware specification and operational procedures. This would permit commercial services to adopt the technology and to support finishing, conversion, and distribution of training materials.

REFERENCES

1. W. P. Harris et al., "Keesler Test of Lincoln Training System Feasibility," Report 72-112, Keesler AFB: School for Applied Aerospace Sciences (31 July 1972); see also Report 73-116, "Study of Peer Training with the Lincoln Training System" (4 April 1973) and supplement thereto, Report 73-123 (25 July 1973), and Report 72-118, "Training High Aptitude Self-Paced Students on the Lincoln Training System" (28 November 1972).

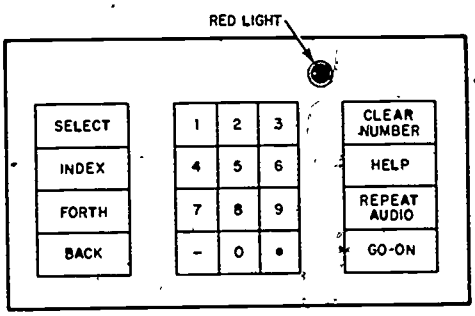
2. J. D. Ford, Jr., D. A. Slough, and R. E. Hurlock, "Computer Assisted Instruction in Navy Technical Training Using a Small Dedicated Computer System: Final Report," Research Report SSR 73-13, Naval Personnel and Training Research Laboratory, San Diego (November 1972).

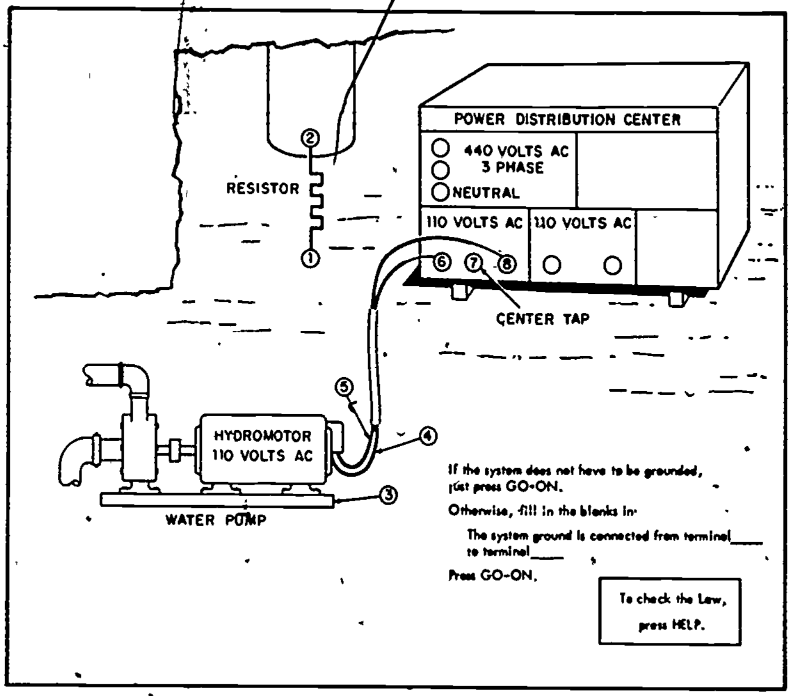
APPENDIX

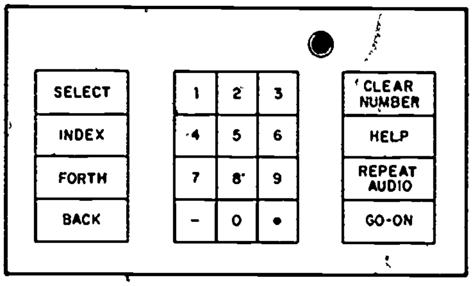
A Student Learning Experience in the Lesson
Problems in Grounding

The following frames are taken from the lesson, Problems in Grounding. In this lesson, the student makes legal connections between motors, power sources, and ground. Little understanding of electrical principles is required, but the student is held strictly to account for grounding equipment legally. We will follow a student as he makes various errors going through a part of this lesson.

First, the student is given a problem to be solved. He is shown a 110V AC motor mounted on a water pump in an underground mine, a power distribution center containing several types of power supplies, and a grounding field. In the audio he is told, "Make all the necessary legal connections between motor, power supply, and ground." After connecting the motor to a center-tapped 110V AC supply, he presses the GO-ON key on the keyboard shown below. This takes him to the frame at the top of the next page.



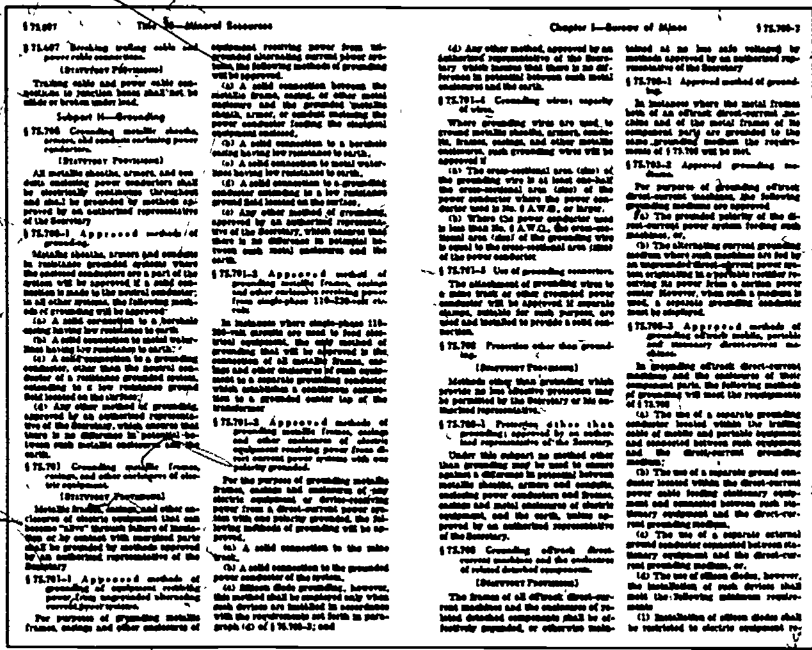




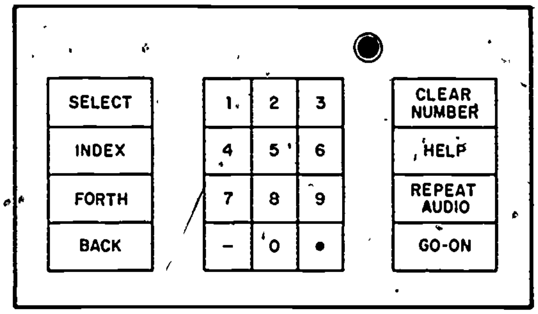
His job is to connect the system ground. He can do one of several things. It the system does not have to be grounded, he just presses GO-ON. If a system ground is required, he indicates where the connection is made. Eight terminals are labeled and a connection is made by pressing the proper pair of numbers on the keyboard.

Ignoring the instructions, he enters 1 and 2 – just to see what will happen. The only thing that does happen is that the red light on the keyboard turns on, indicating a nonsensical answer. Finding the right answer by guessing is impractical even if he follows the directions. There are only two chances in fifty-seven that the correct answer will be chosen by chance.

Obviously, to answer this problem the student must <u>know</u> what to do. In particular he must know the federal regulations. To help him with this, a note in the bottom corner of the display tells him to press the HELP key. He presses HELP and goes to the frame at the top of the next page.

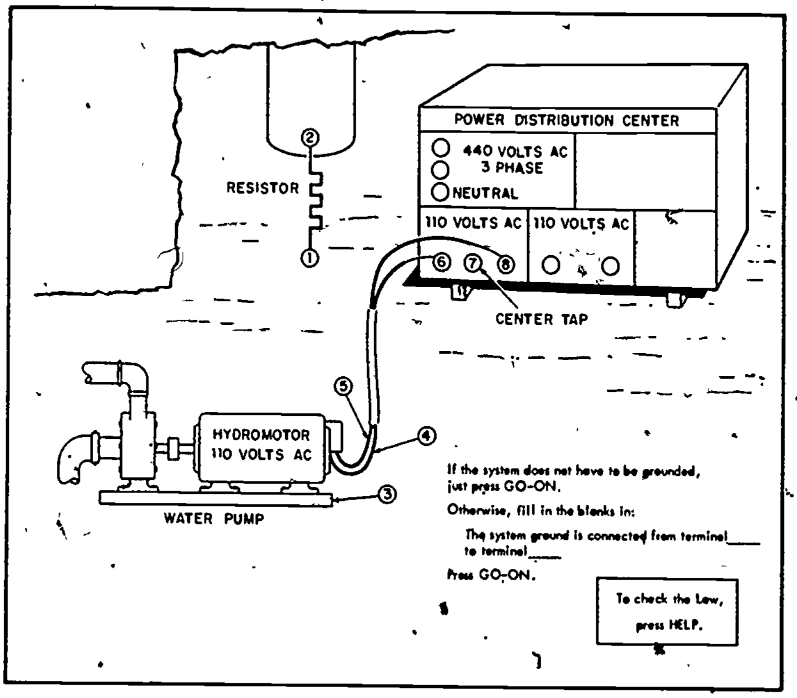

Title 30—Mineral Resources

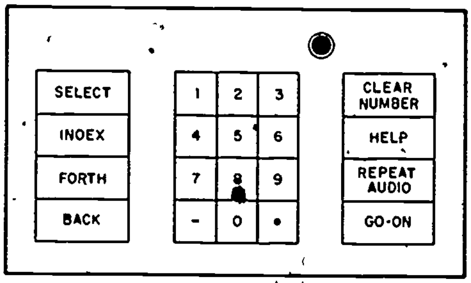
Chapter I—Bureau of Mines



Here he is shown two pages taken from the Law. The audio says, "Find the section of the law that deals with your problem. Read it thoroughly and press GO-ON." After finding the section, he reads it, then presses the GO-ON key.

This takes him back to the same frames as before because after using the HELP key, the student is always returned to the place in the lesson from which he came.





Again he is told, "If a system ground is required, you should connect the system ground. If not, just press GO-ON." Not understanding what a system ground is, he enters 3 and 2 – connecting the equipment frame ground.

Of course this connection is needed before power can be turned on, but he has not followed the instructions on the frame. This error takes him to a definition of system and equipment grounding.

DEFINITIONS

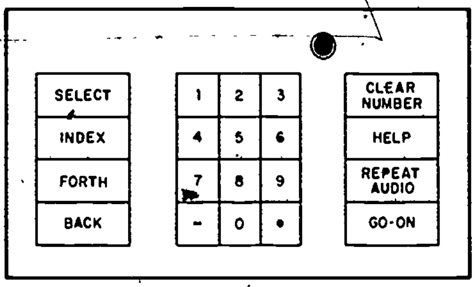
The word 'Grounding' is commonly used in electric power system work to cover both 'System Grounding' and 'Equipment Grounding.'

System Ground: A System Ground is a connection to earth from one of the current carrying conductors of a power source.

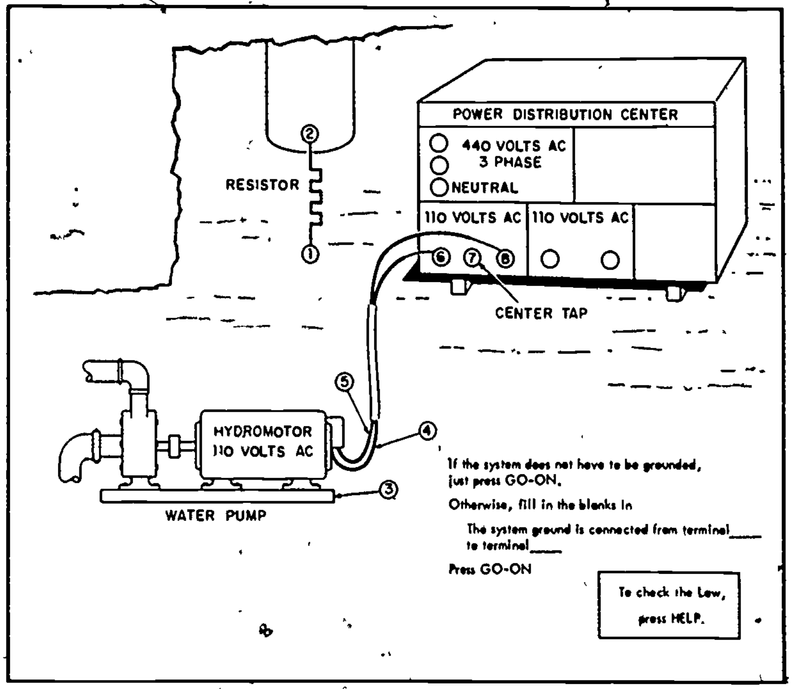
Equipment Ground: An Equipment Ground is a connection to earth from one or more of the noncurrent-carrying metal parts such as metal conduits, metal armor of cables, outlet boxes, cabinets, switch boxes, motor frames, and metal enclosures of motor controllers.

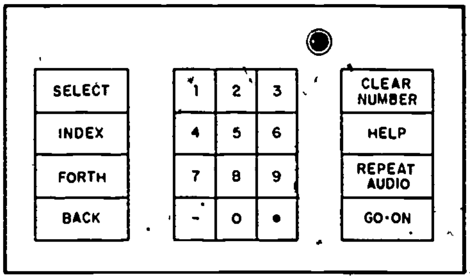
SOLID GROUNDS ARE USED IN BOTH SYSTEM AND EQUIPMENT GROUNDING

Press GO-ON



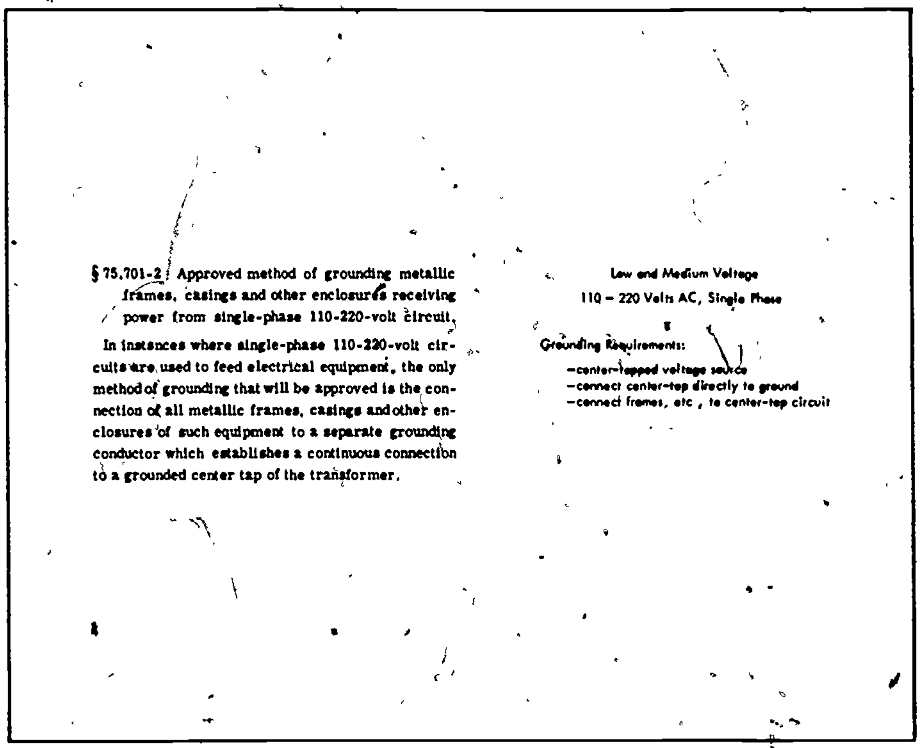
"You seem to be confused about the difference between system grounds and equipment frame grounds. System grounding is the grounding of a power source. Read these definitions, then press GO-ON to try it again." He reads the definitions, realizes his mistake, and presses GO-ON which returns him to the problem.





Again, back to the same frame: "If a system ground is required, you should connect the system ground. If not, just press GO-ON." Whenever the student wants to hear the audio message for a second time, he presses REPEAT. He is uncertain so he presses the REPEAT key and listens to the instructions again. Now he understands the instructions and presses GO-ON, indicating that no system ground is required.

This takes him to a frame showing the section of the Law dealing with grounding of 110V AC systems.



§ 75.701-2 Approved method of grounding metallic frames, casings and other enclosures receiving power from single-phase 110-220-volt circuit.

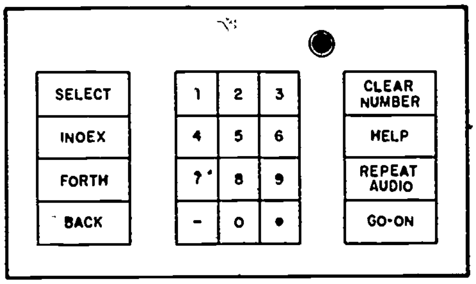
In instances where single-phase 110-220-volt circuits are used to feed electrical equipment, the only method of grounding that will be approved is the connection of all metallic frames, casings and other enclosures of such equipment to a separate grounding conductor which establishes a continuous connection to a grounded center tap of the transformer.

Low and Medium Voltage

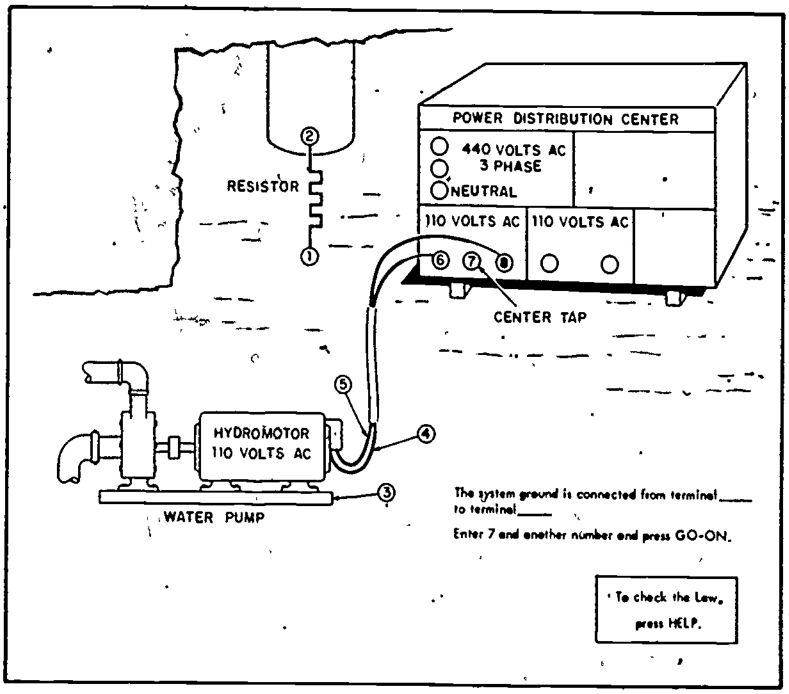
110 – 220 Volts AC, Single Phase

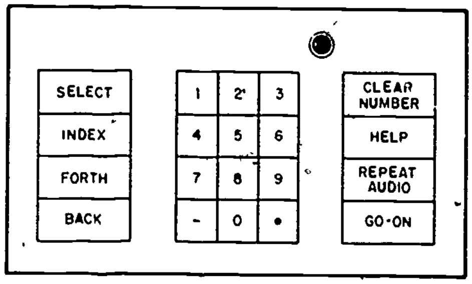
Grounding Requirements:

- center-tapped voltage source
- connect center-tap directly to ground
- connect frames, etc , to center-tap circuit



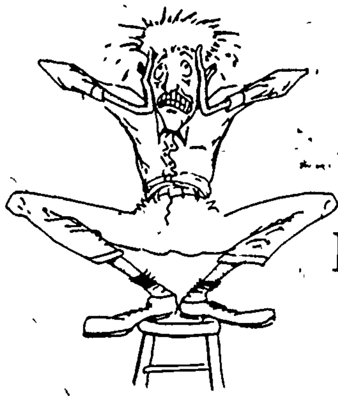
In the audio he is told, "No, the Law requires a system ground. Here is the section from the Code that pertains to system grounding for this type of system. Read the section and if you still don't understand, get someone to explain it before going on." He looks at the legal requirements and presses GO-ON.





Back to the problem again, but this time he is given a hint. "To connect the system ground, you have to connect the center-tap, terminal number seven, to ground. Connect number seven to ground by entering seven and another number to fill in the blanks on the visual display."

However, not knowing what a center-tap is, he again just presses GO-ON — indicating that no system ground is required. In this case, he is repeating his earlier error and the machine is set to sense that he is in serious trouble. So it takes him to a frame telling him to get some help.



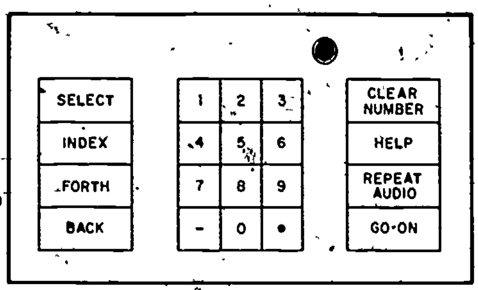
GO

FIND

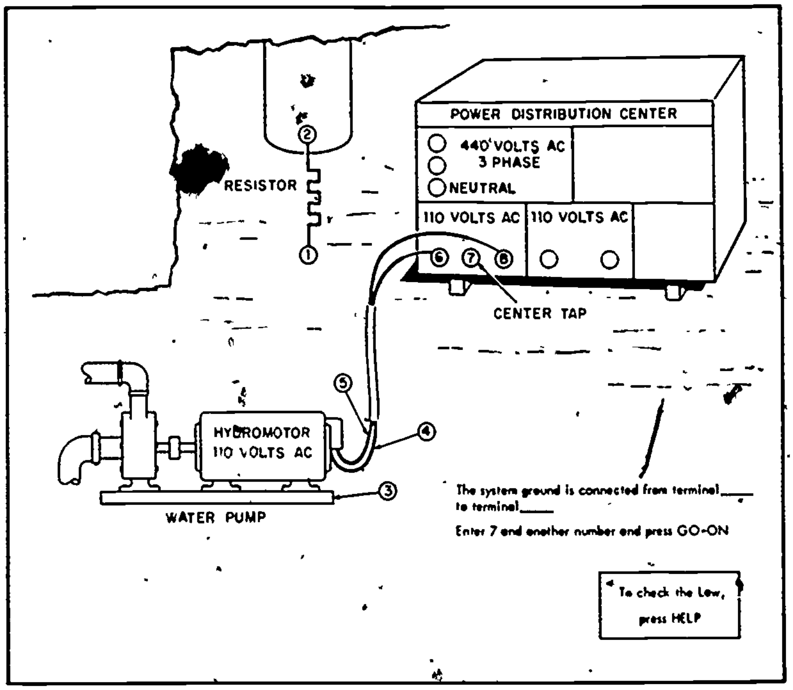
THE

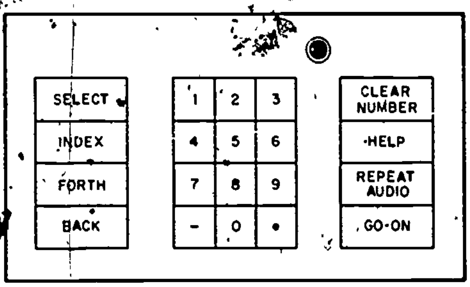
INSTRUCTOR

When you have received the necessary assistance from your instructor, press GO ON.



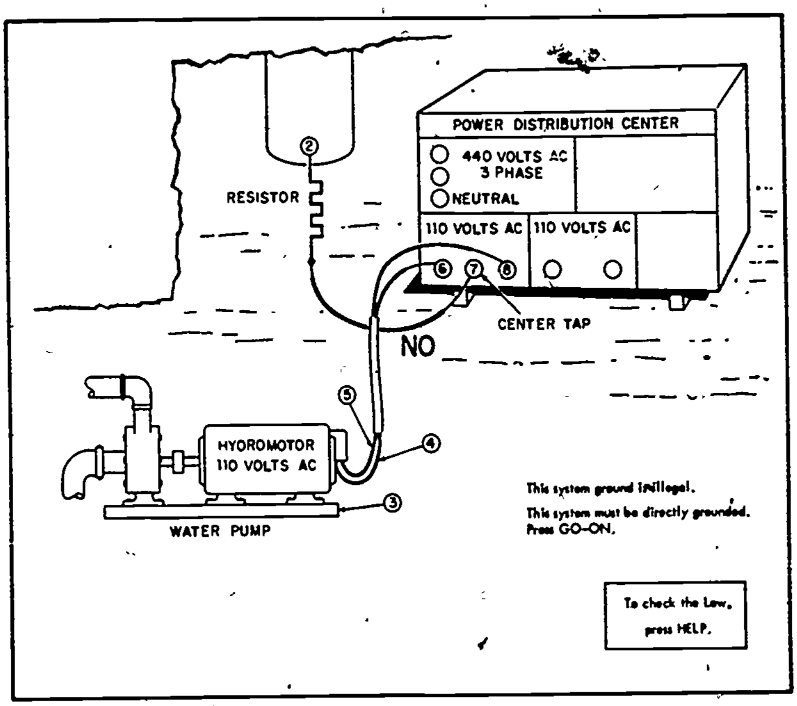
"I cannot help you any further. Find someone who can help you with your problem, then go on with the lesson." The student now gets an explanation of center-taps from his instructor, then presses GO-ON, which takes him back to the same problem for another try.

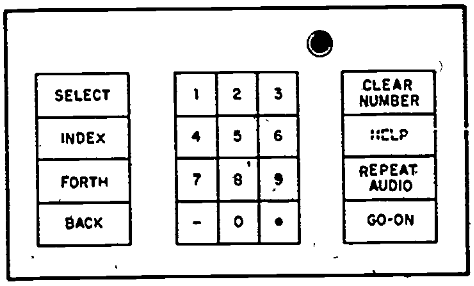




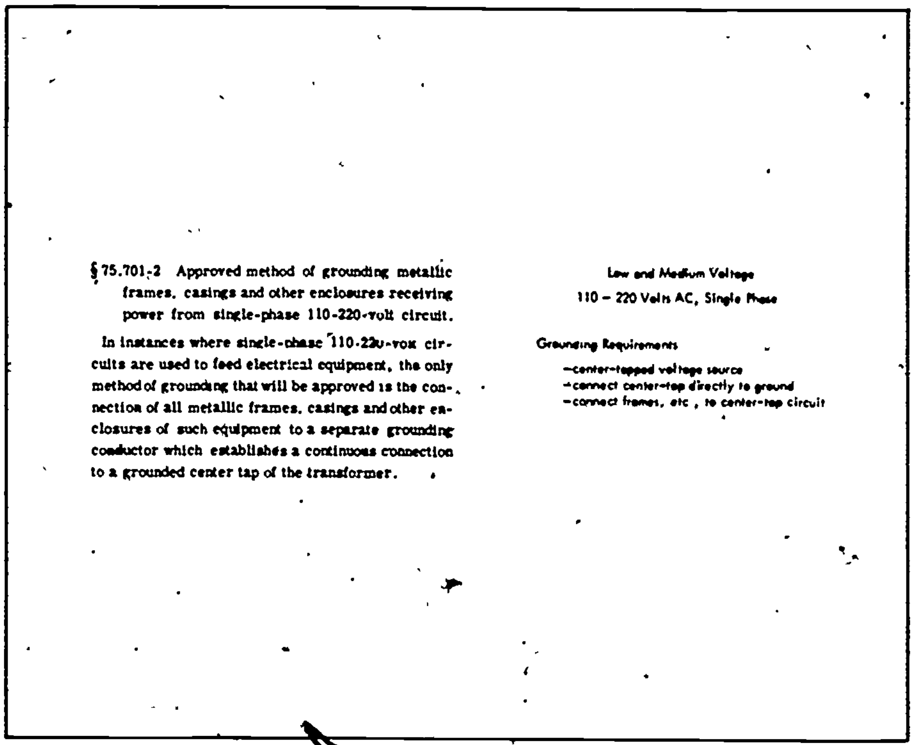
"To connect the system ground, you have to connect the center-tap, terminal number seven, to ground. Connect number seven to ground by entering seven and another number to fill in the blanks on the visual display."

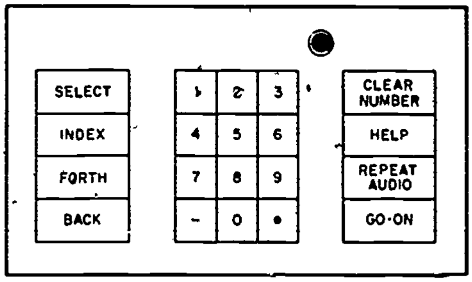
He enters 7 and 1 in the keyboard — resistance grounding the system.



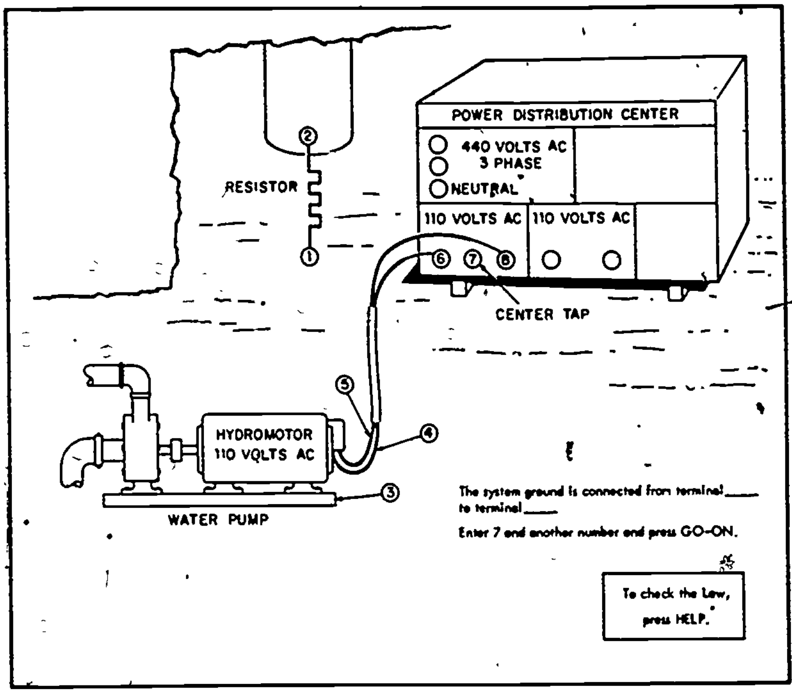


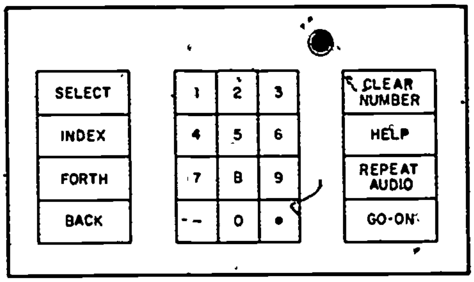
"No, this system ground is illegal. The center-tap must be connected directly to earth." Pressing GO-ON takes him to the next frame to read the Law again.





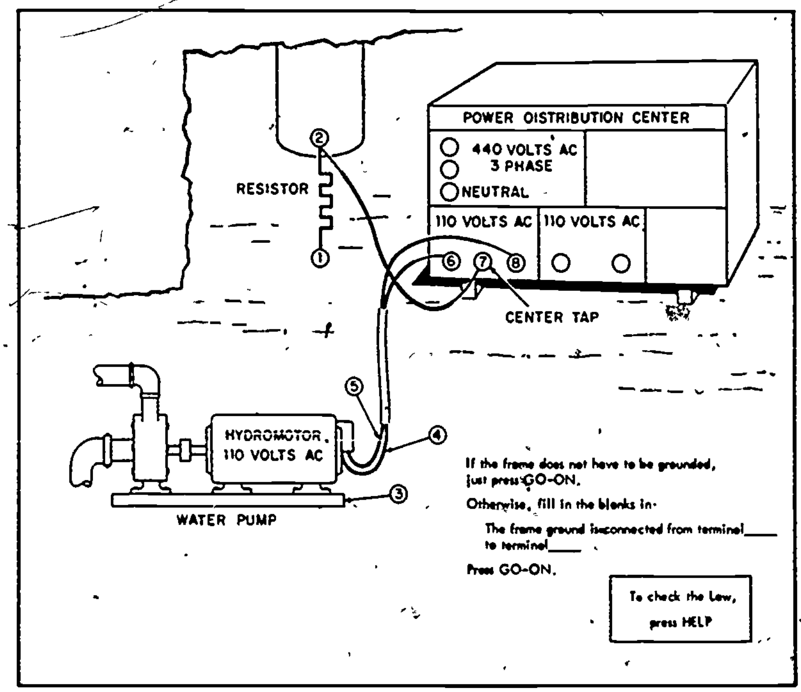
"Here is the section of the Law that requires the center-tap to be directly grounded. Read this section, then press GO-ON and try it again." He looks at the notes on the right-hand border, reads the Law, then presses GO-ON.

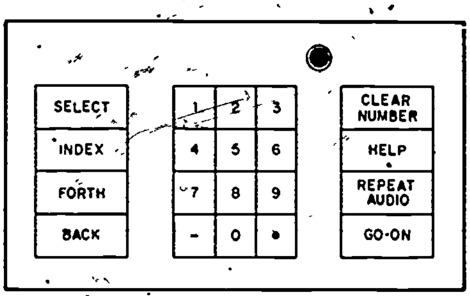




"To connect the system ground, connect the center-tap, terminal number seven, to ground." Finally he remembers all the requirements. He connects the center-tap, terminal 7, directly to ground, terminal 2.

His answer takes him to this frame showing his completed connection and presenting the next part of the problem.





This example shows how this lesson diagnoses and corrects student errors as they occur. Of course, few students will make as many mistakes as were shown above. As soon as the student completes the problem correctly he goes to the next part of the problem.

There are several significant features in this lesson design. Most importantly, guessing is eliminated. Correct answers alone allow progress through the lesson. This means that the better students spend less time learning the material than poorer students, but all students have shown the same level of skill when they are done with the lesson. The diagnosis of types of errors makes this possible - permitting help with individual problems. Repetitive errors send the student to get help from his instructor. Finally, the HELP key lets the student find the information he needs, and trains him to get that information rather than relying on intuition or guesswork. This lesson is designed to help the student proceed through the material at his own pace, to remedy errors as they occur, and to develop good habits toward safety in mining as a whole - obtaining information when needed, checking the legality of work in progress, and making knowledgeable judgements rather than hasty guesses.