USA-CERL TECHNICAL REPORT E-88/06
July 1988
T^3B: Test Mechanical/Electrical CAEADS Modules

US Army Corps of Engineers
Office of the Chief of Engineers

TECHNOLOGY TRANSFER TEST BED PROGRAM

Corps of Engineers National Energy Team (CENET) Technology Transfer Test Bed (T^3B) Demonstration of the LITE and DUCT Programs

by
Cynthia K. Barton

U.S. ARMY CORPS OF ENGINEERS
CENET
NATIONAL ENERGY TEAM

This report documents the FY87 Technology Transfer Test Bed (T^3B) demonstration of the LITE and DUCT computer programs. LITE and DUCT are graphic modules of the Computer-Aided Engineering and Architectural Design System (CAEADS). The programs were developed to assist U. S. Army Corps of Engineers (USACE) in-house mechanical and electrical engineers in performing required analyses during the concept design phase. LITE allows engineers to do lighting design analyses, whereas DUCT enables definition and description of ductwork. The modules were created to ensure the energy efficiency of new military construction through optimized design.

The T^3B program was initiated by USACE to ensure that research and development results in products that meet the users' needs. Each USACE element that participates in a test is reimbursed for time and effort. Testing of modules such as LITE and DUCT by field designers, particularly by Districts in several different regions, will help ensure that the final tools are usable and beneficial to USACE.

The LITE/DUCT test was performed by electrical engineers at the Kansas City and Sacramento District Offices during early 1987. The results are being used to redirect the research effort.

TECHNOLOGY TRANSFER TEST BED PROGRAM

FINDINGS AND RECOMMENDATIONS OF TEST/DEMONSTRATION

WORKUNIT NO./TITLE OF TEST: FAD No. 88-080037, Test Mechanical/Electrical CAEADS Modules

PERFORMING LABORATORY: USA-CERL **PRODUCT/SYSTEM:** LITE and DUCT Graphic Modules

PERFORMING TEST SITES: Sacramento District, Kansas City District

DESCRIPTION/OBJECTIVE OF TEST/DEMONSTRATION:

Sacramento and Kansas City District engineers tested two graphics modules of CAEADS: LITE, with its interface to LCHG and CEL-1, and DUCT, with its interface to SUPERDUCT II. Both programs were used in comparing to actual in-house design projects past the 35% design phase. The objective was to determine the validity of program results, ease of use, and applicability to Corps design.

RESULTS OF TEST DEMONSTRATION:

Overall, the participants were able to use the programs despite a few minor setbacks. Both programs were found to be reasonably accurate in their calculations. Each engineer presented comments and suggestions to improve the efficiency and cost-effectiveness of the programs. Emphasis seemed to be placed more on the LITE and DUCT programs themselves rather than the analysis programs (CEL-1 and SUPERDUCT II).

RECOMMENDATIONS FOR PRODUCT/SYSTEM:

Based on the evaluation sheets returned by the engineers, the DUCT program requires a great deal of revision before it can be used in the field. However, the DUCT program is being eclipsed by commercial software development. Many vendors are beginning to offer graphic layout programs in conjunction with CADD that are far superior in graphic capabilities. However, it is still necessary to evaluate the incorporated analysis portions in a manner similar to the Kansas City DUCT portion of this test. Due to the difficulty arising from the continued use of the SUPERDUCT II program and the results of the test, it is being proposed that the DUCT program be phased out of the research effort at USA-CERL.

On the other hand, LITE and its interface to CEL-1 offer USACE designers a unique analysis capability. While the market is saturated with small programs that perform zonal cavity calculations, the number of commercially available daylighting programs is very small. Therefore, it is felt that USA-CERL should pursue the further development of LITE and its interface to CEL-1. Future T^3B tests will also be necessary to verify the validity of using CEL-1 in the USACE design process.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USA-CERL TR E-88/06	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Construction Engr Research Laboratory 6b. OFFICE SYMBOL (If applicable) CECER-ES	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 4005 Champaign, IL 61820-1305	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION HQUSACE 8b. OFFICE SYMBOL (If applicable) CEEC-EE	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER FAD No. 88-080037 dated 29 September 1987
8c. ADDRESS (City, State, and ZIP Code) 20 Massachusetts Avenue, N.W. Washington, D.C. 20314-1000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Corps of Engineers National Energy Team (CENET) Technology Transfer Test Bed (T^3B) Demonstration of the LITE and DUCT Programs (Unclassified)

12. PERSONAL AUTHOR(S)
Barton, Cynthia K.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM ____ TO ____	1988, July	66

16. SUPPLEMENTARY NOTATION
Copies are available from the National Technical Information Service Springfield, VA 22161

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	
05	02		LITE, DUCT, CAEADS, Technology transfer, Technology Transfer Test Bed

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

This report documents the FY87 Technology Transfer Test Bed (T^3B) demonstration of the LITE and DUCT computer programs. LITE and DUCT are graphic modules of the Computer-Aided Engineering and Architectural Design System (CAEADS). The programs were developed to assist U. S. Army Corps of Engineers (USACE) in-house mechanical and electrical engineers in performing required analyses during the concept design phase. LITE allows engineers to do lighting design analyses, whereas DUCT enables definition and description of ductwork. The modules were created to ensure the energy efficiency of new military construction through optimized design.

The T^3B program was initiated by USACE to ensure that research and development results in products that meet the users' needs. Each USACE element that participates in

(Cont'd)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL DANA FINNEY	22b. TELEPHONE (Include Area Code) (217)352-6511 ext. 389 22c. OFFICE SYMBOL CECER-IMT

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

BLOCK 19. (Cont'd)

a test is reimbursed for time and effort. Testing of modules such as LITE and DUCT by field designers, particularly by Districts in several different regions, will help ensure that the final tools are usable and beneficial to USACE.

The LITE/DUCT test was performed by electrical engineers at the Kansas City and Sacramento District Offices during early 1987. The results are being used to redirect the research effort.

FOREWORD

This work was performed for the Directorate of Engineering and Construction, Headquarters, U. S. Army Corps of Engineers (HQUSACE), as a project in the Technology Transfer Test Bed Program (T^3B) under the Corps of Engineers National Energy Team (CENET). The Work Unit was entitled "Test Mechanical/Electrical CAEADS Modules." J. McCarty, CEEC-EE, was the HQUSACE Technical Monitor.

The field test was administered by the Energy Systems Division (ES), U. S. Army Construction Engineering Research Laboratory (USA-CERL). Dr. G. R. Williamson is Chief, ES. The technical editor was Dana Finney, USA-CERL Information Management Office.

Research and development of the LITE and DUCT modules used in the test were performed by USA-CERL for HQUSACE under Project 4A162781AT45, "Energy and Energy Conservation"; Technical Area A, "New Construction Energy Design"; Work Unit 011, "Computer-Aided Mechanical/Electrical Design and Procedures," also for which Mr. McCarty was Technical Monitor.

Among the features in the LITE program is the ability to perform Illuminating Engineering Society (IES) Zonal Cavity Calculations, and to create a Conservation of Electricity (CEL-1) input file. CEL-1 is a comprehensive daylighting analysis program created by the National Bureau of Standards (NBS) and the Naval Civil Engineering Laboratory (NCEL).

The DUCT program allows mechanical engineers to define and describe ductwork and create a Superduct II input file. The Superduct II program was created by Automated Procedures for Engineering Consultants, Inc. (APEC).

Appreciation is expressed to James Barnett, Kansas City District, and Mary Drewry, Sacramento District, for conducting the LITE test. Gratitude also is extended to James Turner, Kansas City District, and James Dyer, Sacramento District, for conducting the DUCT test.

COL N. C. Hintz is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

TABLES

FIGURES

CORPS OF ENGINEERS NATIONAL ENERGY TEAM (CENET) TECHNOLOGY TRANSFER TEST BED (T^3B) DEMONSTRATION OF THE LITE AND DUCT PROGRAMS

1 INTRODUCTION

Background

The U. S. Army Corps of Engineers (USACE) has studied computer-aided drafting and design (CADD) technology for several years as a means to help architects and engineers conduct rapid analysis of several design options. These systems use graphic display to show designers the possible alternatives, allowing them to select one that optimizes cost and functionality. CADD can improve the potential for high-quality military construction.

The U.S. Army Construction Engineering Research Laboratory (USA-CERL) has developed two computer graphics programs called LITE and DUCT. The programs originally were designed for use with the Computer-Aided Engineering and Architectural Design System (CAEADS). CAEADS was intended for use during the first 35 percent of the design process and was configured to allow designers to integrate several separate graphics modules. LITE and DUCT use input from the ARCH module of CAEADS.

LITE is based on the initial graphic module, called LIGHTING, which was designed to perform calculations using the Illuminating Engineering Society (IES) Zonal Cavity Method. A separate module was created based on a concept called "daylighting," in which facility illumination takes advantage of natural light through the use of fenestration, reflective surfaces, and other features. This module was actually an interface to the existing Conservation of Electricity (CEL-1) program developed by the National Bureau of Standards. Later, the features of LIGHTING and the CEL-1 interface were combined and enhanced to form one comprehensive graphic module called LITE.

A second program, Luminaire Change (LCHG), was developed as a data base manager for the luminaire data base file LUMAIR. LITE uses the information from LUMAIR to perform illuminance calculations. The LUMAIR file is independent of all other projects and can store an unlimited number of luminaires. In contrast to the graphics of LITE, LCHG uses textual interaction with the designer, which makes the system easy to use and understand.

Initial development of LITE was completed in early FY86 and the program was reviewed informally by several field engineers. Both LITE and LCHG were enhanced based on input from these users. Research and development (R&D) for the current LITE and LCHG programs is documented in another USA-CERL Technical Report.[1]

DUCT was developed to assist mechanical engineers in describing the layout of a heating, ventilating, and air-conditioning (HVAC) ductwork system within a building. By

[1] C. Barton, *Development of LITE—A Graphic Module for Lighting Analysis in the Computer-Aided Engineering and Architectural Design System (CAEADS)*, Technical Report E-87/02/ADA179821 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], March 1987).

executing the DUCT program, the engineer can define and describe ductwork, including diffusers, risers, and fittings. The DUCT program also uses the thermal zones and supply air volumes as defined in the ENERGY module of CAEADS. With this information, DUCT allows the engineer to create an appropriate Superduct II input deck.* The Superduct II program can size supply, return, and exhaust systems. After a successful Superduct II run, the DUCT program can use the Superduct II output file to create a double line drawing (to scale) of the sized ductwork.

DUCT has also undergone informal field reviews by mechanical engineers and was enhanced based on the results. The original Superduct II program was written for CYBER computers and resided on CYBERNET for USACE access. In late 1986, USA-CERL had the Superduct II program converted to the Harris.

Development of computer-aided design programs requires close coordination with field designers to produce tools that aid the District's design practices and that fit well into the day-to-day work pattern. Enhancements or modifications to the tools often are needed before these programs can be released throughout USACE; these changes can be identified only by designers and engineers using the system in the field.

USACE has initiated the Technology Transfer Test Bed (T^3B) program to ensure quality products for USACE customers. The T^3B program emphasizes a close interaction between R&D and the end-user to identify and produce technologies meeting the user's needs. The T^3B process ultimately involves field demonstration of a product that has been found successful at the pilot test stage. Each USACE element that participates in a test is reimbursed for time and effort. By having field designers test computer programs--particularly in Districts throughout several regions--the final product can be refined for greatest possible usability and benefit to the customer.

Objective

The objective of this work was to conduct formal field tests of two CAEADS graphic modules as part of the T^3B program: (1) LITE and its interfaces with LCHG and CEL-1, and (2) DUCT and its interface with Superduct II.

Approach

During the developmental phase of LITE and DUCT, the programs were reviewed by experts in the respective fields to determine their accuracy and usability before demonstration. Two USACE District Offices--Kansas City and Sacramento--volunteered to participate in the T^3B program for these modules using existing projects that had already been designed in-house and were in review. The District Offices compared results from these programs with their current methods. Input from the Districts is being evaluated for future research.

*Superduct II is a copyrighted program of Automated Procedures for Engineering Consultants, Inc. (APEC) and is available to USACE T^3B participants on the Harris computer through a licensing agreement between APEC and USA-CERL.

Mode of Technology Transfer

USA-CERL plans to explore the feasibility of adapting LITE for use on the USACE-wide CADD system, Intergraph. If feasible, when the development and testing are complete, transfer to users will be through training courses, tutorial, and a user's guide.

2 LESSONS LEARNED IN THE DEVELOPMENTAL PROCESS

The R&D phase of LITE and DUCT generated "lessons learned" that may be useful in future research involving graphics software. The CEL-1 program, analogous to the Building Loads Analysis and Systems Thermodynamics (BLAST) program used by the ENERGY module of CAEADS, is a public domain program. The Superduct II program is a proprietary commercially available product. In each case, off-the-shelf technologies were used to supplement the abilities inherent in the graphic modules. However, the approach to obtaining analytical results in the modules was quite different. This chapter compares the methods of analysis used in ENERGY, LITE, and DUCT and discusses some of the lessons learned.

In developing the graphic modules, USA-CERL had to consider these questions:

1. Can the analysis part of the module stand alone or should it be incorporated into the graphics software packages?

2. Will an existing analysis program be used as the supplemental analysis or is a new, separate program needed?

3. If an existing program is used, how extensive should its capabilities be (i.e., will it only need to meet the requirements for concept design, or should a more complex program be used which is suited to the information known about the facility at the concept design stage)?

4. If an existing program is used, should the program be public domain or proprietary?

ENERGY

ENERGY was developed to serve as a front end for energy analysis using BLAST. Because many of BLAST's calculations take significant computer time to complete, no analytical capability was included in the ENERGY module. Since BLAST was known to work for detailed building descriptions, research was done to ensure that the BLAST program would be usable in simplified form suitable for concept design applications.[2]

The results of using ENERGY have been reasonably successful. In preparing a BLAST file, much of the preparation time is spent constructing a geometric description of the facility. The graphic front end simplifies this task; as a result, users can compare several alternative energy models for the building with little extra preparation time. The principal issues of the ENERGY module are:

1. ENERGY is not a complete preprocessor for BLAST so the BLAST input file must be edited prior to executing BLAST.

2. Certain analyses (e.g., building heating/cooling loads requirements) done during concept design do not require significant computer resources and should be handled within the framework of the ENERGY module itself. This process would give the user

---

[2]D. Herron, et al., *Use of Simplified Input for BLAST Energy Analysis*, Technical Report E-185/ADA131261 (USA-CERL, May 1983).

faster feedback for making some of the decisions. Annual executions of BLAST must still be done outside the ENERGY module framework.

3. Energy analysis studies are often done mainly for determining the building energy budget rather than investigating different building zone layouts. Thus, a potentially major advantage of the graphic module is being overlooked.

ENERGY cannot fully use all features of BLAST, but can provide the most significant parts of the geometric model. For example, some geometric components (e.g., tilted roofs, skylights) cannot be modeled because they do not exist in the graphic modules. Since BLAST development is controlled by USA-CERL, it has been possible to maintain ENERGY's output to reflect any changes to BLAST.

LITE

LITE's approach is similar to the ENERGY module's in that the time-consuming analysis (by CEL-1) is done outside the LITE framework. CEL-1's input structure is similar in complexity to the geometric data required for BLAST; CEL-1 also requires geometric positioning and modeling of light fixtures. However, the calculation of maintained illuminance levels (based on IES standards), usually performed during concept design, has been fully incorporated into the LITE module.

LITE can invoke all features of the CEL-1 program except for certain architectural features (e.g., light shelves, skylights, clerestories) which are lacking in the graphic modeling environment. However, LITE cannot retrieve any of the analytical results from CEL-1 for incorporation into the LITE data base that might prove useful to the designer in a graphic environment (e.g., contours of lighting levels).

CEL-1 was developed by the Naval Civil Engineering Laboratory (NCEL) and the National Bureau of Standards (NBS). The program remained largely unchanged during LITE's development due to funding limitations. Fortunately, NBS still maintains a degree of expertise in the CEL-1 program code, which USA-CERL was able to tap during the conversion of CEL-1 to different hardware environments.

DUCT

With DUCT, a third approach was taken for the analysis interface. Of the various duct design programs available, Superduct II was selected for its ability to perform several different kinds of duct design calculations (e.g., static regain, constant friction, and constant velocity). Superduct II licensees are encouraged to modify the software to meet their own needs, but are restricted from distributing this modified software to many locations. (Similar distribution licenses would be found with any commercial software.) USA-CERL signed a special agreement with APEC in order to install Superduct II on the Harris computer and distribute this executable version to test sites.

DUCT was designed to fully invoke all features of Superduct II. Since the sizing part of the calculations happens so fast, the duct design calculations could have easily been incorporated into the DUCT program itself.

Conclusions

The lessons learned during development of these modules were used to generate the following recommendations for future work:

1. Incorporate an appropriate level of calculations into the graphic software itself when possible.

2. For batch programs, convert the program to the hardware being used or build in easy accessibility for the user.

3. Retrieval of results can be presented well in the graphic orientation, so consider this fact when constructing the design process.

4. Be judicious in choosing analytical software to be used or developed: watch for "hidden costs" such as time delays required to access privately vended software, and avoid unsupported or rapidly changing software; consider tradeoffs to the user between comprehensive analyses and more simplistic approaches.

3 DETAILS OF THE TEST

Kansas City District

Kansas City District has been involved with CAEADS development and testing since 1985. CAEADS had been installed on the District's Harris 500 computer and a special training account established. The District's electrical engineers (EEs) had been instrumental in developing the LITE and LCHG programs; thus, they already had a working knowledge of the Harris computer, CAEADS as a whole, and the LITE and LCHG programs.

The District engineers were given initial CAEADS training on ARCH, ENERGY, and DUCT in April 1985. The mechanical engineers (MEs) were further briefed on the updated DUCT program and the Harris version of Superduct II during February 1987. The EEs were introduced to LITE and LCHG in April 1986. During June 1986, a representative from NBS conducted a training class on the use of CEL-1. Since CEL-1 runs on CYBERNET, USA-CERL provided Kansas City with a signon.

Sacramento District

Sacramento District was the alpha test site for CAEADS and consequently has been involved in CAEADS development since the early 1980s. However, testing had been conducted on the Amdahl computer system located at the University of Michigan, the USA-CERL contractor for initial development of the system. Thus, the Sacramento engineers were not familiar with the Harris computer or the Harris versions of CAEADS. Due to heavy usage of the Harris computers at Sacramento District, a dedicated 9600-baud data line was procured between the District and Champaign, IL, where the USA-CERL Harris 500 is located.

The engineers were trained during October 1986. The training included basic use of the Harris and CAEADS, and specific instructions on using the ARCH, ENERGY, DUCT, LITE, and LCHG programs. The engineers were tutored in every facet of the programs to prepare for the formal field test. An introduction to CYBERNET was also given to accommodate testing of the LITE/CEL-1 interface. Additional training on LITE was conducted during February 1987.

Test Logistics

The Districts received a formal test plan that listed specific guidelines on conducting the field test. After the Districts approved the plan, T^3B funds were distributed and test specifics were developed to accommodate each District's unique situation. Copies of the DUCT and LITE test plans and test specifics are found in Appendices A and B, respectively.

The Districts elected to perform the tests on existing projects that were past the 35 percent design phase. Comparisons were to be made between the actual design method used for each project and the results from LITE and DUCT. This was to include any manual calculations performed or commercially available software packages used for analysis. Each computer session was to be recorded on the respective program's evaluation sheet provided with the test plan. A written summary of the test was to be submitted with all calculations, computer printouts, and drawings necessary to document the results. This summary was to include speculation on the programs' applicability to the USACE design process as well as suggestions and recommendations as to future use of the programs.

Time log programs were used to track computer usage and time in the individual programs at both Districts. An analysis of the time log files is shown in Appendix C. The logs include time used by USA-CERL personnel when it was necessary to execute the programs to solve problems or answer questions for the engineers performing the test. In addition, since Sacramento engineers were unfamiliar with the Harris versions of CAEADS, USA-CERL had agreed to input the building plans using the ARCH program for the LITE portion of the test. The MEs learned the new program format fairly easily.

Equipment

The Kansas City Mechanical/Electrical Branch had access to three Tektronix 4109 color terminals and three Tektronix 4962 color graphics plotters. The Tektronix 4109 terminals were the developmental environment for LITE and DUCT at USA-CERL. On the other hand, the Sacramento Electrical and Mechanical Sections had access to only one Tektronix 4113 color and one 4014 monochrome terminal. Black-and-white plotters also were connected to the terminals, but were inoperable.

Since Kansas City District already had access to CAEADS on its Harris 500, the LITE and DUCT programs were sent by magnetic tape and loaded onto the system. Thus, participants had direct access to line printers and help from computer experts. As already noted, Sacramento District was to use the dedicated 9600-baud data line to access the USA-CERL Harris 500. Because of this telephone line, it took a long time to access the computer and the engineers often encountered noise on the line. Also, they had no access to line printers and could not talk with computer operators when any problems occurred.

4 RESULTS AND DISCUSSION

In describing results of the demonstration, it is necessary to refer to the programs in terms that are not fully explained in this report. However, Appendices D and E present menu layouts for DUCT and LITE, respectively, along with a short description of the functions of each menu mode. In-depth explanations of the menu modes and their commands are in the *DUCT User's Manual*[3] and *LITE User's Manual*.[4] In addition, a short reference to the LCHG program has been included as Appendix E. Details about the LCHG program may be obtained from the *LCHG User's Manual*.[5]

As instructed, each District submitted a report documenting its efforts in conducting the tests and listing results. The narrative portions are included as Appendix F.

DUCT Test

Two MEs performed the DUCT test, one from the Kansas City District Mechanical/Electrical Section of the Design Branch and the other from the Mechanical Design Section of the Military Design Branch, Sacramento District. These MEs work mainly in designing new Military Construction, Army (MCA) and Army Reserve (MCAR) facilities.

At Kansas City, the test was performed using a flight simulator building for Fort Riley, KS, that was in the final design phase. Figure 1 shows a plot of the building as taken from the DUCT program. Three other programs were used for a comparison: the Trane Constant Friction, Elite Constant Friction, and Intergraph duct-sizing packages.

Sacramento performed the test using a radar/microwave facility at the Sacramento Army Depot that was in the post-final stage. Figure 2 shows a plot of the building taken from the DUCT program.

Although the DUCT test was completed in Kansas City without many problems, Sacramento District experienced difficulty in some areas. Sacramento was unable to begin working with DUCT and submitted the following list of trouble spots for investigation by the BLAST Support Office (BSO):

1. The program was drawing some of the ducts at angles despite the fact that they were input horizontally and/or vertically; some runs were even drawn as arcs.

2. The protractor function was not working properly.

3. At times, the program drew duct runs on the screen but they disappeared when the screen was redrawn. However, when the user attempted to redraw the duct run, the node appeared to still be in place and would not allow a new duct run to be drawn.

4. The program did not properly change duct features from rectangular to round.

---

[3]C. Barton, *DUCT User's Manual*, Draft Automated Data Processing (ADP) Report (USA-CERL, 1987).
[4]C. Barton, *LITE User's Manual*, Draft ADP Report (USA-CERL, 1986).
[5]C. Barton, *LCHG User's Manual*, Draft ADP Report (USA-CERL, 1987).

BSO corrected item 4 and found some of the problems encountered in item 1 to be inherent in the ZOOMIN command. Sacramento was informed of the improvements to DUCT and it was suggested that participants make judicious use of the ZOOMIN command. It was agreed to continue with the test at that point, since the two remaining problems were too difficult to debug in a short time span. Some parts of the test plan were not completed, including the comparison between Superduct II output and that of the other design methods.

Comments About DUCT

The following comments are summarized from final reports on DUCT issued by Sacramento and Kansas City Districts. In some cases, a NOTE from USA-CERL is included to clarify the comment.

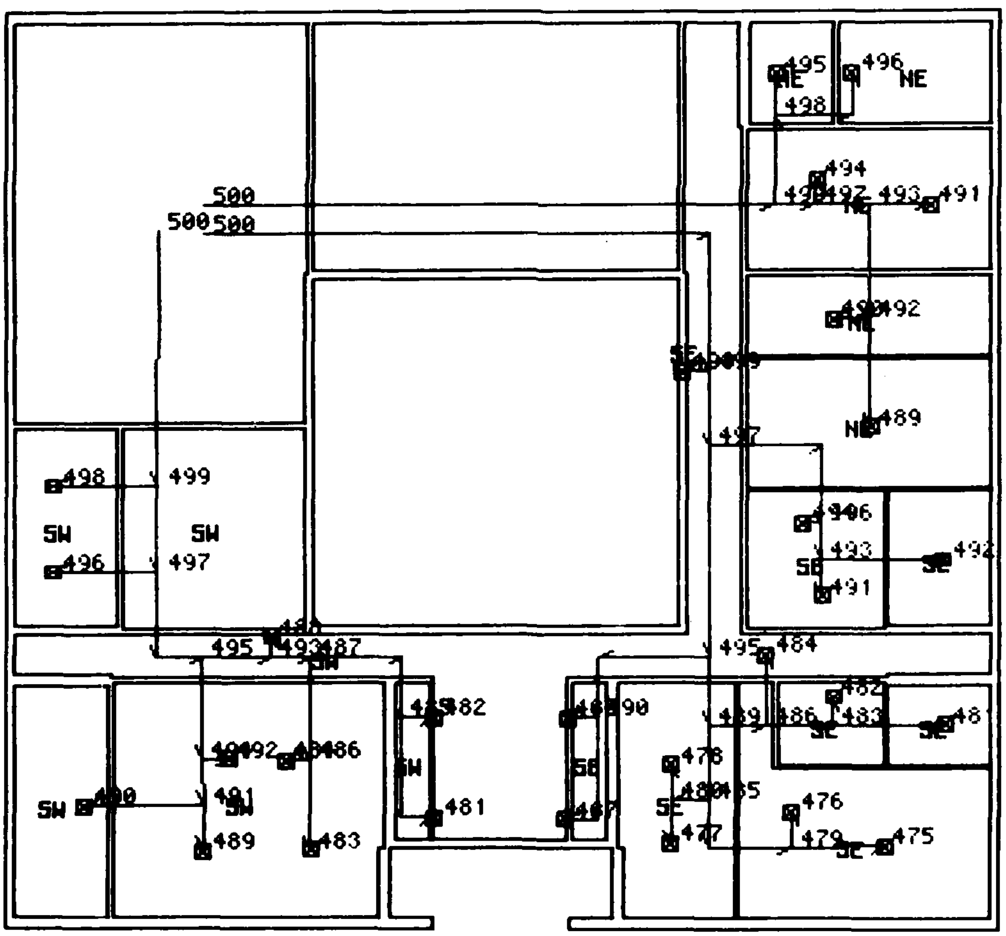

Figure 1. Flight simulator facility, Fort Riley, KS.

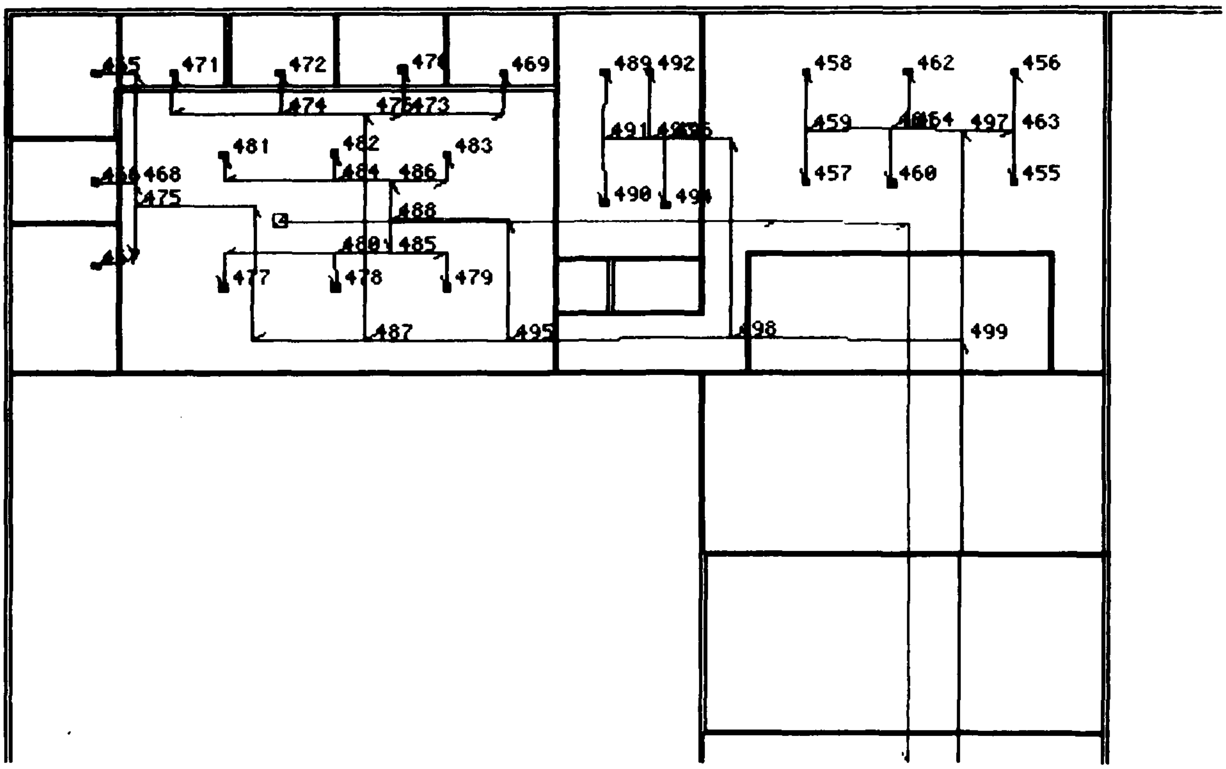

Figure 2. Radar and microwave facility, Sacramento Army Depot. Program is in the ZOOMIN mode.

1. While editing duct layouts, some sections will not delete properly.

2. After the user has executed the ZOOMIN command, several problems occur. The program sometimes draws ductwork at slight angles. When using the crosshairs on the screen, the program picks up a nearby node rather than the actual point being addressed (a node is a point on the ductwork that locates the beginning or end of a duct run, or a change in direction of airflow). It also fails to register a node as being digitized.

NOTE: three separate problems are involved here:

a. Graphic terminals model the screen as a matrix of dots called "rasters." The Tektronix 4014 screen, for example, consists of a matrix of 4096 by 4096 rasters. Positioning the crosshairs to an accuracy of one or two rasters is very difficult. Thus, what may appear horizontal to the user may actually be at a slight angle.

b. Therefore, whenever the crosshairs are used to indicate a point in the layout area, the program checks whether the point is within a "capture distance" (i.e., a certain number of rasters) from (1) any node, (2) the intersection of two lines, or (3) a line. If so, the program assumes that the intended location of the point was at that node, line intersection, or line. This process is called "snapping" the point to a node or a line. Otherwise, the point is assumed to be at the indicated raster position. This feature ensures that crosshair placement need not be exact. The term "capture distance" Is synonymous with "raster tolerance" or just "tolerance." The default tolerance is a fixed number at 16. Thus, the program can pick up a nearby node rather than the actual point being addressed.

c. When the program is in zoomed-in mode, the tolerance stays the same but covers a relatively smaller area. For this reason, it is more difficult to register a node while zoomed in and it appears to the user that the program is failing to register a node. If the tolerance is increased to make it easier to address a node, it will also become easier for the program to pick up nodes other than the point the user wishes to address.

3. When duct sections are erased, the nodes that are connected to those sections are not erased (assuming they are not being used by other duct sections).

NOTE: a node connects the terminal end of three duct sections attached to it: one incoming (terminal end) and two outgoing (initial end). If a duct section is erased, the nodes on the initial and terminal ends are supposed to be erased if they are not already attached to another duct section. If a node is not erased, or the node data are not updated to reflect the erased duct section, the program will not allow the user to attach a new duct section to that node location. This problem is a program error that has been difficult to track.

4. DUCT did not properly keep track of the cubic foot per minute (cfm) values used for each zone. For example, if a 180-cfm diffuser was added, DUCT might respond that 181 cfm had been used.

NOTE: the total cfm per zone is entered by the user in the ENERGY program. DUCT asks for the number of cfm through a diffuser when each diffuser is added to the ceiling plan and connected to a duct section. Thus, if the total cfm for a zone is 3500 and one 500 cfm diffuser is added, DUCT should respond that 500 cfm had been used (with 3000 left). For unknown reasons, it appears that in some cases the program adds 1 or 2 cfm to the total used.

5. The Superduct II input deck created by DUCT had to be edited manually using a Harris editor so that Superduct II would size using the constant friction method.

NOTE: although DUCT would allow the user to specify the constant friction method, the program would not properly build the Superduct II input deck to reflect using that option.

6. Entering duct runs using the VECTOR command in LAYOUT EDIT causes the duct to be drawn to points other than those the user entered.

NOTE: the VECTOR command in LAYOUT EDIT mode allows the user to specify the length and direction (by angle) for a duct section from an initial point. The program apparently is not drawing the duct section at the right angle.

7. According to the user's manual, when a terminal node is input using coordinates, the previous point is supposed to be the relative origin. However, the program always uses the building origin. There should be a choice between the two.

NOTE: the program was checked and it was determined that the statement is in error. Perhaps if the user had entered coordinates that were small (i.e., 10), it would appear as if the duct were being drawn from the building origin.

8. While in the DISPLAY VALUES MODE, the only command that works properly is "Distance Between Points"; all others just echo DISPLAY VALUES MODE.

NOTE: the Display Values Mode allows users to obtain dimensions and other values associated with the building plan. This capability does not apply to any of the ductwork that may be entered while in DUCT which is perhaps the case to which the user is referring.

9. In the DRAW ROOMS and DRAW ZONES modes, the program prompts for the desired level. The manual states that the user must enter an "F" followed by a number. However, if, for example, "F 1" is entered, the program displays the message "CTOR: INVALID CHARACTER." The program will only accept a number.

NOTE: the original programs used the "F #" floor designation as indicated in the user's manual. However, the newer versions have dropped the "F" and require only the number. The manual needs to be updated.

10. Of all the room labels that can be activated in PARAMTER EDIT, the only ones actually printed on the screen are room area and room perimeter.

NOTE: the other room labels may be deactivated in the current program. If so, the menu needs to be updated.

Most of these comments reflect valid problems in performance of the DUCT program. Internally, the ductwork is represented as a tree configuration, which is susceptible to small errors in programming. While most user comments reflect minor problems, others may be very difficult to track and correct.

Recommended Upgrades

In addition to pointing out deficiencies in the DUCT module, participants offered the following specific recommendations on how to improve the program's usability:

1. When using the CHANGE command in LAYOUT EDIT, the program prompts with "LOCATE DUCT" or "LOCATE ROOT." However, whether the user selects 1 or 10 ducts, the program only issues the one prompt. The program should reprompt after each duct section is selected.

2. The ability to input duct runs using coordinates instead of digitizing would be enhanced if an asterisk ("*") is used to show the building origin. Also, there should be a toggle to show the coordinates of the crosshairs on the screen at any time.

3. To enter a point via coordinates rather than by digitizing, the user presses the space bar. However, after entering the point coordinates, the program returns to the crosshairs mode. The space bar should be a toggle so that after it is pressed once, the program enters the coordinates mode, allowing points to be entered successively via coordinates. When the user desires to return to the digitized mode, the space bar would be pressed again.

4. The user's manual explains the JOIN COLLINEAR EDGES command in LAYOUT EDIT by saying that two duct runs which are parallel and share a single node will be joined. This section is confusing and should be rewritten.

5. The program allows the user to delete fittings, but in cases where the user fails to attach new fittings to the node, no warning appears on the screen. Since Superduct II will run without fittings, this situation could cause inaccurate data. Perhaps DUCT could at least point out that there are nodes without fittings when the Superduct II input deck is created.

6. During the EXECUTE SUPER II mode, the program prompts for "Airflow Normalization." What does that mean? The program should let you know if you have diffusers located outside of the building or outside a zone; either case would mean that there is no air going through the duct.

7. After the program has drawn the double line drawing using Superduct II output in RETRIEVE ANALYSIS mode, DUCT should retain the information rather than lose the size and data as it now does.

These recommendations exemplify one of the purposes of the T^3B program. When these suggestions are used to enhance the program, DUCT will be more usable and beneficial to USACE designers. All seven recommendations are valid and, from initial examination, appear easy to incorporate into the program.

LITE Test

Two EEs tested LITE--one from the Kansas City Mechanical/Electrical Section Design Branch, and one from the Sacramento Electrical Design Section, Military Design Branch. Again, the work was primarily for new MCA/MCAR facilities.

Two projects were used for the test at Kansas City District: the Criminal Investigation Division Command (CIDC) building at Fort Leonard Wood, MO (PN224) and the U. S. Army Reserve Center (USARC) warehouse at Fort Riley, KS (PN1238). Figures 3 and 4 show floor plans for PN224 and PN1238, respectively. Both were existing in-house design projects. PN224 was 35 percent complete whereas PN1238 was at the 95 percent stage. Elite lighting calculations were available from the 35 percent design; the EE also used Elite for PN1238.

For the Sacramento test, the organizational maintenance shop (OMS) of the Garden Grove USARC was used. Figure 5 shows the OMS floor plan.

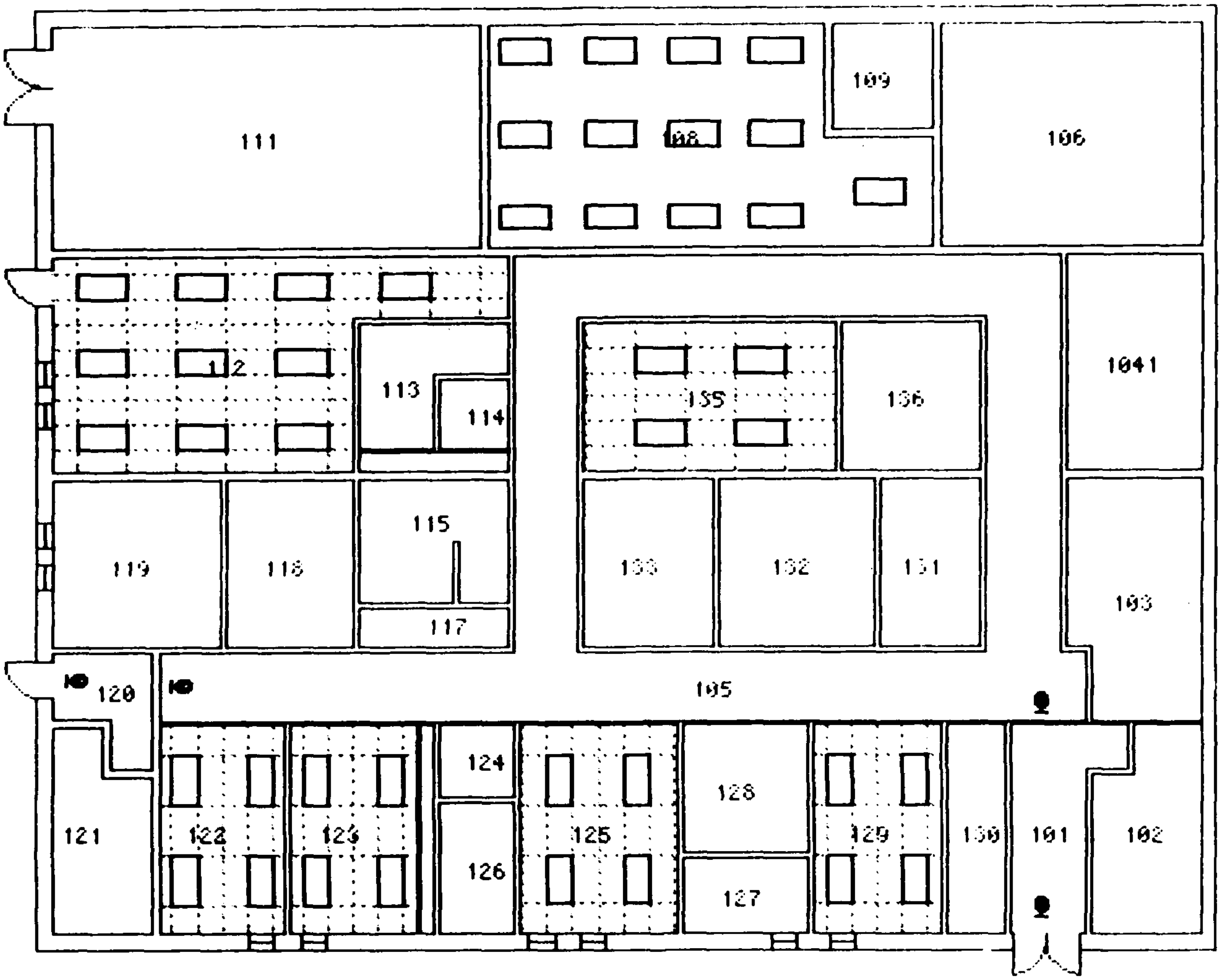

Figure 3. CIDC building, Fort Leonard Wood, MO.

Several times during the test, both District offices met with problems that delayed progress. However, both maintained close contact with USA-CERL and the test was completed.

For Kansas City, most of the problems encountered were not bugs in the program, but were due to the computer setup and user inexperience. Also, an error was found in floor-to-ceiling heights which was traced to the ARCH program. Once this mistake was identified, the ARCH program was corrected on the USA-CERL Harris. The EE used an editor on the Kansas City Harris to insert the correct floor-to-ceiling heights into his data files. Confusion also occurred over the use of the room name and activity labels in ARCH. The consequence was incorrect results when calculating footcandle levels.

Sacramento District found that neither the LCHG nor the LITE program could handle luminaire functions when there were more than nine luminaire types in the LUMAIR data file. However, since Sacramento was using the USA-CERL Harris to perform the test, the program was corrected and reinstalled quickly, so that the test resumed within 1 hour.

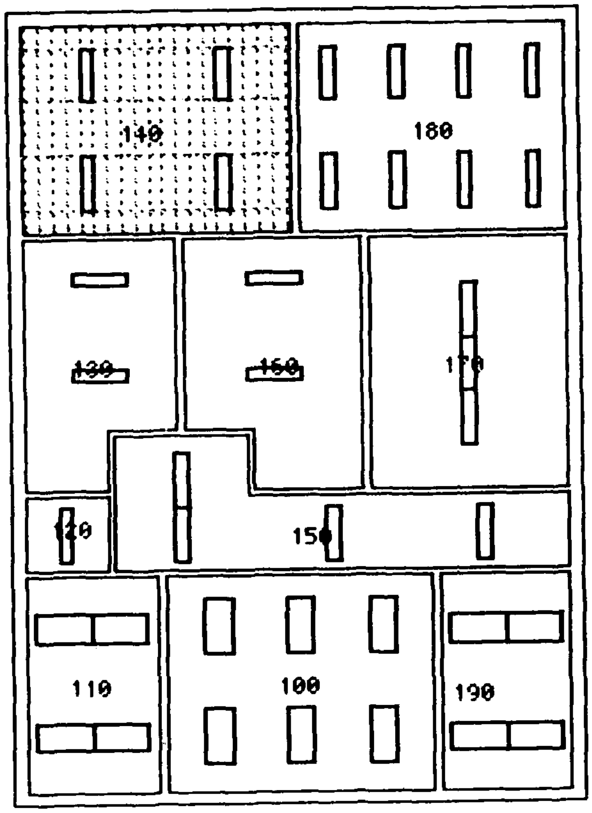

Figure 4. USARC warehouse, Fort Riley, KS.

The next two sections summarize comments generated on the user evaluation sheets that were attached to the formal test plan. Again, when necessary, an explanation is included and flagged by NOTE.

LCHG Program

1. The coefficient of utilization (CU) table, which is based on the IES coefficient of utilization tables,[6] requires the use of the five values which are the percent effective ceiling cavity reflectance and the three values which are the percent wall reflectance in the heading. However, most lighting manufacturers publish smaller tables in their literature. Two solutions are proposed: (a) drop the 10 percent effective ceiling cavity reflectance values from the table and (b) have the user define the size of the table per luminaire type, with a maximum of 3 and 5 as is currently defined.

NOTE: each manufacturer has a different method of presenting CU tables. While most manufacturers only use three effective ceiling cavity reflectances, the IES standard lists five. The LITE program was initially based on the standard five. The LCHG program has been changed to eliminate the 10 percent effective reflectance values. It was easy to drop one of the table headings, but dropping two would require more investigation.

[6]*IES Lighting Handbook: Reference Volume* (Illuminating Engineering Society of North America, New York, 1981).

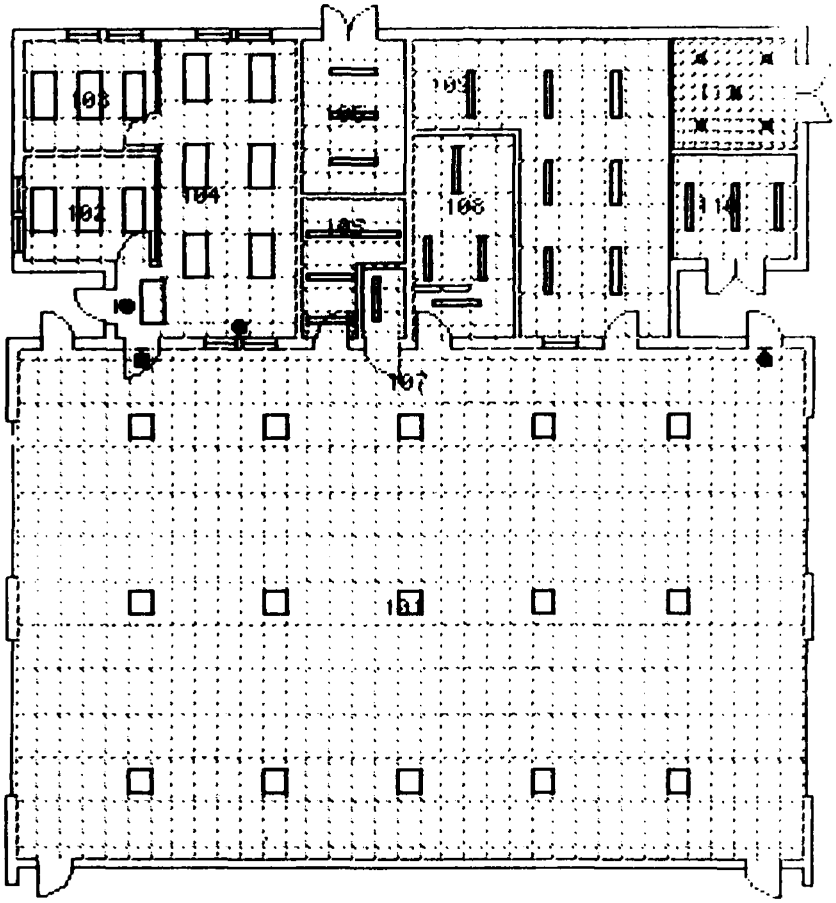

Figure 5. Organizational maintenance shop (OMS), USARC, Garden Grove, CA.

2. When adding a fixture type, there should be a provision for fixtures not included in the 40-06-04 standard.[7] In these cases, the fixture schedule would direct the contractor to a detailed drawing of the fixture within the set of plans. It is suggested that the program print NONE for the type and 0 for the sheet number.

NOTE: the LCHG program prompts the user for descriptive as well as numerical information about each luminaire. (Appendix E lists the data stored for each luminaire type.) The first five prompts ask for the description, 40-06-04 type and sheet number, lamp type, and mounting designation. If a luminaire requires a special detail (i.e., is not in the 40-06-04 standard), the custom has been to return blank answers for the 40-06-04 type and sheet number. As the program is written now, the 40-06-04 type and sheet number are stored as character strings (as opposed to strictly numerical values). If the user types NONE and 0 at the appropriate prompts, that is what will be printed on the fixture schedule and data sheet.

[7] *Lighting Fixtures*, Standard Drawing Number 40-06-04 (Office of the Chief of Engineers [OCE], November 1980).

3. When adding a special fixture, a loop can develop between the prompts for lamp and mounting descriptions if the values for the 40-06-04 sheet number are left blank.

NOTE: as stated for the previous comments, the custom has been to return blank answers for the 40-06-04 type and sheet number if the luminaire is not in the standard. The blank response seems to make the program hang up between the prompts for lamp and mounting descriptions. The only recourse has been to abort from the ADD INDIVIDUAL LUMINAIRE DATA command. If the user remembers to use the NONE and 0 responses, this problem can be corrected.

4. The number of characters allowed for the fixture description should be increased.

NOTE: originally, the maximum length of the fixture description was 19 characters which has been seen to be rather short to accommodate all the information the EEs would like to include in the names to distinguish the luminaire types. The data format has been changed to accommodate 32 characters in the fixture description.

5. The designer has no option of using both the parallel and perpendicular space-to-mounting heights. Since these values are not always the same, this option should be provided.

NOTE: at present, the program performs a check while assuming that space-to-mounting heights are the same in both directions. The addition of another data value, although very time-consuming, is necessary to improve the precision of the program.

6. The user's manual needs to explain the fixture loss and dirt depreciation factors and the relationship of the two values.

NOTE: when calculating the illuminance levels using the IES Zonal Cavity Method, consideration is provided for the "dirtiness" of the room and the depreciation of the fixture in the form of a value called the maintenance factor, MF (or light loss factor). The MF consists of eight values describing the characteristics of the fixture and the room condition. Seven of the values describing each unique fixture are represented by the fixture loss factor (FLF) in the LITE program and are associated with the fixture in the LUMAIR file. Each unique room condition is represented by the dirt depreciation factor (DDF), the eighth value, and is associated with the room in the ARCH data base. The FLF and DDF are then multiplied together to obtain the total MF for each room.

7. When the user is adding a new fixture, the LCHG's first question is, "Is this a special fixture." The manual should be updated to explain the concept of a special fixture as related to the LITE program.

NOTE: the program has been modified so that the first question asked is now, "Is this a fixture which will not be used in any illuminance calculations (i.e., exit light, spotlight, etc.)." The special fixture concept was conceived to handle fixtures for which CU tables are not needed in the luminaire data base. If the answer to the preceding question is "yes," the program will skip over the CU table prompts and automatically initialize the CU table to be 0.

8. There is confusion between use of the word "type" in several places in the program. Specifically, when adding a new fixture, the user is prompted to "Enter type to start with or hit return for none." Later in the prompting sequence, the user is asked to

enter the "type" in the luminaire description. A suggestion is to modify the first prompt to "Enter existing type 1, 2, or 3, etc., from the printed list of luminaires, or hit return if there is no existing list."

NOTE: this user made a valid point, but the suggested prompt is not entirely correct. The intention of this prompt is to ascertain whether two different luminaires have basically the same parameters, with some minor differences. For example, a three-lamp fluorescent grid troffer and a four-lamp fluorescent grid troffer are basically the same except for the name, number of lamps, initial lumens, and watts. If the three-lamp fixture has already been added to the data base, the user would indicate its number as the type to start with when adding a four-lamp fixture. The program then internally creates the four-lamp fixture using the parameters of the three-lamp fixture. When the program prompts the user for all parameters of the four-lamp fixture, the values for the three-lamp fixture are presented as defaults. If a value is the same (lamp type, lamp description) for both fixtures, the user just strikes the carriage return key. If a value is different (e.g., the name, number of lamps), the user simply enters the new value. The program has been altered to improve clarity of the prompt. It now reads: "Enter the number of a luminaire already entered into the data base which is similar to the fixture you wish to add, or just hit return if there is not one available." Later in the program, the type description has been clarified to read "40-06-04 Type."

With the exception of items 1 and 5, the program can be modified easily as recommended. These two suggestions would require some changes in data file format and value manipulation.

LITE Program

1. When adding individual luminaires to a room with a ceiling grid, the program should not prompt for the bearing.

NOTE: the CEL-1 program needs to know how a luminaire has been placed in the ceiling plan, i.e., whether the long axis is running north-south or east-west. This direction is known as the "bearing." When placing luminaires in a room as a group, the LITE program can determine the bearing from the ceiling grid layout. Clearly, the program needs to have the same capability when the user is adding a luminaire individually.

2. When shifting a grid, it would help to be able to state the amount to be shifted as an X and Y coordinate distance from a specified point.

NOTE: the program centers the ceiling grid room by room. If one room is adjacent to another room without an intervening wall, e.g., a reception area and a corridor, the ceiling grid pattern in one room may not line up with the grid pattern of the next room. LITE allows the user to shift the grids around in a room for this purpose. At present, the user must locate a reference point on the grid and then locate the new position for that reference point. This process can become very unwieldy with small increments.

3. Switch designations should be added to the program.

NOTE: USA-CERL has proposed an electrical circuitry program that would include the switching designation. It is considered to be a function separate from the lighting layout and illuminance calculations.

4. Single or double direction arrows should be added to the exit light symbols.

NOTE: in the current program, exit light symbols do not indicate the direction toward which the exit light is pointing. This capability is needed for cases in which the exit sign is mounted in a place other than directly over a door.

5. The program sometimes aborts during LUMINAIR EDIT mode when the user attempts to execute the A command. For example, if there is only one row of valid ceiling grid tiles (e.g., down a corridor) and the user tries to add a group of luminaires that are grid-centered, the program stops and the user is returned to the operating system.

NOTE: the program can be modified so that when this situation occurs, the user is informed to try the tile-centered option while adding groups of luminaires.

6. The light loss factor (LLF) in the CEL-1 input deck created by LITE is not in the required range of 0.0 to 1.0, but rather has a value of 7.0.

NOTE: LITE takes the room dirt depreciation factor from CELL EDIT and the fixture loss factor from the LUMINAIR data base (entered in LCHG) and multiplies them together to obtain the total light loss factor. The program may have a problem with the location of the decimal point when performing the calculation.

7. The colors on the Tektronix 4113 are not the same as on the 4109.

With the exception of item 6, most of these suggestions will require a great deal of work to incorporate. However, all would be possible to implement at some point in the future.

Technical Analysis

DUCT Test

In the DUCT test, Kansas City compared the DUCT/Superduct II package with three other commercially available analysis programs. Initially, all manually calculated friction loss values and sizes were taken from a DUCTULATOR, while the fitting loss coefficients were obtained from the *1981 ASHRAE Handbook of Fundamentals.*[8] Appendix F provides a detailed account of the test results. The test has confirmed the validity of the DUCT/Superduct II program in computing pressure loss calculations. However, the test did not address the question of whether DUCT/Superduct II is a comprehensive duct-sizing program since all sizes were taken from a DUCTULATOR.

As noted earlier, Sacramento was unable to comp: e DUCT with other design methods.

LITE Test

Kansas City District compared illuminance calculations with one commercially available program, Elite, and manual calculations. It should be noted that all methods compared use the IES zonal cavity method to calculate the maintained average level of illumination.

---

[8]*1981 ASHRAE Handbook of Fundamentals* (American Society of Heating, Refrigeration, and Air-Conditioning Engineers [ASHRAE], 1981).

Table 1 lists results of the test using the CIDC building at Fort Leonard Wood, whereas Table 2 summarizes the results for the USARC warehouse at Fort Riley. The final technical analysis by Kansas City is given in Appendix F.

At present, Sacramento does not use computer programs to perform lighting calculations. Thus, all comparisons were made with manual calculations. Photometric data were taken from manufacturer's literature. Table 3 lists the results.

Both Districts found that LITE zonal cavity calculations were comparable. The minor variances were probably due to the difficulty of drawing the building plan as accurately as construction drawings. As Kansas City pointed out, just a slight difference in room dimensions can produce an erroneous area value that induces errors in the room cavity ratio (RCR), floor cavity ratio (FCR), and footcandle level.

For the IES zonal cavity method, the room or area must be rectilinear. This also is true for CEL-1 daylighting calculations. However, the perimeter of every room in a building design may not be defined by only four points. When this situation occurs, manual calculations require that the user divide the room into several areas and calculate illuminance requirements for each area separately. LITE assumes the length and width are the longest overall length and width of the room. The resultant footcandle values are incorrect, but comparable. Elite is unable to address this situation entirely.

Although the Kansas City EE created a CEL-1 input deck and ran the CEL-1 program successfully, he did not address the daylighting output in his report. Sacramento District did not attempt to run CEL-1 due to a lack of training on the program.

Table 1

LITE Versus Elite—CIDC Building (PN224)

Room	ELITE Program						LITE Program				
	Area (sq ft)	RCR*	Design FC**	Fix. Reqd.	Fix. Used	Actual FC	Area (sq ft)	RCR	Fix. Reqd.	Fix. Used	Actual FC
108	624.0	2.32	50	12.0	13	54.13	555.4	2.6	11.0	13	59.05
112	415.9	2.73	50	8.1	9	55.48	479.0	3.0	9.5	10	52.24
122	162.5	4.44	50	3.8	4	52.18	167.9	4.3	3.9	4	51.06
123	162.5	4.44	50	3.8	4	52.18	167.9	4.3	3.9	4	51.06
125	204.4	3.88	50	4.5	4	44.11	211.2	3.8	4.7	4	42.27
129	162.5	4.44	50	3.8	4	52.18	167.9	4.3	3.9	4	51.06
135	240.0	3.67	30	3.1	4	38.53	240.2	3.6	5.1	4	38.86

*RCR = room cavity ratio.
**FC = footcandles.

Table 2

Manual Calculations Versus Elite—USARC Warehouse (PN1238)

Room	Manual Calculation						LITE Program					Elite Program				
	Area (sq ft)	RCR	Design FC	Fix. Reqd.	Fix. Used	Actual FC	Area (sq ft)	RCR	Fix. Reqd.	Fix. Used	Actual FC	Area (sq ft)	RCR	Fix. Reqd.	Fix. Used	Actual FC
100	304	3.2	50	6.5	6	46.0	307.1	3.1	5.92	6	50.67	307.1	3.1	6.08	6	49.32
110	143	4.7	50	3.6	4	55.0	153.5	4.5	3.52	4	56.75	153.5	4.5	3.56	4	56.15
120	32	9.8	10	0.5	1	18.4	33.4	9.5	.53	1	18.75	33.4	9.5	1.00	1	18.55
130	158	4.8	10	1.4	2	14.8	184.2	4.4	1.76	2	11.35	207.3	3.9	1.90	2	10.5[illegible]
140	345	3.0	30	3.7	4	32.8	301.1	3.2	3.33	4	36.03	301.1	3.2	3.44	4	34.89
150	179	6.0	10	2.0	3	14.9	226.3	5.2	2.37	4	16.84	-	-	-	-	-
160	180	4.4	10	1.5	2	13.5	218.2	3.9	1.99	2	10.06	-	-	-	-	-
170	260	3.4	10	2.3	3	13.2	268.2	3.3	2.31	3	12.96	241.2	3.6	2.14	2	9.34
180	300	3.2	50	9.0	8	44.6	297.3	3.2	8.37	8	47.79	297.3	3.2	8.41	8	47.58
190	155	4.5	50	3.8	4	52.5	149.6	4.6	3.46	4	57.77	149.6	4.6	3.50	4	57.16

Table 3

LITE Versus Manual Calculations—OMS Building

Room	Manual Calculations							LITE Program					
	Area (sq ft)	HRC*	RCR	Design FC	Fix. Reqd.	Fix. Used	Actual FC	Area (sq ft)	HRC	RCR	Fix. Reqd.	Fix. Used	Actual FC
101	3220.0	11	1.9	30	13.90	15	32.4	3220.0	8.5	1.53	14.8	15	30.4
102	111.6	6.5	6.2	50	2.93	3	51.1	110.4	6.5	6.23	2.9	3	51.6
103	117.5	6.5	6.0	50	3.02	3	49.6	115.8	6.5	6.0	3.0	3	50.3
104	352.7	6.5	3.9	50	67.08	7	49.4	353.9	6.5	3.97	7.1	7	49.0
105	88.3	7	8.6	20	45.32	4	18.5	87.1	6.5	8.16	3.8	4	20.9
106	133.0	7	6.2	30	2.81	3	31.9	129.3	6.5	5.83	2.1	3	43.1
108	162.0	7	5.8	20	3.66	4	21.8	160.8	6.5	6.55	3.9	4	20.4
109	439.8	7	3.9	30	6.72	7	31.2	434.6	6.5	3.71	5.3	7	39.4
110	104.5	7	6.8	20	3.31	3	18.1	102.9	6.5	6.42	2.4	3	25.5
111	110.0	7	6.6	20	2.47	5	40.4	108.3	4.5	4.33	1.5	5	67.2

*HRC - height of room cavity.

5 IMPLICATIONS OF THE RESULTS

The Kansas City engineers expressed the opinion that the programs they tested were not desirable because of the cost of using them on the Harris computer. Kansas City District has many personal computers that are used to run off-the-shelf software for design analysis. In contrast, Sacramento engineers have limited access to commercial programs. The Sacramento District MEs use some off-the-shelf software, but the EEs still design using manual calculation. In addition, since they were using the USA-CERL Harris, the concept of the programs being too expensive to use did not enter into their analysis of the program as a design tool. Consequently, the Sacramento engineers had a much more favorable opinion of the usefulness of LITE and DUCT and the CAEADS system as a whole than those from Kansas City.

CAEADS was intended to promote multidisciplinary interaction. Architects were to enter the building floor plan first via ARCH. The other disciplines were then able to perform energy analyses using ENERGY, DUCT, and LITE. Currently, Kansas City District architects create design documents on an Intergraph drafting system whereas Sacramento District architects use AUTOCAD on Apollo microcomputers. In some cases, Sacramento District architects were also using CAEADS programs on the Apollo workstations in an alpha test. Since the architects were not using the Harris ARCH program, the MEs and EEs had to input the building plan themselves. This requirement created a manhour overhead that the MEs and EEs could not afford, both in terms of time and cost. USA-CERL and the BSO have procured Apollo workstations for conversion of the ARCH, ENERGY, LCHG, and LITE programs. At the same time, the analytical programs BLAST and CEL-1 will be converted to the Apollo hardware. While Kansas City would not benefit from this new environment, Sacramento and other Districts with Apollos would.

Present Department of Defense (DOD) design criteria require that both active and passive solar be considered on all designs and incorporated if found to be life-cycle cost-effective. Daylighting is considered a passive solar technique. Thus, it is unclear why the test participants disregarded the CEL-1 analysis performed during the test. One factor may be the difficulty in accessing the CEL-1 program. CEL-1 was written for the CYBER computer which is the environment used for the T^3B test. During the test, the CEL-1 program was converted to the Harris computer. With the CEL-1 program now on the same environment as LITE, the time and effort required to perform daylighting analysis became minimal. It should be noted that projected DOD directives will require designers to consider the most cost-effective energy conservation measures while determining electrical power and distribution requirements--which include daylighting studies--as part of the facility design process.[9] Consequently, USA-CERL has proposed an electrical circuitry analysis program to complete the overall electrical portion of CAEADS.[10]

Several participants commented on applicability of the programs to USACE design. Clearly, the DUCT and LITE programs offer more capabilities than are required in early

---

[9]Title 10, Code of Federal Regulations, Part 435, Draft Proposed Subpart A, *Federal Register*, Vol 52, No. 87 (May 6, 1987).

[10]C. Barton and A. Williams, *ECP—A Proposed Program for Electrical Circuitry Analysis* Technical Report E-88/03/ADA190494 (USA-CERL, February 1988).

concept design. The following questions raised important points about the CAEADS concept and the way the programs have evolved:

- Have program designers lost sight of the 35 percent design phase requirements in trying to develop the most comprehensive and complete analysis programs?

- If the programs were smaller in scale and scope, would they be more easily accepted by USACE engineers into the design process?

The test results have left some unanswered questions. It is proposed that future test plans and specifics emphasize the importance of investigating every aspect of a product's usability and validity as a USACE design tool. Considerations include: if the cost of using the program inhibits the user from using the program, what can be done to minimize those costs? If all the effects of cost to the user are eliminated, are the program fundamentals sound and do they promote good design decisions? If the program's current computer environment is not easily accessible, what would be a good alternative? Is a program better for the USACE engineer just because it is available on a personal computer? For CAEADS programs in particular, how appropriate to the design process would a program be if the ME or EE did not have to input the building layout into ARCH? How does the familiarity of current methods affect the ease-of-use rating of new or unfamiliar programs? Researchers must be very judicious in the development of test plans and specifics to ensure the best possible results.

6 CONCLUSIONS AND RECOMMENDATIONS

Two graphic modules of CAEADS have been tested as part of the FY87 T^3B program: LITE, with its interface to LCHG and CEL-1, and DUCT, with its interface to Superduct II. Both programs were used by two USACE Districts--Kansas City and Sacramento--in comparing results to in-house design projects past the 35 percent design phase.

Overall, the participants were able to use the programs despite a few minor setbacks. However, they identified several changes needed to the modules to make them more efficient and cost-effective. Valuable suggestions were generated for improving the programs.

It is evident that the DUCT program requires a great deal of revision before it can be used in the field. Since the T^3B test, the DUCT program is being eclipsed by commercial software development. Many vendors are offering layout programs in conjunction with CADD that have superior graphic capabilities. However, before adopting any of these programs for USACE, it would still be necessary to evaluate the analytical capability through a process similar to the Kansas City DUCT portion of this test. Due to the difficulty arising from continued use of the Superduct II program and the results of the test, it is recommended that the DUCT program be phased out of USA-CERL's research effort.

In contrast, LITE and its interface to CEL-1 offer USACE designers a unique analytical tool. While the market is saturated with small programs that perform zonal cavity calculations, the number of commercially available daylighting programs is very small. Therefore, it is recommended that USA-CERL pursue the further development of LITE and its interface to CEL-1. Future T^3B tests will also be necessary to ensure the validity of using CEL-1 in the USACE design process.

USA-CERL is using input from the T^3B test to upgrade the LITE program and help identify priorities for new tool development. After enhancements and revisions are complete, the program will undergo more formal field-testing. Additional District Offices will be included to ensure that the programs serve a wide range of needs.

Future research in the computer software arena can benefit from the lessons learned while developing and testing the CAEADS programs. Improved research methods will decrease time and effort spent on research and promote meaningful T^3B demonstration results.

APPENDIX A:

DUCT TEST PLAN AND TEST SPECIFICS*

Test Plan

One of the basic objectives of the Computer-Aided Engineering and Architectural Design System (CAEADS) is to have designers use graphic modules with the integrated building data base to run various design analysis programs. Each discipline of the multidisciplinary design team can then concentrate on the aspects of design analysis particular to that discipline. By having an integrated approach to design, it is believed that overall design costs will be reduced. Design analyses during early or concept design also can impact design quality. Thus, providing designers with easy-to-use tools through CAEADS will allow them to evaluate many design alternatives, optimizing cost-effectiveness and end-product quality.

USA-CERL has developed the DUCT program to provide both duct layout capabilities and an interface to a complex duct-sizing program (Superduct II). Since initial implementation is now complete, USA-CERL needs field evaluation of the applicability of DUCT and DUCT/Superduct II to the designer. As a result of this evaluation, DUCT and/or Superduct II may be (1) modified to be more usable, (2) released for general field use, or (3) reevaluated as to the role of such programs in the concept design phase.

To assist the designer in the required evaluations, the proposed test plan for DUCT and DUCT/Superduct II is outlined here. DUCT has already undergone a field review and the function of the program has been changed based on the outcome. During the life of computer software, continual user review will be necessary to ensure that user requirements are met. Though it is not the intent of this test to evaluate Superduct II capabilities, some comments about the program will come naturally and are welcomed. Superduct II has been licensed by USA-CERL for the Corps' use on its Harris computers. Another concept of CAEADS is to use off-the-shelf analysis programs, not necessarily under direct support of USACE, to do the design studies. The desirability of this concept can also be evaluated during this test and comments are encouraged.

Specifically, the basis for this test is to evaluate the usage of DUCT and DUCT/Superduct II during concept design phases of the facility. Comments are equally welcomed for levels above concept design. The evaluation is divided into two parts: DUCT and DUCT/Superduct II.

DUCT Evaluation

The DUCT program is the graphic layout module for CAEADS ductwork design. In addition, diffusers, fittings, and risers can be located and described.

During the test, DUCT should be used extensively, even for projects that might not ordinarily require the features of DUCT/Superduct II. For proper evaluation of software, the user must be more advanced than a beginner, though first impressions are also important.

---

*This document is the one issued to test participants, with minor editorial changes to improve presentation.

The evaluation should follow the outline below:

I. DUCT Program

a. Initial Impressions

(1) Ease of using DUCT
(2) Problems encountered
(3) Applicability to site/USACE designs.

b. Test Evaluation

(1) Ease of using DUCT
(2) Problems encountered
(3) Suggested changes
(4) Applicability to site/USACE designs
(5) Number of times/projects used.

DUCT/Superduct II Evaluation

DUCT can be used to access the major features of Superduct II. Superduct II is a comprehensive duct-sizing program. However, no direct training on Superduct II is provided by either USACE or the Superduct II developers. The evaluation of the DUCT/Superduct II interface must take this situation into account and assess whether training is necessary to learn Superduct II or if the user's manual is sufficient.

II. DUCT/Superduct II

a. Initial Impressions

(1) Superduct II usability
(2) Superduct II completeness
(3) Superduct II applicability to site/USACE designs.

b. Test Evaluation

(1) Completeness of DUCT/Superduct II interface
(2) Problems encountered
(3) Suggested changes
(4) Applicability to site/USACE designs.

Results of Evaluation

The evaluation should be presented in report form and include all of the evaluation sheets completed by the designers. Additional information should include:

1. Background on the projects (e.g., type of building, location), total number of DUCT and DUCT/Superduct II uses.

2. Estimation of cost/benefit in manpower terms; some of the studies may not be done normally, so this estimation should be based on the manpower cost/benefit if the study were done.

3. Perceived or measured accuracy of the results compared with current practice.

4. Features liked and disliked. Prioritization of enhancements that would improve the tool.

5. Quality of graphics.

6. Recommendations for further testing or broader application.

The timeframe for reporting results will be agreed upon between USA-CERL and the USACE field operating agency (FOA).

DUCT Evaluation

1. User: Date:

2. Project:

3. Have you used DUCT before? YES NO

   If yes, how many times? ____

4. Rate your ease of using DUCT:

5. Did you ever need to consult the manual? YES NO

6. Explain any problems you encountered:

7. List any suggested changes or additions to improve DUCT:

8. State the applicability of the program to site/USACE designs:

DUCT/Superduct II Evaluation

1. User: Date:

2. Project:

3. Have you used DUCT to create a Superduct II input deck before? YES NO

   If yes, how many times? ____

4. Rate your ease of using DUCT to create a Superduct II input deck:

5. How accurate was the Superduct II input deck produced by DUCT?

6. Did you ever need to consult the Superduct II manual? YES NO

   If YES, explain what additional information you needed and if you found it in the manual:

7. Explain any problems you encountered when trying to create an accurate Superduct II input deck using DUCT:

8. Did you try to use Superduct II with the input deck created by DUCT? YES NO

   If YES, explain any problems you had when running Superduct II:

9. List any suggested changes or additions to improve the DUCT/Superduct II interface:

10. State the applicability of the program to site/USACE designs:

Test Specifics

Kansas City District

Kansas City will test DUCT/Superduct II calculations compared with: (1) manual calculations of equal friction models, (2) Intergraph-supplied CAD package for duct-sizing, (3) possibly one of the Trane CDS packages, and (4) possibly the Elite duct-sizing package. Requirements for completion of the tests include submittal of drawings, inputs, outputs, and evaluation sheets.

DUCT and Superduct II are accessible by Kansas City on the District's local Harris hardware.

Sacramento District

Sacramento will test DUCT/Superduct II calculations compared with: (1) manual calculations and (2) one of the Trane packages. Rather than try to start doing one project from the beginning with all of these calculations, Sacramento will compare projects for which manual calculations are already done.

Evaluation sheets have been provided with the test plans and are to be used while executing the program.

Requirements for completion of the test include submittal of all drawings, inputs, and outputs generated in the project. Also included should be copies of all plans, manual calculations, etc., that were used during the comparisons. A written narrative is required from the engineer conducting the test stating overall opinion of the DUCT and Superduct II programs including applicability, accuracy, and ease of use. The test is to be completed, and submittals sent to Cindi Barton/USA-CERL, by March 31, 1987.

DUCT and Superduct II are accessible to Sacramento on the USA-CERL Harris through a 9600-baud dedicated telephone line.

APPENDIX B:

LITE TEST PLAN AND TEST SPECIFICS*

Test Plan

LITE/CEL-1

One of the basic objectives of the Computer-Aided Engineering and Architectural Design System (CAEADS) is to have designers use graphic modules with the integrated building data base to run various design analysis programs. Each discipline of the multidisciplinary design team can then concentrate on the aspects of design analysis particular to that discipline. By having an integrated approach to design, it is believed that overall design costs will be reduced. Design analyses during early or concept design also can impact design quality. Thus, providing designers with easy-to-use tools through CAEADS will allow them to evaluate many design alternatives, optimizing cost-effectiveness and end-product quality.

USA-CERL has developed the LITE program to provide both simple lighting calculations and an interface to a complex lighting design program (CEL-1). Since initial implementation is now complete, USA-CERL needs field evaluation of the applicability of LITE and LITE/CEL-1 to the designer. As a result of this evaluation, LITE and/or CEL-1 may be (1) modified to be more usable, (2) released for general field use, or (3) reevaluated as to the role of such programs in the concept design phase.

To assist the designer in the required evaluations, the proposed test plan for LITE, LCHG, and LITE/CEL-1 is outlined here. LITE has already undergone a field review and the function of the program has been changed based on the outcome. During the life of computer software, continual user review will be necessary to ensure that user requirements are met. Though it is not the intent of this test to evaluate the CEL-1 capabilities, some comments on the program will come naturally and are welcomed. Should the CEL-1 portions show enough promise, USACE support for that program may be considered, although currently, CEL-1 is a public domain program under research support from the National Bureau of Standards. Another concept of CAEADS is to use off-the-shelf analysis programs, not necessarily under direct support of USACE, to do the design studies. The desirability of this concept can also be evaluated during the test, and comments are encouraged.

Specifically, the basis for this test is to evaluate the usage of LITE and LITE/CEL-1 during concept design phases of the facility. However, comments are equally welcomed for levels above concept design. The evaluation is divided into two parts: LITE/LCHG and LITE/CEL-1.

LITE/LCHG Evaluation

The LITE program is the graphic layout module for CAEADS lighting design. In addition to reflected ceiling plans, simple zonal cavity calculations are possible as is interface to major features of CEL-1. LITE accesses a file of luminaire data that can be site-modified using the LCHG program.

---

*This document is the one issued to test participants, with minor editorial changes to improve presentation.

During the test, LITE should be used extensively, even for projects that might not ordinarily require the features of LITE/CEL-1. For proper evaluation of software, the user must be more advanced than a beginner, though first impressions are also important. The luminaire data base should be reviewed for site applicability both initially and continually throughout the test.

The evaluation should follow the outline below:

I. LCHG Program

a. Initial Impressions

(1) Data base completeness
(2) Data base accuracy
(3) Data base applicability to site/USACE designs.

b. Test Evaluation

(1) Ease of using LCHG
(2) Problems encountered
(3) Suggested changes
(4) Applicability to site/USACE designs
(5) Number of times used.

II. LITE Program

a. Initial Impressions

(1) Ease of using LITE
(2) Problems encountered
(3) Applicability to site/USACE designs.

b. Test Evaluation

(1) Ease of using LITE
(2) Problems encountered
(3) Suggested changes
(4) Applicability to site/USACE designs
(5) Number of times/projects used.

LITE/CEL-1 Evaluation

LITE can be used to access the major features of CEL-1. The CEL-1 program is a comprehensive tool that allows designers to study the effects of daylighting on both lighting design and energy aspects of the facility. However, no direct training on CEL-1 will be provided by either USACE or the CEL-1 developers. The evaluation of the LITE/CEL-1 interface must take this situation into account and assess whether training is necessary to learn CEL-1 or if the user's manual is sufficient.

III. LITE/CEL-1

a. Initial Impressions

(1) CEL-1 usability
(2) CEL-1 completeness
(3) CEL-1 applicability to site/USACE designs.

b. Test Evaluation

(1) Completeness of LITE/CEL-1 interface
(2) Problems encountered
(3) Suggested changes
(4) Applicability to site/USACE designs.

Results of Evaluation

The evaluation should be presented in report form and include all evaluation sheets completed by the designers. Additional information should include:

1. Background on the projects (e.g., type of building, location), total number of LITE, LCHG, and LITE/CEL-1 uses.

2. Estimation of cost/benefit in manpower terms; some of the studies may not be done normally, so this estimation should be based on the manpower cost/benefit if the study were done.

3. Perceived or measured accuracy of the results compared with current practice.

4. Features liked and disliked. Prioritization of enhancements that would improve the tool.

5. Quality of graphics.

6. Recommendations for further testing or broader application.

The timeframe for reporting results will be agreed upon between USA-CERL and the USACE FOA.

LITE Evaluation

1. User: Date:

2. Project:

3. Have you used LITE before? YES NO

   If yes, how many times? ____

4. Rate your ease of using LITE:

5. Did you ever need to consult the manual? YES NO

6. Explain any problems you encountered:

7. List any suggested changes or additions to improve LITE:

8. State the applicability of the program to site/USACE designs:

LCHG Evaluation

1. User: Date:

2. Have you used LCHG before? YES NO

   If yes, how many times? ____

3. Rate your ease of using LCHG:

4. Did you ever need to consult the manual? YES NO

5. Explain any problems you encountered:

6. List any suggested changes or additions to improve LCHG:

7. State the applicability of the program to site/USACE designs:

LITE/CEL-1 Evaluation

1. User: Date:

2. Project:

3. Have you used LITE to create a CEL-1 input file before? YES NO

   If yes, how many times? ____

4. Rate your ease of using LITE to create a CEL-1 input file:

5. How accurate was the CEL-1 input file produced by LITE?

6. Did you ever need to consult the CEL-1 manual? YES NO

   If YES, explain what additional information you needed and if you found it in the manual:

7. Explain any problems you encountered when trying to create an accurate CEL-1 input file using LITE:

8. Did you try to use CEL-1 with the input file created by LITE? YES NO

   If YES, explain any problems you had when running CEL-1:

9. List any suggested changes or additions to improve the LITE/CEL-1 interface:

10. State the applicability of the program to site/USACE designs:

Test Specifics

Kansas City District

Kansas City will test LITE compared with: (1) Elite calculations, (2) manual calculations, and (3) CEL-1 calculations. Elite is the program normally used for the District's lighting calculations, but it has never had a full-scale comparison made with manual calculations. Ideally, the users will produce at least a few example comparisons of LITE versus Elite versus manual calculations.

Also, Kansas City will try to compare exterior/security lighting calculations with those of CEL-1. If possible, the GE lighting program of this type will be used for comparison.

Rather than try to use one project from the beginning with all these calculations, the District will compare projects for which manual or Elite calculations have already been done.

Building types discussed for the test include a gymnasium, a CIDC building, and a reserve center. Requirements upon their completion are all drawings, inputs, outputs, and evaluation sheets generated.

LITE is accessible by Kansas City on the local Harris.

Sacramento District

Sacramento will compare the results of LITE with manual calculations. Ideally, the users will produce at least a few example comparisons of LITE versus manual calculations and other current methods.

Rather than trying to do one project from the beginning with all these calculations, the District will compare projects for which manual calculations have already been done.

Evaluation sheets have been provided with the test plans and are to be used while executing the program.

Requirements for completion of the test include submittal of all drawings, inputs, and outputs generated during the project. Also provided should be copies of all plans, manual calculations, etc., that were used during the comparisons. A written narrative is required from the engineer conducting the test stating overall opinion of LITE and LCHG programs, including applicability, accuracy, and ease of use. The test is to be completed, and submittals sent to Cindi Barton/USA-CERL, by March 31, 1987.

LITE is accessible to Sacramento on the USA-CERL Harris through a 9600-baud dedicated telephone line.

APPENDIX C:

TIME LOG ANALYSIS

Kansas City District

User Totals:

User Name	Total Elapsed Time	Total CPU Time	Average CPU Time	Date Last Accessed	Number of Times Accessed
USER ER-MECH-ELCT					
CINDI BARTON		0:54:17	0:10:51	9 MAR 87	5
ARCH	0:08:52	0:00:23	0:00:05	9 MAR 87	4
LITE	0:19:40	0:00:33	0:00:05	9 MAR 87	6
USER ER-MECH-ELCT					
JIM TURNER		1:50:18	0:27:34	23 MAR 87	4
ARCH	1:32:05	0:02:40	0:00:32	25 MAR 87	5
DUCT	8:01:25	0:17:39	0:00:40	31 MAR 87	26
ENERGY	0:31:59	0:01:32	0:00:46	25 MAR 87	2
LITE	0:29:43	0:01:26	0:01:26	30 MAR 87	1
SUPERDUCT	0:01:54	0:00:54	0:00:02	31 MAR 87	26
USER ER-MECH-ELCT					
JIM BARNETT		13:02:37	0:41:11	4 MAR 87	19
ARCH	6:39:02	0:15:52	0:00:20	18 MAR 87	47
LITE	19:58:43	0:50:46	0:00:40	19 MAR 87	76
ALL USERS:	37:43:23	15:47:12	0:29:52		28

Program Totals:

User Name	Total Elapsed Time	Total CPU Time	Average CPU Time	Date Last Accessed	Number of Times Accessed
USER ER-MECH-ELCT		15:47:12	0:33:49	23 MAR 87	28
ARCH	8:19:59	0:18:55	0:00:20	25 MAR 87	56
DUCT	8:01:25	0:17:39	0:00:40	31 MAR 87	26
ENERGY	0:31:59	0:01:32	0:00:46	25 MAR 87	2
LITE	20:48:06	0:52:45	0:00:38	30 MAR 87	83
SUPERDUCT	0:01:54	0:00:54	0:00:02	31 MAR 87	26
ALL USERS:	37:43:23	15:47:12	0:29:52		28

Sacramento District

User Totals:

User Name	Total Elapsed Time	Total CPU Time	Average CPU Time	Date Last Accessed	Number of Times Accessed
USER BARTON					
CINDI BARTON		1:26:18	0:28:46	29 MAY 87	3
ARCH	5:05:19	0:13:10	0:01:38	31 OCT 86	8
LITE	0:11:39	0:01:17	0:00:15	20 MAY 87	5
LCHG	0:01:53	0:00:12	0:00:04	11 MAY 87	3
USER SACRAMENTO					
CINDI BARTON		1:28:32	0:11:04	29 MAY 87	8
LITE	0:29:47	0:02:03	0:00:11	29 MAY 87	11
LCHG	0:01:57	0:00:11	0:00:05	14 MAY 87	2
USER SACRAMENTO					
JAMES A DYER		12:44:28	0:24:39	4 JUN 87	31
ARCH	2:57:02	0:04:12	0:00:42	9 APR 87	6
DUCT	6:41:22	0:12:59	0:00:33	3 JUN 87	23
ENERGY	1:04:46	0:05:15	0:00:39	3 JUN 87	8
SUPERDUCT	0:01:22	0:00:24	0:00:04	3 JUN 87	6
USER SACRAMENTO					
MARY A. DREWRY		20:55:18	0:48:16	29 MAY 87	26
LITE	14:47:39	0:31:34	0:01:18	21 MAY 87	24
LCHG	3:42:24	0:02:11	0:00:26	14 MAY 87	5
USER SACRAMENTO					
SCOTT BARMANN		2:33:29	1:16:44	8 APR 87	2
ARCH	1:31:11	0:01:35	0:00:31	8 APR 87	3
DUCT	0:28:01	0:00:32	0:00:16	12 FEB 87	2
ENERGY	0:06:26	0:00:18	0:00:18	12 FEB 87	1
SUPERDUCT	0:00:03	0:00:02	0:00:02	12 FEB 87	1
ALL USERS:	31:44:54	39:07:29	0:33:04		70

Program Totals:

User Name	Total Elapsed Time	Total CPU Time	Average CPU Time	Date Last Accessed	Number of Times Accessed
USER BARTON		1:26:18	0:28:46	29 MAY 87	3
ARCH	5:05:19	0:13:10	0:01:38	31 OCT 86	8
LITE	0:11:39	0:01:17	0:00:15	20 MAY 87	5
LCHG	0:01:53	0:00:12	0:00:04	11 MAY 87	3
USER SACRAMENTO		37:41:47	0:33:45	4 JUN 87	67
ARCH	4:28:13	0:05:47	0:00:38	9 APR 87	9
DUCT	7:09:23	0:13:31	0:00:32	3 JUN 87	25
ENERGY	1:11:12	0:05:33	0:00:37	3 JUN 87	9
LITE	15:17:26	0:33:37	0:00:57	29 MAY 87	35
SUPERDUCT	0:01:25	0:00:26	0:00:03	3 JUN 87	7
LCHG	3:44:21	0:02:22	0:00:20	14 MAY 87	7
ALL USERS:	31:44:54	39:07:29	0:33:04		70

APPENDIX D:

DUCT REFERENCE

Figure D1 shows the DUCT main menu. An explanation of commands follows.

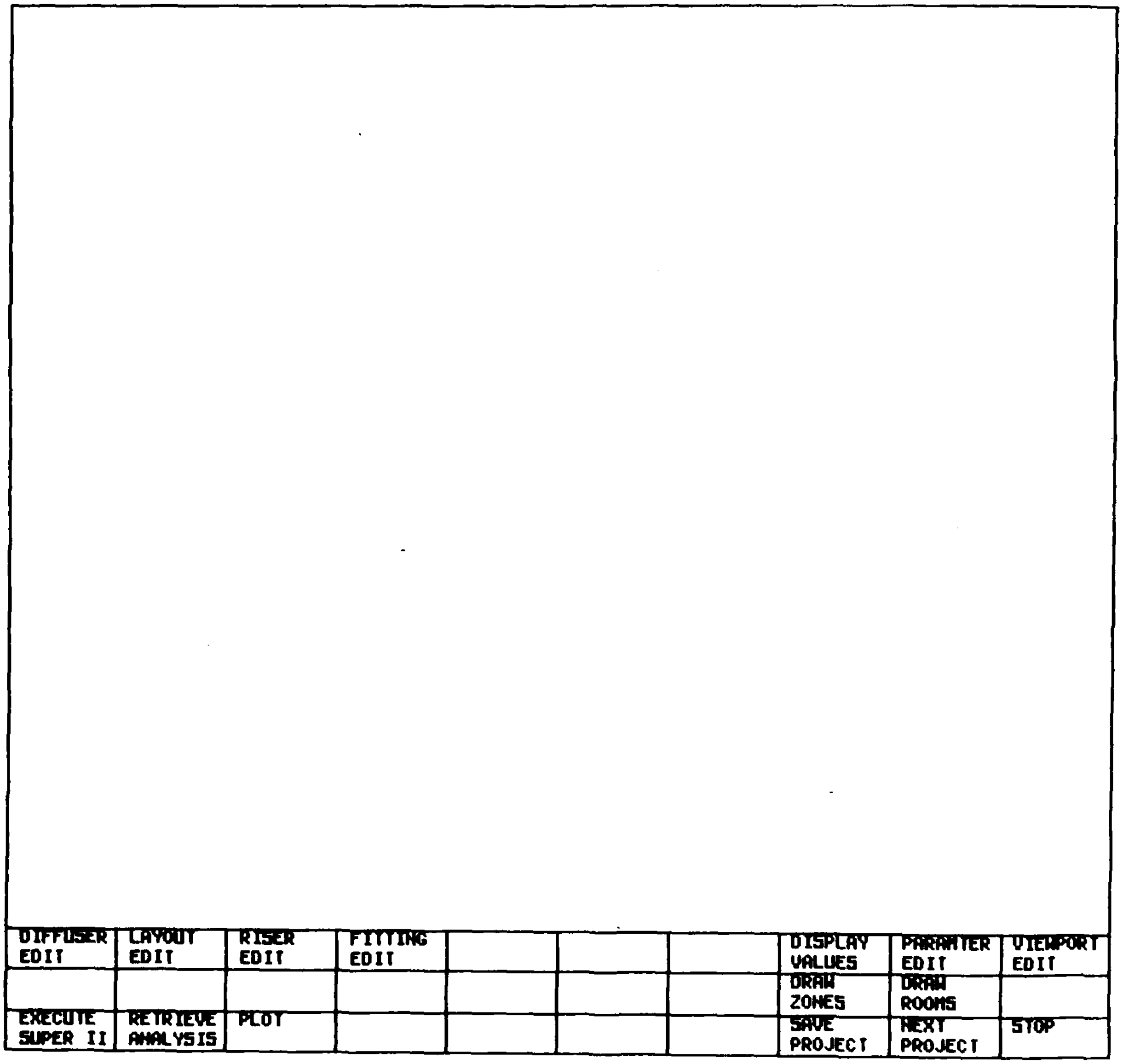

Figure D1. DUCT main menu.

DIFFUSER EDIT
- *Draws diffusers
- *Describes diffusers
- *Deletes diffusers
- *Modifies diffuser description

DISPLAY VALUES
- *Displays coordinates of nodes, distances between nodes, angles, and lengths of lines, wall material types, and wall thicknesses

DRAW NETWORK
- *Draws network diagram of an existing level and sets that level as the current level

DRAW ROOMS
- *Draws rooms diagram for an existing level and sets that level as the current level

EXECUTE SUPER II
- *Creates a Superduct II input deck

FITTING EDIT
- *Lists fitting types
- *Modifies fitting type

LAYOUT EDIT
- *Draws ductwork
- *Describes ductwork
- *Deletes ductwork
- *Modifies ductwork descriptions

NEXT PROJECT
- *Initializes a new or retrieves an existing project

PARAMETER EDIT
- *Revises parameters which control operation of DUCT

PLOT
- *Sends a picture file to copiers or files

RETRIEVE ANALYSIS
- *Creates a double line drawing of the ductwork based on the output calculations made by Superduct II

RISER EDIT
- *Draws risers
- *Describes risers
- *Deletes risers
- *Modifies riser descriptions

SAVE PROJECT
- *Stores the current version of the project in the project file

STOP

*Terminates the DUCT program

VIEWPORT EDIT

*Allows modifications of the viewport size

*Allows panning of the viewport area

APPENDIX E:

LITE AND LCHG REFERENCES

LITE Program

Figure E1 shows the LITE main menu. An explanation of commands follows.

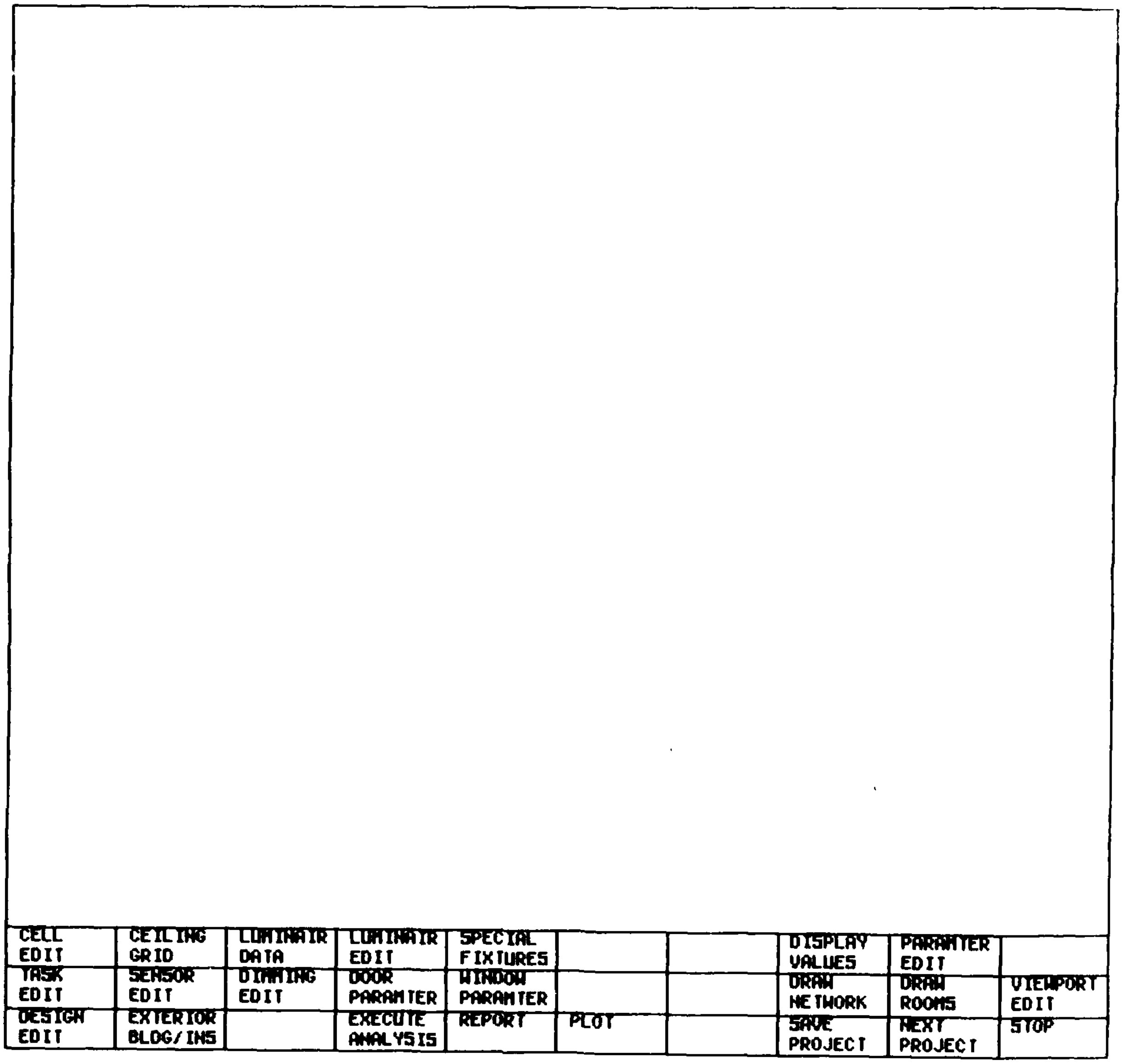

Figure E1. LITE main menu.

CELL EDIT

*Adds and deletes lighting cells
*Changes lighting cell geometry
*Modifies cell discretization
*Modifies cell occupancy schedule
*Modifies cell footcandle level
*Modifies cell work plane height
*Modifies cell dirt depreciation factor

CEILING GRID

*Adds and deletes ceiling grids

DESIGN EDIT

*Adds and deletes design grid
*Shows design grid
*Changes luminaire type
*Changes height of design grid
*Changes orientation of luminaires
*Changes illuminance requirements
*Activates and deactivates luminaire locations

DIMMING EDIT

*Defines control method
*Defines control values
*Defines control indicator
*Defines control target area
*Shows control target area
*Adds luminaires to dimming group
*Turns luminaires off/on

DISPLAY VALUES

*Displays coordinates of nodes, distances between nodes, angles, and lengths of lines, wall material types, and wall thicknesses

DOOR PARAMETER

*Shows door type and reflectance
*Changes door reflectance
*Defines default door reflectance
*Sets ignore/reactivate door reflectance

DRAW NETWORK

*Draws network diagram of an existing level and sets that level as the current level

DRAW ROOMS

*Draws rooms diagram for an existing level and sets that level as the current level

EXTERIOR BLDG/INS
*Adds and deletes other buildings and ground inserts
*Changes building/insert reflectances
*Changes building/insert dimensions
*Changes building/insert height
*Adds and deletes building/insert label

EXECUTE ANALYSIS
*Specifies building latitude and longitude
*Specifies longitude at center of time zone
*Specifies station ID
*Creates CEL-1 input deck

LUMINAIR DATA
*Lists all luminaires types in data file
*Lists the parameters of an individual luminaire type

LUMINAIR EDIT
*Adds and deletes luminaire locations individually and by group
*Changes type of luminaire instance
*Changes luminaire orientation
*Gets a luminaire type from the data file
*Lists all luminaire types in the project file
*Deletes a luminaire type from the project file
*Calculates footcandle levels
*Calculates required number of fixtures per cell

NEXT PROJECT
*Initializes a new or retrieves an existing project

PARAMTER EDIT
*Revises parameters that control operation of DUCT

PLOT
*Sends a picture file to copiers or files

REPORT
*Creates a building lighting summary file
*Creates a fixture schedule

SENSOR EDIT
*Adds and deletes interior sensors
*Adds and deletes exterior sensors

SPECIAL FIXTURES
*Adds and deletes symbols for exit lights, floodlights, etc.

TASK EDIT
*Adds and deletes individual task locations
*Adds and deletes task grids
*Shows task grids
*Specifies ESI option
*Specifies Z coordinate of tasks

SAVE PROJECT

*Stores the current version of the project in the project file

STOP

*Terminates the DUCT program

VIEWPORT EDIT

*Allows modifications of the viewport size
*Allows panning of the viewport area

WINDOW PARAMETER

*Changes type of opening
*Displays type of opening
*Defines window types: glazing, transmittance, shade, drapes, blinds, light shelves, and exterior barriers

LCHG Program

Figure E2 shows the LCHG program main menu commands. Each command is summarized below.

```
E - EXIT

P - PRINT LIST OF LUMINAIRE TYPES
K - PRINT INDIVIDUAL LUMINAIRE DATA
A - ADD INDIVIDUAL LUMINAIRE DATA
D - DELETE INDIVIDUAL LUMINAIRE
C - CHANGE INDIVIDUAL LUMINAIRE DATA

R - REPORT
```

Figure E2. Main menu commands.

EXIT

Exits the LCHG program

PRINT LIST OF LUMINAIRE TYPES

Lists on the screen all luminaire types defined in the LUMAIR file. Only the name and sequence number are listed.

PRINT INDIVIDUAL LUMINAIRE DATA

Shows on the screen a table of all parameters for a single luminaire type defined in the LUMAIR file. The format used is as follows:

#.description	IES#:	LENGTH:	GAIN:
TYPE:	LUMENS:	WIDTH:	COEFA:
SHEET NO:	WATTS/F:	HEIGHT:	COEFB:
LAMP:	WATTS/L:	S/MH:	COEFC:
mtg. desc.	#LAMPS:	FLF:	VLT/F:

ADD INDIVIDUAL LUMINAIRE DATA

Allows the user to add a luminaire type to the LUMAIR file. The program prompts the user for the information through a sequence of questions.

DELETE INDIVIUDAL LUMINAIRE DATA

Allows the user to delete a luminaire type from the LUMAIR file

CHANGE INDIVIDUAL LUMINAIRE DATA

Allows the user to change specific parameters of a luminaire type. The program transfers control to Change Menu where the user selects the letter corresponding to the parameters to be changed. The program then prompts with the current value and the user enters the new value. Figure E3 lists the Change Menu subcommands.

REPORT

Creates a table listing each luminaire with all its parameters and places it in a file designated by the user.

N - NAME AND DESCRIPTION
H - IES HANDBOOK NUMBER
I - INITIAL LUMENS
F - FIXTURE LOSS FACTOR
D - DIMENSIONS
W - WATTS PER FIXTURE
J - # OF LAMPS/WATTS PER LAMP
S - S/MH RATIO
V - FIXTURE VOLTAGE
G - MINIMUM GAIN
Q - QUADRATIC COEFFICIENTS
C - CU TABLE
R - RETURN TO MAIN MENU

Figure E3. Change menu subcommands.

APPENDIX F:

TEST PARTICIPANT WRITTEN REPORTS

Each District participating in the T^{3}B test submitted a written report documenting its efforts and any results. The narrative portions of the reports are given in this appendix, with minor editorial changes to correct spelling and grammar.

DUCT/Superduct II

Kansas City District

1. Purpose.

The purpose of this test was to evaluate the usage of DUCT and DUCT/Superduct II during the concept design phase of facilities and to compare DUCT usage with other available duct-sizing programs. Manual calculations were also prepared for comparison purposes.

2. Background.

The project used for testing was PN409, a flight simulator building currently in the final design phase for Fort Riley, KS. The three duct systems sized serve three separate zones of offices along the east, south, and west perimeter of the building.

3. Technical Data.

The following set of criteria was used for the design of the ducts:

- Supply ducts
- Rectangular galvanized steel
- No. lining used
- Sized by constant friction method
- Sized for 0.070 in. w.g. friction loss per 100 ft
- Mitered elbows with single thickness vanes
- Rectangular galvanized steel runouts
- No. fire dampers or elevation changes considered.

Since assigning actual sizes to ductwork is more easily accomplished using a DUCTULATOR than a computer program, only the results of the pressure loss calculations were considered in comparing the various sizing programs. All of the manual calculation friction loss values and sizes were taken from a DUCTULATOR, and the fitting loss coefficients were obtained from the *1981 ASHRAE Handbook of Fundamentals*. The three other programs used for the test comparison include:

- Trane Constant Friction duct-sizing program

- Elite Constant Friction duct-sizing program

- Intergraph duct-sizing program

The user took some time to become familiar with the features and operation of each package before the actual test was conducted.

4. Ease-of-Use Evaluation.

DUCT uses the concept of graphics input for duct layout and sizing, which is good in theory, but was found to be tedious in practice. Difficulty was encountered in both the layout of the duct and in creating the Superduct II input deck. Duct sections were difficult to edit and delete. And, once a layout was created, making changes to the layout which involved deleting and reconstructing sections was troublesome. When changes were made to the duct-sizing criteria, these changes were not carried through to the Superduct II input deck. The deck had to be edited manually to force sizing by the constant friction method at 0.070-in. w.g. However, the greatest drawback to using the DUCT/Superduct II package was that the floor plan and zones had to be defined first using the ARCH and ENERGY packages before duct analysis could occur. ARCH is not currently being used by architects at the Kansas City District, which forces the engineer to draw the building himself.

The following text summarizes the perceived ease of use of the other sizing programs used, ranked in order from easiest to most difficult:

1. Trane - the easiest program to use. Duct systems were quickly described and fittings were easily specified. No more than 20 min were required to analyze each duct system. The program has help menus available, so no manuals were consulted or required.

2. Intergraph - the graphic layout was very smooth and editing the layout was not a problem. Fittings were specified easily and results were obtained quickly. The Intergraph did, however, require more time for familiarization than any of the other programs.

3. Elite - duct description was easy, but fittings with the proper loss coefficients were difficult to specify. The manual had to be consulted on several occasions.

4. Manual Calculations - tedious.

The DUCT/Superduct II, in comparison, was more tedious to use than the Elite package but less difficult than manual calculations.

5. Technical Analysis.

Table F1 summarizes the results of the pressure loss calculations obtained by the various programs:

These results confirm the validity of the DUCT/Superduct II package pressure loss calculations, as well as the other packages tested, with the exception of Intergraph.

Excluding Intergraph, there was about a 15 percent difference between the pressure loss computed by the programs and by the manual calculations. However, even with the 15 percent difference, all of these values would likely result in the selection of the same fan, since the choice of fan size is based on pressure loss in increments of at least 0.25 in. w.g. The Intergraph calculated consistently higher pressure losses for each duct system, which causes a default to a higher value than was used in the manual calculations and specified in DUCT and the other program.

6. Applicability to USACE Designs.

While the results produced by the DUCT/Superduct II package are technically sound, the program has no special features and provides no added benefits that would encourage its use in USACE designs. In fact, its use was more time-consuming than the other programs tested. The graphics produced by the DUCT program are fine for inclusion in design analyses, but are not of production quality as are those produced by the Intergraph system. And since computer time on the Harris is not cheap, as in the case of the PC-based sizing programs, the use of DUCT/Superduct II does not represent the most economical duct design option.

7. Recommendations.

It is recommended that no further testing or development be considered for DUCT/Superduct II. Even if the minor problems associated with the DUCT package were corrected, as it stands, there are more beneficial programs currently available at a lower price per use which provide the same information.

8. Attached Documentation.

- DUCT test plan evaluation sheets
- Sample DUCT input procedures
- DUCT/Superduct II sizing results
- Manual calculations
- Intergraph sizing results
- Elite sizing results
- Trane sizing results.

Table F1

Summary of Pressure Loss Calculations

Duct System Program	1	2	3	Sum of 1,2,3
DUCT/Superduct II	0.23	0.30	0.25	0.78
Trane	0.21	0.28	0.24	0.73
Elite	0.23	0.31	0.23	0.77
Manual calcs.	0.20	0.27	0.24	0.71
Intergraph	0.31	0.36	0.33	1.00

Sacramento District

1. Purpose.

The purpose of this report is to evaluate the DUCT/Superduct II combination. Part of this evaluation was to compare it to other computerized methods of sizing ductwork. However, due to the number of features in the program that are not working, any comparison to another computer program is going to show DUCT/Superduct II to be inferior. A guess could be made as to what the results of the test would be if all the features were functioning as they were supposed to be, but it would only be a guess. And the more features that need fixing, the more inaccurate the guess would be. Similarly, the accuracy of Superduct II is not in question; the question "Does DUCT make Superduct II easier to run." Therefore, this report will address the remaining problems with DUCT and will not contain any comparisons to other programs.

2. Problems Encountered.

The following are problems that were considered major; any one of these would make DUCT difficult enough to use that another program would be preferred:

1. The program, while in "ZOOMED IN" mode, sometimes draws ductwork at slight angles. This causes problems with input and editing of the ductwork.

2. The program, while in "ZOOMED IN" mode, sometimes fails to register a node being digitized (a node is a point on the ductwork which locates the beginning or end of a duct run or a change in direction or airflow). This can require multiple input of one duct run.

3. When a point is chosen using the "crosshairs" on the screen, the program sometimes jumps to a nearby node if in "ZOOMED IN" mode. This can make input difficult and force the user to have to change the layout just so it can be input. There also seems to be a problem deleting nodes once a duct run has been erased.

Any of the problems listed below would not affect the ease of use of the program significantly, but as a group, they have a large effect.

LAYOUT EDIT:

a. Entering duct runs using the Vector feature causes the duct to be drawn to points other than those you have specified.

b. According to the manual, when you input a terminal point (a node) using coordinates, the previous point is supposed to be the relative origin. In actuality, the program always uses the building origin. I think you should have a choice between the two.

DISPLAY VALUES:

a. The only feature that works is "Distance between points"; all the others just echo DISPLAY VALUES MODE.

DRAW ROOMS/ZONES:

a. The manual gives an example of designating the desired floor (F1, F2, etc). If you type in "F1" you receive the message: "CTOR: INVALID CHARACTER"; it will only accept a number.

PARAMTER EDIT:

a. Of all the labels you can turn on (to be printed on the screen), the only ones that were actually printed were room area and room perimeter.

b. Apparently, the feature that allows you to use different character types doesn't work yet; both types looked the same.

VIEWPORT EDIT:

a. Zooming in using the "V" feature appeared to be fine as did enlarging the viewport with "V", but I couldn't make "Zoom Out" work completely after I had enlarged the viewport. It wouldn't go any farther than the enlarged viewport.

3. Applicability to Corps Design.

If the CAEADS package were implemented as a whole (assuming all the programs worked) and if there were an efficient way to transfer the drawings to a drafting program, then there would be no question that DUCT/Superduct II would improve the efficiency of the design process.

4. Recommendations.

LAYOUT EDIT:

a. When you execute the "Change" command and after you answer the questions, the program says "LOCATE DUCT" or "LOCATE ROOT DUCT," but every time you select a duct by digitizing it, the cursor stays at the end of the line. Even if you choose five ducts, the prompt only prints once. This may not seem like a problem except for the fact that the way you end this command is by typing in an exclamation point (!). If you consider than an "!" will also stop a command in the middle of its execution, then you will realize that if you don't know the command is still running and hit "!", the step will be unfinished and will cause problems later (not all the ducts will be changed, if any). If the prompt "LOCATE DUCT" would reappear after each duct, then you would always know when you can stop the command safely.

b. The ability to input duct runs using coordinates instead of digitizing would be enhanced if you had an asterisk "*" at the building origin and if you had a toggle to show (somewhere on the screen) the coordinates of the crosshairs at any time.

c. If you hit the space bar when asked for a point, the program prompts you to type in coordinates but then returns to expecting digitizing input right away. The space bar should be a toggle so that if you hit it once you enter the coordinates mode and then stay in that mode until you hit the space bar again. If you are going to enter one point using coordinates, the odds are that you will have several more.

d. The manual explains the "Join Colinear Edges" command by saying that two duct runs which are parallel and share a single node will be joined. This is confusing and should be rewritten.

FITTING EDIT:

a. The program allows you to delete fittings, but doesn't say anything if you never input a new fitting. Since Superduct II will run without the fittings, this could cause inaccurate data. Perhaps DUCT could at least point out that there are nodes without fittings when you are creating a Superduct II deck.

EXECUTE SUPER II:

a. What is "Airflow Normalization?" The program should let you know if you have diffusers located outside of the building or outside a zone (either case would mean that there is no air going through the duct).

RETRIEVE ANALYSIS:

a. If would be nice if DUCT could retain the information from the Superduct II run rather than just draw the lines and forget the sizes as it does now.

LITE/CEL-1

Kansas City District

1. Purpose.

The purpose of this test was to evaluate the usage of LITE and LITE/CEL-1 during the concept design phase of a facility. To perform this test, two projects were used for analysis, PN224 and PN1238.

2. Project Background.

PN224 was the CIDC Building at Fort Leonard Wood, MO, and PN1238 was the USARC warehouse at Fort Riley, KS, PN224 was an existing in-house design project which was 35 percent complete. PN1238 was an existing in-house design project which was 95 percent complete. PN224 had an existing ARCH file on CAEADS whereas the ARCH file for PN1238 had to be created. Elite lighting calculations were available from the 35 percent design and manual calculations were available from the 95 percent design.

3. Photometric Data.

In order to perform the test, a luminaire data file was constructed using the LCHG program. Photometric data were taken from the Elite data base. Manual calculations were based on IES data. The CEL-1 calculations were based on the photometric files provided in CEL-1.

4. Problems Encountered.

Initially, the test was conducted using the *LITE User's Manual* dated February 1986. The LCHG initial evaluation was performed using that manual, which varied significantly from the final manual dated May 1986. Once a new manual was received, I determined that it did concur with the program. Evaluation sheets are attached to this report.

5. Technical Analysis.

In comparing CAEADS to Elite, it appeared that the FCR value was consistently higher in the CAEADS report. RCR values were comparable, but the footcandle values were slightly higher on CAEADS. Room number 170 for PN224 and room numbers 130, 160, and 180 of PN1238 cannot be analyzed on either Elite or CAEADS. CAEADS calculations are incorrect because it uses the maximum length and maximum width in the room which gives an erroneous area value, inducing errors in the RCR, FCR, and footcandle level. ELITE is not capable of calculating the footcandle level in a room with more than four walls.

For PN224, in comparing CAEADS with Elite, I found that the actual room dimensions did not totally agree. This induced some variance in the calculations but no significant problems were observed other than those stated above.

6. Applicability of Concept Design.

The LITE program does not offer a benefit to the designer that would influence him to use it in the design process at the 35 percent design stage. The cost/benefit of the program is actually less than the Elite software, because you are not only paying for designer manhours but also computer time for using the Harris computer. I would estimate that the actual manhour design time required is increased by 50 percent for an experienced computer user, and by 100 percent for an infrequent user, because of the complexity of using the program. All reports provided by the LITE program are also provided by the Elite software with the exception of a fixture quantity list. The LITE program provides a plot of the lighting layout, but this is not desirable because the normal 35 percent lighting plan is also used to continue to the 95 percent design stage which shows branch circuiting, panelboards, etc. The plot produced by LITE is unusable beyond the 35 percent stage of design. The LITE program creates the CEL-1 input deck, but normally in Military Construction projects, this would never be needed.

7. Recommendations.

After performing the test to evaluate the usage of LITE in the 35 percent design, it is my recommendation that any further development of the LITE program be dropped. Even if the technical problems identified were resolved, the LITE program does not provide a benefit which would encourage the designer to use it. If there were a need for the use of the CEL-1 capabilities, a program could be written for a PC which would prompt you for inputs and then create an input deck.

8. Attached Documentation.

- LITE calculations, with fixture schedules for PN224 and PN1238
- Elite calculations for PN224 and PN1238
- Manual calculations for PN1238
- LCHG photometric summary
- Elite photometric summary
- CEL-1 input decks as created by LITE
- CEL-1 output printouts
- Plots as provided by LITE on the Tektronix 4692
- Evaluation sheets.

Sacramento District

The purpose of this report is to evaluate the usefulness of LITE, LCHG, and LITE/CEL-1 in doing the simple calculations for the number of fixtures, footcandles, and fixture location in the concept stage of a building design.

For this report I've considered the USARC at Garden Grove, CA, focusing only on the organization maintenance shop (OMS) section, which is at 65 percent completion as of this date.

The design criteria were based on Design Guide 1110-3-107, *Design Guide for U.S. Army Reserve Facilities* (HQDA, September 1984); NFPA 70, NEC 1984, and *Guide Specifications for Reserve Centers.*

Problems were largely of my own making except for the single fixture deletion problem (see LITE evaluation sheets for explanation) and the glitch over the fixture data exchange between LITE and LCHG programs, which has been resolved.

I find the present system of catalog searching for fixtures and doing basic manual calculations in the concept stage refreshing rather than tedious.

The summary and comparison of manual versus computer calculations with backup data can be found at the end of this report.

The design process does not require lighting in the concept design stage, but we in the Electrical Design Section do the lighting to help the Estimating Section obtain an accurate estimate for the project for budgeting purposes.

I truly feel LITE and LITE/CEL-1 would be more appropriate in the final design stage of a contract when floor plans are closer to being finalized than in concept. Between concept design and final design, there can even be a site change, not to mention redesign of the building. I feel these computer programs would be more valuable as a backup for energy calculations and engineering design assumptions.

Attached are:

- Short-form GS for Army Reserve Centers
- OMS comparison calculations
- OMS lighting fixture schedule
- Lighting fixture catalog sheets
- LITE evaluation sheets (10)
- LCHG evaluation sheets (6).

DISTRIBUTION

Chief of Engineers
ATTN: Tech Monitor
ATTN: CEIM-SL (2)

US Army Engineer Sacramento District
ATTN: CESPK-ED

US Army Engineer Kansas City District
ATTN: CEMRK-ED

Defense Technical Info. Center 22314
ATTN: DDA (2)

6
7/88