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EXPOSURE: AN EXPERT SYSTEM FIRE CODE

Richard L. Smith

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Center for Fire Research
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Sponsored in part by:
U.S. Air Force Engineering and Services Center
Airbase Fire Protection and Crash Rescue System Branch
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ABSTRACT

This report addresses the issue of developing an expert or knowledge-based system that deals with the problem of preventing the spread of fire between buildings. A knowledge-based program, EXPOSURE, has been developed that facilitates using more appropriate technology, expanding the problem domain, and providing cost-effective solutions. EXPOSURE can solve the problem of the prevention of the spread of fire between buildings for the case when the exposed building has combustible walls. The use of the expert system EXPOSURE and NFPA 80A produce significantly different recommended minimum separation between buildings. In some cases EXPOSURE calls for significantly greater separation and in others significantly less. In one case the separation required by NFPA 80A was more than five times greater than what EXPOSURE recommended. This program demonstrates that significant cost savings in achieving the desired level of fire safety and in assuring the levels of safety can be obtained by use of expert system fire codes.

Key Words: Artificial intelligence, expert systems, fire codes, building codes, exposure, computer programs

A. INTRODUCTION

This report is one of three that summarizes the technical accomplishments achieved on an Air Force contract titled "Fire Protection Design Assessment System." The project's objective, briefly, was to develop an expert system to determine fire safety specifications for the design of buildings. As a first step, we have selected the problem of the prevention of the spread of fire between adjacent buildings as addressed by a standard practice NFPA 80A [1]. This report describes a computer program, EXPOSURE, which is an expert system version of NFPA 80A. The other two reports deal with EXPOSURE80A (a system which requires strict compliance with NFPA 80A as opposed to an expert system) [2] and the calculation of the radiation from a fire incident on a building [3].

This paper discusses a way of improving fire safety building codes by using expert systems or knowledge-based systems. The distinction between these two types of artificially intelligent computer programs is not important in the context of this report and these terms are used interchangeably.

A.1. Importance of improving fire codes

The total expenditure on construction in the U.S. is about $400 billion. Building construction is a highly regulated business in that there are building codes for every aspect of the building [4]. Nearly half of the building codes relate to fire safety [5]. Compliance with fire safety codes that are too conservative may be unnecessarily expensive.

The Fire Safety Evaluation System (FSES) developed at the Center of Fire Research grew into NFPA 101M, Alternative Approaches to Life Safety [6]. Estimates of savings from this improved approach are hard to obtain, but there is anecdotal evidence indicating savings of millions of dollars. Some estimates of the total savings run into billions of dollars [7] [8]. Expert system will enable the incorporation of additional and perhaps more appropriate technology into the fire codes providing additional economies.

Direct fire losses in the United States in 1988 were estimated as 6215 deaths, 30,800 injuries, and direct property loss of about $8.35 billion [9]. These figures do not include cost of fire protection in construction, fire insurance, and operating fire departments. If a means was provided to:

a. make the technological base for fire codes stronger,
b. reduce the arbitrariness in the applications of fire codes,
c. reduce over and under design for safety, and
d. make the process of applying or checking a building's compliance with fire codes more manageable,

the cost of fire protection and losses could be significantly cut, perhaps by several billion dollars annually.

A.2. Shortcomings of fire codes

While fire safety building codes are the keystone of fire safety, they have serious shortcomings [10] [11]. Some of their major problems are:

1. They are hard to interpret, understand, and/or apply;
2. They do not cover all applications; and
3. They require a substantial understanding of fire codes and fire protection engineering to bring a building into full compliance.

The main users of fire codes include architects, building owners, code officials, and fire protection professionals. Some of these users do not have familiarity with the codes to comply efficiently and accurately with them. The innovative design of some buildings requires the application of state-of-the-art technology to demonstrate their level of fire safety. Fire science and fire protection engineering are highly complex and sometimes empirical technologies. The correct application of the most appropriate technology is challenging even for many fire protection professionals so it is clearly often difficult for the other users.

Many aspects of building design are being automated. It is inevitable that some computerized form of fire codes will come into widespread use [4]. Because of the complexity of the problem and the need to deal with exact and inexact knowledge, one promising form for this automation to take is that of an expert system [11] [12].

A.3. Overview of this report

The particular fire code selected for this project is the one that deals with the prevention of the spread of fire from a burning structure to a neighboring structure. In the past major conflagration have often resulted when fires have spread to neighboring buildings. The potential for fire spread to a neighboring building is, therefore, of primary concern when evaluating the fire safety of any building. Also, after rescuing people from a burning building, a fire department's top priority is to stop the spread of the fire to adjacent structures [13].

EXPOSURE addresses the same basic problem as NFPA 80A but expands the class of users to include non-fire safety professionals. This is a major shift in skill level required by the user from fire protection professional to non-professional. EXPOSURE also incorporates more appropriate technology and has a greater degree of flexibility because it takes more advantage of the computational capability of a computer.

The next section will describe the background of the exposure problem and NFPA 80A. This leads to the description of the initial expert system version of this fire code, EXPOSURE. Finally, the results of applying NFPA 80A and EXPOSURE to the same buildings are compared and the implications of this work for the development of automated fire codes are discussed.

B. Background for the Exposure Problem and NFPA 80A

The spread of fire from a burning building to a neighboring building has been discussed in the literature [14] [15] [16] [17]. Therefore, the technical problem and its solution will only be summarized.

The exposure problem can be described as the prevention of the energy from the fire of one building from doing damage to an adjoining building. Conventional wisdom, based on general observation of fires, is that the most common mechanisms for damage are radiation and direct contact with the flames. To analyze the problem, the strength of the fire in the burning building as a function of time, the extent of the flames, the radiation falling on the exposed building, and the damage mechanism of the exposed surfaces need to be known. Solutions to the exposure problem will deal with these points either explicitly or implicitly.

As its title indicates NFPA 80A: Recommended Practice for Protection of Buildings from Exterior Fire Exposures [1] is a recommended practice. The basic problem it addresses involves two buildings. The burning building is called the exposing building, while the other which is threatened is called the exposed building. To do the complete exposure problem one has to assume first one and then the other building is the exposing building.

A key concept needed to use 80A is that of a fire containment compartment. A fire containment compartment can be defined as a region of a burning building that has physical surfaces that enclose and will contain any fire expected to occur within it. If one of these surfaces is an exterior wall, that surface need not contain the fire. The extreme limit in size for a fire containment compartment is the entire building. However, normally a complex building will have a number of fire containment compartments. In order to comply with NFPA 80A, a fire in any compartment of the burning building must not spread to the adjoining building.

The universe of problems to which 80A is applicable is to a major extent defined by the explicit or implicit assumptions made for 80A. A few of the key ones for NFPA 80A are:

1. All combustible materials have a piloted ignition threshold equal to that of oven dried wood, i.e., 0.3 cal./sq. cm./sec. or 66 Btu./sq. ft./min.

2. The exposed and exposing walls are parallel.

3. Openings are assumed to be uniformly distributed over the exposing wall and the separation between openings will be no more than one-third of the separation between the two buildings.

4. Only buildings with walls capable of fitting into the following categories are considered:
   a) frame or combustible,
   b) fire-resistive wall (3-hour minimum),
   c) veneered wall (combustible construction covered by a minimum of four inches of masonry), or
   d) non-combustible (fire resistance less than 3 hours).

In addition, one must be able to determine if the walls can contain the fire
   a) less than 20 minutes,
   b) 20 minutes or more, but less than the duration of the fire, or
   c) the duration of the fire.

5. All fires can be classified as one of three severities, light, moderate, and severe, by using either the average combustible load per unit area or the average flame spread rating for interior flame spread.

6. All doors, windows, and other openings of a building transmit without attenuation the radiation of the fire within it.

The underlying physics of 80A is that the burning building radiates through the openings in the exposing wall as a blackbody. The severity determines the temperature of this blackbody and thereby the strength of this source of radiation flux. The required minimum separation is the distance for which the maximum radiation falling on the exposed wall is just 0.3 cal./sq. cm./sec.

C. Description of EXPOSURE

EXPOSURE was developed on a Symbolics computer and has been written in Symbolics Common Lisp, Flavors, and Joshua[1]. In particular, significant use has been made of Symbolics graphics, windowing, and menu facilities.

The following will describe:

1. the appearance of EXPOSURE to the user in a typical application,
2. the underlining assumptions and technological base in comparison to those of 80A, and
3. the general structure of the program.

The program assumes its user has identified two buildings, at least one of which may cause a fire in the other and he has their floor plans and their relative location. The user will be expected to read the requested information off these plans and enter them into this program.

C.1. Appearance of EXPOSURE

At the start of the program the introduction screen, Figure 1, introduces the user to the system by giving the purpose, credit to the sponsor, author, and identifies the fire protection engineer expert. Upon touching any key, the second screen, Figure 2, appears and explains how to operate the mouse and gives instructions on how to proceed. The "Tutor" and "Help" options have not been implemented. If the mouse is clicked on "Start" then the screen appears as shown in Figure 3. The user must enter his name. The system allows him to proceed only if his name has been entered as one who can operate the system. Assuming the user is authorized to continue, then the screen configuration shown in Figure 4 appears. This is the beginning of the graphic editor and the menu system for entering information on the two buildings. The user has the option of recalling an existing file for editing or of creating a new configuration.

Figures 5, 6, 7, 8, and 9 depict various menus and views of the building as the information is being entered or edited. Figure 5 shows the selection of an already existing file to be loaded. Figure 6 shows the top view of two buildings of the exposure problem with the reference bench mark shown as an x with a circle around it. To add a building, the user clicks on the command "Add Building" in the lower window and a menu appears as shown in Figure 7. If instead of adding a building, one wishes to change a

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[1] Note: Certain commercial products are identified in this report in order to adequately specify the computer programs. Such identification does not imply recommendation by the National Institute of Standards and Technology, nor does it imply that these products identified are necessarily the best available for the purpose.

building's configuration or specifications the user clicks on the appropriate command and a menu as shown in Figure 8 appears.

Figures 9, 10, 11, and 12 display various input menus relating to entering information on the walls and openings. Figure 9 shows the exposing wall with the four windows uniformly spaced. Figure 10 shows the same wall with the menu for editing this wall. Figure 11 depicts the menu for the addition of a new opening in a wall. Finally, Figure 12 shows the menu for editing the properties of an opening in the wall.

If the user cycles through all the walls, eventually the screen appears again as in Figure 6. When he has finished entering information about the buildings, the user clicks on "analyze," as shown in Figure 6. The screen as shown in Figure 13 then appears. If the user clicks the mouse on "Start", which is found near the top of the screen, after a few minutes the screen as shown in Figure 14 appears. In this time the program does the required computations and finally suggests several solutions based upon a rough cost estimation of each solution.

C.2. Basic Assumptions

In general, it is impossible to find an acceptable solution to every exposure problem for a pair of buildings. An acceptable answer is normally one that is not too expensive to implement. Therefore, the domain addressed must be limited to one in which solutions can be found that will prevent the spread of fire in all reasonable situations and that are consistent with an acceptable level of risk or cost. In addition, some assumptions are made to simplify the problem domain initially addressed. If the program is developed further, some of these will be modified or dropped. These assumptions are:

1. The fire department will be actively fighting the fire no later than 20 minutes after ignition. It is assumed that the fire fighters will control the spread of fire caused by flying brands.

2. Piloted ignition is the method of fire propagation between buildings when the element ignited is on the exterior of the building.

3. Weather conditions such as wind are ignored.

4. Buildings are one story high with flat roofs.

5. Only two buildings at one time are considered.

6. All interior walls are discounted; each building thus has one fire compartment.

7. All buildings burn at a maximum constant temperature for 3 hours.

8. No flames are outside the openings of the exposing wall.

9. All buildings are rectangular in shape.

10. The exposing and exposed walls are parallel (This is required because of the program's interface. The radiation calculation portion can deal with nonparallel walls).

11. Only wall-to-wall exposure is considered. No wall-to-roof or roof-to-wall. Therefore, any flames coming out of the roof of the exposing building are neglected.

12. The only openings allowed are windows and doors.

13. All the windows and doors with a rating of less than 3 hrs. become open at flashover.

C.3. Major Steps in EXPOSURE

EXPOSURE executes four major steps in obtaining a solution of the exposure problem: (1) identify the problems, (2) find reliable solutions, (3) estimate the relative costs of the solutions, and (4) provide for the user to select solutions.

Presently the first major step has been implemented for a combustible exterior wall, the second step has been implemented for failures only and only a few solution types, the third and fourth steps have not been implemented.

Let us now go back over these major steps giving additional details.

Major Step 1: Identify the Problems

Three classifications to describe the damage done through exposure have been arbitrarily created: no damage, failure, and hazard. The no damage classification is clear. A failure indicates a reasonable possibility of fire spreading from one building to another. A hazard indicates some minor fire damage or the ignition of a small part of the exposed building. If it is ignition, it is at a level that may not ignite a major portion of the building. Either the program or the user must identify unacceptable hazards. Only failure of a combustible wall has been implemented.

We may divide this major step into a series of substeps.

Substep 1. Determine which walls are exposing which walls. This requires the user to identify these walls.

Substep 2. Determine the strength of the source of radiation. Our analysis shows that NFPA 80A severity levels of light, moderate, and severe corresponds to the radiation emitted by an ideal black body at temperatures of 1102, 1311, and 1559 K respectively. For EXPOSURE an analytical expression for the maximum temperature under natural draft conditions was used. The equation is

$$T = 290 + DT\ (5/9)$$

where DT is the maximum temperature rise in Fahrenheit. Law [15] gives the following expression for DT:

$$DT = 8025\ (1 - \exp(-.18n))(1 - \exp(-.25u))/n^{.5}$$

where

$n = At/X$

$X = \sum_{i=1}^{m} Awi\ (hi)^{.5}$

m is the number of windows

hi is the height of the ith window in ft.

Awi is the area of the ith window in sq. ft.

$u = L/(Aw\ At)^{.5}$

$At = 2Af + 2H(D + W) - Aw$

Af = floor area in sq. ft.

Aw = total window area in sq. ft.

L = fire load in lbs./sq. ft.

H = height of compartment in ft.

D = depth of compartment in ft.

W = width of compartment in ft.

Substep 3. Determine the configuration factor for the exposing and exposed walls. The guide number table of NFPA 80A rests upon the calculation of the configuration factor for the case of parallel walls and a uniform distribution of openings. EXPOSURE has the ability to compute the maximum configuration factor on the exposed wall due to any placement of rectangular openings in the exposing wall. These walls need not be parallel.

Substep 4. Identify subregions of the exposed wall with problems and the nature of the problem. Presently EXPOSURE assumes the entire exposed wall is one subregion of combustible material. If the radiation falling upon the wall exceeds the piloted ignition threshold of the combustible material, the system recognizes a failure and looks for solutions.

Major Step 2: Find Reliable Solution.

A solution is a set of actions that eliminates all the failures and unacceptable hazards. These actions must not create new failures or unacceptable hazards.

The only types of solutions that have been implemented are:

1. increase the separation,
2. change the combustible material to one having a higher piloted ignition threshold, and
3. add an exterior automatic water curtain on the exposed building.

In addition, a very simplistic cost estimator is included for illustration.

Major steps 3 and 4, which have not been implemented, were planned to allow the accurate estimation of the relative costs of the solutions and provide for the user to select a solution. The solutions would have been prioritized based upon their estimated relative cost. Also, whenever the system proposed a solution, the user would have been given the following options for each solution:

1. acceptance of the proposed solution,
2. acceptance of the proposed solution and request additional protection, or
3. rejection of the proposed solution.

D. Comparisons between NFPA 80A and EXPOSURE

The buildings used to compare NFPA 80A and EXPOSURE are shown in Figure 6. One of the buildings, bldg-a, has no openings in the wall facing the other building, bldg-b. Figure 6 shows these two buildings with bldg-a at the top of the screen. Bldg-b's exterior walls are 3-hour fire walls. The wall of bldg-b facing bldg-a has at least one opening. Three different cases of exterior wall material for bldg-a: plain wood, wood covered with a thin layer of combustible material, and a non-wood combustible material are considered. The piloted ignition threshold for these surfaces were taken to be 1.255, 1.75, and 2.5 w/sq cm. Bldg-b will be assumed to have three-quarter hour rated windows which are protected by a deluge exterior automatic water curtain. Two window patterns are assumed: 1. uniform (i.e., four uniformly spaced windows, each 7.5 ft. wide and 16.67 ft. high as shown in Figure 9) and 2. one big opening 30 ft. wide and 16.67 ft. high in the middle of the exposing wall. In both cases the total area of the openings was 500 sq. ft. The heights of the buildings were taken to be 20 ft.

Tables 1, 2,and 3 show the results of applying NFPA 80A and EXPOSURE to buildings with various siding material, depth of the exposing building, and fire load. In Table 1 the exposing building, bldg-b, is 100 ft. square and the fire load of 50 lbs./sq. ft. was taken so there was a severe fire according to NFPA 80A. For Table 2 the exposing building depth (the dimension perpendicular to the exposing wall) was reduced to 10 ft. Note that in all cases NFPA 80A gave the same minimum separation of 60 feet. However, EXPOSURE gave minimum separations ranging from a low of 11 feet to a high of 56 feet. The values for the minimum separation for NFPA 80A has an additional 5 feet safety margin built into it. So to compare the minimum separations one should add 5 to the EXPOSURE results. For Table 3. the exposing building is restored to 100 feet square, but the fire load density is reduced to 6.9 lbs./sq. ft. While in Tables 1 and 2 EXPOSURE gave smaller values for the minimum separation, in Table 3 we see EXPOSURE gives significantly larger values.

If it is true as we have asserted that NFPA 80A and EXPOSURE rest upon the same basic physics how do we explain this seemingly total lack of agreement? There are three principle sources that could cause this disagreement: source temperature, configuration factor, and ignition criteria. Each of these will be dealt with in turn.

First, regarding the ignition criteria, NFPA 80A and EXPOSURE use the same criteria only for plain wood since EXPOSURE uses the actual piloted ignition threshold for the exposed materials while NFPA 80A uses the piloted ignition threshold for wood for all combustibles. Therefore, only the plain wood cases should be considered when trying to see the agreement because of the same basic physics.

Another part of the explanation of why the results of NFPA 80A and EXPOSURE differ by so much is due to the estimation of the temperature of the source. NFPA 80A used just three temperatures for the source each corresponding to a severity classification based only on the properties of average fire load and average flame spread rating. These temperatures are estimated by the author to be 829 C (1524 F) for the light classification, 1038 C (1900 F) for moderate, and 1286 C (2347 F) for severe. The average flame spread rating is assumed to be in the range 0 to 25. This would result in a light severity classification based on this property. Then the load per sq. ft., would determine the severity classification of the building. Therefore, a fire load of 0 to 7 lbs./sq. ft. would result in a light classification. If an ambient temperature of 17 C (62.6 F) is assumed then it follows from the above that:

a light classification corresponds to a temperature rise of 812 C (1494 F);

a moderate classification (a fire load of 7 to 15 lbs./sq. ft.) corresponds to a temperature rise of 1021 C (1870 F); and

a severe classification (a fire load of 15 lbs./sq. ft. or greater) corresponds to an estimated temperature rise of 1269 C (2316 F).

EXPOSURE uses the analytical expression previously given (see page 8) to estimate the increase of the burning building's temperature. The behavior of this analytical expression can be seen in Figures 15, 16, and 17. For Figure 15 there are two curves. One for a building with 500 sq. ft. of windows and another with 1000 sq. ft. In Figure 15, it is apparent that the temperature rise of 812 C (1494 F) for a fire load of 0 to 7 lbs./sq. ft. underestimates the temperature significantly in the upper portion of the fire load range. In the 7 to 15 lbs./sq. ft. range the temperature rise of 1021 C (1870 F) is significantly low for both cases considered. Finally the temperature rise of 1269 C (2316 F) exceeded any temperature rise that could be achieved for the burning building. Therefore, in the severe case, NFPA 80A uses a higher source temperature than EXPOSURE.

Figure 16 shows the maximum temperature rise based on Law's expression [15] as the window area is varied. Note that NFPA 80A does not allow for this effect. Also, Figure 17 shows the maximum temperature rise as a function of building depth (or total fuel load) for average fire loading of 10 and 50 lbs./sq. ft. Again note that NFPA 80A does not take in account the effect of the depth upon the maximum temperature rise.

The final source of disagreement arises from the determination of the configuration factor. To minimize this an approach suggested in NFPA 80A Appendix was used. Instead of applying a transparency to the entire wall, the smallest rectangle that just encloses all the openings was used. In the single opening case, this smallest rectangle is just the window itself. If this approach is used to determine the minimum separation, a minimum separation of 70.7 feet is obtained. This becomes 65.7 feet after removing the 5 feet safety margin. Then if EXPOSURE is forced to believe that its source temperature is 1286 C, it gives a minimum separation of 64.0 feet. This difference of 1.7 feet is insignificant. Thus at this one point where both methods are in agreement as to the temperature of the source, configuration factor, and failure mechanism there is reasonable agreement. The disagreements stem from EXPOSURE using a more accurate determination of the configuration factor, a more analytical estimation of the maximum temperature, and a more accurate failure criteria.

E. Conclusions

EXPOSURE allows one to:

1. use an analytical expression (or expressions) for the temperature of the source,
2. use actual material properties such as the piloted ignition threshold, and
3. compute a more accurate configuration factor.

In the comparison of the results of the expert system EXPOSURE to NFPA 80A significant differences are observed. In some cases EXPOSURE calls for significantly greater separation and in others significantly less.

As indicated above, EXPOSURE allows the use of an analytical expression or expressions for the temperature of the source. It is quite possible that additional expert opinion might not support the use of the Law's equation that was used in this program for the temperature of the source. Using expert system programming techniques that allows the incorporation of heuristic knowledge, a rule could be added to this program that would specify under what conditions an equation should be used or when another expression for the temperature of the source should be used.

A second place where expert system programming techniques are of great value is in obtaining a solution to an unsafe condition. There are an infinity of possible ways of make the radiation level falling on an exposed wall be in at an acceptable value. The separation can be changed a little and something else can be changed. To search for an optimal solution would involve a search of an infinite set of possible solutions. Clearly this is not feasible to do. The way to handle this is by using heuristics to limit this search so an adequately good solution is found, not an optimal one. In these two places the usefulness of using expert system programming techniques are clearly demonstrated.

EXPOSURE allows the use of more appropriate technology, performs more sophisticated analysis, and thereby obtains more accurate results than those provided through the use of conventional fire codes. The program can accommodate innovative materials by allowing the use of the piloted ignition threshold of the innovative material. It can also deal with innovative designs because the fire safety impact of such design features as the exact location of openings can be evaluated. Innovation could allow lower cost construction and greater safety. Also, compliance with a fire code like EXPOSURE will be much easier for the typical user.

Since EXPOSURE is not a completed program nor has it undergone extensive testing, its results must be used cautiously. However, EXPOSURE demonstrates that expert system fire codes can:

a. make the technological base for fire codes stronger,
b. reduce the arbitrariness in the applications of fire codes,
c. reduce over and under design for safety, and
d. make the process of applying or checking a building's compliance with fire codes more manageable.

Therefore, these results clearly indicate that significant cost-savings and improved safety can be realized by using expert system fire codes such as EXPOSURE.

F. Possible Future Work

This program could be further developed so that the advantages become much greater. Dropping any of the limiting assumptions listed for EXPOSURE would require additional development. Further items for future development of the program that hold promise of having significant impact include:

1. Expanding the graphic editor to allow such things as nonparallel walls.

2. Including flames outside the openings.

3. Including effects of weather such as wind.

4. Allowing nonpiloted ignition as a mechanism for igniting exposed targets inside the exposed building.

5. Adding a failure mode and solutions for noncombustible walls.

6. Incorporating piloted ignition data for construction materials.

Finally, in the future it also would be desirable to have the program compare the cost of protection to the value of what is being protected.

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MINIMUM SEPARATION (in ft.)

	NFPA 80A	EXPOSURE
Uniform Openings		
plain wood	60	44
covered wood	60	33
non-wood	60	24
One Opening		
plain wood	60	56
covered wood	60	47
non-wood	60	38

Table 1. Comparisons between NFPA 80A and EXPOSURE with Severe Classification (50 lbs/sq. ft.) and Bldg-b 100' X 100'

MINIMUM SEPARATION (in ft.)

	NFPA 80A	EXPOSURE
Uniform Openings		
plain wood	60	19
covered wood	60	15
non-wood	60	11

Table 2. Comparisons between NFPA 80A and EXPOSURE with Severe Classification (50 lbs/sq. ft.) and Bldg-b 10′ X 100′

MINIMUM SEPARATION (in ft.)

	NFPA 80A	EXPOSURE
Uniform Openings plain wood	19	38
One Opening plain wood	19	51

Table 3. Comparisons between NFPA 80A and EXPOSURE with Light Classification (6.9 lbs/sq. ft.) and Bldg-b 100' X 100'

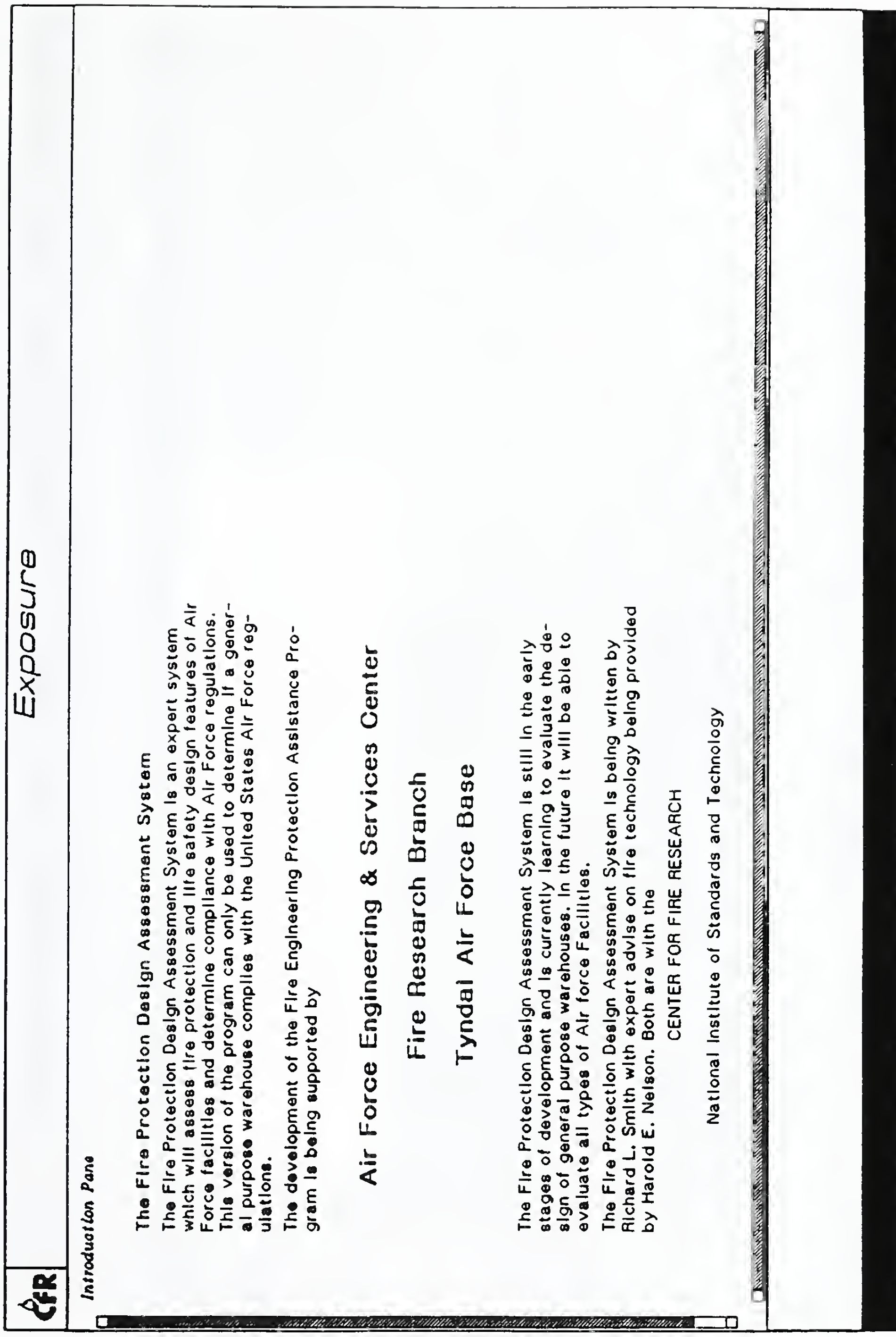

Figure 1. Introduction Screen

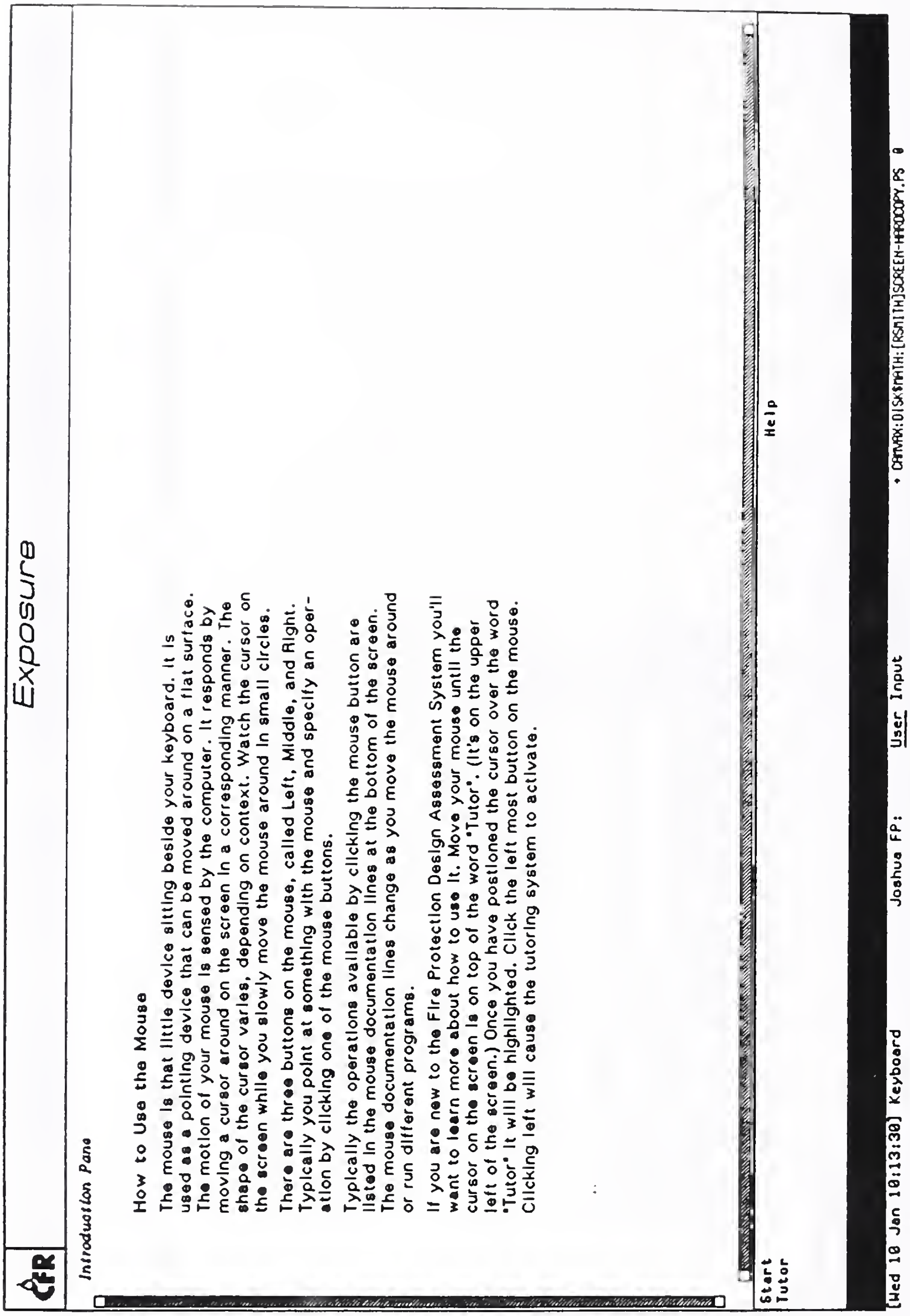

Figure 2. Instruction for Use of Mouse Screen

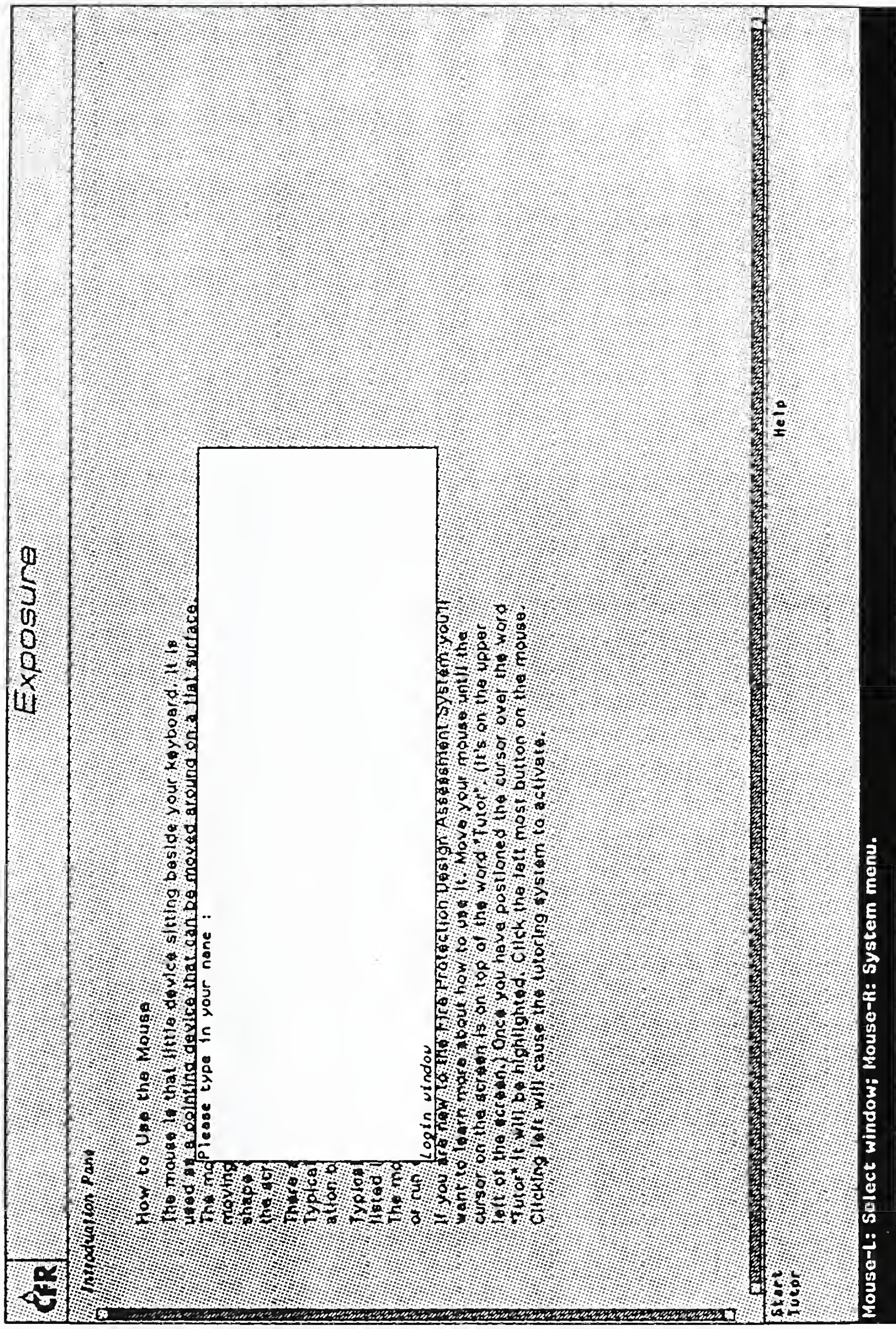

Figure 3. Sign in Screen

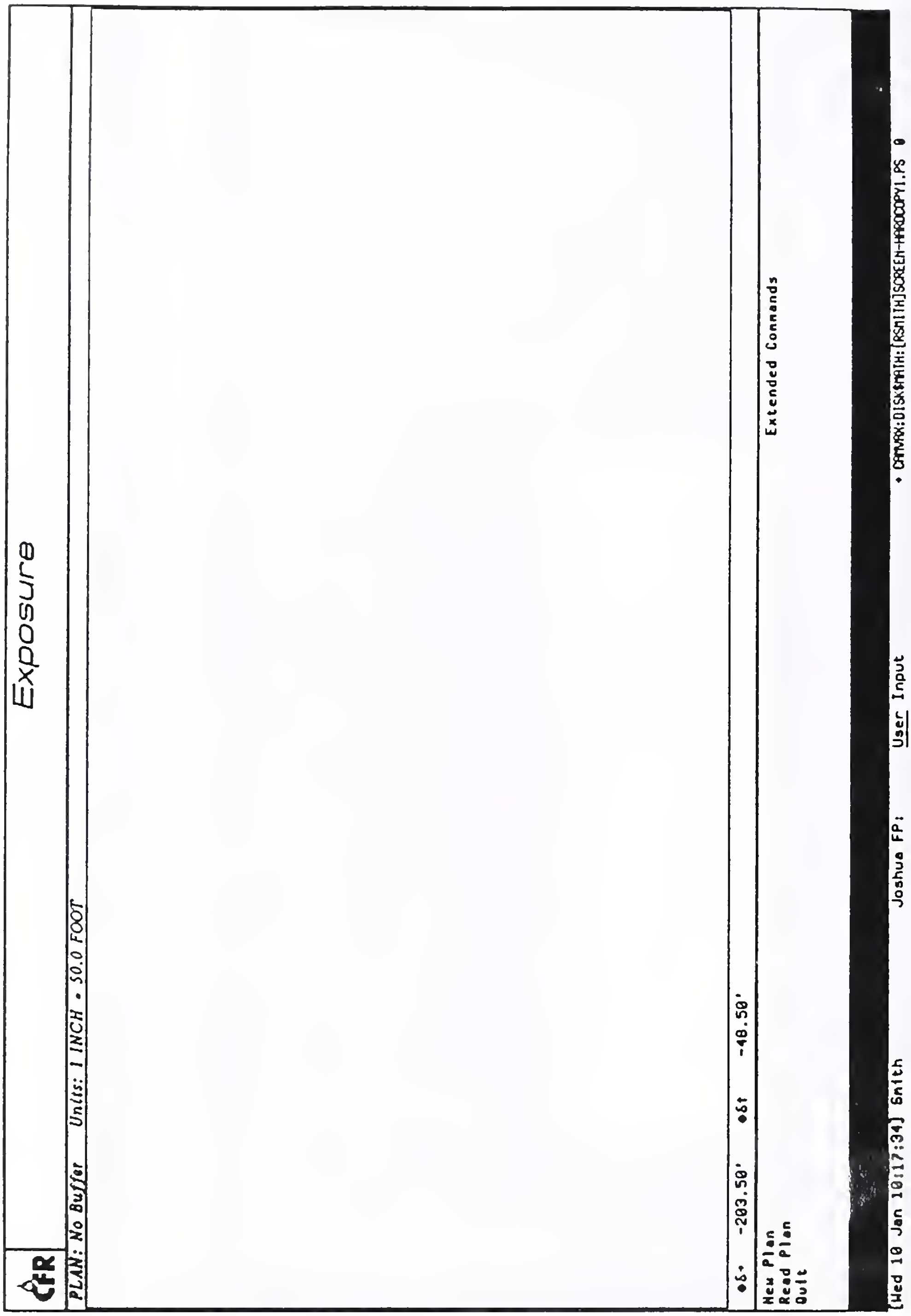

Figure 4. Graphic Editor Screen

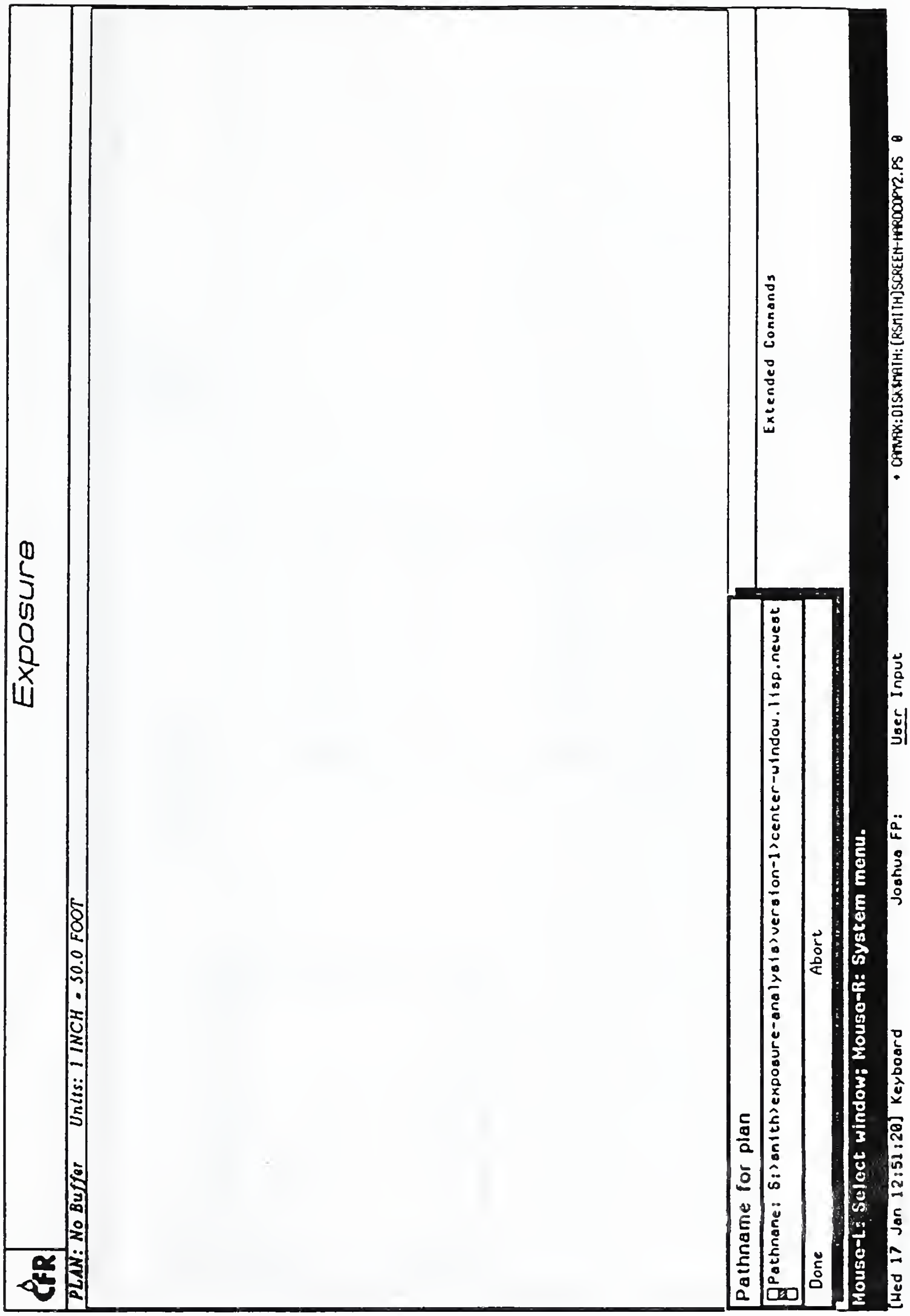

Figure 5. Read Plan Menu

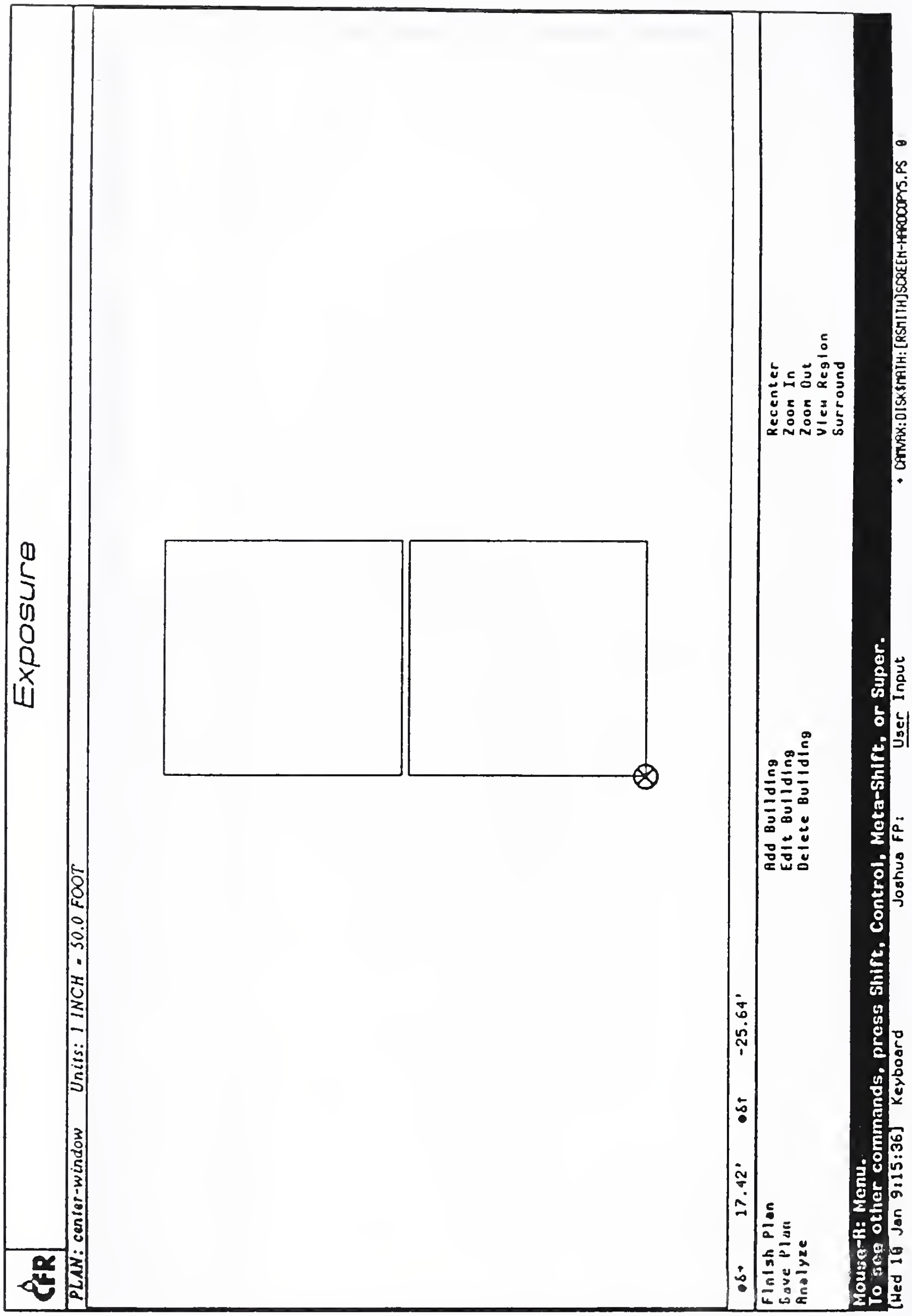

Figure 6. Top View of Two Buildings

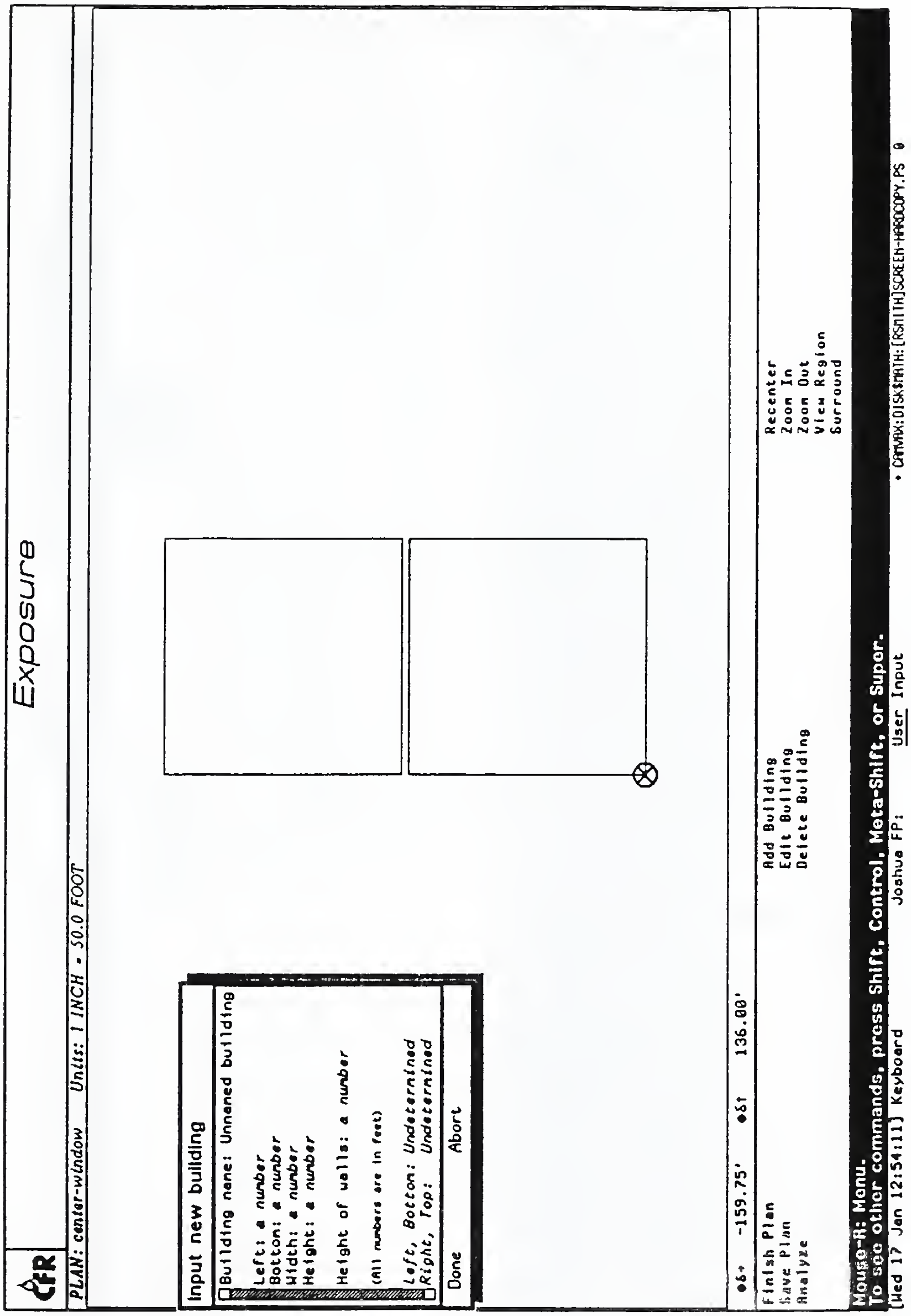

Figure 7. Input New Building Menu

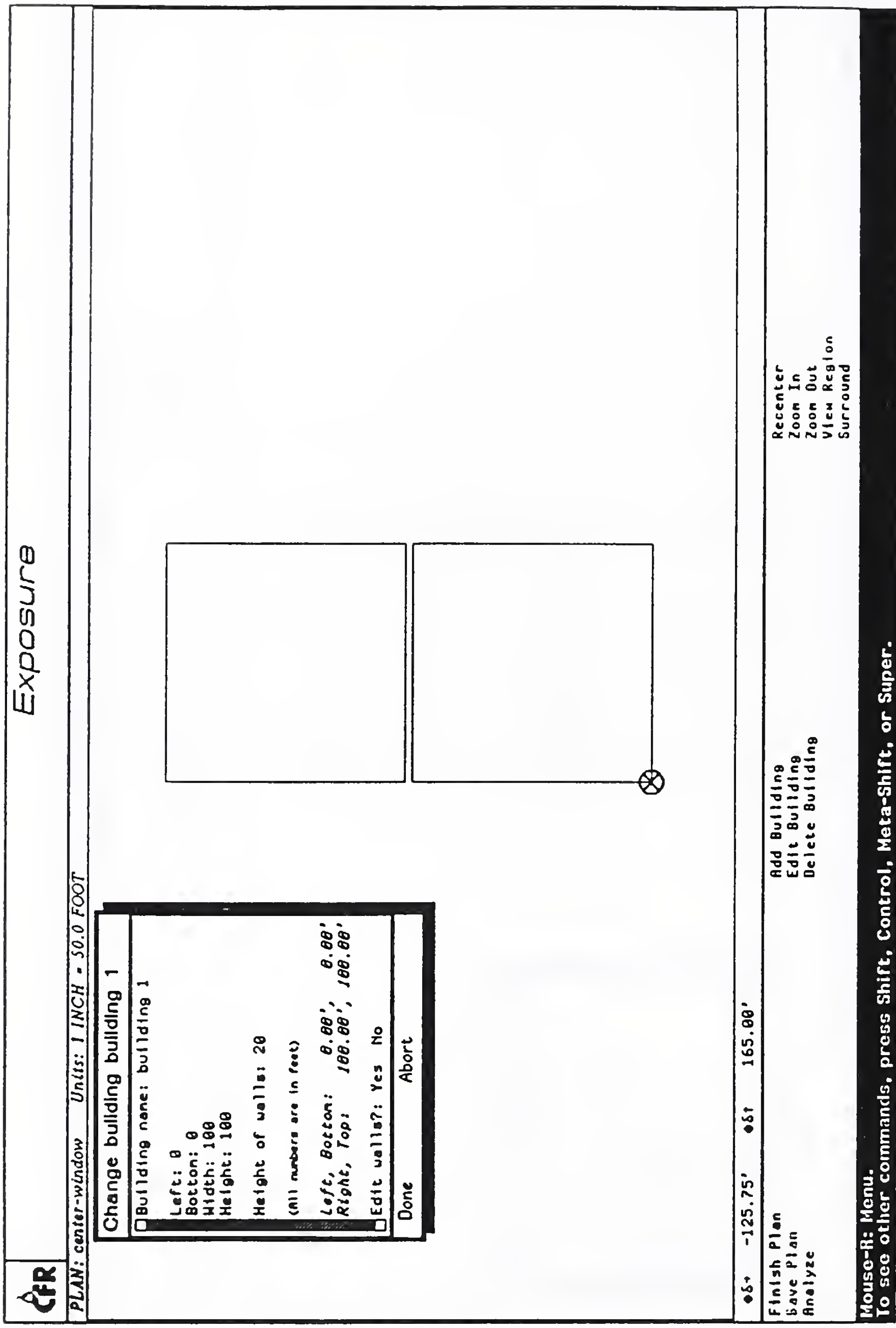

Figure 8. Edit Building Menu

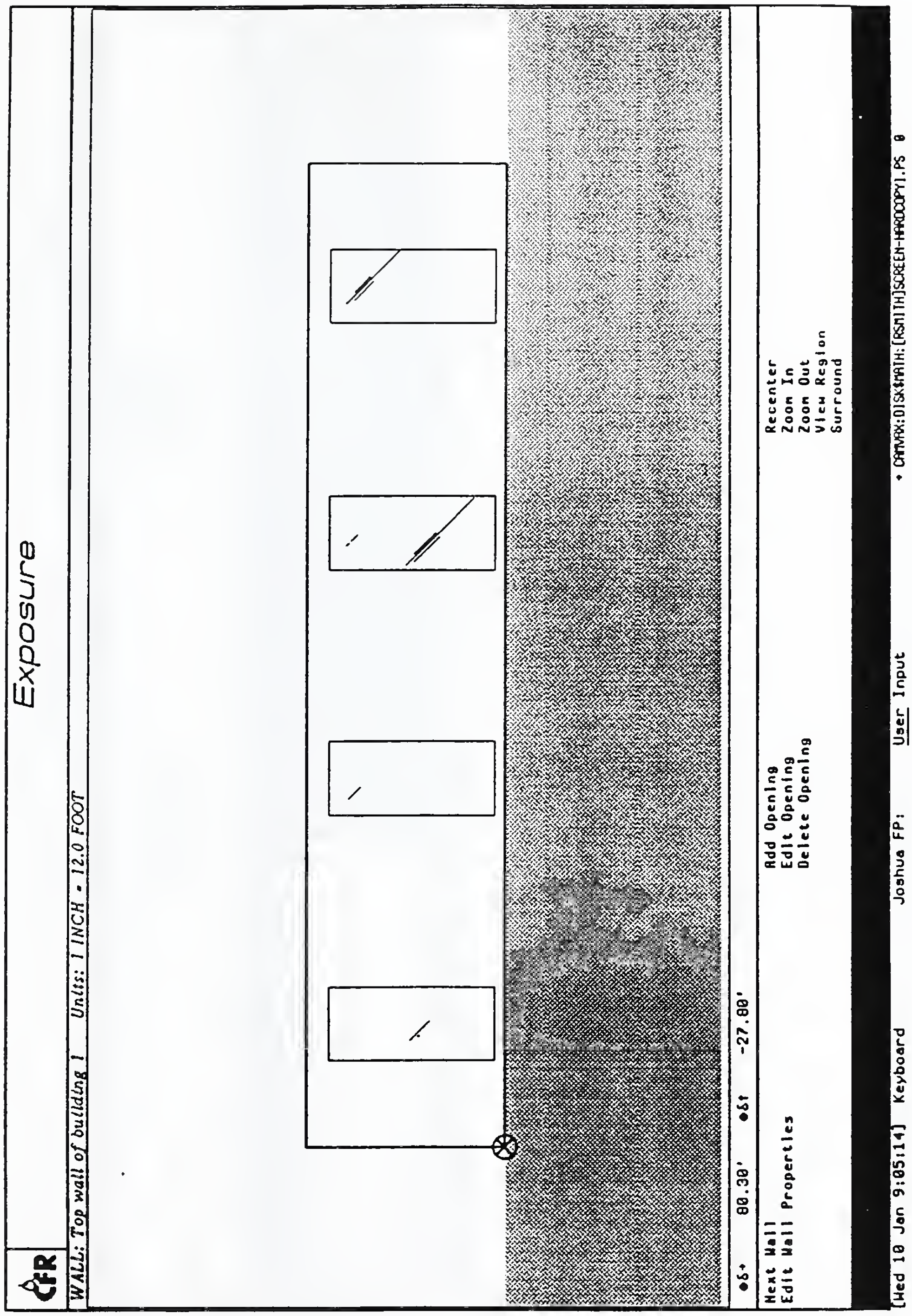

Figure 9. Elevation View of a Wall

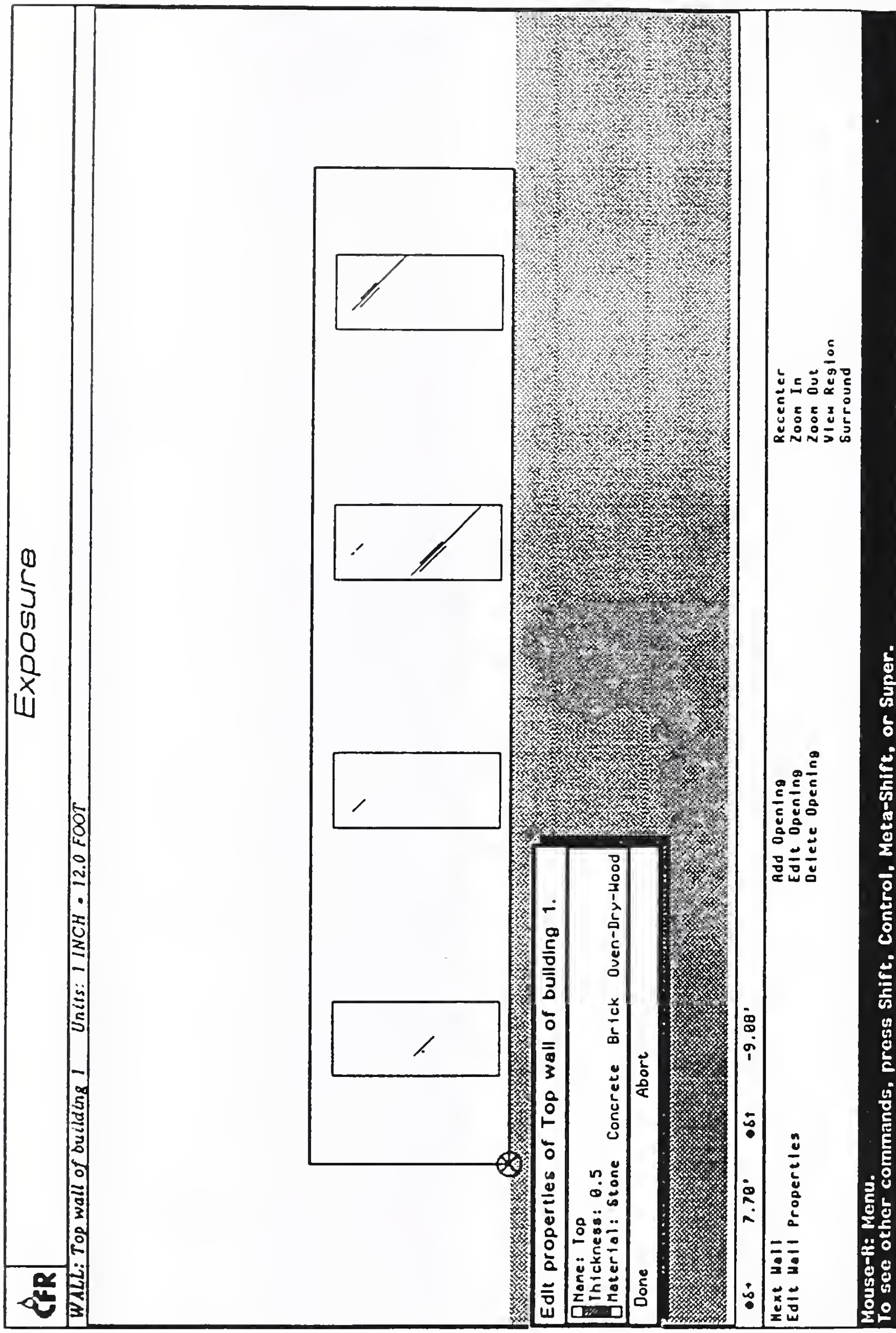

Figure 10. Wall Properties Menu

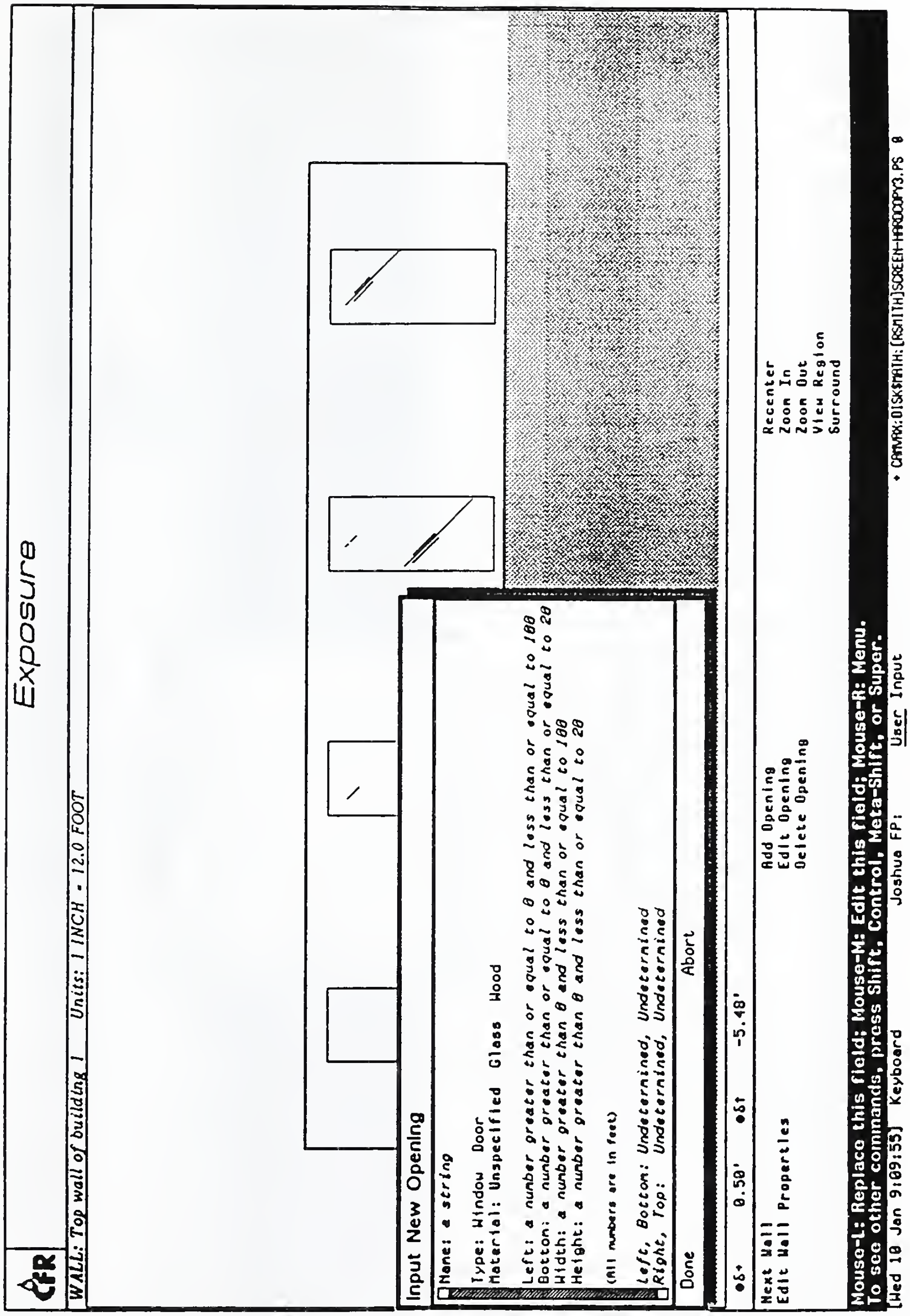

Figure 11. New Opening Menu

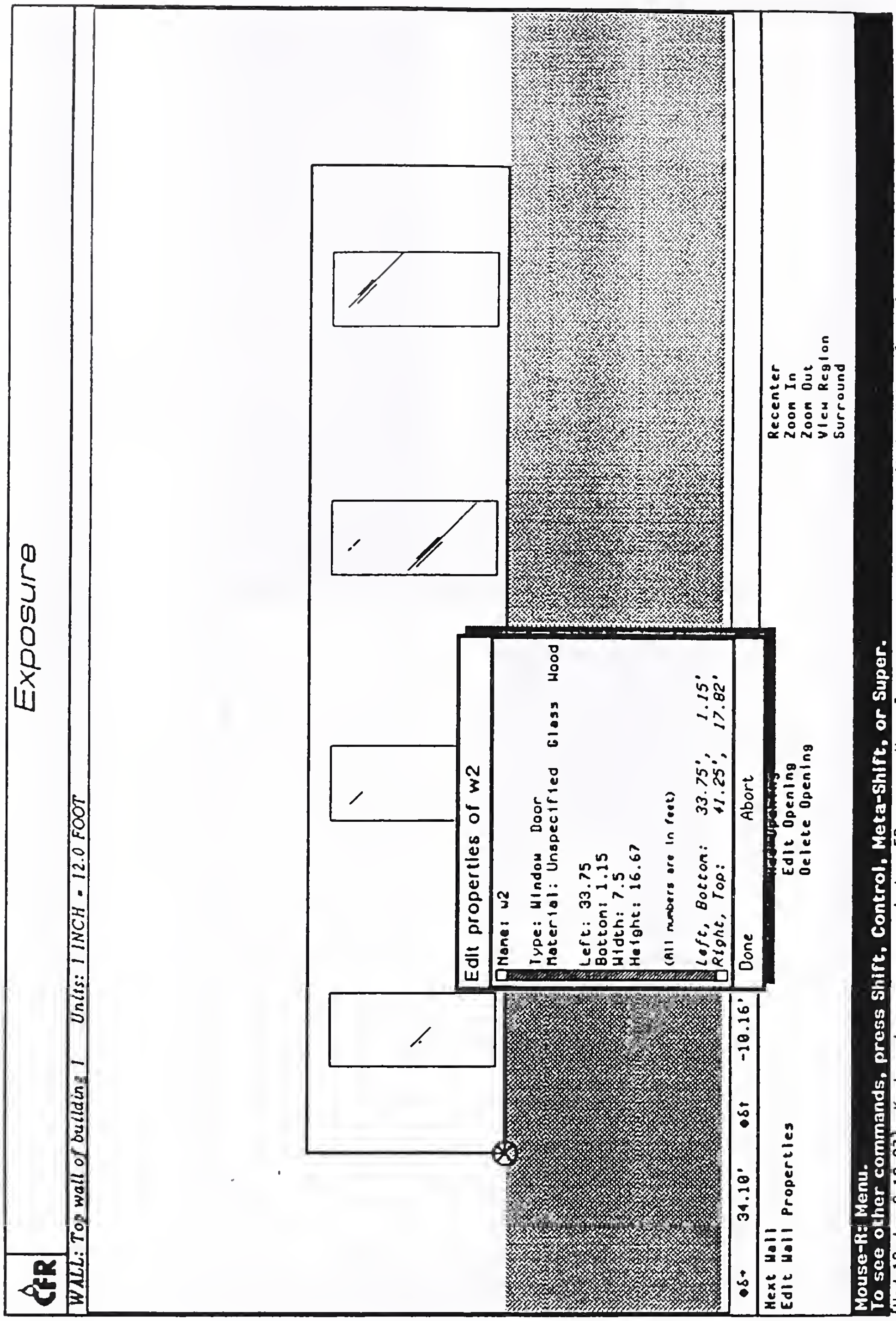

Figure 12. Menu for Editing Properties of an Opening

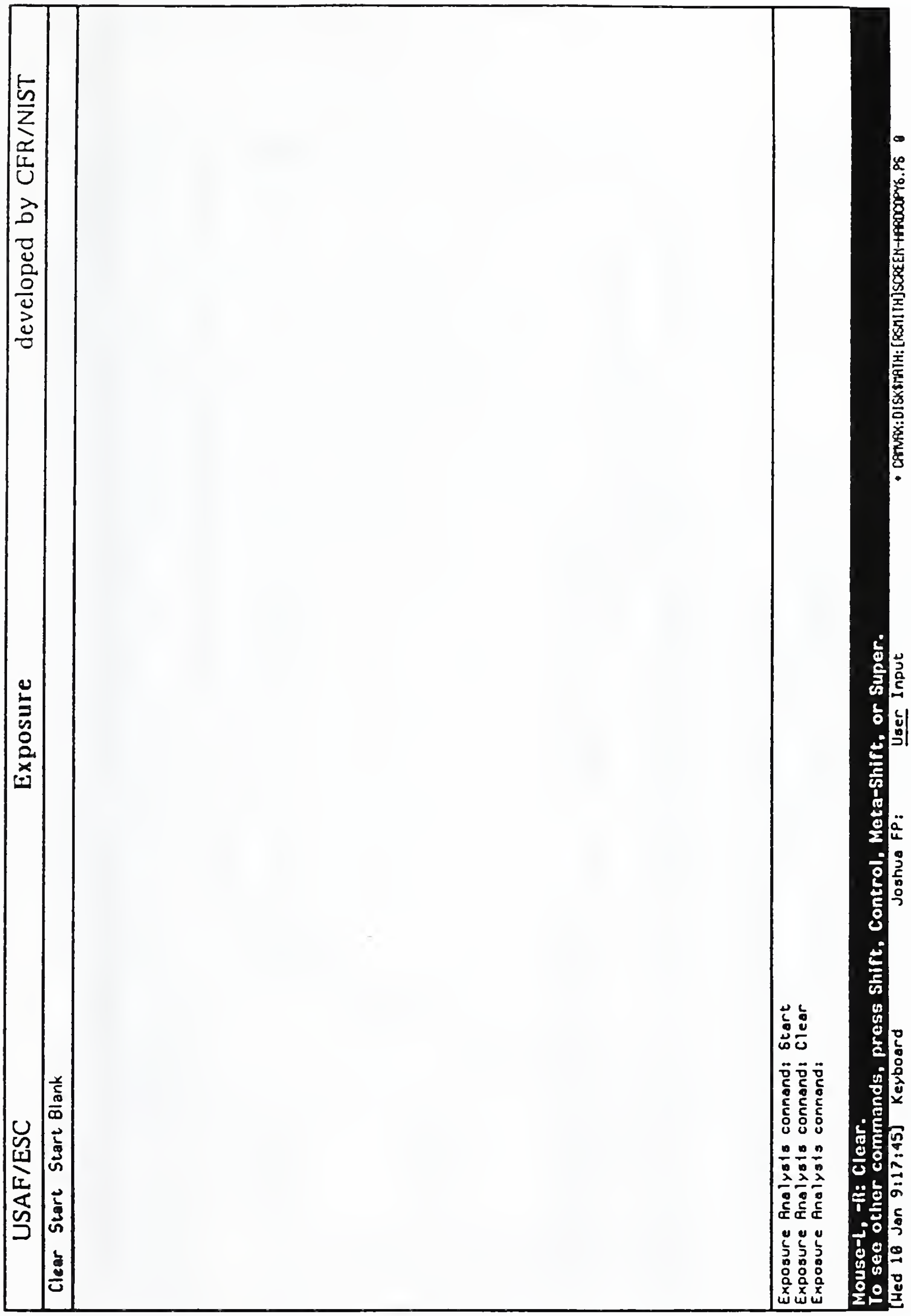

Figure 13. Initial Screen for Analyzing Input

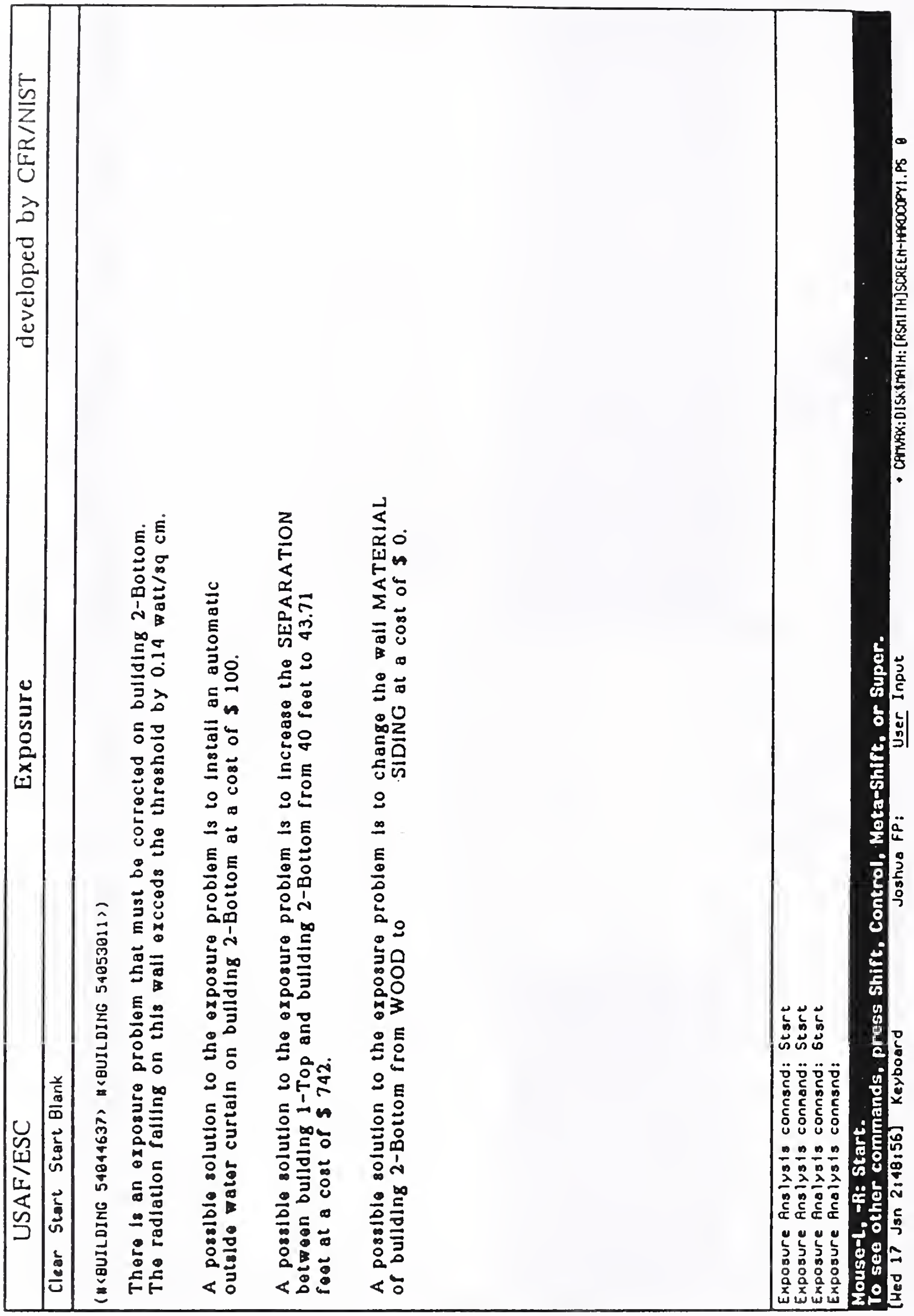

Figure 14. EXPOSURE's Solutions to the Exposure Problem

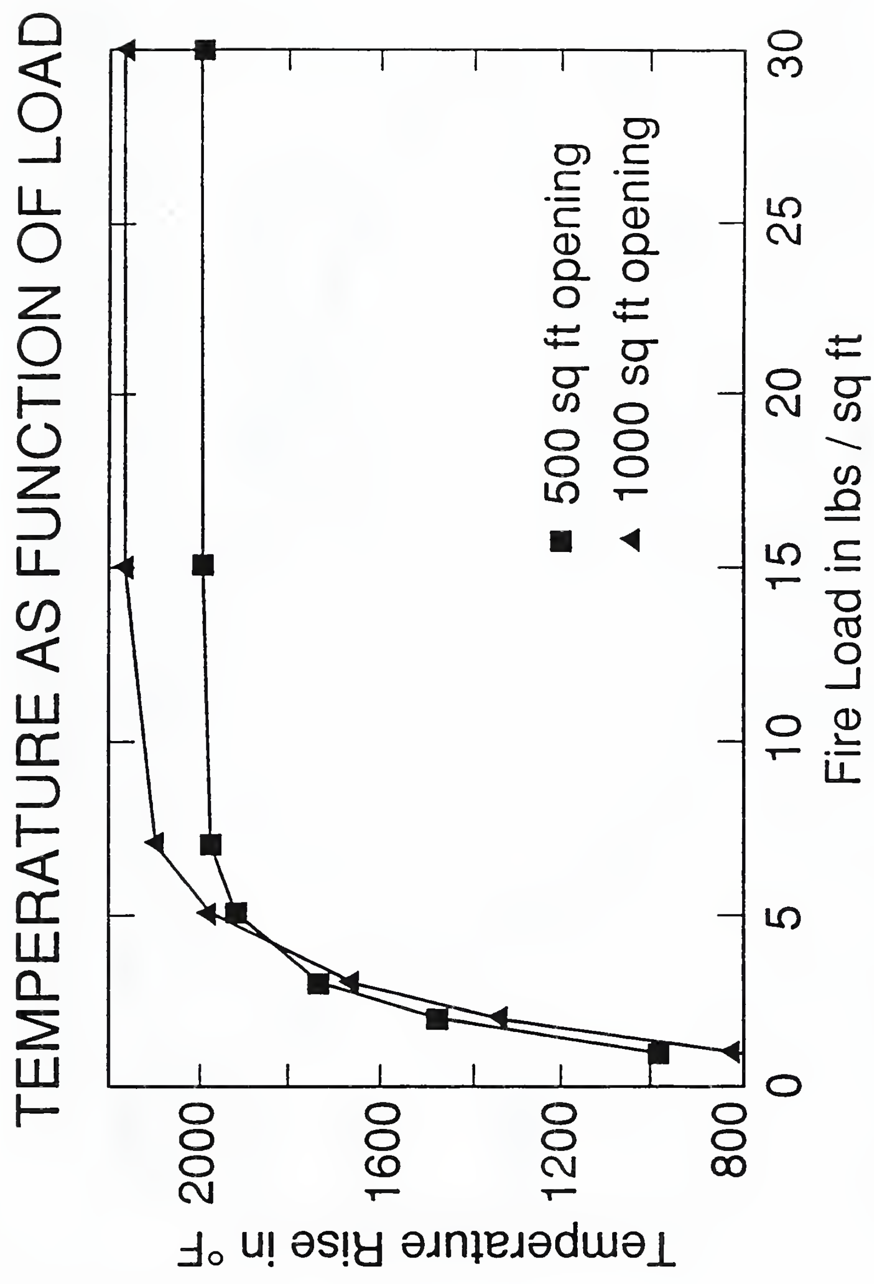

Figure 15. Maximum Building Temperature Rise as a Function of Fire Load

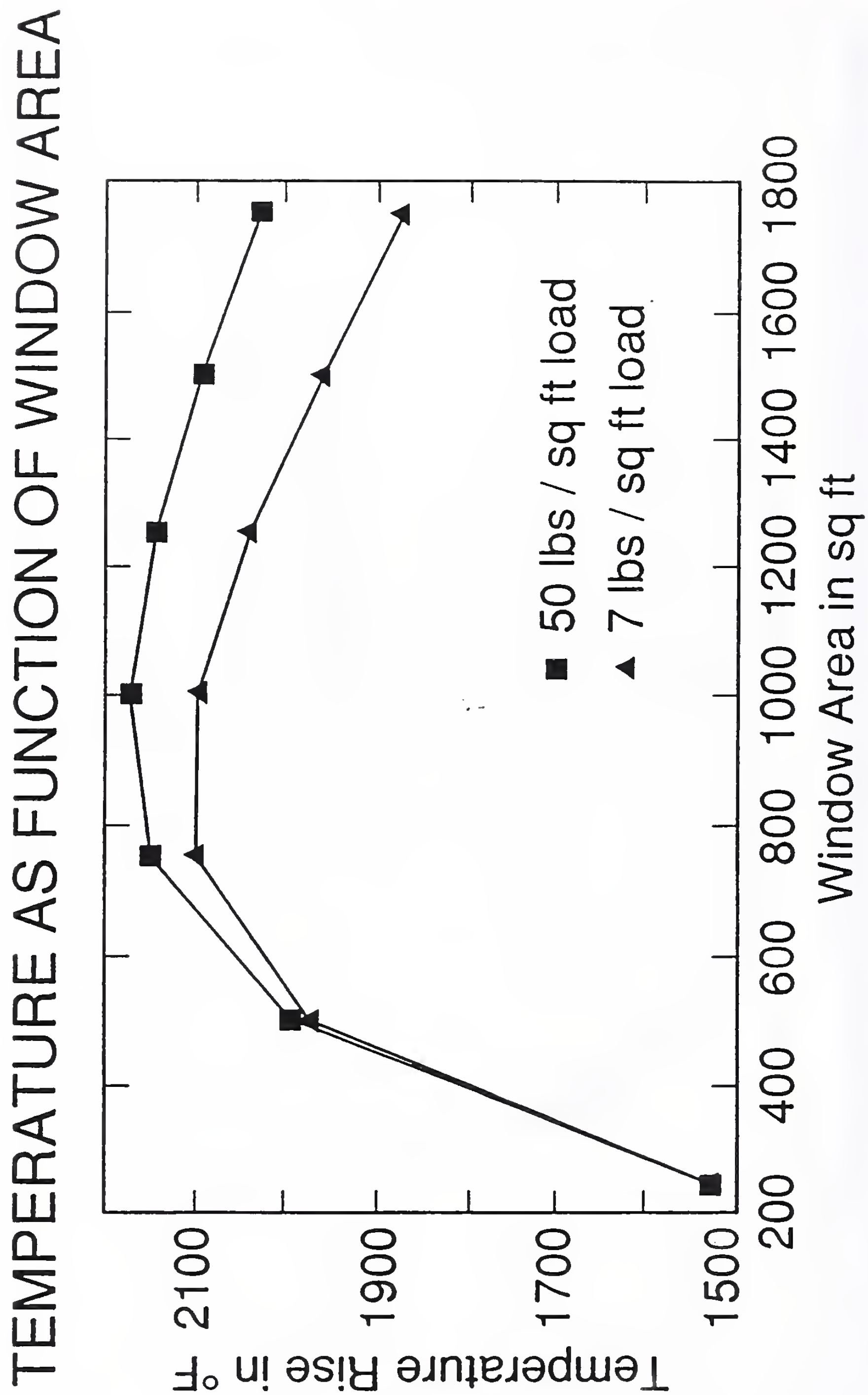

Figure 16. Maximum Building Temperature Rise as a Function of Window Area

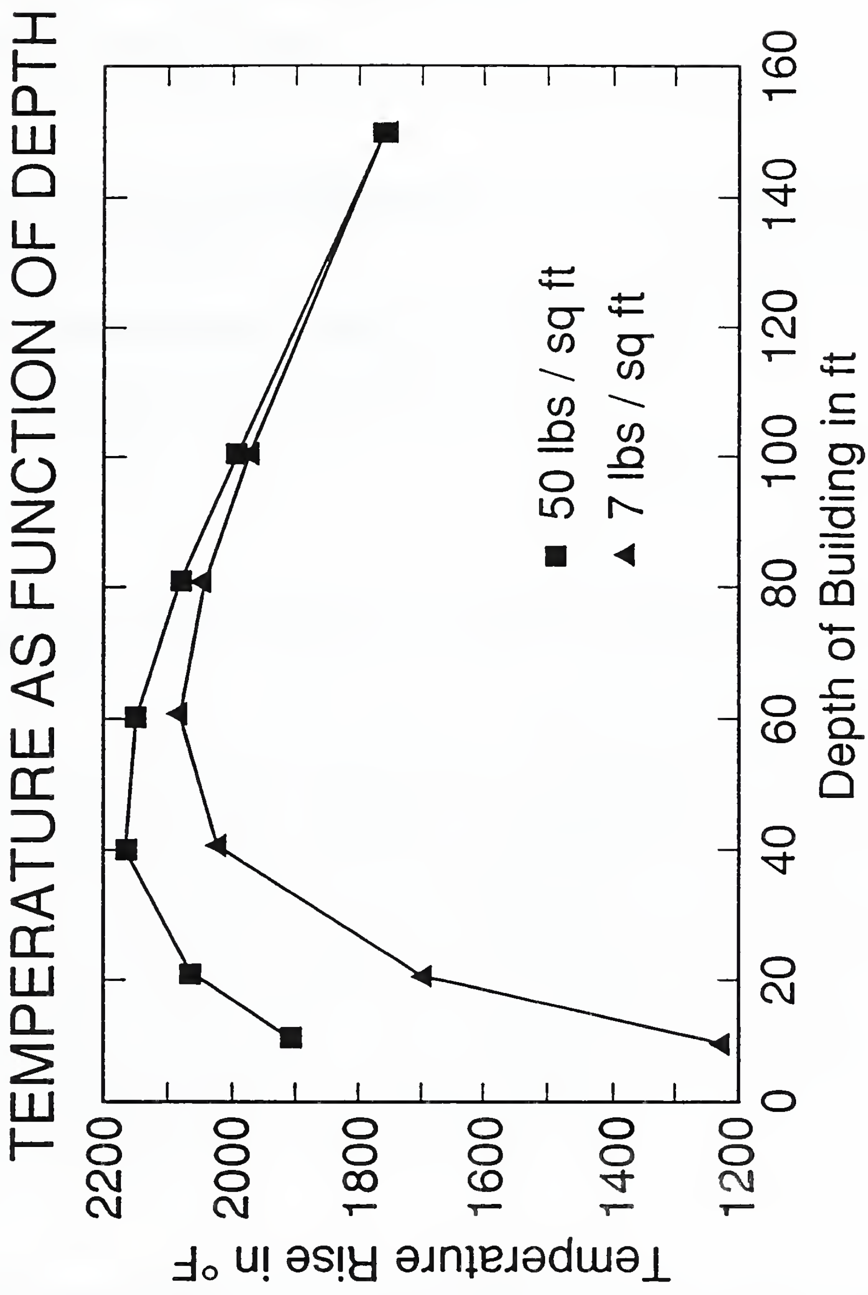

Figure 17. Maximum Building Temperature Rise as a Function of Building Depth

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10. SUPPLEMENTARY NOTES

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

This report addresses the issue of developing an expert or knowledge-based system that deals with the problem of preventing the spread of fire between buildings. A knowledge-based program, EXPOSURE, has been developed that facilitates using more appropriate technology, expanding the problem domain, and providing cost-effective solutions. EXPOSURE can solve the problem of the prevention of the spread of fire between buildings for the case when the exposed building has combustible walls. The use of the expert system EXPOSURE and NFPA 80A produce significantly different recommended minimum separation between buildings. In some cases EXPOSURE calls for significantly greater separation and in others significantly less. In one case the separation required by NFPA 80A was more than five times greater than what EXPOSURE recommended. This program demonstrates that significant cost savings in achieving the desired level of fire safety and in assuring the levels of safety can be obtained by use of expert system fire codes.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

artificial intelligence; building codes; computer programs; expert systems; exposure; fire codes

13. AVAILABILITY

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