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FINAL REPORT

DEVELOPMENT OF A SHELTER BLAST AND FIRE VULNERABILITY DATA SYSTEM

November 1971

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Work Unit 2526C

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13. ABSTRACT

This study investigates the data and methods required for developing a Shelter Blast and Fire Vulnerability Data System. The objective is to develop an inexpensive method of determining the blast and fire vulnerability of fallout shelters by using available building data and existing vulnerability models.

Numerous sources of structural data are examined including computerized listings of specifications of fallout shelter facilities, various types of maps, and aerial photography. A methodology is developed and procedures are specified for converting the data available in these source documents to suitable indicators of blast and fire vulnerability. Cost analyses of the various data collection and conversion methods are given to allow comparative evaluation of economic feasibility versus expected accuracy in detail.

Although the study concerns itself with existing data sources, much pertinent information is identified which should be collected in future fallout shelter surveys.

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Results of the analyses indicate that collection of data from Sanborn maps, although coverage is not complete and up-to-date for all areas, can provide the most accurate data but at the highest cost (approximately $6 per facility). An appreciable amount of data on specific shelter facilities may, through computerized internal editing routines, be procured from the Phase I Fallout Shelter Surveys to supplement or replace certain portions of data accumulated from Sanborn maps. Environmental data for fire vulnerability assessment may be collected from aerial photography. A less exact, although still useful and economical data collection procedure (eighty cents per facility), involves direct application of fallout shelter survey data plus area fire risk indices developed from Geological Survey maps. The latter maps alone, at a cost of twenty cents per facility, may be useful for initial application to nationwide damage assessment problems as they are sufficiently accurate to indicate the general magnitude of fire, blast, and fallout risks by geographic area.

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I. INTRODUCTION

The scope of the project is to develop a method of vulnerability analysis of community shelters for fire and blast effects resulting from nuclear attack. The method is to be capable of providing computer-based data on:

1. Vulnerability of major metropolitan civil defense shelters to initial ignition from nuclear attack.

2. Vulnerability to fire spread within each shelter and for each block in which a shelter is located.

3. Vulnerability to blast of shelter buildings in terms of their structural characteristics, dimensions, and building use.

4. Vulnerability of shelter occupants to blast and debris in relation to the type and dimensions of exterior walls and openings, interior walls and partitions, nature of floors and roof, and location of occupants within the building.

The degree of vulnerability is to be computable by use of major casualty and fire models already developed by the Government. Information sources such as the All-Facilities Listing, Sanborn maps, city planning maps, and aerial photography needed for correlation with the casualty, blast, and fire models are to be specified. A methodology is to be developed and a guide and procedures specified for converting the data available in these source documents to vulnerability estimates based on casualty, blast, and fire models. The method is to be applied to Providence, Rhode Island. Finally, a cost analysis is to be made for the alternative feasible methods of obtaining and applying the required vulnerability data.

II. GENERAL APPROACH

This section contains a basic outline of analytical procedures employed. Subsequent sections expand the procedures in greater detail and provide conclusions reached at various states of the analysis.

1. Review basic input data requirements for various vulnerability models.

2. Review possible source materials for data required.

3. Correlate data availability with model input requirements.

4. Develop the best mode or several alternative modes of data collection in consideration of existing data sources, cost, accuracy, and potential applicability to the various models.

5. Develop techniques and detailed procedures for analysts to derive required vulnerability data from source documents.

III. ANALYSIS OF FIRE MODEL INPUT REQUIREMENTS

Fire models may be divided into two general classes: highly detailed scientific research models and more generalized models applicable to nationwide attack under a wide variation of weapon deposition and meteorological conditions. The latter wide application models must of course provide results consistent with the more precise research models.

Differences among various fire prediction and spread models have been discussed objectively and in detail elsewhere.[1,2] Discussed here are some of the common points of similarity among the models. This analysis is designed to identify these critical and minimum input parameters. It is immediately apparent that all models, to some extent, extend detailed sampling of critical fire ignition and spread parameters to simplified modes of more general applications. It appears quite proper and even necessary that such procedures be instituted if the task of collecting data for nationwide application is to be made feasible. Although the modes and degrees of sophistication in collecting such parameters vary widely, the following data seem applicable to sampling:

1. Numbers and sizes of window openings and distribution of these parameters.
2. Nature and frequency of window coverings.
3. Nature and distributions of interior fuel arrays.
4. Expectancy of window shielding by exterior objects.
5. Variations in window transmission factors.

Other parameters may become important as model development moves forward. It is to be expected that parameters of the type noted above may be distinctively different among various occupancy-use classes.

Several models[3,4,5,6] currently recognize differences in fire risk among the various occupancy-use classes. Figure 1 illustrates the range

VARIATION IN RESIDENTIAL FIRE SPREAD RISK-FIREFLY

A. HIGH RISK AREAS: High density land use residential or mixed residential-commercial -- 4 cases

B. MODERATE RISK AREAS: Moderate density land use, single family residential -- 8 cases

C. LOW RISK AREAS: Low density single family residential to very low land use high rise apartment-school-hospital complexes -- 3 cases

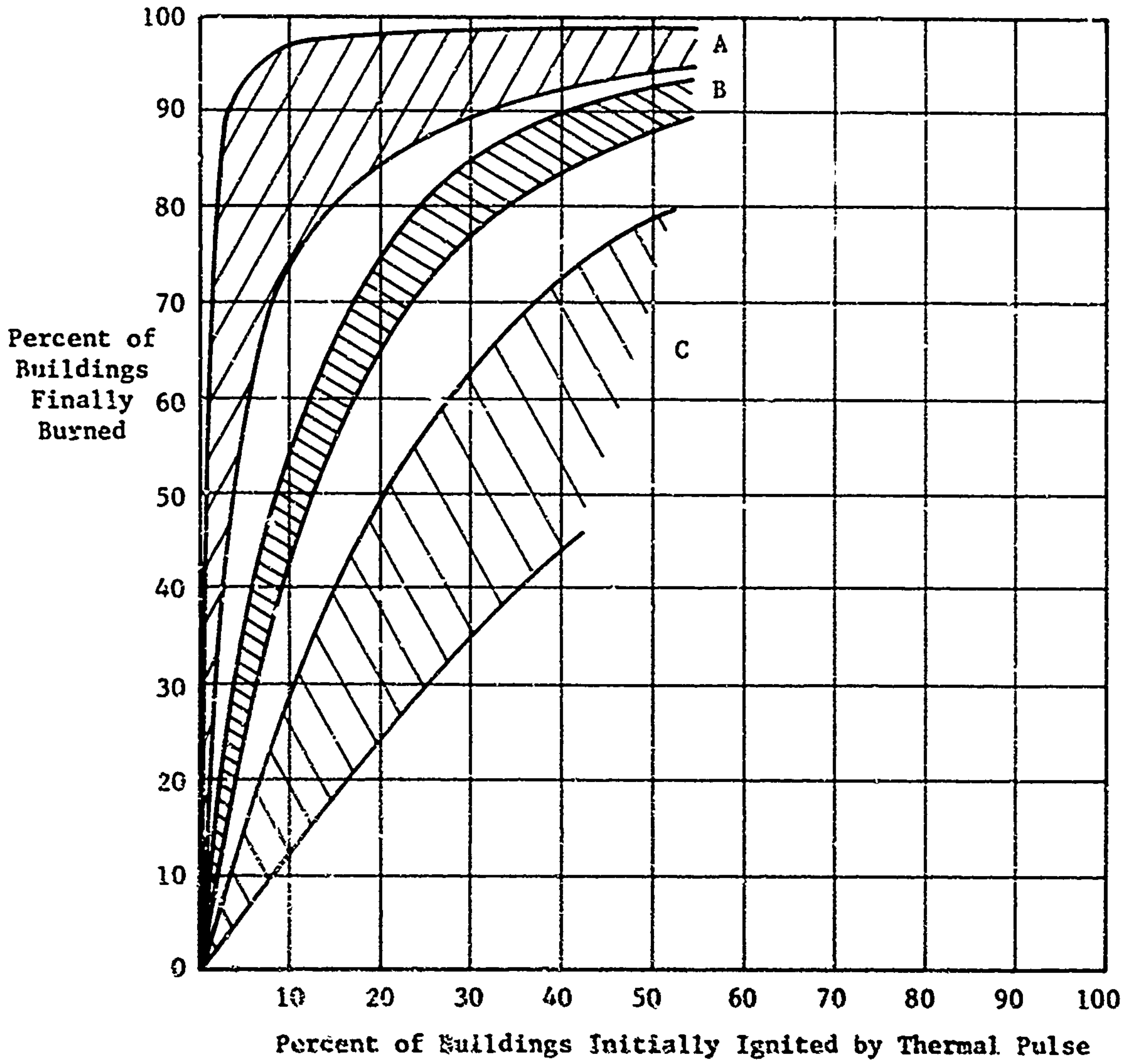

Figure 1

of fire hazard among various residential areas as predicted by FIREFLY.[7] These 15 samples were taken from 10 different cities. It is not necessary, of course to assume such variations are "model" dependent. Figure 2 portrays variation in final burn predicted by another model (IITRI)[3] for tracts of differing types within San Jose. Generalized curves for only a few of the IITRI tract types were plotted as development of these curves required prior selection of data from areas where spread by firebrands could be estimated to be relatively uniform. For example, the curve for Type I tracts embedded within builtup areas and having somewhat uniform exposure to firebrands is markedly different from data selected from the upwind periphery of the built-up area where no firebrands could have been predicted from large vacant areas upwind. It is evident, and important, that despite lack of quantitative agreement between two models, each demonstrates an appreciable sensitivity relative to the physical differences among various areas.

The IITRI[3] Model, as applied to San Jose, utilizes 14 different tract types, 8 of which were residential with building densities ranging from 8 to 15% with various size structures and mixes of 1 and 2 story structures A downtown area, a commercial area, several school and industrial areas with various building densities and building heights were also included. The URS[4] Model utilizes 9 area types including single family dwellings, multi-family dwellings, downtown, strip development, shopping center, industrial (2 different densities), and public buildings (2 types). FIREFLY analyses[7] have examined 19 different areas in detail, including 4 central business areas, 14 residential or mixed residential-commercial areas with building densities ranging from 12% to 38%, and one very low building density redevelopment area. Although differing in detail, the general ranges of interest expressed are quite similar among the various models.

Reference 7, FIREFLY analyses, has previously reported singular differences of fire risk among shelter type structures within a similar area environment. A more recent IITRI study of fire spread in high-density, high-rise buildings[8] has expanded upon the variation in risk among individual buildings of a specific class, primarily due to variability of fuel loading and construction detail. It may be anticipated that not only building type but also its usage and fuel loading exposure to initial thermal radiation, and

VARIATION OF FIRE RISK WITH AREA USE-BUILDING CONFIGURATION

IITRI MODEL -- SAN JOSE

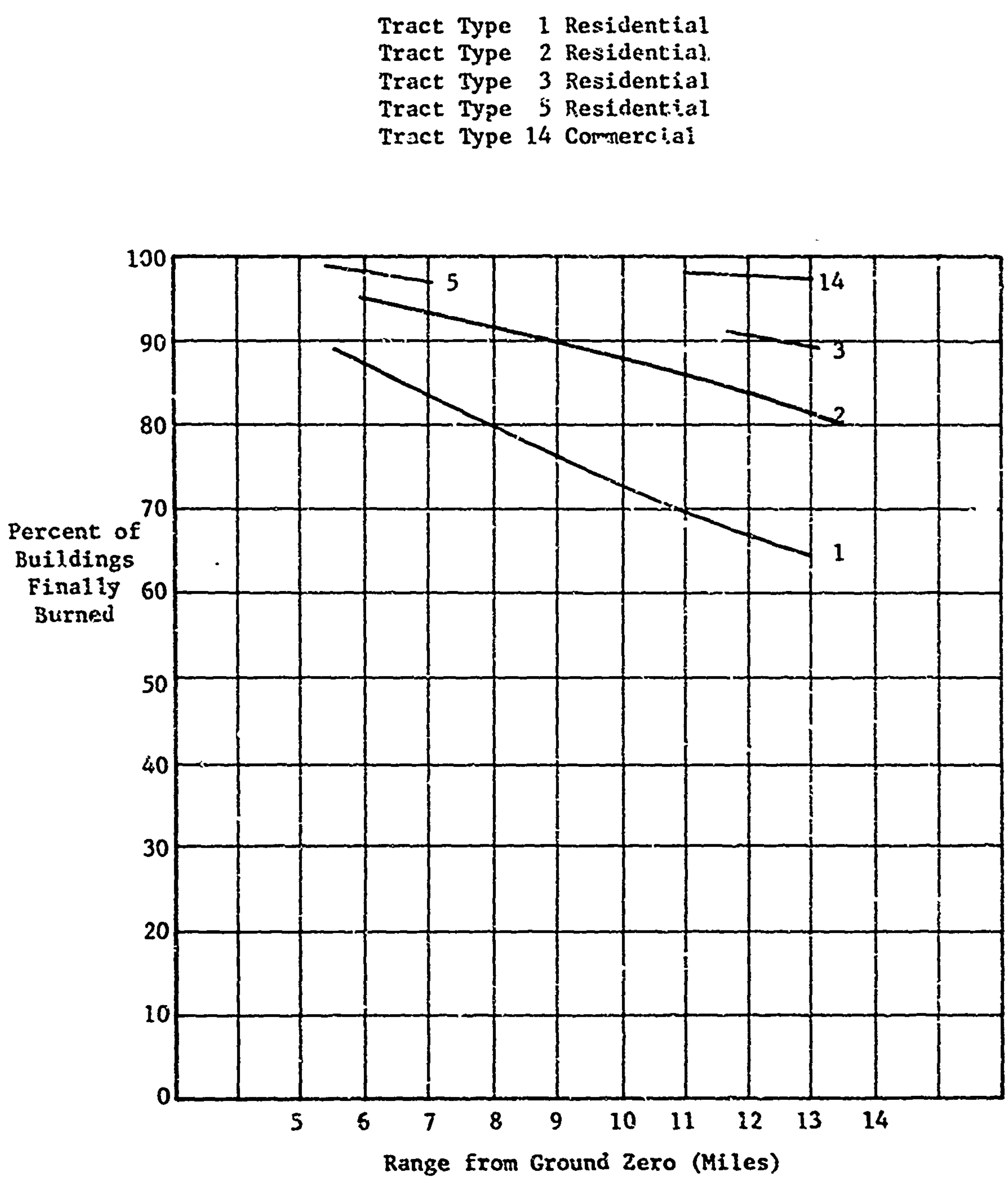

Figure 2

exposure to potential radiation from environmental buildings will become increasingly important considerations in evaluation of fire risk as the state of the art advances.

The important matter remaining to be considered is the level of detail that it is feasible to obtain, nationwide, and perhaps even as important, the amount of detail that can be successfully utilized on a nationwide basis if it were available.

Prior to examining the ramification of data detail, the mode of its application must be examined. As the thrust of this study is directed toward evaluation of individual shelter facilities, a generalized shelter fire risk statement may be written in terms of a "model independent" fire risk evaluation process as follows.

$$\text{Total Shelter Fire Risk} = 1 - (1 - P_A P_S)^n \, (1 - P_I)$$

Where: P_A is the average probability that a building will burn from any cause in a specified use-occupancy class area under specified conditions. P_A may be as calculated by any of the various models.

P_S is the conditional probability that fire will spread to the shelter building if it is within the range of critical thermal radiation intensity of a neighboring building. P_S is a function of physical characteristics of building construction and of building contents.

n is the number of buildings that would, if burning, directly threaten fire spread to the shelter facility. n may be specific for a given shelter, the average for shelters in a given area type, or may have distributions according to use and area type, i.e., schools in residential areas.

P_I is the probability that the shelter facility will be ignited and burned as the result of thermal pulse radiation. It will be dependent upon physical data (window area, building dimensions, construction, use, etc.) much of which may be derivable from existing NFSS Phase I survey material, and external shielding considerations which may be highly relatable to n and area type.

IV. ANALYSIS OF DATA SOURCES

A. Resume of Data

1. The Sanborn map[10] is designed primarily for the information of fire and casualty insurance underwriters. The maps are scaled to a high degree of detail including backyard garages, sheds, and in some cases, it is expected, facilities of a bygone age. Construction detail, such as woodframe, concrete block, brick veneer, steel frame, etc., are represented by notes and/or color code. Concrete or noncombustible floor and roof elements are noted as are wall thicknesses and details of stairwells, elevator shafts, unprotected openings, etc. These charts are the best available source for analysis of fire risks. They also contain much creditable material applicable to blast ratings, although finer details of curtain wall mountings, concrete floor type and thickness are lacking. Special notes relating to especially combustible contents or other fire hazards are frequently given. Maps are originally established for most cities over 2,000 population, although only the larger cities (1,400 volumes of maps) are being updated. Only the more extensive of suburban and peripheral areas are included in detail. Some detail (generally not important to the uses for which the maps were designed) is lacking. Basement information is frequently incomplete, or even presence of basement is sometimes omitted. Window areas are not given except in some special cases. Windows are frequently not noted at all unless they occur in areas where they present an unusual fire hazard.

2. Aerial photographs are useful media for assessing area fire risk, although not as definitively as may be done from Sanborn maps. The Map Information Office of the U.S. Geological Survey maintains records of aerial coverage of the United States and furnishes data on availability of photo-

graphs and references the Federal, State, or commercial agencies from which they may be obtained. Photographs from two of these agencies have been reviewed and used in test problems. Geological Survey Photography and Agricultural Stabilization and Conservation Service Photography are similar in format, ranges of enlargement, scale, and cost. Agricultural photos, periodically updated, are rarely more than 8 years old and are generally more recent. Geological Photographs are updated most frequently in rapidly developing areas. Geological Survey photographs of Richmond, Virginia, for example, were made in 1962 and updated in 1968. Agricultural photography of the same area was made in 1965. It is thus inferred that canvassing various sources will generally yield reasonably up-to-date material. Other materials relating to efficient and accurate location of individual shelters on aerial photographs are subsequently enumerated.

3. Census Bureau Address Coding Guides are available on tape for major urban areas. The coding guide cross-references address to county, city, census tract, block number within the tract, and range of addresses contained within the block face. This information is immediately transferrable to census maps detailing streets by name and blocks within tracts by number. With this information, transfer to aerial photographs becomes relatively simple.

4. Geological Survey Maps provide a vast amount of information at relatively nominal cost. Their availability closely parallels that of Geological Survey photography from which an appreciable amount of their topographic and man-made features are synthesized by highly detailed photogrammetric methods. In all except heavily builtup areas, which are distinctively tinted, individual buildings are indicated. Larger structures are scaled to size and shape. Occasionally an updated map is published with most recent aerial photography material overprinted in a distinct color (Richmond-

1968). Many prominent "landmark" buildings (schools, churches, public buildings, etc.) are designated by name, and the extent of open area around them delineated. Many shelter facilities in prominent structures may be identified immediately. Street and block detail of census maps are readily referenced to Geological Survey Maps and, through photogrammetric detail of the latter, to aerial photographs. These maps are not only valuable adjuncts in application of aerial photographs but may be an economical, although less accurate, source in conjunction with Census Bureau demographic detail, shelter facility listings containing use-structural type codes, and shelter facility names reflective of land usage.

5. National Fallout Shelter Survey (NFSS) Phase 1 data were collected by field surveys undertaken for the purpose of identifying and evaluating structures possibly useful as fallout shelters. Subsequent editing and processing[9] were conducted to evaluate available space per proposed shelter facility by fallout protection factor (PF). Original data contained a large amount of physical information concerning the structure which is potentially applicable to similar assessment of fire and blast vulnerability. Among data items of predominant interest are physical vulnerability (PV) codes identifying 33 different building types. Also included are use codes identifying 40 generalized use classifications. These latter data are also contained in updated Phase 2 facility floor and part listings which must be referenced to determine which proposed facilities were initially selected and currently maintained. Because of the potential importance of these data a complete subsection IV.B is subsequently devoted to its analysis.

6. Several comprehensive surveys of urban areas have been made by Bracciaventi, et al.[18,19] These data contain 10 residential and 6 non-residential use classes, generally parallel-

ing the range of interest of the various models. Window openings, covering, fuel arrays, etc. are tabulated for various use classes. The extreme variance in fuel loading, especially in industrial plants, suggests that further data subsets would be useful; textile mills and steel fabrication plants for example are two different things relative to fuel content.

Research Triangle Institute[14] survey data have already been mentioned as providing useful statistical information which in some aspects has been shown to be reasonably compatible with that obtained from Sanborn Fire maps. An IITRI study of fire spread in high-density, high-rise buildings[8] reflects the further potential of selective sampling for particular use-class configurations. Continued use and exploitation of such materials are obviously an essential adjunct to nationwide fire risk prediction schemes.

B. Analysis of Existing NFSS Data

Physical data relating to potential fallout facilities were collected during Phase I of the National Fallout Shelter Survey. These data were subsequently processed to determine fallout protection factors for the various facilities.[9] Phase II Facility Listings processed from original data contain little material directly applicable to blast and fire vulnerability other than physical vulnerability and use codes.[11] However, original files contain appreciable information of possible value in providing more specific fire and blast risk evaluations for each facility. Both files have been evaluated as possible contributors to a more comprehensive vulnerability data system.

The physical vulnerability codes carried over from Phase I surveys to Phase II listings were examined first. These codes, listed in reference 11, categorize shelter facilities into 33 structural types. The most important subdivisions by type are:

wood-framed buildings	-- 21-22
wall-bearing buildings	-- 31-38
steel-framed buildings	-- 41-49
reinforced concrete frame buildings	-- 51-59

For example, the "thirty" series, wall-bearing buildings, range from single story dwellings to multi-story monumental type buildings. Blast overpressures related to the collapse of various type structures within this group range from 3 psi to 10 psi.[12]

Discrimination as to relative blast hazards to shelterees within buildings of the wall-bearing class might be made with reasonably good accuracy, providing that original codings were correct. Additionally, a majority of buildings within this group might be expected to have floors and roofs of wood and/or interior timber framing. Thus risk of fire spread, given one or more fires in room contents, might be expected to be significantly different from that in a steel or concrete framed building with concrete floors.

The general accuracy of the original PV coding was checked against Sanborn Fire maps for 50 NFSS facilities in Providence, R.I., all carrying codes identifying them as being in the wall-bearing group. According to the fire maps:

35 were wall-bearing with wooden interior framing, floors and roof.

8 were wall-bearing, "fireproof", with concrete floors and roof hung on interior steelwork or trusses. In these cases no possible selection of PV codes could have properly identified the blast and fire risk of the hybrid type of construction occasionally employed before about 1930.

7 were steel-framed buildings with relatively light curtain walls of 12" brick or brick and cinderblock. These ratings were of course completely erroneous, reflecting neither the true blast or fire hazards to personnel in various parts of the building, above or below grade.

Despite errors in coding, plus much less-than-perfect correlation between combustibility of interior framing and wall type, 70% of the

PV codes in this group would have provided data compatible to that obtained from Sanborn maps. Therefore the original Phase I survey data was examined in detail to ascertain whether an editing or internal consistency check routine might be developed to detect and alleviate the inconsistencies.

The presence of wooden floors and associated interior framing greatly increases the risk of fire spread throughout a masonry building. NFSS data were checked to determine whether floor mass thickness coding might identify it as wood. Promise of such identifications being feasible is evident from the following results:

35 buildings, wall-bearing PV code (NFSS) and wooden floors (Sanborn)

- 34 mass thickness codes of 1, 10 lbs/sq. ft.
- 1 mass thickness codes of 2, 20 lbs/sq. ft.

15 buildings,* steel frame PV code (NFSS) and concrete floors (Sanborn)

- 3 mass thickness codes of 6, 60 lbs/sq. ft.
- 3 mass thickness codes of 8, 80 lbs/sq. ft.
- 9 mass thickness codes of 10 or more, 100 lbs/sq. ft.

Similar results were obtained in analysis of roof structures using NFSS mass thickness coding. It must be noted that all of these relationships arise from NFSS Physical Vulnerability identifications that have been confirmed from Sanborn maps as being substantially correct.

From among the original data set of 50 buildings with NFSS wall bearing codes, the fifteen singled out by Sanborn maps as being "fireproof" were examined by use of floor mass thickness. Nine of the group were identified as having concrete floors or roofs by mass thickness ranging from 40 to 80 $lbs/ft.^2$ Two indicated concrete floors on the first floor only. NFSS data on the remaining four buildings indicated floor mass thickness of 10 $lbs/ft.^2$, from which wooden floors would erroneously be inferred. Sanborn map data were quite explicit in all

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* Independent random selections not included in first sampled 50.

of these cases, supplying physical data to support ratings of "fireproof" or "fireproof X", except for exposed steel beams in basement, roof, etc. A certain amount of inaccuracy through mutually supporting errors in two or more survey items must be anticipated.

The examination of NFSS data was extended to include PV codes for various buildings supported by structural steel frames. From among 18 such buildings in Providence, 15 were confirmed by Sanborn maps to be substantially as represented. All had concrete floors and roofs. As previously noted all had floor and roof mass thickness of 60 lbs/ft.^{2} or more. Three buildings listed by NFSS as steel framed were portrayed as wall bearing by Sanborn maps, although two had steel or iron posts supporting wooden floors, and one had concrete floors in corridors only above the first floor. Structural detail in these buildings (constructed before 1920) might well have proved confusing to modern surveyors. In two of the three buildings the combustible nature of the floors are detectable by NFSS floor mass thickness codings of 10 lbs/ft.^{2}.

In summation, the samples reviewed indicate that the number of errors made by assessing building combustibility solely on basis of PV codes might be reduced by 2/3 through use of an almost trivial compatibility cross check between PV codes and mass thickness data.

The check described above provides data useful to blast vulnerability of various structural type shelters although some further analysis is required. That class of buildings initially coded as having load-bearing walls and confirmed by floor mass thickness check to have the conventionally associated wood floors was processed first. Larger, heavier walled buildings have been observed to be more resistant to blast.[12] Analysis by E.H. Smith[13] notes especially that the thickness of the load-bearing walls, plus the height of the building contributing to its dead weight, are important factors in predicting blast failure overpressures. Therefore NFSS wall mass thickness data has been examined to ascertain its possible value in establishing blast failure criteria for the various structures. NFSS data was compared to mass thickness data computed from Sanborn wall thickness and material information.

Table 1 gives the results of general comparisons of Sanborn and NFSS data on wall thickness. NFSS mass thickness was reduced from mass thickness data assuming mass thickness of brick at 10 lbs/sq. ft. for each inch of wall thickness. Allowance for interior lath or plaster that may have been included in NFSS calculations was neglected. About one-third of the sample buildings were common to both the Sanborn and NFSS bases, all buildings in both data sets had light (wooden) floors and roofs. The difference between the two data sets are not especially significant, except possibly for the upper stories of the larger buildings. The standard deviation of the NFSS sample was consequently the larger.

The NFSS data appears sufficiently consistent to be useful in establishing wall thickness for blast calculation. However it should be remembered that these are "select" data that have been retained after an initial internal consistency check between PV coding and mass thickness floor and roof coding. Further, the consistency within the groupings shown suggests that standard statistical data for such building classes might be applicable in lieu of more laborious building-by-building evaluation. In fact, uncertainties in predicting building collapse, such as variations in mortar influencing resistance to tensile or shearing stress, orientation of buildings with high length to width ratios toward blast wave, and even limitations in the state of the art may still prescribe generalization of structures into standard classical types.

The propriety of applying generalized statistical data was further investigated. From the data contained within Table 1, that portion common to both Sanborn and NFSS bases was examined and compared point by point. The results are shown in Figure 3 which is self-explanatory. The average difference between NFSS and Sanborn is only 1.3 inches. The standard deviation about this average difference is almost 4 inches. If the bias among the two samples is approximately removed

TABLE 1

COMPARISON OF FIRE MAP AND NFSS DATA -- LOAD-BEARING WALLS

3-STORY BRICK

	SANBORN DATA			NFSS DATA		
	Cases	Average (in.)	σ (in.)	Cases	Average	σ
1st Floor	19	13.9	2.4	26	14.4	3.1
3rd Floor	19	12.0	0.0	26	13.8	3.2

4-STORY BRICK

	Cases	Average (in.)	σ (in.)	Cases	Average	σ
1st Floor	24	17.5	1.9	29	18.3	4.8
3rd Floor	24	13.1	1.8	29	15.0	4.2

5-STORY BRICK

	Cases	Average (in.)	σ (in.)	Cases	Average	σ
1st Floor	17	18.8	3.0	24	20.0	4.3
3rd Floor	17	16.0	3.0	24	18.8	4.1
5th Floor	17	13.6	2.0	24	15.5	3.9

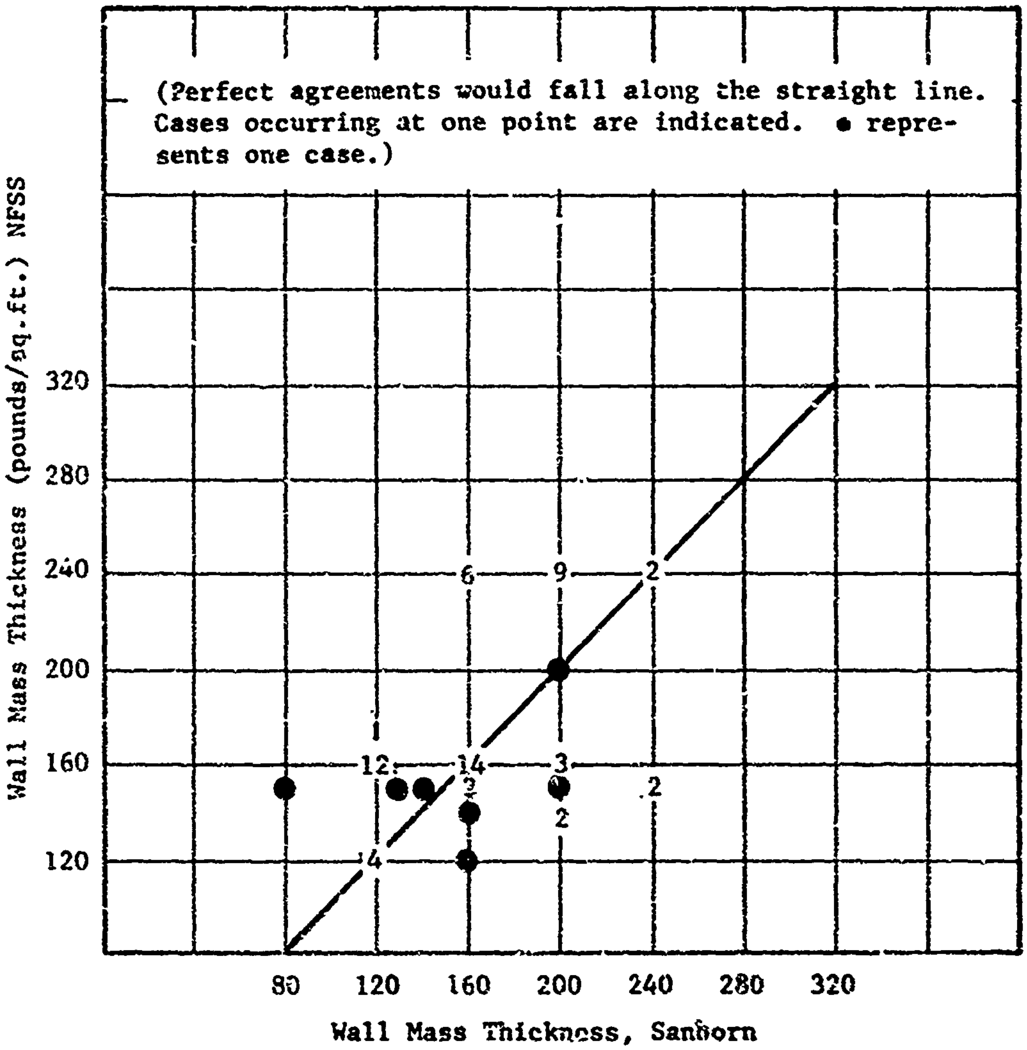
FIGURE 3

COMPARISON OF NFSS & SANBORN DATA

Twenty-four Load Bearing Brick Wall Buildings,

3, 4, or 5 Stories in Height. Comparisons

Made of Data at 1, 3, & 5th Story Levels.



by reducing NFSS thickness by one inch, the standard deviation about the revised mean difference is not reduced. Actually it is increased slightly. In short, differences in opinion among two sets of observers (Sanborn and NFSS) are substantially greater ($\sigma = 4$ inches) than those which would accrue if statistical averages were applied, Table 2.

One more check was made before leaving the brick wall bearing class of NFSS shelter structures. A small amount of independent data collected during a limited recent survey of NFSS shelter buildings by RTI[14] were consulted.

The RTI survey included 25 buildings originally identified by NFSS as being 3-5 story load bearing structures. Unfortunately RTI data revealed that only 8 of the 25 met the specifications for the type of structure under consideration. One more was located from the group originally coded by NFSS as steel framed. The buildings were scattered among Providence, New Orleans, and Detroit data. The sample was too small to construct floor by floor averages for various height buildings. Therefore the samples were individually compared to the Sanborn and NFSS average for the building height-floor level class of the sample. The aggregate of all differences, including 21 data points, was analyzed. The results were of extreme interest. The compatibility of the Sanborn average with the RTI sample is quite good. Even the standard deviation is close to that which might have been predicted from the Sanborn statistics provided in Table 1.

The RTI data again infers that the NFSS average may be biased toward too heavy walls. As the RTI sample is small, a statistical check was made using "Students" method of testing significance between means of small samples. The test showed the difference was significant, with appreciably less than 1% probability that the mean difference calculated might have been due to the random selection of samples.*

* In all fairness to the quality of NFSS data, it must be remembered that these data were collected primarily for the purpose of evaluating fallout protection spaces and factors, not necessarily structural strength, and quite properly included considerations appropriate to its intended use, such as summing mass thickness of interior partions with exterior walls. From the sample of wall-bearing buildings passing internal consistency check, wall mass thickness data are probably quite sufficient for the purpose intended.

TABLE 2

COMPARISON OF SEVERAL DATA SOURCES

	Averaged Differences	Standard Deviation
Sanborn average -- RTI Sample	+ 0.08 in.	2.4 in.
NFSS average -- RTI Sample	+ 2.11 in.	2.7 in.

On the basis of the total analysis conducted above it is believed that for buildings identified as wall bearing with light combustible interiors:

a. Blast vulnerability ratings may be assigned statistically, based on building height.

b. Statistically assigned ratings will be at least as good and often better than those which might be obtained by recycling NFSS wall mass thickness data.

Buildings not identifiable as being in the wall bearing combustible interior class fall into two broad categories. Each category presents particularly unique blast vulnerability characteristics.

The first is relatively modern steel or concrete framed buildings with light curtain walls. Blast vulnerability of shelterees above grade may be directly associated with the failure of curtain walls at relatively low overpressures[15]. Fatalities among basement shelterees occur with massive collapse of the first floor. Blast overpressures producing first floor collapse vary appreciably, depending upon the type of floor construction, but will generally occur at blast levels higher than those blowing away curtain walls.

A second generalized group of fire resistant buildings, usually of older construction, have load bearing walls with interior steel work supporting concrete floors. The interior steel construction may be in the form of a semi-independent steel frame, or consist of steel trusses anchored into the load bearing wall, with or without supporting steel columns or lateral bracing. Since such steel work is designed primarily to carry the weight of the floor, it contributes little resistance to lateral displacement and destruction of the walls, which are frequently massive, especially among the oldest building in the group. Such "hybrid" structures are fairly numerous among NFSS Shelter types. It is important to identify such buildings as in many cases they provide appreciably greater blast protection to above grade occupants than do the more modern, light curtain walled structures.

Wall thickness is an obvious discriminator between buildings of the two basic groups described above. Again Sanborn wall thickness data (adjusted to mass thickness dependent upon material)[16] was compared to NFSS for a set of buildings for which data from the two sources was readily available. Figure 4 shows virtually no correlation between the two sets of observations. NFSS data appears in general to overestimate wall thickness. A comparison between NFSS and RTI data sample contained only six buildings in Providence with steel frames and non-combustible floors or walls. Five of the six were originally coded in the NFSS data base as being structures with load bearing walls. Floor mass thickness check of original data would have identified the non-combustible nature of the interiors in four out of the five cases. Figure 5 illustrates lack of agreement between RTI and NFSS data. Again NFSS mass thickness estimates appear to be excessive. In only one of the cases was data from all three data bases available. In this one case, identified by an asterisk, RTI and Sanborn data was reasonably consistent with NFSS data being substantially different from either. The Sanborn data were converted to mass thickness on the basis of solid brick, although map comments noted an unspecified amount of cinder block in the walls.

As the result of the analysis conducted here it was concluded that recycling of NFSS wall mass thickness data for the purpose of obtaining more refined data concerning blast vulnerability of walls would not be justified. As it might be claimed that the Providence sample is not representative of NFSS data as a whole, a check between original NFSS PV codes and RTI data was made extending the comparisons to include New Orleans, Detroit, San Jose, and Albuquerque. The results are shown in the following tabulations:

63 buildings coded as load bearing walls, NFSS

RTI Data

11 load-bearing wooden floors and roof (except concrete 1st floor in several cases
33 load-bearing, concrete floors: about half with wooden roofs
6 steel frame, concrete floors, some wooden roof decks
13 Reinforced concrete frame, some wooden roof decks

FIGURE 4

COMPARISON OF NFSS & SANBORN DATA

Steel Frame Buildings

Wall Mass Thickness

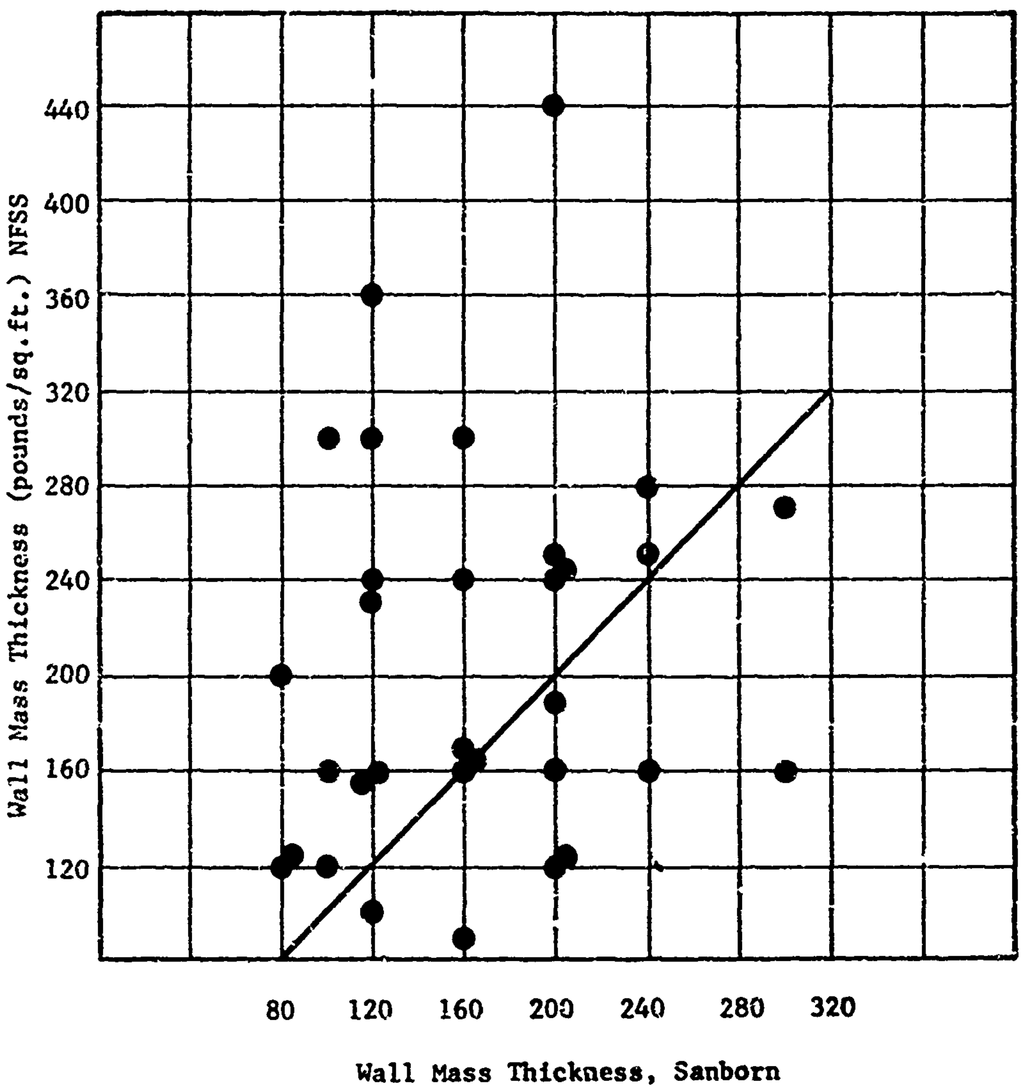
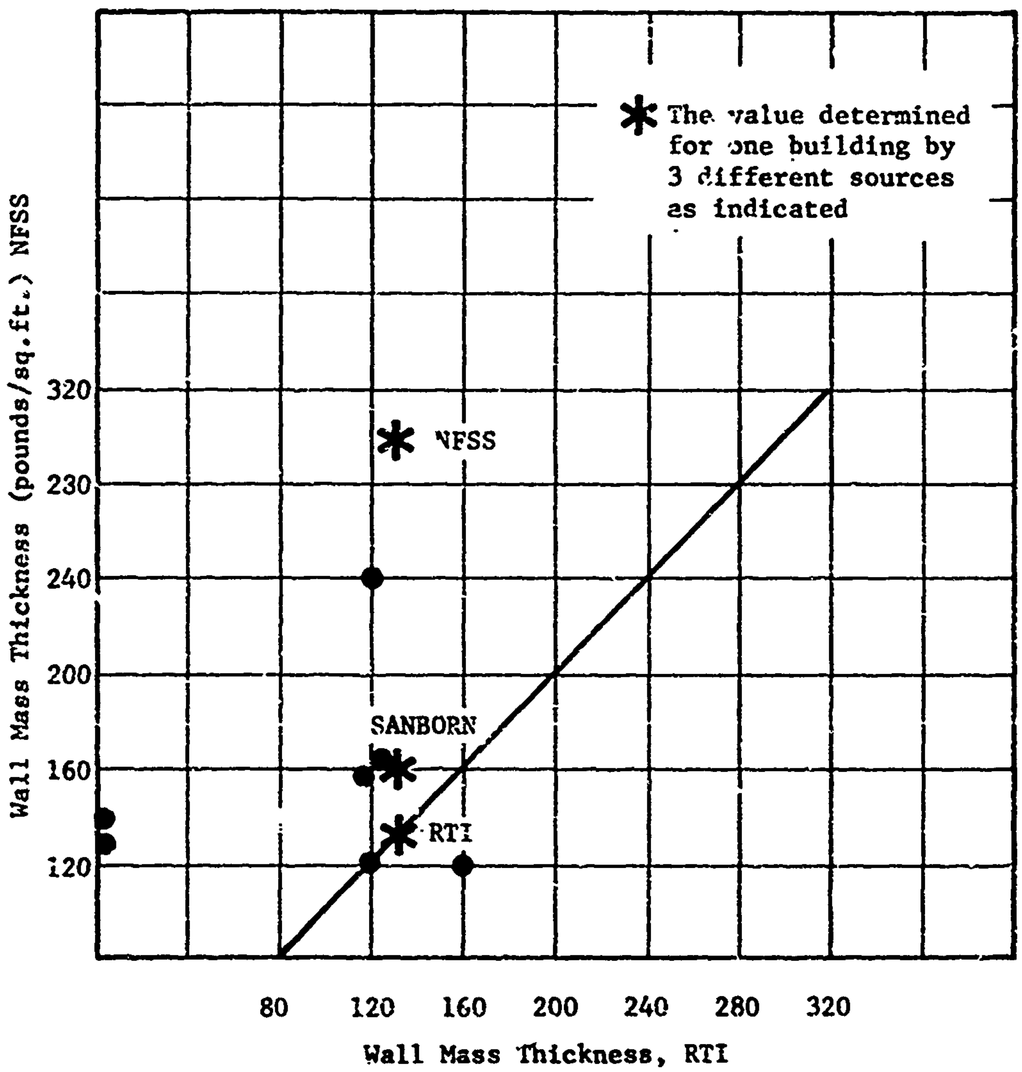


FIGURE 5

COMPARISON OF NFSS & RESEARCH TRIANGLE INSTITUTE SURVEY DATA

Steel Frame Buildings

Wall Mass Thickness



18 buildings coded as steel framed, NFSS

RTI Data

2 load-bearing, wood floors (above 1st floor) and roof
4 load-bearing, floors and all but 1 roof deck non-combustible
8 steel frame floors and all but 1 roof deck non-combustible
4 reinforced concrete framed, concrete floors and roofs

68 buildings coded as reinforced concrete framed, NFSS

RTI Data

3 load-bearing, wooden floors (above 1st floor) and roof
34 load-bearing, concrete floors, about 75% with concrete roofs
8 steel frames, concrete floors, all but two with concrete roofs
23 reinforced concrete framed -- concrete floors, all but two with concrete roofs

RTI vs. NFSS data checks show that the opportunities of improving combustibility indices of shelter structures are appreciable. In general the data suggest there may be fewer buildings with combustible interiors within the shelter files than might be inferred by PV codes alone. It also suggests that the number of buildings with light curtain walls may be somewhat fewer than is indicated by NFSS data.

The problem still remains in assigning blast vulnerability criteria, especially in those "hybrid" buildings with load bearing walls presenting considerably greater resistance to blast than do the more modern light curtain walled structures. However, many of these structures may be dated by construction practices unique to the time of their construction. Therefore an analysis of wall thickness versus date of construction was conducted.

Sanborn and RTI data for steel framed or hybrid non-combustible buildings were separately analyzed to find average wall thickness for several construction periods, Table 3. The Sanborn data was taken

TABLE 3

VARIATION OF WALL THICKNESS WITH YEAR OF CONSTRUCTION

AVERAGE WALL THICKNESS, INCHES, NUMBER OF CASES IN PARENTHESIS

YEAR	LOWER FLOORS		UPPER FLOORS	
	SANBORN	RTI	SANBORN	RTI
1930-Present	12.0 (2)	11.4 (29)	12.0 (2)	10.1 (17)
1920-1929	14.0 (12)	13.9 (8)	12.7 (12)	10.8 (5)
1900-1919	18.0 (6)	15.9 (10)	14.0 (6)	11.9 (8)
Before 1900	23.1 (7)	19.3 (3)	18.3 (7)	15.3 (3)

TOTAL OF BOTH SAMPLES

AVERAGE THICKNESS, INCHES AND STANDARD DEVIATION, INCHES

YEAR	LOWER FLOORS			UPPER FLOORS		
1930-Present	11.4	3.5	(31)	10.3	3.6	(19)
1920-1929	14.0	3.1	(20)	12.2	2.0	(17)
1900-1919	16.7	3.9	(16)	12.8	2.7	(14)
Before 1900	22.0	3.8	(10)	17.4	4.4	(10)

solely from Providence. RTI data included samples from Providence, New Orleans, San Jose, Detroit, and Albuquerque. The data from the two sources were grouped. The standard deviation about the mean is lower (by a factor of more than two) than the RMS of the differences between Sanborn and NFSS observations of the same set of structures, Figure 4.

In summary, the following conclusions were drawn.

1. PV codes assigned during initial NFSS may frequently fail to define a shelter structure with sufficient accuracy that reasonable blast or fire vulnerability ratings may be made. This is in part due to inaccurate ratings, and in part due to inadequacies in the coding system itself, especially in defining construction practices frequently employed before 1930.

2. A substantial part of the difficulty in assessing basic fire vulnerability of a structure may be alleviated by a data check of NFSS mass thickness of floors. Although some error may be expected, NFSS data is generally sufficiently accurate to differentiate between wooden and concrete floors.

3. Wall mass thickness data as recorded by NFSS is too variable in quality to discriminate between relatively light curtain walls and much more blast resistant load-bearing walls. However construction standards of the early twentieth century were sufficiently stylized that reasonably good distinctions may be made based on date of construction alone.

   A logical routine applicable to computer processing has been designed to recycle Phase I NFSS data to provide reasonable approximations of blast and fire vulnerability for individual structures. This routine provides window area analysis by floor and identification of use class (fuel loading of contents). The routine is detailed in Appendix I.

C. Analysis of Problems Relating to Interior Partitions

Cognizance was given to the problem of collecting and/or developing meaningful data on interior partitions which may influence estimates of blast vulnerability of shelter occupants. Considerable internal partition data is available on Sanborn maps. However, the presence of such information appears to be primarily influenced by its contribution to the evaluation of fire risk, rather than to the problem at hand, i.e., blast protection. Basement data is especially truncated and is frequently not shown at all. NFSS data no longer contains independent interior partition information. It appears that partition mass thickness was summed with exterior walls for PF calculations.[9]

As detailed data concerning interior partitions appears to be difficult and expensive to obtain, some effort has been expended in estimating the significance of deleting such information from blast vulnerability analysis.

Data developed by Research Triangle Institute[14] was sampled to determine the prevalence of various internal partition types in basements and below grade in 82 NFSS structures. Table 4 following summarizes this sampling.

It may be seen immediately that a large majority of above grade partitions (about 90%) would fail to withstand overpressures approaching the range where risk of fatalities by translation to completely exposed persons would begin to be significant. This value is taken as about 3.5 psi for a 5 MT surface burst weapon, as calculated from curves given in the Effects of Nuclear Weapons (reference 12). This fatality criterion is also in close agreement with values calculated by E.H. Smith & Co.[15] for exposed personnel.

Because of the higher frequency of more substantial internal partition areas in basements the significance of partition was examined in somewhat more detail.

TABLE 4

DISTRIBUTION OF INTERIOR PARTITIONS BY TYPE

	BASEMENT	FIRST FLOOR	UPPER FLOORS
No Partition	30%	19%	17%
Timber Studwalls	4%	19%	20%
Light Tile, Gypsum or Movable	18%	23%	26%
Non-load Bearing Concrete Block	13%	19%	22%
Non-load Bearing Brick (12" or less)	5%	8%	5%
Non-load Bearing Concrete	4%	0%	2%
Load Bearing Concrete Block (12" or less)	4%	4%	0%
Load Bearing Brick (12" or less)	5%	2%	3%
Load Bearing Brick (14" or more)	5%	6%	5%
Load Bearing Concrete (8" or more)	12%	0%	0%

Twenty-three of the RTI survey buildings with basement partitions were examined to estimate the possible influence of such partitions in preventing fatalities. No buildings with light basement partition (less than 12" non-load bearing brick panels, concrete block, tile, etc.) were included in the analysis. As available data does not include orientation of partitions relative to basement window openings, the estimates were necessarily rough based on average overpressure levels within the interior of the buildings. The analytical procedure involved:

a. Comparing internal basement overpressures with incident outside overpressures at the time significant structural failure of the buildings would be fatal to basement occupants.

b. Noting whether basement partitions would be a significant factor in preventing fatalities at overpressures less than those required for massive failure of the building or the floor above the basement.

Calculations of interior overpressures were based on curves developed by E.H. Smith.[13] Light curtain walls in steel or concrete framed buildings were assumed to be dismounted so rapidly at overpressures of 5 psi or greater that overpressures on the floor above the basement would be equal to the incident outside overpressure. Wall openings were taken as the average of the four building faces as reported by RTI. Partition, wall, and floor construction for each building was taken as reported by RTI. Floor construction was fitted to a table developed by E.H. Smith & Company to estimate probable collapse overpressure. Resume of analysis of the 23 buildings is given as follows.

There are nine cases with no basement apertures. Fatalities of basement occupants are contingent solely upon collapse of floor above basement or massive collapse of buildings, interior partition not being a substantial factor.

In seven cases basement overpressures of less than 2 psi were estimated at the time that the building would collapse or the 1st floor would fail massively with fatal results to basement occupants. Basement aperture percentages in these cases ranged from 2% to 11% of wall areas. General overpressure build-up in basement would be limited to less than 2 psi prior to the time when external overpressures were sufficient to produce massive failure of heavy wall bearing buildings, or to collapse 1st floors of framed buildings with light curtain walls. Excluding limited areas of jet formation through basement windows, the generalized overpressure values in the basement would probably not cause significant injuries at overpressures less than those required for collapse of building or first floor.

In four cases, basement overpressure of 2 to 3.5 psi were estimated at time of complete building collapse. Basement apertures were 10 to 18%. Apertures in load bearing walls above were not much greater, so fatality criteria were calculated on complete collapse of building. A few injuries or fatalities could be prevented by heavy partitions at overpressures just below the collapse value.

In three cases basement overpressures were estimated at 4 psi at time of 1st floor or building collapse. Basement apertures ranged from from 15 to 23%. In two cases estimates were based on total collapse of wall bearing buildings. The other case was a concrete framed building with light curtain walls. As basement window openings were appreciable, floor collapse was delayed until difference between basement and external overpressure reached floor failure criterion. These cases represent the highest estimated basement overpressures in the sample, and probably stand at the threshold of significance of heavy basement partitions in reducing fatalities.

No specific calculations were performed in the case of 59 buildings with lighter basement partitions. Light partitions may generally be anticipated to fail at overpressure levels at which they might otherwise become significant in protecting shelterees.

In only seven of the 89 basements could partitions have become of some significance in providing blast protection. These estimates are relatively gross, there being some recent work (15, 17) indicating much more rapid filling, and hence much larger overpressures in enclosed areas with window areas greater than about 5%. At any rate, the range of uncertainty within which basement partitions might become a significant factor would be increased to about 14 of the 89 cases. It may be reasonably assumed that development of more definitive criteria for evaluating the complexities of the problem would be an appropriate prerequisite to launching an extensive program to collect data concerning basement partitions.

D. Model Requirements Versus Data Sources

1. Ratings of Data Sources

Basic parameters relating to shelter facility fire and/or blast vulnerability are listed below. For each basic data group, various data sources are listed in decreasing order of detail and accuracy, and generally decreasing collection effort.

a. Building construction details

(1) Sanborn Fire Maps

(2) NFSS PV codes as confirmed or modified by internal consistency checks utilizing Phase I data files plus statistical characteristics of buildings identified by type.

b. Window openings by floor

(1) NFSS Phase I data, plus statistical distribution by use code and construction code

c. Window covering and transmission factors, and internal fuel arrays

(1) NFSS data use code, plus statistical distribution by use code, based on existing survey data

d. Area type identifying basic fire ignition and fire spread risk

(1) Sanborn Fire Maps

(2) Aerial photographs plus Census Bureau Address Coding Guides

(3) Geological survey maps plus Census data and shelter data identifying general nature of land usage

e. Exposure of shelter to risk of fire spread from its environmental area

(1) Sanborn Fire Maps

(2) Aerial photographs

(3) Geological survey maps plus statistical distributions of risk by area type and shelter use type

f. Exposure to weapon thermal radiation

(1) Sanborn Fire Maps

(2) Aerial photographs plus NFSS data concerning building height

(3) Geological survey maps plus statistical distributions of risk by area type and shelter use type

2. Resume of Data Collection and Cost Analysis

a. Sanborn Maps

The large amount of detailed information that can be derived from Sanborn Fire Maps can best be described by referring the reader to Appendix II, where detailed instructions for tabulating such information have been described. Fifty separate data items have been specified for tabulation. Many data items require use of multiple choice codes in order to specify the level of detail required for reasonably definitive analysis of fire and blast vulnerability for any one facility. Other items relating to fire spread risk from surrounding buildings and to shadowing from thermal pulse by surrounding buildings provide basic data only. It must be processed further to be specifically meaningful. The decision to orient spread and shadowing data in this form was based primarily on the following considerations.

(1) The interpretation of these data may vary somewhat from model to model.

(2) The final reduction of the data could undoubtedly be performed more efficiently in bulk by computer codes than by manual analysis at this point.

The average direct analytical labor per shelter is estimated at 1 hour. This does not include extraction of window data from NFSS files, a process that also could most efficiently be computerized. Sanborn Fire maps generally cover four to six square miles of urban area, New York alone requiring 79 volumes. Using Providence as a more typical base, an average of 140 facilities per volume may be estimated, although in specific cases this may vary within wide limits. It may be anticipated that the cost of map rental should be relatively small in respect to direct analytical labor required to extract data. Estimating labor cost at about $5.00 per hour, plus $1.00 map rental per shelter on the average, the most optimistic estimate of direct costs, excluding supervision, administration, and overhead must be in the vicinity of $6.00 per shelter facility.

b. Aerial Photographs

The detailed procedures for applying aerial photographs and associated Census Bureau Address Coding Guides and Geological Survey Maps are provided in Appendix III. Fundamentally, the address coding guide allows rapid geographic identification of any specified address. The Geological Survey Map incorporates graphic detail of street patterns and information scaled and synthesized from aerial photography. Using these materials the transition from address to aerial photographs is relatively rapid and accurate. Guides are provided for visual identification of area types, and to assess the approximate risk to shelter facilities by fire spread from adjacent buildings. The procedure will produce greatest accuracy when the use-construction characteristics of a given shelter are independently assessed by computerized analyses of NFSS Phase I data. Appendix III details collection methodology.

Each shelter facility in Providence, R.I., was individually rated as a test of these procedures. The ratings are provided by facility number in Appendix IV. Data includes the tract and block number of each facility which, as a by-product of the procedure developed, will allow development of finer-grained shelter locations as they relate to population distributions. Such refined shelter locations are also advantageous when evaluating effects of lower yield weapons.

Individual facility ratings have been summarized and are presented in Tables 5 and 6, following.

The 691 shelters in Providence were located from addresses, processed and coded with total expenditure of 90 man-hours of labor. Although aerial photographs each cover about 9 square miles of territory, overlapping areas required to assure continuous near vertical coverage reduces effective coverage to about two square miles. A cross check of aerial coverage of Richmond confirmed these effective coverage criteria for planning purposes. Estimated costs of basic materials and labor in processing Providence data were:

Photo Cost (24 x 24 enlargements)	$ 40.50
Geographic Survey Map	.50
Address Coding Guide	35.00
Total Material Cost	$ 76.00
Analysis @ $5.00/hour	450.00
Total Cost	$526.00

The estimated total cost per shelter, exclusive of administrative and supervisory overhead, is about 80¢ per shelter, a reduction from cost of using Sanborn maps by almost a factor of 8.

Data tabulation is essentially less complex and more rapid than in the case of Sanborn maps. Although some loss in accuracy is anticipated, it is believed that the loss is small in proportion to reduced collection costs.

TABLE 5

DISTRIBUTION OF SHELTERS IN PROVIDENCE BY LAND USE ASSOCIATION

Land Use Class	Number of Shelter Facilities	%
0 (relatively isolated)	14	2.0
1 (redevelopment-residential-institutional)	166	24.0
2 (low density-residential)	19	2.7
3 (moderate density-residential)	135	19.5
4 (moderate density commercial-industrial)	155	22.4
5 (high density commercial-industrial)	88	12.7
6 (high density residential-mixed)	114	16.5
TOTAL	691	

TABLE 6

DISTRIBUTION OF SHELTERS BY FIRE SPREAD EXPOSURE WITHIN LAND USE CLASSES

Land Use Class	Exposure to Fire Spread Code (Percent)*					
	0	1	2	3	4	Avg.
0	100.0	0.0	0.0	0.0	0.0	0.0
1	38.0	44.0	17.5	0.5	0.0	0.8
2	14.3	57.1	28.6	0.0	0.0	1.1
3	7.4	31.8	45.9	13.3	1.5	1.7
4	5.8	20.6	45.8	25.8	7.7	2.2
5	1.1	5.7	13.6	38.6	40.9	3.1
6	4.4	15.7	37.7	26.3	15.7	2.3

* Fire spread code indicates the number of neighboring structures threatening shelter by short range (radiant) fire spread.

c. Rating by Statistical Application

The possibilities of even briefer statistical application was tentatively evaluated. Source materials used here were Geological Survey Maps plus metropolitan Census Maps. From Census Maps outlines of all tracts or evaluation districts are rapidly transcribed to Geological Survey Maps. A survey of shelters within a tract by use and name generally identified many "landmark" buildings identified by name on Geological maps. Schools, hospitals, universities, public buildings, churches, athletic stadiums, field houses, armories, etc. are frequently identified immediately. and their relative isolation from their environment often assessed with considerable accuracy from map detail. Such examination of shelter facilities by name, plus tract population and size yielding population density, generally allow a subjective assessment of the tract into one of the types classically associated with urban configurations.[13] In such cases shelter identifiable only as being within a tract of specified nature may be assigned risk codes derivable statistically from more detailed analyses such as presented in section b. above. Accuracy in assessment of specific shelters cannot be expected, although the generalized risk to shelters within a given area may be reasonably predicted.

A test run was made in which about 1600 shelters in the state of Maine were given approximate fire ratings. Comments concerning the experience gained are provided:

(1) Many large blocks of shelter facilities can be rated "en masse" as having negligible fire risk. Such facilities included naval coast artillery emplacements and fire control centers, lighthouses, semi-buried storage igloos, etc. It was necessary, upon observation of large numbers of such facilities, to establish a unique code to identify the "negligible fire risk" category.

(2) Many shelter facilities were located in schools, hospitals, armories, power plants, etc. which were shown by Geological maps to be rather substantially isolated from fire spread environments.

(3) Large groups of shelter facilities were located in institutional areas such as colleges, military or naval reservations, technical schools, etc. where building density was sufficiently light that individual configurations of building arrays were detailed on survey maps, and the general nature of fire spread risks could be rapidly assessed.

(4) Clustering of shelters in heavy land use areas was generally apparent, the name and use code of the structures giving reliable clues as to the nature of the area.

(5) Shelters in peripheral residential areas were generally confined to smaller schools, churches, etc. with occassional grouping of shelter addresses along single streets where building name and usage clearly indicated commercial strip development.

(6) Even small towns for which no graphical references were obtained showed typical "Main Street" and "Courthouse Square" patterns of shelter addresses. In such places even generalized ratings should be initially adequate pending operational analysis of which of such areas are indeed subject to any appreciable direct weapons effects risk, in which case more detailed examination might be warranted.

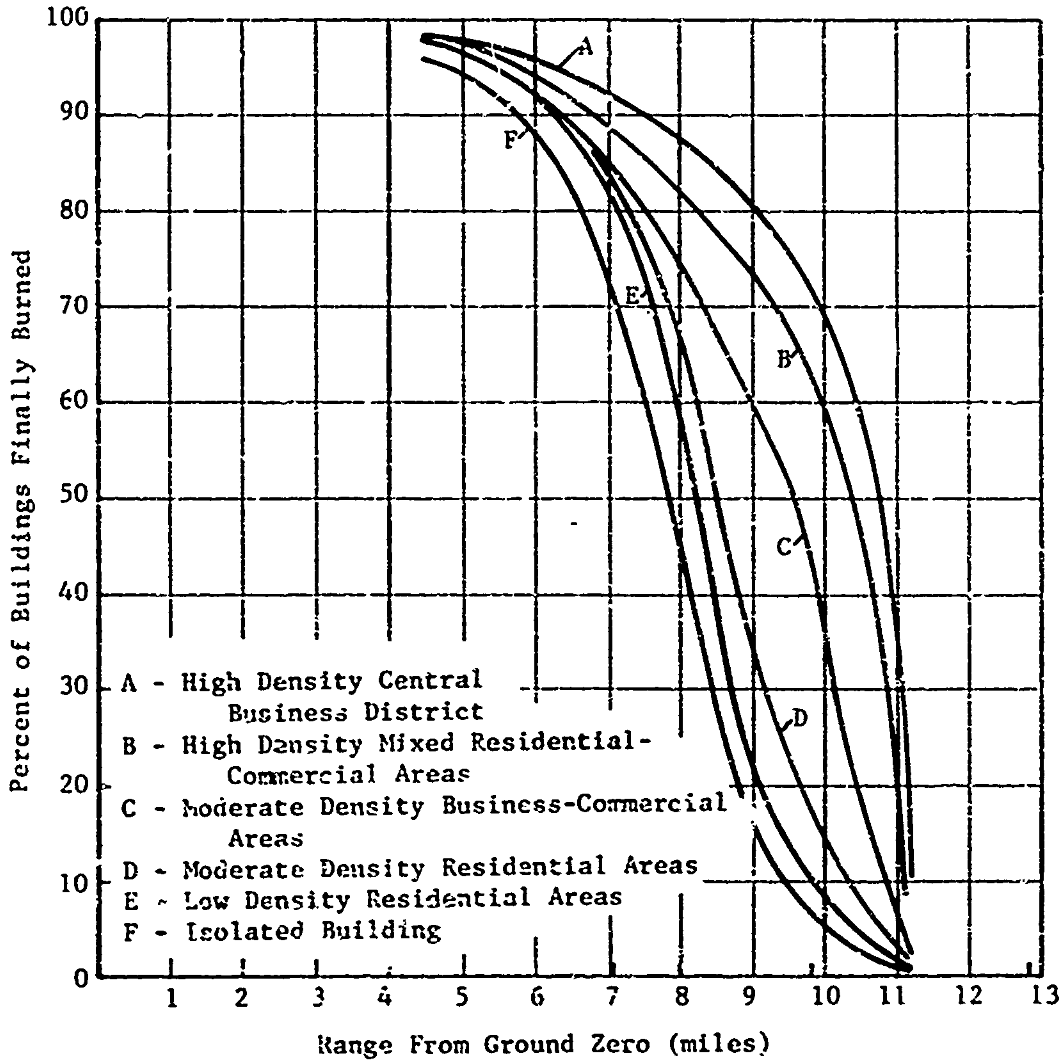
Approximate associations of shelter systems with typical urban environments proceeds quite rapidly using methodologies described above. Sixteen hundred shelters were rated with expenditure of less than 60 man-hours, or at a cost of about 20c per facility. Figure 6 illustrates a statistical application of these data, showing the variation in response of a typical masonry shelter building when exposed to various urban environments. Calculations were based on the average number of buildings within each individual area threatening short range fire spread to a shelter within the area. Spread exposure data was derived from Table 6. Basic fire risk to the building threatening shelter was based on average values for the individual areas. The large variation in risk to an

Figure 6

VARIATION IN FIRE RISK AS A FUNCTION OF AREA USE-OCCUPANCY CLASSES

FIXED BUILDING TYPE - 1 or 2 STORY MASONRY BUILDINGS - COMBUSTIBLE INTERIORS

5 MEGATON AIR BURST



individual building of a specified type as a function of the type of area to which it is exposed is immediately obvious. Calculations included variations in fuel loading (content) of the shelter structure in accordance with average expectancy by area use. That part of the calculation involving ignition by thermal pulse applied average shielding factors appropriate to the shelter type and area.

Figure 7 illustrates the sensitivity of applying average spread risk to a specified shelter type when the overall fire risk in the environmental area is known. For example the dashed curve labeled average (N = 1.7) on Figure 7 is the same curve as that labeled "D" in Figure 6. The remainder of the curves in Figure 7 represent the distribution of fire risk among identical buildings in a fixed area type in consideration of the probability that the building will be subject to fire spread from 0, 1, 2, 3, or 4 surrounding buildings rather than the average exposure of 1.7, as taken from the Providence sample. This sample indicates that while statistical applications may be quite adequate for broader scale planning, appreciable error in evaluating specific shelters must be expected about 20% of the time.

Figure 7

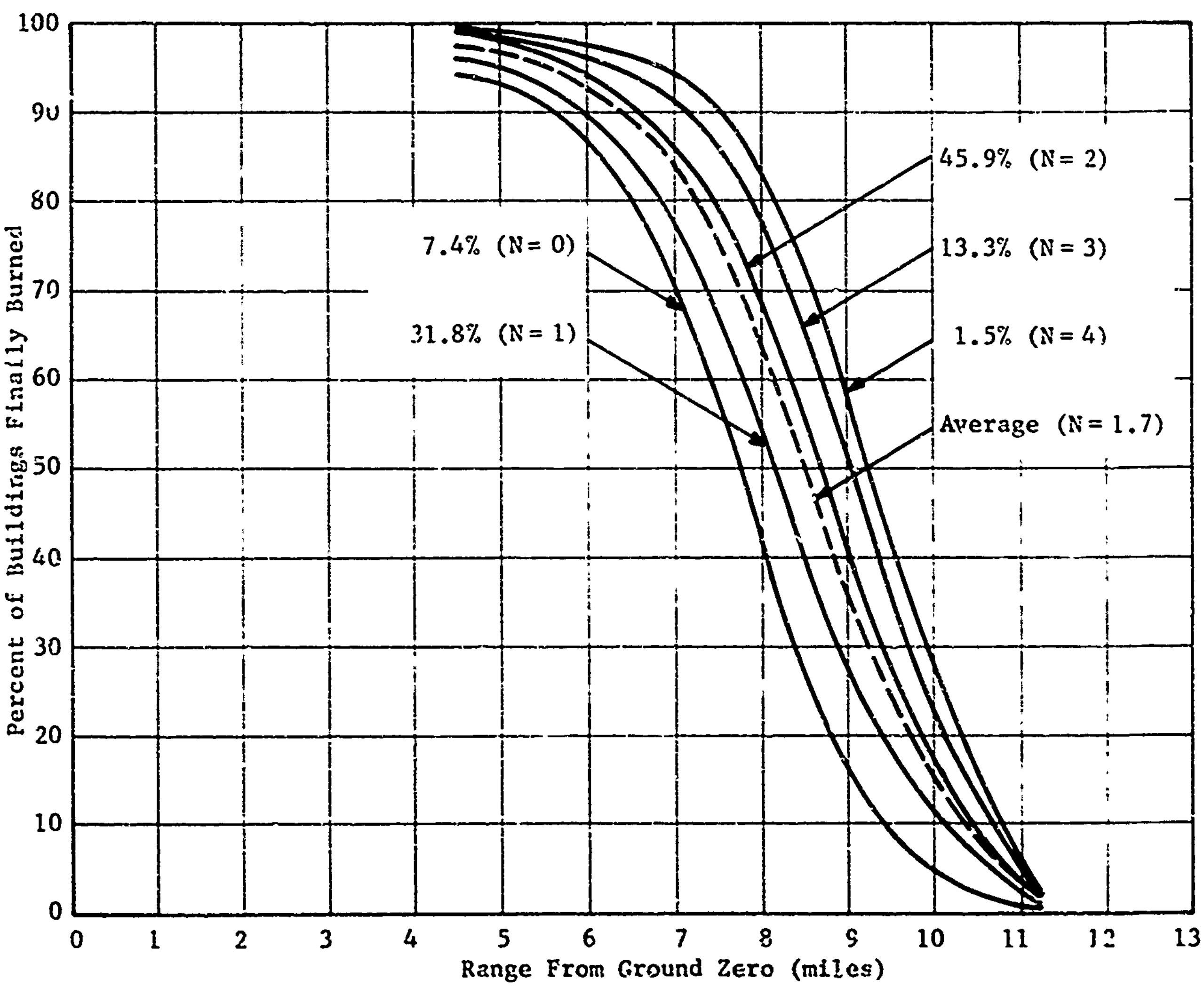
VARIATION IN FIRE RISK AS A FUNCTION OF EXPOSURE TO NEIGHBORING BUILDINGS

FIXED BUILDING TYPE -- 1 or 2 STORY MASONRY

FIXED AREA TYPE -- MODERATE DENSITY RESIDENTIAL

Probability of occurrence based on Providence statistics for number of spread threats for shelter buildings in a moderate density residential area (N = number of buildings threatening spread to shelter: Table 7)

Five Megaton Air Burst



V. CONCLUSIONS

A. Three methods of producing shelter blast and fire vulnerability data systems have been developed and compared as to accuracy and relative cost.

1. Sanborn Fire maps will yield greatest accuracy for analysis of fire vulnerability of specific shelter structures and although not designed for such usage will generally provide creditable data pertaining to analysis of blast vulnerability. The maps contain such a bulk of usable data that it's tabulation and interpretation would be expensive, approximately $6.00 per facility on the average for direct expenses of which not more than 20% is estimated for map rental. This estimate assumes that subsequent interpretation of tabulated data, especially regarding fire spread calculations and shadowing from surrounding buildings, may be most economically computerized. The latter costs have not been included in the estimate. Major shortcoming of utilizing fire maps include:

   a. Lack of quantitative data regarding number and size of window openings, necessitating further reference to NFSS files for this detail.

   b. Lack of refined construction detail relative to blast vulnerability analyses. This factor is most serious in regards to analysis of blast vulnerability of fire resistant floors directly above basement shelters.

   c. Lack of uniform map coverage in smaller or suburbanizing communities.

2. Aerial photographs, used in conjunction with reprocessed NFSS data files will yield blast and fire vulnerability data which although inferior to that obtainable from fire maps may be collected at much lesser cost (approximately 80¢) excluding cost of developing programs to recycle NFSS data. Major deficiencies in utilizing photos and NFSS data include:

a. Reduction in accuracy of fire vulnerability data. Samples indicate that disregarding details of fireproofing the basic combustibility of a shelter structure could, by reanalyzing NFSS data, be determined to about 90% of the accuracy expected from fire maps. Some further reduction of fire spread risk accuracy through use of aerial photos rather than fire maps may be expected. The significance of the latter may be small relative to the current state of the art.

b. Reduction in accuracy of blast vulnerability data. About 15% of the data would contain significant errors as compared to results obtained by use of fire maps.

3. Geological Survey maps may be used in conjunction with statistical procedures to produce data at the least cost, approximately 20c per shelter facility on the average, excluding cost or recycling existing NFSS data. Although the methodology is the least accurate, it will still produce data of substantially better quality than that now being applied in nationwide vulnerability assessments.

B. It is probable that the best compromise between accuracy and economy may be achieved through selective use of several of the methodologies discussed. Reprocessing NFSS files to identify and remove internal inconsistencies appears to be a logical starting point as this procedure promises to produce a substantial improvement in existing data at modest costs. Subsequently it may be desired to extend tentative fire vulnerability ratings by one of the more economical methods. Finally, more detailed analysis might be made for those areas where predicted levels of blast and fire effects may be determined through application of comprehensive series of nationwide assessments against the tentative data base.

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APPENDIX A

ROUTINE TO ANALYZE PHASE I DATA AND PRODUCE IMPROVED SHELTER FIRE AND BLAST INFORMATION

INPUT DATA

The following data, contained in tapes described in Description of Computer Program for National Fallout Shelter Survey, Reference 9, are essential to the analysis described herein.

Standard location code

Facility number

Part number

Stories

Year built

Physical Vulnerability Code

Use Code

Mass thickness, basement floor (in case of sub-basement shelter)

Mass thickness, first floor

Mass thickness, upper floor(s)

Mass thickness, roof

GENERAL PROGRAM DESCRIPTION

The program initially utilizes mass thickness codes to determine the basic nature of the building construction. The interim determinations are contained in the Construction Analysis (CA) codes listed below:

CA CODES

1	Basement only, very light roof
2	Basement only, moderate roof
3	Basement only, heavy roof
4	Wood floor(s) and roof
5	Wood floor(s) and non-combustible roof
6	Wood 1st floor, concrete upper floors, wood roof
7	Wood 1st floor, concrete upper floors, non-combustible roof

CA CODES (continued

8 Concrete 1st floor, wood upper floors and roof
9 Concrete 1st floor, wood upper floors, non-combustible roof
10 Concrete floor(s), wood roof
11 Concrete floor(s), concrete roof

Construction Analysis (CA) codes are next compared to Physical Vulnerability Codes for consistency and certain Analysis Decisions (AD) output determined in accordance with codes listed following:

AD CODES

1 Frame or masonry PV code consistent with mass thickness data and assumption of combustibility.

2 Questionable combinations of PV and mass thickness data indicating unusual or improbable construction such as

  a Buildings >8 stories coded as masonry load bearing walls with confirming mass thickness data.
  b Buildings coded as wood framed with mass thickness indication of concrete floors

3 Inconsistent data: number of stories reported not consistent with floors for which mass thickness was reported.

4 Indicates building initially coded masonry load bearing wall has been nominated for reassignment to non-combustible rating by year of construction groupings, before 1900, 1900-1910, 1910-1930, later than 1930.

5 Indicates building initially coded steel framed has been nominated for reassignment to PV code indicative of masonry building with combustible floors and roof.

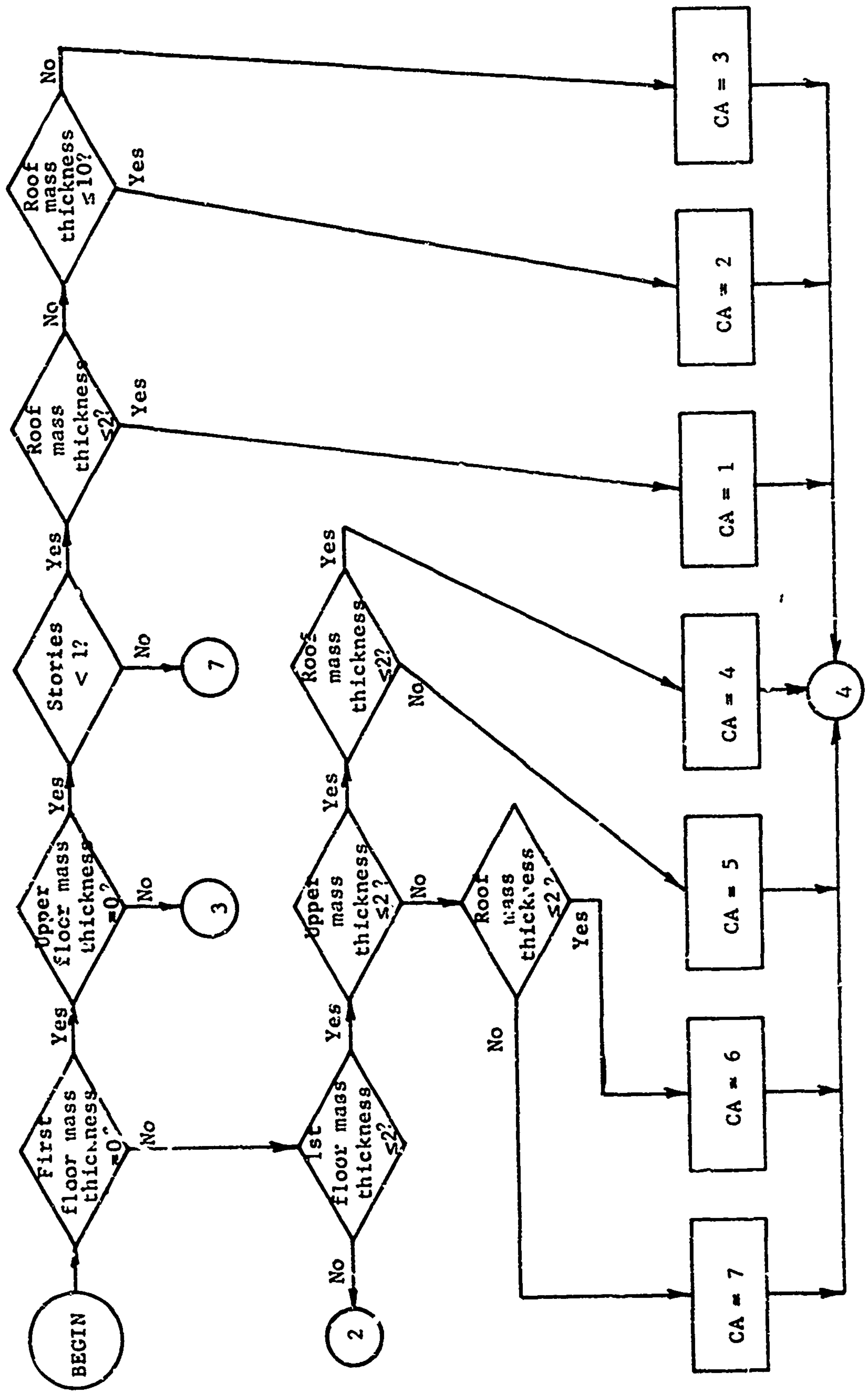
6 Indicates building initially coded steel framed has been confirmed non-combustible and rated by year of construction groups.

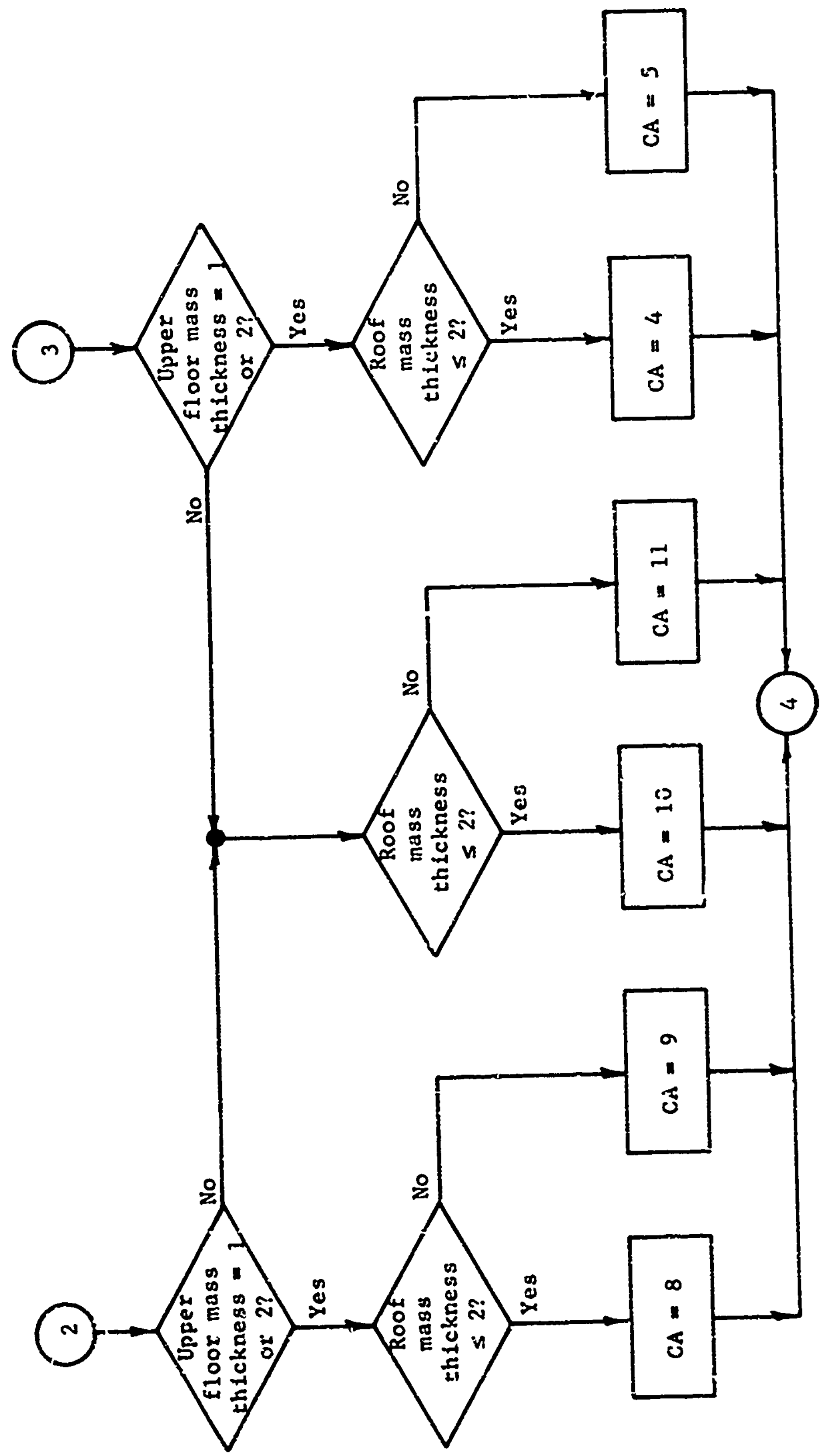
7 Indicates that building initially coded reinforced concrete framed has been nominated for reassignment to PV code indicative of masonry building with combustible floors and roof.

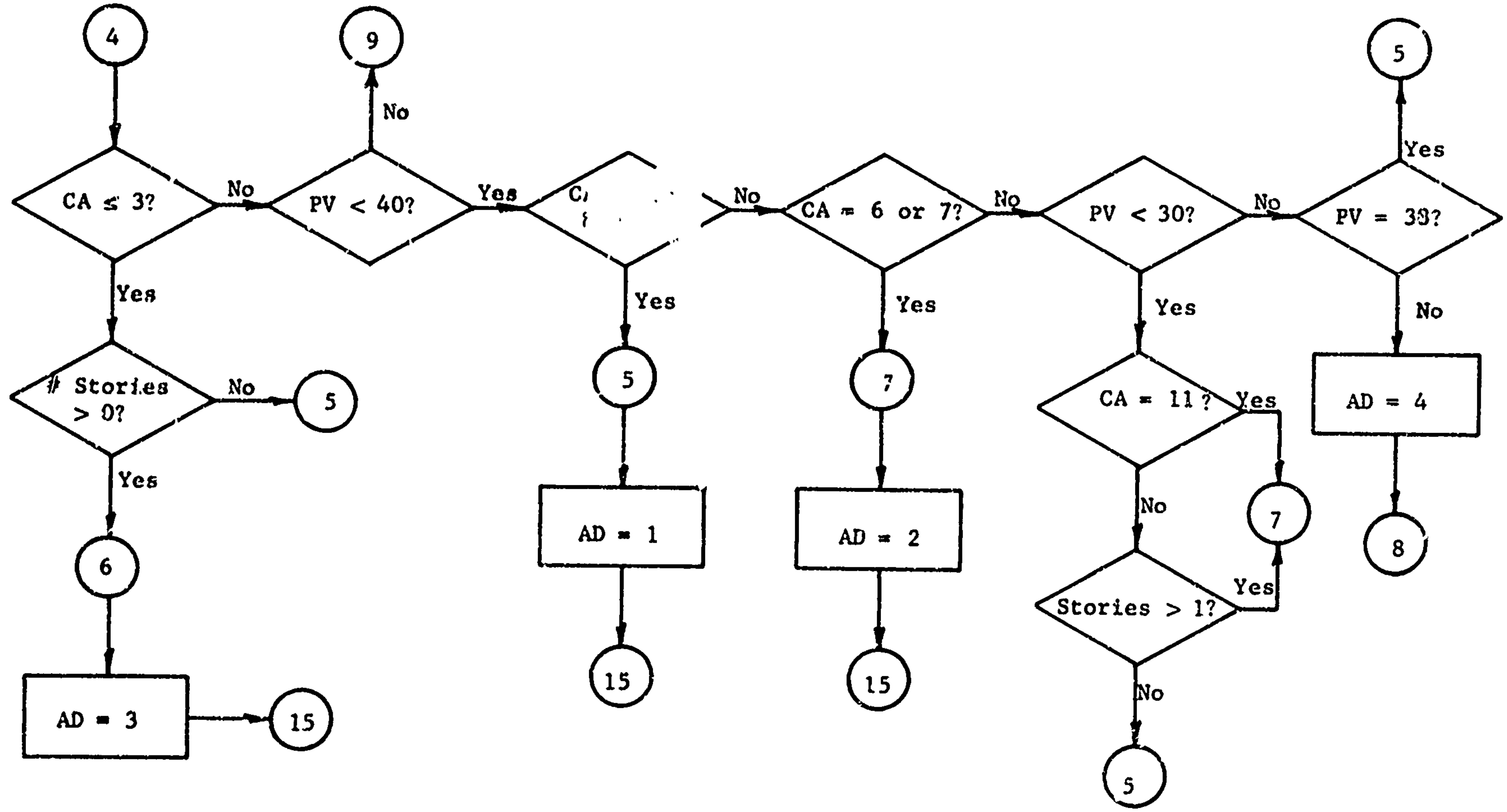
AD CODES (continued)

8 Indicates that building initially coded reinforced concrete framed has been confirmed non-combustible and rated by year of construction group.

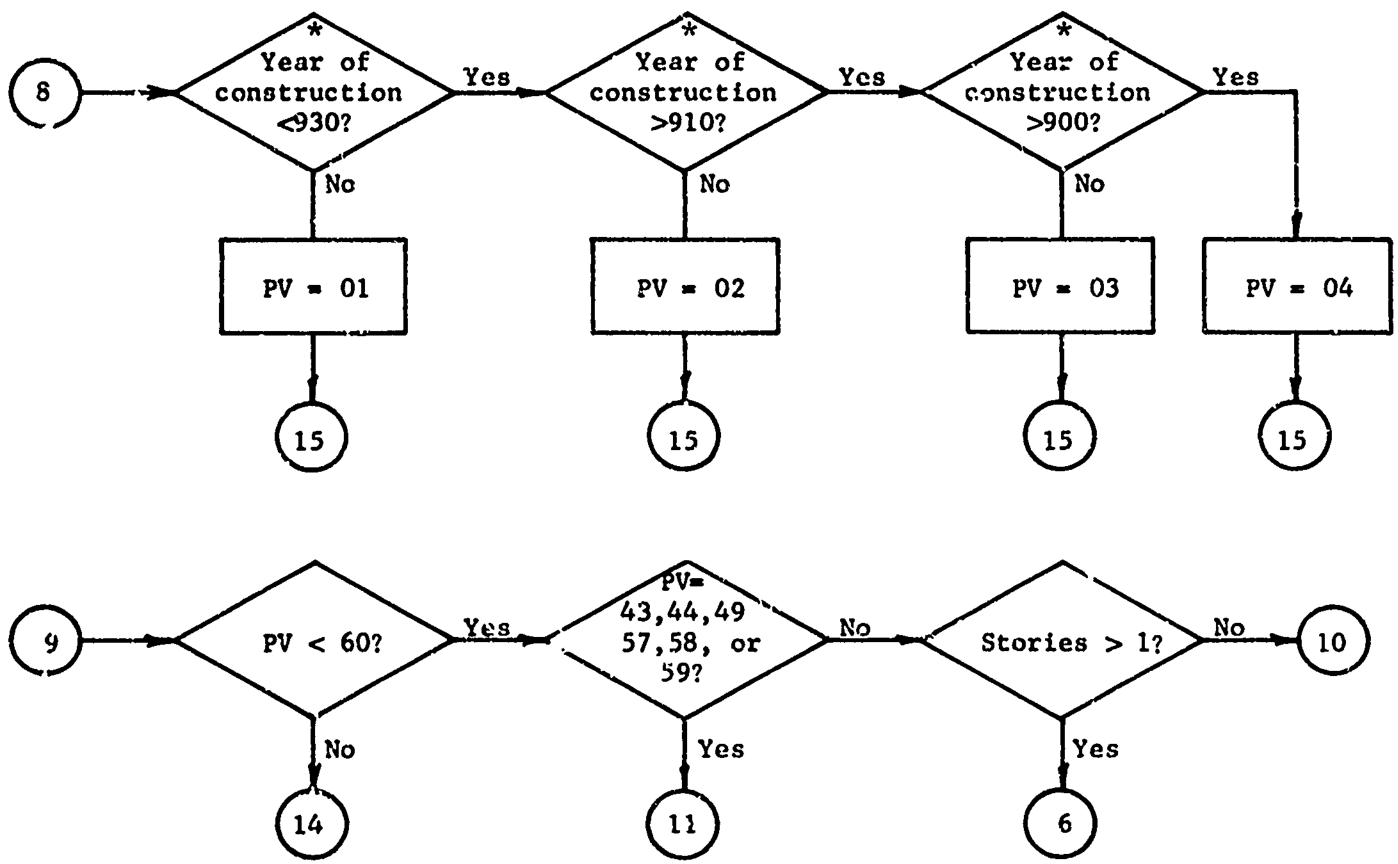
9 Indicates that building initially coded ··osite steel and reinforced concrete framed has been nominated for reassignment to PV code indicative of masonry building with combustible floors and roof.


BEGIN
First floor mass thickness =0?
Yes
No
Upper floor mass thickness =0?
Stories < 1?
Roof mass thickness ≤2?
Roof mass thickness ≤10?
1st floor mass thickness ≤2?
Upper mass thickness ≤2?
Roof mass thickness ≤2?
CA = 1
CA = 2
CA = 3
CA = 4
CA = 5
CA = 6
CA = 7
2
3
4
7

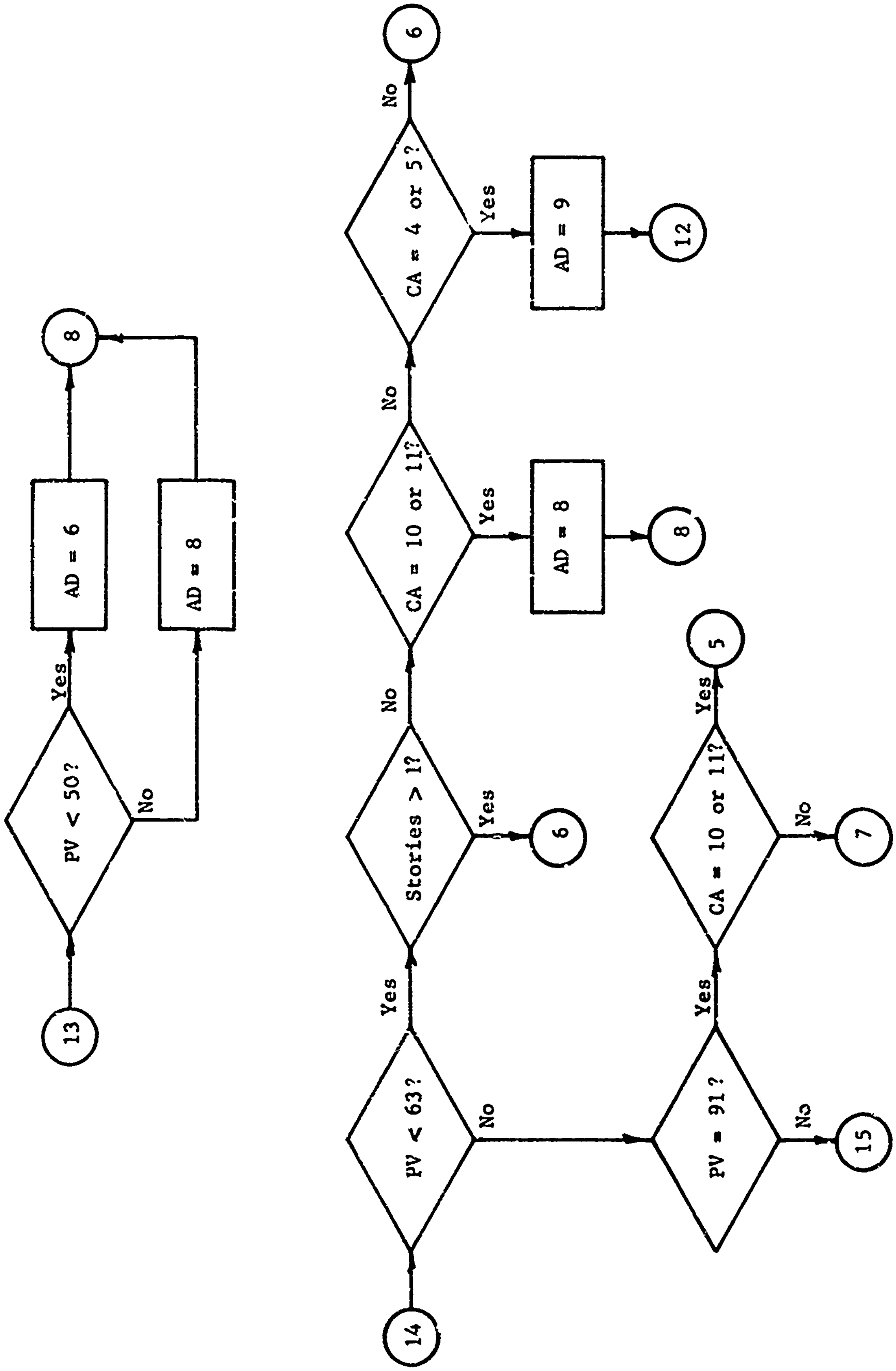

3
Upper floor mass thickness = 1 or 2?
Yes
No
Roof mass thickness ≤ 2?
Yes
No
CA = 4
CA = 5
2
Upper floor mass thickness = 1 or 2?
Yes
No
Roof mass thickness ≤ 2?
Yes
No
CA = 8
CA = 9
Roof mass thickness ≤ 2?
Yes
No
CA = 10
CA = 11
4

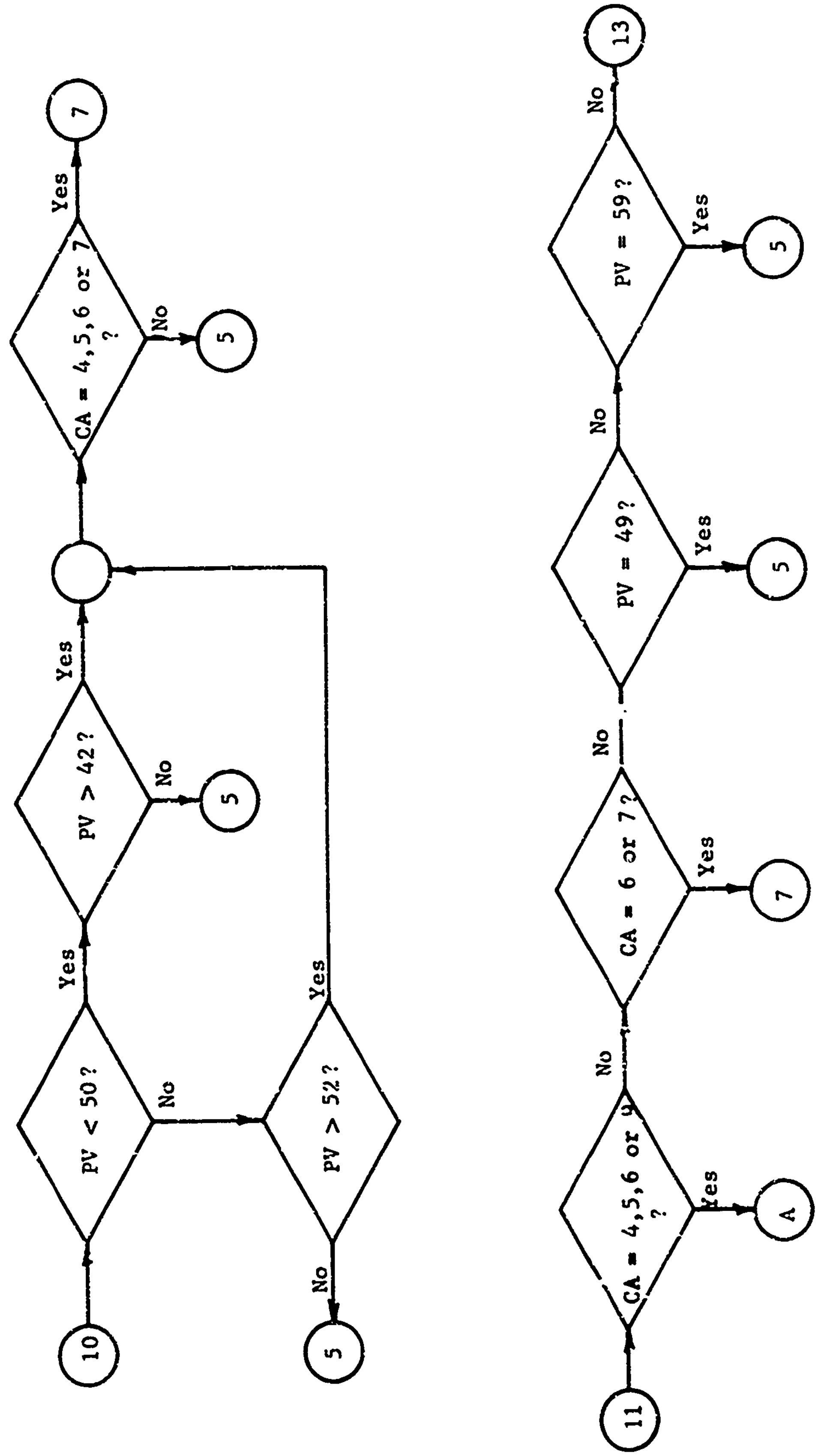


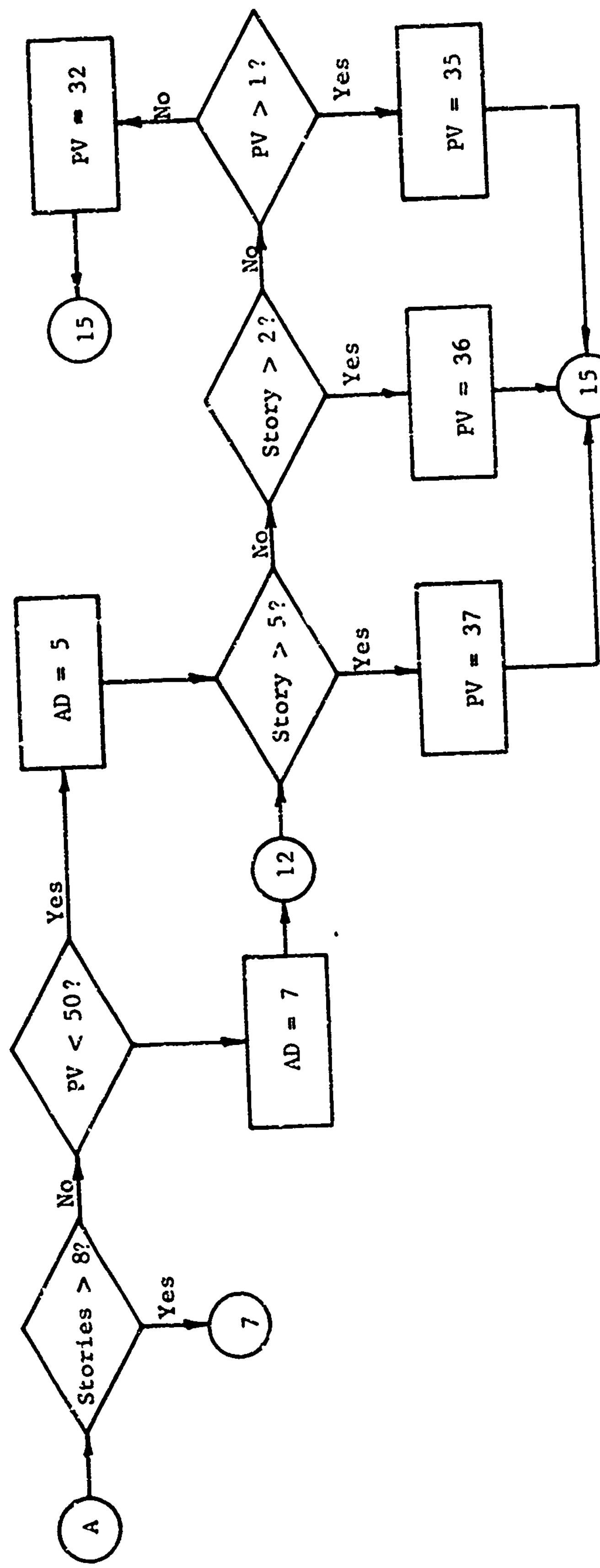
4
CA ≤ 3?
No
Yes
PV < 40?
9
No
Yes
Stories > 0?
No
5
Yes
6
AD = 3
15
C/
Yes
5
AD = 1
15
No
CA = 6 or 7?
Yes
7
AD = 2
15
No
PV < 30?
Yes
CA = 11 ?
Yes
7
No
Stories > 1?
Yes
No
5
No
PV = 39?
Yes
5
No
AD = 4
8

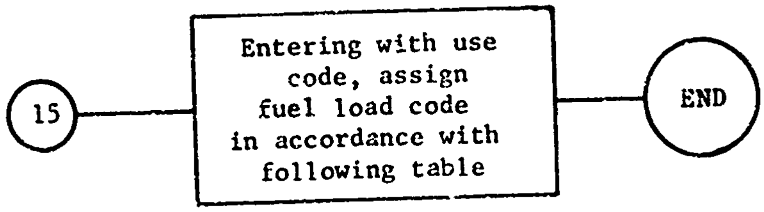


* NOTE: Screen year of construction of last three digits only.


13
PV < 50?
Yes
No
AD = 6
AD = 8
8
14
PV < 63?
Yes
No
Stories > 1?
Yes
No
6
CA = 10 or 11?
Yes
No
AD = 8
8
CA = 4 or 5?
Yes
No
AD = 9
12
6
PV = 91?
Yes
No
15
CA = 10 or 11?
Yes
No
5
7


10
PV < 50?
Yes
No
PV > 42?
Yes
No
5
PV > 52?
Yes
No
5
CA = 4,5,6 or 7 ?
Yes
No
7
5
11
CA = 4,5,6 or 9 ?
Yes
No
A
CA = 6 or 7?
Yes
No
7
PV = 49?
Yes
No
5
PV = 59?
Yes
No
5
13


A
Stories > 8?
Yes
7
No
PV < 50?
Yes
AD = 5
AD = 7
12
Story > 5?
Yes
PV = 37
No
Story > 2?
Yes
PV = 36
No
PV > 1?
Yes
PV = 35
No
PV = 32
15
15



USE CODE	FUEL LOAD CODE
11-29	1
31-39	2
41-42	1
43	0
44-51	1
52-53	2
54	3
55-59	1
61-79	2
81-83	
84-85	3
86-99	2

APPENDIX B

FORMAT AND INSTRUCTIONS FOR DATA COLLECTION FROM SANBORN FIRE MAPS

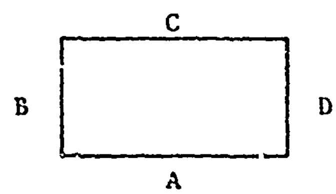
COLUMN NUMBER	DESCRIPTION AND INSTRUCTIONS
1-8	Standard Location Area Code
9-13	Facility Number
14-15	Exterior Dimension, Side A, Instruction No. 1 and 2
16-17	Exterior Dimension, Side B, Instruction No. 1 and 2
18-21	Year of Construction, 0000 if unknown
22	Building Content -- Instruction No. 3
23	Basic Construction Type -- Instruction No. 4
24	1st Floor -- Instruction No. 5
25	Upper Floors -- Instruction No. 5
26	Roof -- Instruction No. 5
27	Walls -- Instruction No. 6
28-29	Wall thickness, 1st floor -- Instruction No. 7
30-31	Wall thickness 2nd floor -- Instruction No. 7
32-33	Story where significant change occurs -- Instruction No. 8
34-35	Wall thickness at and above story of change
36-37	Distance to nearest building, Side A -- Instruction No. 9
38-39	Distance to nearest building, Side B -- Instruction No. 9
40-41	Distance to nearest building, Side C -- Instruction No. 9
42-43	Distance to nearest building, Side D -- Instruction No. 9
44-45	Base Dimension of building facing Side A -- Instruction No. 10
46-47	Base Dimension of building facing Side B -- Instruction No. 10

COLUMN NUMBER	DESCRIPTION AND INSTRUCTIONS
48-49	Base Dimension of building facing Side C -- Instruction No. 10
50-51	Base Dimension of building facing Side D -- Instruction No. 10
52-53	Potential Flame Height of building facing Side A -- Instruction No. 11
54-55	Potential Flame Height of building facing Side B -- Instruction No. 11
56-57	Potential Flame Height of building facing Side C -- Instruction No. 11
58-59	Potential Flame Height of building facing Side D -- Instruction No. 11
65-66	Description of area most typical of shelter surroundings -- Instruction No. 12
67-68	Maximum number of stories in shelter
69-70	Range of 1st building along radial no. 1, 10's of feet -- Instruction No. 13
71-72	Height of 1st building along radial no. 1, stories -- Instruction No. 13
73-74	Range to 2nd building along radial no. 1, 10's of feet -- Instruction No. 13
75-76	Height of 2nd building along radial no. 1, stories -- Instruction No. 13
1	Enter 2 (card number)
2-5	SLA number
6-10	Facility number
11-18	Repeat of data 67-76 measured along radial no. 2 -- Instruction No. 13
19-26	Repeat of data 67-76 measured along radial no. 3 -- Instruction No. 13
27-34	Repeat of data 67-76 measured along radial no. 4 -- Instruction No. 13
35-42	Repeat of data 67-76 measured along radial no. 5 -- Instruction No. 13
43-50	Repeat of data 67-76 measured along radial no. 6 -- Instruction No. 13
51-58	Repeat of data 67-76 measured along radial no. 7 -- Instruction No. 13
59-66	Repeat of data 67-76 measured along radial no. 8 -- Instruction No. 13
67-74	Repeat of data 67-76 measured along radial no. 9 -- Instruction No. 13

COLUMN NUMBER	DESCRIPTION AND INSTRUCTIONS
1	Enter 3 (card number)
2-5	SLA number
6-10	Facility number
19-26	Range and height data along radial no. 10
27-34	Range and height data along radial no. 11
35-42	Range and height data along radial no. 12
43-50	Range and height data along radial no. 13
51-58	Range and height data along radial no. 14
59-66	Range and height data along radial no. 15
66-74	Range and height data along radial no. 16

SANBORN MAP DATA COLLECTION INSTRUCTIONS

1. Side A is always the "address" side of the building. For example if facility address is 160 Westminster Avenue, Side A is the side fronting on Westminster Avenue. Sides B, C, and D are assigned clockwise from Side A.



2. For purposes of measuring exterior dimensions of shelter facility, Side A will be the average of front and back wall lengths if building is not symetrical. Side B will be the average total wall lengths along sides B and D.

3. Use following code for building fuel content ratings

Negligible	0
Light	1
Moderate	2
Heavy	3

4. Code as identified by following table (basic construction type)

Load bearing walls	1
Steel Frame	2
Reinforced Concrete Frame	3
Load bearing walls in combination with interior steel framing or support	4

5. Code identified by following table (roof type)

Not applicable (upper floor in one story building for example)	0
Combustible deck and supports	1
Combustible deck, non combustible supports	2
Non combustible	3
Rated "fireproof"	4

6. Code identified by following table (wall type)

Not applicable (walls in completely underground facility, for example)	0
Wooden siding and framing	1
Non-combustible siding on wooden framing	2
Masonry curtain	3
Concrete curtain	4
Masonry panel	5
Concrete panel	6
Metal curtain or panel	7
Masonry load bearing	8
Concrete load bearing	9

7. Enter in whole inches as indicated on maps, except for cinder block, concrete block, structural tile, where thickness will be reduced by one-half. For example a wall with 8 inches of cinderblock and 4 inches of brick veneer will be cod[illegible]ches. (wall thickness)

8. Story at which thickness is [illegible] inches less than that indicated for second floor.

9. Measure distance to center of building facing side A, B, C, or D. If several buildings face one side of shelter buildings, chose the one offering largest potential flame area. Enter data in 10's of feet.

10. Measure dimension of side parallel to side A, B, C, D as appropriate. Enter data in 10's of feet.

11. Use Gage-Babcock Tables, enter height in feet

12. Use following table for area descriptions

0 Shelter structure relatively isolated, being separated from other structures by more than 150 feet on all sides.

1 High rise apartments, garden apartments redevelopment areas, very low density institutional areas (block density less than 10%).

2 Low density, primarily residential areas with block densities less than 20%. Visual indications include: back yard separation large compared to size of buildings; side by side separations generally equal to building depth, or closer separations interrupted by several potential fire breaks of 70 feet or more within block.

3. Moderate density, primarily residential areas with block densities 20% to 30%. Visual indications include: backyard separations large compared to size of buildings, side by side separations about ½ dimension of building depths, no appreciable interuptions in side by side spacing.

4. Business areas with block densities of 55-70%. Areas are readily identificable from aerial photographs, area not covered by buildings generally being completely vacant lots or parking areas.

5. Business areas with block densities of 70 to 100%. As such areas have quite distinctive appearances on aerial photographs it is convenient to outline them and identify block numbers immediately when analyzing Census tracts where such groupings exist. This is usually an efficient procedure since large numbers of shelter facilities are generally contained within such groupings.

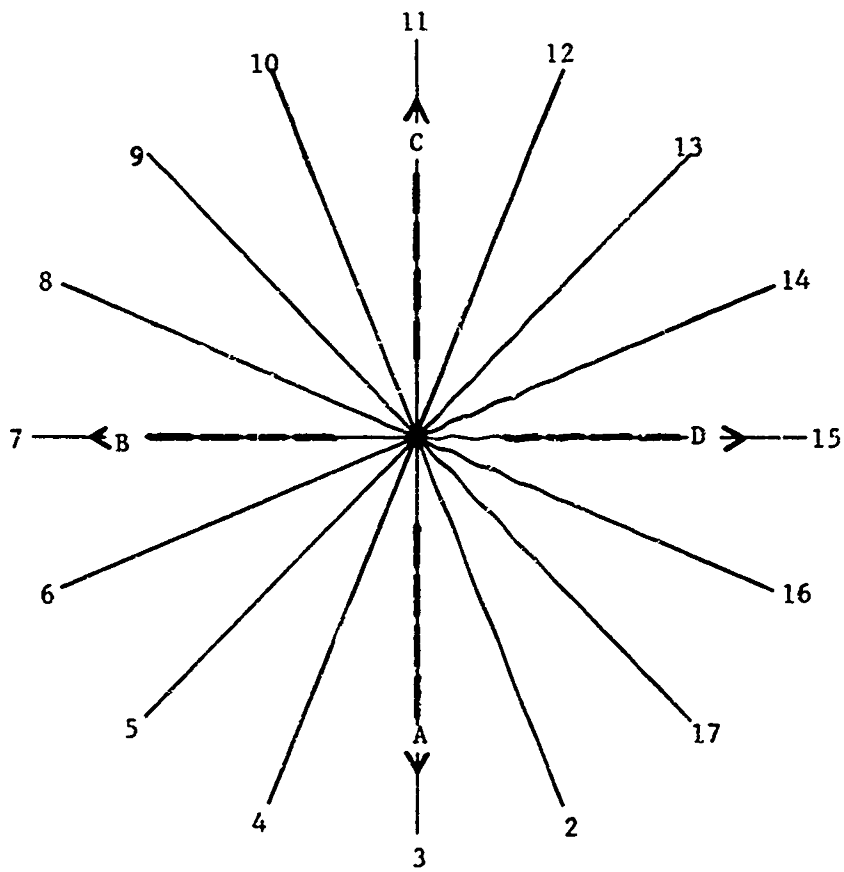
6. High density residential or mixed residential commercial areas with block densities 30 to 55%. Visual indications include: close side by side spacings of ½ building depth or less, narrow blocks with low back to back spacing or two or more building clusters between rows.

7. Industrial areas with block densities less than 55%

8. Industrial areas with block densities 55-70%.

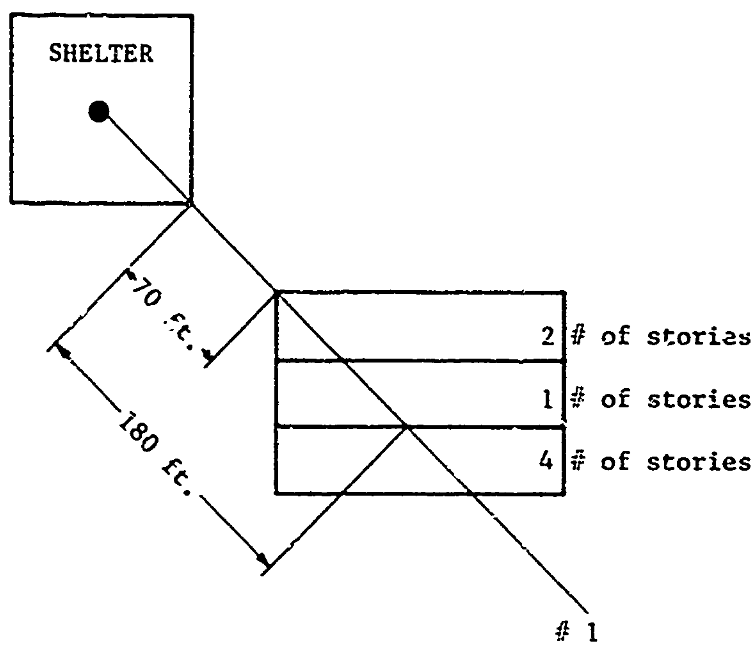
9. Industrial areas with block densities greater than 70%.

13. a. Set up template (similar to one illustrated below) so center of template is at center of shelter facility and dashed arrows point toward sides A, B, C, and D.



13. b. Measure distance along radial 1 between shelter face and nearest building intercepted by radial. Enter this distance in nearest 10's of feet on work sheet. Enter immediately following the height in stories of building intercepted. Continue along radial and enter identical information for the next building along radial whose height is greater than first building intercepted. If there is no taller building along radial enter 0000 columns assigned for next building. Repeat for all 16 radials. Example calculation is given following:

Column	
69-70	07
71-72	02
73-74	18
75-76	04



APPENDIX C

USE OF AERIAL PHOTOGRAPHS TO ESTABLISH FIRE SPREAD RISK PARAMETERS

Aerial photographs of scale 1:20,000 (1 inch = 660') are most suitable for analytical use in consideration of both detail and economy. Locating buildings with known addresses uponphotos is facilitated by using the following materials:

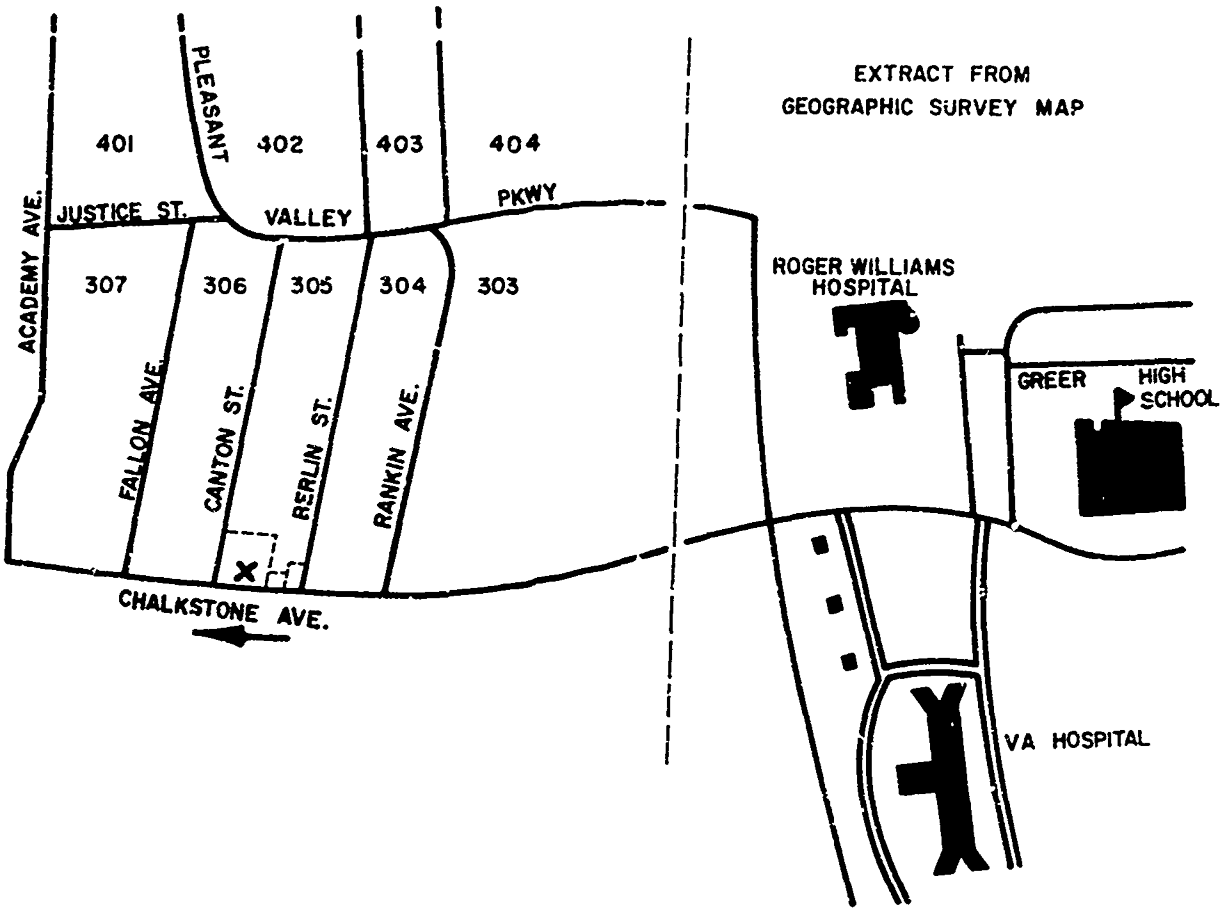
1. Geological Survey Topographic Maps, 7½ minute series, scale 1:24,000
2. U.S. Census Bureau Address Coding Guides
3. U.S. Census Bureau Metropolitan Maps

The following procedures should be used for locating shelters:

1. Transcribe Census tract boundaries from U.S. Census Bureau Metropolitan Maps to Geological Survey Map
2. Scan Geological Survey Map for prominent "land mark" buildings, which are frequently schools, hospitals, churches, public buildings or other structures which generally serve as shelter facilities. These buildings are accurately located and named on the map. The map detail itself is to an appreciable extent a synthesis of aerial photography, designating by variation in tint heavily built up, wooded, or open areas, major roads, etc. These features aid in rapid orientation of map features with photographs. This preliminary screening is expecially important as many shelters located in prominent facilities are identified in shelter files by name rather than complete street address. It will be helpful at this stage to transfer tract outline in blue pencil to the photograph itself, utilizing the distinctive topographic features apparent on both map and photo graph.
3. Shelters not identified during preliminary screening may be located through use of Census Bureau Address Coding Guides. The coding guide provides the Census tract number and the range of addresses contained within an identified block number within the tract.

For example, the address coding guide for Providence, R.I. identifies the shelter facility at 1039 Chalkstone Avenue as being in:

Census tract 23
Block 305, address range 1025 to 1047

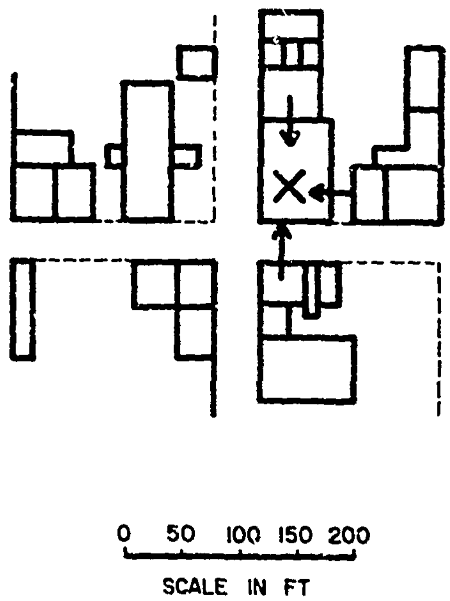


Block No. 305 is rapidly identified in tract 23. The shelter facility address is about 2/3 the way along the block as indicated by "X." The sequence of street addresses is quickly determined by checking block number of Chalkstone address just beyond the range of 305. When "working" a new street, indicating direction in which addresses increase by an arrow on Geological Survey maps will be helpful in establishing the general run of the street addressing scheme in a particular area. Relocate position of shelter on Geological map, whose street patterns are also highly detailed although generally named for only major thoroughfares. The l--ter map shows a distinctive pattern of open and builtup areas and "land mark" buildings several blocks west of the shelter. The area is similarly distinctive on the aerial photograph and leads to rapid location of the shelter block. In this case the photo showed only three buildings along the block face. Two were very small structures and the third was a very large building occupying more than half of the eastern portion of the block. As the shelter file identified the facility as a theater, positive identification was easy. The facility use, such as school, church, theater, warehouse, etc. frequently infers building size or configurations that facilitates identifications once the general location within the block face is established. In those cases when the buildings along the block face are essentially the same, it is generally not important whether precisely the right one is selected or not, as long as it is not at either end of the block in which case identification by address range may be made. In some cases all facilities within a building complex (universities, hospitals, etc.) may be given a common address, in which case averaged characteristics of the complex must be assigned. In some instances cross-referencing building height, number of shelter spaces, and use given in shelter file may lead to more specific identifications of main buildings, gymnasium, field houses, auditoriums, etc. Shadow lengths are useful in identifying taller structures, or central heat, power, or boiler houses -- by smoke stack shadow. It is expected that the analyst's efficiency and accuracy in making such identification will be enhanced by some training and experience in aerial photo interpretation techniques.

When a shelter is located, the number of sides from which it is threatened by fire spread are identified, using the following table. The building dimensions listed are those of the sides of buildings facing shelter. Spread distances tabulated are approximate and represent about as fine a distinction as may be made from the photographs which will be used. Scale of each photograph, 1 in = 660 feet, should be checked as some variations will be encountered. Geological Survey Topographic Maps may be used for this purpose. An engineering scale, 100 divisions/inch and a good set of dividers are necessary for best results. Taller buildings near the edge of the photograph will be appreciably oblique, necessitating some especial care in measurements. However overlap of photos are sufficient that most areas may be located near photo centers where the view is more essentially vertical. The characteristics of the photographs mentioned here, as well as shadow lengths, are frequently useful in establishing approximate building heights.

Building Dimension	Spread Range
Dwellings and small commercial	
20 ft.	30 ft.
40 ft.	45 ft.
60 ft.	55 ft.
Large Commercial structures, under 6 stories	
100 ft.	60 ft.
150 ft.	70 ft.
200 ft. and over	75 ft.
Buildings over 6 stories, (generally fire resistant construction)	
50 ft.	35 ft.
100 ft.	45 ft.
150 ft.	55 ft.

A sketch of the shelter facility of 1039 Chalkstone, taken from an aerial photograph, shows that the structure, located in a moderate density commercial area, is threatened by fire spread from three sides.



Verbal descriptions of areas presenting varying fire risks are given in table 12 on page 63.

APPENDIX D

LIST OF FIRE SPREAD RISK PARAMETERS FOR PROVIDENCE, R.I.

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0039	417	02011	58	61	4	2
	413	02014	32	54	4	3
	413	02019	41	89	4	3
	503	02025	32	53	6	3
	511	02026	35	53	6	2
	412	02027	41	53	6	4
	518	02029	36	22	6	2
	101	02038	21	42	4	2
	410	02042	36	61	4	3
	516	02045	35	26	6	2
	405	02058	36	61	6	3
	401	02062	32	59	6	3
	411	02073	32	61	4	4
	107	02079	41	43	4	3
	303	02082	38	31	6	2
	503	02085	32	61	4	2
	623	02087	36	11	6	3
	519	02091	35	53	6	3
	101	02093	58	54	4	0
	624	02095	43	26	0	0
	107	02105	32	51	4	1
	502	02106	41	61	6	0
1724 0040	711	02155	58	61	4	2
	725	02156	34	29	0	0
	613	02157	32	53	4	1
	611	02158	57	51	4	2
	204	02161	57	45	4	1
	301	02162	71	54	4	0
	213	02163	43	55	4	2
	106	02164	43	19	6	0
	206	02167	43	19	6	1
	111	02168	32	55	4	2
	608	02171	41	47	6	1
	401	02172	36	21	6	0
	103	02174	35	54	6	3
	608	02179	71	99	4	0
	212	02185	36	11	6	2
	301	02186	43	79	4	3
	208	02189	36	31	6	2
	608	02190	31	72	4	0

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0041	503	02264	35	26	6	1
	206	02276	32	31	6	2
	201	02278	36	12	6	4
	106	02279	37	41	6	2
	106	02280	36	41	6	2
	402	02281	32	31	6	1
	504	02282	43	11	6	2
	101	02287	36	11	6	3
	606	02290	36	61	6	3
	606	02291	36	21	6	1
	608	02292	36	21	6	1
	103	02294	36	59	6	2
	503	02295	36	22	6	0
	308	02299	21	11	6	2
	201	02303	36	51	6	1
	303	02304	21	11	6	3
	106	02306	43	41	6	2
1724 0042	301	02344	35	61	6	4
	408	02357	36	32	6	2
	401	02360	32	21	6	4
	305	02361	57	61	6	3
	111	02362	35	21	6	1
	501	02371	35	21	6	1
1724 0043	204	02413	43	54	6	2
	101	02420	36	54	4	2
	101	02421	36	54	4	3
	604	02423	35	43	1	0
	602	02425	36	32	1	0
	608	02427	36	11	1	0
	608	02428	36	11	1	0
	608	02429	36	11	1	0
	608	02430	36	11	1	1
	608	02431	36	11	1	0
	608	02432	36	11	1	0
	608	02434	36	11	1	0
	608	02435	36	11	1	0
	608	02436	36	11	1	1
	608	02437	36	11	1	0

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0043	608	02438	36	11	1	0
	608	02439	36	11	1	0
	608	02440	36	11	1	0
	608	02441	36	11	1	1
	608	02442	36	11	1	0
	608	02443	36	11	1	0
	608	02444	36	11	1	0
	608	02445	36	11	1	0
	608	02446	36	11	1	0
	608	02447	36	11	1	0
	608	02448	36	11	1	0
	608	02449	36	11	1	0
	608	02450	36	11	1	1
	608	02451	36	11	1	1
	608	02452			1	1
	608	02453			1	2
	608	02454			1	3
	608	02458	41	61	6	0
1724 0044	204	02487	36	54	6	1
	412	02492	36	61	4	3
	408	02493	32	54	6	3
	304	02495	57	72	6	2
	413	02502	35	54	4	3
1724 0045	204	02559	37	61	4	2
	111	02560	58	61	4	2
	204	02569	58	61	4	4
	211	02572	36	11	4	3
	213	02584	37	61	4	2
	229	02589	43	72	4	2
	224	02593	36	61	4	3
	105	02597	36	61	4	2
	806	02605	36	61	4	3
	805	02607	57	21	6	2
	304	02609	57	41	4	1
	225	02614	43	41	4	1
	220	02617	43	41	4	3
	609	02620	36	41	4	2
	305	02622	43	41	4	3

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0045	305	02626	57	41	4	1
	305	02628	43	41	4	[illegible]
	305	02629	43	41	4	3
	305	02631	36	41	4	2
	305	02632	43	41	4	3
	101	02633	58	43	4	3
	101	02634	58	43	6	2
	212	02635	58	43	4	2
	101	02636	43	43	4	2
	305	02638	36	41	4	2
	305	02639	37	41	4	1
	305	02640	37	41	4	1
	305	02641	57	51	4	1
	305	02642	36	41	4	2
	305	02644	71	41	4	0
	811	02645	36	22	4	2
	216	02646	35	61	4	2
	806	02647	36	11	4	2
	808	02648	32	61	6	2
	404	02649	36	11	6	4
	704	02650	36	11	6	4
	614	02651	36	11	6	2
	811	02653	43	51	4	2
	224	02654	58	61	4	2
	305	02658	57	12	4	1
	305	02659	57	29	4	1
	811	02661	36	23	4	2
	811	02662	36	22	4	2
	811	02663	36	22	4	2
	811	02664	36	22	4	2
	811	02665	36	29	4	2
	811	02666	32	29	4	2
	811	02667	43	29	4	2
	812	02668	31	31	4	1
1724 0046	116	02823	57	51	4	4
	318	02825	57	43	5	4
	318	02828	43	12	5	4
	318	02829	41	71	5	4
	311	02834	35	71	5	3

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0046	259	02837	32	71	5	3
	222	02838	36	55	5	4
	222	02839	35	53	5	4
	220	02842	36	51	5	3
	304	02843	36	79	4	2
	320	02851	36	22	4	2
	320	02855	57	22	4	2
	321	02856	36	23	4	0
	329	02860	36	39	4	3
	305	02862	36	61	5	3
	263	02864	36	51	4	2
	264	02865	36	51	4	2
	264	02866	37	54	4	2
	265	02867	37	61	4	3
	250	02871	36	51	4	1
	250	02872	37	51	4	2
	260	02873	36	61	5	3
	271	02875	36	54	4	2
	229	02878	57	55	5	4
	229	02880	36	55	5	.
	229	02881	36	51	5	4
	229	02882	36	51	5	4
	254	02884	36	51	5	4
	229	02885	36	55	5	4
	253	02886	36	59	5	4
	254	02888	37	51	5	4
	251	02889	43	55	4	2
	234	02890	38	45	4	3
	207	02[illegible]	43	45	5	2
	253	02[illegible]	36	52	5	3
	254	02893	36	52	5	3
	251	02894	43	51	5	3
	234	02895	43	51	5	4
	207	02896	43	51	5	4
	253	02914	57	51	4	3
	253	02919	32	55	5	3
	255	02924	37	51	5	2
	227	02925	36	51	5	2
	227	02930	36	51	5	4
	112	02931	57	51	5	3

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0046	312	02936	37	51	5	4
	312	02937	36	53	5	4
	220	02939	43	51	5	4
	220	02940	36	53	5	4
	219	02941	36	53	5	4
	128	02943	36	11	5	4
	128	02945	36	51	5	4
	255	02947	36	86	5	3
	254	02948	36	53	5	4
	229	02951	43	51	5	3
	231	02952	36	51	4	1
	237	02953	37	51	4	2
	230	02954	36	51	4	3
	208	02957	36	51	5	3
	208	02959	36	59	5	4
	208	02961	36	51	5	2
	138	02962	57	11	5	1
	134	02963	57	51	5	4
	217	02964	43	51	5	4
	217	02965	43	51	5	4
	216	02966	43	53	5	4
	225	02967	43	59	4	4
	214	02968	36	45	4	3
	216	02969	43	53	5	4
	215	02970	43	53	5	4
	111	02974	37	51	4	1
	142	02976	37	31	4	2
	224	02978	36	52	5	4
	224	02979	37	53	5	4
	224	02980	36	53	5	4
	223	02981	37	51	5	4
	223	02982	36	53	5	4
	223	02983	37	53	5	4
	226	02985	36	53	5	4
	258	02986	37	11	5	3
	259	02990	36	53	5	3
	259	02991	36	59	5	3
	257	02992	36	53	5	3
	215	02993	43	53	5	4
	215	02994	43	51	5	4

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0046	149	03000	36	51	4	2
	204	03002	36	23	5	0
	203	03003	36	45	5	1
	244	03005	37	51	4	1
	201	03006	36	51	5	1
	308	03013	36	53	5	4
	307	03014	36	55	5	3
	307	03015	36	71	5	3
	219	03018	36	31	4	4
	307	03024	36	61	5	2
	129	03025	43	51	5	3
	309	03026	57	59	5	3
	129	03027	36	11	5	3
	126	03029	37	49	5	3
	209	03030	43	55	5	3
	269	03031	36	51	4	3
	236	03032	38	51	4	2
	209	03033	36	51	5	3
	208	03034	43	51	5	3
	202	03035	36	51	5	2
	148	03036	36	53	4	3
	209	03037	57	51	5	2
	208	03038	43	51	5	2
	123	03040	56	26	5	3
	209	03041	43	55	5	2
	257	03042	58	54	5	3
	321	03043	57	11	4	0
	211	03044	42	51	5	3
	149	03045	36	51	4	4
	203	03046	36	45	5	1
	203	03047	38	45	5	2
	203	03048	22	51	5	3
	319	03050	38	11	4	1
	116	03051	38	11	4	2
	126	03053	43	45	5	3
	243	03054	36	51	4	2
1724 0047	402	03128	36	53	6	4
	402	03130	36	59	6	4
	403	03132	36	53	6	4
	302	03140	36	51	6	3

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0047	302	03141	32	55	6	2
	302	03142	35	72	6	3
	209	03144	36	53	6	4
	209	03145	36	32	6	2
	117	03153	21	11	6	4
	105	03156	36	51	4	4
	105	03157	36	51	4	4
	201	03168	38	11	4	2
	104	03170	35	61	4	4
1724 0048	307	03204	36	61	6	4
	306	03205	41	22	6	3
	206	03209	34	11	6	2
	404	03214	36	21	6	2
	404	03226	31	22	6	2
	404	03227	35	21	6	2
1724 0049	217	03257	35	61	6	4
	105	03267	32	59	4	3
	104	03271	57	86	6	3
	201	03277	36	53	4	3
	201	03279	36	53	4	3
	113	03280	36	11	4	3
	111	03281	36	11	4	2
	309	03282	35	51	6	2
	208	03285	35	53	6	3
	502	03287	34	11	6	4
	103	03289	36	51	6	3
	206	03291	32	79	4	2
	502	03301	31	31	6	4
1724 0050	203	03324	41	53	6	2
	108	03327	51	11	1	1
	108	03328	51	11	1	0
	108	03329	51	11	1	1
	509	03330	35	61	6	4
	403	03331	36	59	6	3
	404	03334	51	21	6	2
	404	03335	61	32	6	1
	106	03337	36	54	4	3
	106	03339	57	54	4	4

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0050	509	03342	36	61	6	4
	110	03343	36	72	4	2
	403	03344	36	53	6	3
	108	03345	51	11	1	1
1724 0051		03373	36	21	6	1
		03375	37	47	6	1
		03376	34	31	6	2
1724 0052	503	03409	36	43	6	1
	509	03411	34	31	6	2
	303	03419	58	49	6	2
	203	03424	36	11	6	2
	408	03426	32	31	6	3
	102	03428	34	31	6	2
1724 0053	219	03464	32	62	4	3
	103	03471	35	61	4	3
1724 0054	212	03513	35	51	3	1
	703	03514	35	54	6	3
	202	03516	35	79	6	3
1724 0055	105	03545	32	55	6	2
	106	03550	52	21	3	1
1724 0056	412	03574	36	32	3	3
	401	03576	36	22	3	0
	410	03577	43	21	3	1
	203	03581	57	11	1	0
	203	03582	57	11	1	0
	302	03583	57	11	1	0
	306	03584	51	51	1	1
	203	03585	57	11	1	0
	210	03586	21	11	1	1
	210	03587	21	11	1	1
	203	03588	21	11	1	0
	203	03589	21	11	1	1
	203	03590	21	11	1	1
	203	03591	21	11	1	1
	203	03592	21	11	1	1

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0056	210	03593	57	11	1	1
	210	03594	57	11	1	1
	210	03595	57	11	1	1
	210	03596	57	11	1	2
	210	03597	57	11	1	2
	203	03598	57	11	1	2
	203	03599	57	11	1	2
	203	03600	57	11	1	1
	203	03601	57	11	1	1
	203	03602	21	11	1	1
	203	03603	21	11	1	2
	203	03604	21	11	1	1
	302	03605	21	11	1	1
	306	03606	21	11	1	2
	306	03607	21	11	1	1
	306	03608	21	11	1	1
	306	03609	21	11	1	1
	302	03610	21	11	1	1
	302	03611	21	11	1	1
	302	03612	21	11	1	1
	302	03613	21	11	1	0
	306	03614	21	11	1	2
	306	03615	21	11	1	2
	306	03616	21	11	1	1
	302	03617	21	11	1	1
	302	03618	21	11	1	2
	306	03619	21	11	1	1
	306	03620	21	11	1	2
	306	03621	21	11	1	1
	112	03622	32	31	3	0
	203					
	203	03623	21	11	1	1
	*	03629	35	79	6	3
1724 0057	312	03673	32	62	4	1
	307	03693	35	72	6	3
	301	03720	36	61	4	2
	301	03728	35	51	4	2
	613	03731	32	53	4	3

* (in SLA 0034) same as facility 03516

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0057	613	03734	32	55	4	2
	608	03757	36	21	6	2
	203	03765	35	51	4	4
	205	03771	35	72	4	3
	101	03776	35	61	0	0
	301	03782	32	55	4	2
	212	03784	32	52	4	2
	206	03785	36	43	4	2
	706	03797	35	29	6	1
	210	03798	35	55	4	2
1724 0058	403	03842	34	11	1	1
	403	03843	34	11	1	2
	403	03844	36	11	1	1
	403	03845	36	11	1	0
	403	03846	36	11	1	0
	403	03847	36	11	1	0
	403	03849	36	11	1	0
	403	03850	36	11	1	0
	403	03851	36	11	1	0
	403	03852	36	11	1	0
	403	03853	36	11	1	0
	403	03854	36	11	1	0
	403	03855	36	11	1	0
	402	03857	36	11	3	1
	208	03860	32	59	3	1
	402	03864	22	47	3	1
1724 0059	501*	03899	36	22	0	0
	710	03905	36	22	3	1
	207	03905	21	59	3	2
1724 0060	417	03932	35	22	6	1
	303	03944	36	54	4	3
	303	03950	35	54	4	2
	308	03951	35	51	4	3
	101	03965	34	11	1	0

* Block 501 - T-24, SL 0062

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0060	101	03966	34	11	1	0
	101	03967	37	41	1	0
	101	03969	36	41	1	0
	301	03982	36	61	4	2
1724 0061	505	04051	32	31	3	1
	201	04054	36	41	1	1
	201	04055	36	12	1	1
	305	04056	32	71	3	2
	307	04057	32	26	3	1
	205	04058	36	[illegible]	1	1
	205	04059	36	12	1	1
	505	04060	34	39	3	2
	505	04061	35	21	3	2
	203	04062	36	22	0	0
	205	04065	43	12	1	1
1724 0062	302	04083	35	21	0	0
	101	04084	43	12	1	0
	101	04086	43	12	1	0
	101	04090	36	12	1	0
	101	04091	36	12	1	0
	101	04092	57	71	1	0
	101	04093	35	23	1	0
	101	04094	36	23	1	0
	409	04095	43	23	1	0
	409	04096	32	33	1	0
	409	04097	57	22	1	0
	501	04099	32	79	0	0
	409	04100	41	12	1	0
	409	04103	41	3	1	0
	409	04104	41	23	1	0
	101	04105	43	12	1	1
	101	04106	43	12	1	1
	409	04107	34	32	1	0
	409	04109	43	21	1	0
	409	04110	38	31	1	0

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0063	108*	04129	43	45	4	1
	104*	04130	36	45	0	0
	106*	04131	43	71	4	2
	108*	04132	43	23	4	0
	106*	04133	38	31	4	1
	211	04134	43	21	3	1
	112	04136	35	21	6	1
	111	04137	35	55	3	3
	207	04138	43	86	4	2
	313	04146	34	54	4	3
	303**	04148	34	61	4	2
	204	04150	36	61	4	1
	317	04151	32	54	1	1
	103	04152	38	31	6	2
	102	04153	38	31	6	3
	205	04154	43	51	5	4
	309	04155	43	51	5	2
	309	04156	58	51	5	2
	309	04157	58	51	5	3
	205	04158	58	54	5	4
	205	04159	51	69	5	3
	309	04160	58	23	5	2
	205	04161	43	51	5	4
	105*	04164	32	51	3	2
1724 0064	103	04230	36	61	2	1
	414	04240	51	26	6	1
	610	04241	35	21	2	1
	610	04247	57	53	3	2
	305	04251	36	45	0	0
1724 0065	314	04270	35	46	3	2
	503	04274	34	49	3	1
	312	04276	32	45	1	2
	312	04280	34	11	1	2
	312	04282	34	11	1	2

* Actual location is in SL 0046, near boundary with 0063

** Actual location is in SL 0060

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0065	313	04287	34	11	1	2
	313	04289	34	11	1	2
	313	04295	34	11	1	2
	313	04299	34	11	1	2
	313	04301	34	11	1	2
	312	04305	34	11	1	2
	312	04309	34	11	1	2
	312	04312	34	11	1	2
	312	04314	34	11	1	2
	312	04318	34	11	1	2
	312	04320	34	11	1	2
	516	04321	34	11	1	2
	516	04322	36	41	1	1
	516	04323	36	41	1	0
	516	04324	36	41	1	0
	516	04325	34	41	1	1
	516	04326	34	41	1	0
	516	04327	34	41	1	1
	516	04328	36	41	1	0
	516	04329	36	41	1	0
	313	04330	34	11	1	2
	313	04335	34	11	1	2
	313	04337	34	[illegible]	1	2
	516	04338	71	41		0
1724 0066	208	04354	43	21	2	0
	408	04356	61	54	3	3
	111	04359	43	53	3	3
	109	04371	32	31	0	0
1724 0067	411	04437	35	51	4	2
	415	04441	36	21	3	2
	413	04442	36	61	4	1
	115	04447	32	59	2	2
	328	04450	35	21	6	2
	306	04451	51	55	4	1
	204	04454	35	21	2	0
	401	04456	35	31	3	4
	305	04457	35	55	4	3
	305	04459	35	51	4	3

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0067	416	04461	36	72	3	2
	615	04463	36	21	3	2
1724 0068	107	04526	35	43	4	2
	113	04529	32	44	4	1
	104	04532	36	54	4	2
1724 0069	104	04564	43	22	3	2
	101	04570	32	69	3	1
	101	04571	34	22	3	1
	101	04572	36	29	3	3
	313	04576	36	39	3	3
	313	04592	36	72	3	2
	311	04605	36	21	3	3
	410	04606	36	11	3	3
	313	04608	35	11	3	2
	401	04609	36	45	3	2
	301	04611	36	11	1	1
	301	04612	36	11	1	1
	301	04613	36	11	1	1
	301	04614	36	11	1	1
	301	04615	36	11	1	1
	301	04617	36	11	1	1
	301	04618	36	11	1	1
	301	04619	36	11	1	1
	301	04620	36	11	1	1
	432	04623	36	59	4	3
	418	04624	35	11	3	2
	302	04627	41	21	3	1
	302	04628	41	21	3	1
	302	04629	41	21	3	1
	306	04632	41	31	3	2
1724 0070	107	04650	32	31	3	1
	107	04651	35	21	3	3
	312	04653	32	26	3	2
	105	04660	35	21	3	2
1724 0071	406	04686	36	41	3	0
	101	04688	36	49	3	0

SLA	BLOCK	FACILITY	PV	USF	AREA	EXPOSURE
1724 0071	303	04694	35	51	3	1
	403	04695	36	21	3	1
	316	04697	32	31	3	1
	507	04699	32	53	4	1
	321	14681	36	47	3	1
1724 0072	517	04723	43	29	0	0
	437	04724	43	22	0	0
	517	04725	43	72	3	2
	315	04726	36	21	3	1
	302	04728	36	11	3	2
	523	04729	36	32	2	1
	402	04730	43	11	3	2
	310	04735	32	31	3	1
	207	04736	37	42	2	1
	101	04739	35	51	0	0
	204	04742	38	41	1	2
	204	04743	71	41	1	0
	204	04744	38	41	1	1
	204	04747	38	41	1	0
	204	04748	38	41	1	0
	204	04749	38	41	1	1
1724 0073	102	04759	36	21	2	1
	408	04761	57	31	3	1
	416	04767	21	11	3	2
	401	04769	36	11	3	2
	428	04771	43	21	3	3
	401	04772	43	11	3	1
	304	04774	32	54	3	2
	305	04775	36	51	4	1
	305	04776	43	51	4	1
	306	04778	36	11	3	2
	313	04783	36	11	4	1
	213	04784	57	54	6	3
	420	04789	36	11	6	3
	423	04791	34	11	6	2
	402	04792	21	11	6	3

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1724 0073	427	04811	32	11	6	2
	306	04817	36	11	6	2
	306	04818	57	51	6	2
	303	04819	43	51	3	2
	311	04824	36	51	3	3
	315	04828	36	51	3	0
1734 0074	403	04819	36	26	0	0
	211	04822	36	12	3	1
	202	04825	35	51	3	1
	119	04826	42	23	2	1
	119	04827	35	79	2	1
	210	04829	36	25	3	2
	202	04832	36	51	3	1
	117	04834	35	39	2	1
	409	04839	35	51	4	2
	406	04845	36	23	3	1
	407	04846	36	79	3	2
	509	04847	36	25	3	1
	509	04848	36	23	3	2
	510	04850	36	23	3	2
	510	04851	43	23	3	1
	508	04853	35	59	3	3
	503	04857	36	12	3	3
	503	04859	36	23	3	2
	503	04861	36	23	3	3
	503	04865	36	23	3	3
	503	04864	36	23	3	2
	314	04871	36	53	3	4
	309	04880	34	72	4	3
	303	04884	36	51	3	2
	305	04885	43	11	3	2
	502	04886	43	26	3	1
	504	04888	36	23	4	4
	502	04889	36	23	3	2
	507	04889	36	23	4	1
	507	04891	43	12	4	2
	505	04893	43	23	4	2
	613	04894	36	29	3	2
	614	04895	36	31	3	1
	616	04896	36	26	3	1
	615	04897	36	12	3	0

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1734 0074	616	04898	36	12	3	2
	616	04901	34	23	3	2
	616	04902	36	12	3	3
	616	04903	36	12	3	3
	505	04904	36	21	4	0
	508	04906	57	12	3	2
	408	04909	36	19	3	1
	408	04910	57	12	3	2
	405	04911	57	12	3	2
	409	04912	57	55	4	3
	202*	04917	43	24	4	2
	609	04918	43	59	4	2
	501	04919	32	29	4	1
	505	04920	43	26	4	2
	501	04921	43	26	4	2
	312	04926	36	23	3	3
	311	04928	36	23	4	1
	311	04930	57	23	3	2
	406	04931	36	23	3	2
	503	04932	36	23	3	2
	405	04933	36	23	3	2
	405	04934	36	23	3	2
	405	04935	36	23	3	2
	503	04936	36	23	3	2
	503	04938	36	23	3	2
	503	04939	36	23	3	2
	503	04940	36	23	3	2
	405	04941	35	23	3	2
	405	04942	36	23	3	2
	510	04943	71	89	3	0
	613	04944	71	81	3	0
	710	04945	43	22	2	0
	405	04947	71	23	3	0
	616	04948	71	23	3	0
	510	04951	36	11	3	2
	201	04955	57	51	3	2
	209	04958	36	23	3	2
	607	04949	36	23	4	3
	503	04960	31	23	3	2
	406	04962	36	23	3	2

* Actual location in SLA 0046

SLA	BLOCK	FACILITY	PV	USE	AREA	EXPOSURE
1734 0074	406	04963	34	23	3	2
	311	04965	57	23	3	1
	501	04966	71	23	-	0
	116	04967	57	22	3	2
	502	04968	57	26	3	1
	104	04969	57	22	1	0
	503	04970	36	23	3	2
	305	04973	57	23	3	1
	102	04974	41	22	1	1
	503	04975	57	21	3	2
	303	04976	57	23	2	1
	302	04977	57	23	3	1
	404	04978	35	23	2	1
	404	04980	57	23	2	1
	404	04981	57	12	2	2
	404	04982	57	12	2	2
	404	04983	57	12	2	2
	404	04984	57	12	2	1
	503	04987	71	26	3	0
1724 0075	101	05044	35	53	6	1
	518	05048	36	21	6	3
	518	05050	36	32	6	3
	401	05052	35	51	2	1
	113	05054	36	11	6	2
	407	05061	34	11	2	1
	408	05062	34	11	2	1
	516	05063	36	11	6	4
	310	05064	57	51	5	3