NATIONAL BUREAU OF STANDARDS REPORT

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LIVE LOAD STUDIES OF CONVEYOR SYSTEMS AND POSTAL FACILITIES

Final Report

Prepared for

Post Office Department

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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LIVE LOAD STUDIES OF CONVEYOR SYSTEMS AND POSTAL FACILITIES

Final Report

by

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Abstract

A total of approximately 1,040,000 sq. ft. of floor space in postal mail handling facilities has been surveyed for occupancy loads in this study. Seven major postal facilities located in different regions across the country were surveyed over their entire work floor area. These seven facilities ranged in height from 1 to 3 stories. The information on loading recorded during the surveys is presented in this report in great detail in arithmetic averages and summaries and in basic statistical parameters. This is done so that basic data on actual loadings will be available for assessment of the loading that could result from a change in the fundamental mail handling processes that are being used presently. Observations of current loading conditions (exclusive of Christmas season peaks) show that

1. Ceiling loads, which incorporate bulk mail on conveyors, did not exceed 100 psf in areas greater than 200 sq. ft;
2. Floor loads on areas of structural slab size did not exceed 60 psf.

Table of Contents

			Page
1.	Introduction		1
	1.1 Scope		2
2.	General		5
	2.1 Building Facilities		5
	2.2 Building Occupancy Loads		6
	2.3 Work Areas		8
3.	Results of Survey		9
	3.1 Presentation of Data		9
		3.1.1 Mail Loads on Conveyors	9
		3.1.2 Ceiling Loads	10
		3.1.3 Floor Loads	11
	3.2 Analysis of Data		16
		3.2.1 Mail Loads on Conveyors	17
		3.2.2 Ceiling Loads	19
		3.2.3 Floor Loads	22
4.	Conclusions and Recommendations		32
	4.1 Conclusions		32
	4.2 Recommendations		36
5.	References		39
6.	Tables and Figures		40

LIVE LOAD STUDIES OF CONVEYORS

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FINAL REPORT

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1. Introduction

A study has been conducted on actual loadings imposed on postal mail handling facilities resulting from mail handling processes. The main objective of this study was to survey the existing loads in a representative sample of mail handling facilities to develop comprehensive information on the magnitudes and distributions of actual loads imposed on the facilities. Also, loads and forces related to conveyor systems were measured and evaluated. This information would then serve as the basis for engineering recommendations concerning the appropriate structural live loads to be used in the design of future postal facilities.

The program was planned to develop a sufficiently large sample of comprehensive data that could be handled by statistical procedures and calculations to determine the proper loads that major mail handling facilities should be designed for in consideration of safety and economy. The nature of postal activities in this country is such that the peak volume of mail for processing comes each year for several weeks just before Christmas time and consequently the mail load on a facility is assumed to be highest during this period. Nevertheless, the NBS survey team was restricted from visiting postal facilities during the "Christmas rush" period. As a result of this restriction, an important characteristic element of loading history is missing and, at best, can only be arrived at by conjecture. This means that a statistical treatment of the data will need to be reinforced with engineering judgment on upper limit values for determination of proper design loads.

1.1 Scope

The investigation covered a sample consisting of 7 "major postal facilities" ranging in height from 1 to 3 story levels. The principle criteria for selecting a facility were: (1) amount of mechanization equipment; (2) age of structure; and (3) location of facility. The aim was to study the loads in highly mechanized facilities of modern construction and where possible, in those representing different regions of the country.

Selection of the sample of facilities was influenced to a great extent by a conclusion drawn from the preliminary studies that the number of stories in a mail handling facility is an important factor for live load evaluation. Consequently, facilities that were surveyed were chosen to represent categories of one, two, and multi-story structures. The facilities were surveyed in groups according to their number of stories in order to accommodate the data reduction and evaluation, and reporting.

In original planning of the sample, three multi-story mail handling facilities were scheduled for surveying. However, as the work progressed, the conclusion was reached that the data from one of the three multi-story facilities could be considered redundant. In this regard, one facility in this group was eliminated. More recently a second facility was eliminated for reasons of funding (reference: letter from J. N. Wiernicki, POD to J. R. Wright, BRD, NBS, dated June 2, 1970, REPT: C. C. Arnolts: par 68257). This left the data from only one multi-story facility, Omaha, Nebraska, to be used to determine characteristic loadings for this category of facilities.

The facilities that were surveyed for loads are listed below.

Group	Facility	Number of Stories
I	Greensboro, North Carolina	1
	Chicago (AMF), Illinois	1
	Buffalo, New York	1
II	Houston, Texas	2
	New Orleans, Louisiana	2
	Los Angeles (AMF), California	2
III	Omaha, Nebraska	3

The preliminary data from the surveys of the facilities were submitted to the Post Office Department in 4 separate interim reports [1, 2, 3, 4][1/]. These interim reports served to show the type of data and its preliminary handling techniques along with an indication of the status of the project.

This is the final report in which it is intended to summarize the results from the 7 facilities surveyed and to present an analysis of the data with design load recommendations in consideration of the information collected.

[1/] Numbers in bracket indicate the references in Section 5.

2. General

The survey techniques and data evaluation procedures as well as all definitions of loads and floor areas were presented in the earlier interim reports [1, 2]. However, because of their importance to the understanding of the rationale for the data analysis, the definitions for building occupancy loads and areas on the work room floor are presented here for convenience of reference.

2.1 Building Facilities

The buildings that were surveyed for loads in this investigation are classed by the POD as "Major Postal Facilities." A major postal facility is one that has a work floor area greater than 50,000 sq. ft. [5]. The space provided in these facilities is divided generally into four major areas:

1. Workroom area
2. Mail handling support services areas
3. Platform or docking areas
4. Administration, personnel, and public services areas

The workroom is a large open bay floor in which the mail processing activities are centered. The floor area is lined with regularly spaced structural columns which superficially divide the floor space into "grid squares" [1]. The other areas serve to support, in different ways, the activities on the workroom floor.

The workroom floor is divided into designated work areas to accommodate specific mail processing activities. The work areas are of different sizes, depending on amount and type of activity, and usually cover a number of grid squares. Within the work areas the activities and types of equipment employed for processing the mail toward its destination are the principle factors which affect the characteristics of the occupancy loads.

2.2 Building Occupancy Loads

The loads that are imposed on the structure due to the mail handling processes are defined as follows:

(1) Mail load - all types of mail in various containers being processed or stored within the facility.

(2) Fixed mechanization load - load due to the weight of mail processing equipment either anchored to the ceiling or bolted to the floor (i.e., bulk mail-conveyors, parcel and sack sorting machines, letter sorting machines, etc.)

(3) Mobile mail handling and miscellaneous operating equipment - items that are used to contain the

mail that is being processed or stored on the work floor, also different types of maintenance equipment (i.e., baskets, hand trucks, tables, bag racks, motorized sweepers, etc.)

(4) People - the weight of the maximum number of people assigned to a specific area.

The loads are ordered into two groups according to the manner in which they are supported by the structure. They are ceiling supported loads and floor loads as follows:

I. Ceiling Loads

1) Fixed mechanization (e.g., ceiling suspended conveyors)

2) Mail

II. Floor Loads

1) Fixed mechanization (e.g., floor mounted conveyors) and workroom equipment

2) Mobile mail handling and miscellaneous operating equipment

3) Mail

4) People

The ceiling loads and floor loads in a 1-story facility are basically independent of each other. However, in a multi-story facility consideration must be given to the combined effect of the ceiling loads of one story and the floor loads of the story above it.

2.3 Work Areas

It was stated earlier that it is the mail processing activities and consequently the types of equipment employed for processing the mail within the workroom which are the principal factors affecting the characteristics of the occupancy loads. The workroom floor is divided into designated "work areas" for specific mail processing activities. For the purposes of this study the activities were covered by 10 work area categories designated as follows:

Area 1 - "Culling, Facing and Cancelling"
Area 2 - "Letter Distribution"
Area 3 - "Main Office Carriers"
Area 4 - "Flats Distribution"
Area 5 - "Pouching"
Area 6 - "Sawtooth Platform Area"
Area 7 - "Outgoing Parcel Post"
Area 8 - "Incoming Parcel Post"
Area 9 - "Outgoing Non-preferential"
Area 10 - "Temporary Storage"

Detailed descriptions of the activities and types of equipment found in each of the areas listed above are given in an earlier report [2].

3. Results of Survey

3.1 Presentation of Data

Data obtained during the survey are presented together with results in various forms by means of Tables and Figures in Section 5. Table 1-a lists some physical data generally describing the facilities which were surveyed. Table 1-b is a more detailed listing of the distribution of workroom space into the different work areas at each facility.

3.1.1 Mail Loads on Conveyors

Table 2 is a sample of conveyor mail load data. Each value is the mail load, in pounds, on a 10-ft. length of conveyor (here, 3 1/2 ft. wide), observed at regular intervals as the conveyor belt carried the mail through the conveyor section being observed. Values were recorded at intervals of 2 ft. of belt travel. Tabular values are in order by rows starting at the top and reading from left to right. Additional details describing this technique of data acquisition are given in an earlier report [1].

Figure 1 is a sample histogram of observed conveyor belt mail loads in lb/sq. ft. based on the data of Table 2. Numerous zero values resulting from empty 10-ft. belt lengths were deleted to avoid clogging the load scale zero position. Much of this type of data is repetitious and is not included for the sake of brevity.

3.1.2 Ceiling Loads

Values of uniformly distributed and concentrated loads caused by selected suspended conveyors and their structural support are not again presented here to conserve space. Since these data, as originally reported, were not considered to require further processing the reader is referred to the interim reports [1, 2, 3, 4] for ceiling data pertaining to the various facilities. However, it is important to repeat the fact that the selected sections of mechanization were purposely chosen because of their apparent heavy loads as evidenced by complex construction. In summary, for the mechanization sections observed, the range of calculated gross uniformly distributed loads (with live load) varied from 19 psf to 340 psf, and the range of concentrated (hanger) loads, from 200 lb to 1640 lb.

Figure 2 is a plot of the uniformly distributed loads of the mechanization sections versus the plan areas of the sections observed in all 7 facilities. The curve was drawn to represent the upper limit boundary load values of the collected data.

3.1.3 Floor Loads

Tables 3-a through 3-g and 4-a through 4-g present the basic data used in subsequent interpretations. Tables 3-a through 3-g list the frequency of occurrence of various uniformly distributed load intensities (UDL) for grid squares in each work area in each facility. Similarly, Tables 4-a through 4-g list the frequency of occurrence of various percentages of occupied space for grid squares in each work area in each facility. The tabular value intervals (2 psf and 5 percent) were determined with the aid of the empirical practical guide [6]:

$$\text{Interval} = \frac{\text{Maximum Value}}{1 + 3.3 \log \text{(No. of values)}}$$

for satisfactory definition of all groups of data used in subsequent histograms. Intermediate values (of psf, and of percent) are counted as occurrences of the tabular value to which they are closest. It is to be noted that certain work activity areas were not encountered at some facilities.

Table 5 summarizes values of work areas, mean grid square UDL and mean grid square occupied space percentages in each of the 7 facilities surveyed. For the facilities having more than one story, Table 6 shows the distribution of work areas between different floors when such a division occurred. In the case of Omaha, for the purpose of comparing with other facilities in this report, the Ground Floor, 1st Floor and 2nd Floor were renamed 1st, 2nd and 3rd floors, respectively.

Table 7 lists the mean values of grid square UDL in combined work areas of the same type for various groups of facilities. In the same manner, Table 8 lists the mean values of grid square occupied space percentages in combined work areas of the same type for various groups of facilities.

Table 9 shows values of grid square UDL and grid square percent occupied space for the total of each facility and for the totals of different groups of facilities.

Table 10 is a summary of maximum uniformly distributed load intensities determined for different size areas in each of the surveyed facilities. Code identifications of grid squares and grid sectors refer to designations and floor plans used in Interim Reports 2, 3, and 4.

Table 11 contains values of grid square uniformly distributed load calculated by applying observed upper limit loads over a grid square area equal to the average percentage of observed occupied space, and dividing the total load by the grid square area. Table 12 lists values of equivalent uniformly distributed load (EUDL) which would cause the same maximum bending moment in a 1-way grid square slab subjected to observed upper limit loads applied over a centrally located portion of the grid square equal to the average percentage occupied space. The manner of upper limit loading involved in developing both Tables 11 and 12 is described more fully in Section 3.2.3, Analysis of Data-Floor Loads.

For ease of locating them, the remainder of the figures (i.e., those pertaining to floor loads) are divided into two sets, the first set pertaining to grid square UDL, the second to grid square occupied space percentages. It will be noted that one set of figures parallels the other in the source of the data which are presented graphically.

Figures 3-a through 3-j are histograms of grid square uniformly distributed load intensities (UDL) in each of 10 different work areas for the combined data of the 3 one-story facilities. Figures 4-a through 4-i present the same kind of information for the combined data of the four 2 and 3-story facilities; (no area #9 was encountered in the survey of these facilities). Figures 5-a through 5-j similarly present the same kind of grid square UDL information for the combined data of all 7 facilities.

Figures 6-a through 6-g are histograms of grid square UDL for each of the 7 facilities without distinction between work areas in a facility. The following graphs (Figures 7-a through 7-g) are cumulative frequency distributions for each of the 7 immediately preceding respective histograms.

Figure 8 is a histogram of grid square UDL values without distinction between work areas for combined data from the 3 one-story facilities; Figure 9 is the cumulative frequency distribution for the same data. The next two pairs of figures present similar information for the other groups of the surveyed facilities. Figure 10 is a histogram of lumped grid square UDL values from the four 2 and 3-story facilities and Figure 11 is the corresponding cumulative frequency distribution. Figure 12 is a histogram of all grid square UDL values from the combined 7 facilities and Figure 13 is the corresponding cumulative frequency distribution.

The following figures were described earlier as being the second of two parallel sets and pertain to grid square occupied space percentages.

Figures 14-a through 14-j are histograms of grid square occupied space percentages in each of 10 different work areas for the combined data of the 3 one-story facilities.

Figures 15-a through 15-j present the same kind of information for the combined data of the four 2 and 3-story facilities; (no area #9 was encountered in the survey of these facilities). Figures 16-a through 16-j similarly present the same kind of grid square percent occupied space information for the combined data of all 7 facilities.

Figures 17-a through 17-g are histograms of grid square occupied space percentages for each of the 7 facilities without distinction between work areas in a facility. The following graphs (Figures 18-a through 18-g) are cumulative frequency distributions for each of the 7 immediately preceding respective histograms.

Figure 19 is a histogram of grid square occupied space percentages without distinction between work areas for combined data from the 3 one-story facilities; Figure 20 is the cumulative frequency distribution for the same data. The next two pairs of figures present similar information for other groups of the surveyed facilities. Figure 21 is a histogram for all grid square occupied space percentages from the four 2 and 3-story facilities and Figure 22 is the corresponding cumulative frequency distribution. Figure 23 is a histogram of all grid square occupied percentages from the combined 7 facilities and Figure 24 the corresponding cumulative frequency distribution.

3.2 Analysis of Data

The information presented in Table 1-a gives an indication of the overall coverage of the survey which resulted in the acquisition of the large sample of data for this study. It is also to be noted that there was included in the load data, the weight of personnel based on information obtained from facility officials regarding the maximum number of people assigned to various activities. The weight of individuals was conservatively taken to be 175 lbs. for men and women alike. Although the weight of personnel was included in the floor load data, it was not considered a major contributing factor. The mean value of personnel loads in all of the different work areas of all facilities was 0.8 psf. Even two isolated instances of 3, and 4 psf in small "Main Office Carriers" areas (approx. 2000 sq. ft.) were considered to be small compared to anticipated design levels. In these two cases the personnel weight represented 1/4 of the total floor load.

Also of general interest are the values in Table 1-b which are percentages of facility workrooms assigned to various mail processing activities. Although no firm pattern is established, if the values of Table 1-b are ranked for each of the 7 facilities there appears a tendency for work areas 2 and 4 to have the higher apportionment percentages more frequently, followed next (and equally) by work areas 1, 7, 8, and 10.

The loads investigated in this study fall into three categories: 1. Bulk mail load on storage conveyors; 2. Suspended mechanization loads; 3. Live floor loads. The three categories of loads, by the very nature of their differences, had to be analyzed in different ways.

3.2.1 Mail Loads on Conveyors

The main purpose of the various examinations to which the conveyor mail load data were subjected, was to obtain a realistic value which could be included as part of the total in estimating ceiling-suspended mechanization loads applied to ceilings through hangers. Such data of conveyor mail loads were obtained in quantity and detail as described in the earlier interim reports [1, 2]. For example, the values of Table 1 may be thought of as the successive total live loads (caused by mail) experienced at intervals of 2 ft of belt travel by a given pair of hangers supporting a 10-ft length of a conveyor. Alternatively, the same values are expressed as the uniformly distributed live load over the belt area of the same 10-ft section of conveyor as presented in Figure 1.

However, an evaluation of the effort and the means employed to acquire this and similar types of conveyor mail information [1], together with a consideration of the percentage of it which was helpful, resulted in curtailment of this detailed approach. Nevertheless, added attempts were made at the last 2 facilities surveyed to detect conveyor mail loads which might exceed what had so far been observed. This was done with a permanently recording, threshold-value type of detector attached to a conveyor hanger rod for a period of about 2 weeks but with negative results. An assessment of the conveyor mail load data which was available from the preceding surveyed facilities, therefore, resulted in the adoption of the observed maximum loading as a basis for estimating total ceiling-suspended conveyor loads. The maximum loading observed over a 10 ft. length of a combination storage-transport conveyor at Chicago AMF was 25 psf. Further examination of the data and records of the mode of conveyor operation confirm that such loading was not an isolated occurrence. The proximity of 25 psf to the presently specified maximum conveyor design live load (30 psf) would indicate the latter to be reasonably suitable. A reconsideration of mail processing methods suggests a modification of an earlier judgment [2] regarding the likelihood of such loading exceeding this level of intensity. Post Office Department limitations on sack and parcel weights, along with photo-electric cell control of conveyors, would tend to restrict the density of loading along a conveyor belt. The above cited maximum values occurred in a 10-ft observation length under conditions of close storage packing of the conveyor. Peak periods of mail handling would increase the lengths of uninterrupted stretches of closely packed mail passing through a 10 ft observation length but, the likelihood of the belt load density being increased is small because of the above restricting factors.

3.2.2 Ceiling Loads

The field data for suspended mechanization loads were recorded in the form of dimensions and types of construction materials for selected sections of conveyors and other processing machinery. The area occupied by a mechanization section and its location within the plan of the building were also recorded. Sections were selected which represented the different types of conveyor units and different combinations of units in a common area. These data were reduced to total weights bearing within specific horizontal areas. Calculations were made to determine values of the total load uniformly distributed over the horizontal area for each mechanization section.

In addition, the hanger loads for conveyor suspension rods were calculated for two different support arrangements: 1. With suspension rods located at the four corners for small conveyor sections; 2. With suspension rods supporting large conveyor sections every 5 ft in a rectangular coordinate grid system. The four-corner support calculations were made for conveyor sections with areas of 75 sq ft or less (the smallest section examined was 4 ft by 3 ft = 12 sq ft). The 5-ft rectangular grid support points arrangement was chosen since it conforms to the POD specification for arrangement of insert anchor points to support suspended mechanization systems. Values for uniformly distributed loads were computed for dead weights of mechanization sections alone, and for mechanization with mail live load added on the conveyor belt areas where they existed. The mail live loads used were those currently specified by POD for design (30 psf). The computed hanger rod loads for the 5 ft-spaced coordinate grid support points were based on the minimum number of support points in a 5-ft grid system which were calculated to fall within the plan area of the mechanization.

The range of suspended mechanization loads mentioned in Section 3.1.2 (19 psf to 340 psf, with live load) was for 58 values obtained throughout the 7 facilities. These, of course, are related (although not respectively) to a wide range of areas of examination: 11,620 sq. ft. to 12 sq. ft. The generally inverse relationship between the areas and loads is brought out by the plot of the 58 cases in Figure 2. Note again that the selected sections of mechanization were purposely chosen because of their apparent heavy loads as evidenced by complex construction. Further definition was obtained by fitting an approximate upper boundary curve to the data. Two inferences can be drawn from this empirical relation. 1. There appears to be a limit to the intensity of loading that can be expected in a mechanization-filled area of a given size. 2. The rate at which the indicated maximum intensity varies with area size, changes abruptly in the vicinity of 100 to 200 sq. ft. of area (or 90 to 100 psf). That is, load intensities greater than approximately 100 psf can be expected to occur only in relatively small areas. Of particular interest, in Figure 2, is the boundary region associated with areas of grid square size as represented by those in the surveyed facilities. For this range of grid square areas (about 1900 to 700 sq. ft.) the indicated expected maximum intensity of total ceiling load falls within the narrow range of about 70 to 80 psf. The highest actually encountered was 84 psf for a 700 sq. ft. grid square filled with mechanization. This sample had been examined to include such a possibility even though it was, in fact, not a case of mechanization which was totally ceiling-supported [3]. The choice of the 100 psf value to represent upper limit loading of this type would be reasonably conservative for grid square areas in this approximate size range.

3.2.3 Floor Loads

The occupancy loads on the floor in the workroom area of a facility are in a state of constant change. The total mail load within the facility fluctuates with the input-output movement of the mail; and the specific (discrete) loading within the facility changes as the mail is transported from one point to another in the normal processing operations. The total load fluctuations are significant only in considering seasonal peaks (Christmas mail, etc.) and even then the information is of little or no use for engineering design purposes unless it can be conveniently converted to a distribution within the facility. Significant factors for the analysis of loading on the workroom floor are the characteristic magnitudes and distributions of loads, and the limits that these parameters can be expected to have.

The floor areas on which the loads are applied are divided into two categories: 1. Activity associated areas;

2. Structurally significant areas. The activity associated areas are the work areas. The structurally significant areas are the grid square and grid sector areas. The grid square represents the basic floor and ceiling element that the characteristic loading relates to in terms of first order design loads. Therefore, the loadings within work areas have been evaluated in terms of their effect on grid squares (floor or ceiling structural panels).

The analysis of the floor loads is based on the data in the two Tables 3- and 4-series. These values are the first step in reduction of field data in all facilities pertaining to loading and occupancy of grid squares. In review, this part of the survey involved the recording of the weights, size and approximate locations of all items (and their contents) on the workroom floor [1]. Personnel weights were added later by assignment. Since it was believed that areas of different mail processing activities might present different floor loads information, floor plans of facilities were used to note the specific work area locations. A further breakdown of the floor area was made by defining the areas bounded by column lines as grid squares. The grid squares were then divided into 1/2-span mid-strips and 1/4-span column-strips corresponding to the structural strips considered in bending moment design of a two-way flat slab. The overlapping of the strips in the two directions formed a pattern of grid area sectors which provided a general location scheme. In cases where the boundary of a work area did not coincide with a column line, the work area then contained partial grid squares.

In pursuing the questions of a possible difference in loading conditions of 1. Different work areas; and 2. Facilities of different numbers of stories, the mean values of grid square uniformly distributed load, and of occupied space percentage were chosen as characterizing values. The results of a first consideration of grid square loading and occupancy conditions in each of the work areas of each surveyed facility is given in Table 5. For general information, Table 6 shows the distribution of work areas by floors when the work areas are split. However, in the following analyses, each single activity work area in a facility is considered as a whole. Since, generally, many single work areas in any one facility did not provide a large enough sample of grid squares to form a well defined histogram, such graphs at this level are not presented. Therefore, data was assembled from like work areas in multiple facilities, grouped by their number of stories. This facility grouping was used in connection with answering question (2.), stated above, of whether there might be a possible loading difference in facilities of different numbers of stories. The same method of grouping was also used in the consideration which follows. In the 3 (1-story) facilities surveyed, the major concern with floor loads was centered on specific activity-related movable equipment, mail, etc., which contributed to the load and occupancy of a designated work area. As a result, some sections of permanently floor-mounted mechanization were not included as they were in facilities surveyed later. The facility grouping was also used to investigate the effect of such deletions on the overall results. (Any effect is seen later to be of no practical importance).

The results of combining the data for like work areas in various groups of facilities is summarized in Tables 7 and 8 and presented graphically in the Figures 3-, 4-, 5-, 14-, 15-, 16-series. Within each facility group, the mean values of grid square UDL and grid square percentage occupied space in Tables 7 and 8 were subjected to statistical tests [7] at the 1% level of significance to determine if the means of different work areas differed significantly. In all facility groups (1-story, 2 and 3-story, All) the tests indicated either no difference between means of different work areas, or differences which were statistically significant but were judged to be practically unimportant from an engineering viewpoint.

Recognizing no practical difference between the loading conditions (of weight and of space) of different work areas, the data in each of the facilities were lumped without distinguishing between work areas and replotted as the histograms of the Figure 6-series. Corresponding cumulative frequency distributions may be found for comparison in the Figure 7-series. The characteristic values for each facility are summarized in Table 9.

The lumped data of each facility were then combined into two groups (1-story, 2 and 3-story) and similarly tested for significant difference between means of grid square UDL and between means of grid square occupied space of the two groups. Again, it was concluded that there were no differences of practical importance. Figures 8 thru 11 and 19 thru 22 illustrate the frequency of grid square loadings and occupancies in these groupings the characteristic values of which are also summarized in Table 9.

In general, with regard to loading and occupancy, the data also showed lack of practical difference between the respective means of seven 1st floors, four 2nd floors and one 3rd floor; and between the means of the 1st floors in the two different groups of facilities. It is of interest to note that the slight differences observed between the

1st, 2nd and 3rd floors (i.e., between the respective nominal mean values 9, 10, and 11 psf; and between 28, 31, and 31%) show an increase in loading with floor level (although small) rather than a decrease as had originally been presumed.

Based on a statistical comparison of the means, there is no justification for not pooling the data. It was, therefore, judged admissible to combine all observations of grid square loading, and of grid square occupancy, from all facilities surveyed, in order to obtain the histograms and cumulative frequency distributions of Figures 12, 13 and Figures 23, 24. The characteristic values of these, also, are summarized in Table 9. The mean values which are representative of grid square loading and percentage occupancy for the 1283 determinations obtained in surveying 1.04 million sq. ft. of workroom space are nominally 10 psf and 30%.

Nevertheless, attention is also directed to the possibility of higher levels of floor load occurring. In this regard, consideration is given to cumulative probability levels obtained from the frequency distributions for the data. For example, observe the 99% probable loads tabulated in Table 9, (i.e., the load which would probably not be exceeded in 99 out of every 100 grid squares). This is also done for percentage occupancy of grid squares. It is to be noted, however, that the 99% probable occupancy percentages in the 2 and 3-story facilities were determined after exclusion of certain grid squares wholly or mostly filled with permanent floor mechanization which were not subject to random occupancy.

Additional records of upper limit observed loads are given in Table 10. These refer to maximum loadings measured on areas of different sizes described in earlier reports [2, 3, 4]. The grid square maximum load values for Table 10 were deliberately chosen for complete (whole) grid squares and in some instances are less than the 99% level values obtained from the cumulative frequency distributions for all grid square observations which include partial grid squares. As in the case of the ceiling loads analysis, it is also apparent in Table 10 that the intensity of extreme loadings increases with decrease in area of observation.

A further analysis was made to determine possible floor load levels higher than those observed. This was done by computing values of uniformly distributed loads resulting from maximizing grid square loadings for various conditions. In earlier reports [2, 3, 4] this was done in an overly conservative manner in that the maximized load distributions were obtained from the work area cumulative fraction load curves and applied to a complete grid square area. The equivalent uniformly distributed load values (EUDL) for equal maximum bending moment in a one-way slab obtained in this way made no allowance for maneuvering space. The approach taken in the following determinations employs a more realistic procedure for obtaining a maximum credible loading.

Information regarding the frequency of discrete load intensities, observed in the various work areas of each facility, was obtained, as before, from the respective cumulative fraction load curves. However, the profile of upper value load intensities was applied not to the complete area of a grid square in a given work area but, rather, to a percentage of the grid square equal to the mean percentage of occupancy in that work area. Further, work areas of the same activity on more than one floor in a facility were not treated as a combined area (as in earlier reports) in order to avoid unrealistic maximization of discrete loads within a given work area. In Table 11 the UDL's are upper limit values determined by considering the loads and occupied space described above to be placed randomly in the grid square (simulating survey conditions). These upper UDL's are calculated by dividing the sum of the applied maximized loads by the whole grid square area. Note that these upper limit loads, though artificially maximized, are not excessively greater than the 99% level of observed UDL's in Table 9.

The same method of load maximizing over partial grid square occupancy was used to obtain the values of Table 12. However, Table 12 contains calculated equivalent uniformly distributed loads which develop the same bending moment in a one-way grid square slab as would the maximized loads over a centrally (not randomly) located average percentage of occupied space. Within this central area, the applied discrete loads (which were derived from the respective work area's cumulative fraction load curve), were arranged in order of decreasing intensity from the center to the outer edge of the occupied space. Even such "reduced" values of maximized EUDL appear very conservative when compared with observed 99% level grid square UDL's in Table 9. Further, regarding observed high load intensities, it is recalled that the very highest grid square UDL recorded in the entire survey of 1283 grids (cf. Table 10) was 58.8 psf for a whole grid square which was 88% occupied by nutting trucks

The loads information that was collected during the study outside of the "Christmas rush" period showed some interesting results. The data indicates that there is no practical difference between loading conditions (weight and space) of different work areas. Also, there were suprisingly similar values for loadings irrespective of floor level or number of stories in a facility. These results did not support the assumption made at the outset of the loads study that the loading would vary with facility height. It was taken for granted, following preliminary studies of POD documents and general discussions with officials, that as the number of stories changes between facilities so would the arrangements and distributions of work areas which would directly affect the loading by floor level. However, because the loadings did not show any practical difference for different work areas, the assumption that loading varied with the number of stories was based on a false premise. It would appear, therefore, that in considering facility loads, on the basis of the observed data, differentiation between work areas, between story levels, and between facility categories (by number of stories) is not justified.

It was stated earlier that an important characteristic element of the loading on facilities, represented by the data collected in the surveys, is missing. This characteristic element pertains principally to floor loads, and is assumed to be a product of the peak volume of mail that develops throughout the country during the "Christmas rush" period. This information is needed to eliminate uncertainties regarding the magnitude and extent of peak loadings. Also, since these loadings occur every year for at least two to three weeks, they must be considered working loads under which undesirable structural performance (cracking, etc.) is to be avoided.

In considering the information collected in the study, there were found three principal values of live floor loads pertaining to grid square loadings. They are as follows:

1. The mean value of the frequency distribution for loadings on all grid squares in the survey --- 10 psf

2. The value of grid square loading at the 99 percent probability level for the frequency distribution covering all grid squares in the survey --- 30 psf

3. The maximum loading found on a grid square for the entire survey of 1283 grids --- 59 psf

In an effort to obtain a value for "maximum credible[1/]" loading, various studies were conducted which combined observed data with professional judgment. In the preliminary (interim) reports, EUDL values were computed with a technique that was considered, at the time, very conservative. It is now considered not "credible". In support of this, it was found that the maximum grid square loading of 59 psf covered 88 percent of the grid square area (essentially complete coverage), the type of items being loaded nutting trucks. To illustrate, Figure 25 shows loaded nutting trucks closely spaced on a workroom floor (New Orleans). The loading conditions found for the grid square shown (located behind the man in the photograph) were 36 psf and 48 percent occupied area. Note also from Table 10, that the maximum grid sector UDL, for all facilities, of 137 psf (caused by sacks of mail stacked on the floor) is in a grid square having a UDL of only 24 psf. An example of this type of floor loading is seen in Figure 26 where the

[1/] Defined to be events which might occur with very small (but finite) probability.

grid square loading was 19 psf. However, here again, a Christmas season examination might reveal more congested or intensive loading.

Two methods were used to derive, from observed data, credible loadings for postal mail handling facilities. Both methods used the characteristic features of maximum loads and average occupied space for a given work area applied to the area of a grid square. These methods are described in Section 3.2.3, of this report in relation to: 1. "Maximized grid square UDL values in Table 11; 2. EUDL values in Table 12. The highest load values computed by these methods were 52 psf (work area 10 in New Orleans) with method #1; and 159 psf (work area 10 in Omaha) with method #2.

4.2 Recommendations

Design load recommendations are made for the three categories of load investigated in this study. They are: 1. Bulk mail load on storage conveyors; 2. Suspended mechanization loads; 3. Live floor loads. The recommended loads were chosen based on the data collected in the surveys of the facilities and in consideration of the fact that the data does not reflect the loads at Christmas time. Due to the manner in which the loads for categories 1 and 2, above, relate to processing operation controls and to the structure itself their upper limit boundaries are assumed with a high degree of confidence. This is not the case for category 3, live floor loads; and substantial comment is presented in support of the choice of a load value and options for design.

> For bulk mail load on storage conveyors, it is recommended that 30 psf be used for design. This is the value that is currently being used.
>
> For suspended mechanization loads, it is recommended that 100 psf be used without any load reduction.

In choosing a live floor load to be used for the design of a building, many questions must receive attention and be satisfied before the choice can be considered a reasonable one. The important questions all bear on safety and economy. But in the final analysis, the questions all tend toward a consideration of the "consequence of failure." For slab-on-ground construction, loading to failure would mean, at most, a costly repair. However, the complete failure of an upper level floor section in a multi-story building could cause serious injury or death to people involved.

For single story facilities with slab-on-ground construction, it is recommended that a design load of 60 psf be used. This is suggested for use with the load factors involved in the design methods presently used.

Since a facility should be designed to safely and economically support the maximum loading that it can be expected to experience over its lifetime, recurring Christmas loads should be recorded and analyzed to determine their effect on the presently available frequency distributions. To select a design value for live floor loads without inclusion of such data necessitates a more conservative choice in order to avoid excessive risk of overloading. Therefore, for multi-story facilities, it is recommended that the live floor load design values in current use continue to be used.

5. List of References

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6. Tables and Figures

List of Tables

Table 1a - General physical data of surveyed post office facilities

Table 1b - Distribution of workroom floor space into work areas.

Table 2 - Sample of conveyor mail load data: Pounds on a 10-ft length of 42-in conveyor determined at intervals of 2 ft of belt travel.

Table 3a - Frequencies of various uniformly distributed load intensities for grid squares in Greensboro facility.

Table 3b - Chicago

Table 3c - Buffalo

Table 3d - Houston

Table 3e - New Orleans

Table 3f - Los Angeles

Table 3g - Omaha

Table 4a - Frequencies of various percentages of occupied space for grid squares in Greensboro facility.

Table 4b - Chicago

Table 4c - Buffalo

Table 4d - Houston

Table 4e - New Orleans

Table 4f - Los Angeles

Table 4g - Omaha

Table 5 - Summary of work areas, mean values of grid square UDL and mean values of grid square % occupied space.

Table 6 - Work area distribution by floors in 2 and 3 story facilities.

Table 7 - Mean values of grid square uniformly distributed load intensities in combined similar work areas for various groups of facilities.

Table 8 - Mean values of grid square occupied space percentages in combined similar work areas for various groups of facilities.

Table 9 - Summary of grid square UDL and % occupied space values for totals of different groups of facilities.

Table 10 - Maximum uniformly distributed load intensities observed in different size floor areas.

Table 11 - Maximized grid square UDL determined by applying upper limit discrete loads over average occupied grid square area.

Table 12 - Equivalent uniformly distributed loads (EUDL for 1-way slab) determined by applying upper limit discrete loads over central average occupied grid square area.

List of Figures

Figure 1 - Sample histogram of observed conveyor belt loadings, in psf, based on data of Table 2.

Figure 2 - Plot of suspended mechanization loads vs. plan area of mechanization sections.

Figure 3a - Histogram of grid square uniformly distributed load intensities in work area 1 for 3 combined one-story facilities.

Figure 3b - Work area 2

Figure 3c - Work area 3

Figure 3d - Work area 4

Figure 3e - Work area 5

Figure 3f - Work area 6

Figure 3g - Work area 7

Figure 3h - Work area 8

Figure 3i - Work area 9

Figure 3j - Work area 10

Figure 4a - Histogram of grid square uniformly distributed load intensities in work area 1 for 4 combined 2 and 3-story facilities.

Figure 4b - Work area 2

Figure 4c - Work area 3

Figure 4d - Work area 4

Figure 4e - Work area 5

Figure 4f - Work area 6

Figure 4g - Work area 7

Figure 4h - Work area 8

Figure 4i - Work area 10

Figure 5a - Histogram of grid square uniformly distributed load intensities in work area 1 for all 7 combined facilities.

Figure 5b - Work area 2

Figure 5c - Work area 3

Figure 5d - Work area 4

Figure 5e - Work area 5

Figure 5f - Work area 6

Figure 5g - Work area 7

Figure 5h - Work area 8

Figure 5i - Work area 9

Figure 5j - Work area 10

Figure 6a - Histogram of grid square uniformly distributed load intensities in Greensboro facility.

Figure 6b - Chicago

Figure 6c - Buffalo

Figure 6d - Houston

Figure 6e - New Orleans

Figure 6f - Los Angeles

Figure 6g - Omaha

Figure 7a - Cumulative frequency distribution of grid square uniformly distributed load intensities in Greensboro facility.

Figure 7b - Chicago

Figure 7c - Buffalo

Figure 7d - Houston

Figure 7e - New Orleans

Figure 7f - Los Angeles

Figure 7g - Omaha

Figure 8 - Histogram of grid square uniformly distributed load intensities in 3 combined one-story facilities.

Figure 9 - Cumulative frequency distribution of grid square uniformly distributed load intensities in 3 combined one-story facilities.

Figure 10 - Histogram of grid square uniformly distributed load intensities in 4 combined 2 and 3-story facilities.

Figure 11 - Cumulative frequency distribution of grid square uniformly distributed load intensities in 4 combined 2 and 3-story facilities.

Figure 12 - Histogram of grid square uniformly distributed load intensities in all 7 combined facilities.

Figure 13 - Cumulative frequency distribution of grid square uniformly distributed load intensities in all 7 combined facilities.

Figure 14a - Histogram of grid square occupied space percentages in work area 1 for 3 combined one-story facilities.

Figure 14b - Work area 2

Figure 14c - Work area 3

Figure 14d - Work area 4

Figure 14e - Work area 5

Figure 14f - Work area 6

Figure 14g - Work area 7

Figure 14h - Work area 8

Figure 14i - Work area 9

Figure 14j - Work area 10

Figure 15a - Histogram of grid square occupied space percentages in work area 1 for 4 combined 2 and 3-story facilities.

Figure 15b - Work area 2

Figure 15c - Work area 3

Figure 15d - Work area 4

Figure 15e - Work area 5

Figure 15f - Work area 6

Figure 15g - Work area 7

Figure 15h - Work area 8

Figure 15i - Work area 10

Figure 16a - Histogram of grid space occupied space percentages in work area 1 for all 7 combined facilities.

Figure 16b - Work area 2

Figure 16c - Work area 3

Figure 16d - Work area 4

Figure 16e - Work area 5

Figure 16f - Work area 6

Figure 16g - Work area 7

Figure 16h - Work area 8

Figure 16i - Work area 9

Figure 16j - Work area 10

Figure 17a - Histogram of grid square occupied space percentages in Greensboro facility.

Figure 17b - Chicago

Figure 17c - Buffalo

Figure 17d - Houston

Figure 17e - New Orleans

Figure 17f - Los Angeles

Figure 17g - Omaha

Figure 18a - Cumulative frequency distribution of grid square occupied space percentages in Greensboro facility.

Figure 18b - Chicago

Figure 18c - Buffalo

Figure 18d - Houston

Figure 18e - New Orleans

Figure 18f - Los Angeles

Figure 18g - Omaha

Figure 19 - Histogram of grid square occupied space percentages in 3 combined one-story facilities.

Figure 20 - Cumulative frequency distribution of grid square occupied space percentages in 3 combined one-story facilities.

Figure 21 - Histogram of grid square occupied space percentages in 4 combined 2 and 3-story facilities.

Figure 22 - Cumulative frequency distribution of grid square occupied space percentages in 4 combined 2 and 3-story facilities.

Figure 23 - Histogram of grid square occupied space percentages in all 7 combined facilities.

Figure 24 - Cumulative frequency distribution of grid square occupied space percentages in all 7 facilities.

Figure 25 - Loaded nutting trucks closely spaced on workroom floor.

Figure 26 - Mail sacks piled directly on the floor.

Facility	Number of Floors	Workroom Occupiable Area Surveyed	Occupied Area	Occupied Area	Grid Size	No. of Grids	Total No. of Floor Items	Total Floor Load Surveyed
		sq ft	sq ft	%	ft,sq ft			kips
Greensboro	1	86,554	19,359	22.4	33 x 33= 1089	85	2305	563
Chicago AMF	1	51,027	12,287	24.1	35¼ x 30¼= 1066	56	1485	353
Buffalo	1	159,799	43,531	27.2	36 x 54= 1944	101	5084	1395
Houston	2	193,703	58,093	30.0	27½ x 27½= 756	311	6021	1825
New Orleans	2	221,981	71,665	32.3	28 x 25= 700	351	6911	2320
Los Angeles AMF	2	155,875	45,285	29.0	36 x 32= 1152	180	5845	1661
Omaha	3	167,752	47,752	28.5	33 x 31= 1023	199	4344	1676
Totals		1,036,691				1283	31995	9793

Table 1a - General physical data of surveyed post office facilities

WORK AREA	GREENSBORO	CHICAGO	BUFFALO	HOUSTON	NEW ORLEANS	LOS ANGELES	OMAHA
	Percent of Total Workroom Surveyed						
1	9.8	21.4	7.0	11.7	4.9	11.2	9.8
2	8.5	36.7	17.3	34.5	18.3	54.6	16.9
3	12.5	--	1.2	--	0.9	--	1.9
4	10.8	8.5	20.0	14.4	7.9	11.3	15.2
5	2.4	7.9	--	3.9	6.4	11.7	3.2
6	13.1	--	--	--	--	--	17.4
7	14.2	7.7	19.4	6.3	18.2	5.7	15.2
8	10.0	6.4	13.4	16.9	13.6	4.1	6.8
9	16.8	--	17.6	--	--	--	--
10	1.9	11.4	4.1	12.3	29.8	1.4	13.6

Table 1b - Distribution of workroom floor space into work areas.

SUMS OF STRINGS OF 5 CONSECUTIVE READINGS (PERIOD 2)

45.000	23.000	5.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	9.000	17.000	28.000	39.000	39.000	30.000	22.000
34.000	29.000	29.000	29.000	29.000	6.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	13.000	17.000	17.000	17.000	17.000
4.000	.000	.000	5.000	34.000	34.000	34.000	34.000	29.000	.000
.000	.000	.000	.000	.000	12.000	17.000	17.000	17.000	17.000
5.000	.000	.000	.000	.000	4.000	8.000	8.000	8.000	8.000
4.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	4.000	17.000	17.000	17.000
17.000	25.000	27.000	33.000	33.000	44.000	49.000	34.000	28.000	51.000
105.000	121.000	121.000	140.000	172.000	122.000	89.000	89.000	78.000	33.000
37.000	80.000	122.000	120.000	147.000	154.000	163.000	201.000	236.000	253.000
254.000	225.000	176.000	150.000	115.000	159.000	165.000	197.000	269.000	308.000
278.000	256.000	226.000	284.000	255.000	278.000	284.000	319.000	186.000	201.000
189.000	223.000	197.000	218.000	231.000	271.000	265.000	284.000	327.000	341.000
276.000	261.000	200.000	124.000	68.000	170.000	180.000	198.000	237.000	241.000
112.000	76.000	58.000	26.000	45.000	45.000	45.000	45.000	38.000	4.000
61.000	76.000	91.000	103.000	142.000	119.000	111.000	134.000	127.000	94.000
101.000	105.000	105.000	100.000	130.000	112.000	117.000	79.000	95.000	84.000
61.000	50.000	100.000	96.000	67.000	125.000	165.000	171.000	178.000	178.000
120.000	130.000	108.000	146.000	170.000	184.000	129.000	95.000	49.000	25.000
15.000	44.000	114.000	127.000	133.000	129.000	119.000	54.000	52.000	68.000
68.000	49.000	44.000	22.000	.000	.000	.000	23.000	27.000	33.000
53.000	59.000	111.000	136.000	194.000	259.000	264.000	189.000	209.000	193.000
165.000	199.000	239.000	239.000	232.000	175.000	145.000	127.000	137.000	108.000
126.000	138.000	121.000	92.000	126.000	152.000	141.000	185.000	188.000	178.000
134.000	128.000	146.000	201.000	217.000	266.000	293.000	282.000	231.000	269.000
253.000	274.000	233.000	246.000	193.000	160.000	119.000	159.000	169.000	162.000
241.000	289.000	300.000	249.000	253.000	201.000	136.000	70.000	65.000	63.000
87.000	147.000	176.000	184.000	177.000	151.000	155.000	157.000	207.000	193.000
246.000	244.000	314.000	292.000	328.000	273.000	211.000	110.000	77.000	56.000
51.000	107.000	113.000	118.000	195.000	215.000	188.000	235.000	255.000	162.000
135.000	182.000	226.000	220.000	263.000	294.000	218.000	190.000	174.000	121.000
124.000	210.000	167.000	260.000	350.000	317.000	231.000	259.000	248.000	239.000
329.000	412.000	418.000	386.000	334.000	289.000	211.000	151.000	108.000	123.000
132.000	172.000	243.000	323.000	387.000	405.000	384.000	318.000	245.000	152.000
142.000	196.000	249.000	258.000	288.000	299.000	251.000	200.000	240.000	239.000
196.000	175.000	195.000	188.000	167.000	204.000	233.000	274.000	239.000	228.000
186.000	163.000	119.000	115.000	126.000	114.000	163.000	189.000	221.000	205.000
184.000	120.000	88.000	105.000	154.000	199.000	290.000	302.000	237.000	196.000
155.000	68.000	38.000	27.000	81.000	100.000	100.000	118.000	154.000	136.000
166.000	250.000	259.000	245.000	257.000	240.000	193.000	203.000	181.000	148.000
118.000	97.000	110.000	173.000	192.000	212.000	279.000	284.000	227.000	182.000
155.000	73.000	22.000							

Table 2 - Sample of conveyor mail load data: Pounds on a 10-ft length of 42-in conveyor determined at intervals of 2 ft of belt travel.

FACILITY: GREENSBORO

Grid UDL, psf	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	1	2	3	1	0
4	1	1	1	1	0	5	9	3	2	1
6	5	0	0	2	1	1	0	1	4	0
8	1	0	5	4	1	2	1	1	2	0
10	1	2	4	1		3			3	1
12		3	0	1					2	
14			0							
16			1							
Total	9	6	11	9	2	12	12	8	14	2

Facility Total: 85

Table 3a - Frequencies of various uniformly distributed load intensities for grid squares in Greensboro facility.

FACILITY: CHICAGO

Grid UDL, psf	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	1	0	*	0	0	*	0	0	*	0
2	2	0		0	0		0	0		1
4	3	1		0	0		2	2		0
6	2	7		0	3		1	0		1
8	3	9		1	0		2	1		1
10	1	1		3	1		0			3
12	0	0					0			
14	1	1					0			
16		1					0			
18							1			
Total	13	20	--	4	4	--	6	3	--	6

Facility Total: 56

* not present

Table 3b - Frequencies of various uniformly distributed load intensities for grid squares in Chicago facility.

FACILITY: BUFFALO

Grid UDL, psf	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	0	0	0	0	*	*	0	0	0	0
2	1	1	0	0			2	3	0	0
4	1	0	0	0			8	7	0	1
6	2	2	0	1			2	1	3	0
8	1	1	0	3			0	0	4	0
10	1	5	1	8			4	0	5	2
12		7	0	5			1	0	3	1
14		3	0				1	0	2	
16		1	0				0	1	0	
18			0				1	0	1	
20			0					0	1	
22			1					0	1	
24								1		
Total	6	20	2	17	--	--	19	13	20	4

Facility Total: 101

* not present

Table 3c - Frequencies of various uniformly distributed loads intensities for grid squares in Buffalo facility.

FACILITY: HOUSTON

Grid UDL, psf	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	0	0	*	0	0	*	0	1	*	0
2	0	6		0	0		6	13		2
4	3	9		6	3		8	24		6
6	3	13		5	1		2	12		10
8	3	24		6	3		2	7		9
10	5	13		8	1			1		3
12	5	6		4	0			2		3
14	3	2		2	1			1		2
16	2	5		0						1
18	4	4		3						0
20	1	10		2						2
22	2	6		3						0
24	0	2		1						1
26	1	5		0						1
28	2			1						0
30	0			1						0
32	0									0
34	0									0
36	0									0
38	1									0
40										0
42										0
44										0
46										0
48										0
50										0
52										0
54										0
56										0
58										1
Total	35	105	--	42	9	--	18	61	--	41

Facility Total: 311

* not present

Table 3d - Frequencies of various uniformly distributed load intensities for grid squares in Houston facility.

FACILITY: NEW ORLEANS

Grid UDL, psf	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	0	0	0	0	0	*	1	1	*	2
2	0	1	0	0	2		4	8		10
4	1	3	0	1	1		7	12		12
6	2	14	0	5	5		11	7		10
8	6	10	0	5	7		18	7		5
10	3	11	0	6	2		9	2		11
12	0	11	1	5	2		8	1		14
14	0	4	0	3	2		2	2		8
16	2	0	1	5	0		1	0		7
18	1	4	0	1	1		0	4		5
20	2	1	0	0			1			5
22		3	0	0			0			6
24		1	1	1			0			3
26							0			0
28							0			1
30							0			1
32							1			2
34							0			0
36							0			2
38							0			1
40							0			
42							0			
44							0			
46							0			
48							1			
50							0			
52							0			
54							1			
Total	17	63	3	32	22	--	65	44	--	105

Facility Total: 351

* not present

Table 3e - Frequencies of various uniformly distributed loads intensities for grid squares in New Orleans facility.

FACILITY: LOS ANGELES

Grid UDL, psf	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	0	0	*	0	0	*	0	0	*	0
2	1	4		4	2		2	0		2
4	3	10		5	5		0	1		1
6	2	3		4	2		4	2		2
8	3	8		5	4		2	3		1
10	2	22		2	1		1			0
12	1	19		2	1		1			1
14	1	11		2	0					2
16	1	7		1	0					0
18	3	2			1					0
20	0	2			1					0
22	2	3			1					0
24		0								0
26		0								1
28		1								
Total	19	92	--	25	18	--	10	6	--	10

Facility Total : 180

* not present

Table 3f - Frequencies of various uniformly distributed loads intensities for grid squares in Los Angeles facility.

FACILITY: OMAHA

Grid UDL, psf	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	0	0	0	0	0	1	1	0	*	0
2	1	1	0	1	0	3	4	3		0
4	1	2	0	3	0	8	12	3		1
6	1	6	1	3	2	1	4	5		2
8	6	5	2	8	4	5	1	2		2
10	2	8	1	5		4	1	2		2
12	0	4		4		3	0	0		4
14	3	4		2		5	0	1		5
16	1	0		2		0	2			5
18	1	3		1		0	1			1
20	2	1		1		1	0			1
22	2	0				0	0			1
24	0	1				0	1			0
26	0					0				2
28	0					0				1
30	1					0				0
32						0				0
34						0				1
36						0				
38						0				
40						0				
42						0				
44						0				
46						0				
48						0				
50						1				
Total	21	35	4	30	6	32	27	16	--	28

Facility Total: 199
* not present

Table 3g - Frequencies of various uniformly distributed load intensities for grid squares in Omaha facility.

FACILITY: GREENSBORO

Grid Occup. Space, %	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	1	0	0	0	0	0	0	0	0	0
5	0	1	0	0	0	0	0	0	1	0
10	1	0	1	1	0	6	0	0	0	0
15	1	0	0	0	0	1	2	1	2	1
20	2	0	3	4	1	2	3	2	4	0
25	3	0	3	1	1	2	4	2	4	0
30	1	1	2	1		1	3	3	3	0
35		2	1	2						1
40		1	0							
45		1	1							
Total	9	6	11	9	2	12	12	8	14	2

Facility Total: 85

Table 4a - Frequencies of various percentages of occupied space for grid squares in Greensboro facility.

FACILITY: CHICAGO

Grid Occup. Space, %	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	1	0	*	0	0	*	0	0	*	0
5	2	0		0	0		0	0		1
10	1	0		0	0		0	0		0
15	5	2		0	1		0	0		0
20	0	4		0	2		0	2		2
25	3	8		0	0		1	1		0
30	1	4		3	0		2			0
35		0		0	0		1			0
40		0		1	1		1			1
45		0					0			2
50		1					1			
55		0								
60		1								
Total	13	20	--	4	4	--	6	3	--	6

Facility Total: 56

* not present

Table 4b - Frequencies of various percentages of occupied space for grid squares in Chicago facility.

FACILITY: BUFFALO

	WORK AREAS									
Grid Occup. Space, %	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	0	1	0	0	*	*	0	0	0	0
5	1	0	0	0			1	0	0	0
10	0	1	0	0			1	1	1	0
15	2	0	0	0			2	6	0	1
20	1	3	1	1			4	4	3	0
25	2	1	0	3			4	0	4	1
30		4	0	4			3	1	5	0
35		6	0	4			3	0	4	0
40		4	0	4			0	0	2	1
45			1	1			0	0	1	1
50							0	0		
55							1	1		
Total	6	20	2	17	--	--	19	13	20	4

Facility Total: 101

* not present

Table 4c - Frequencies of various percentages of occupied space for grid squares in Buffalo facility.

FACILITY: HOUSTON

Grid Occup. Space, %	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	0	5	*	0	0	*	0	0	*	0
5	0	5		0	0		2	3		2
10	5	3		1	1		4	5		4
15	4	15		4	0		3	6		5
20	2	12		3	2		5	5		6
25	3	16		7	4		1	11		5
30	3	13		7	0		1	8		2
35	0	10		2	1		2	7		7
40	3	5		7	1			8		5
45	5	0		1				1		0
50	1	4		0				4		0
55	1	3		2				0		1
60	2	4		4				0		0
65	0	2		0				0		0
70	1	3		2				0		0
75	1	2		0				1		0
80	0	2		1				2		1
85	1	0		0						0
90	2	0		0						1
95	1	0		1						0
100		1								2
Total	35	105	--	42	9	--	18	61	--	41

Facility Total: 311

* not present

Table 4d - Frequencies of various percentages of occupied space for grid squares in Houston facility.

FACILITY: NEW ORLEANS

Grid Occup. Space, %	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	0	0	0	0	2	*	0	1	*	1
5	0	0	0	0	0		2	2		7
10	0	3	0	1	0		3	3		8
15	5	8	0	2	3		4	4		8
20	3	11	0	4	2		5	10		9
25	4	9	0	3	2		4	6		14
30	0	4	0	7	5		12	4		7
35	0	7	1	4	3		10	4		15
40	2	4	1	4	2		8	1		12
45	0	6	0	3	2		8	1		5
50	2	3	0	2	0		6	3		7
55	0	4	0	0	0		1	1		4
60	1	1	0	1	0		0	0		2
65		0	1	0	1		1	0		2
70		1		0			0	1		0
75		1		1			0	2		1
80		0					1	1		0
85		1								0
90										0
95										0
100										3
Total	17	63	3	32	22	--	65	44	--	105

Facility Total: 351

* not present

Table 4e - Frequencies of various percentages of occupied space for grid squares in New Orleans facility.

FACILITY: LOS ANGELES

Grid Occup. Space, %	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	0	1	*	2	1	*	2	0	*	0
5	2	7		2	1		0	0		0
10	0	5		2	1		0	0		1
15	3	8		3	2		0	1		1
20	2	15		2	4		0	1		2
25	1	18		7	2		3	1		1
30	4	20		2	2		4	2		0
35	1	7		0	1		0	1		1
40	0	6		0	1		1			1
45	0	1		0	0					0
50	1	3		5	0					0
55	0	1			0					1
60	1				0					0
65	1				0					0
70	3				1					0
75					1					0
80					1					1
85										0
90										0
95										1
Total	19	92	--	25	18	--	10	6	--	10

Facility Total: 180

* not present

Table 4f - Frequencies of various percentages of occupied space for grid squares in Los Angeles facility.

FACILITY: OMAHA

Grid Occup. Space, %	WORK AREAS									
	1	2	3	4	5	6	7	8	9	10
	Number of Occurrences									
0	0	0	0	0	0	0	1	0	*	0
5	2	1	0	2	0	5	3	1		0
10	0	2	0	3	0	1	0	2		0
15	1	7	1	1	0	7	3	3		2
20	1	8	1	4	0	4	7	0		1
25	4	2	1	7	2	1	4	0		8
30	2	4	1	5	1	3	3	2		7
35	1	5		5	2	2	2	5		2
40	2	3		0	1	2	1	3		3
45	1	1		2		0	1			1
50	1	2		0		2	1			1
55	4			1		2	0			2
60	0					1	1			1
65	0					0				
70	1					1				
75	0					0				
80	0					1				
85	0									
90	0									
95	0									
100	1									
Total	21	35	4	30	6	32	27	16	--	28

Facility Total: 199

* not present

Table 4g - Frequencies of various percentages of occupied space for grid squares in Omaha facility.

	WORK AREAS										
	1	2	3	4	5	6	7	8	9	10	Total
Gr-boro											
Area, sq.ft.	8512	7392	10806	9315	2069	11298	12306	8671	14535	1650	86554
Grid UDL, psf	5.9	10.0	9.2	7.6	7.3	6.3	3.9	4.2	7.4	7.6	6.7
Grid % Occ.	18.9	31.7	25.9	23.9	22.5	16.2	23.3	24.4	21.8	25.0	22.8
Chicago											
Area, sq.ft.	10917	18727	--	4329	4046	--	3923	3265	--	5820	51027
Grid UDL, psf	5.8	7.9	--	9.2	7.1	--	7.8	5.0	--	7.3	7.2
Grid % Occ.	15.4	27.0	--	32.5	23.7	--	35.0	21.7	--	29.2	25.0
Buffalo											
Area, sq.ft.	11178	27576	1944	31996	--	--	31011	21384	28116	6595	159800
Grid UDL, psf	6.1	10.7	15.7	10.0	--	--	7.0	5.9	11.1	8.9	9.1
Grid % Occ.	17.5	29.2	35.0	32.9	--	--	25.0	20.4	29.2	31.2	27.7
Houston											
Area, sq.ft.	22661	66874	--	27902	7460	--	12220	32748	--	23838	193703
Grid UDL, psf	14.0	11.5	--	12.0	7.1	--	3.9	4.9	--	10.1	9.8
Grid % Occ.	39.7	30.6	--	37.5	25.0	--	17.8	29.8	--	31.7	31.7
New Orleans											
Area, sq.ft.	10956	40559	2100	17523	14339	--	40481	30117	--	65906	221981
Grid UDL, psf	10.6	10.5	17.2	11.2	8.3	--	9.7	6.7	--	12.3	10.4
Grid % Occ.	27.9	32.5	46.7	33.6	28.4	--	33.7	29.5	--	32.4	32.0
Los Angeles											
Area, sq.ft.	17424	85217	--	17651	18306	--	8808	6336	--	2133	155875
Grid UDL, psf	11.1	11.0	--	7.2	8.3	--	6.5	6.8	--	9.5	9.7
Grid % Occ.	34.7	24.9	--	24.0	29.7	--	23.5	25.8	--	39.5	27.0
Omaha											
Area, sq.ft.	16499	28382	3243	25507	5342	29152	25472	11352	--	22803	167752
Grid UDL, psf	12.9	10.5	7.8	9.6	7.3	9.3	6.5	6.1	--	15.0	10.0
Grid % Occ.	38.3	25.7	22.5	26.0	31.7	28.3	24.3	26.6	--	32.7	28.5

Table 5 - Summary of work areas, mean values of grid square UDL and mean values of grid square % occupied space.

	WORK AREAS (Sq. Ft.)										
	1	2	3	4	5	6	7	8	9	10	Total
Houston											
1st Flr	3524	-	-	-	-	-	12220	32748	-	23838	72330
2nd Flr	19137	66874	-	27902	7460	-	-	-	-	-	121373
Facility Total	22661	66874	-	27902	7460	-	12220	32748	-	23838	193703
New Orleans											
1st Flr	-	4494	2100	7125	-	-	33246	30117	-	24761	101843
2nd Flr	10956	36065	-	10398	14339	-	7235	-	-	41145	120138
Facility Total	10956	40559	2100	17523	14339	-	40481	30117	-	65906	221981
Los Angeles											
1st Flr	3744	35037	-	7632	-	-	-	6336	-	2133	54882
2nd Flr	13680	50180	-	10019	18306	-	8808	-	-	-	100993
Facility Total	17424	85217	-	17651	18306	-	8808	6336	-	2133	155875
Omaha											
1st Flr	-	-	-	-	-	29152	-	-	-	14665	43817
2nd Flr	-	-	3243	16162	-	-	25472	11352	-	2342	58571
3rd Flr	16499	28382	-	9345	5342	-	-	-	-	5796	65364
Facility Total	16499	28382	3243	25507	5342	29152	25472	11352	-	22803	167752

Table 6 - Work area distribution by floors in 2 and 3 story facilities.

Grid Square UDL, psf

	WORK AREAS	1	2	3	4	5	6	7	8	9	10
1-story facilities	no. grids	28	46	13	30	6	12	37	24	34	12
	mean UDL	5.9	9.4	10.1	9.3	7.0	6.2	6.2	5.3	9.7	8.0
	st. dev.	3.2	3.3	4.4	2.1	1.7	2.9	4.1	5.0	4.4	3.2
2 & 3-story facilities	no. grids	92	295	7	129	55	32	120	127	--	184
	mean UDL	12.6	11.0	12.0	10.3	8.1	9.4	7.8	5.7	--	12.1
	st. dev.	6.9	5.6	6.2	5.5	4.4	8.8	7.4	3.7	--	8.5
All facil.	no. grids	120	341	20	159	61	44	157	151	34	196
	mean UDL	11.0	10.8	10.8	10.1	8.0	8.5	7.4	5.7	9.7	11.9
	st. dev.	6.9	5.4	5.0	5.0	4.2	7.7	6.8	3.9	4.4	8.3

Table 7 - Mean values of grid square uniformly distributed load intensities in combined similar work areas for various groups of facilities.

Grid Square % Occupied Space

	WORK AREAS	1	2	3	4	5	6	7	8	9	10
1-story facilities	no. grids	28	46	13	30	6	12	37	24	34	12
	% occup.	16.9	28.6	23.3	30.2	23.3	16.3	26.1	21.9	26.2	29.2
	st. dev.	8.6	11.0	10.9	8.0	8.8	7.4	9.9	9.1	8.5	14.1
2 & 3-story facilities	no. grids	92	295	7	129	55	32	120	127	--	184
	% occup.	36.2	28.7	32.9	31.2	28.6	28.3	28.3	29.1	--	32.7
	st. dev.	22.6	16.4	16.5	16.5	16.5	20.3	14.6	16.5	--	20.0
All facil.	no. grids	120	341	20	159	61	44	157	151	34	196
	% occup.	31.7	28.7	29.3	31.0	28.1	25.0	27.8	28.0	26.2	32.5
	st. dev.	21.8	15.8	13.0	15.3	15.9	18.4	13.6	15.8	8.5	19.7

Table 8 - Mean values of grid square occupied space percentages in combined similar work areas for various groups of facilities.

SUMMARY

Grid UDL's & % Occupied Space

Grid UDL, psf

	Gr-boro	Chicago	Buffalo	Houston	New Orleans	Los Angeles	Omaha
no. grids	85	56	101	311	351	180	199
mean UDL	6.7	7.2	9.1	9.8	10.4	9.7	10.0
st. dev.	3.1	3.3	4.5	7.2	7.5	5.3	6.5
99% level UDL	16	18	22	28	36	26	30

	1-story (3)	2 & 3-story (4)
no. grids	242	1041
mean UDL	7.9	10.1
st. dev.	4.0	6.8
99% level UDL	22	32

	All Facil. (7)
no. grids	1283
mean UDL	9.6
st. dev.	6.4
99% level UDL	30

Grid % Occupied Space

	Gr-boro	Chicago	Buffalo	Houston	New Orleans	Los Angeles	Omaha
no. grids	85	56	101	311	351	180	199
mean % occ.	22.7	25.0	27.7	31.7	32.0	27.0	28.5
st. dev.	8.7	11.3	10.7	20.2	16.8	16.4	15.2
99% level % occ.	45	60	50	85	70	60	60

	1-story (3)	2 & 3-story (4)
no. grids	242	1041
mean % occ.	25.3	30.4
st. dev.	10.5	17.8
99% level % occ.	55	80

	All Facil. (7)
no. grids	1283
mean % occ.	29.4
st. dev.	16.8
99% level % occ.	75

Table 9 - Summary of grid square UDL and % occupied space values for totals of different groups of facilities.

Facility	Work Floor				Work Area				
	Total Load kips	Area sq.ft.	UDL psf	Occupied Space %	Code	Total Load kips	Area sq.ft.	Maximum UDL psf	Occupied Space %
Greensboro	563	86,554	6.5	22.4	10	15	1,650	9.2	30.9
Chicago	353	51,027	6.9	24.1	4	39	4,329	9.1	31.3
Buffalo	1395	159,799	8.7	27.2	3	25	1,944	12.7	27.1
Houston									
1st floor	508	72,330	7.0	29.4	1	56	3,524	15.9	39.2
2nd floor	1316	121,373	10.8	30.3	1	243	19,137	12.7	36.7
Total	1825	193,703	9.4	30.0	1	299	22,661	13.2	37.1
New Orleans									
1st floor	1051	101,843	10.3	31.9	3	36	2,100	17.2	45.6
2nd floor	1269	120,138	10.6	32.6	7	85	7,235	11.7	38.0
Total	2320	221,981	10.5	32.3	3	36	2,100	17.2	45.6
Los Angeles									
1st floor	561	54,882	10.2	27.4	10	37	2,133	17.2	70.5
2nd floor	1099	100,993	10.9	30.0	2	617	50,180	12.3	27.9
Total	1661	155,875	10.7	29.0	10	37	2,133	17.2	70.5
Omaha									
1st floor	482	43,817	11.0	27.8	10	211	14,665	14.4	28.7
2nd floor	459	58,571	7.8	25.7	10	38	2,342	16.2	41.2
3rd floor	736	65,364	11.3	31.4	10	92	5,796	15.9	38.6
Total	1676	167,752	10.0	28.5	10	342	22,803	15.0	32.5

Table 10 - Maximum uniformly distributed load intensities observed in different size floor areas.

Facility	Grid Square					Grid Sector					
	Code* Grid sq. (work area)	Work Area UDL psf	Area sq.ft.	Maximum Grid UDL psf	Occupied Space %	Code* Sector (Gr.sq.) (work area)	Work Area UDL psf	Grid Square UDL psf	Area sq.ft.	Maximum Sector UDL psf	Occupied Space %
Greensboro	C-10 (3)	7.9	1089	15.9	41	3-4 (K-5) (6)	6.9	10.8	68	54	97
Chicago	E-1 (2)	7.4	1066	14.5	32	1-2 (E-1) (2)	7.4	14.5	67	87	58
Buffalo	E-14 (2)	11.1	1944	13.9	33	1-2 (A-4) (7)	6.9	12.4	121	55	81
Houston											
1st floor	J09 (10)	10.7	756	58.8	88	1-2 (J09) (10)	10.7	58.8	47.2	67	100
2nd floor	K02 (1)	12.7	756	26.3	57	1-2 (E01) (1)	12.7	38.7	47.2	86	80
1st & 2nd floor	J09 (10)	10.7	756	58.8	88	1-2 (E01) (1)	13.2	38.7	47.2	86	80
New Orleans											
1st floor	C08 (7)	8.9	700	54.9	51	2-3 (C08) (7)	8.9	54.9	43.8	111	95
2nd floor	E-18 (2)	10.8	700	23.5	57	1-2 (P04) (7)	11.7	33.9	43.8	137	96
1st & 2nd floor	C08 (7)	9.4	700	54.9	51	1-2 (P04) (7)	9.4	33.9	43.8	137	96

* Cf. Ref. [2], [3]

Table 10 (cont.- i) - Maximum uniformly distributed load intensities observed in different size floor areas.

Facility	Grid Square					Grid Sector					
	Code* Grid sq. (work area)	Work Area UDL psf	Area sq.ft.	Maximum Grid UDL psf	Occupied Space %	Code* Sector (Gr.sq.) (work area)	Work Area UDL psf	Grid Square UDL psf	Area sq.ft.	Maximum Sector UDL psf	Occupied Space %
Los Angeles											
1st floor	G09 (2)	11.3	1152	17.3	41	1-2 (F-10) (2)	11.3	26.3	72	39	89
2nd floor	B09 (1)	12.2	1152	22.5	63	0-3 (B12) (2)	12.3	27.5	144	125	19
1st & 2nd floor	B09 (1)	11.8	1152	22.5	63	0-3 (B12) (2)	11.9	27.5	144	125	19
Omaha											
1st floor	D12 (6)	9.3	1023	49.7	68	1-2 (C13) (10)	14.4	21.2	63.9	163	86
2nd floor	C07 (7)	6.6	1023	23.0	62	1-2 (C10) (7)	6.6	15.2	63.9	70	38
3rd floor	A12 (1)	12.9	1023	31.2	99	1-4 (B13) (10)	15.9	20.9	63.9	84	56
1st, 2nd & 3rd floor	D12 (6)	9.3	1023	49.7	68	1-2 (C13) (10)	15.0	21.2	63.9	163	86

* Cf. Ref. [3], [4]

Table 10 - Maximum uniformly distributed load intensities (cont.- ii) observed in different size floor areas.

WORK AREA	GREENSBORO	CHICAGO	BUFFALO	HOUSTON 1st floor	HOUSTON 2nd floor	NEW ORLEANS 1st floor	NEW ORLEANS 2nd floor	LOS ANGELES 1st floor	LOS ANGELES 2nd floor	OMAHA 1st floor	OMAHA 2nd floor	OMAHA 3rd floor
	Maximized UDL for Average Occupied Space, psf											
1	12	17	11	24	52	--	33	15	37	--	--	26
2	15	18	24	--	22	20	27	16	21	--	--	25
3	11	--	11	--	--	23	--	--	--	--	12	--
4	15	16	22	--	36	22	18	8	15	--	19	16
5	8	13	--	--	14	--	21	--	22	--	--	13
6	15	--	--	--	--	--	--	--	--	24	--	--
7	11	13	21	10	--	43	40	--	13	--	16	--
8	12	9	16	17	--	22	--	12	--	--	14	--
9	15	--	30	--	--	--	--	--	--	--	--	--
10	11	17	17	40	--	52	29	24	--	46	23	31

Table 11 - Maximized grid square UDL determined by applying upper limit discrete loads over average occupied grid square area.

WORK AREA	GREENSBORO	CHICAGO	BUFFALO	HOUSTON 1st floor	HOUSTON 2nd floor	NEW ORLEANS 1st floor	NEW ORLEANS 2nd floor	LOS ANGELES 1st floor	LOS ANGELES 2nd floor	OMAHA 1st floor	OMAHA 2nd floor	OMAHA 3rd floor
	EUDL for Maximum Loads on Average Occupied Space, psf											
1	51	79	51	66	147	--	123	39	122	--	--	67
2	45	65	63	--	67	59	66	52	63	--	--	86
3	44	--	35	--	--	59	--	--	--	--	41	--
4	58	61	59	--	88	62	54	31	46	--	66	54
5	36	58	--	--	58	--	64	--	66	--	--	41
6	54	--	--	--	--	--	--	--	--	81	--	--
7	32	51	73	42	--	105	112	--	53	--	57	--
8	47	38	60	51	--	66	--	40	--	--	41	--
9	57	--	91	--	--	--	--	--	--	--	--	--
10	30	95	49	103	--	141	88	45	--	159	68	113

Table 12 - Equivalent uniformly distributed loads (EUDL for 1-way slab) determined by applying upper limit discrete loads over central average occupied grid square area.

SAMPLE SIZE IS 443 MAXIMUM VALUE IS 11.943
TOLERANCE LIMITS (.00, 8.80) FOR COVERAGE= .90, PROBABILITY= .90
STANDARD DEVIATION= 2.9 MEAN= 3.8

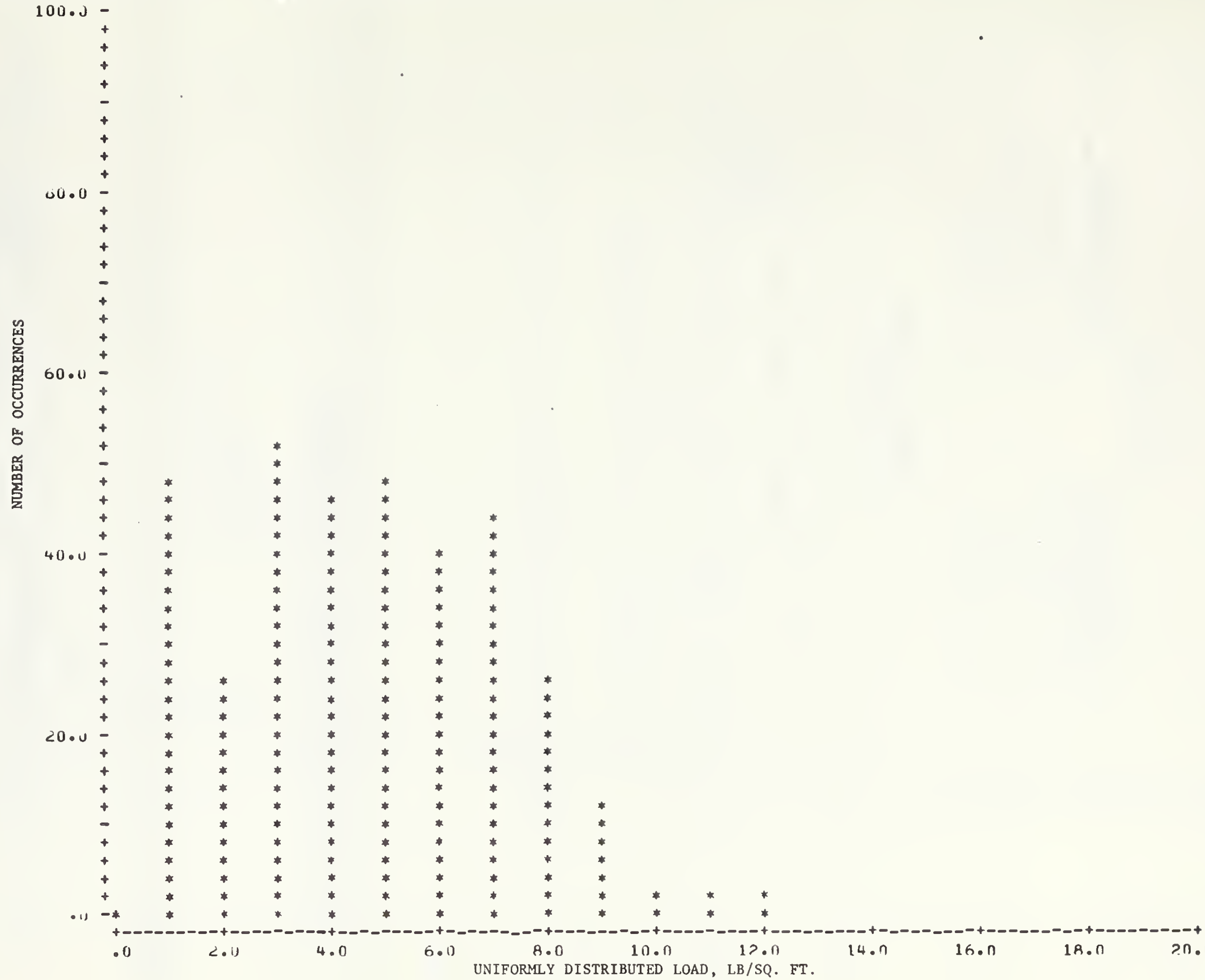

Figure 1 - Sample histogram of observed conveyor belt loadings, in psf, based on data of Table 2.

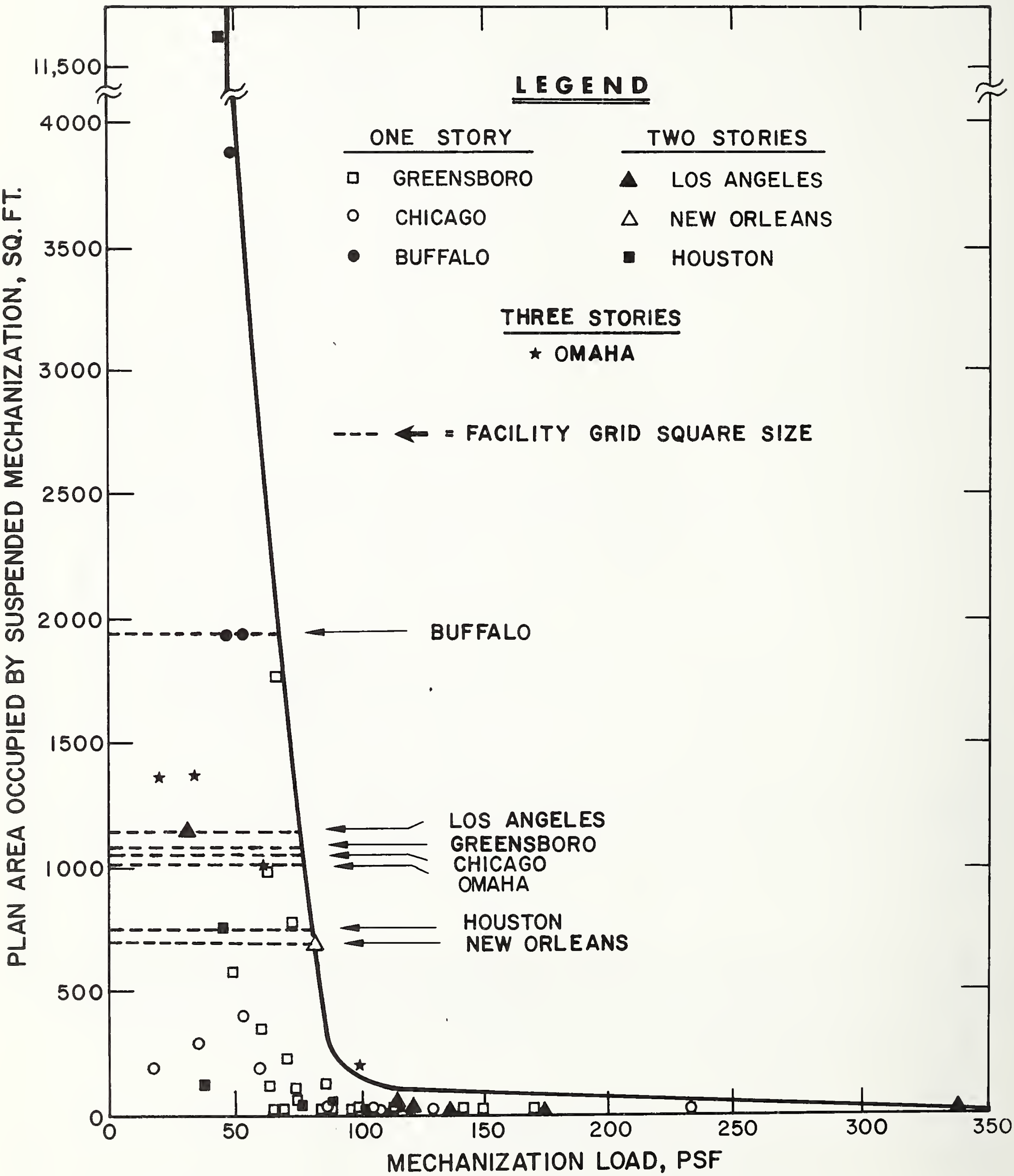

Figure 2 - Plot of suspended mechanization loads vs. plan area of mechanization sections.

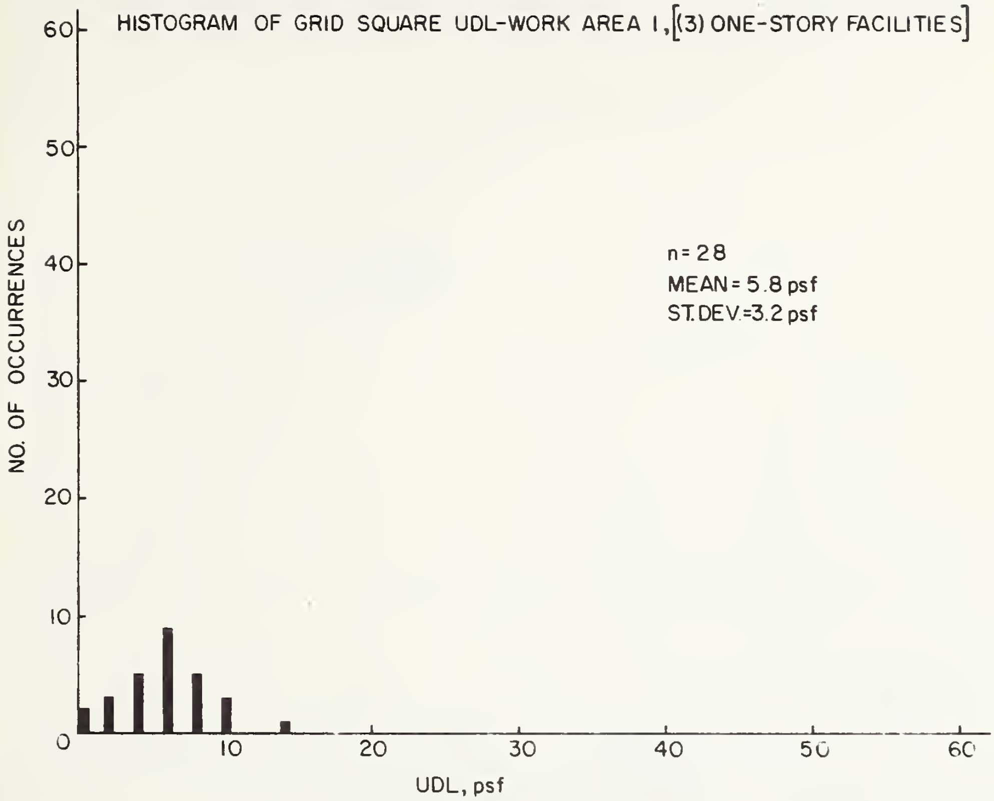

Figure 3a - Histogram of grid square uniformly distributed load intensities in work area 1 for 3 combined one-story facilities.

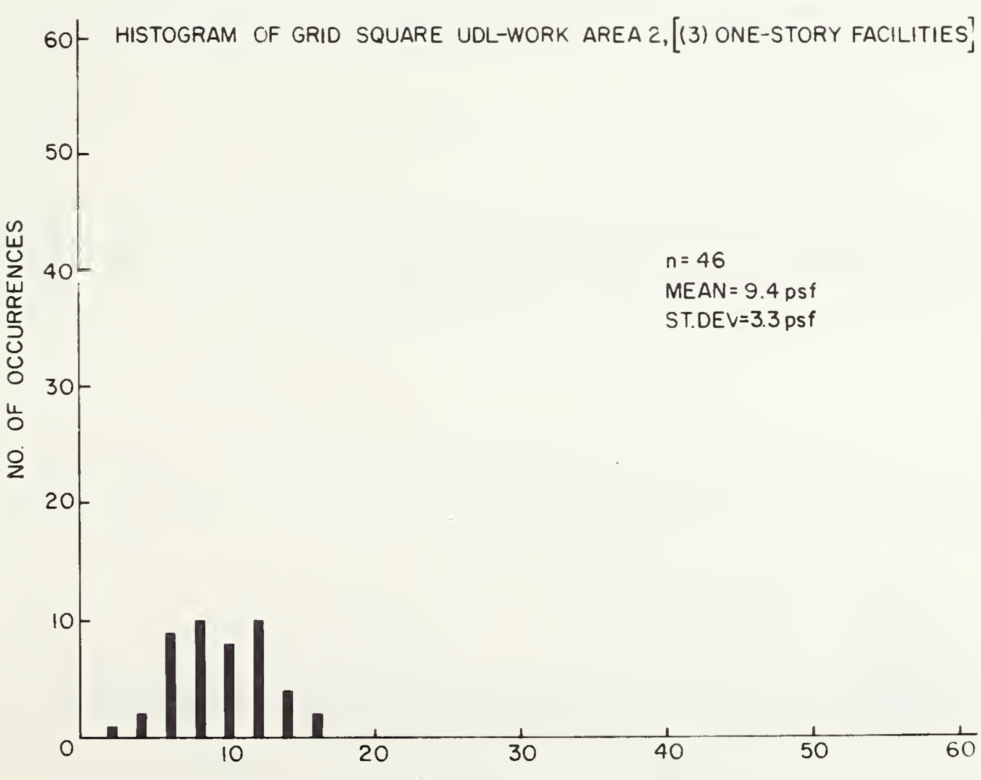

Figure 3b - Histogram of grid square uniformly distributed load intensities in work area 2 for 3 combined one-story facilities.

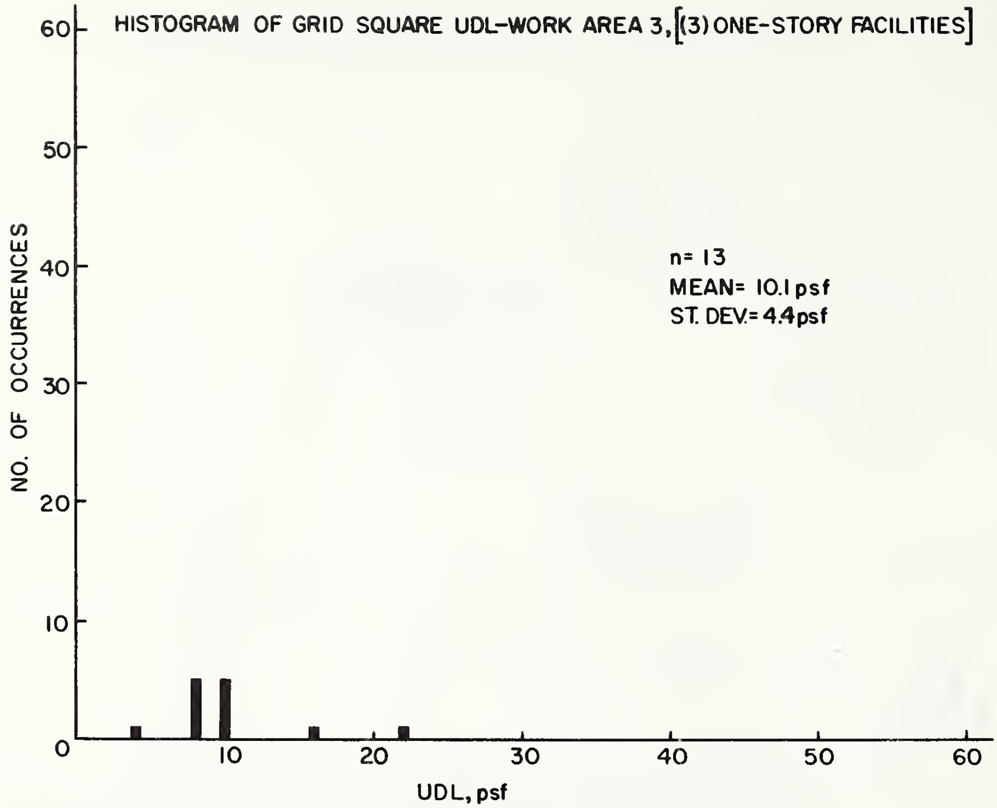

Figure 3c - Histogram of grid square uniformly distributed load intensities in work area 3 for 3 combined one-story facilities.

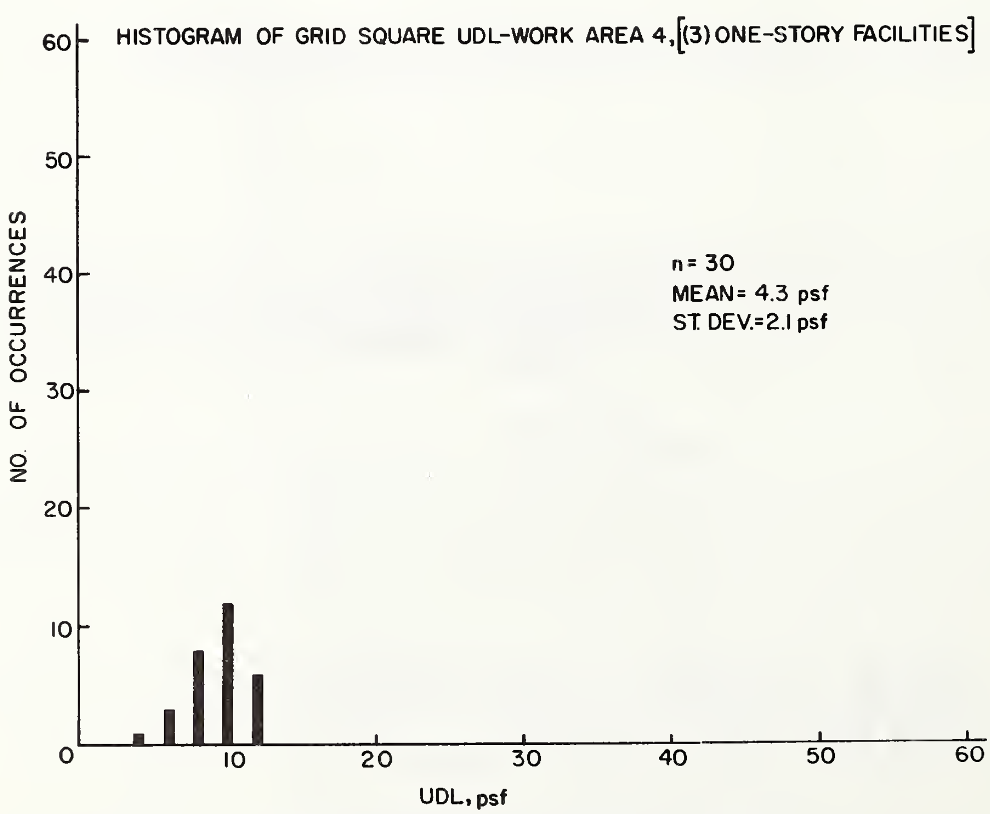

Figure 3d - Histogram of grid square uniformly distributed load intensities in work area 4 for 3 combined one-story facilities.

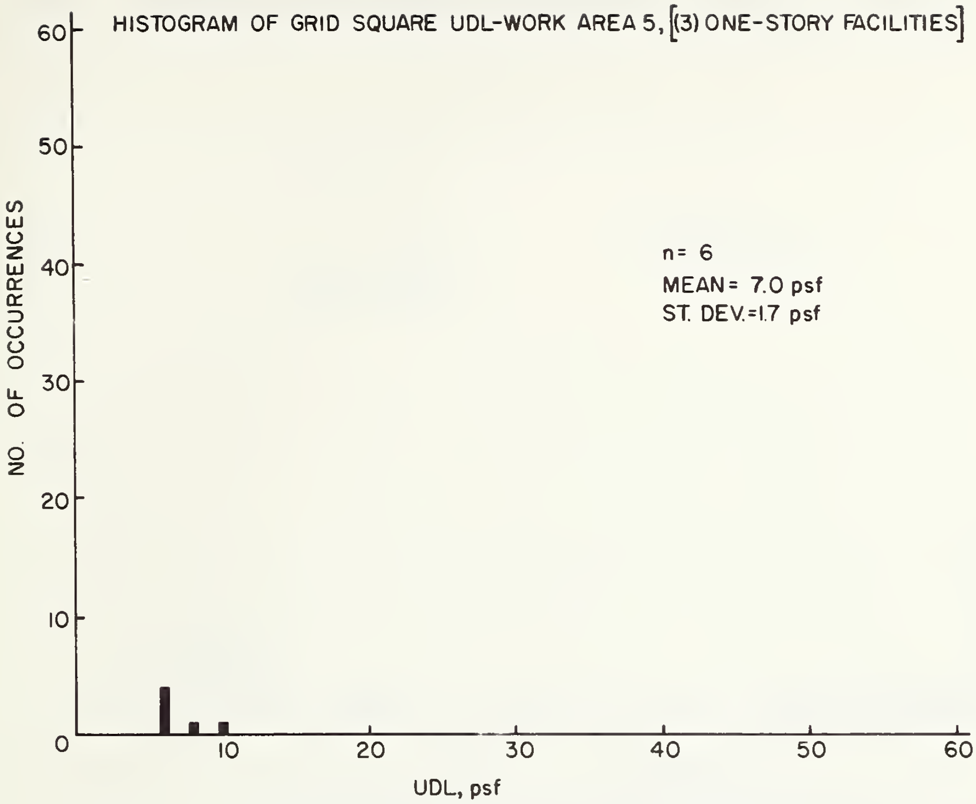

Figure 3e - Histogram of grid square uniformly distributed load intensities in work area 5 for 3 combined one-story facilities.

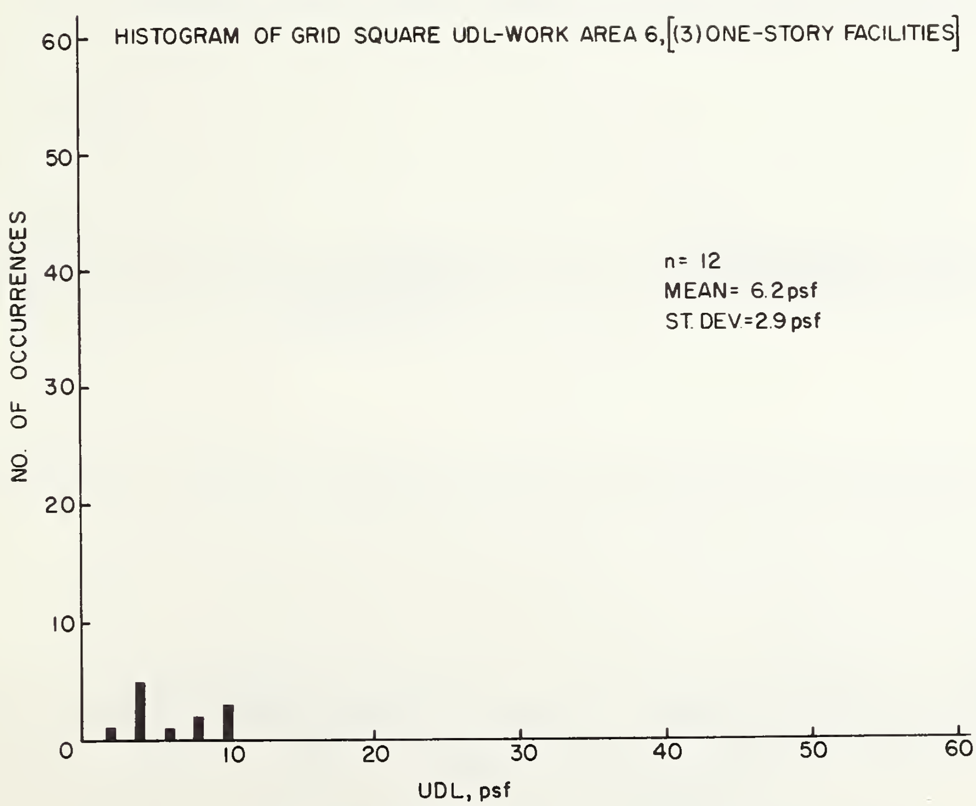

Figure 3f - Histogram of grid square uniformly distributed load intensities in work area 6 for 3 combined one-story facilities.

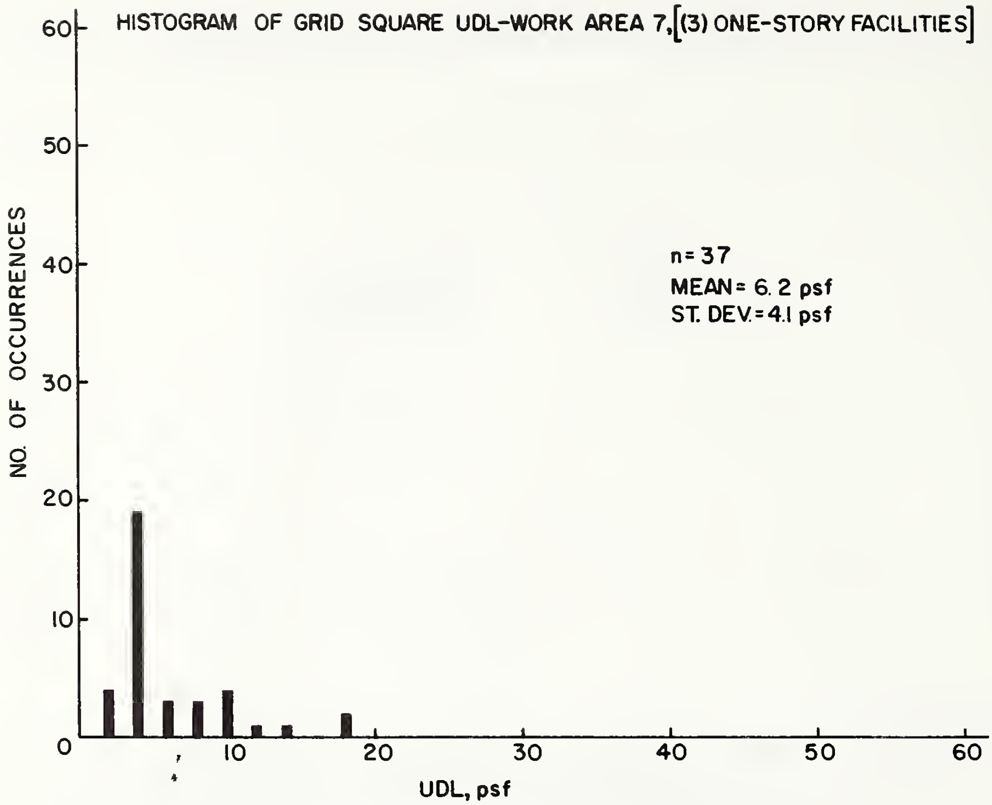

Figure 3g - Histogram of grid square uniformly distributed load intensities in work area 7 for 3 combined one-story facilities.

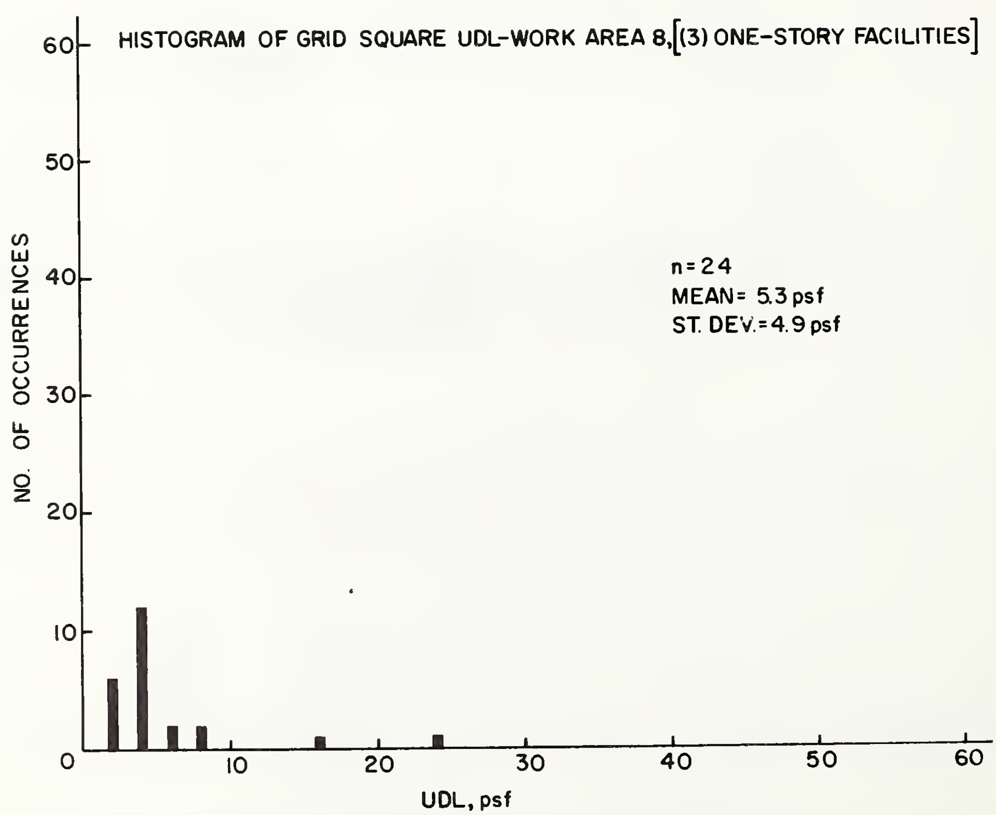

Figure 3h - Histogram of grid square uniformly distributed load intensities in work area 8 for 3 combined one-story facilities.

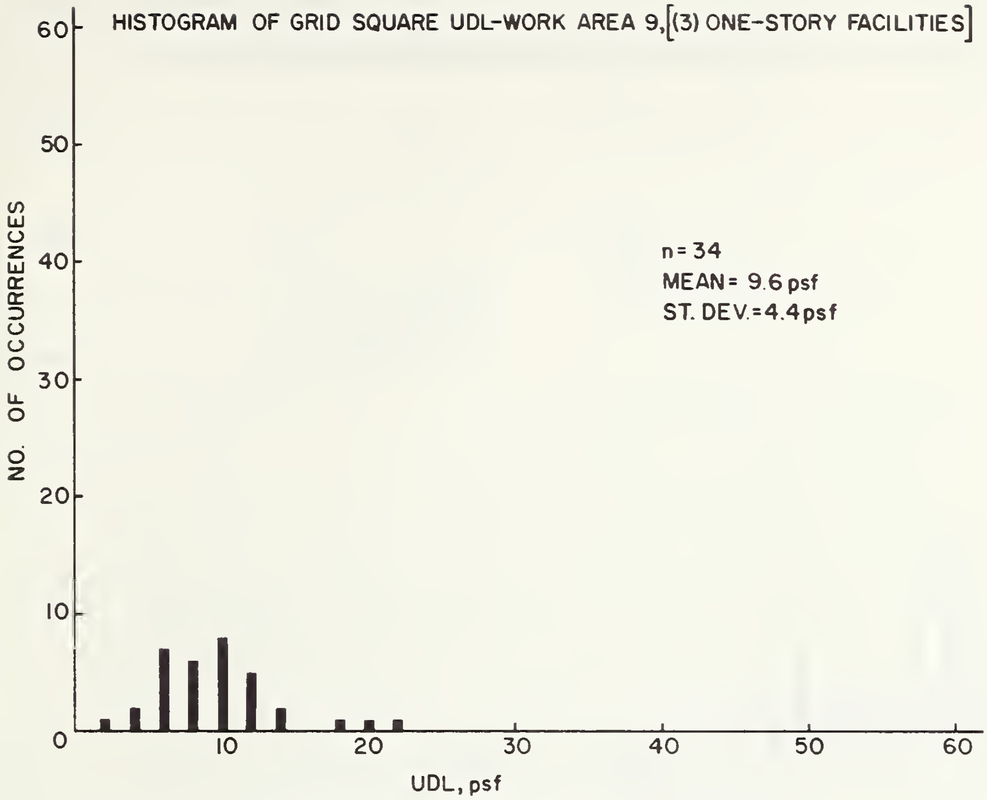

Figure 3i - Histogram of grid square uniformly distributed load intensities in work area 9 for 3 combined one-story facilities.

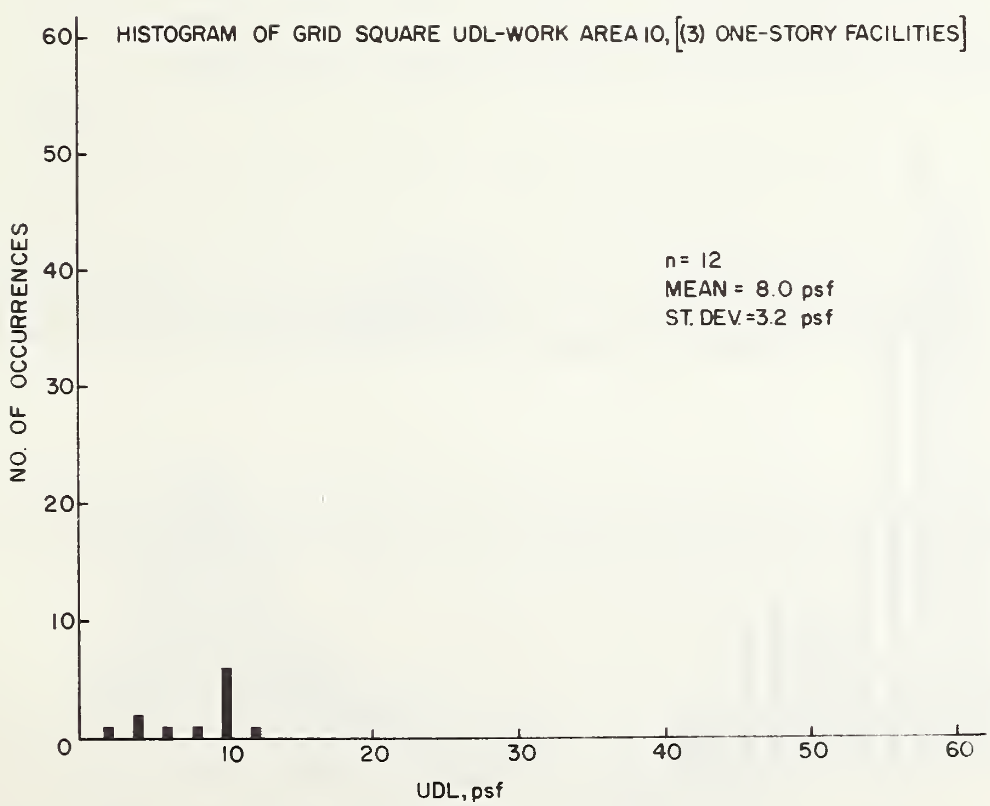

Figure 3j - Histogram of grid square uniformly distributed load intensities in work area 10 for 3 combined one-story facilities.

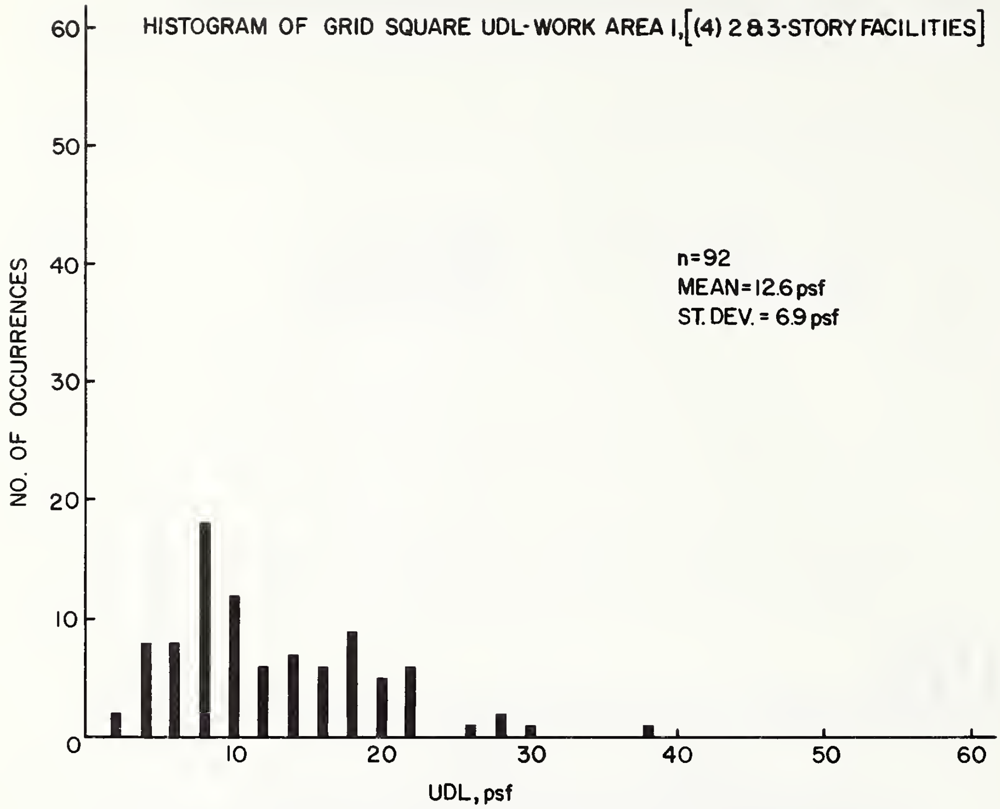

Figure 4a - Histogram of grid square uniformly distributed load intensities in work area 1 for 4 combined 2 and 3-story facilities.

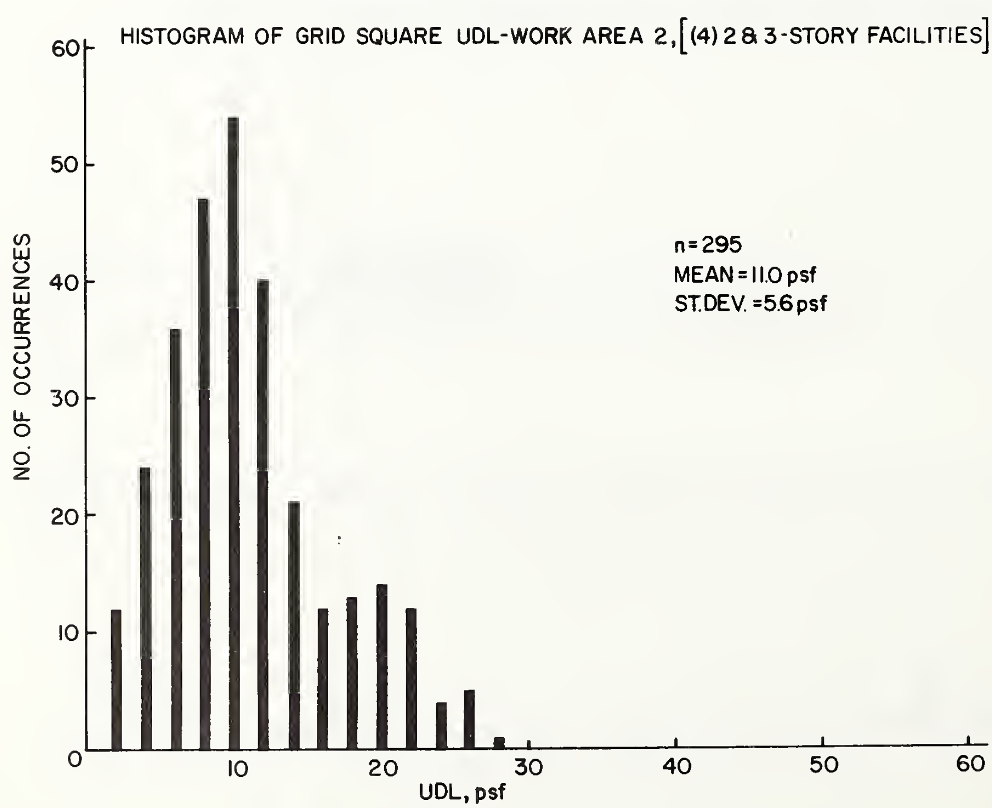

Figure 4b - Histogram of grid square uniformly distributed load intensities in work area 2 for 4 combined 2 and 3-story facilities.

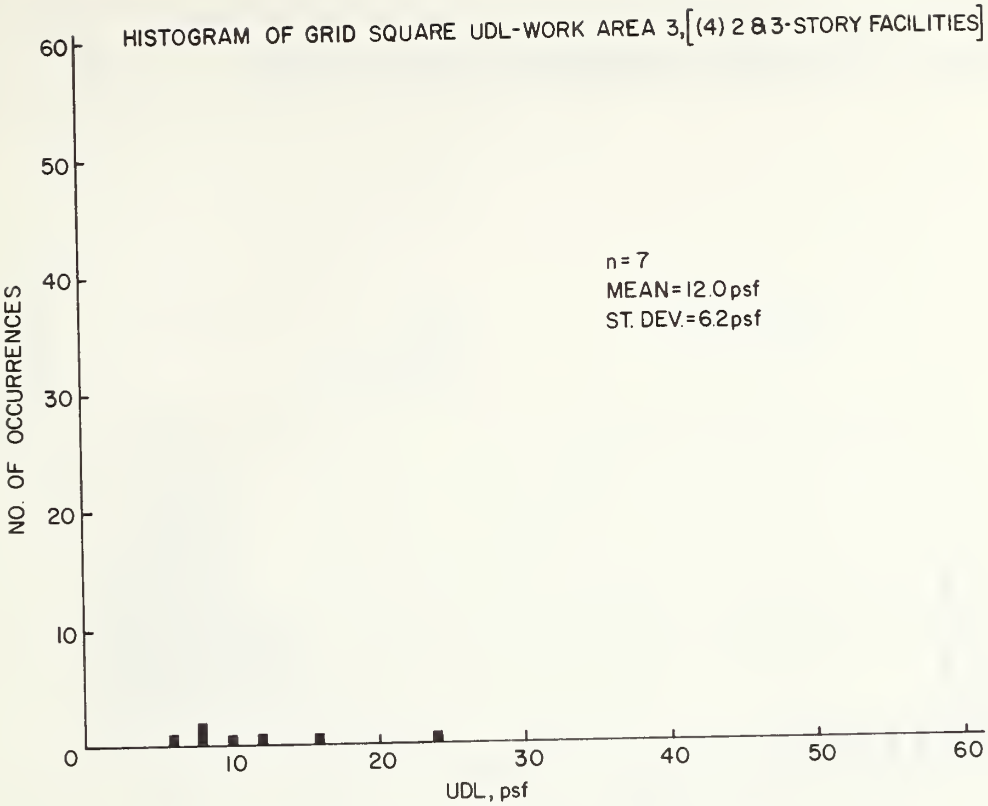

Figure 4c - Histogram of grid square uniformly distributed load intensities in work area 3 for 4 combined 2 and 3-story facilities.

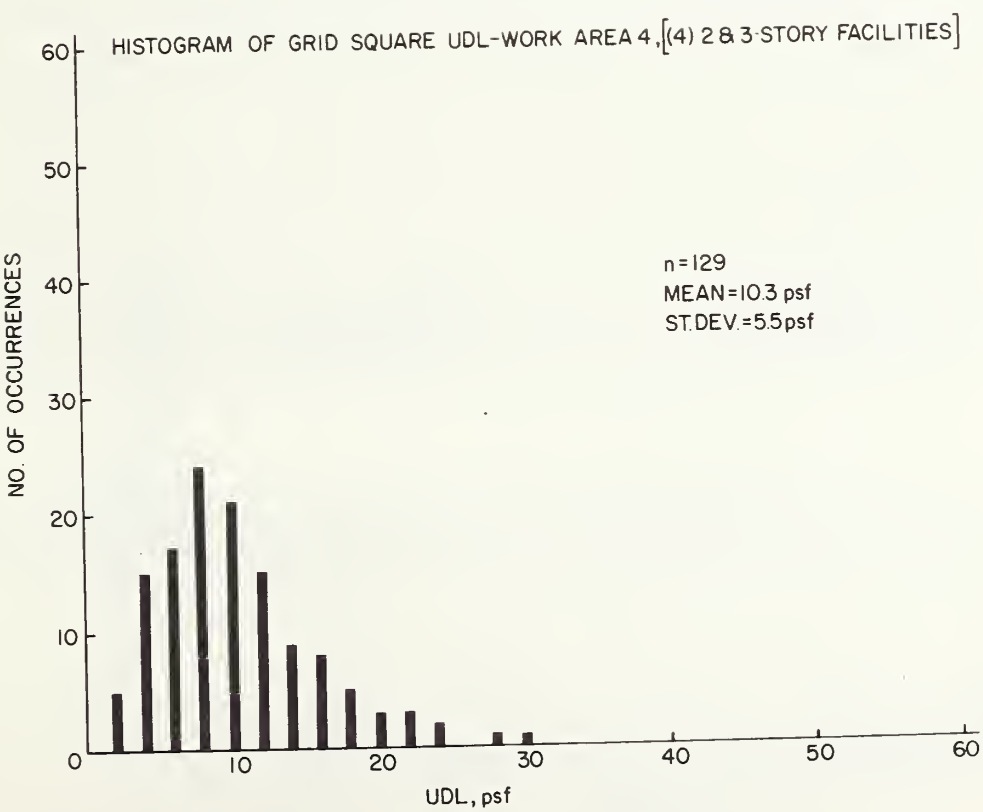

Figure 4d - Histogram of grid square uniformly distributed load intensities in work area 4 for 4 combined 2 and 3-story facilities.

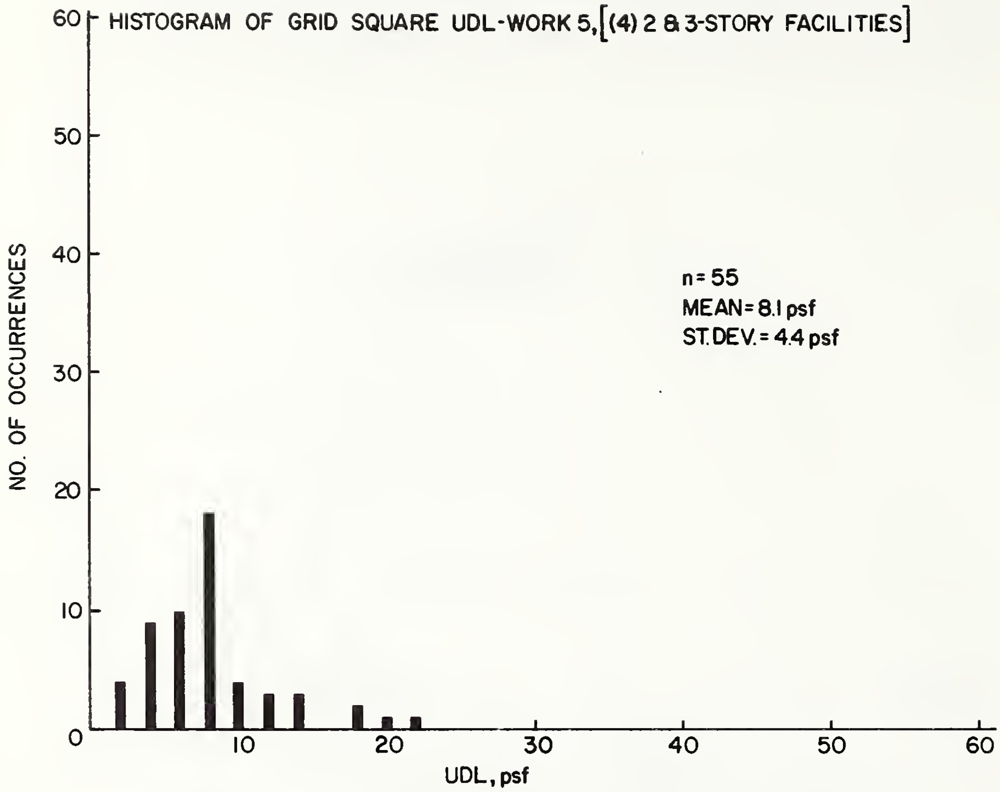

Figure 4e - Histogram of grid square uniformly distributed load intensities in work area 5 for 4 combined 2 and 3-story facilities.

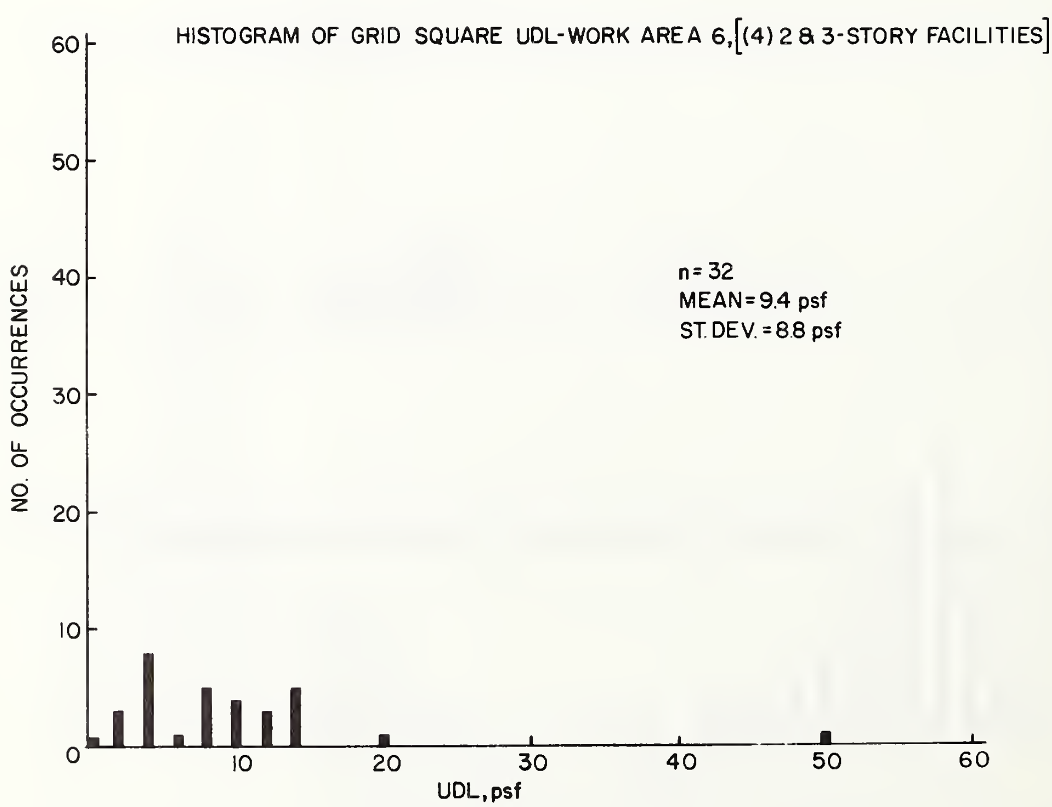

Figure 4f - Histogram of grid square uniformly distributed load intensities in work area 6 for 4 combined 2 and 3-story facilities.

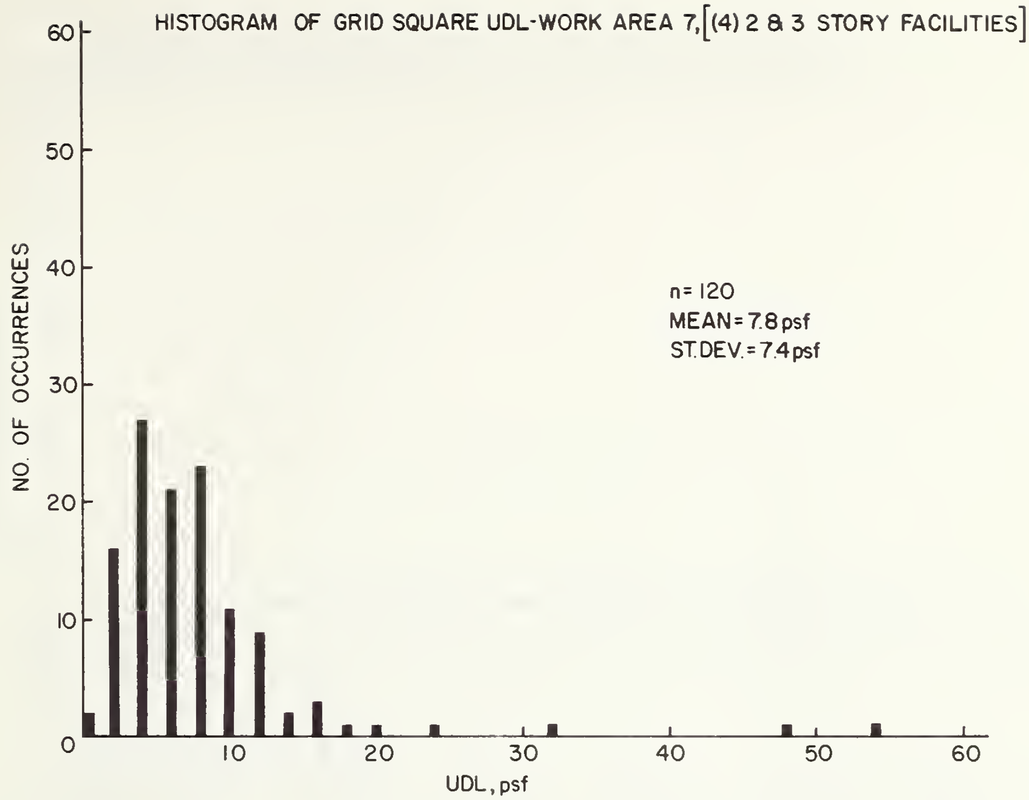

Figure 4g - Histogram of grid square uniformly distributed load intensities in work area 7 for 4 combined 2 and 3-story facilities.

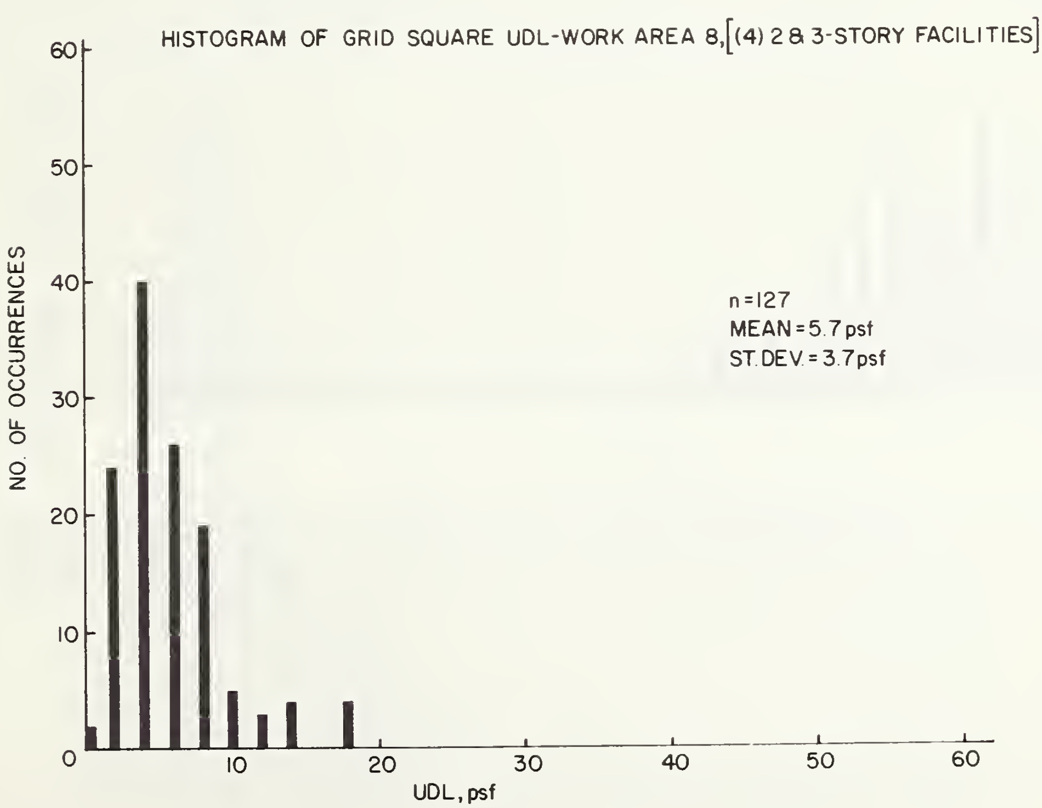

Figure 4h - Histogram of grid square uniformly distributed load intensities in work area 8 for 4 combined 2 and 3-story facilities.

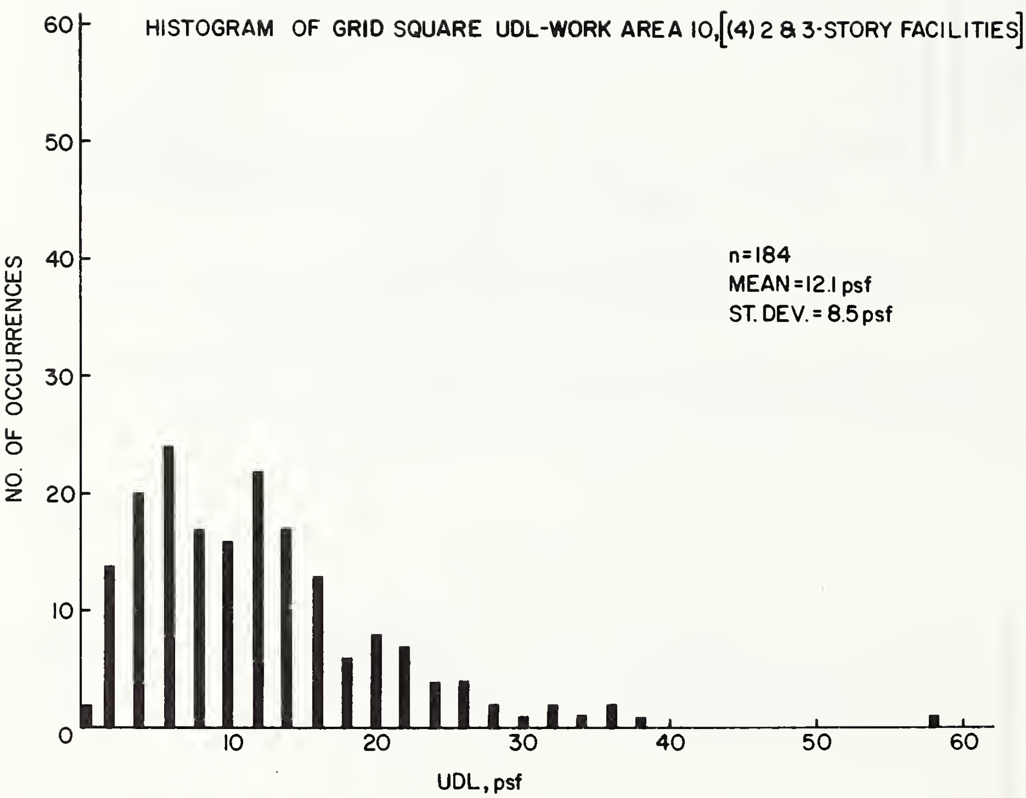

Figure 4i - Histogram of grid square uniformly distributed load intensities in work area 10 for 4 combined 2 and 3-story facilities.

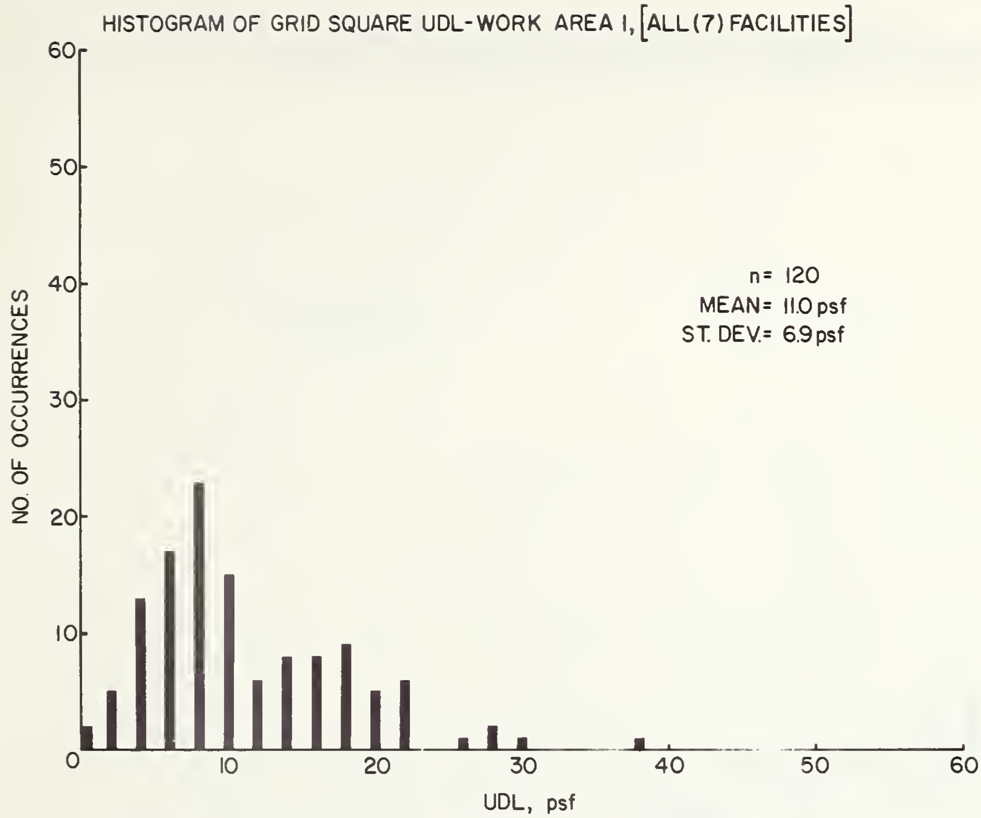

Figure 5a - Histogram of grid square uniformly distributed load intensities in work area 1 for all 7 combined facilities.

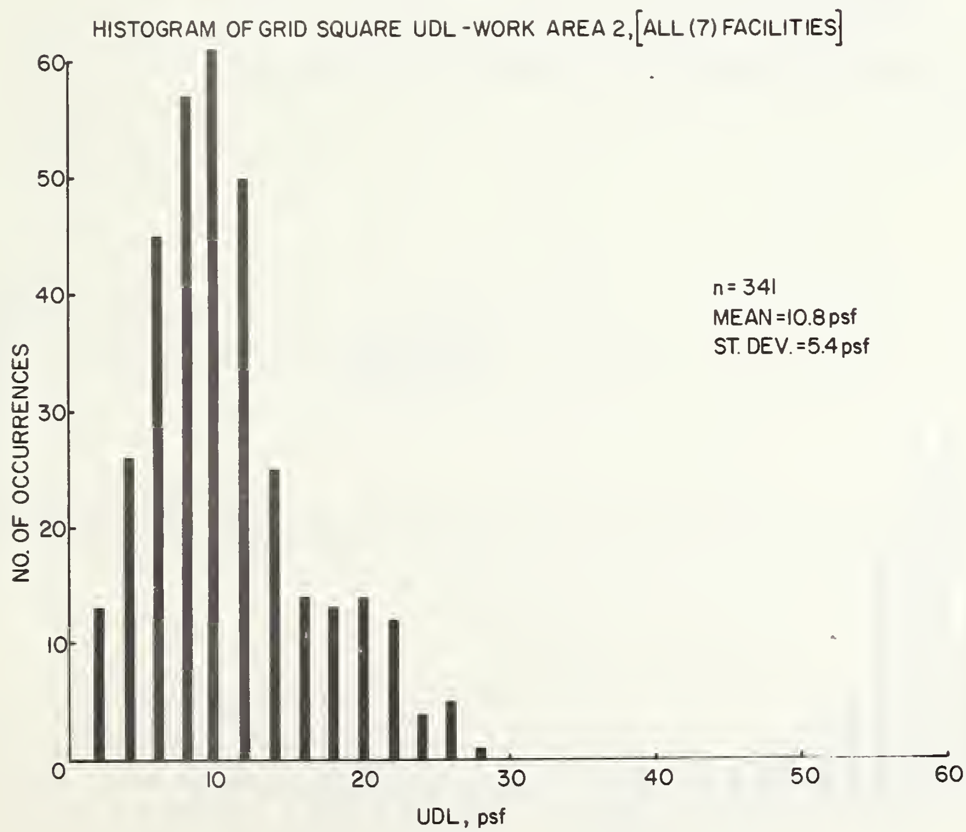

Figure 5b - Histogram of grid square uniformly distributed load intensities in work area 2 for all 7 combined facilities.

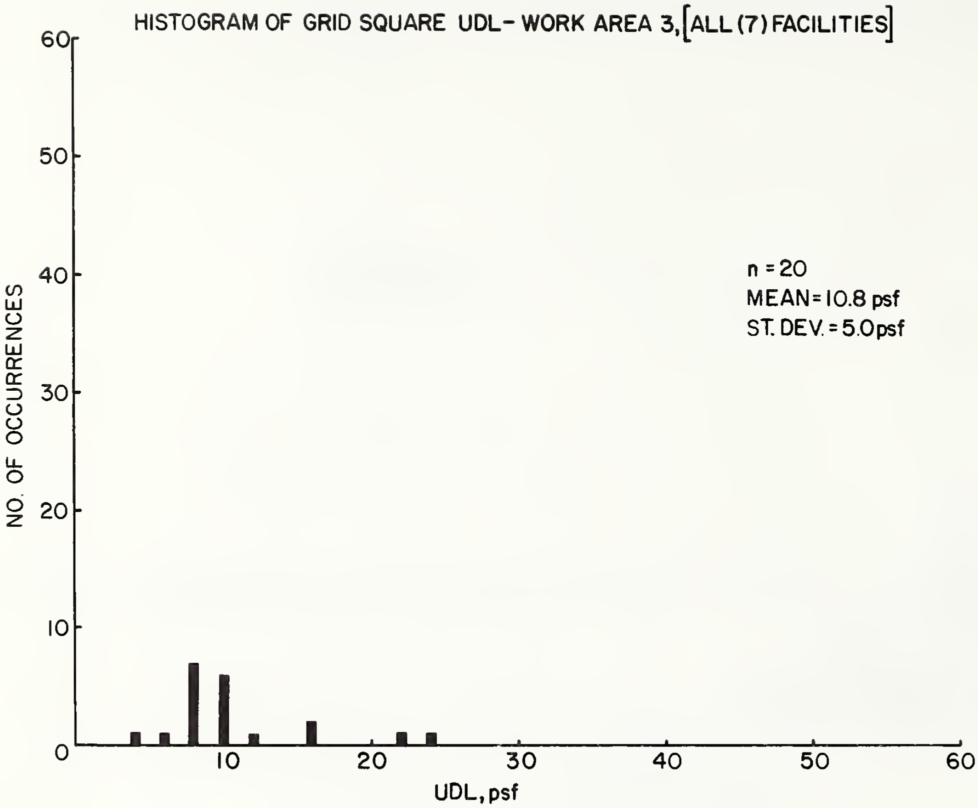

Figure 5c - Histogram of grid square uniformly distributed load intensities in work area 3 for all 7 combined facilities.

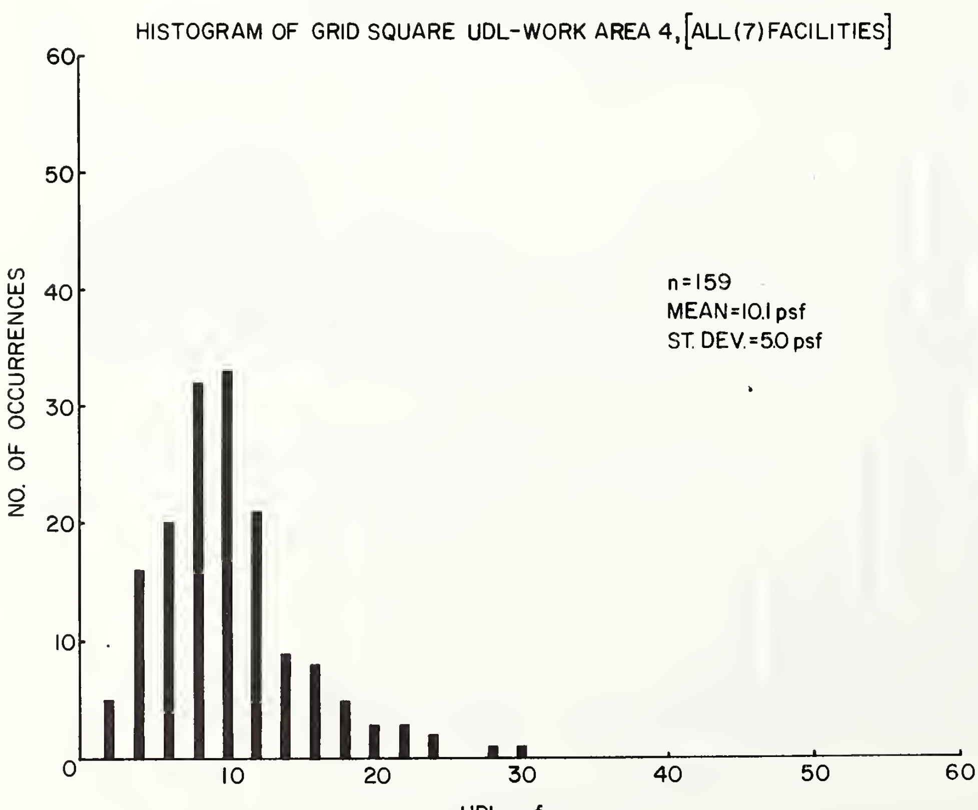

Figure 5d - Histogram of grid square uniformly distributed load intensities in work area 4 for all 7 combined facilities.

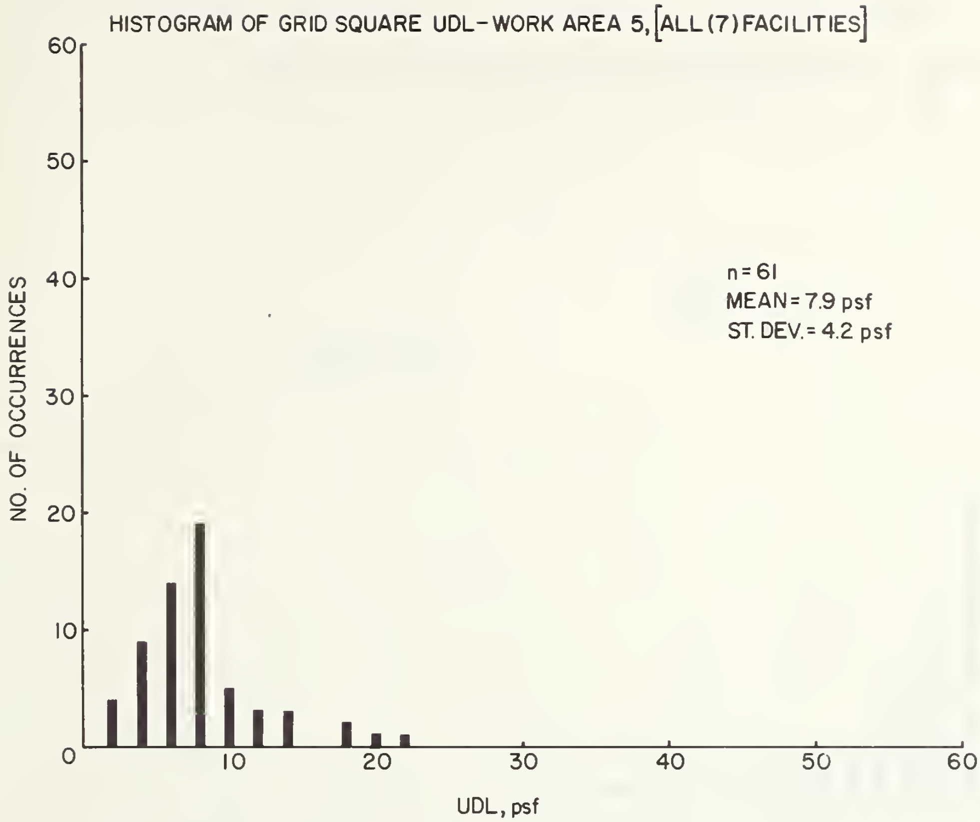

Figure 5e - Histogram of grid square uniformly distributed load intensities in work area 5 for all 7 combined facilities.

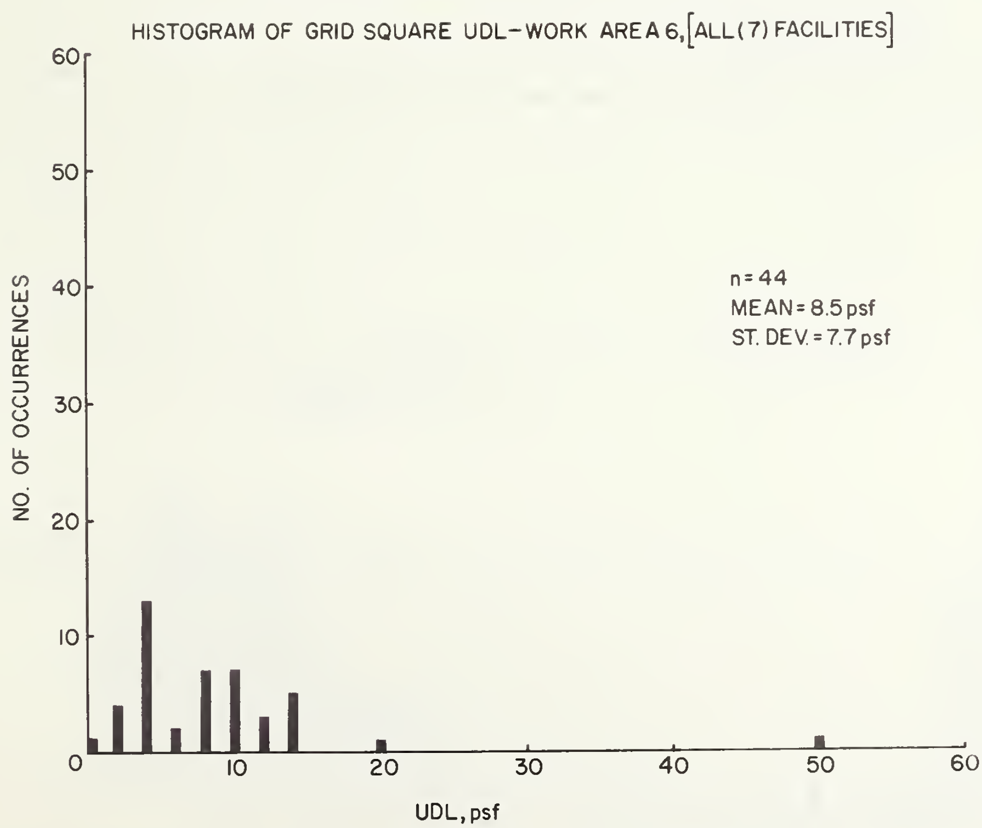

Figure 5f - Histogram of grid square uniformly distributed load intensities in work area 6 for all 7 combined facilities.

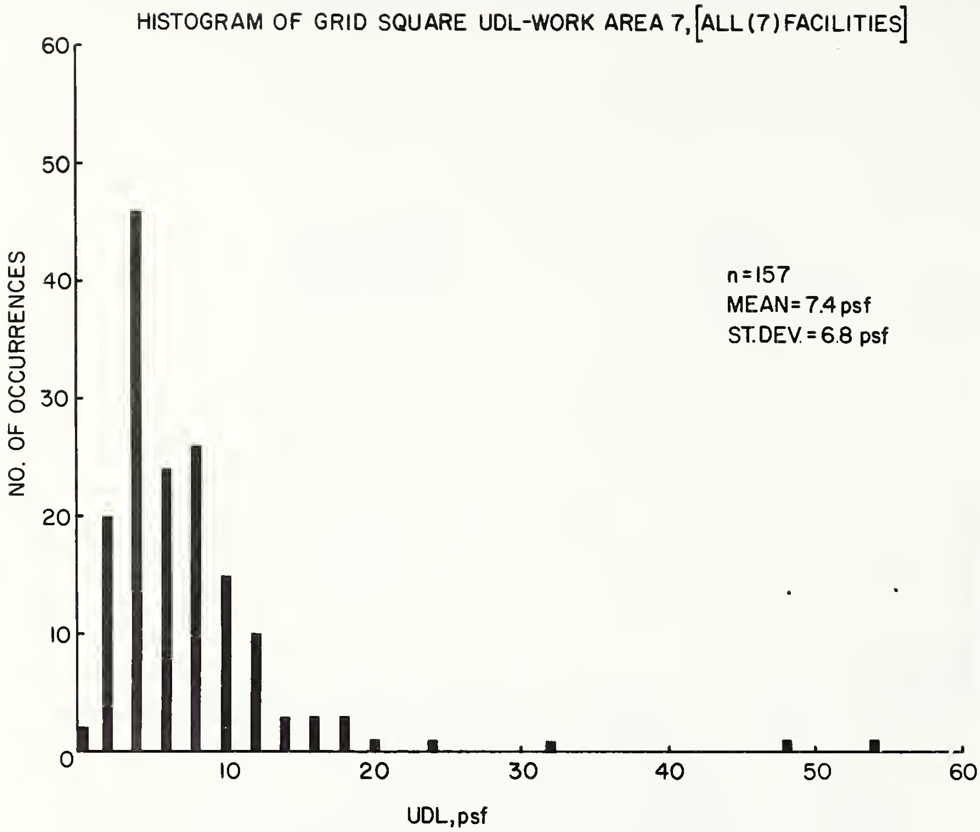

Figure 5g - Histogram of grid square uniformly distributed load intensities in work area 7 for all 7 combined facilities.

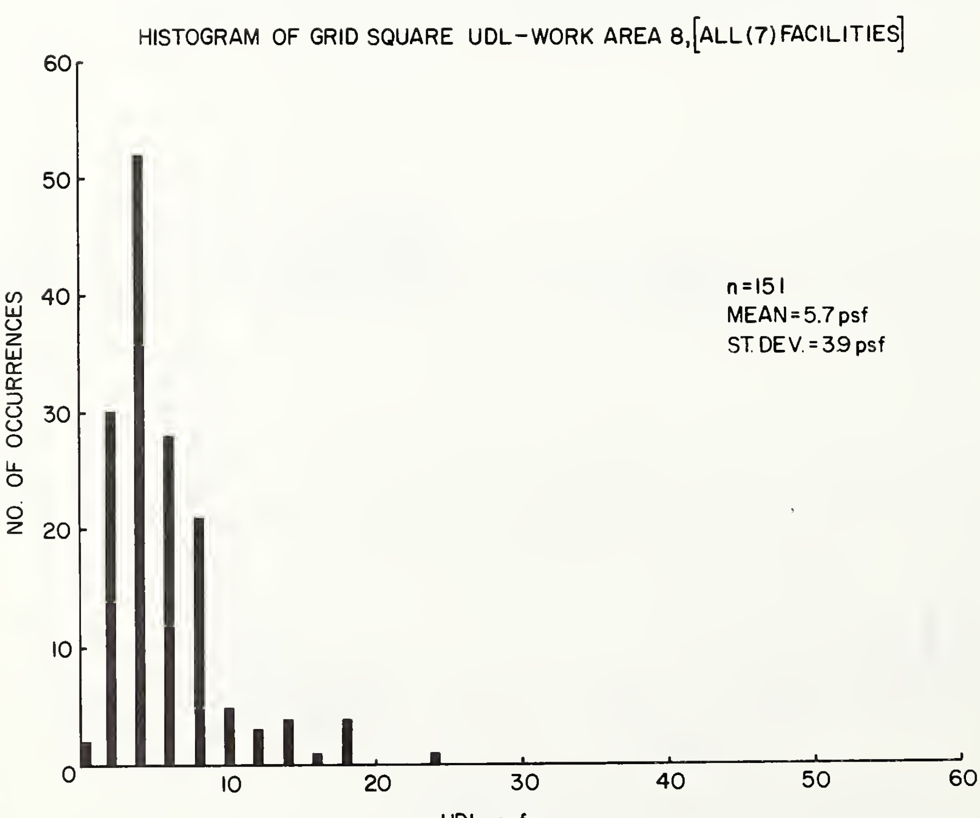

Figure 5h - Histogram of grid square uniformly distributed load intensities in work area 8 for all 7 combined facilities.

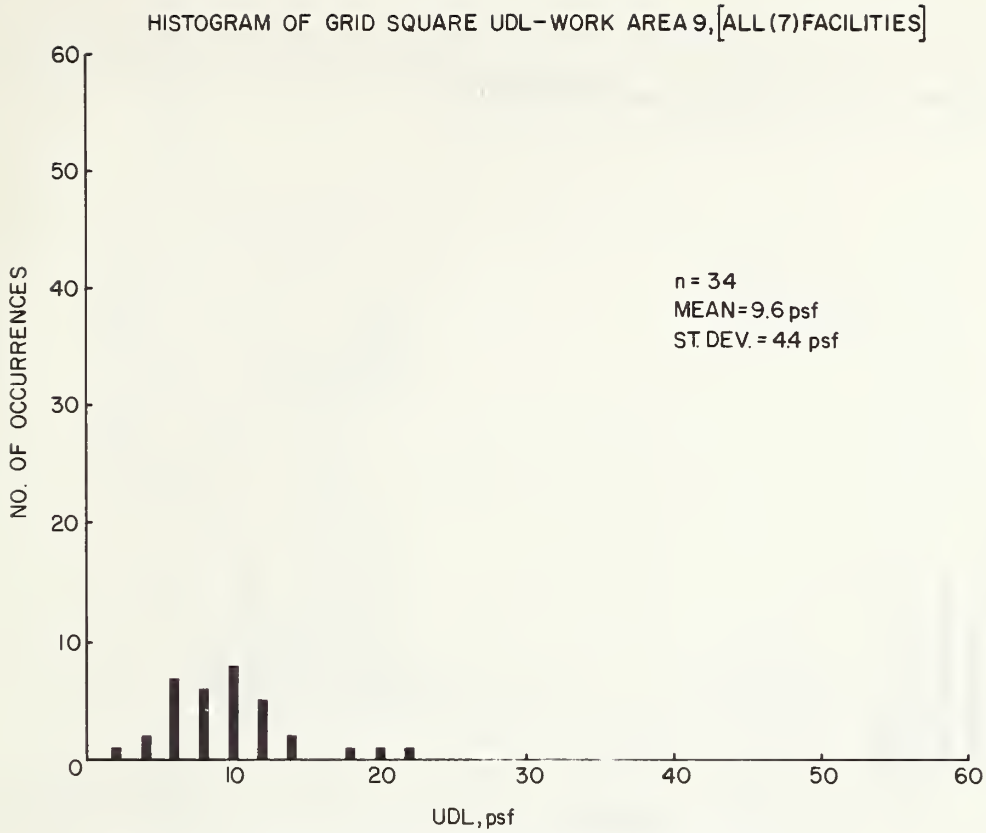

Figure 5i - Histogram of grid square uniformly distributed load intensities in work area 9 for all 7 combined facilities.

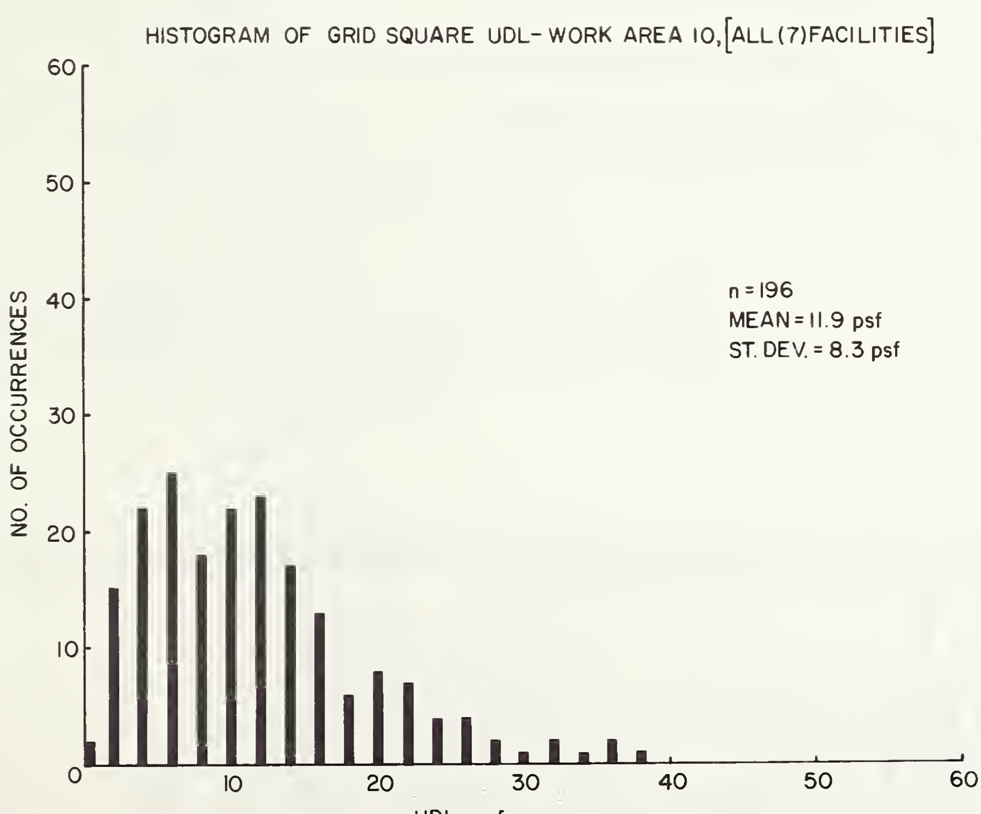

Figure 5j - Histogram of grid square uniformly distributed load intensities in work area 10 for all 7 combined facilities.

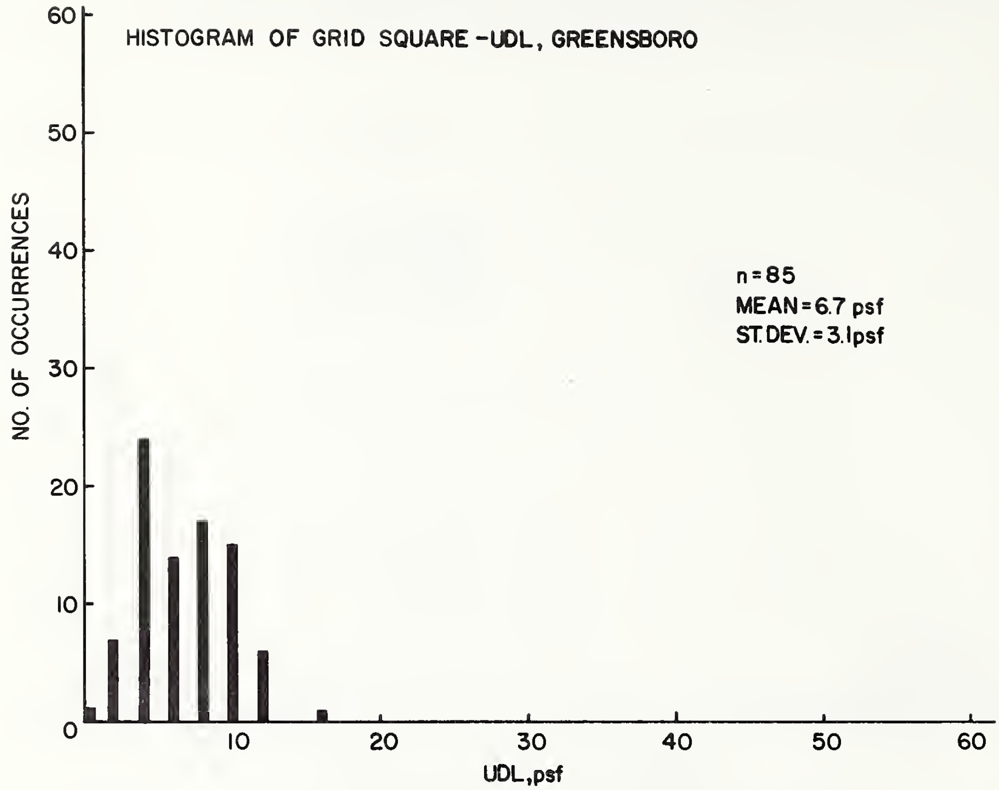

Figure 6a - Histogram of grid square uniformly distributed load intensities in Greensboro facility.

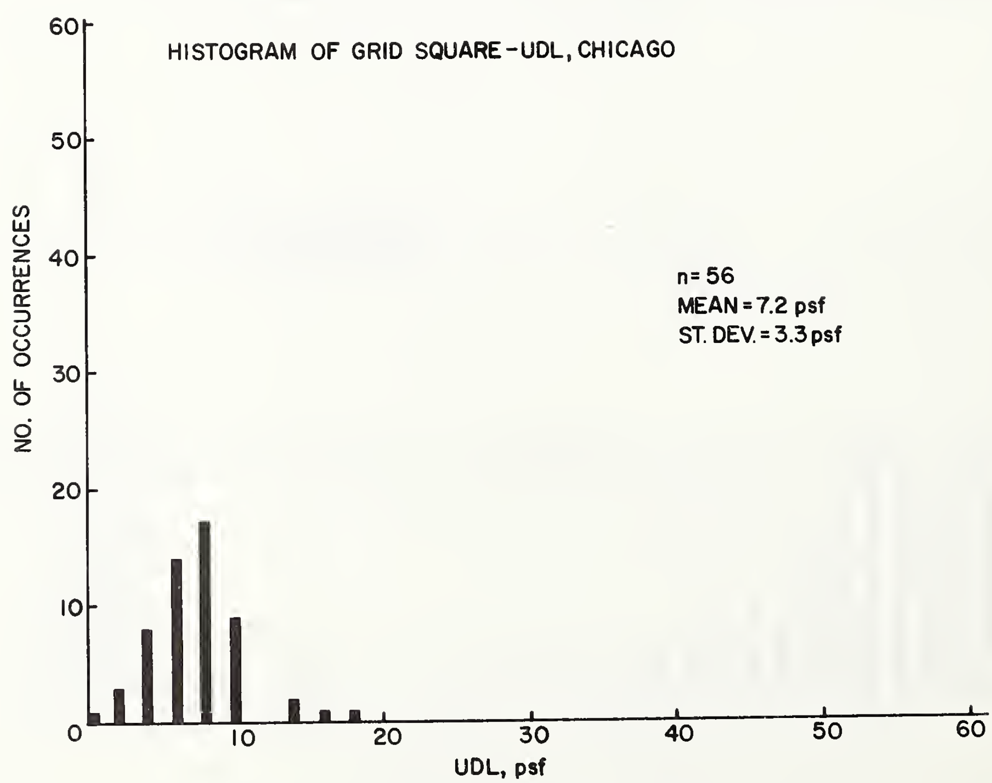

Figure 6b - Histogram of grid square uniformly distributed load intensities in Chicago facility.

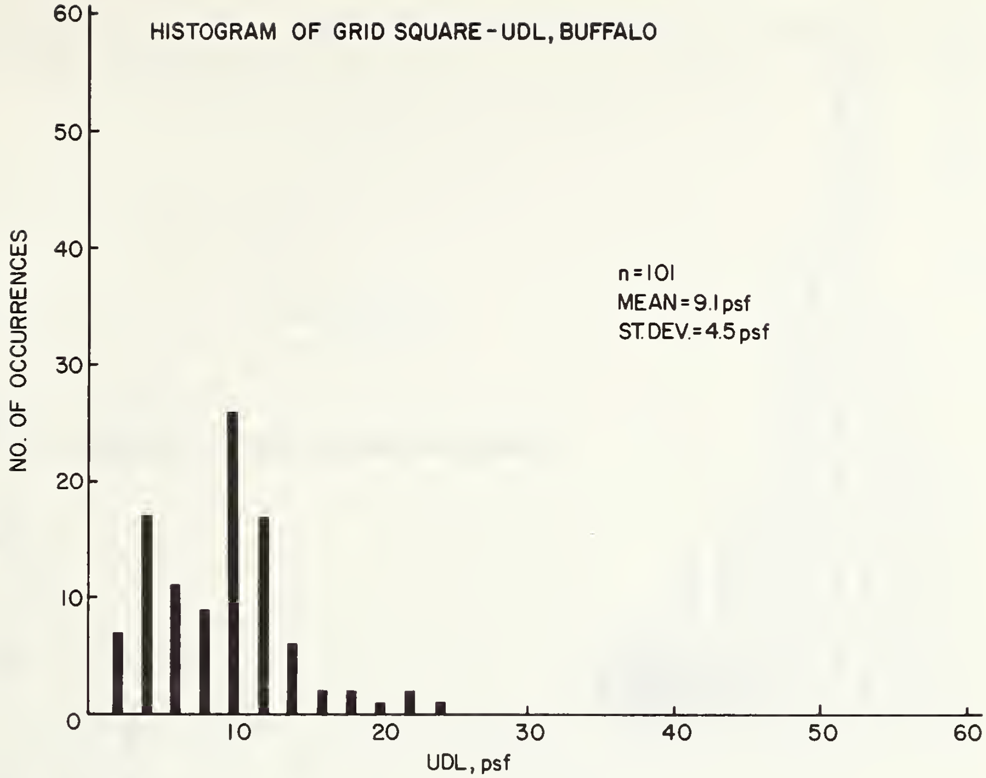

Figure 6c - Histogram of grid square uniformly distributed load intensities in Buffalo facility.

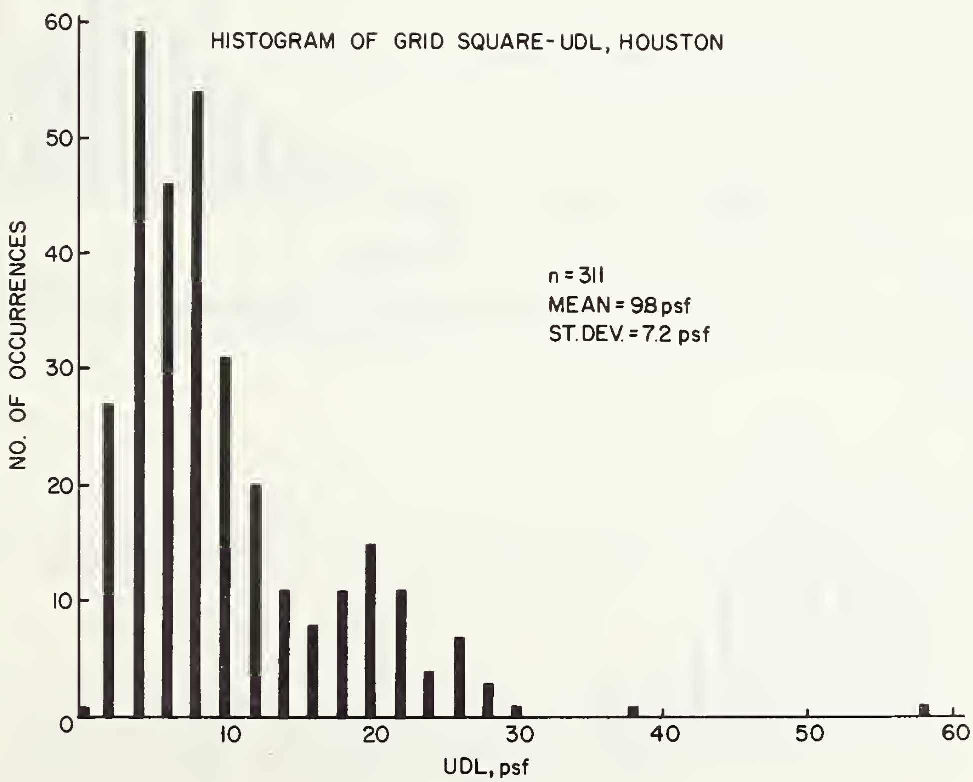

Figure 6d - Histogram of grid square uniformly distributed load intensities in Houston facility.

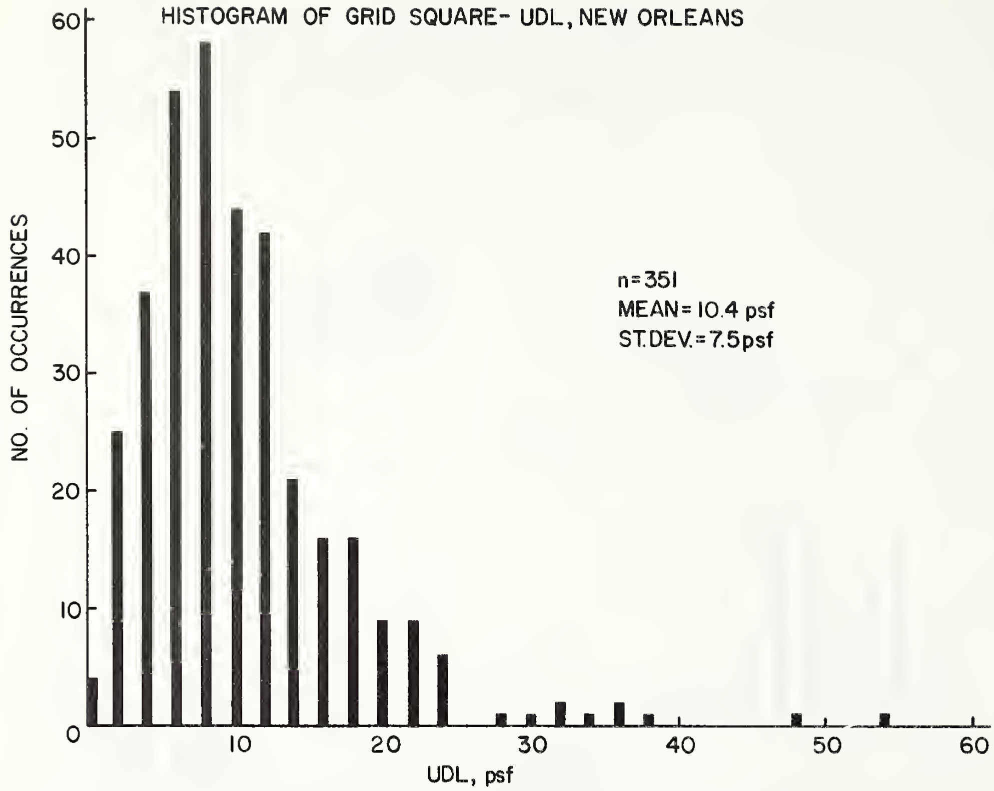

Figure 6e - Histogram of grid square uniformly distributed load intensities in New Orleans facility.

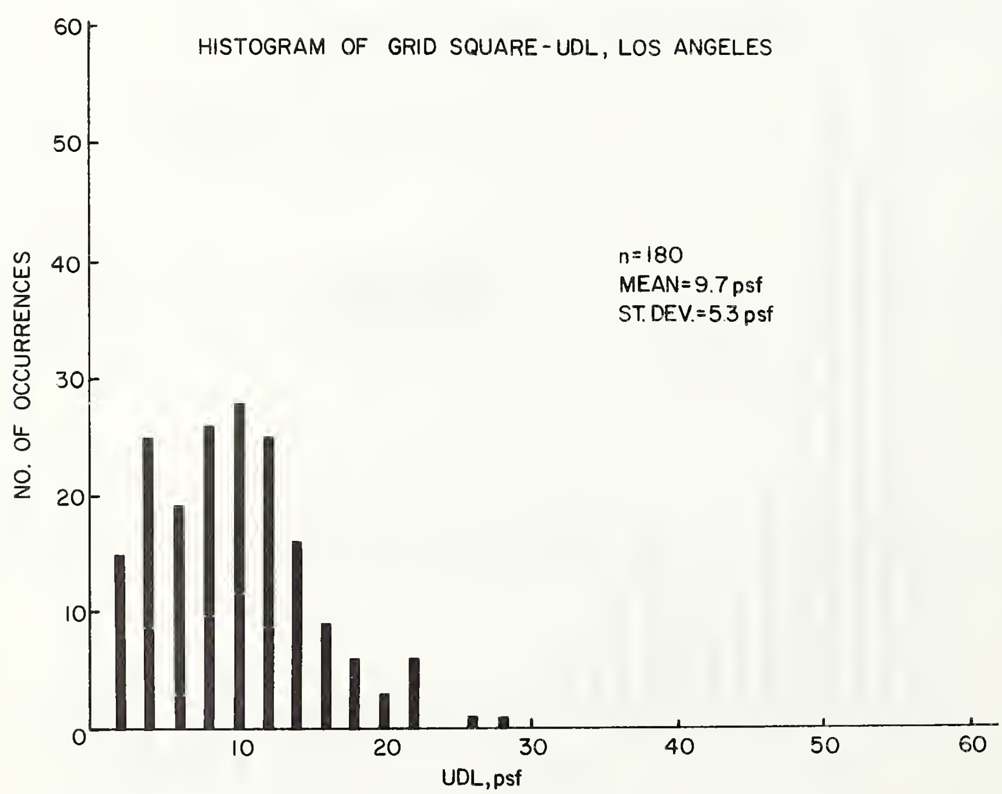

Figure 6f - Histogram of grid square uniformly distributed load intensities in Los Angeles facility.

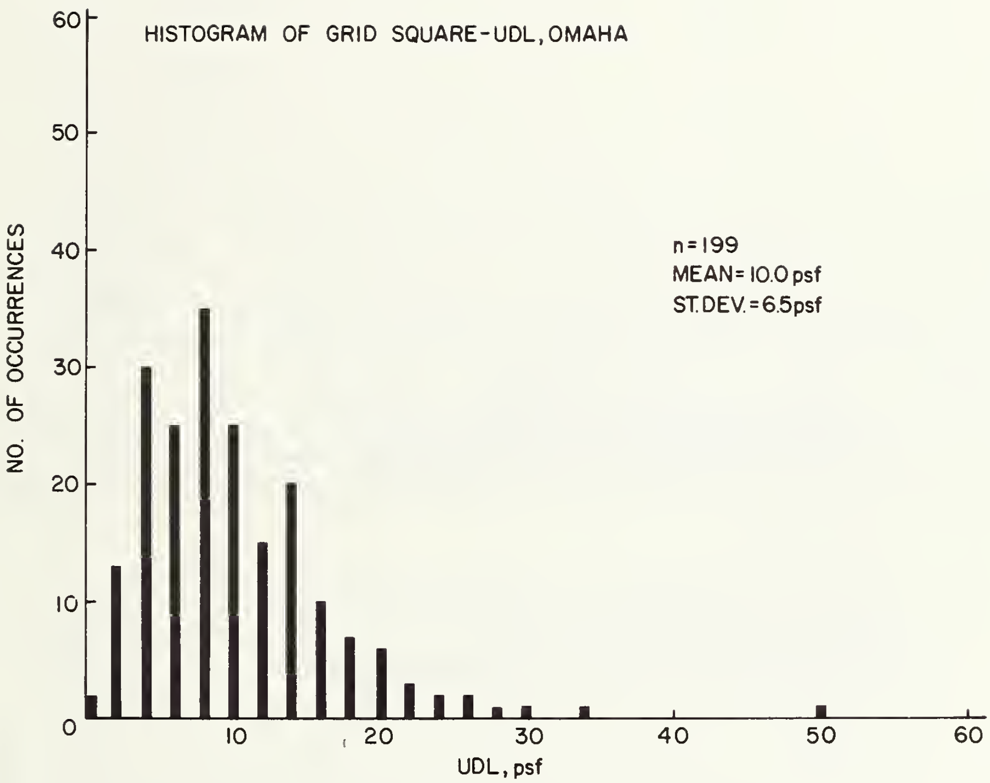

Figure 6g - Histogram of grid square uniformly distributed load intensities in Omaha facility.

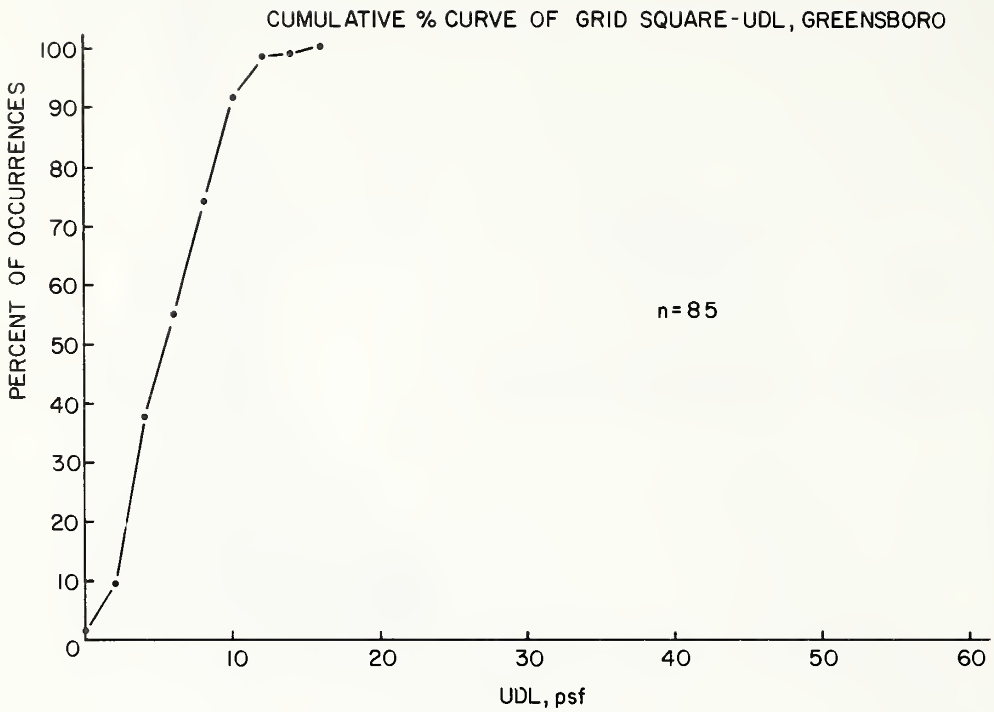

Figure 7a - Cumulative frequency distribution of grid square uniformly distributed load intensities in Greensboro facilities.

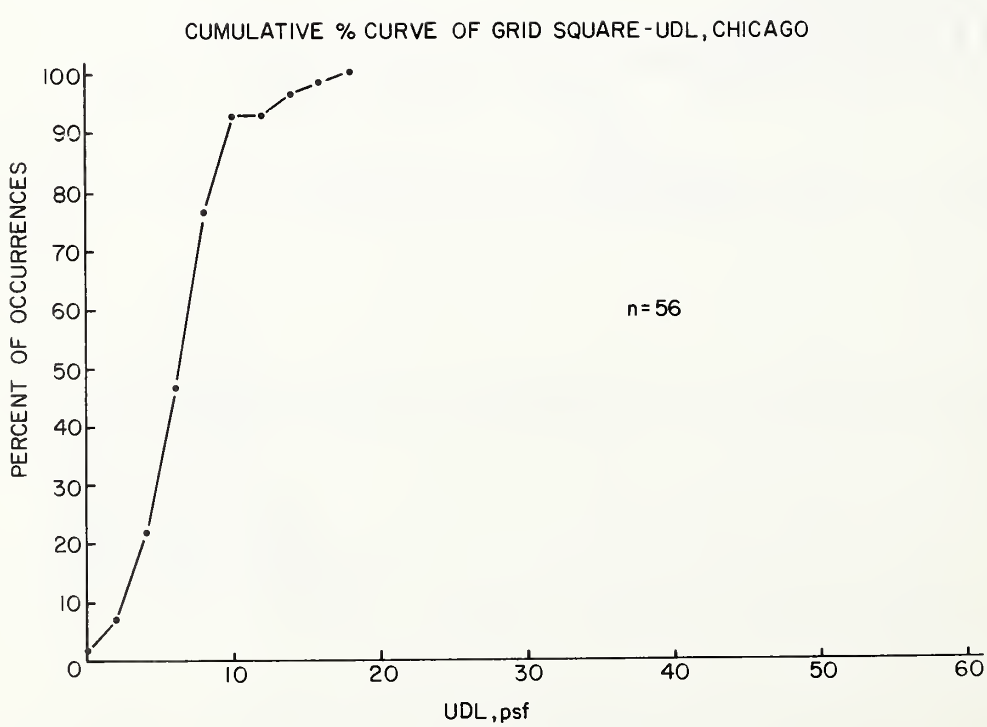

Figure 7b - Cumulative frequency distribution of grid square uniformly distributed load intensities in Chicago facilities.

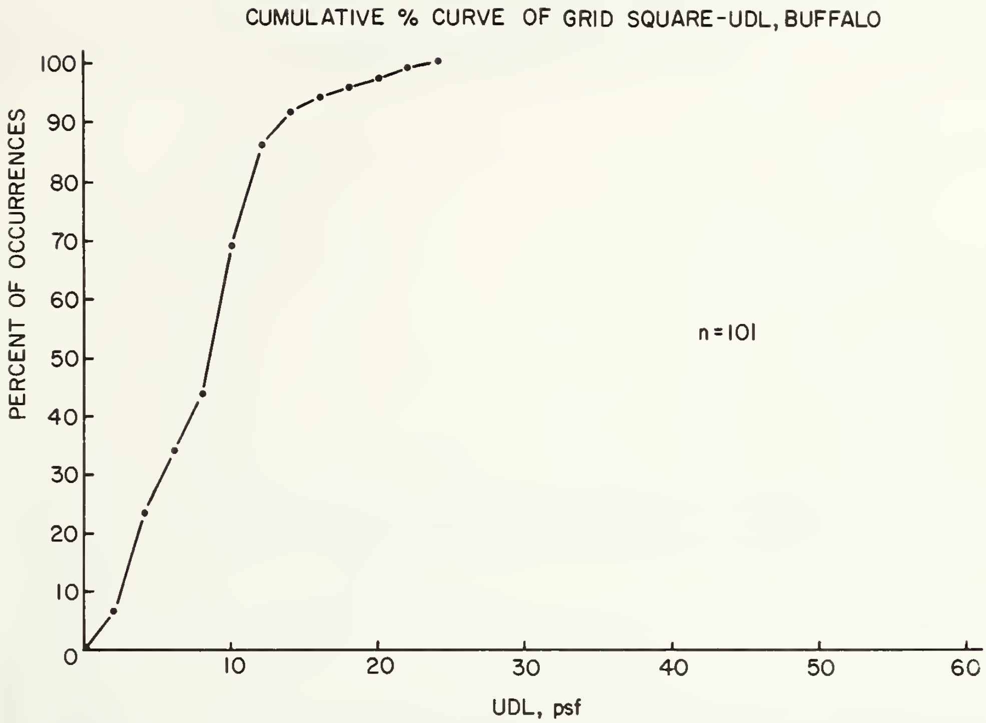

Figure 7c - Cumulative frequency distribution of grid square uniformly distributed load intensities in Buffalo facilities.

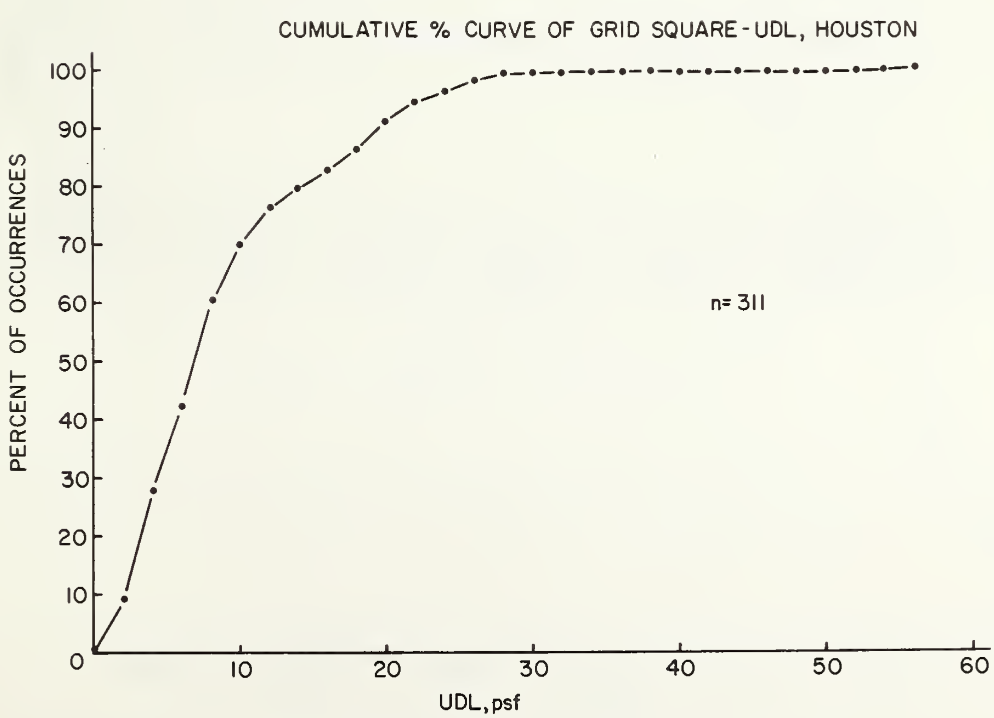

Figure 7d - Cumulative frequency distribution of grid square uniformly distributed load intensities in Houston facilities.

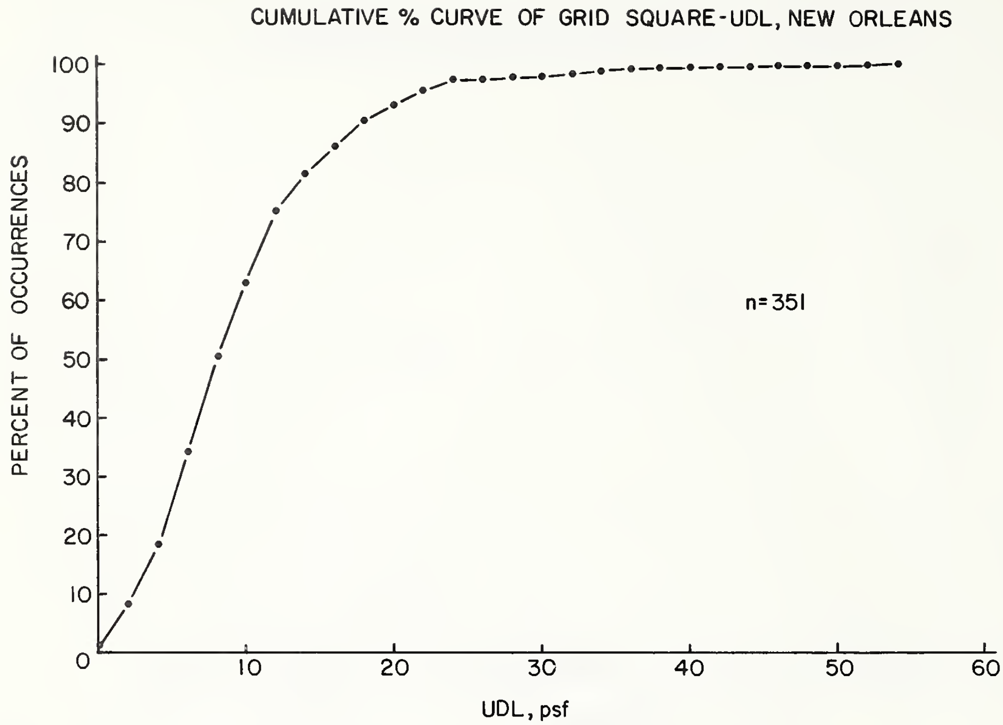

Figure 7e - Cumulative frequency distribution of grid square uniformly distributed load intensities in New Orleans facilities.

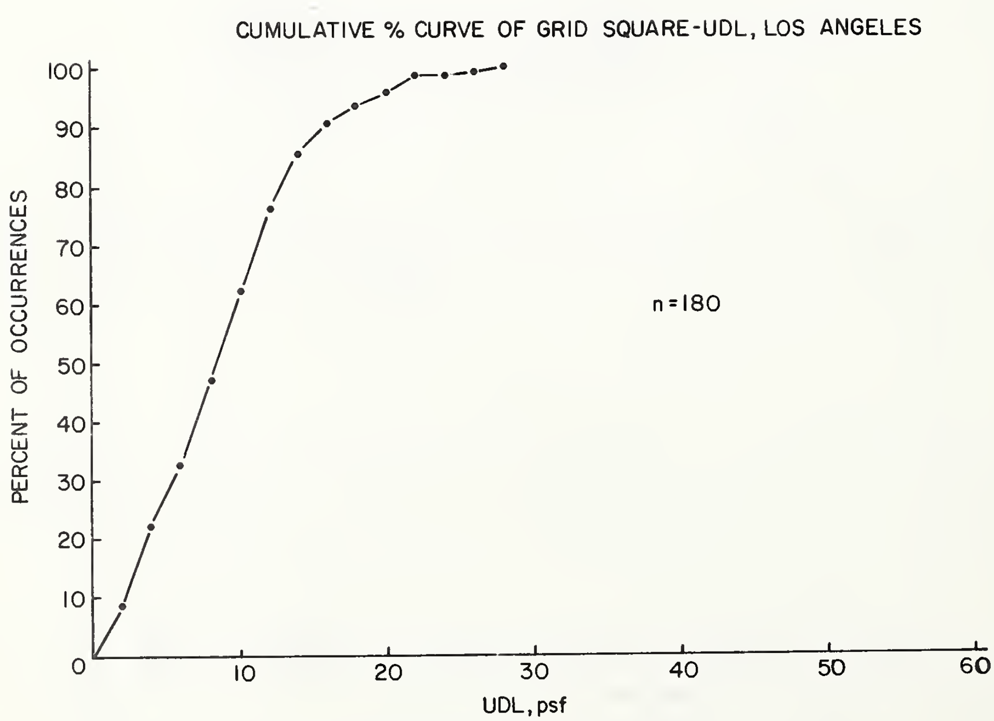

Figure 7f - Cumulative frequency distribution of grid square uniformly distributed load intensities in Los Angeles facilities.

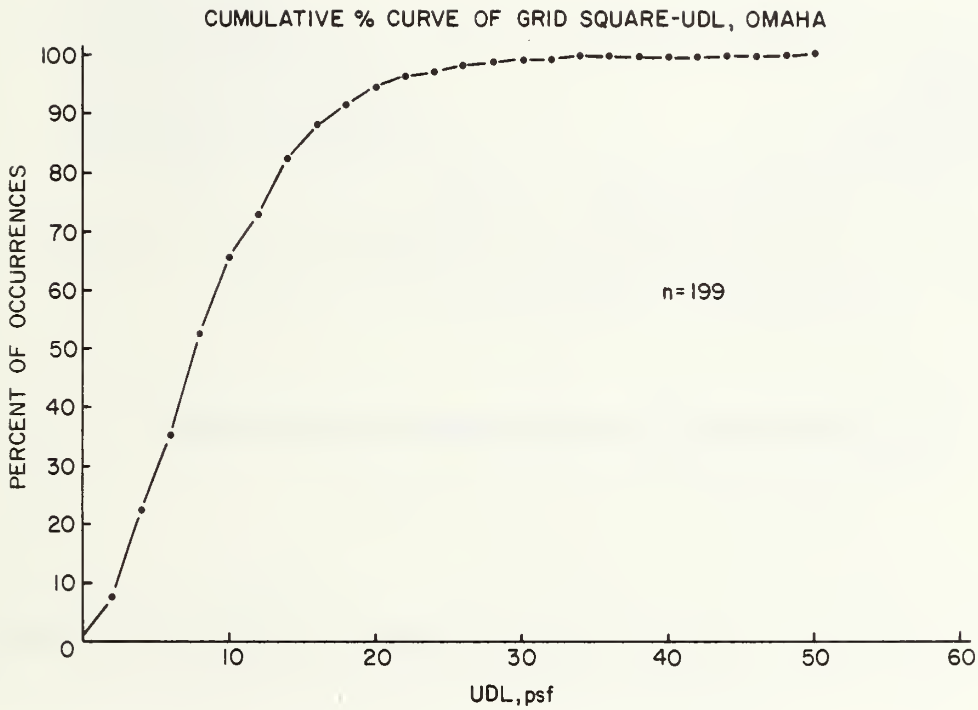

Figure 7g - Cumulative frequency distribution of grid square uniformly distributed load intensities in Omaha facilities.

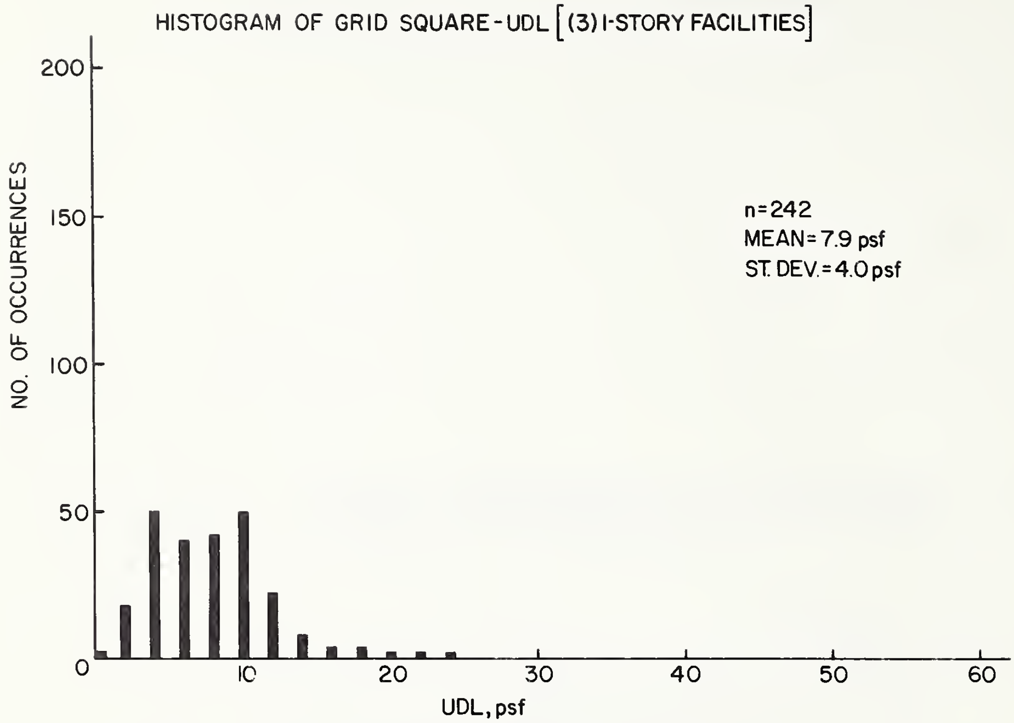

Figure 8 - Histogram of grid square uniformly distributed load intensities in 3 combined one-story facilities.

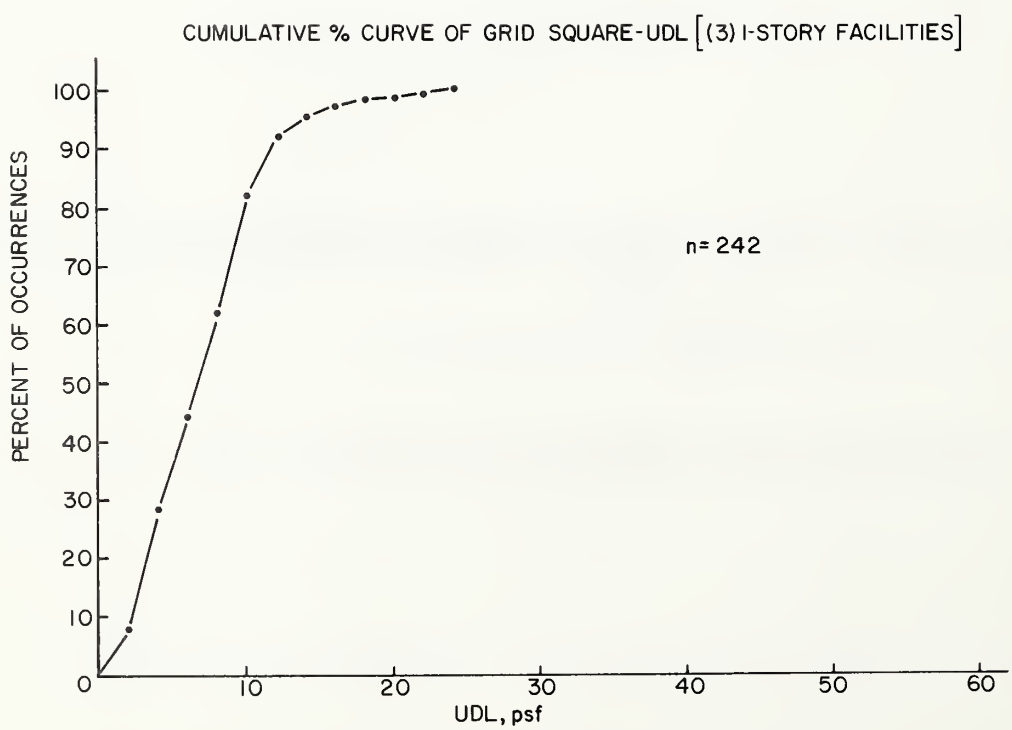

Figure 9 - Cumulative frequency distribution of grid square uniformly distributed load intensities in 3 combined one-story facilities.

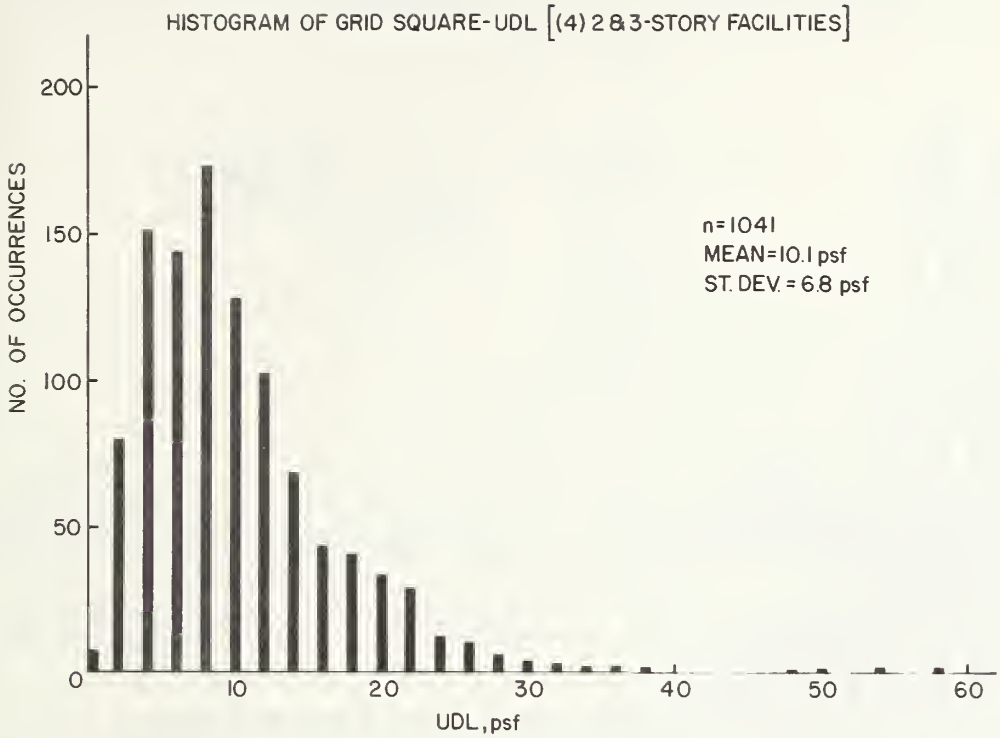

Figure 10 - Histogram of grid square uniformly distributed load intensities in 4 combined 2 and 3-story facilities.

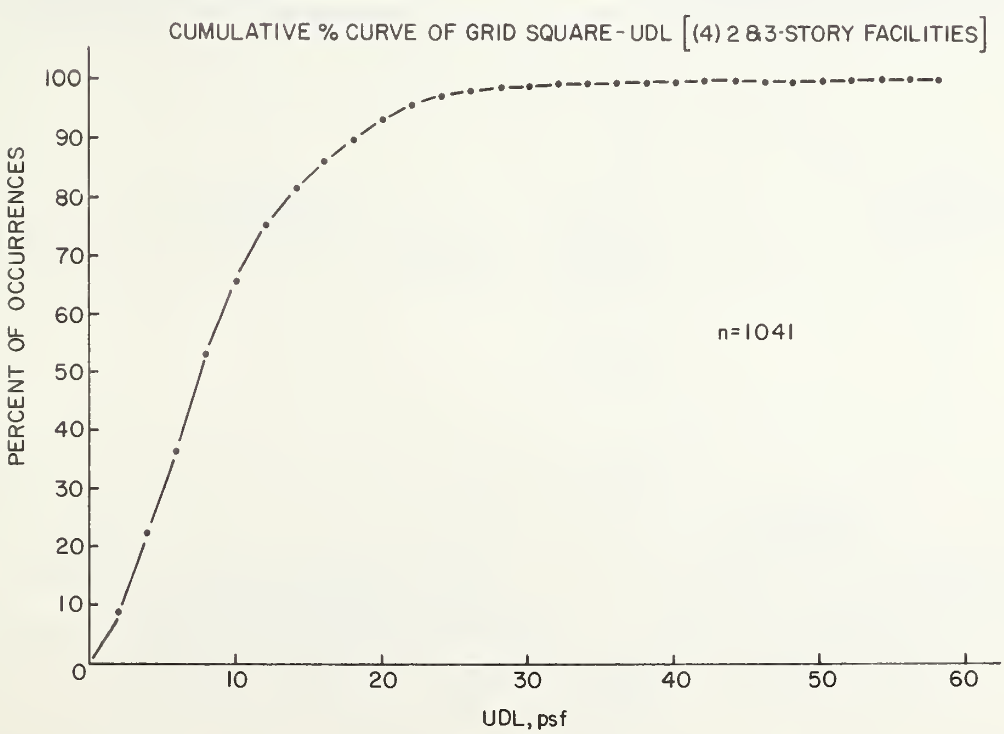

Figure 11 - Cumulative frequency distribution of grid square uniformly distributed load intensities in 4 combined 2 and 3-story facilities.

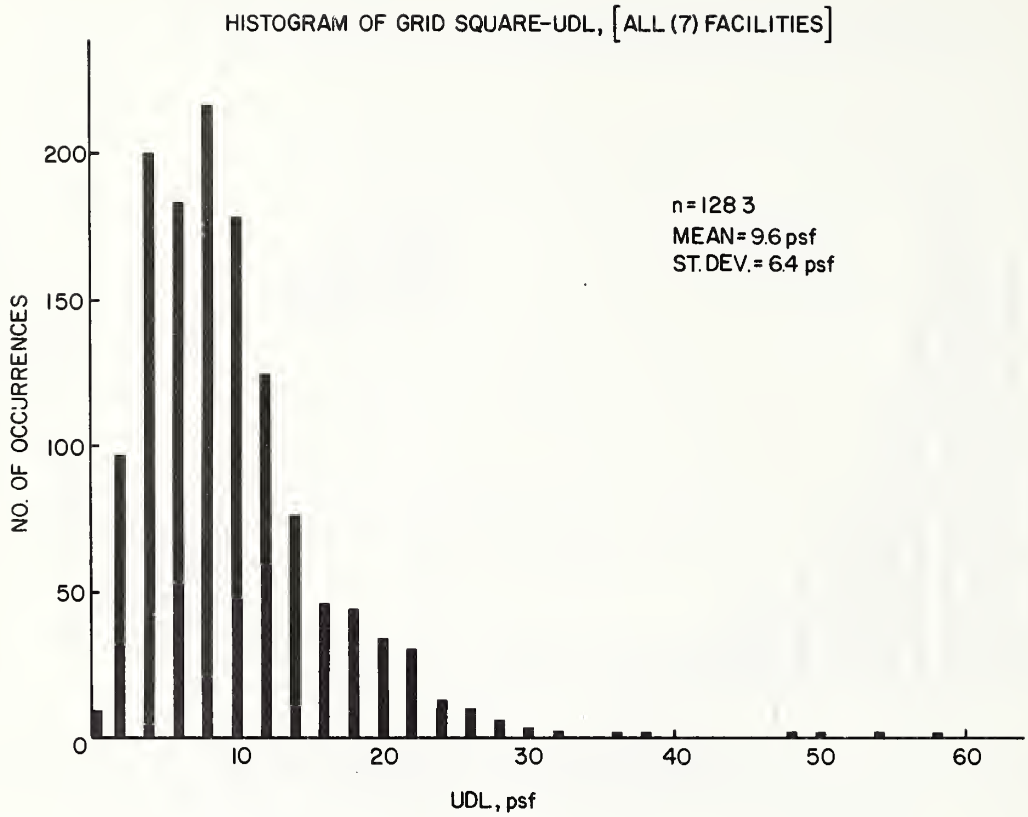

Figure 12 - Histogram of grid square uniformly distributed load intensities in all 7 combined facilities.

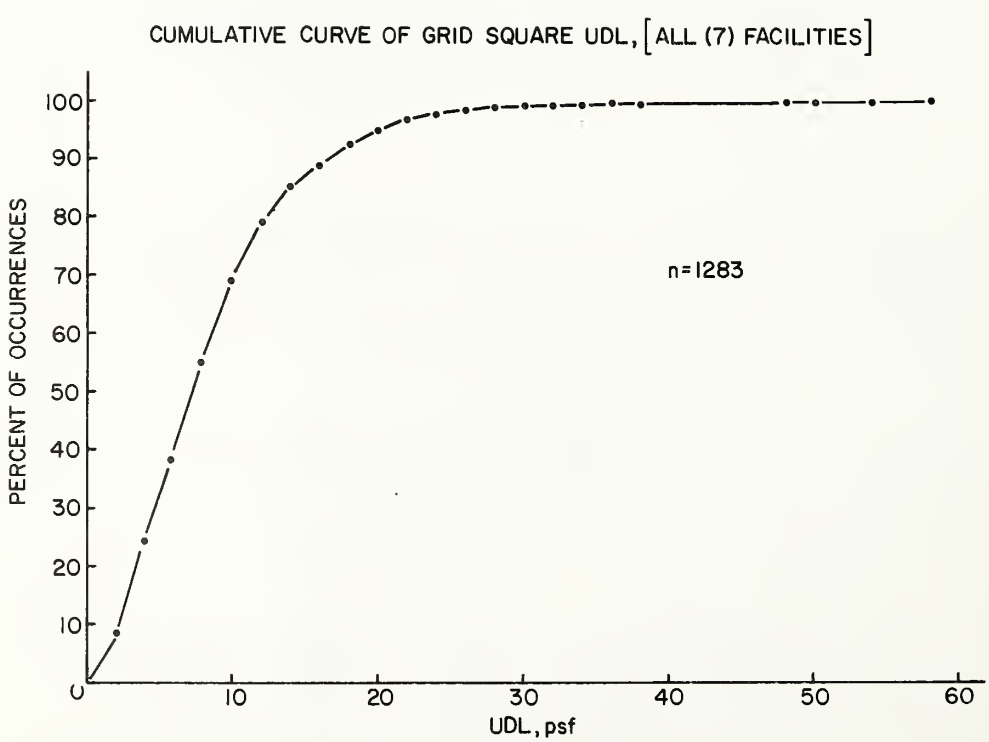

Figure 13 - Cumulative frequency distribution of grid square uniformly distributed load intensities in all 7 combined facilities.

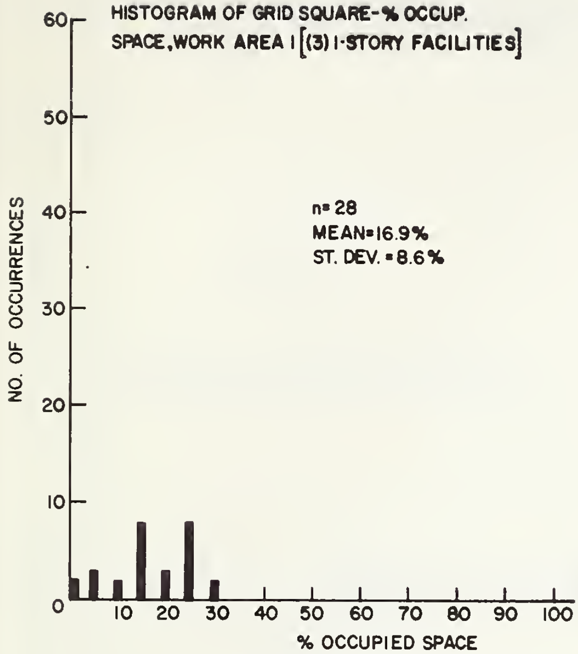

Figure 14a - Histogram of grid square occupied space percentages in work area 1 for 3 combined one-story facilities.

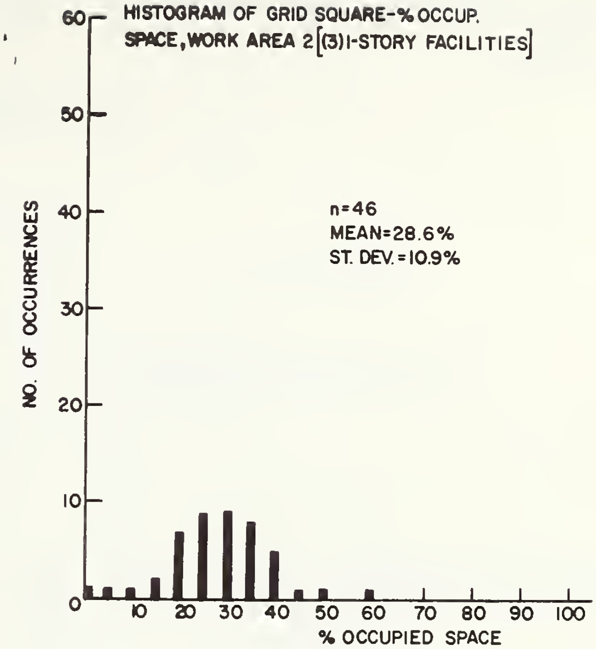

Figure 14b - Histogram of grid square occupied space percentages in work area 2 for 3 combined one-story facilities.

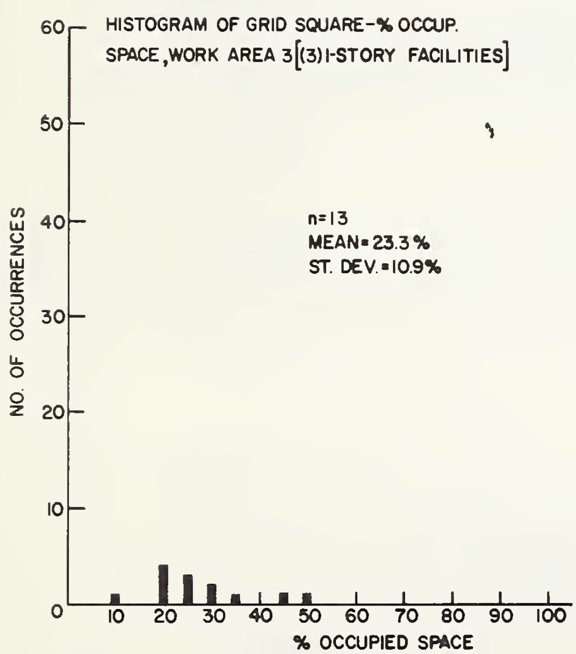

Figure 14c - Histogram of grid square occupied space percentages in work area 3 for 3 combined one-story facilities.

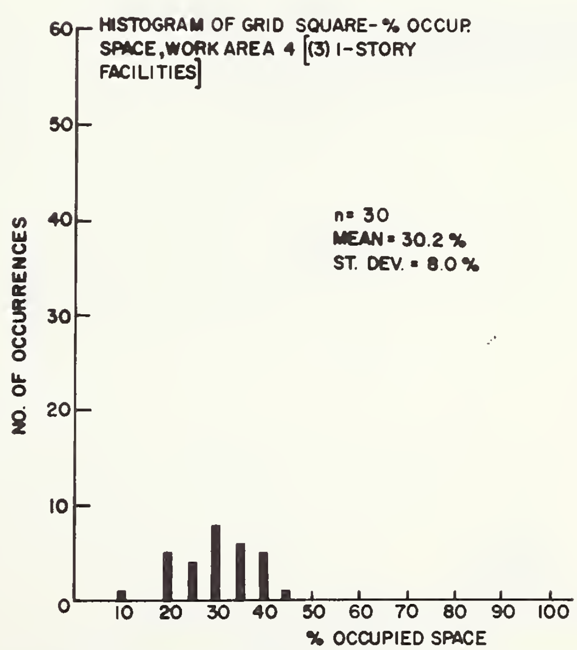

Figure 14d - Histogram of grid square occupied space percentages in work area 4 for 3 combined one-story facilities.

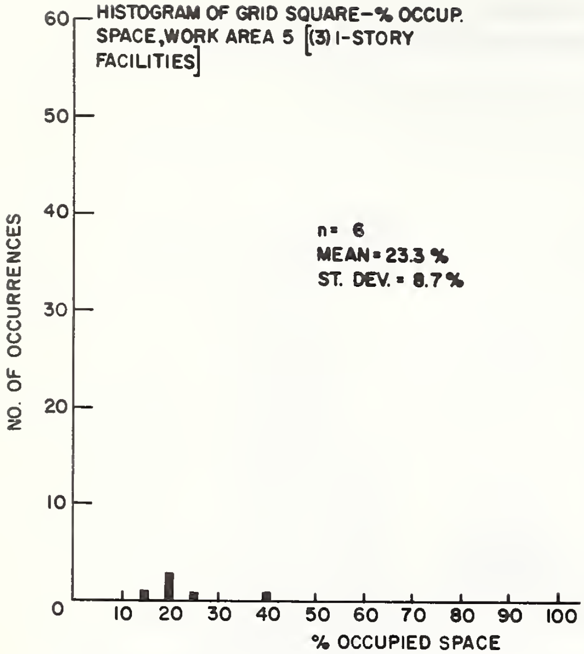

Figure 14e - Histogram of grid square occupied space percentages in work area 5 for 3 combined one-story facilities.

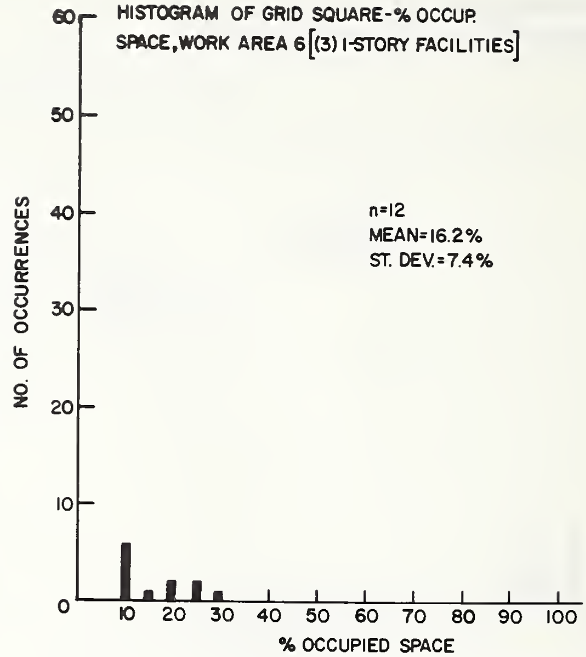

Figure 14f - Histogram of grid square occupied space percentages in work area 6 for 3 combined one-story facilities.

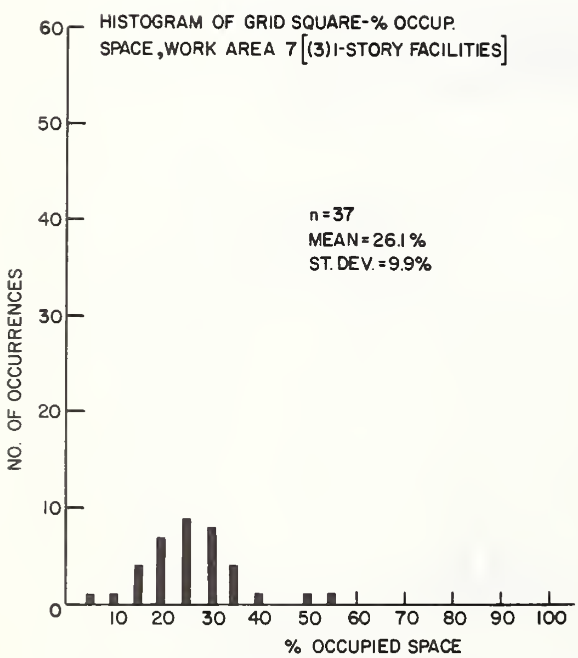

Figure 14g - Histogram of grid square occupied space percentages in work area 7 for 3 combined one-story facilities.

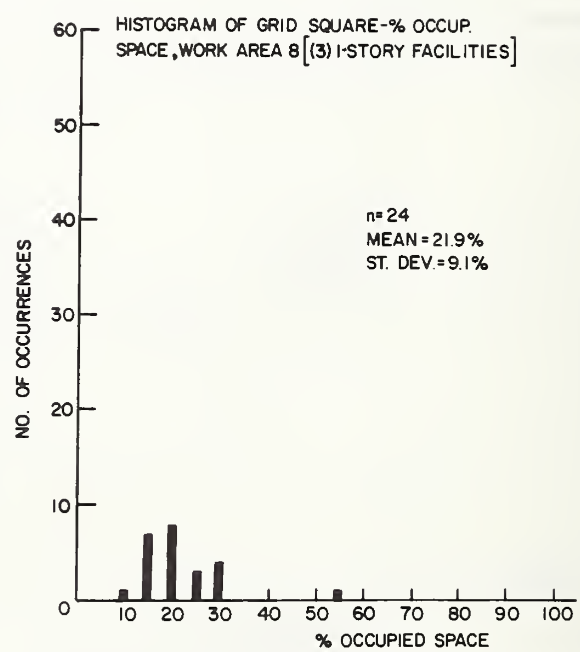

Figure 14h - Histogram of grid square occupied space percentages in work area 8 for 3 combined one-story facilities.

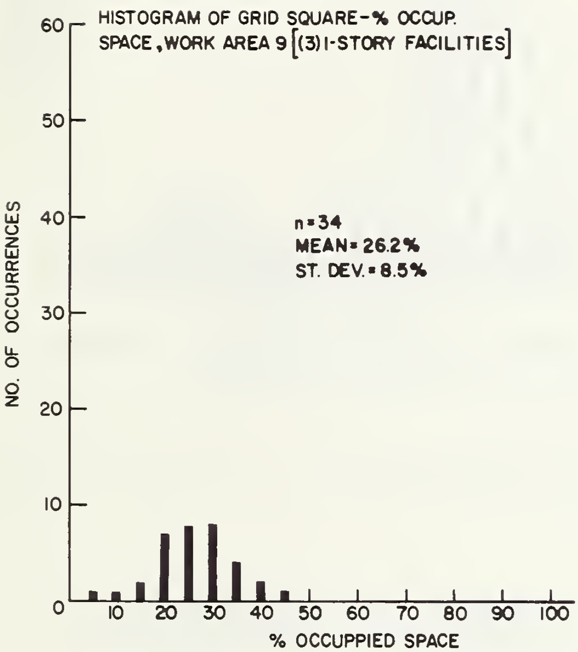

Figure 14i - Histogram of grid square occupied space percentages in work area 9 for 3 combined one-story facilities.

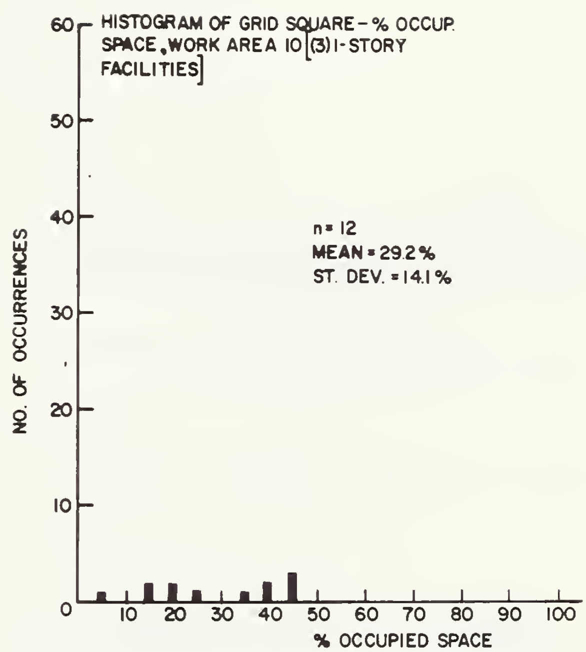

Figure 14j - Histogram of grid square occupied space percentages in work area 10 for 3 combined one-story facilities.

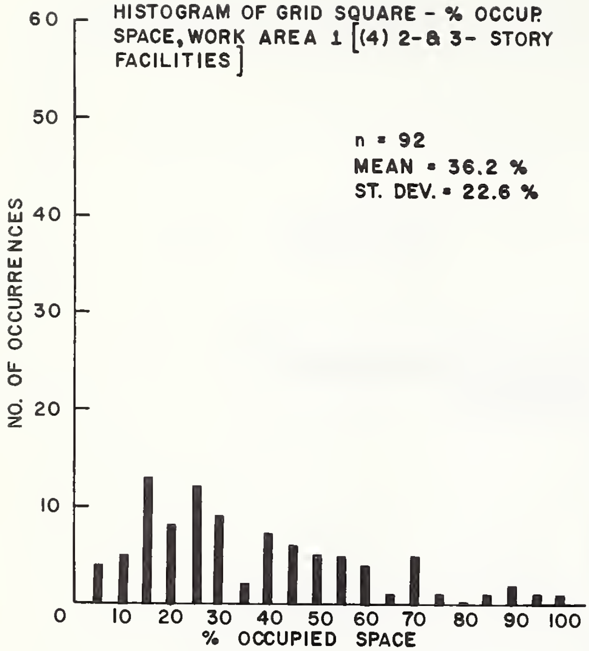

Figure 15a - Histogram of grid square occupied space percentages in work area 1 for 4 combined 2 and 3-story facilities.

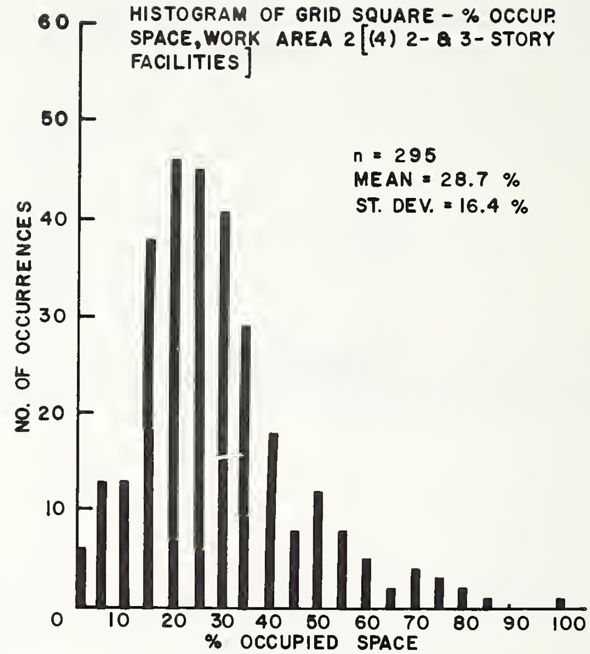

Figure 15b - Histogram of grid square occupied space percentages in work area 2 for 4 combined 2 and 3-story facilities.

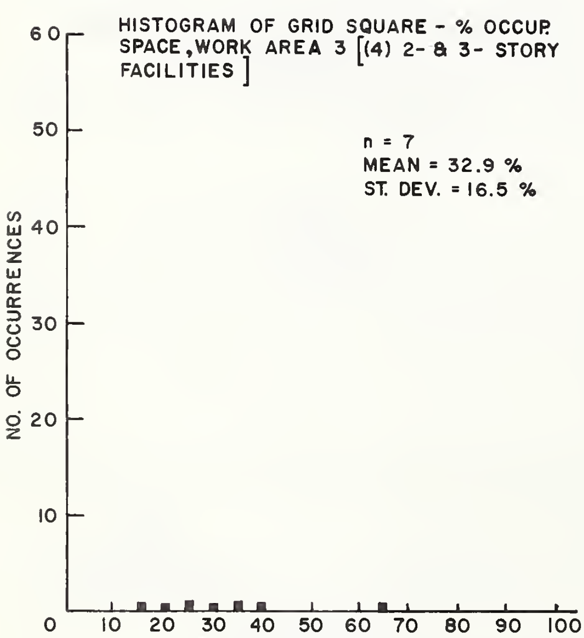

Figure 15c - Histogram of grid square occupied space percentages in work area 3 for 4 combined 2 and 3-story facilities.

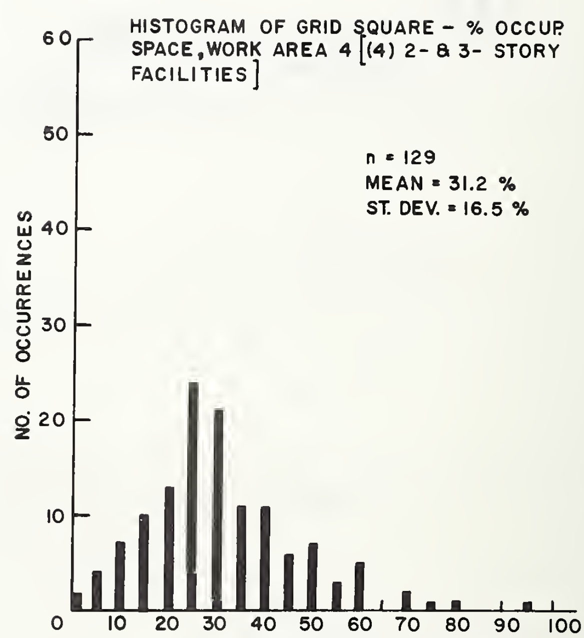

Figure 15d - Histogram of grid square occupied space percentages in work area 4 for 4 combined 2 and 3-story facilities.

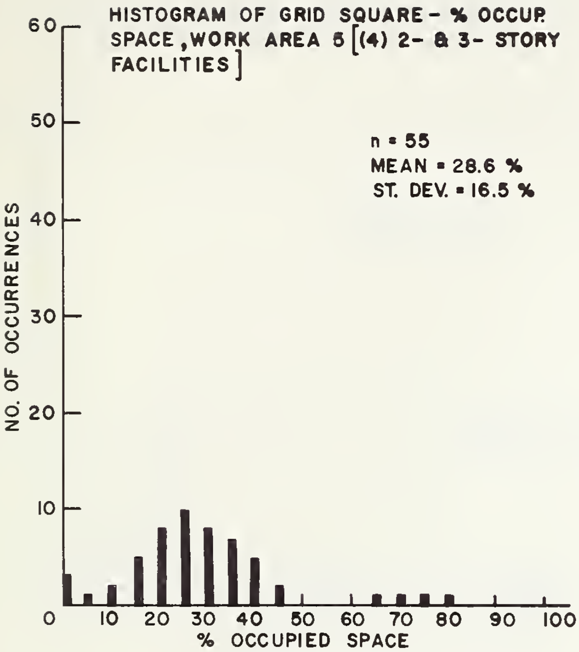

Figure 15e - Histogram of grid square occupied space percentages in work area 5 for 4 combined 2 and 3-story facilities.

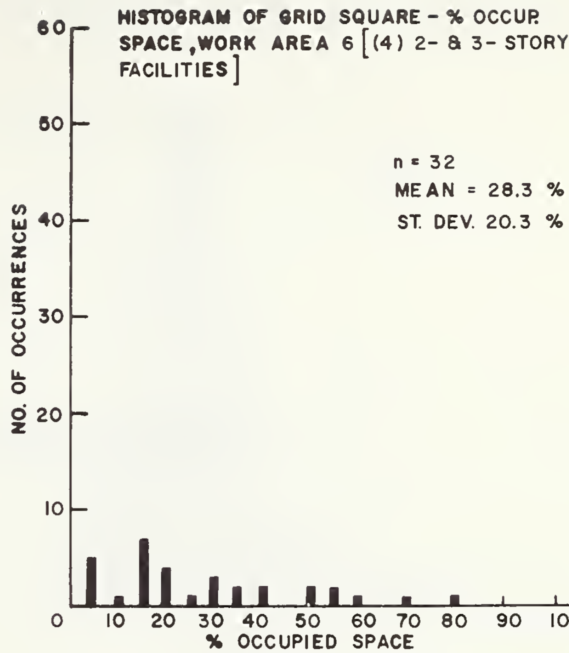

Figure 15f - Histogram of grid square occupied space percentages in work area 6 for 4 combined 2 and 3-story facilities.

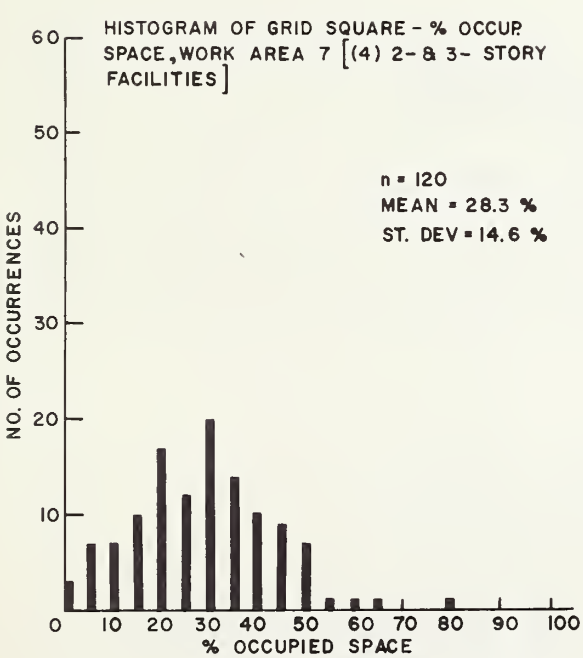

Figure 15g - Histogram of grid square occupied space percentages in work area 7 for 4 combined 2 and 3-story facilities.

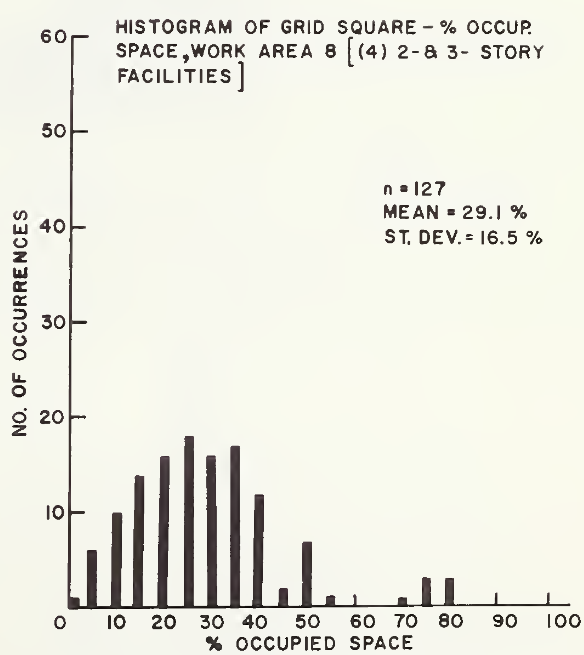

Figure 15h - Histogram of grid square occupied space percentages in work area 8 for 4 combined 2 and 3-story facilities.

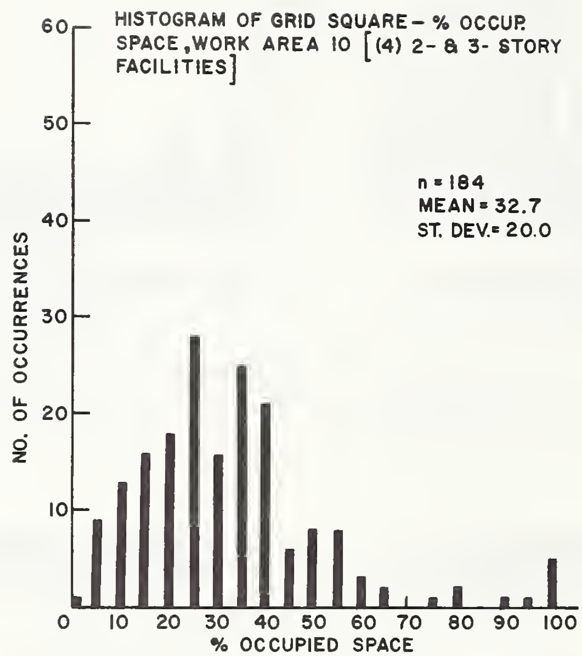

Figure 15i - Histogram of grid square occupied space percentages in work area 10 for 4 combined 2 and 3-story facilities.

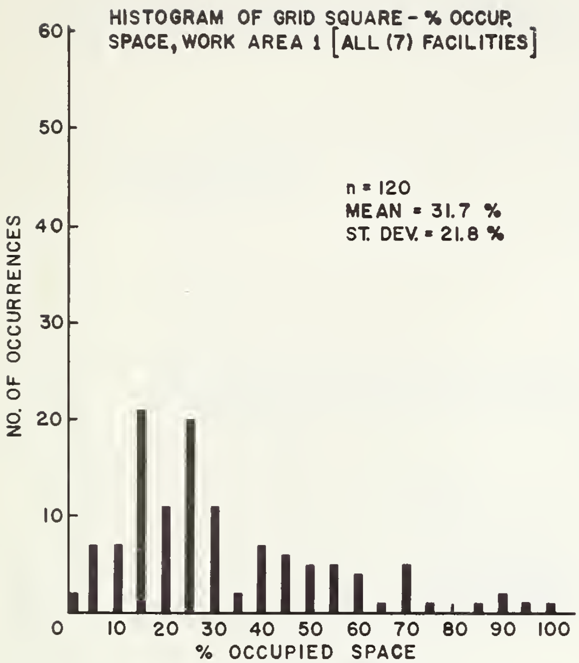

Figure 16a - Histogram of grid space occupied space percentages in work area 1 for all 7 combined facilities.

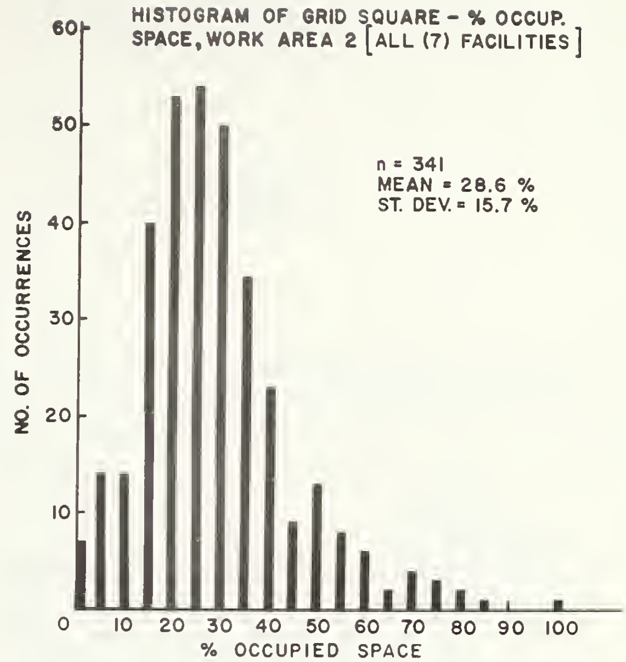

Figure 16b - Histogram of grid space occupied space percentages in work area 2 for all 7 combined facilities.

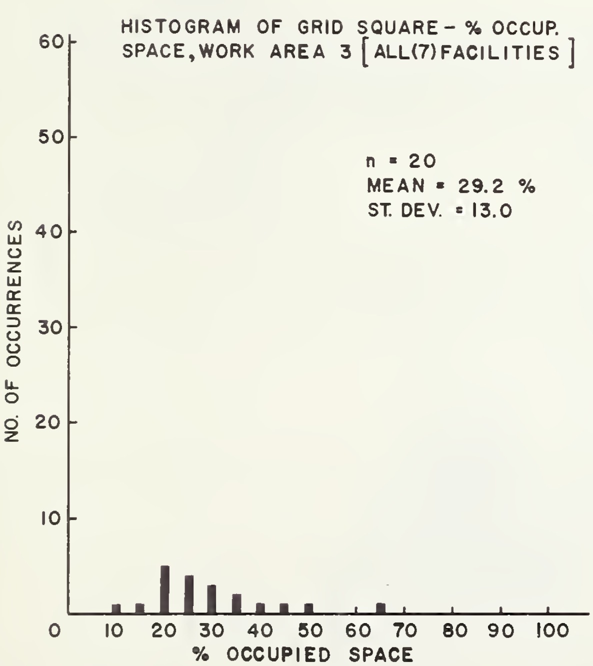

Figure 16c - Histogram of grid space occupied space percentages in work area 3 for all 7 combined facilities.

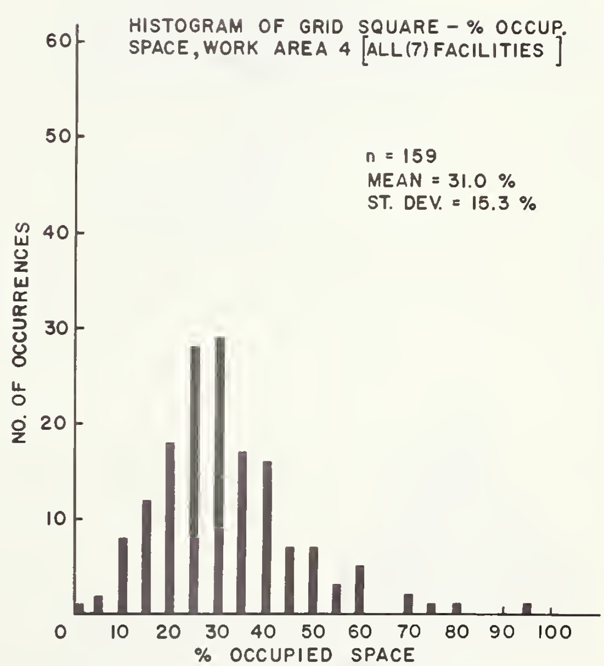

Figure 16d - Histogram of grid space occupied space percentages in work area 4 for all 7 combined facilities.

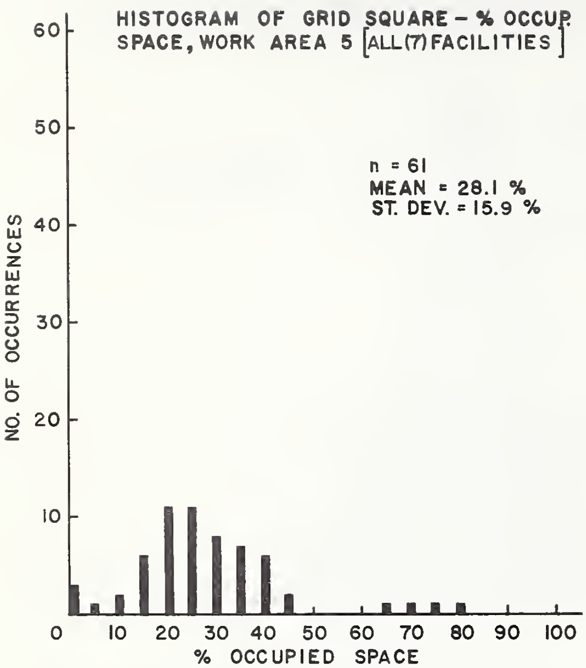

Figure 16e - Histogram of grid space occupied space percentages in work area 5 for all 7 combined facilities.

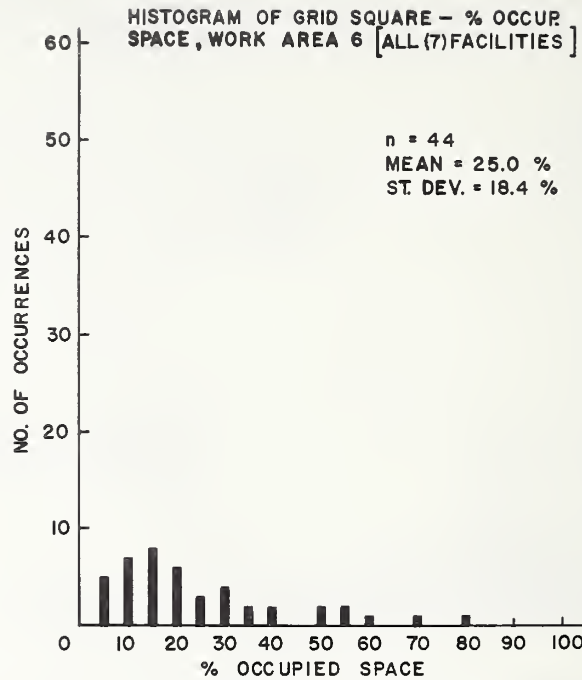

Figure 16f - Histogram of grid space occupied space percentages in work area 6 for all 7 combined facilities.

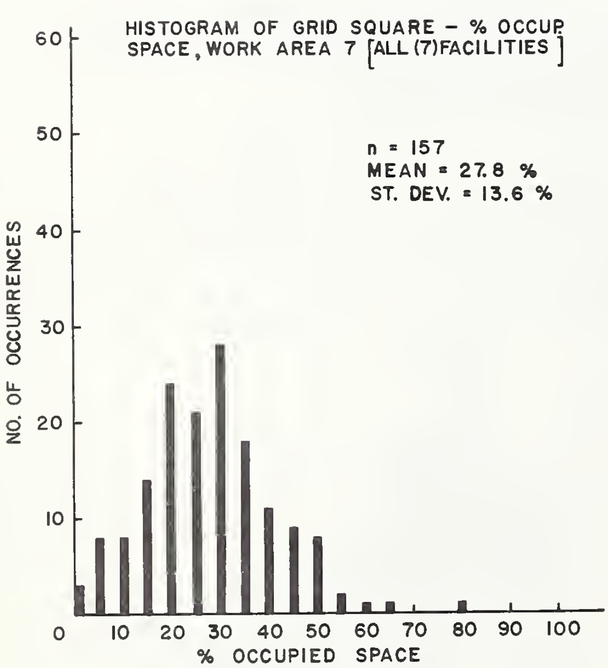

Figure 16g - Histogram of grid space occupied space percentages in work area 7 for all 7 combined facilities.

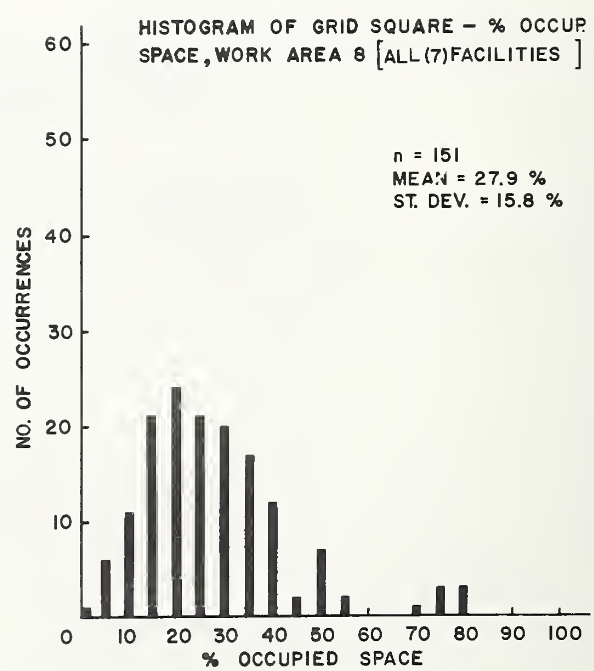

Figure 16h - Histogram of grid space occupied space percentages in work area 8 for all 7 combined facilities.

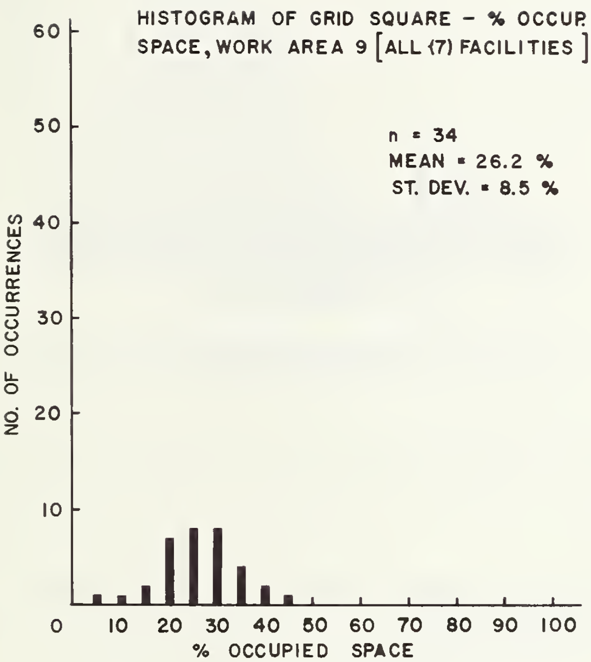

Figure 16i - Histogram of grid space occupied space percentages in work area 9 for all 7 combined facilities.

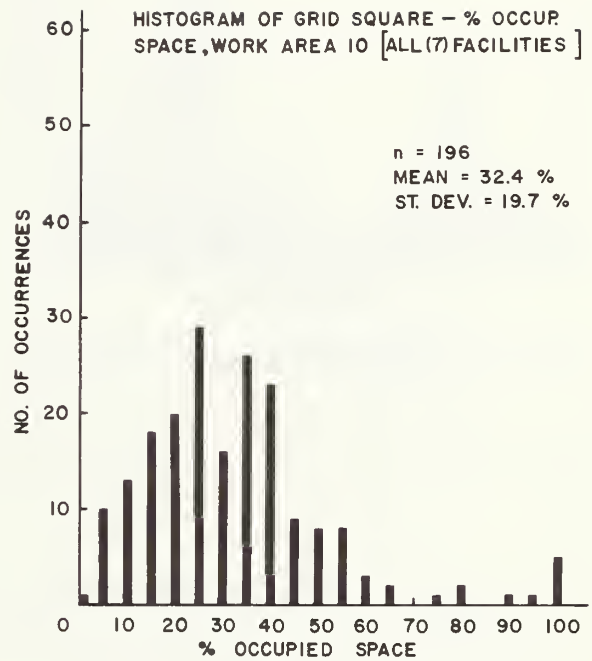

Figure 16j - Histogram of grid space occupied space percentages in work area 10 for all 7 combined facilities.

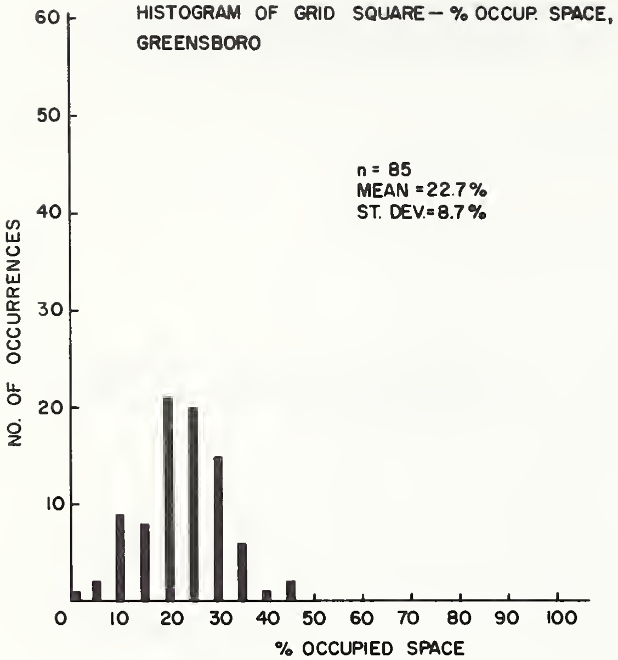

Figure 17a - Histogram of grid square occupied space percentages in Greensboro facility.

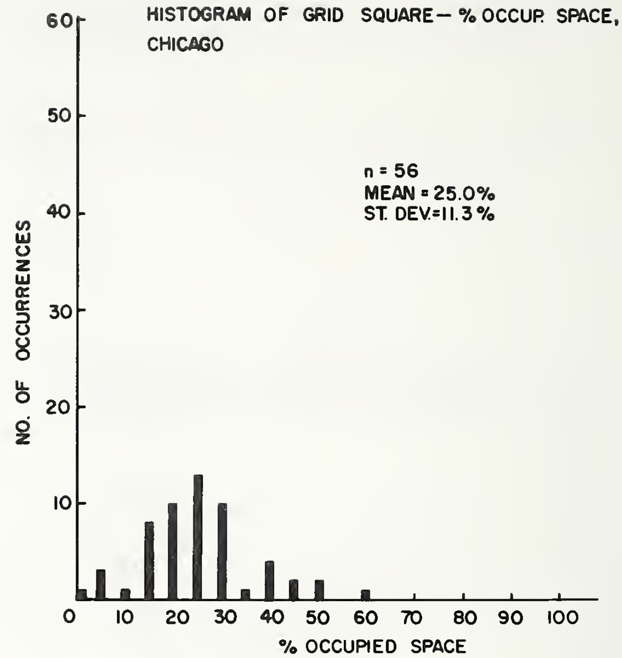

Figure 17b - Histogram of grid square occupied space percentages in Chicago facility.

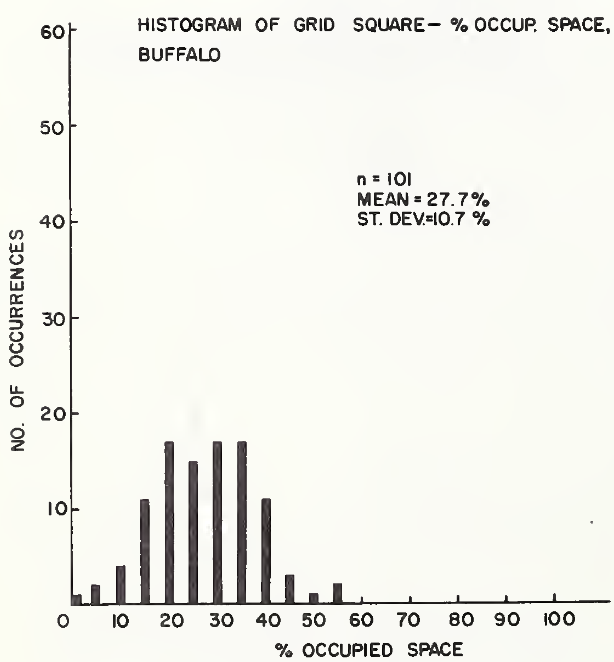

Figure 17c - Histogram of grid square occupied space percentages in Buffalo facility.

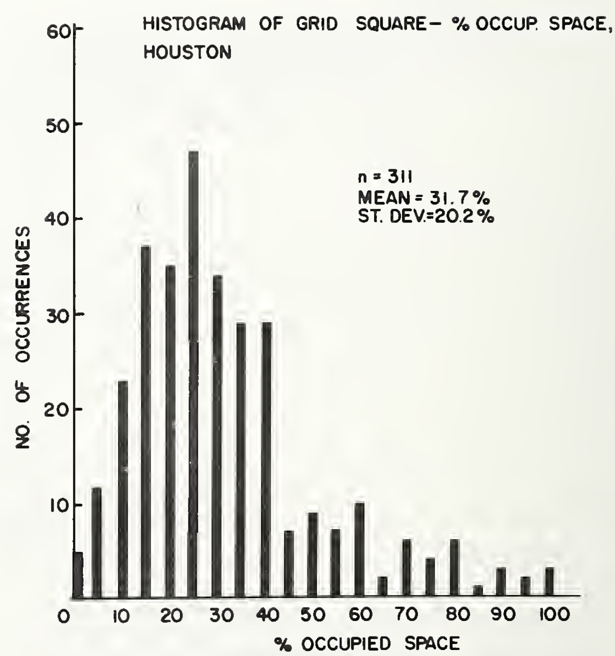

Figure 17d - Histogram of grid square occupied space percentages in Houston facility.

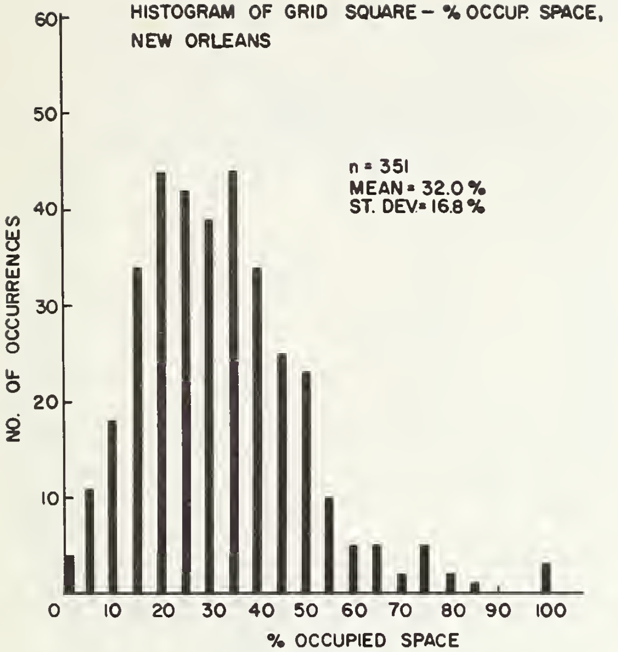

Figure 17e - Histogram of grid square occupied space percentages in New Orleans facility.

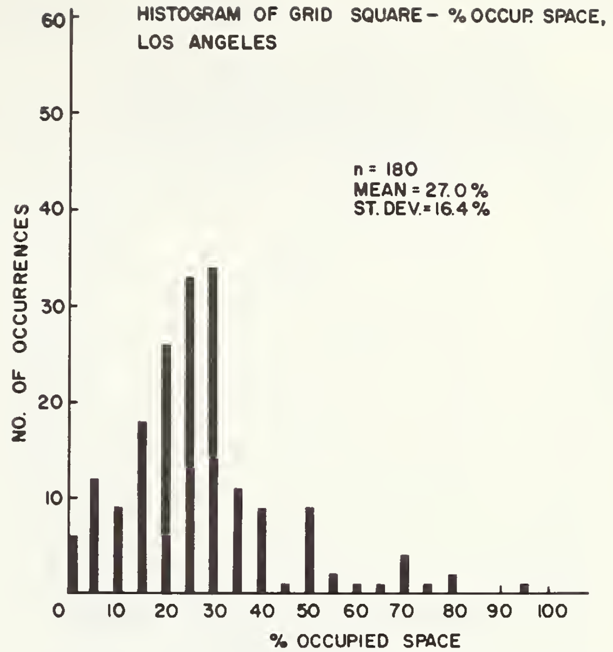

Figure 17f - Histogram of grid square occupied space percentages in Los Angeles facility.

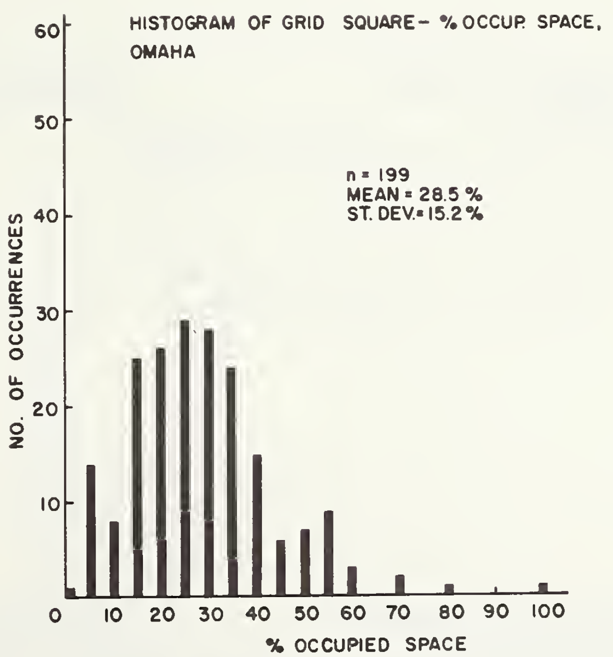

Figure 17g - Histogram of grid square occupied space percentages in Omaha facility.

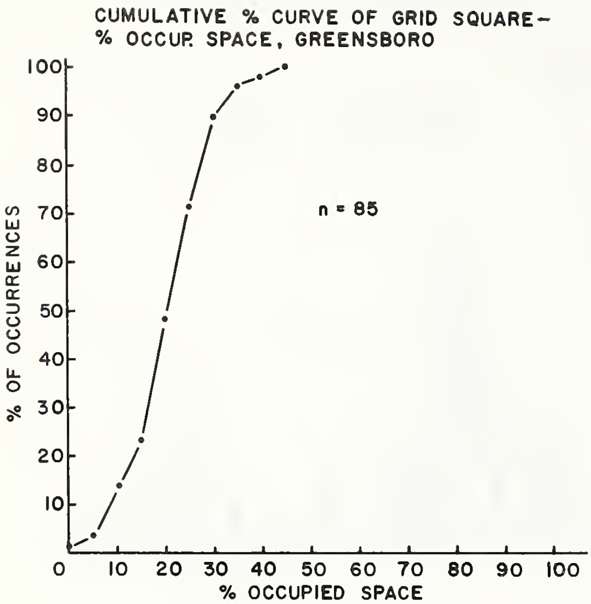

Figure 18a - Cumulative frequency distribution of grid square occupied space percentages in Greensboro facility.

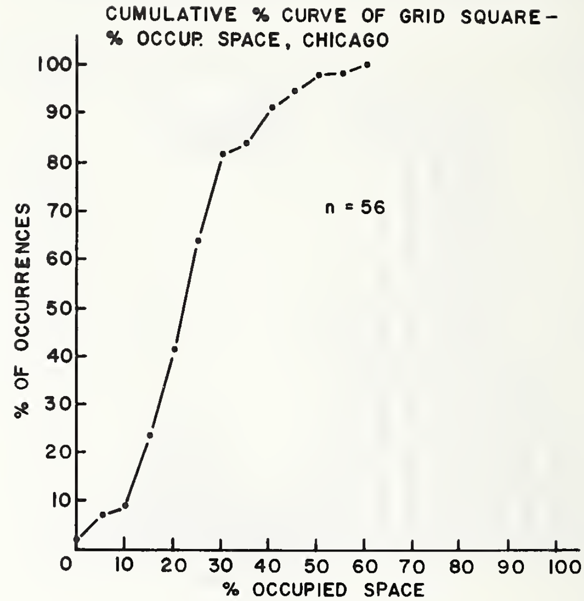

Figure 18b - Cumulative frequency distribution of grid square occupied space percentages in Chicago facility.

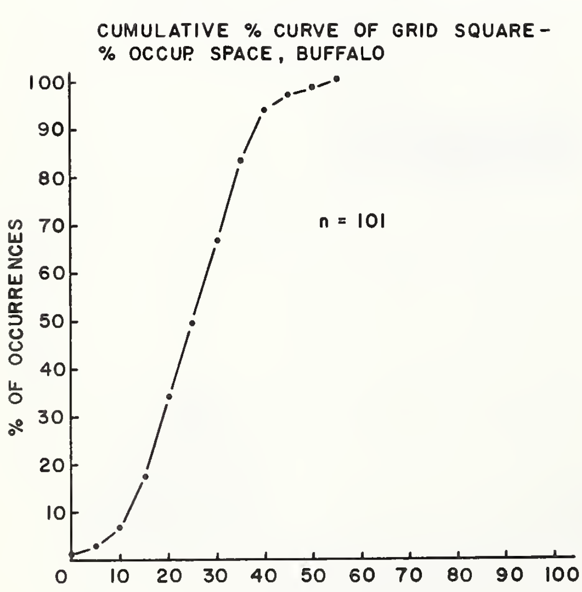

Figure 18c - Cumulative frequency distribution of grid square occupied space percentages in Buffalo facility.

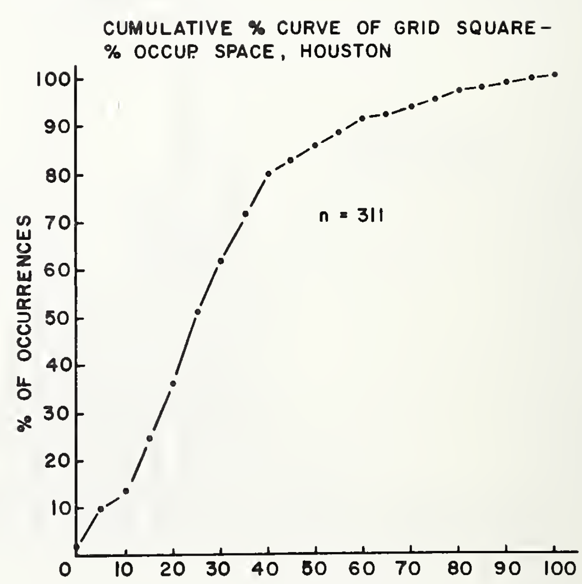

Figure 18d - Cumulative frequency distribution of grid square occupied space percentages in Houston facility.

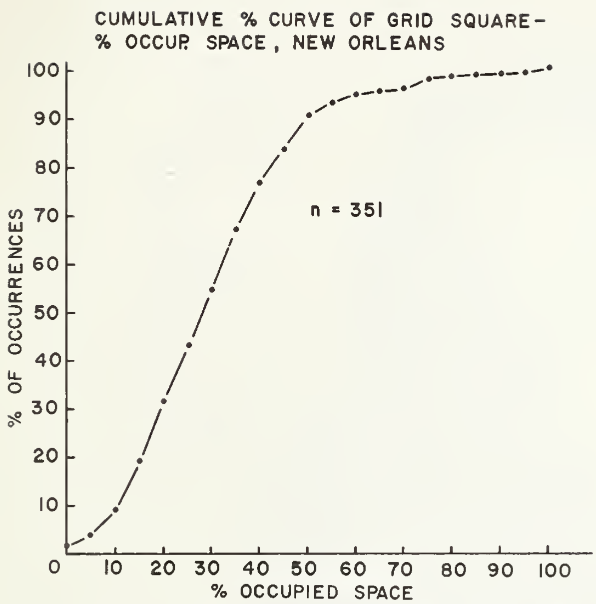

Figure 18e - Cumulative frequency distribution of grid square occupied space percentages in New Orleans facility.

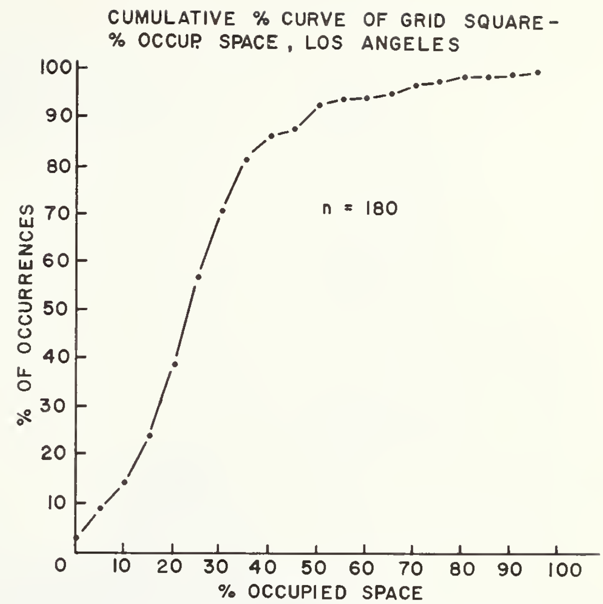

Figure 18f - Cumulative frequency distribution of grid square occupied space percentages in Los Angeles facility.

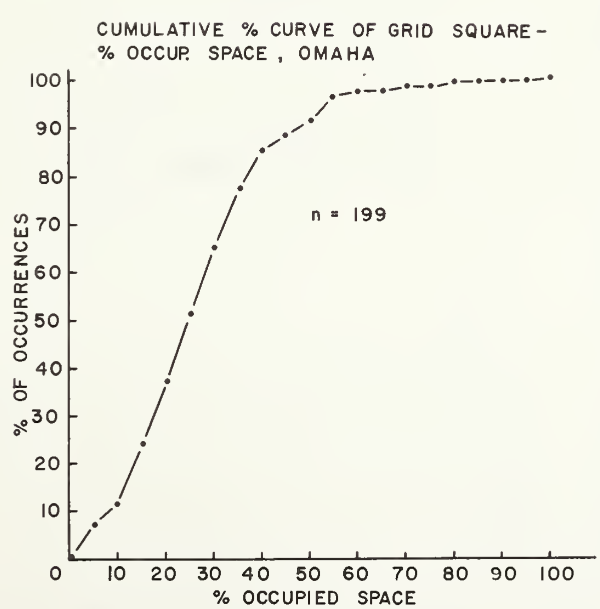

Figure 18g - Cumulative frequency distribution of grid square occupied space percentages in Omaha facility.

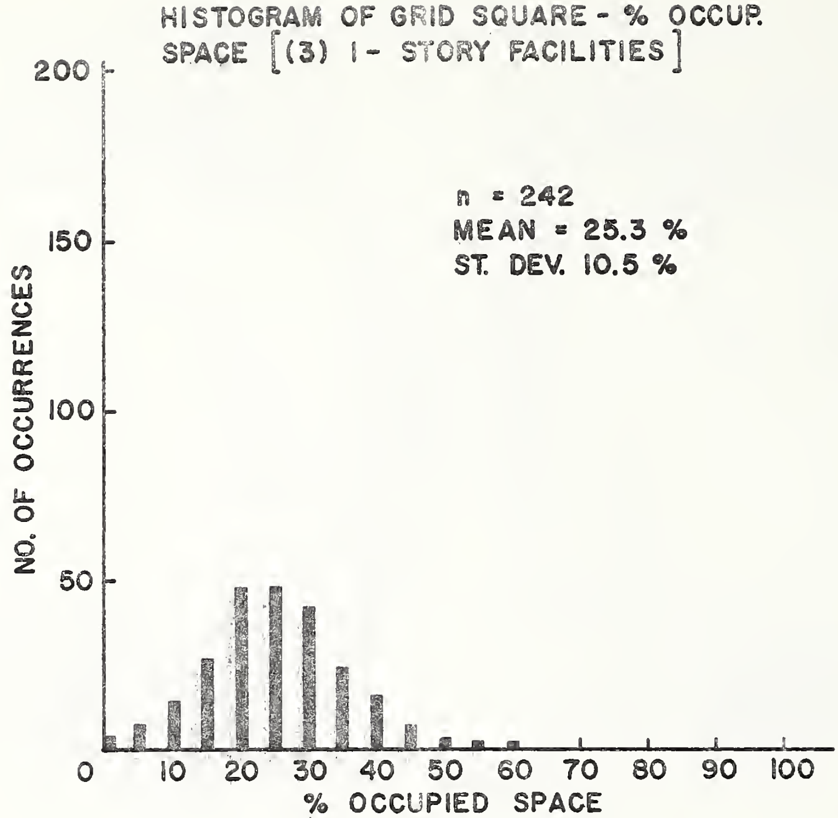

Figure 19 - Histogram of grid square occupied space percentages in 3 combined one-story facilities.

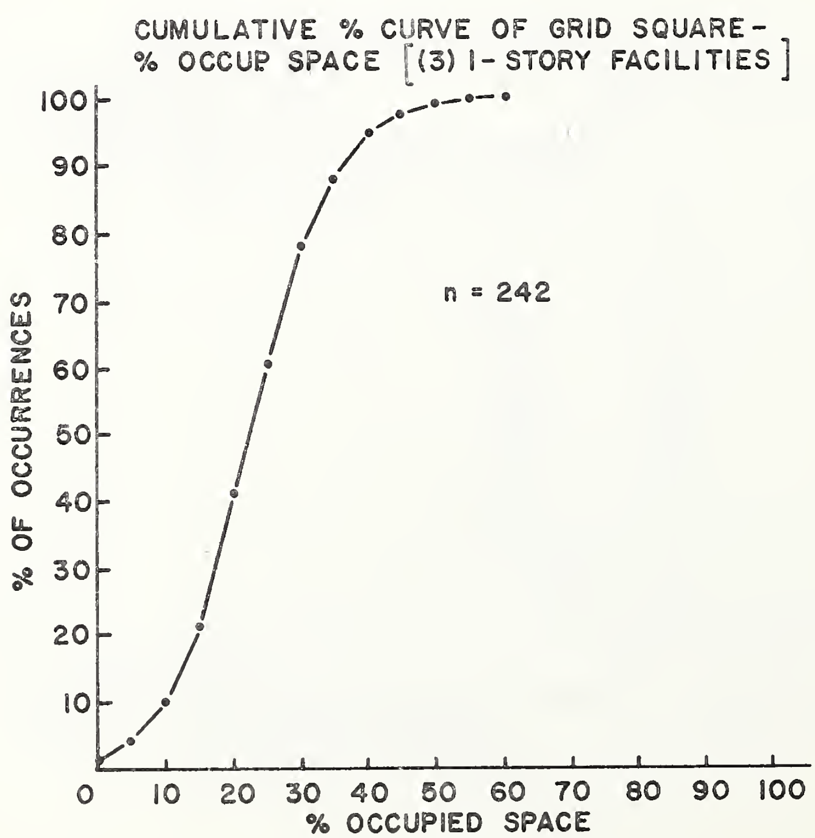

Figure 20 - Cumulative frequency distribution of grid square occupied space percentages in 3 combined one-story facilities.

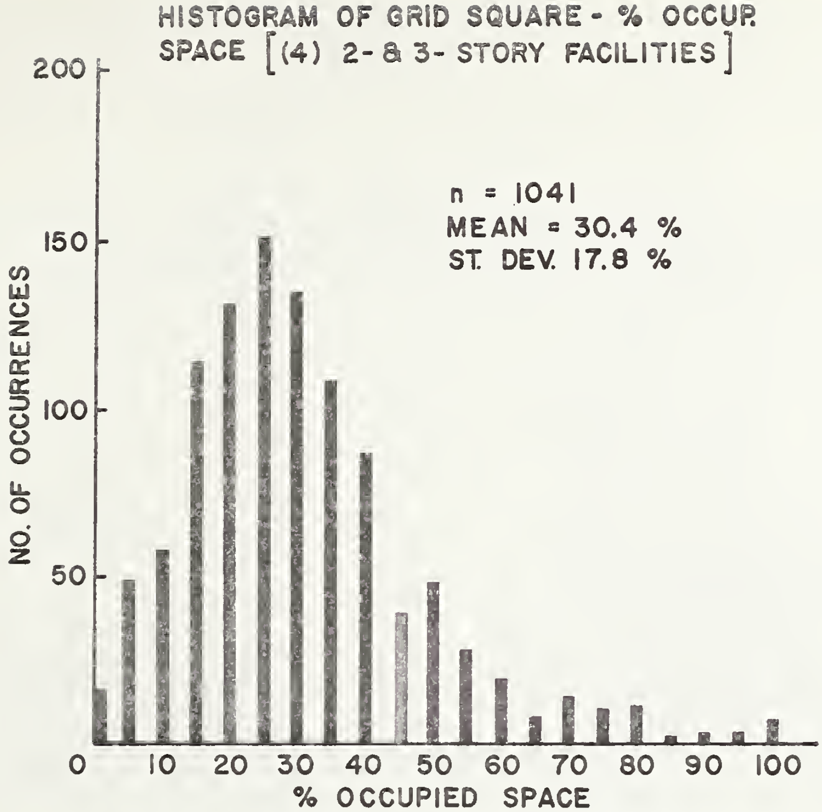

Figure 21 - Histogram of grid square occupied space percentages in 4 combined 2 and 3-story facilities.

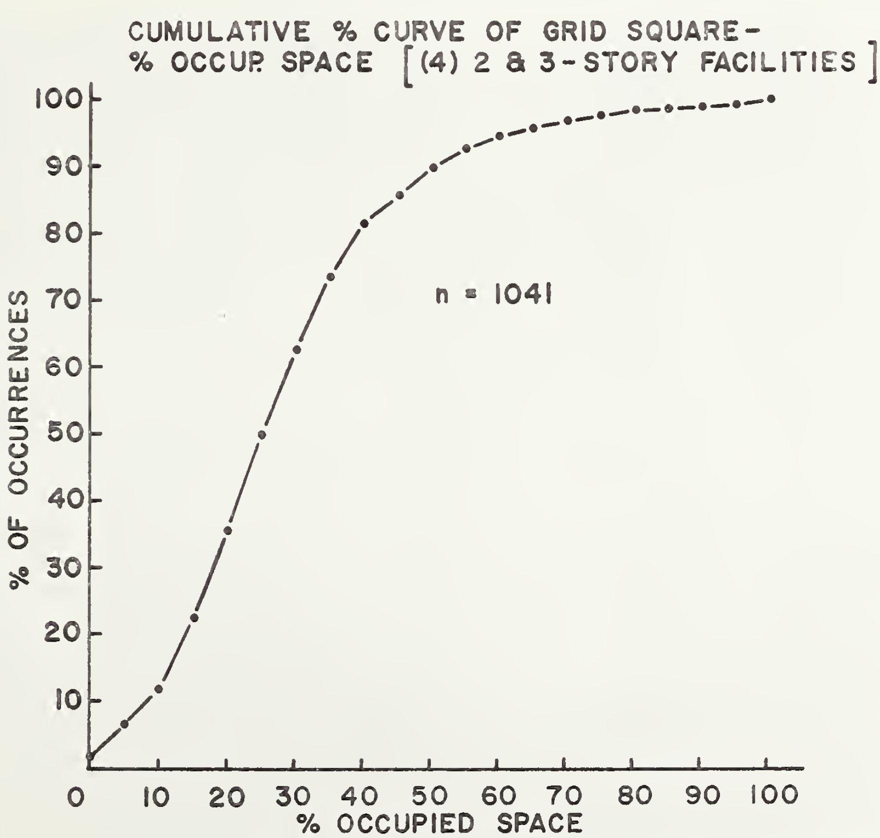

Figure 22 - Cumulative frequency distribution of grid square occupied space percentages in 4 combined 2 and 3-story facilities.

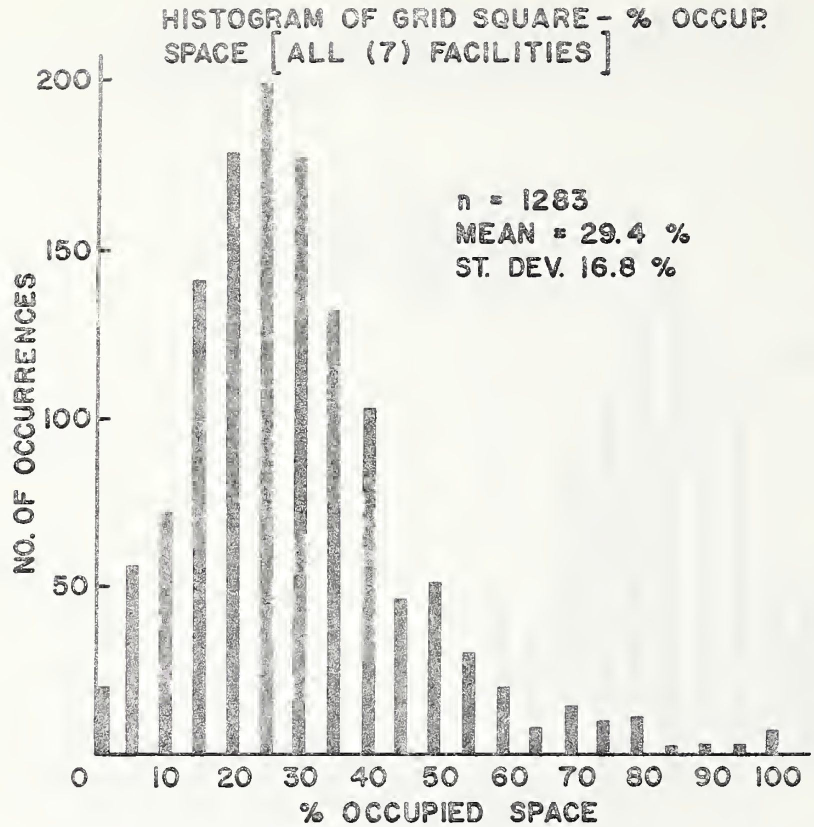

Figure 23 - Histogram of grid square occupied space percentages in all 7 combined facilities.

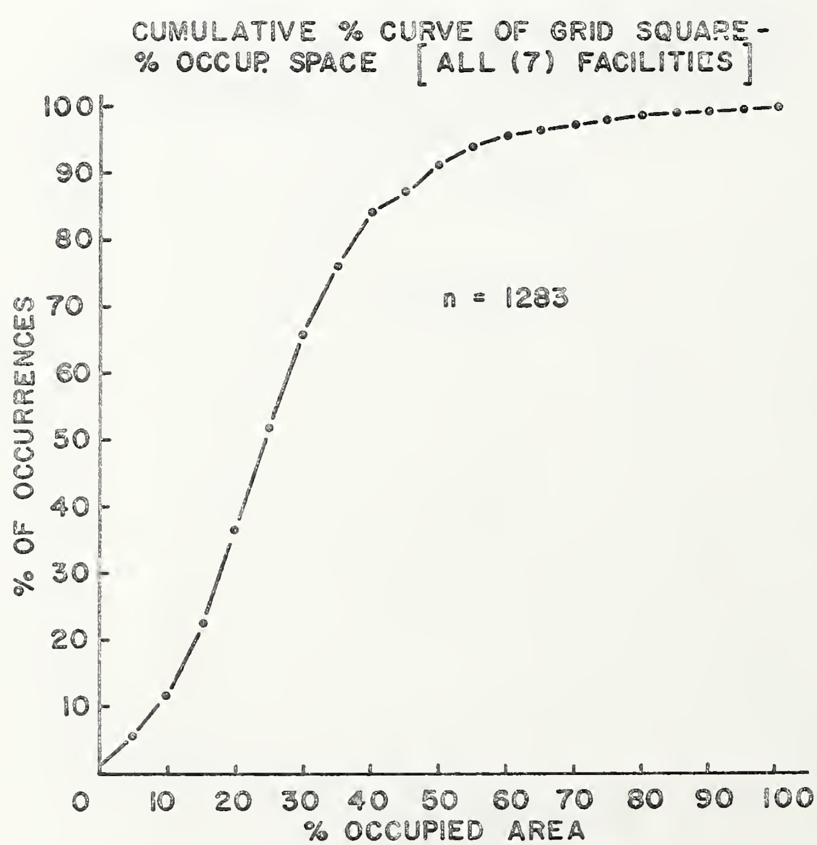

Figure 24 - Cumulative frequency distribution of grid square occupied space percentages in all 7 facilities.

Figure 25 - Loaded nutting trucks closely spaced on workroom floor.

Figure 26 - Filled mail sacks piled directly on workroom floor.

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