Live Loads on Floors in Buildings

United States Department of Commerce
National Bureau of Standards
Building Materials and Structures Report 133

BUILDING MATERIALS AND STRUCTURES REPORTS

On request, the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., will place your name on a special mailing list to receive notices of new reports in this series as soon as they are issued. There will be no charge for receiving such notices.
If 100 copies or more of any report are ordered at one time, a discount of 25 percent is allowed.
Send all orders and remittances to the *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

The following publications in this series are available by purchase from the Superintendent of Document at the prices indicated:

BMS2	Methods of Determining the Structural Properties of Low-Cost House Constructions	10¢
BMS3	Suitability of Fiber Insulating Lath as a Plaster Base	15¢
BMS4	Accelerated Aging of Fiber Building Boards	10¢
BMS5	Structural Properties of Six Masonry Wall Constructions	20¢
BMS6	Survey of Roofing Materials in the Southeastern States	15¢
BMS8	Methods of Investigation of Surface Treatment for Corrosion Protection of Steel	15¢
BMS9	Structural Properties of the Insulated Steel Construction Co.'s "Frameless-Steel" Constructions for Walls, Partitions, Floors, and Roofs	10¢
BMS10	Structural Properties of One of the "Keystone Beam Steel Floor" Constructions Sponsored by the H. H. Robertson Co	10¢
BMS11	Structural Properties of the Curren Fabrihome Corporation's "Fabrihome" Constructions for Walls and Partitions	10¢
BMS12	Structural Properties of "Steelox" Constructions for Walls, Partitions, Floors, and Roofs Sponsored by Steel Buildings, Inc	15¢
BMS15	Structural Properties of "Wheeling Long-Span Steel Floor" Construction Sponsored by the Wheeling Corrugating Co	10¢
BMS16	Structural Properties of a "Tilecrete" Floor Construction Sponsored by Tilecrete Floors, Inc	10¢
BMS17	Sound Insulation of Wall and Floor Constructions	20¢
Supplement to BMS17,	Sound Insulation of Wall and Floor Constructions	5¢
Supplement No. 2 to BMS17,	Sound Insulation of Wall and Floor Constructions	15¢
BMS18	Structural Properties of "Pre-fab" Constructions for Walls, Partitions, and Floors Sponsored by the Harnischfeger Corporation	10¢
BMS20	Structural Properties of "Twachtman" Constructions for Walls and Floors Sponsored by Connecticut Pre-Cast Buildings Corporation	10¢
BMS21	Structural Properties of a Concrete-Block Cavity-Wall Construction Sponsored by the National Concrete Masonry Association	10¢
BMS23	Structural Properties of a Brick Cavity-Wall Construction Sponsored by the W. E. Manufacturers Association of New York, Inc	10¢
BMS24	Structural Properties of a Reinforced-Brick Wall Construction and a Brick-Tile Cavity-Wall Construction Sponsored by the Structural Clay Products Institute	15¢
BMS25	Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs	20¢
BMS26	Structural Properties of "Nelson Pre-Cast Concrete Foundation" Wall Construction Sponsored by the Nelson Cement Stone Co., Inc	10¢
BMS27	Structural Properties of "Bender Steel Home" Wall Construction Sponsored by the Bender Body Co	10¢
BMS28	Backflow Prevention in Over-Rim Water Supplies	15¢
BMS29	Survey of Roofing Materials in the Northeastern States	20¢
BMS30	Structural Properties of a Wood-Frame Wall Construction Sponsored by the Douglas Fir Plywood Association	15¢
BMS32	Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association	15¢
BMS34	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1	15¢

[List continued on cover page III]

UNITED STATES DEPARTMENT OF COMMERCE • Charles Sawyer, *Secretary*
NATIONAL BUREAU OF STANDARDS • A. V. ASTIN, *Director*

Live Loads on Floors in Buildings

John W. Dunham, Guttorm N. Brekke
and George N. Thompson

Building Materials and Structures Report 133

Issued December 19, 1952

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 20 cents

Foreword

This report summarizes available information on floor loads in buildings, including the results of a recent survey that has provided data on several occupancies about which detailed information has been lacking. Variations in loading within the same occupancy are shown, and a method of live-load reduction for structural members supporting large floor areas is described.

It has been found possible to increase allowable stresses for some building materials as a result of better quality control and increased knowledge of strength characteristics. However, loads and stresses are so intimately associated that good information on loads is essential in order to realize the full advantage of economical design and to conserve scarce materials. It is believed that the data presented in this report will assist in accomplishing these objectives.

A. V. Astin, *Director.*

CONTENTS

Tables

Live Loads on Floors in Buildings

John W. Dunham,* Guttorm N. Brekke, and George N. Thompson

Information is presented on floor loads found in various occupancies such as office buildings, stores, factories, and warehouses. Most of this consists of the results of a recent survey in which the weight and distribution of goods, equipment, and occupants were obtained floor by floor and area by area. Such data are needed as a check on permissible minimum live loads in building codes and as a basis for design of buildings. Although there are indications in the survey that building codes may set higher figures than are warranted for certain occupancies, the amount of information available is still too small to justify firm conclusions. A method of reducing the assumed value for live load on structural members supporting large floor areas is described. Supplementary investigations of floor loading are recommended to clear up questions that have arisen in connection with the survey.

1. Introduction

Structural design of buildings is dependent upon knowledge of the loads to which such structures may be subjected and upon knowledge of building materials and structural systems. Through accumulation of data obtained in laboratory tests, much progress has been made in knowledge of the strength of building materials. The approximate weights of such materials have also been established. The characteristic behavior of different structural systems is receiving increased attention. Data on the loads affecting buildings are, however, rather meager, particularly with respect to the actual loads imposed by goods, equipment, and persons in typical occupancies such as offices, stores, and factories. Building regulations are in fairly close agreement as to the minimum loads to be assumed in designing buildings that contain such occupancies, in spite of the small amount of information upon which to base such requirements. However, with increasing urgency for conservation of materials, because of considerations of both scarcity and cost, it seems advisable to review pertinent data on loads and to summarize them for the use of designers and building code authorities. The information presented herein consists of results of investigations previously published, much of which is not readily available, and of a recent survey that has provided many new data.

There appear to be several reasons why relatively little work has been done in the past in the way of checking up the weight of building contents. Values given in handbooks, although of uncertain origin in some instances, have been in good agreement and have been generally assumed to represent a reasonable approximation of probable loads. The expense and trouble associated with actually weighing the contents of buildings have deterred efforts to obtain more comprehensive information. Relatively few cases of building collapse due to incorrect load assumptions have occurred, and so there has been no compelling reason for intensive work on load determinations.

Although there has been general acceptance of conventional load values, investigations from time to time by interested persons have been made that have thrown some light on the accuracy of common load assumptions. Most of these have been concerned with office buildings. [1, 2]. [1]

An early study of available data was that made by the Department of Commerce Building Code Committee, which prepared a report on recommended live-load assumptions, published by the Bureau in 1925 [3]. The report, now out of print, makes reference to information on loads found in a variety of occupancies, including dwellings, hotels, and other residential occupancies, hospitals, schools, office buildings, library stack rooms, manufacturing buildings of different kinds, and packing plants. Data on densely crowded groups of persons, as in elevators, are also given.

With reference to the loads in manufacturing buildings, the committee observed that the data were regrettably scant but were all that could be obtained from an earnest appeal to the architectural and engineering professions.

Although during the next quarter century, practices changed to some extent in the loading of some occupancies, such as offices and storerooms, little information was published giving the results of actual surveys. However, results of an investigation of loads in two Federal office buildings undertaken by the Public Buildings Administration were published in 1946 [4]. One building, the Internal Revenue Building in Washington, D. C., proved to have floor loads of 40 lb/ft^2 or less in 88 percent of its area. Certain areas were found to be much more heavily loaded, the maximum average live load of 106 lb/ft^2 occurring on 825 ft^2 of the second floor. In the other case, the Veterans' Administration Building in Washington, D. C., 97¾ percent of the area carried an average live load of 40 lb/ft^2 or less, but there was a maximum average live load on 1,176 ft^2 of 90 lb/ft^2.

In 1945, when the National Bureau of Standards published a report containing the recommendations of the Sectional Committee on Building Code Requirements for Minimum Design Loads in Buildings—A58, of the American Standards

*Supervising Structural Engineer, Public Buildings Service, General Services Administration.

[1] Figures in brackets refer to references at the end of this report.

Association [5], no new information obtained in surveys was presented and recommended minimum design values were about the same as in the previous document, although there was one notable exception in the case of the recommended assumption for office loads, which was increased from 50 lb/ft ^{2} in the case of the previous recommendation to 80 lb/ft ^{2} in the new report.

There were several reasons for this changed recommendation. An impression had been obtained by some of the committee members that office building loads were increasing, partly because of more intensive use of office space than formerly and partly because of the growing use of mechanical devices for calculating and other purposes. Facilities were not available for field investigation at that time, but a questionnaire was addressed to building managers asking for their views. The results were inconclusive but a number of replies indicating the possibility of loads greater than 50 lb/ft ^{2} was one factor in influencing the committee's judgment. Another, and perhaps more important development, was the introduction of a new method of providing for reduction of floor live loads in accordance with the probability of loading over extensive areas that permitted allowance for possible concentrations over limited areas and for a rather rapid reduction in design live load as the area concerned increased.

In 1947, the Office of Technical Services in the Department of Commerce sponsored a number of investigations intended to assist in the solution of various business and industrial problems. Among the subjects selected was an investigation of the weights of combustible contents in various occupancies. Accurate knowledge of such weights is important in establishing the potential fire severity of such occupancies. When plans for this work were under way, it was pointed out that the total weight of the contents was also of interest because of its relation to building design and that this weight could be readily ascertained by a very slight addition to the program. Accordingly, the work was planned to include the total live load in selected areas. The National Bureau of Standards undertook responsibility for the program and arranged to have the field work done by the Public Building Administration (now the Public Buildings Service) because of the long experience of that organization in the design and management of buildings. Reports of the results of the survey constitute the principal part of this publication.

Necessarily, the survey was somewhat limited because the amount of work involved in such an undertaking is much greater than is generally realized, and the funds were sufficient to include only a few buildings. Nevertheless, the work was performed systematically and provided an amount of detail that threw much light on floor loadings in typical occupancies, including the extent to which such loadings varied on different parts of the same floor.

Building codes require that all buildings shall be designed to carry their loads safely, and give a list of minimum assumed unit live loads for the more common occupancies. Actual loading of these occupancies may differ from the values given, but it is probable that in ordinary practice most buildings are designed at the minimum values. It thus becomes important that these values shall represent the worst conditions for which it is reasonable to provide. For occupancies not given, values used must be approved by the building department.

In the presentation of results of surveys and other information that follows, an arrangement by broad groups, such as is used in building codes, is employed. Within these groups, the minimum unit live loads usually found in building codes for typical occupancies in the groups, or in some cases a range of such loads, are given for comparison with unit live loads found in the surveys. The maximum unit live loads in the surveys are of principal interest. It should be remembered, however, that even these may not represent the heaviest conditions of loading, since there may be load concentrations not evident in the unit figures which are based on average conditions over rather large areas.

2. Residential Occupancy

The permissible minimum live load for purposes of design given in most building codes for residential occupancy is 40 lb/ft ^{2}. There are occasional instances where codes permit 30 lb/ft ^{2} on upper floors of single-family dwellings, and the same figure has been advocated by some authorities for general use throughout dwellings.

Various reasons have been advanced for the selection of 40 lb/ft^2 for residential occupancy. Some authorities have pointed out that it takes care of maximum possible loading when persons are assembled at teas, funerals, and other occasions. Other authorities believe that the figure was not intended to represent the actual loads in a dwelling but was selected because a wood-joist floor designed for a lesser load was generally considered too limber for the comfort of the occupants. From the latter point of view, the use of 40 lb/ft^2 is thus an indirect method of obtaining desired rigidity in wood-joisted construction.

Although there have been numerous estimates and assumptions made as to live loads in residential occupancy, no published results of figures obtained from weighing the contents of dwellings have been found. Figures for combustible contents given in BMS92, Fire-Resistance Classifications of Building Constructions, probably approximate closely the total live loads so far as movable property is concerned [6]. These figures show a maximum of 7.3 lb/ft^2 except in one portion occupied by a library, in which the figure is 10.6 lb/ft^2. Because the weight of persons is not included, some assumption would have to be made for this and added to the figures given. There is also the pos-

sibility of additional weight in the form of incombustible furnishings.

In the case of hotel rooms, which come within the general residential group, there is a published figure of 4.1 lb/ft² [3]. This applies only to the weight of furniture, however, and therefore does not represent the complete live load.

3. Business Occupancy

The permissible minimum live load for purposes of design given in building codes for business occupancy varies to some extent. If office space in buildings is taken as an example, the range in building codes recommended by various organizations for national or regional use and in building code standards is from 50 to 80 lb/ft².

More attention has been given to loading in office buildings than in any other occupancy. The results of early surveys are described in detail in the following extract from a report of the Department of Commerce Building Code Committee [3].

> *Offices*—The information available on this occupancy is much more complete than for any other. It has been carefully presented in recent technical periodicals and only a resume sufficient to support the committee's recommendations is included here.
>
> Actual weights of furniture and occupants on three complete floors and in a number of selected heavy occupancies in the Equitable Building, New York, N. Y., are reported by C. T. Coley, manager of the building, as follows:

Maximum, minimum, and average live loads in Equitable Building

	Offices	Maximum	Minimum	Average
		Lbs./ft²	*Lbs./ft²*	*Lbs./ft²*
Light-occupancy floor (twentieth)	67	55.4	0.87	10.26
Medium-occupancy floor (thirty seventh)	64	30.73	3.27	10.67
Heavy-occupancy floor (eleventh)	62	33.84	5.0	13.96
Total and average	193	-----	----	11.6
Selected heavy occupancies throughout the building	14	78.3	21.4	42.4

The weights given do not include the radiators, which would add approximately 1 pound per square foot for all exterior bays.

The weight of the partitions was not included in the calculations. These, in general, are 3-inch hollow tile plastered each side, and one which was being removed was found to weigh 30 pounds per square foot, or approximately 350 pounds per linear foot.

The weight of occupants, taken at 150 pounds per person, is probably high, as most of the occupants are females, and some studies indicate that an average weight of same would not exceed 120 pounds.

Careful sketches of load arrangement prepared by Mr. Coley made it possible to throw some light on the prevailing method of assuming uniformly distributed live loads as a basis for office floor design, and help to indicate what relation such assumptions should bear to actual total loads. Examination of bays for which the live load was more than 25 pounds per square foot showed wide variation in the distribution of such loads. The larger proportion was found, as might be expected, within a zone approximately 3 feet wide around the walls, the remainder being distributed variously in the centers of the rooms. In one or two cases, however, the major portion of the load was located away from the walls and this condition must be provided for by designers. There is also the probability that practically all furniture may be collected in the central portion of a floor area when occupants are moving, or when decorating or cleaning is in progress.

The sketches show that the heavier loads, such as library shelves and double filing cabinets, are likely to be located away from walls and partitions. This is obviously for ease of access, and the same consideration demands that when total loads per square foot are high they must be quite uniformly distributed.

The heaviest loading discovered was one incidental to office purposes, being made up chiefly of card filing cases, but the stack room of a law library on one floor would have averaged 87 pounds per square foot if the shelves had been completely filled.

Only eight articles of furniture (safes) were found over 2,000 pounds in weight. A number of sectional filing cases and bookcases with contents weighed much more, but these weights were distributed over such a large area they could not be regarded as concentrated. Of 36 safes and safe cabinets, 23 weighed less than 1,000 pounds; 5 between 1,000 and 2,000 pounds; 2 weighed 2,200 pounds; 2, 2,360 pounds; 1, 2,800 pounds; 1, 3,000 pounds; 1, 3,500 pounds, and 1, 4,250 pounds.

As would naturally be expected, the live loads were found to be lighter next to the exterior walls of the building. Single-row filing cases, cabinets, safes, bookcases, and bins are usually located against blank interior walls. Whether by accident or otherwise, the heavier loads were not found where partitions cut up the floor space into small rooms, indicating that allowance may not be necessary both for movable partitions and heavy floor loads.[2]

Several instances were found where two adjacent floor bays supported average loads of 25 pounds or more, but in no case were two adjacent bays found loaded in excess of an average of 40 pounds per square foot.

There are but two or three instances in the floor plans discussed where three or more offices or storerooms meet at the same column, and it is probable that this condition will be found but rarely in buildings designed for a sufficiency of light and ventilation.

An investigation by M. W. McIntyre of the Union Central Life Insurance Co.'s building in Cincinnati gave quite similar results. All files, desks, etc., were considered as being 100 per cent full or furnished with all necessary accessories. Following are tabulated the results of Captain McIntyre's investigations

Weight of employees, computed at the rate of 150 pounds each, added from 0.9 to 1.75 pounds per square foot of floor area.

Office live loads in Union Central Life Insurance Building

	Number of square feet	Number of pieces of furniture	Total weight of furniture	Weight of furniture per square foot
			Pounds	*Pounds*
Section A	10,339	635	104,478	10.05
Section B	9,303	637	27,085	2.91
Section C	7,348	273	36,306	4.92
Section D	10,339	702	121,388	11.74
Average	9,332	561.5	72,314	7.405

[2] Authors' note: Observation of loading under present conditions indicates some exceptions from this statement.

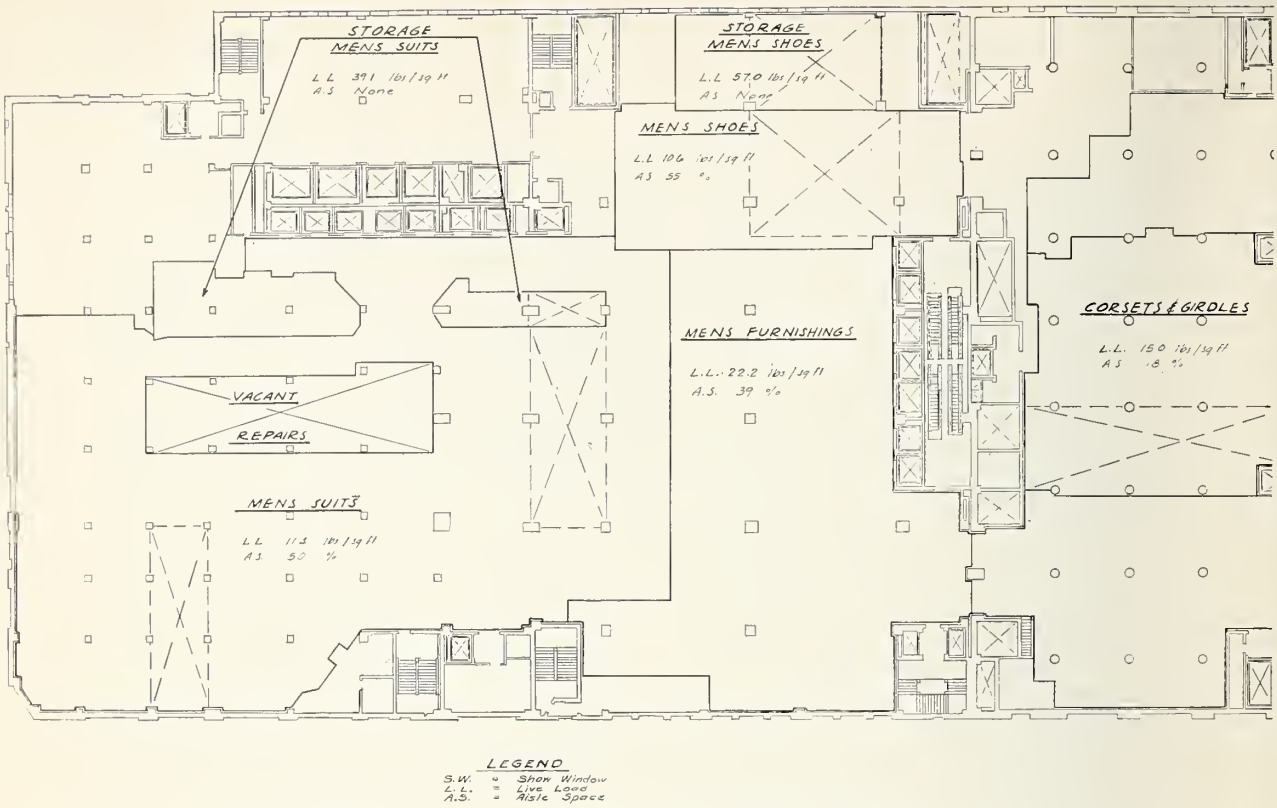

FIGURE 1. *Second-floor plan, department store, New York, N. Y.*

TABLE 1. *Live loads in department store, New York, N. Y.*—Continued

Department	Area			Unit live load	
	Part surveyed	Whole department	Aisle space	As surveyed	With aisles crowded [a]
	ft²	*ft²*	*Percent*	*lb/ft²*	*lb/ft²*
Sixth floor					
Women's shoes	1,720	21,358	64	15.4	51.8
Storage (women's shoes)	1,100	12,085	0	42.0	-------
Towels	2,020	6,882	41	12.8	37.4
Blankets	1,470	6,811	42	11.8	37.0
Sheets and linens	970	17,379	39	20.3	43.7
Notions	1,220	2,238	34	14.1	34.5
Patterns	420	2,525	64	19.9	58.3
Yard goods	1,970	26,904	41	15.6	40.2
Total	-------	96,182	------	--------	--------
Seventh floor					
Linoleum	810	3,070	64	7.5	45.9
Rugs	3,360	27,651	44	8.7	35.1
Candles	200	200	21	32.3	44.9
Lamps and shades	990	7,868	73	9.4	53.2
Curtains	970	14,430	67	5.2	45.2
Closet shop	510	8,109	78	11.6	58.4
Wallpaper	900	1,190	77	10.1	56.3
Assorted yard goods	[c]	23,303	41	15.6	40.2
Total	-------	85,821	------	--------	--------

TABLE 1. *Live loads in department store, New York, N. Y.*—Continued

Department	Area			Unit live load	
	Part surveyed	Whole department	Aisle space	As surveyed	With aisles crowded [a]
	ft²	*ft²*	*Percent*	*lb/ft²*	*lb/ft²*
Eighth floor					
Food	1,970	10,190	63	16.7	54.5
Glassware	1,730	9,438	66	10.6	50.2
Chinaware	1,930	19,244	64	14.7	53.1
Pictures and frames	1,820	7,253	69	7.0	48.4
Luggage	1,930	8,149	38	7.4	30.2
Total	-------	54,274	------	--------	--------
Ninth floor					
Bedroom furniture	3,960	24,929	53	4.8	36.6
Dining room and occasional furniture	2,680	55,847	39	4.1	27.5
Modern furniture	2,180	12,513	34	13.2	33.6
Total	-------	93,289	------	--------	--------
Grand total	-------	790,793	------	--------	--------

[a] At rate of 60 lb/ft² additional loading for aisle space.
[b] See similar department on first floor.
[c] See similar department on third floor.
[d] See similar department on this floor.
[e] See "yard goods" on sixth floor.

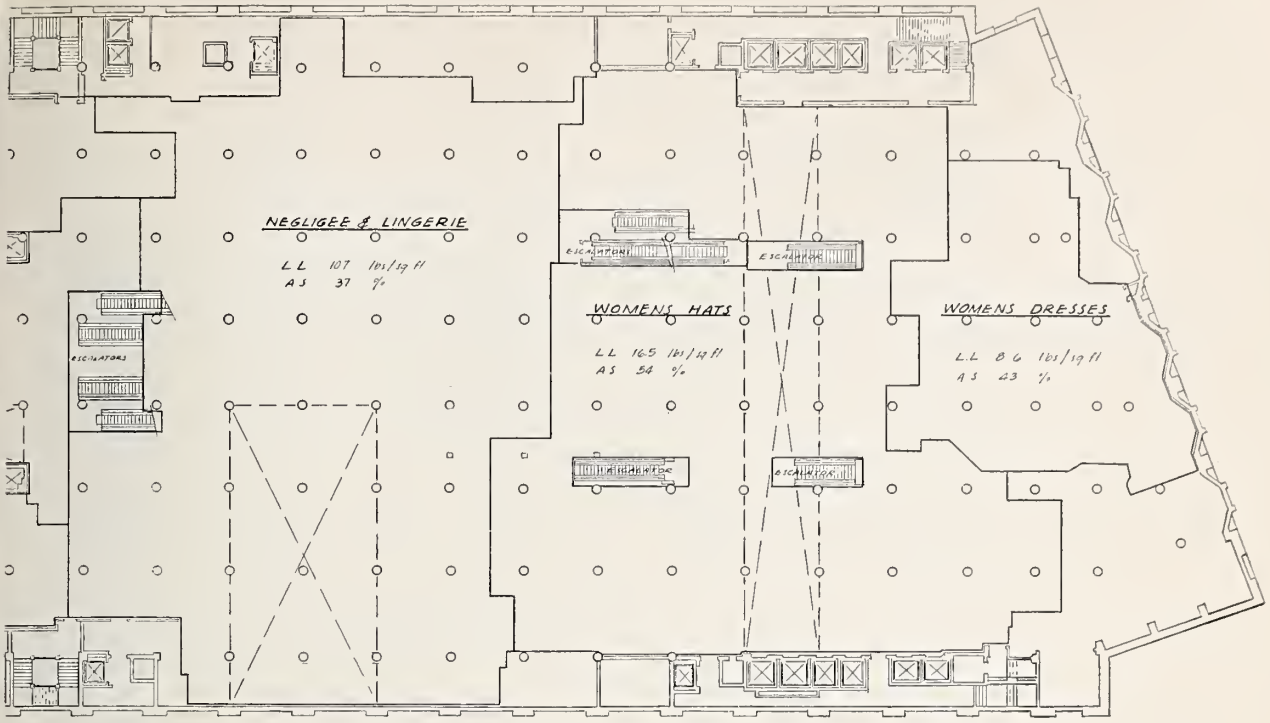

FIGURE 1—Continued

TABLE 2. *Variation in live loads in department store, New York, N. Y.*

Unit load (lb/ft²)	Area	Portion of total area
	ft²	*Percent*
20.0 to 24.9	21,282	2.7
25.0 to 29.9	74,527	9.4
30.0 to 34.9	111,442	14.1
35.0 to 39.9	119,305	15.1
40.0 to 44.9	198,883	25.1
45.0 to 49.9	148,463	18.8
50.0 to 54.9	86,688	11.0
55.0 to 59.9	23,803	3.0
60.0 to 64.9	6,400	0.8
Total	790,793	100.0

TABLE 3. *Live loads in department store, Washington, D. C*

Department	Area [a]		Unit live load	
	Whole department	Aisle space	As surveyed	With aisles crowded [b]
First floor				
	ft²	*Percent*	*lb/ft²*	*lb/ft²*
Dry cleaning counter	320	37	15.1	37.3
Books	3,450	28	21.4	38.2
Candy	1,600	29	16.5	33.9
Notions	9,750	43	17.8	43.6
Umbrellas	350	20	26.3	38.3
Service	150	60	30.7	66.7
Cosmetics	6,350	40	16.6	40.6
Handbags and leather goods	2,800	38	13.4	36.2
Hat bar	300	27	17.7	33.9
Stationery	5,500	41	16.0	40.6
Costume jewelry	2,900	37	13.2	35.4
Jewelry	3,350	36	16.7	38.3
Total	36,820	----	----	--------
Second floor				
Drygoods, patterns, and art goods	8,752	32	9.7	28.9
Ladies' shoe stock room	2,000	30	32.8	--------
Children's shoe stock room	955	20	28.1	--------
Shoe sale space	3,944	35	5.8	26.1
Storage (men's hats, shoes, tobacco, etc.)	809	20	32.2	--------
Men's clothing	16,227	50	15.1	45.1
Total	32,687	----	----	--------

See footnotes at end of table.

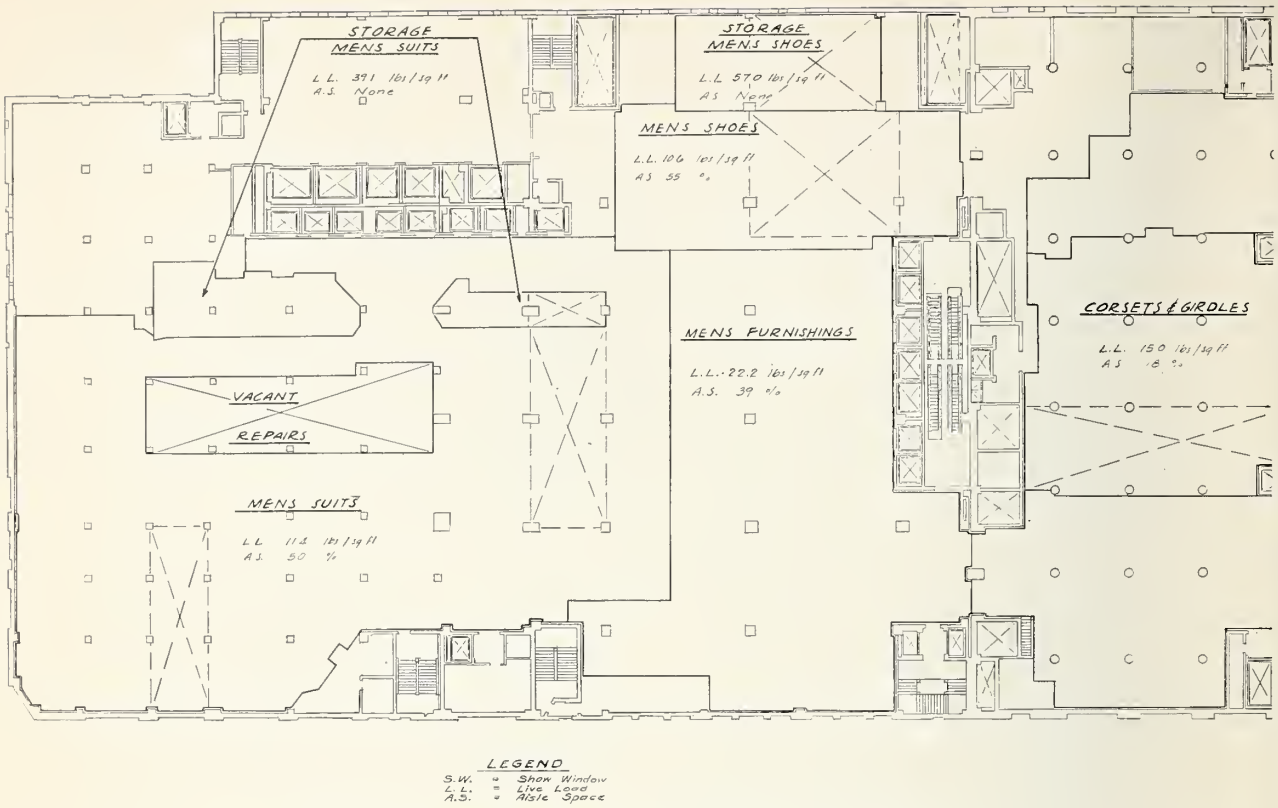

FIGURE 1. *Second-floor plan, department store, New York, N. Y.*

TABLE 1. *Live loads in department store, New York, N. Y.*—Continued

Department	Area			Unit live load	
	Part surveyed	Whole department	Aisle space	As surveyed	With aisles crowded [a]
	ft^2	ft^2	Percent	lb/ft^2	lb/ft^2
Sixth floor					
Women's shoes	1,720	21,358	64	15.4	51.8
Storage (women's shoes)	1,100	12,085	0	42.0	
Towels	2,020	6,882	41	12.8	37.4
Blankets	1,470	6,811	42	11.8	37.0
Sheets and linens	970	17,379	39	20.3	43.7
Notions	1,220	2,238	34	14.1	34.5
Patterns	420	2,525	64	19.9	58.3
Yard goods	1,970	26,904	41	15.6	40.2
Total		96,182			
Seventh floor					
Linoleum	810	3,070	64	7.5	45.9
Rugs	3,360	27,651	44	8.7	35.1
Candles	200	200	21	32.3	44.9
Lamps and shades	990	7,868	73	9.4	53.2
Curtains	970	14,430	67	5.2	45.2
Closet shop	510	8,109	78	11.6	58.4
Wallpaper	900	1,190	77	10.1	56.3
Assorted yard goods	[e]	23,303	41	15.6	40.2
Total		85,821			
Eighth floor					
Food	1,970	10,190	63	16.7	54.5
Glassware	1,730	9,438	66	10.6	50.2
Chinaware	1,930	19,244	64	14.7	53.1
Pictures and frames	1,820	7,253	69	7.0	48.4
Luggage	1,930	8,149	38	7.4	30.2
Total		54,274			
Ninth floor					
Bedroom furniture	3,960	24,929	53	4.8	36.6
Dining room and occasional furniture	2,680	55,847	39	4.1	27.5
Modern furniture	2,180	12,513	34	13.2	33.6
Total		93,289			
Grand total		790,793			

[a] At rate of 60 lb/ft^2 additional loading for aisle space.
[b] See similar department on first floor.
[c] See similar department on third floor.
[d] See similar department on this floor.
[e] See "yard goods" on sixth floor.

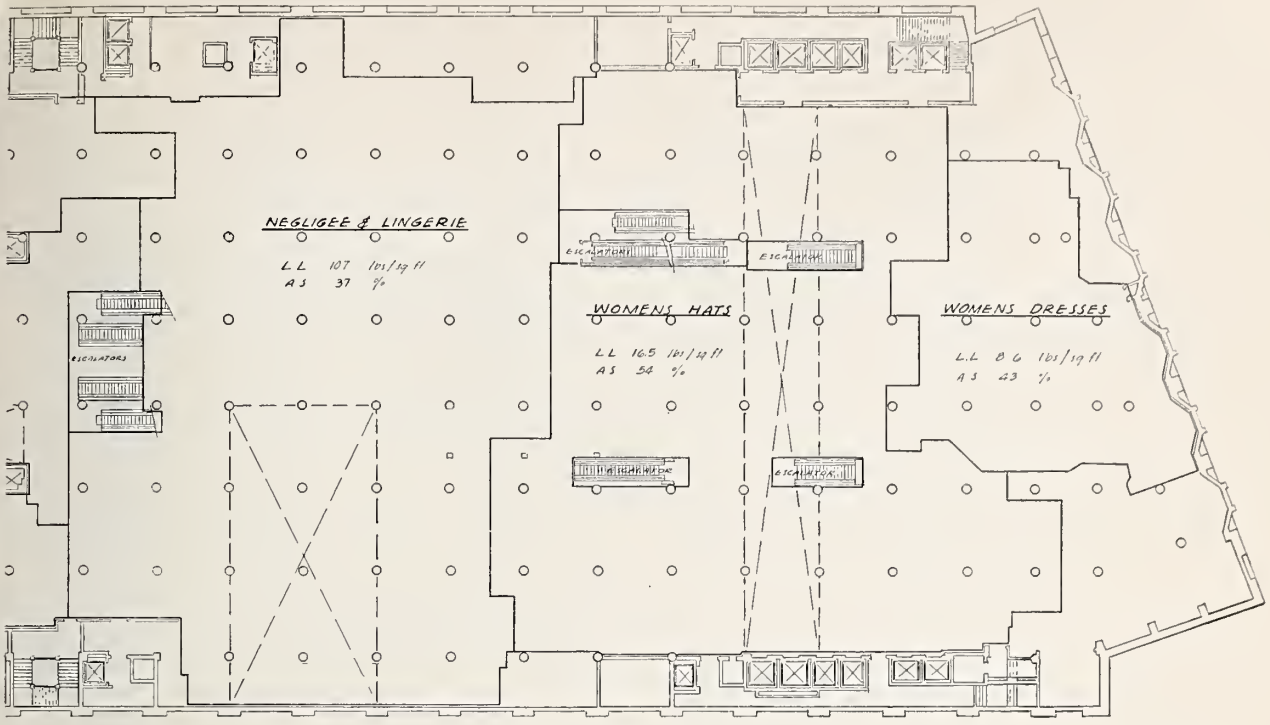

FIGURE 1—Continued

TABLE 2. *Variation in live loads in department store, New York, N. Y.*

Unit load (lb/ft²)	Area	Portion of total area
	ft²	*Percent*
20.0 to 24.9	21,282	2.7
25.0 to 29.9	74,527	9.4
30.0 to 34.9	111,442	14.1
35.0 to 39.9	119,305	15.1
40.0 to 44.9	198,883	25.1
45.0 to 49.9	148,463	18.8
50.0 to 54.9	86,688	11.0
55.0 to 59.9	23,803	3.0
60.0 to 64.9	6,400	0.8
Total	790,793	100.0

TABLE 3. *Live loads in department store, Washington, D. C*

Department	Area [a]		Unit live load	
	Whole department	Aisle space	As surveyed	With aisles crowded [b]
First floor				
	ft²	*Percent*	*lb/ft²*	*lb/ft²*
Dry cleaning counter	320	37	15.1	37.3
Books	3,450	28	21.4	38.2
Candy	1,600	29	16.5	33.9
Notions	9,750	43	17.8	43.6
Umbrellas	350	20	26.3	38.3
Service	150	60	30.7	66.7
Cosmetics	6,350	40	16.6	40.6
Handbags and leather goods	2,800	38	13.4	36.2
Hat bar	300	27	17.7	33.9
Stationery	5,500	41	16.0	40.6
Costume jewelry	2,900	37	13.2	35.4
Jewelry	3,350	36	16.7	38.3
Total	36,820	----	----	--------
Second floor				
Drygoods, patterns, and art goods	8,752	32	9.7	28.9
Ladies' shoe stock room	2,000	30	32.8	--------
Children's shoe stock room	955	20	28.1	--------
Shoe sale space	3,944	35	5.8	26.1
Storage (men's hats, shoes, tobacco, etc.)	809	20	32.2	--------
Men's clothing	16,227	50	15.1	45.1
Total	32,687	----	----	--------

See footnotes at end of table.

TABLE 3. *Live loads in department store, Washington, D. C.*—Continued

Department	Area [a]		Unit live load	
	Whole department	Aisle space	As surveyed	With aisles crowded [b]
Third floor				
	ft²	*Percent*	*lb/ft²*	*lb/ft²*
Women's hats	4,300	50	8.7	38.7
Lingerie and dresses	5,700	40	13.0	37.0
Ladies' ready-to-wear	16,350	45	6.7	33.7
Ladies' gowns and furs	18,500	53	6.5	38.3
Total	44,850	----	----	--------
Fourth floor				
Boys' clothing	3,830	33	15.9	35.7
Infant and juvenile clothing	11,934	40	8.8	32.8
Camera and radio	3,958	30	12.0	30.0
Music	2,870	50	25.0	55.0
Junior misses	14,022	60	5.6	41.6
Total	36,614	----	----	--------
Fifth floor				
Gift shop	2,800	30	19.4	37.4
China and glass	11,400	39	12.3	35.7
Linen and towels	5,500	35	10.7	31.7
Bedding	4,350	32	10.4	29.6
Bedroom furniture	15,800	40	6.2	30.2
Carpenter and paint shop	2,600	0	22.5	--------
China and glass storage	440	0	19.3	--------
General wrapping	1,550	0	10.6	--------
Total	44,440	----	----	--------
Sixth floor				
Furniture display rooms	8,145	0	7.3	--------
Employees' cafeteria	1,496	0	7.0	--------
Rug department	10,925	35	11.3	32.3
Foyer	780	85	3.5	54.5
Storage and shipping (rug and linoleum)	822	0	23.4	--------
Furniture	14,200	25	4.2	19.2
Miscellaneous furniture and office	2,468	0	7.6	--------
Interior decorating	1,420	0	13.0	--------
Total	40,256	----	----	--------
Seventh floor				
Luggage	4,250	39	6.0	29.4
Pictures	2,100	38	15.8	38.6
Lamps	4,100	65	9.7	48.7
Draperies	9,000	46	8.7	36.3
Drapery storage No. 1	960	0	23.6	--------
Drapery storage No. 2	550	0	42.8	--------
Auditorium	800	----	5.4	--------
Offices	4,000	0	10.7	10.7
Waiting room at tearoom	1,200	100	1.6	61.6
Fountain room and fountain	2,900	0	11.9	--------
Tearoom	8,300	0	8.6	--------
Linen storage (tearoom)	380	0	30.2	--------
Total	38,540	----	----	--------

TABLE 3. *Live loads in department store, Washington, D. C.*—Continued

Department	Area [a]		Unit live load	
	Whole department	Aisle space	As surveyed	With aisles crowded [b]
Eighth floor				
	ft²	*Percent*	*lb/ft²*	*lb/ft²*
Paint	1,749	24	22.6	37.0
Household goods	7,781	30	7.9	25.9
Groceries	3,500	37	8.3	30.5
Cold storage for groceries	400	0	24.1	--------
Refrigerators, etc	2,307	23	15.0	28.8
Electrical	1,400	50	12.9	42.9
Bathroom fittings	3,205	46	9.0	36.6
Cafeteria	3,834	0	4.9	--------
Central wrapping	2,556	0	11.3	--------
Bakery	3,210	0	10.9	--------
Paper storage	360	0	24.6	--------
Fur fitting	2,000	0	4.1	--------
Office	7,230	0	10.9	--------
Total	39,532	----	----	--------
Grand total	313,739	----	----	--------

[a] The entire department was surveyed in each case.
[b] At rate of 60 lb/ft² additional loading for aisle space.

TABLE 4. *Variation in live loads in department store, Washington, D. C.*

Unit load (lb/ft²)	Area	Portion of total area
	ft²	*Percent*
0.0 to 4.9	5,834	1.7
5.0 to 9.9	21,209	6.8
10.0 to 14.9	22,866	7.3
15.0 to 19.9	14,640	4.7
20.0 to 24.9	5,142	1.6
25.0 to 29.9	31,384	10.0
30.0 to 34.9	54,447	17.4
35.0 to 39.9	91,554	29.2
40.0 to 44.9	39,336	12.5
45.0 to 49.9	20,327	6.5
50.0 to 54.9	2,780	0.9
55.0 to 59.9	2,870	.9
60.0 to 64.9	1,200	.4
65.0 to 69.9	150	.1
Total	313,739	100.0

5. Assembly Occupancy

"Assembly occupancy" includes theaters, dance halls, auditoriums, churches, and schools.

Building codes recommended by various organizations for national or regional use and building code standards give permissible minimum live loads of from 50 to 60 lb/ft² for orchestra floors of theaters and for floors of assembly halls with fixed seats, and 100 lb/ft² for those with movable seats. Dance halls are assigned 100 to 120 lb/ft². For schools, classrooms with fixed seats are required to be designed for 40 to 60 lb/ft², and those with movable seats from 40 to 100 lb/ft².

Information on loading of school floors appears in the report of the Department of Commerce Building Code Committee already referred to [3]

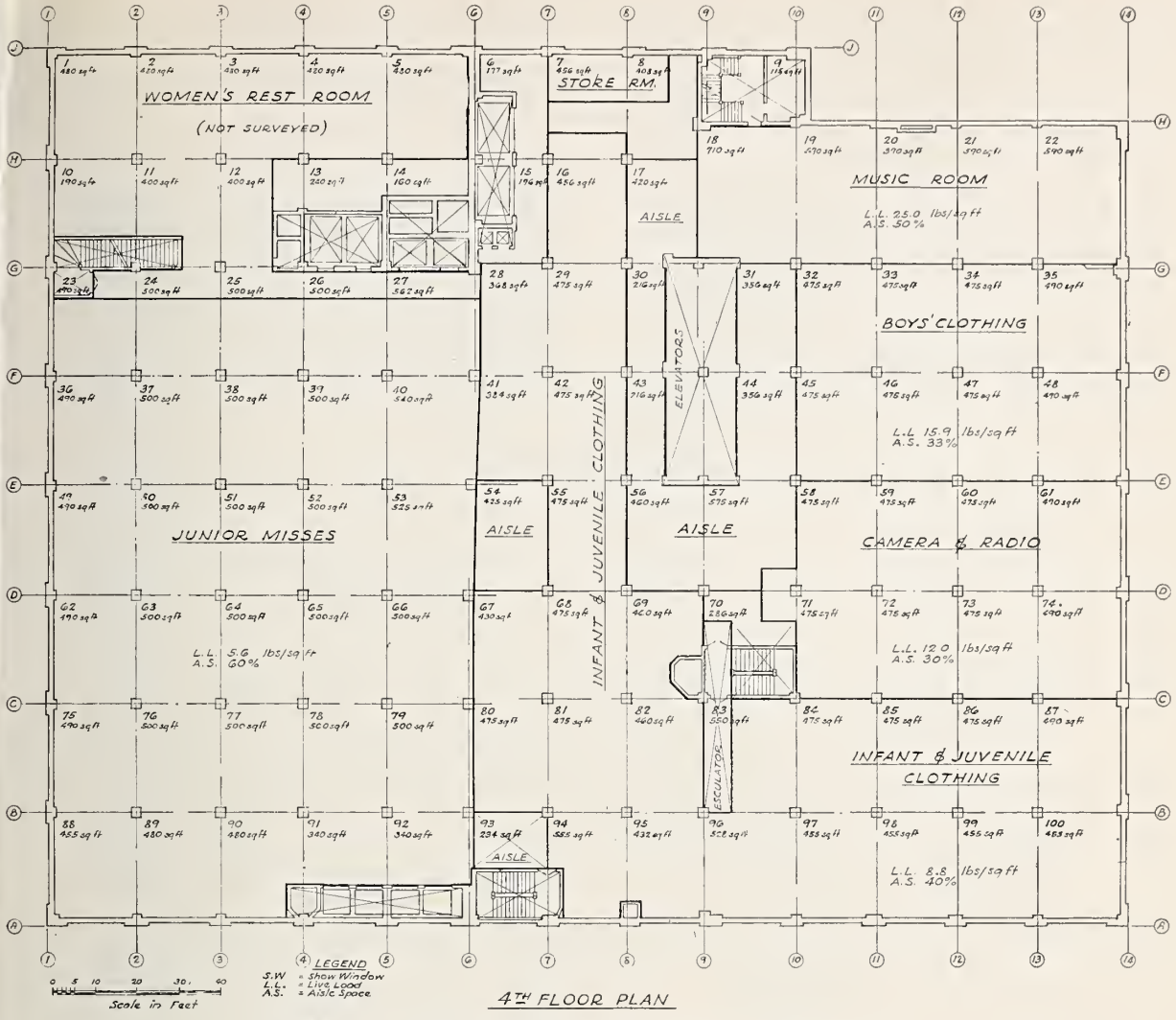

FIGURE 2. *Fourth-floor plan, department store, Washington, D. C.*

Schools.—According to investigations by Norman M. Stineman (American Architect, April 11, 1923) a standard classroom has 736 square feet area and accommodates 45 pupils. The average weight of furniture and inmates is about 7,500 pounds, or 10 pounds per square foot. He estimates the maximum possible load as 2 adults in each seat and 30 around walls, giving total live load of 28 pounds per square foot.

In the course of loading tests for schoolhouse floors made by the Milwaukee Board of Education (Engineering News-Record, May 6, 1920) a room 24 feet 5 inches by 32 feet (781.3 square feet) normally for the accommodation of a teacher and 48 pupils was crowded with 258 pupils, filling all seats double, and all aisles and open spaces. There resulted a total weight per square foot, including desks, of 41.7 pounds.

Under normal conditions with 48 pupils at an average weight of 115.6 pounds, plus weight of desks and teachers, the average floor load was 10.83 pounds per square foot. Filled under normal conditions with adults, as in the case of night school, the load amounted to 12.9 pounds per square foot.

Other investigators put the live load in school classrooms normally filled at 14 pounds per square foot, and at 22 pounds if the aisles are crowded.

Crowded rooms.—Densely crowded groups have been shown by several investigators to weigh at least 140 pounds per square foot, but those results were obtained by strenuous methods, and it is held unlikely that they will occur under ordinary conditions. Observations of the loading obtained under normal conditions in the elevators at the Grand Central Terminal in New York showed a maximum of 73 persons on 92 square feet of floor area. With an estimated weight of 130 pounds each this gives a load of 100 pounds per square foot. Crowds of students at Iowa State University, packed for the purpose of testing balcony construction under dynamic loads, weighed 116 pounds per square foot.

6. Institutional Occupancy

Such occupancies as hospitals, sanitariums, homes for the aged, and jails come under "Institutional" classification. Building codes recommended by various organizations for national or regional use and building code standards agree on 40 lb/ft² as a suitable figure for permissible mini-

mum live load in private rooms. Figures for wards range from 40 to 80 lb/ft.[2] Other figures are given for special locations.

The report of the Department of Commerce Building Code Committee [3] presents the following information:

> *Hospitals.*—Through the courtesy of those in charge of the New York State hospitals for the insane at Brooklyn and Rochester, actual live-load measurements were obtained for several large wards in each institution. The data are in the following table:
>
> A survey of a large dormitory in the Willard, N. Y., State hospital checks the above figures very closely. The room accommodated 86 beds in a total area of 2,600 square feet. The live loads were as follows:

	Pounds
86 beds, at 85 pounds each	7, 300
86 mattresses, etc., at 45 pounds	3, 870
86 patients, at 135 pounds	11, 600
Total load	22, 770
Average load per square foot	8. 75

In 1940, inquiry was made of officials of the above institutions as to whether there had been any changed conditions since the original survey that might have caused changes in the live loads indicated. The information received was to the effect that nothing significant had occurred and that the live loads were probably about the same as those given in the 1924 report, from which the above is a quotation.

Live loads in crowded wards

Ward number	Dimensions	Total number of beds	Average weight of bed equipment and occupant	Total floor load	Load per square foot
Brooklyn State Hospital					
			Pounds	*Pounds*	*Pounds*
8 and 10 [1]	43 feet by 58 feet	62	275	17, 050	6. 9
9 [1]	do	65	275	17, 875	7. 2
21 dormitory [1]	do	62	295	18, 290	7. 3
22 dormitory [1]	do	65	295	19, 175	7. 7
Rochester State Insane Hospital					
9, east [2]	49 feet 6 inches by 34 feet 6 inches	46	256	11, 776	6. 9
9, west [2]	50 feet by 34 feet 6 inches	52	256	13, 312	7. 7
52 [2]	48 feet by 28 feet	36	276	9, 936	7. 5
53, dormitory 1 [2]	36 feet by 47 feet	43	276	11, 868	7. 0
53, dormitory 2 [2]	21 feet by 36 feet	18	276	4, 968	6. 6
53, dormitory 3 [2]	49 feet by 28 feet	45	276	12, 420	9. 0

[1] Wards 8, 9, and 10, females, average weight, 145 pounds; domitories 21 and 22, males, average weight, 165 pounds. Radiators not included.
[2] Ward 9, females, average weight, 130 pounds; wards 52 and 53, males, average weight, 150 pounds. Radiators not included.

7. Industrial Occupancy

Obviously, the "Industrial" classification will contain widely varying examples of floor loading, since it includes occupancies involved in manufacturing, fabrication, and assembly of all kinds of industrial products. Building codes recommended by various organizations for national or regional use and building code standards give minimum design loads from 75 to 125 lb/ft^2 for light manufacturing. For heavy manufacturing, some give values of from 125 to 150 lb/ft^2, and others do not assign any particular value.

Information has become available on several occupancies within this classification through the survey made by the Public Buildings Administration. The results are given below. Floor plans of each example surveyed are shown in figures 3 to 10.

A number of different methods were employed in determining the loading in the examples given below. In some cases, all material found in the areas indicated was weighed; in others, typical items were weighed and the total weight computed. Where neither of these methods seemed practicable, inquiry was made of the plant manager, manufacturer, or other source of information as to the weight of the item involved, or catalogs were consulted. In some instances, built-in items were measured and their weight calculated; this method was also used in the case of some movable items. Where weight of persons was included, this was based on the maximum number found to be present during normal operations and a unit weight of 150 lb a person.

The particular methods used depended upon the conditions found. Special situations for which allowance had to be made are given in each case.

It will be apparent that the weights of machines and other heavy equipment have been averaged over fairly large areas. Although there is a tendency to place heavy machinery on ground floors or on special foundations reaching to the ground, some machines encountered in the survey were on upper floors and their weights shown in the tables were averaged over areas considerably greater than those immediately adjacent to the machines. Some instances of this kind will be cited in connection with buildings to which they apply.

Mattress Factory, Chicago, Ill.:

Offiees were omitted from this survey. The results of the survey are given in tables 5 and 6. Figure 3 shows a floor in the faetory.

TABLE 5. *Live loads in mattress factory, Chicago, Ill.*

Building and area	Occupaney or use	Area	Unit live load
	Basement		
		ft^2	lb/ft^2
South	Storage	3,881	28.2
S. Central	do	1,058	34.2
Central S. side	do	3,144	28.7
Central N. side	Storage and hair conditioning	2,918	39.0
Total		11,001	----
	First floor		
South A	Shipping	3,017	6.0
S. Central B	do	2,495	8.8
Central C	do	4,783	9.5
North (except repair shop).	do	4,745	25.6
Repair shop	Machine repairs	1,620	27.2
Garnett	Garnetting	7,063	36.0
Total		23,723	----
	Second floor		
South	Storage	3,804	8.5
S. Central	do	3,234	10.8
Central	Tufting and edging	7,310	6.7
North	Tufting and storage	6,174	12.1
Total		20,522	----
	Third floor		
South A	Storage, cloth	2,510	25.2
South B	Cloth inspection	460	9.7
S. Central C	Cloth storage	2,598	25.2
S. Central D	Sewing	1,081	10.3
Central E	do	2,593	9.7
Central F	Cutting cloth	4,355	6.6
Central G	Repairing machines	152	36.8
Central H	Office	135	11.0
North	Filling mattresses	6,100	14.8
Total		19,984	----
	Fourth floor		
Central A	Boxing mattresses	1,860	16.5
	Fifth floor		
South A	Nailing box spring frames	235	41.2
South B	Assembling box spring frames	1,271	11.7
South C	Chair frames	460	19.6
South D	Assembling beds	648	18.9
South E	Painting	1,222	5.9
Central F	Box spring frames	1,088	9.8
Central G	Storage	456	8.9
Central H	do	2,376	8.6
Total		7,756	----
Grand total		84,846	----

Mattress Factory, Atlanta, Ga.:

Only those buildings, or parts of buildings, in whieh some operation eoneerned with the making and shipping of felt and spring bed mattresses was being eonducted, were surveyed. Offiees were omitted. Temporary wood partitions were included as live load.

TABLE 6. *Variation in live loads in mattress factory, Chicago, Ill.*

Unit load	Area	Portion of total area
lb/ft^2	ft^2	*Percent*
5.0 to 9.9	33,959	40.0
10.0 to 14.9	17,995	21.2
15.0 to 19.9	2,968	3.5
20.0 to 24.9	-------	---------
25.0 to 29.9	18,498	21.8
30.0 to 34.9	1,058	1.3
35.0 to 39.9	10,133	11.9
40.0 to 44.9	235	0.3
Total	84,846	100.0

The heaviest maehines on a framed floor found in either of the mattress faetory surveys were garnetting maehines weighing about 25,500 lb apieee. The effeet of sueh eoneentrations may be illustrated by referenee to the second floor of building 3, whieh is shown on figure 4. If the weight of one of these maehines is averaged over the two bays that it oeeupies, the result is about 70 lb/ft^2. On the other hand, if the weight is divided by the area of the base of the maehine alone, the average load is about 154 lb/ft^2. The results of the survey are given in tables 7 and 8. Figure 4 shows a floor in the faetory.

TABLE 7. *Live loads in mattress factory, Atlanta, Ga.*

Panel or area	Occupaney or use	Area	Unit live load
	Building 1, Seeond floor		
		ft^2	lb/ft^2
A	Spring assembly	805	12.6
B	Spring storage	900	5.6
C	Spring assembly	1,124	5.8
D	do	453	17.6
E	Lockers	207	15.5
	Total	3,489	------
	Building 2, Seeond floor		
A	Temporary storage	1,743	8.0
B	Cotton felt mattress	1,312	6.6
C	Mattress stapling	635	6.2
D	Mattress make-up	635	4.4
E	Mattress tape edging	942	7.9
F	Mattress button tufting	1,243	8.0
G	Mattress re-ginning	440	24.0
H	Spring receiving	472	11.9
I	Stapling	472	8.0
J	Cotton felt mattress	864	9.0
K	Cotton tufting	1,115	6.8
L	Roll edging	950	7.8
	Total	10,823	------
	Building 2A, Seeond floor		
A	Box spring assembly	816	17.0
B	Box spring make-up	900	11.0
C	Box spring make-up	648	4.3
D	Box spring storage	1,263	5.2
E	Quilting tops	1,450	5.3
F	Temporary storage	990	17.4
G	Packaging	2,115	6.0
	Total	8,182	------

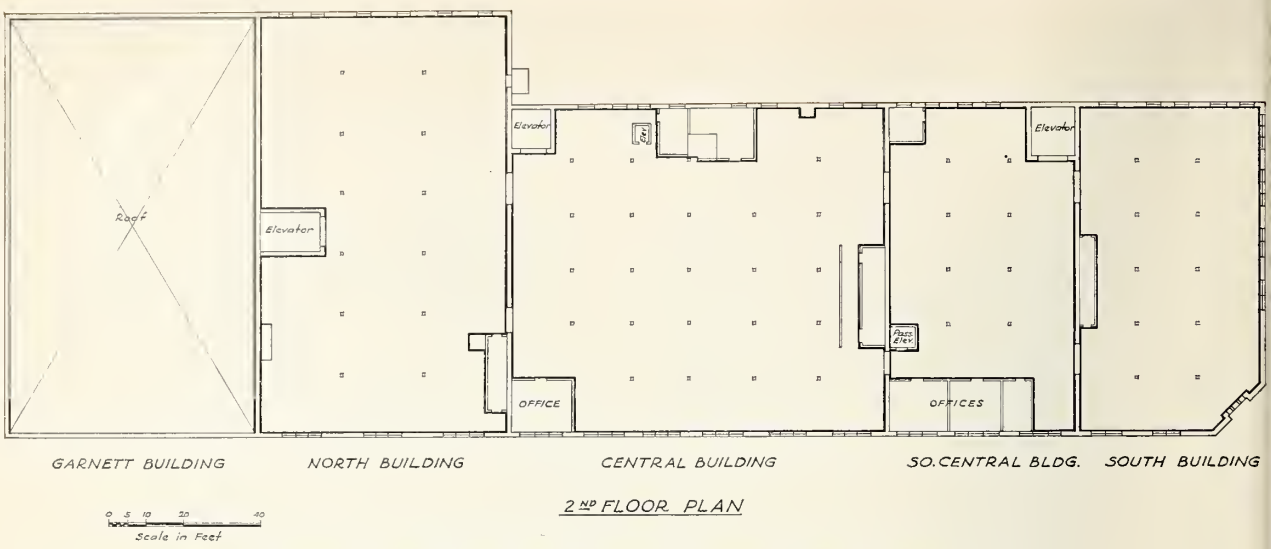

FIGURE 3. *Second-floor plan, building 3, mattress factory, Chicago, Ill.*

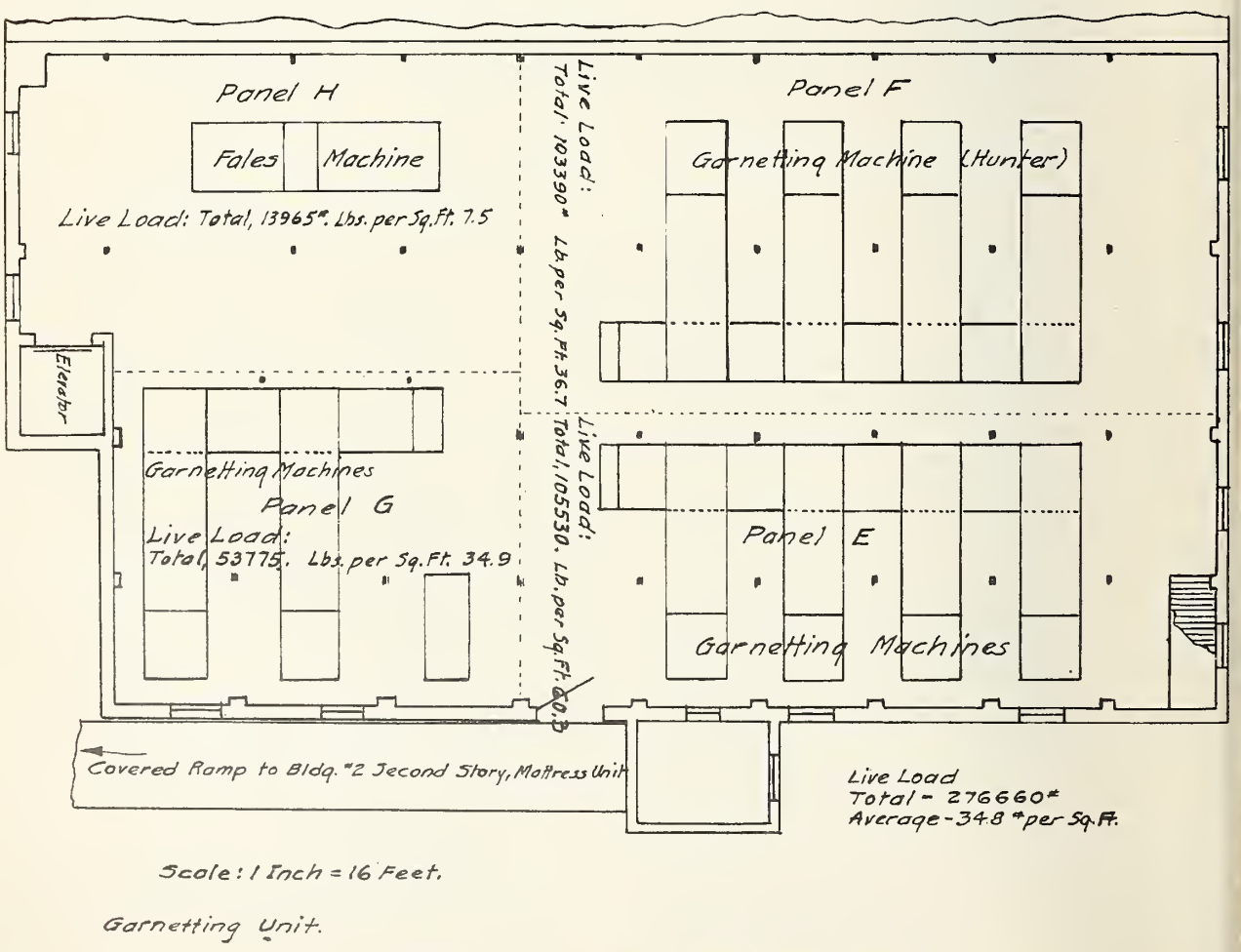

FIGURE 4. *Second-floor plan, building 3, mattress factory, Atlanta, Ga.*

TABLE 7. *Live loads in mattress factory, Atlanta, Ga.*—Con.

Panel or area	Occupancy or use	Area	Unit live load
	Building 2B, Second floor		
		ft²	*lb/ft²*
A	Stock room	1,556	59.3
B	Sewing room	2,160	5.7
	Total	3,716	------
	Building 3, First floor		
A	Cotton cleaner, picker	561	22.4
B	Cotton mixers	1,080	6.5
C	Cotton stores	825	9.3
D	Cotton batting, etc., stores	6,170	15.2
	Total	8,636	------
	Building 3, Second floor		
E	Garnetting	1,750	60.3
F	Garnetting	2,816	36.7
G	Garnetting	1,540	34.9
H	Fales	1,853	7.5
	Total	7,959	------
	Building 4, Garnett Annex		
All	Garnett Annex	4,810	21.4
	Building 5, Cotton Warehouse		
Whole	Cotton warehouse	8,010	101.3
	Building 6, Shipping		
All	Shipping	15,640	27.6
	Garnett Parts Stores		
All	Garnett parts stores	740	93.9
	Grand total	72,005	------

TABLE 8. *Variation in live loads in mattress factory, Atlanta, Ga.*

Unit load	Area	Portion of total area
lb/ft²	*ft²*	*Percent*
0.0 to 4.9	1,283	1.8
5.0 to 9.9	22,046	30.6
10.0 to 14.9	2,177	3.0
15.0 to 19.9	8,626	12.0
20.0 to 24.9	5,811	8.1
25.0 to 29.9	15,640	21.7
30.0 to 34.9	1,540	2.1
35.0 to 39.9	2,816	3.9
40.0 to 54.9	------	------
55.0 to 59.9	1,556	2.2
60.0 to 64.9	1,750	2.5
65.0 to 89.9	------	------
90.0 to 94.9	740	1.0
95.0 to 99.9	------	------
100.0 to 104.9	8,010	11.1
Total	72,005	100.0

Men's Clothing Factory, New York, N. Y.:

The premises surveyed contain all operations from the receiving of the original bolt of cloth to the shipping of the finished suit or coat. The results of the survey are given in tables 9 and 10. Figure 5 shows a floor in the factory.

TABLE 9. *Live loads in men's clothing factory, New York, N. Y.*

Department	Area	Unit live load
	First Building, Fifth floor	
	ft²	*lb/ft²*
Cutting	16,285	11.0
Shrinking and storage	4,275	13.3
Pattern design	440	8.6
Storage	7,085	19.6
Offices	3,145	10.8
Total	31,230	------
	First Building, Sixth floor	
Receiving and storage	5,005	8.7
Suit storage	6,800	11.1
Labels and assembly	1,680	13.6
Packing	2,980	13.5
Corridor	460	10.5
Total	16,925	------
	Second Building, Third floor	
Office	190	11.1
Coat room and storage	465	15.1
Storage (cloth in bundles)	315	27.9
Machine repair	115	47.0
Hand sewing No. 1	1,350	6.9
Hand sewing No. 2	5,135	7.9
Hand sewing No. 3	1,215	8.0
Storage and receiving	1,400	8.8
Pressing No. 1	840	20.3
Pressing No. 2	4,445	19.9
Machine sewing No. 1	1,475	16.0
Machine sewing No. 2	1,860	17.3
Total	18,805	------
Grand total	66,960	------

TABLE 10. *Variation in live loads in men's clothing factory, New York, N. Y.*

Unit load	Area	Portion of total area
lb/ft²	*ft²*	*Percent*
5.0 to 9.9	14,545	21.7
10.0 to 14.9	35,815	53.5
15.0 to 19.9	15,330	22.9
20.0 to 24.9	840	1.3
25.0 to 29.9	315	0.4
30.0 to 44.9	------	------
45.0 to 49.5	115	.2
Total	66,960	100.0

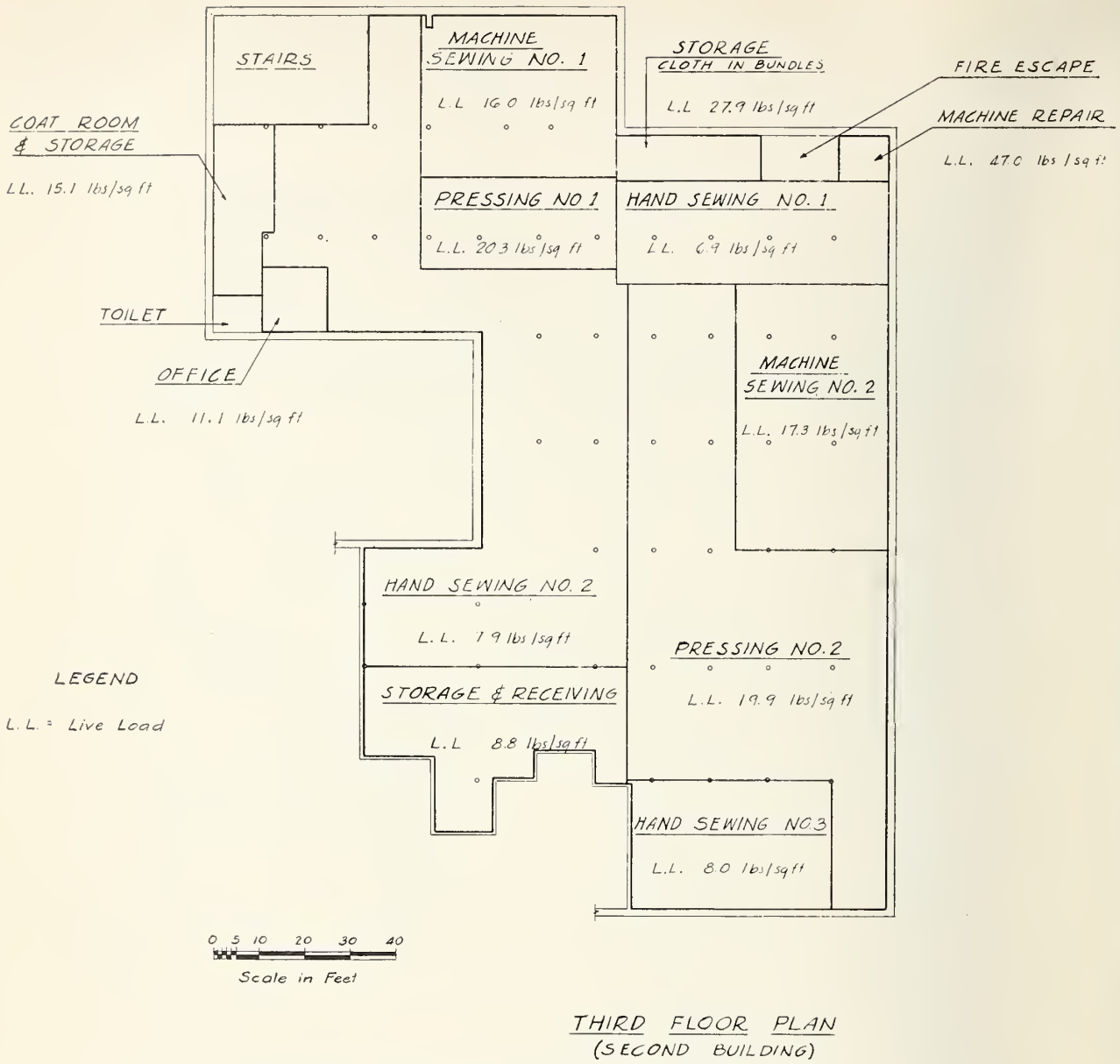

FIGURE 5. *Third-floor plan, men's clothing factory, New York, N. Y.*

Dress Factory, Philadelphia, Pa.:

No aisle space was considered. The counts of persons taken are believed to represent adequately the maximum live load caused by people under similar factory conditions. The results of the survey are given in tables 11 and 12. Figure 6 shows a floor in the factory.

TABLE 11. *Live loads in dress factory, Philadelphia, Pa.*

Department	Area	Unit live load
Second floor		
	ft^2	lb/ft^2
Cloth storage	850	38.9
Buttons, thread, etc. (storage)	515	24.2
Sample dresses (storage)	160	9.4
Stationery storage	125	41.5
Storage and shipping	5,420	9.5
Women's dressing room	280	7.7
Designers' office	1,650	9.0
Financial office	1,060	11.1
Front office	1,085	14.0
Anteroom	75	15.4
Men's room	115	21.4
Closet	60	60.5
Hall	895	8.4
Total	12,290	------
Third floor		
Emergency restroom	145	9.0
Office	195	15.1
Pattern storage	80	34.4
Restroom and reserve area	2,410	5.8
Sewing room	2,635	13.8
Examination and inspection	490	19.4
Pattern design	700	6.7
Cutting	2,415	7.1
Machine repair	250	36.7
Pressing, etc	2,915	5.5
Women's dressing rooms	215	15.2
Total	12,450	------
Grand total	24,740	------

TABLE 12. *Variation in live loads in dress factory, Philadelphia, Pa.*

Unit load	Area	Portion of total area
lb/ft^2	ft^2	*Percent*
5.0 to 9.9	16,990	68.8
10.0 to 14.9	4,780	19.4
15.0 to 19.9	975	3.9
20.0 to 24.9	630	2.5
25.0 to 29.9	--------	---------
30.0 to 34.9	80	0.3
35.0 to 39.9	1,100	4.4
40.0 to 44.5	125	0.5
45.0 to 59.9	--------	---------
60.0 to 64.9	60	0.2
Total	24,740	100.0

Furniture Factory, Gettysburg, Pa.:

The results of the survey are given in tables 13 and 14. Figure 7 shows the plan of the factory.

TABLE 13. *Live loads in furniture factory, Gettysburg, Pa.*

Building Number	Area	Occupancy or use	Area	Unit live load
			ft^2	lb/ft^2
2	a	Millwork	5,450	24.2
2	b	do	3,100	27.8
2	c	do	760	24.1
2	d	Glue room	1,030	18.6
2	e	Office	130	5.2
2	f	Pattern room	130	10.7
3		Staining	3,900	7.9
4		Spraying	10,200	9.4
5		Finishing	5,920	7.5
5	a	Paint shop	216	60.8
7	Basement	Millwork	5,600	28.9
7	First floor	do	5,600	29.2
7	a	Storage (lumber from dry kilns).	598	98.0
8	Basement	Cabinet work and storage (plywood panels loaded on trucks).	7,450	51.5
8	First floor	Cabinet manufacturing	7,100	16.4
9		do	4,650	18.1
10	Basement	Storage (3-ply plywood)	2,800	62.9
10	First floor	Spraying	2,750	7.4
11		Storage (veneer and packing material).	2,750	30.9
12		Storage (3-ply plywood)	2,360	84.4
13		Varnish vault	600	11.6
16		Rubbing and polishing	6,200	5.1
17		Storage (furniture)	5,850	12.2
18	First floor	do	7,400	17.8
18	Second floor	Storage (furniture and packing material).	7,400	12.0
19		Finishing	1,750	6.5
20	First floor	Shipping and storage (furniture, some crated ready to ship).	9,675	15.5
20	Second floor	Storage (furniture, chairs).	10,625	13.7
	Total		121,994	----

TABLE 14. *Variation in live loads in furniture factory, Gettysburg, Pa.*

Unit load	Area	Portion of total area
lb/ft^2	ft^2	*Percent*
5.0 to 9.9	30,850	25.3
10.0 to 14.9	24,605	20.1
15.0 to 19.9	29,855	24.5
20.0 to 24.9	6,210	5.1
25.0 to 29.9	14,300	11.7
30.0 to 34.9	2,750	2.3
35.0 to 49.9	--------	---------
50.0 to 54.9	7,450	6.1
55.0 to 59.9	--------	---------
60.0 to 64.9	3,016	2.5
65.0 to 79.9	--------	---------
80.0 to 84.9	2,360	1.9
85.0 to 94.9	--------	---------
95.0 to 99.9	598	0.5
Total	121,994	100.0

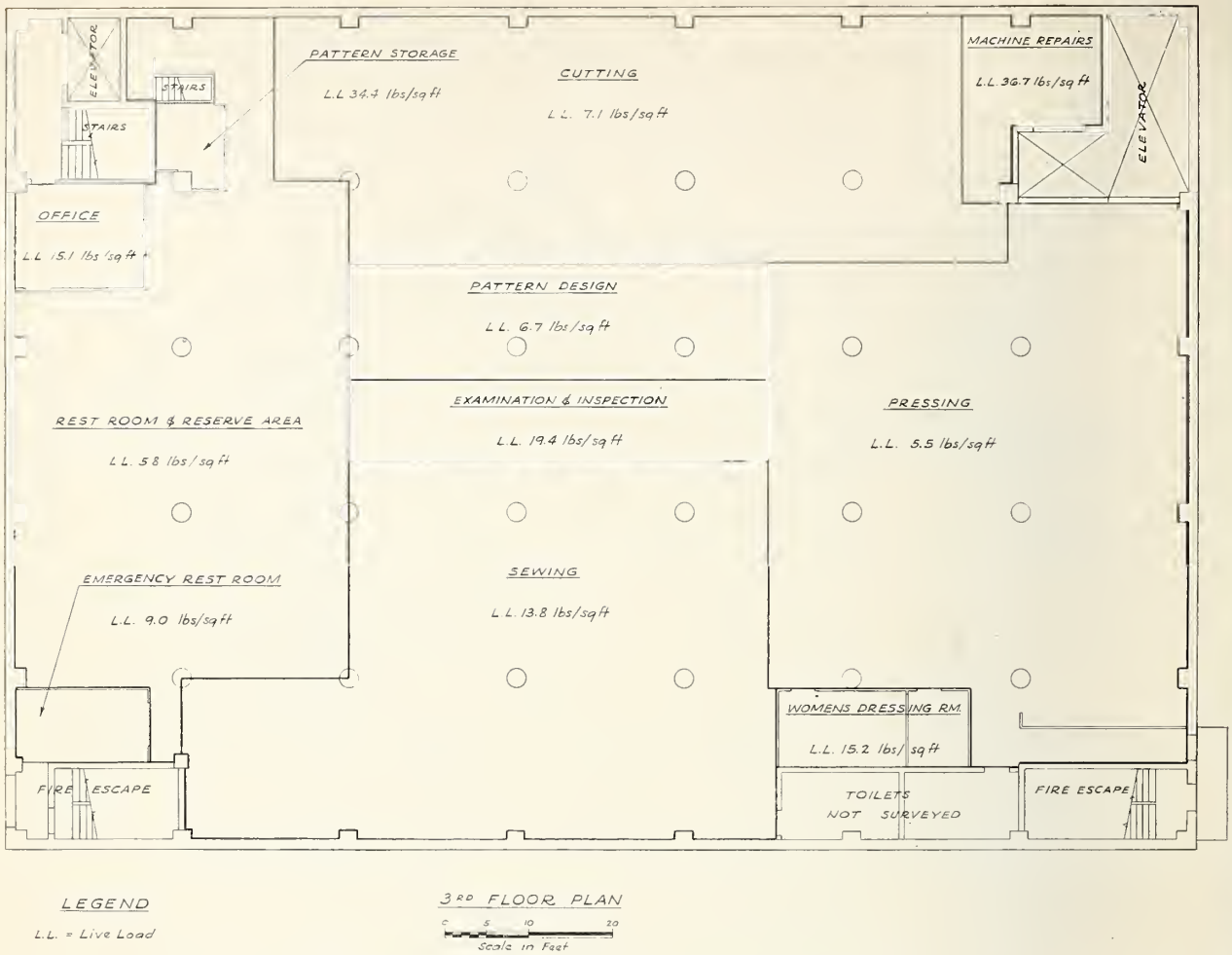

FIGURE 6. *Third-floor plan, dress factory, Philadelphia, Pa.*

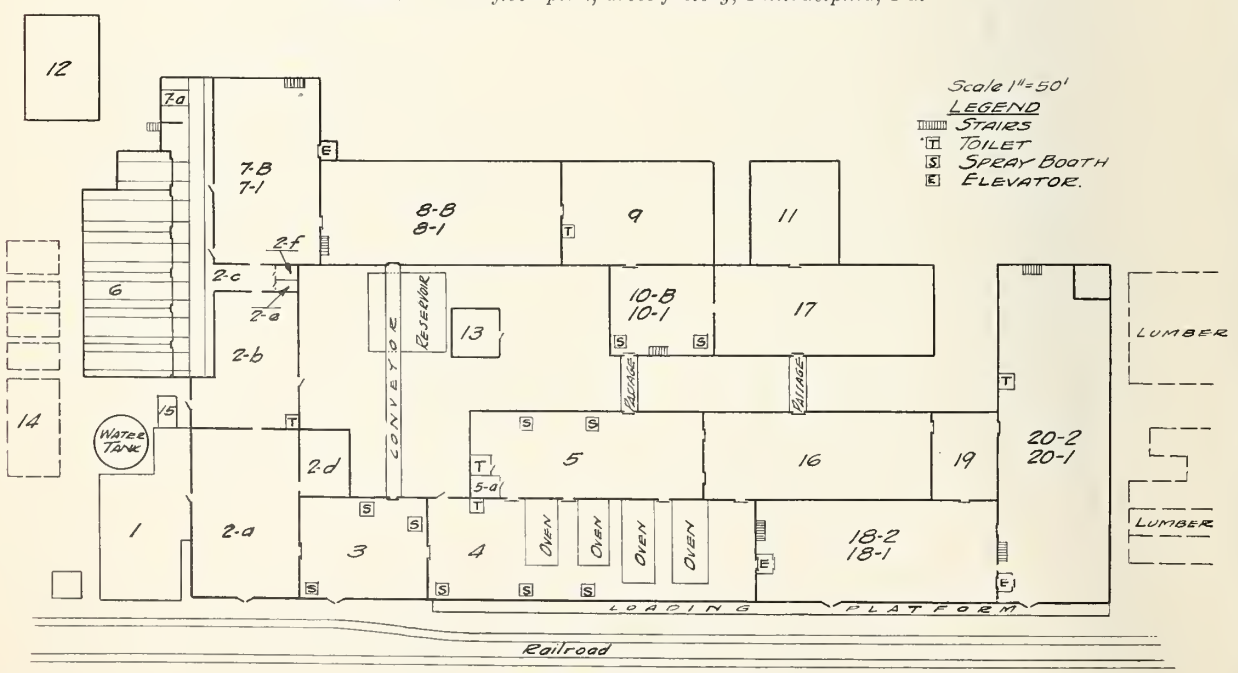

FIGURE 7. *Furniture factory, Gettysburg, Pa.*

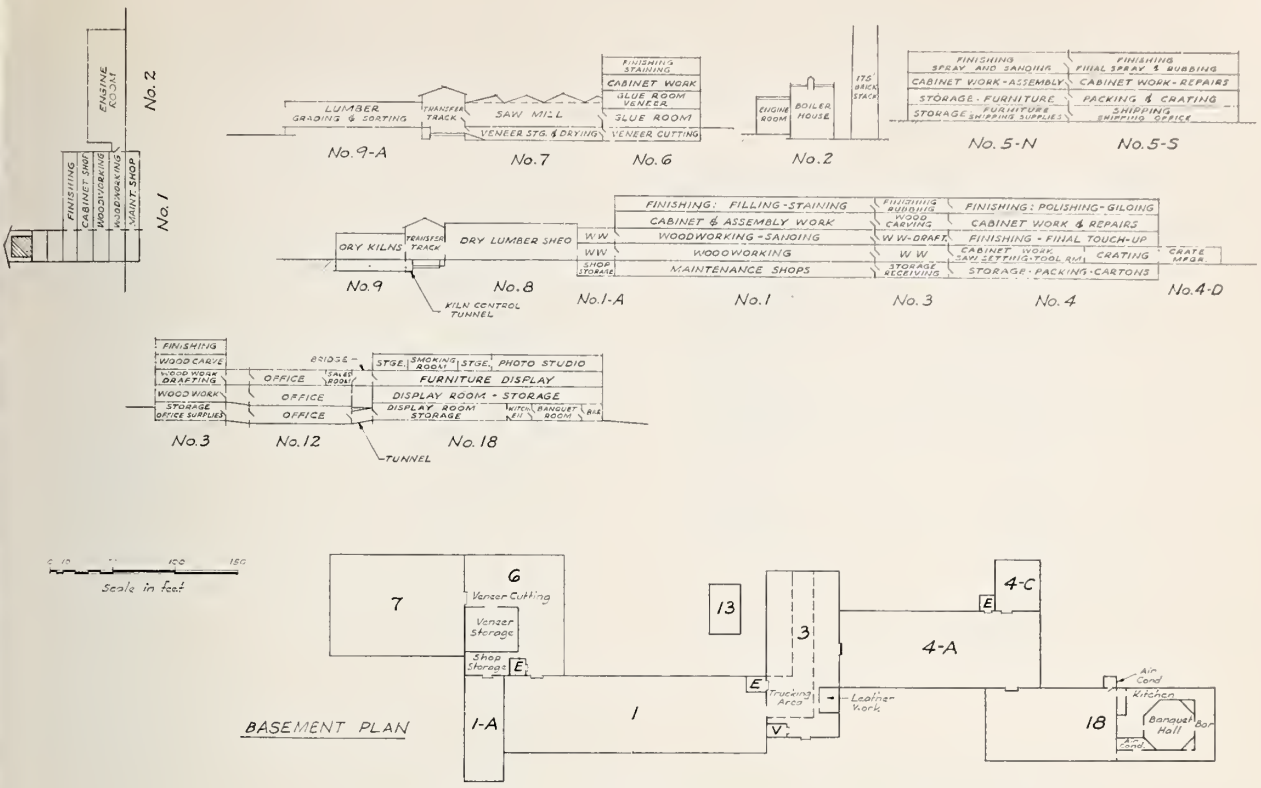

FIGURE 8. *Furniture factory, Grand Rapids, Mich.*

Furniture Factory, Grand Rapids, Mich.:

This furniture plant produces, as a specialty, a wide variety of utilitarian and decorative tables that are of high quality in construction and design. All of the buildings, or portions of buildings, occupied in the actual production, shipping, and display of furniture were surveyed. Office space and service buildings were not included in the survey. The heaviest of the machines found on framed floors in this survey were an automatic shaper, weighing 12,000 lb, on the first floor of building 3, a hydraulic press, weighing 15,000 lb, on the second floor of building 6, and a joiner, gluer, and drier, weighing 12,000 lb, on the first floor of building 7. The areas occupied by these machines were not available. The results of the survey are given in tables 15 and 16. Figure 8 shows the basement plan of the factory and the operations on the several floors.

TABLE 15. *Live loads in furniture factory, Grand Rapids, Mich.*

Building number	Floor	Occupancy or use	Area	Unit live load
			ft^2	lb/ft^2
1	B	Maintenance shops	11,500	24.9
1	1	Woodworking	11,500	20.5
1	2	do	11,500	15.2
1	3	Cabinet and assembly work	11,500	5.4
1	4	Finishing	11,500	4.1

TABLE 15. *Live loads in furniture factory, Grand Rapids, Mich.*—Continued

Building number	Floor	Occupancy or use	Area	Unit live load
			ft^2	lb/ft^2
1-A	B	Storage	2,900	23.4
1-A	1	Woodworking	2,900	8.7
1-A	2	do	2,900	30.0
3	B	Storage	5,730	27.9
------	-----	Leather room	500	27.6
3	1	Woodworking	8,800	22.5
3	2	Woodworking and drafting	7,990	11.1
------	2	Drafting	860	13.2
3	3	Cabinet shop wood carving	9,780	16.4
3	4	Finishing-rubbing	8,880	3.6
4-A	B	Storage	9,280	30.9
4-C	B	do	1,200	24.1
4-A	1	Cabinet shop	4,960	11.6
4-A	1	Saw setting and tool shop	600	23.7
4-B	1	Crating	3,600	9.3
4-C	1	Shipment make-up	1,200	6.7
4-D	1	Crate manufacture	4,990	14.9
4-E	1	Cabinet shop	3,750	7.3
4	2	Finishing-final	10,932	6.3
4	3	Cabinet work and repair shop	10,780	4.6
4	4	Finishing-rubbing, gilding	10,732	4.4
5-N	1	Storage	15,400	23.8
5-S	1	Shipping	15,000	3.4
5-S	1	Shipping office	204	6.7
5-N	2	Storage	15,200	7.0
5-S	2	Packing and crating	15,200	4.4
5-N	3	Cabinet work, assembly	15,300	4.8
5-S	3	Cabinet work, repairs	15,300	2.8
5-N	4	Finishing	15,300	2.3
5-S	4	do	15,300	3.1

TABLE 15. *Live loads in furniture factory, Grand Rapids, Mich.*—Continued

Building number	Floor	Occupancy or use	Area	Unit live load
			ft^2	lb/ft^2
6	B–A	Veneer cutting	5,300	12.8
6	B–B	Veneer storage	2,100	119.7
6	B–C	Maintenance parts storage	720	44.6
6	1	Glue room	7,700	16.7
6	2	Glue room, veneer	7,900	28.4
6	3	Finishing	7,880	7.4
6	4	Finishing, staining	7,880	6.6
7	B	Veneer storage and drying	7,660	31.0
7	1	Sawing	7,500	32.1
8	1	Air drying building	10,200	73.9
9	1	Dry kilns	8,100	105.3
9–A	1	Lumber grading shed	2,600	20.9
10	1	Storage for shipment	6,000	8.5
10–A	1	do	2,380	29.8
12	2	Salesroom	1,200	4.0
13	B	Lacquer vault	830	18.1
13	1	do	830	43.7
18	B	Storage	6,426	2.0
18	B	Kitchen	750	12.8
18	B	Banquet and bar	1,900	6.5
18	1	Storage	9,940	6.2
18	2	Exhibition	9,940	3.6
18	3	Photo studio	4,970	2.1
18	3	Smoking room	720	7.0
18	3	Storage	4,100	8.7
		Total	418,494	----

TABLE 16. *Variation in live loads in furniture factory, Grand Rapids, Mich.*

Unit load	Area	Portion of total area
lb/ft^2	ft^2	*Percent*
0.0 to 4.9	155,828	37.2
5.0 to 9.9	87,706	21.0
10.0 to 14.9	24,850	6.0
15.0 to 19.9	29,810	7.1
20.0 to 24.9	54,500	13.0
25.0 to 29.9	16,510	4.0
30.0 to 34.9	27,340	6.5
35.0 to 39.9	-------	---------
40.0 to 44.9	1,550	0.4
45.0 to 69.9	-------	---------
70.0 to 74.9	10,200	2.4
75.0 to 104.9	-------	---------
105.0 to 109.9	8,100	1.9
110.0 to 114.9	-------	---------
115.0 to 119.9	2,100	0.5
Total	418,494	100.0

Newspaper Plant, Washington, D. C.:

This survey included the building housing the printing plant and some offices of the newspaper. The heaviest machines were the presses, which were located on the first floor; however, these machines extended through the first floor and were supported on special pile footings, consequently were not included in the survey. The results of the survey are given in tables 17 and 18. Figure 9 shows a floor in the plant.

TABLE 17. *Live loads in newspaper plant, Washington, D. C.*

Department	Area	Unit live load
First floor		
	ft^2	lb/ft^2
Press room	3,870	24.8
Stereotype department	648	77.4
Office	127	10.1
Oil room	190	27.4
Machine room	426	46.0
Newsstand	228	16.6
Corridor	550	4.1
Total	6,039	------
Mezzanine floor		
Delivery room	7,177	21.5
Offices	865	13.4
Corridor	292	21.4
Total	8,334	------
Second floor		
Storeroom	764	70.3
Art department	511	13.7
Dark room	149	10.8
Etching department	602	14.0
Offices	745	10.6
Do	154	14.9
Workroom	318	30.9
Storeroom	363	71.6
Service department	1,082	30.2
Machine room	2,549	13.7
Corridor	470	1.6
Total	7,707	------
Third floor		
Associated Press	3,880	10.2
Wirephoto department	1,260	17.0
Library	231	26.0
Offices	912	5.8
Storeroom	190	92.8
Do	154	60.0
Corridor	570	1.3
Total	7,197	------
Fourth floor		
Storeroom	272	59.6
Dark room	222	15.0
Storeroom	145	49.1
Workroom	434	35.2
Offices	502	15.7
Do	671	6.6
Adv. photo department	276	9.6
Offices	390	7.7
Do	639	11.2
Do	2,040	11.9
Corridor	1,577	1.0
Total	7,168	------
Fifth floor		
Telephone switchboard and equipment	520	25.6
Storeroom	194	51.6
Offices	447	14.4
Do	1,290	13.6
Conference room, board of trade	1,294	7.6
Offices	2,041	11.3
Corridors	1,348	1.1
Total	7,134	------

TABLE 17. *Live loads in newspaper plant, Washington, D. C.*—Continued

Department	Area	Unit live load
Sixth floor		
	ft^2	lb/ft^2
Offices	1,786	9.7
Corridor	740	6.3
Lobby	371	2.0
Office	324	16.5
Advertising and accounting	3,890	21.0
Total	7,111	------
Seventh floor		
Office	1,900	11.4
Do	140	32.5
Art oorm	496	18.6
Photographers	439	9.9
De ntallaboratory	126	17.5
City room	3,446	15.2
Corridor	692	3.2
Lobby	371	2.0
Total	7,610	------

TABLE 17. *Live loads in newspaper plant, Washington, D. C.*—Continued

Department	Area	Unit live load
Eighth floor		
	ft^2	lb/ft^2
Stereotype room	1,296	73.2
Composing room	6,300	58.2
Office	54	13.1
Lobby	176	4.3
Total	7,826	------
Ninth floor		
Picture file room	914	26.3
Monotype room	390	57.2
Composing room A	1,600	54.4
Composing room B	990	14.2
Office	232	13.9
Storeroom	165	66.0
Office	54	6.2
Lobby	300	6.5
Loeker room	1,494	13.8
Total	6,139	------
Grand total	72,265	------

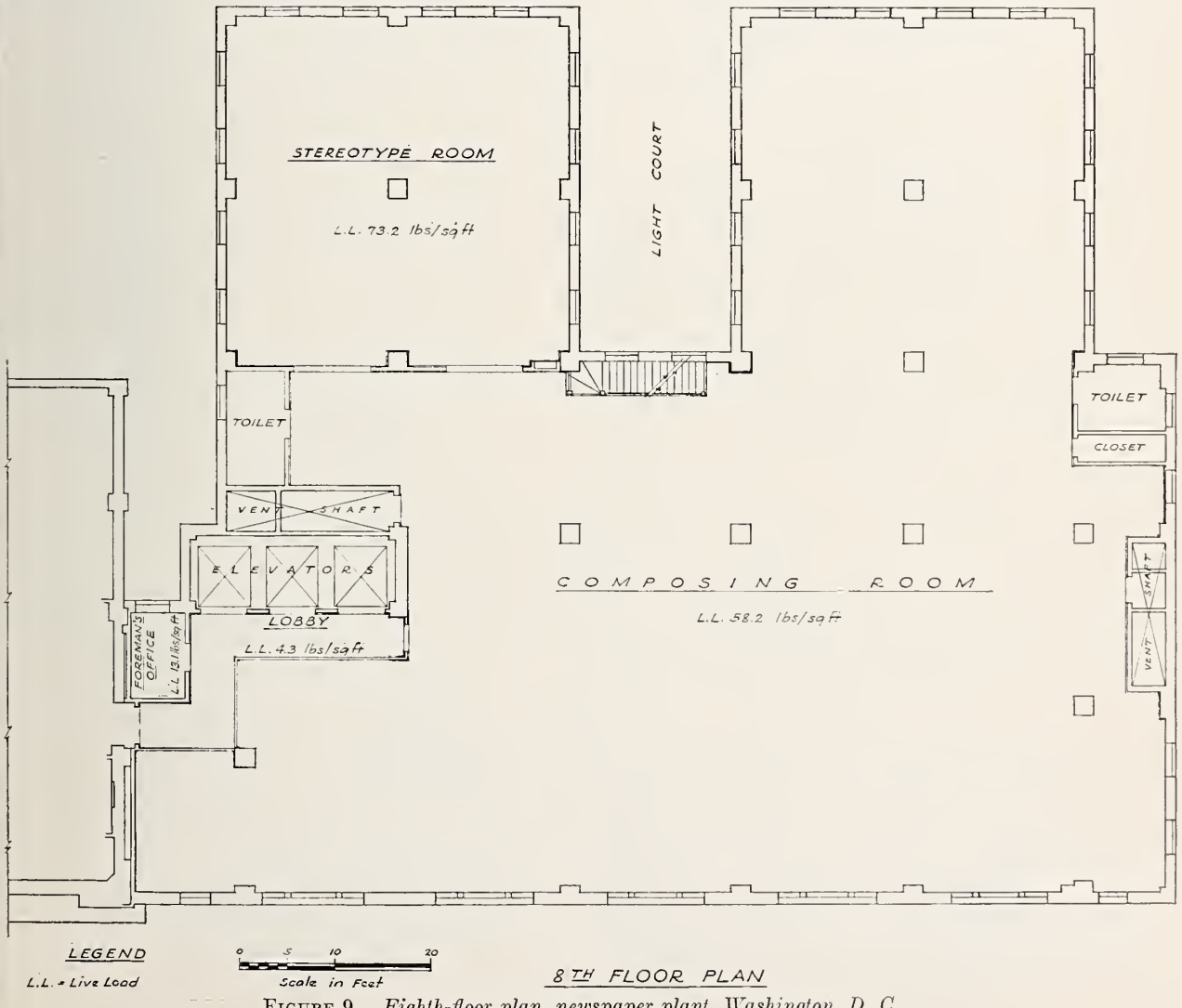

FIGURE 9. *Eighth-floor plan, newspaper plant, Washington, D. C.*

TABLE 18. *Variation in live loads in newspaper plant, Washington, D. C.*

Unit load	Area	Portion of total area
lb/ft²	*ft²*	*Percent*
0.0 to 4.9	6,125	8.5
5.0 to 9.9	6,862	9.5
10.0 to 14.9	20,709	28.7
15.0 to 19.9	6,604	9.1
20.0 to 24.9	15,229	21.1
25.0 to 29.9	1,855	2.6
30.0 to 34.9	1,540	2.1
35.0 to 39.9	434	0.6
40.0 to 44.9	---	---
45.0 to 49.9	571	.8
50.0 to 54.9	1,794	2.5
55.0 to 59.9	6,962	9.6
60.0 to 64.9	154	0.2
65.0 to 69.9	165	.2
70.0 to 74.9	2,423	3.3
75.0 to 79.9	648	0.9
80.0 to 89.9	---	---
90.0 to 94.9	190	.3
Total	72,265	100.0

Printing Plant, Washington, D. C.:

Within each area the aisle space has been given as a percentage of the total area. This aisle space was usually kept open to provide for the transfer of large skids loaded with 20 to 30 reams of paper from one part of the plant to another.

Very heavy machinery loads on framed floors were found in this survey. In panel B of the second floor of building 4 a press, together with its feeders and operators, and a ¼-in. steel plate on the floor weighed 60,000 lb. An obsolete machinery layout of this area gives reason to believe that this load occupied about one and one-half bays of the building, or 360 ft². This would mean a load of 168 lb/ft². In panel B of the second floor of building 5 a rotary press, together with its cross-feed, operators, paper, and steel floor, weighed 151,400 lb. The old machine layout referred to above indicates that this load was probably carried on two full bays of floor, having an area of about 600 ft², making an average load on two bays of 252 lb/ft². The results of the survey are given in tables 19 and 20. Figure 10 shows a floor in the plant.

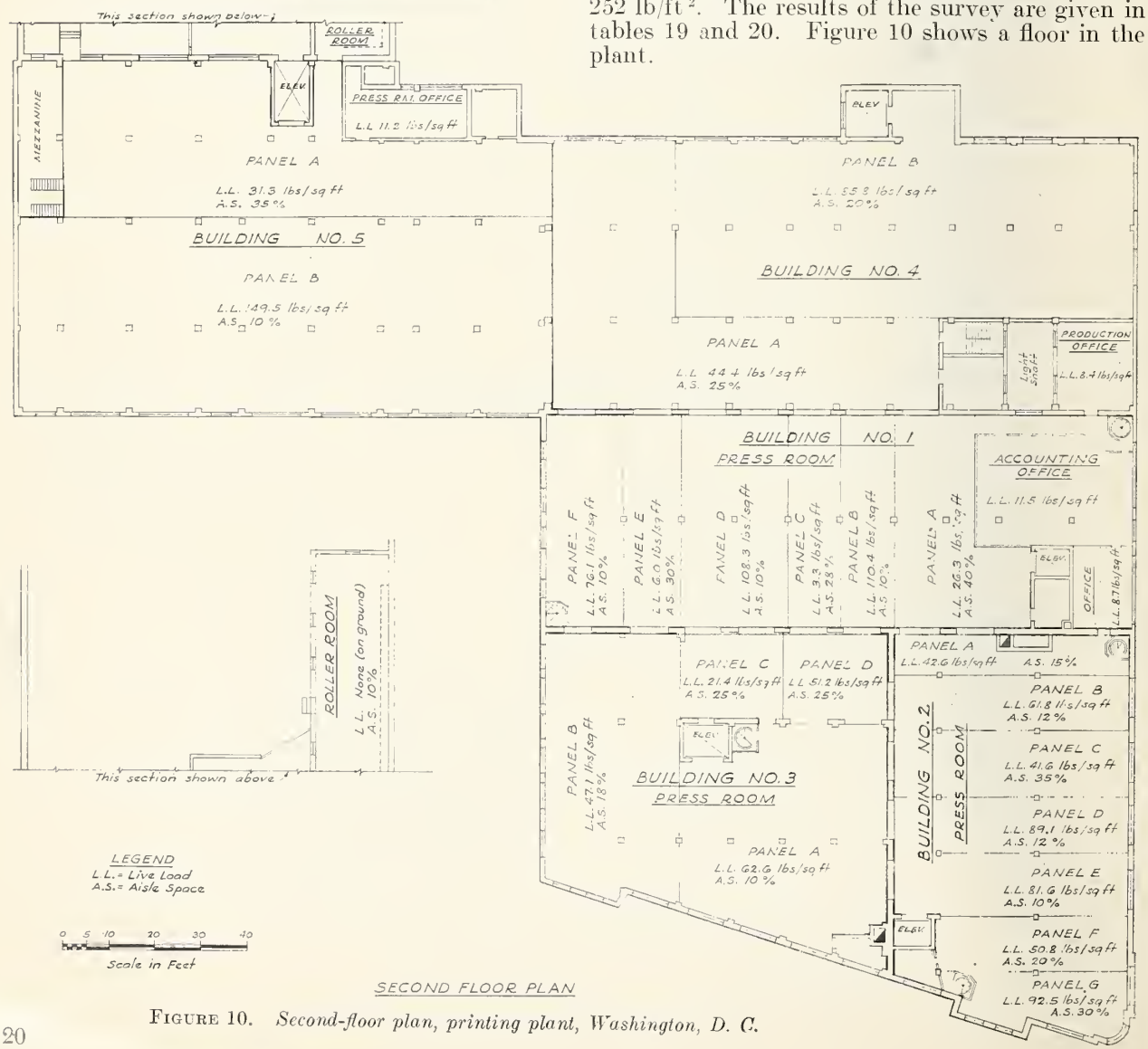

FIGURE 10. *Second-floor plan, printing plant, Washington, D. C.*

TABLE 19. *Live loads in printing plant, Washington, D. C.*

Building No.	Department	Area	Unit live load
	First floor		
		ft²	*lb/ft²*
1	Private office	384	8.3
1	Reception office	476	5.4
1	Shipping office	245	5.6
1	Commercial bindery:		
	Panel A	453	32.6
	Panel B	337	10.0
	Panel C	610	36.2
	Panel D	610	39.1
	Panel E	600	10.0
	Panel F	602	23.6
	Panel G	602	34.2
	Panel H	331	23.5
	Panel I	331	18.4
	Panel J	440	23.8
2	Commercial bindery:		
	Panel A	437	32.8
	Panel B	357	33.2
	Panel C	1,254	50.8
	Panel D	2,664	17.9
3	Commercial bindery:		
	Panel A	1,240	44.0
	Panel B	1,138	7.0
	Panel C	365	59.7
	Panel D	955	35.9
4	Sales office	454	8.1
4	Private office	240	5.7
4	Panel A	1,591	81.7
4	Panel B	1,924	54.2
4	Panel C	3,248	35.2
4	Panel D	549	50.4
4	Panel E	767	29.3
5	Commercial bindery	9,250	63.1
	Total	32,454	-------
	Second floor		
1	Accounting office	747	11.5
1	Office	304	8.7
1	Press room:		
	Panel A	1,185	26.3
	Panel B	610	110.4
	Panel C	600	3.3
	Panel D	1,200	108.3
	Panel E	662	6.0
	Panel F	880	76.1
2	Press room:		
	Panel A	466	42.6
	Panel B	738	61.8
	Panel C	880	41.6
	Panel D	738	89.1
	Panel E	880	81.6
	Panel F	598	50.8
	Panel G	534	92.5
3	Press room:		
	Panel A	2,293	62.6
	Panel B	1,988	47.1
	Panel C	450	21.4
	Panel D	502	51.2
4	Production office	380	8.4
4	Panel A	3,200	44.4
4	Panel B	4,850	85.8
5	Press room office	438	11.2
5	Panel A	3,348	31.3
5	Panel B	5,624	149.5
	Total	34,095	-------
	Third floor		
2	Composing room:		
	Panel A	200	41.0
	Panel B	956	51.3
	Panel C	656	76.1
	Panel D	788	36.7
	Panel E	356	100.4
	Panel F	300	39.5
	Panel G	350	131.7
	Panel H	420	73.8
	Panel I	451	93.2
2	Monotype department	332	82.4
3	Composing room:		
	Panel A	651	32.5
	Panel B	1,089	47.5
	Panel C	248	27.7
	Panel D	662	57.6
3	Proofreading room	711	17.9
3	Type storage room	767	168.4
3	Job press department	1,789	43.9
	Total	10,726	-------
	Grand total	77,275	-------

TABLE 20. *Variation in live loads in printing plant, Washington, D. C.*

Unit load	Area	Portion of total area
lb/ft²	*ft²*	*Percent*
5.0 to 9.9	4,883	6.3
10.0 to 14.9	2,122	2.8
15.0 to 19.9	3,706	4.8
20.0 to 24.9	1,823	2.4
25.0 to 29.9	2,200	2.9
30.0 to 34.9	5,848	7.6
35.0 to 39.9	6,511	8.4
40.0 to 44.9	7,775	10.1
45.0 to 49.9	3,077	4.0
50.0 to 54.9	5,783	7.5
55.0 to 59.9	1,027	1.3
60.0 to 64.9	12,281	15.9
65.0 to 69.9	-------	-------
70.0 to 74.9	420	0.5
75.0 to 79.9	1,536	2.0
80.0 to 84.9	2,803	3.6
85.0 to 89.9	5,588	7.1
90.0 to 94.9	985	1.3
95.0 to 99.9	-------	-------
100.0 to 104.9	356	0.4
105.0 to 109.9	1,200	1.6
110.0 to 114.9	610	0.8
115.0 to 129.9	-------	-------
130.0 to 134.9	350	.4
135.0 to 144.9	-------	-------
145.0 to 149.9	5,624	7.3
150.0 to 164.9	-------	-------
165.0 to 169.9	767	1.0
Total	77,275	100.0

8. Storage Occupancy

The live loads on warehouse floors vary widely because of the many different kinds of materials stored. Building codes recommended by various organizations for national or regional use and building code standards give permissible minimum design load figures for light and heavy storage. In the case of light storage, the range is narrow, from 120 to 125 lb/ft², while with heavy storage a minimum value of 250 lb/ft² is customary.

Methods of determining loading used in common for the two cases surveyed were the noting of weights marked on barrels and other containers and computing the weight of persons at 150 lb each for the number found in a given area. Other methods are mentioned under the particular case to which they apply.

The results of the survey by the Public Buildings Administration appear in tables 21, 22, 23, and 24. Figures 11 and 12 show floor plans having the heaviest unit loads in the case of this occupancy.

Warehouse, New York, N. Y.:

Weights of various smaller items were established by weighing them directly. The walls and partitions that were carried by the floor slabs were measured and the weight computed.

In addition to the loads shown in the tables and drawing, there was one electric fork truck on each floor. The maximum live load caused by each truck is 6,000 lb, and in computing column loads this truck may be assumed in any position designated as aisle space on the nine floors.

TABLE 21. *Live loads in warehouse, New York, N. Y.*

Bay	Area	Basement	First floor	Second floor	Third floor	Fourth floor	Fifth floor	Sixth floor	Seventh floor	Eighth floor	Ninth floor
	ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2	lb/ft^2
1	560	1.1	17.1	46.3	93.8	109.4	49.2	171.5	118.7	41.8	73.8
2	526	77.4	22.5	70.9	118.9	194.8	73.4	49.6	223.1	82.7	112.7
3	492	156.6	25.9	40.2	0.0	80.3	96.2	60.4	256.6	59.5	181.0
4	454	97.0	32.3	39.7	204.1	115.2	92.5	82.3	241.7	144.6	114.9
5	432	[a]	34.9	14.4	105.8	86.5	79.6	37.9	175.8	78.9	46.4
6	405	[a]	7.8	36.2	60.6	64.0	64.2	79.2	88.4	38.0	72.7
7	396	72.2	72.6	64.4	21.8	17.1	48.5	16.8	105.9	57.2	75.7
8	399	225.7	42.5	59.8	41.7	39.9	55.5	67.2	122.8	45.2	62.9
9	399	55.1	55.9	87.7	59.2	63.1	58.8	67.7	90.4	43.3	55.2
10	399	36.6	26.0	90.5	23.0	43.5	52.1	102.1	71.7	4.1	37.3
11	547	136.1	25.9	65.6	155.4	147.3	78.3	135.9	194.5	139.4	150.9
12	405	129.4	66.4	138.7	127.9	90.9	46.9	197.5	151.1	157.3	197.0
13	399	134.6	73.4	80.9	53.3	80.1	62.9	150.8	102.2	6.4	45.4
14	399	121.0	106.2	94.4	139.6	152.5	70.2	111.8	174.1	85.4	83.0
15	399	178.8	30.2	44.1	157.0	105.3	87.0	50.1	198.0	86.7	64.6
16	396	78.6	37.0	70.7	83.0	179.7	180.2	60.6	212.4	72.2	86.0
17	[b] 405	94.5	24.1	87.3	80.6	74.8	72.4	131.1	116.1	53.6	99.1
18	406	40.2	23.4	8.4	42.6	43.4	27.4	63.8	18.4	16.2	58.7
19	396	92.2	49.8	50.9	117.4	122.9	132.3	105.2	160.3	28.7	46.0
20	400	99.5	106.9	55.9	136.8	110.4	123.5	92.4	160.9	45.4	96.3
21	400	88.5	48.4	62.3	71.3	133.2	92.1	111.7	67.9	53.1	39.7
22	400	93.2	55.0	80.8	143.5	122.3	184.2	150.0	57.6	6.8	53.3
23	406	96.1	54.8	63.0	228.3	139.3	59.1	112.1	50.9	158.6	139.1
24	411	213.7	65.7	90.3	198.4	97.5	155.1	163.4	155.3	229.5	75.0
25	405	137.6	62.5	156.5	154.1	134.3	81.6	194.4	155.1	89.3	73.4
26	405	79.8	68.7	85.6	141.6	100.7	106.0	131.1	157.4	80.2	65.0
27	405	78.5	118.2	126.4	33.8	124.6	78.9	146.0	100.3	97.8	75.3
28	402	24.8	55.6	135.6	56.3	66.9	72.2	105.4	98.9	101.7	58.2
Total area, all bays on all floors, 117,438 ft^2											

[a] Bays 5 and 6 in basement were not surveyed.
[b] Area of bay 17 in basement, 200 ft^2; in all floors above, 405 ft^2.

TABLE 22. *Variation in live loads in warehouse, New York, N. Y.*

Unit load	Area	Portion of total area
lb/ft^2	ft^2	*Percent*
0.0 to 4.9	1,451	1.2
5.0 to 9.9	1,610	1.4
10.0 to 14.9	432	0.4
15.0 to 19.9	2,164	1.8
20.0 to 24.9	2,534	2.2
25.0 to 29.9	2,240	1.9
30.0 to 34.9	1,690	1.4
35.0 to 39.9	3,689	3.1
40.0 to 44.9	4,265	3.6
45.0 to 49.9	5,269	4.5
50.0 to 54.9	3,610	3.1
55.0 to 59.9	6,899	5.9
60.0 to 64.9	5,712	4.9
65.0 to 69.9	3,773	3.2
70.0 to 74.9	6,815	5.8
75.0 to 79.9	5,165	4.4
80.0 to 84.9	4,680	4.0
85.0 to 89.9	4,444	3.8
90.0 to 94.9	4,823	4.1
95.0 to 99.9	3,775	3.2
100.0 to 104.9	2,010	1.7
105.0 to 109.9	3,789	3.2
110.0 to 114.9	2,585	2.2
115.0 to 119.9	2,746	2.3
120.0 to 124.9	2,399	2.0

TABLE 22. *Variation in live loads in warehouse, New York, N. Y.*—Continued

Unit load	Area	Portion of total area
lb/ft^2	ft^2	*Percent*
125.0 to 129.9	1,215	1.0
130.0 to 134.9	2,410	2.1
135.0 to 139.9	4,464	3.8
140.0 to 144.9	1,259	1.1
145.0 to 149.9	952	0.8
150.0 to 154.9	2,555	2.2
155.0 to 159.9	4,286	3.7
160.0 to 164.9	1,207	1.0
165.0 to 169.9		
170.0 to 174.9	959	0.8
175.0 to 179.9	1,227	1.0
180.0 to 184.9	1,288	1.1
185.0 to 189.9		
190.0 to 194.9	1,478	1.3
195.0 to 199.9	1,620	1.4
200.0 to 204.9	454	0.4
205.0 to 209.9		
210.0 to 214.9	807	.7
215.0 to 219.9		
220.0 to 224.9	526	.5
225.0 to 229.9	1,216	1.0
230.0 to 239.9		
240.0 to 244.9	454	0.4
245.0 to 254.9		
255.0 to 259.9	492	.4
Total	117,438	100.0

FIGURE 11. *Seventh-floor plan, warehouse, New York, N. Y.*

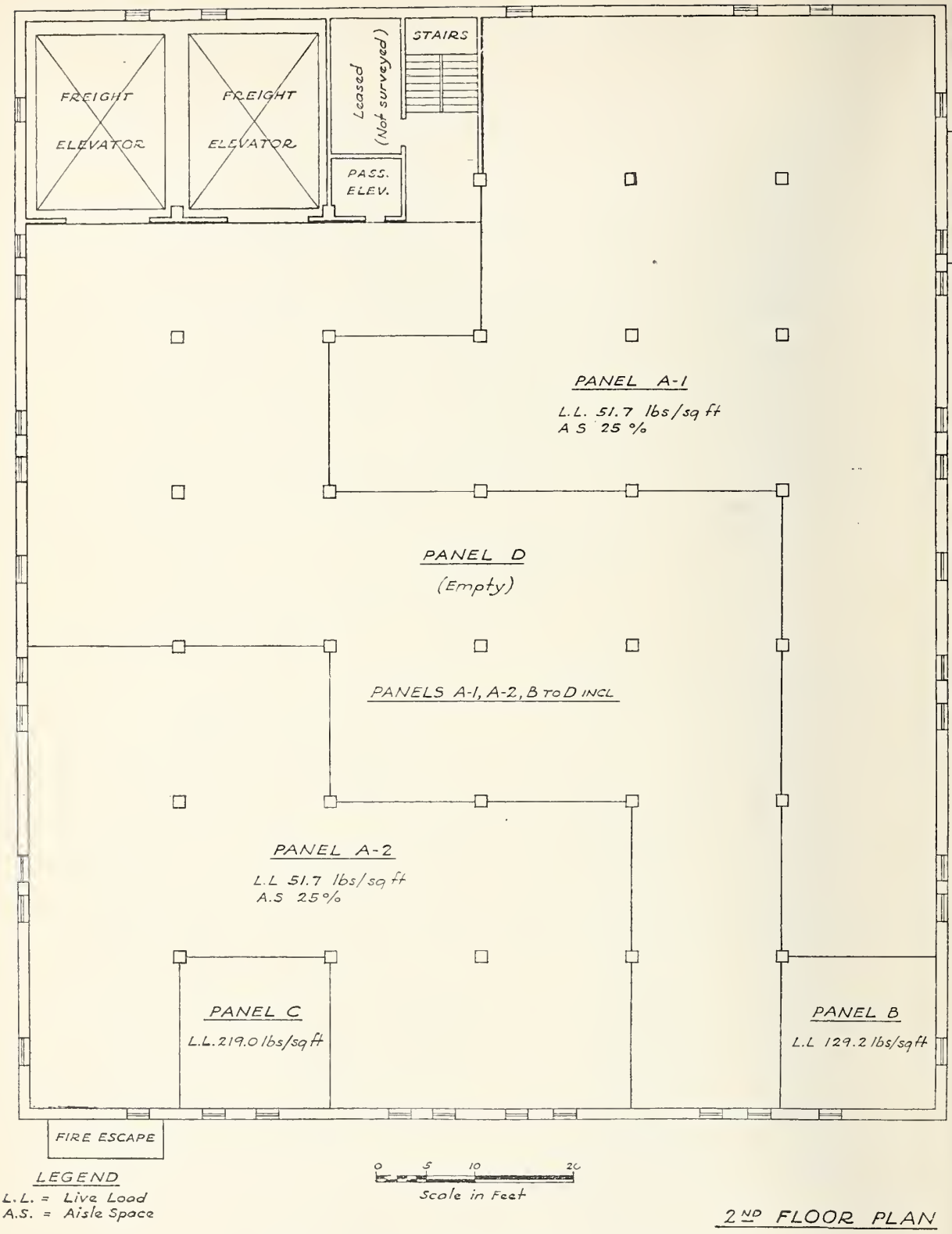

FIGURE 12. *Second-floor plan, warehouse, Washington, D. C.*

Warehouse, Washington, D. C.:

A general merchandise warehouse and its offices were the subject of this survey.

Weights of typical items, such as furniture, packages of canned fruit, canned vegetables, cooking oil, etc., were established by weighing representative pieces. Some items, such as built-in construction, that could not be weighed were measured and the weight computed.

TABLE 23. *Live loads in warehouse, Washington, D. C.*

Department	Area	Unit live load
	ft²	*lb/ft²*
First floor		
Private office	192	10.2
General office	1,167	8.8
Vestibule	236	3.2
Sales office	653	9.5
Storage room A	95	24.2
Panel A	234	22.9
Panel B	234	29.8
Panel C	684	35.3
Panel D	225	181.5
Panel E	410	27.5
Panel F	2,640	8.1
Panel G	270	0.0
Total	7,040	-------
Second floor		
Panels A–1 and A–2	5,100	51.7
Panel B	221	129.2
Panel C	231	219.0
Panel D	3,425	0.0
Total	8,977	-------
Third floor		
Storeroom A	95	2.1
Panels A–1 and A–2	3,295	54.9
Panel B	468	121.8
Panel C	234	63.0
Panel D	710	11.8
Panel E	473	24.4
Panel F	238	75.8
Panel G	238	34.6
Panel H	239	280.7
Panel I	958	0.0
Panel J	1,763	.0
Total	8,711	-------
Fourth floor		
Storeroom A	95	41.1
Panel A	7,600	77.4
Panel B	474	303.5
Panel C	589	0.0
Total	8,758	-------
Fifth floor		
Storeroom B	650	118.8
Panel A	7,760	95.1
Panel B	589	0.0
Total	8,999	-------
Sixth floor		
Storeroom A	95	20.2
Storeroom B	255	18.6
Storeroom C	518	40.0
Panel A	6,890	33.6
Panel B	958	0.0
Panel C	589	.0
Total	9,305	-------
Seventh floor		
Storeroom A	95	70.7
Storeroom B	184	6.6
Storeroom C	589	13.2
Panel A	7,848	30.4
Panel B	589	0.0
Total	9,305	-------
Eighth floor		
Storeroom A	95	18.8
Panels A–1 and A–2	2,213	22.3
Panel B	4,287	21.1
Panel C	713	39.3
Panel D	754	0.0
Total	8,062	-------
Grand total	69,157	-------

TABLE 24. *Variation in live loads in warehouse, Washington, D. C.*

Unit load	Area	Portion of total area
lb/ft²	*ft²*	*Percent*
0.0 to 4.9	10,815	15.7
5.0 to 9.9	4,644	6.7
10.0 to 14.9	1,491	2.2
15.0 to 19.9	350	0.5
20.0 to 24.9	7,397	10.7
25.0 to 29.9	644	0.9
30.0 to 34.9	14,976	21.7
35.0 to 39.9	1,397	2.0
40.0 to 44.9	613	0.9
45.0 to 49.9	-------	-------
50.0 to 54.9	8,395	12.2
55.0 to 59.9	-------	-------
60.0 to 64.9	234	0.3
65.0 to 69.9	-------	-------
70.0 to 74.9	95	.1
75.0 to 79.9	7,838	11.4
80.0 to 94.9	-------	-------
95.0 to 99.9	7,760	11.2
100.0 to 114.9	-------	-------
115.0 to 119.9	650	0.9
120.0 to 124.9	468	.7
125.0 to 129.9	221	.3
130.0 to 179.9	-------	-------
180.0 to 184.9	255	.3
185.0 to 214.9	-------	-------
215.0 to 219.9	231	.3
220.0 to 279.9	-------	-------
280.0 to 284.9	239	.3
285.0 to 299.9	-------	-------
300.0 to 304.9	474	0.7
Total	69,157	100.0

9. Variation in Loading

The data show fairly large differences in loading on different areas within the same occupancy. In some cases, such as a library or storage room in office occupancy, it may be possible to anticipate and provide for unusually heavy loads. In others, as in department stores, there may be frequent shifts of goods from one part of a floor to another or from floor to floor in response to changes in

sales policy, seasonal demands, or other considerations, with the result that unit loads on given areas may change several hundred percent.

It is apparent that there is a problem in the selection of a representative minimum unit-load value for each typical occupancy and in the determination of a reasonable reduced unit-load value for a large area supported by a given structural member. In the case of a small area, the total load will be the minimum unit load multiplied by the area; but in the case of larger areas, a reduction is considered permissible for loads carried by columns and girders, and sometimes beams, based on recognition of the fact that in many occupancies such members seldom, if ever, are loaded to the extent of the unit live load multiplied by the total area supported. A method of reduction that is gaining wide acceptance in building codes is as follows [5]:

> For live loads of 100 pounds or less per square foot, the design live load on any member supporting 150 lb/ft² or more may be reduced at the rate of 0.08 percent per square foot of area supported by the member, except that no reduction shall be made for areas to be occupied as places of public assembly. The reduction shall exceed neither R as determined by the following formula, nor 60 percent:
>
> $$R = 100 \times \frac{D+L}{4.33L},$$
>
> in which
>
> R = reduction in percent
> D = dead load per square foot of area supported by the member
> L = design live load per square foot of area supported by the member.

For live loads exceeding 100 lb/ft², no reduction shall be made, except that the design live loads on columns may be reduced 20 percent.

The design load L in the above formula is the highest average live load that it is proposed to permit on room-sized areas (specifically, areas up to 150 ft²). An individual member carrying less than 150 ft² of floor would be designed for L. It can also be thought of as the allowable load for which the floor should be posted, in situations where posting is advisable.

High concentrations of load on very small areas, such as safes, are ordinarily provided for in building codes by a requirement that the floor must be capable of supporting a 2,000-lb load on a specified limited area at any location.

The significance of R is that it is a limiting value of the reduction in terms of the live load and dead load such that, if the entire structure were loaded at the rate of L, no part would be overstressed by more than 30 percent.

The effect of the foregoing method of reducing design live loads can be illustrated by an example. Assume, for instance, that L equals 100 lb/ft², D equals 100 lb/ft², and that the floor bays are 20 ft sq with the slabs spanning in one direction. The slabs would be designed for a live load of 100 lb/ft². The beams and the top stories of columns carrying 400 ft² each would be designed for 68 lb/ft². The lower stories of the columns would be designed for 54 lb/ft², which is the maximum reduction permitted by the formula. It is of interest to compare this value with the range of values found for large areas in the department-store surveys in this report.

10. Discussion

Safe building design requires the use of a combination of assumed loads and working stresses which will result in structures that will not be seriously overstressed in any part by the imposed loads.

The data obtained in the survey made by the Public Buildings Administration afford a chance of seeing in specific instances what the result of any given combination of live loads and stresses would have been. The more extensive and detailed such surveys are for a given occupancy, the firmer are the conclusions to be drawn from them. The data represent not the most severe loading possible, but the actual average loading in each case on a given area of a given occupancy. It appears from the data that a large percentage of the floor area in most occupancies is much less heavily loaded than the most heavily loaded bay. This suggests possible further economies in the design of members carrying large floor areas. However, the data available are still small in quantity and there are conditions of local load concentrations that must not be overlooked. With additional information gained from further surveys, it should be possible to answer more definitely several questions, among them how representative are the minimum live-load assumptions now given in building codes recommended by various organizations for national or regional use.

Consideration of the use of the data presented herein leads to several suggestions for future surveys that would clear up some of the questions left open.

One such survey would be an investigation of the actual loads in department stores during the Christmas season. This could be done by selecting several bays that appeared to be busiest, measuring the areas therein that might be occupied by people, and subsequently counting the number of people in those areas from time to time during the Christmas shopping period. Photographs could also record the extent of crowding.

Another survey, or series of surveys, which would not be unduly expensive, would be to determine the most heavily loaded single bay of a floor in each of a number of manufacturing plants. This could be done by selecting the five bays that appeared, upon casual examination, to be most heavily loaded, and surveying those five bays in detail.

A third type of survey would consist of checking the loading in a number of occupancies where no published information is available that is less than twenty years old. Conditions may have changed

to such an extent as to make a redetermination of values for use in assumptions for design desirable.

If it is found through additional work in this field that substantial reductions can be made in minimum assumed unit loads for some occupancies and that significant economies in construction are indicated through use of the lowered figures, there are still some considerations that merit attention. One of these is the fact that local authorities are not always in a position to keep a close check on changes in occupancy and, consequently, buildings may become overloaded although they were safe as designed for their original tenant. Another consideration is that it may be economically desirable to design for such future changes through using a higher unit load figure than is absolutely necessary because it then becomes possible to accommodate a greater variety of occupancies as time goes on. In this case, the problem becomes one of weighing initial savings against the advantages of flexibility of use over a long period.

In any event, it is important to have available a reasonably complete and up-to-date set of figures that can serve as the basis for engineering design.

11. Selected References

[1] The amount of possible strain on a crowded floor, American Architect and Building News, p. 34 (April 15, 1893).

[2] A study of office-building live loads, Eng News-Record, **90**, 584 (March 29, 1923).

[3] Minimum live loads allowable for use in design of buildings, Report of the Department of Commerce Building Code Committee, Nov. 1, 1924. (out of print)

[4] John W. Dunham, Design live loads in buildings, Trans. Am Soc Civil Engrs. **112**, 725 (1947).

[5] American standard building code requirements for minimum design loads in buildings and other structures, NBS Miscellaneous Publications M179 (1945).

[6] Report of Subcommittee on Fire-Resistance Classifications of the Central Housing Committee on Research, Design, and Construction, Fire-resistance classifications of building constructions, NBS Building Materials and Structures Report BMS92 (1942).

Washington, January 24, 1952.

U. S. GOVERNMENT PRINTING OFFICE: 1952

BUILDING MATERIALS AND STRUCTURES REPORTS

[Continued from cover page II]

BMS36 Structural Properties of Wood-Frame Wall, Partition, Floor, and Roof Constructions With "Red Stripe" Lath Sponsored by The Weston Paper and Manufacturing Co -- 10¢
BMS38 Structural Properties of Two "Dunstone" Wall Constructions Sponsored by the W. E. Dunn Manufacturing Co -- 10¢
BMS39 Structural Properties of a Wall Construction of "Pfeifer Units" Sponsored by the Wisconsin Units Co -- 10¢
BMS44 Surface Treatment of Steel Prior to Painting -- 10¢
BMS47 Structural Properties of Prefabricated Wood-Frame Constructions for Walls, Partitions, and Floors Sponsored by American Houses, Inc -- 20¢
BMS48 Structural Properties of "Precision-Built" Frame Wall and Partition Constructions Sponsored by the Homasote Co -- 15¢
BMS50 Stability of Fiber Building Boards as Determined by Accelerated Aging -- 10¢
BMS51 Structural Properties of "Tilecrete Type A" Floor Construction Sponsored by the Tilecrete Co -- 10¢
BMS52 Effect of Ceiling Insulation Upon Summer Comfort -- 15¢
BMS53 Structural Properties of a Masonry Wall Construction of "Munlock Dry Wall Brick" Sponsored by the Munlock Engineering Co -- 10¢
BMS54 Effect of Soot on the Rating of an Oil-Fired Heating Boiler -- 10¢
BMS55 Effects of Wetting and Drying on the Permeability of Masonry Walls -- 10¢
BMS58 Strength of Soft-Soldered Joints in Copper Tubing -- 10¢
BMS60 Strength, Absorption, and Resistance to Laboratory Freezing and Thawing of Building Bricks Produced in the United States -- 30¢
BMS62 Structural Properties of a Precast Joist Concrete Floor Construction Sponsored by the Portland Cement Association -- 15¢
BMS63 Moisture Condensation in Building Walls -- 15¢
BMS65 Methods of Estimating Loads in Plumbing Systems -- 15¢
BMS66 Plumbing Manual -- 35¢
BMS67 Structural Properties of "Mu-Steel" Prefabricated Sheet-Steel Constructions for Walls, Partitions, Floors, and Roofs, Sponsored by Herman A. Mugler -- 15¢
BMS68 Performance Test for Floor Coverings for Use in Low-Cost Housing: Part 3 -- 20¢
BMS69 Stability of Fiber Sheathing Boards as Determined by Accelerated Aging -- 10¢
BMS70 Asphalt-Prepared Roll Roofings and Shingles -- 20¢
BMS71 Fire Tests of Wood- and Metal-Framed Partitions -- 20¢
BMS72 Structural Properties of "Precision-Built, Jr." Prefabricated Wood-Frame Wall Construction Sponsored by the Homasote Co -- 10¢
BMS73 Indentation Characteristics of Floor Coverings -- 10¢
BMS74 Structural and Heat-Transfer Properties of "U. S. S. Panelbilt" Prefabricated Sheet-Steel Constructions for Walls, Partitions, and Roofs Sponsored by the Tennessee Coal, Iron & Railroad Co -- 20¢
BMS75 Survey of Roofing Materials in the North Central States -- 15¢
BMS77 Properties and Performance of Fiber Tile Boards -- 10¢
BMS78 Structural, Heat-Transfer, and Water-Permeability Properties of Five Earth-Wall Constructions -- 25¢
BMS79 Water-Distributing Systems for Buildings -- 20¢
BMS80 Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 4 -- 15¢
BMS81 Field Inspectors' Check List for Building Constructions (cloth cover, 5 x 7½ inches) -- 30¢
BMS82 Water Permeability of Walls Built of Masonry Units -- 25¢
BMS83 Strength of Sleeve Joints in Copper Tubing Made With Various Lead-Base Solders -- 15¢
BMS84 Survey of Roofing Materials in the South Central States -- 15¢
BMS86 Structural, Heat-Transfer, and Water-Permeability Properties of "Speedbrik" Wall Construction Sponsored by the General Shale Products Corporation -- 15¢
BMS87 A Method for Developing Specifications for Building Construction—Report of Subcommittee on Specifications of the Central Housing Committee on Research, Design, and Construction -- 20¢
BMS89 Structural Properties of "Precision-Built, Jr." (Second Construction) Prefabricated Wood-Frame Wall Construction Sponsored by the Homasote Co -- 15¢
BMS90 Structural Properties of "PHC" Prefabricated Wood-Frame Construction for Walls, Floors, and Roofs Sponsored by the PHC Housing Corporation -- 15¢
BMS92 Fire-Resistance Classifications of Building Constructions -- 30¢

[List continued on cover page IV]

BUILDING MATERIALS AND STRUCTURES REPORTS

[Continued from cover page III]

BMS94	Water Permeability and Weathering Resistance of Stucco-Faced, Gunite-Faced, and "Knap Concrete-Unit" Walls	15¢
BMS95	Tests of Cement-Water Paints and Other Waterproofings for Unit-Masonry Walls	25¢
BMS96	Properties of a Porous Concrete of Cement and Uniform-Sized Gravel	10¢
BMS99	Structural and Heat-Transfer Properties of "Multiple Box-Girder Plywood Panels" for Walls, Floors, and Roofs	15¢
BMS100	Relative Slipperiness of Floor and Deck Surfaces	10¢
BMS101	Strength and Resistance to Corrosion of Ties for Cavity Walls	10¢
BMS102	Painting Steel	10¢
BMS103	Measurements of Heat Losses From Slab Floors	15¢
BMS104	Structural Properties of Prefabricated Plywood Lightweight Constructions for Walls, Partitions, Floors, and Roofs Sponsored by the Douglas Fir Plywood Association	30¢
BMS105	Paint Manual With Particular Reference to Federal Specifications	$1.25
BMS106	Laboratory Observations of Condensation in Wall Specimens	10¢
BMS108	Temperature Distribution in a Test Bungalow With Various Heating Devices	15¢
BMS109	Strength of Houses: Application of Engineering Principles to Structural Design	$1.50
BMS110	Paints for Exterior Masonry Walls	15¢
BMS111	Performance of a Coal-Fired Boiler Converted to Oil	15¢
BMS112	Properties of Some Lightweight-Aggregate Concretes With and Without an Air-Entraining Admixture	10¢
BMS113	Fire Resistance of Structural Clay Tile Partitions	15¢
BMS114	Temperature in a Test Bungalow With Some Radiant and Jacketed Space Heaters	25¢
BMS115	A Study of a Baseboard Convector Heating System in a Test Bungalow	15¢
BMS116	Preparation and Revision of Building Codes	15¢
BMS117	Fire Resistance of Walls of Lightweight Aggregate Concrete Masonry Units	20¢
BMS118	Stack Venting of Plumbing Fixtures	15¢
BMS119	Wet Venting of Plumbing Fixtures	20¢
BMS120	Fire Resistance of Walls of Gravel-Aggregate Concrete Masonry Units	15¢
BMS121	Investigation of Failures of White-Coat Plasters	25¢
BMS122	Physical Properties of Some Samples of Asbestos-Cement Siding	15¢
BMS123	Fire Tests of Wood-Framed Walls and Partitions With Asbestos-Cement Facings	15¢
BMS124	Fire Tests of Steel Columns Protected With Siliceous Aggregate Concrete	15¢
BMS125	Stone Exposure Test Wall	30¢
BMS126	The Self-Siphonage of Fixture Traps	20¢
BMS127	Effect of Aging on the Soundness of Regularly Hydrated Dolomitic Lime Putties	15¢
BMS128	Atmospheric Exposure Tests of Nailed Sheet Metal Building Materials	20¢
BMS129	Fire Endurance of Shutters for Moving-Stairway Openings	10¢
BMS130	Methods and Equipment for Testing Printed-Enamel Felt-Base Floor Covering	15¢
BMS131	Fire Tests of Gunite Slabs and Partitions	15¢
BMS132	Capacities of Plumbing Stacks in Buildings	20¢
BMS133	Live Loads on Floors in Buildings	20¢