

PROBLEM IN FACTORY BUILDING

BY

R. J. KOCH

ARMOUR INSTITUTE OF TECHNOLOGY

1920

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Koch, R. J.

A practical problem in
factory building design and

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A PRACTICAL PROBLEM
IN FACTORY BUILDING ²²⁰³₁₉₂₀
DESIGN AND CONSTRUCTION

A THESIS

PRESENTED BY

RAYMOND J. KOCH

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

CIVIL ENGINEER

MAY 27, 1920

APPROVED:

Alfred Phillip

Professor of Civil Engineering

W. B. ...

Dean of Engineering Studies

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A PRACTICAL PROBLEM IN

FACTORY BUILDING

DESIGN

AND

CONSTRUCTION

BY

Raymond J. Koch

A PRACTICAL PROBLEM IN FACTORY BUILDING, DESIGN AND CONSTRUCTION.

PROBLEM:

The writer was appointed by the Ilg Electric Ventilating Co. of Chicago to look after their interests and to make a study of the type of building which would be best suited to their needs, both industrially and structurally. Subsequently the writer also acted as superintendent for the owner during the construction of the plant.

The plat of survey marked Exhibit No.1, shows the site which had been selected for the erection of the Company's new plant. The site is bounded by George St. on the north, Crawford Ave. on the east, and the main line of the Chicago Milwaukee & St. Paul Railway Co. on the west. A switch track was to serve this property, but its location was to be determined after the building was settled.

The points that had to be settled were: what shape of building was best suited for present needs and lended itself most easily for future expansion, what height building should be erected, should the building be built of reinforced concrete, structural steel or heavy timber.

METHOD OF ATTACK:

In order to proceed intelligently on this problem the first thing that required attention was the product manufactured, the processes in the manufacturing, the present floor area allotted to various processes and departments, and the co-relation between various departments.

PRODUCT MANUFACTURE:

The particular output of the Company is electrical ventilating equipment. This consists of fans and blowers made up of castings and sheet metal on which electric motors are mounted as a source of propulsion.

PROCESS OF MANUFACTURE:

By dividing up the various finished products into their pieces and tracing back their parts to their origin it was possible to make a chart of the various departments through which the individual parts pass until the final assembly of the article is completed for shipment. Exhibit

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No. 2 gives the department chart referred to above. In this chart the numbers refer to the departments as listed below:

1. Raw Stock department
- 2a Punch Press and Forge departments
- 2b Machine department
- 2c Commercial Blower Fabricating department
- 3 Motor Winding department
- 4 Motor Assembly department
- 5a Fan Wheel department
- 5b Fan Frame department
- 6 Blower Assembly department
- 7 Sheet Metal department
- 8 Painting department
- 9 Testing department
- 10 Finishing department
- 11 Semi Finished stock department
- 12 Shipping department

For instance, if we take a small blower which consists of a cast iron housing, sheet metal wheel and a motor and refer to the chart we find that a casting is drawn from the Raw Stock (#1) and goes to the Fan Frame dept. (5b) where it is machined, ground and finished into a blower housing. The housing then proceeds to the Blower Assembly dept. (#6) where it meets the wheel which has been built while passing through the Raw Stock room (#1), Fan Wheel dept. (#5a) and Painting dept. (#8). In the Blower Assembly dept. the wheel is placed in the housing, the unit painted in the Paint shop (#8) and then is placed in the Semi Finished stock room (#11). Upon an order the blower is drawn from the semi finished rooms, returns to the Blower Assembly dept. (#6) where motor is attached and then goes on test in (#9). Upon passing a satisfactory test the set goes to the Shipping dept. (#12) and thus leaves the plant.

FLOOR AREAS:

At the time that it was decided that a new plant was required the floor area of the Company's old plant was 58,000 sq.ft. To provide for expansion for a period of from three to five years it is necessary to provide for approximately 100,000 sq.ft. of space in their new plant. The following table therefore, was gotten up showing the present area allotted to each department together with the new area. In determining the new area required in each department, due consideration was given to the fact that some departments were more crowded than others and consequently in order to even up operating conditions, a cramped department was allotted a little more than the nominal percentage of increase in the new layout. The fol-

lowing table gives the present and adjusted areas:

		<u>Present</u>	<u>Adjusted</u>
1	Raw Stock dept.	6500	7600
2a	Punch Press and Forge depts.	2440	4000
2b	Machine dept.	5100	9600
2c	Commercial Blower Fabricating dept.	2050	3600
3	Motor Winding dept.	3710	6000
4	Motor Assembly dept.	770	1600
5a	Fan Wheel dept.	1800	2000
5b	Fan Frame dept.	500	1600
6	Blower Assembly dept.	1030	2400
7	Sheet Metal dept.	4480	5600
8	Painting dept.	500	2000
9	Testing dept.	3580	4200
10	Finishing dept.	640	1200
11	Semi Finished stock dept.	10070	12600
12	Shipping dept.	2050	6000

TYPE OF BUILDING:

Upon making a study of Exhibit No.2 we get the correlation of the various departments. The problem then resolves itself into arranging the departments and their respective floor areas in such a way as to result in a progressive means of manufacturing. In order to determine the exact shape of building which best suited the Company's needs, a number of different types were considered. First of all the question of a single story or multi-story building presented itself. From the nature of the Company's product it is easily seen that a large amount of ground floor area was required in order to eliminate the consumption of a great deal of horse power on account of raising heavy castings to a second or third floor. Upon further consideration, however, it was seen that while a great deal of ground floor space was necessary the Company could at the same time very nicely locate certain departments on a second floor without increasing the manufacturing costs an appreciable amount. It was also seen that it would not be practical to consider a building more than two stories in height, and consequently all efforts so far as department layout, were confined to the one and two story buildings.

The one story layout Exhibit No.3 shows what was finally arrived upon as the ideal department layout for this type building. The objections presented against a one story building were, the large percentage of the available ground area such a building required, the far greater cost per square foot involved in the construction of such a type building, due not only to the expense of a sawtooth roof, but also on account of sprinkler mains, gas mains and the like. Another item which operated against this type of

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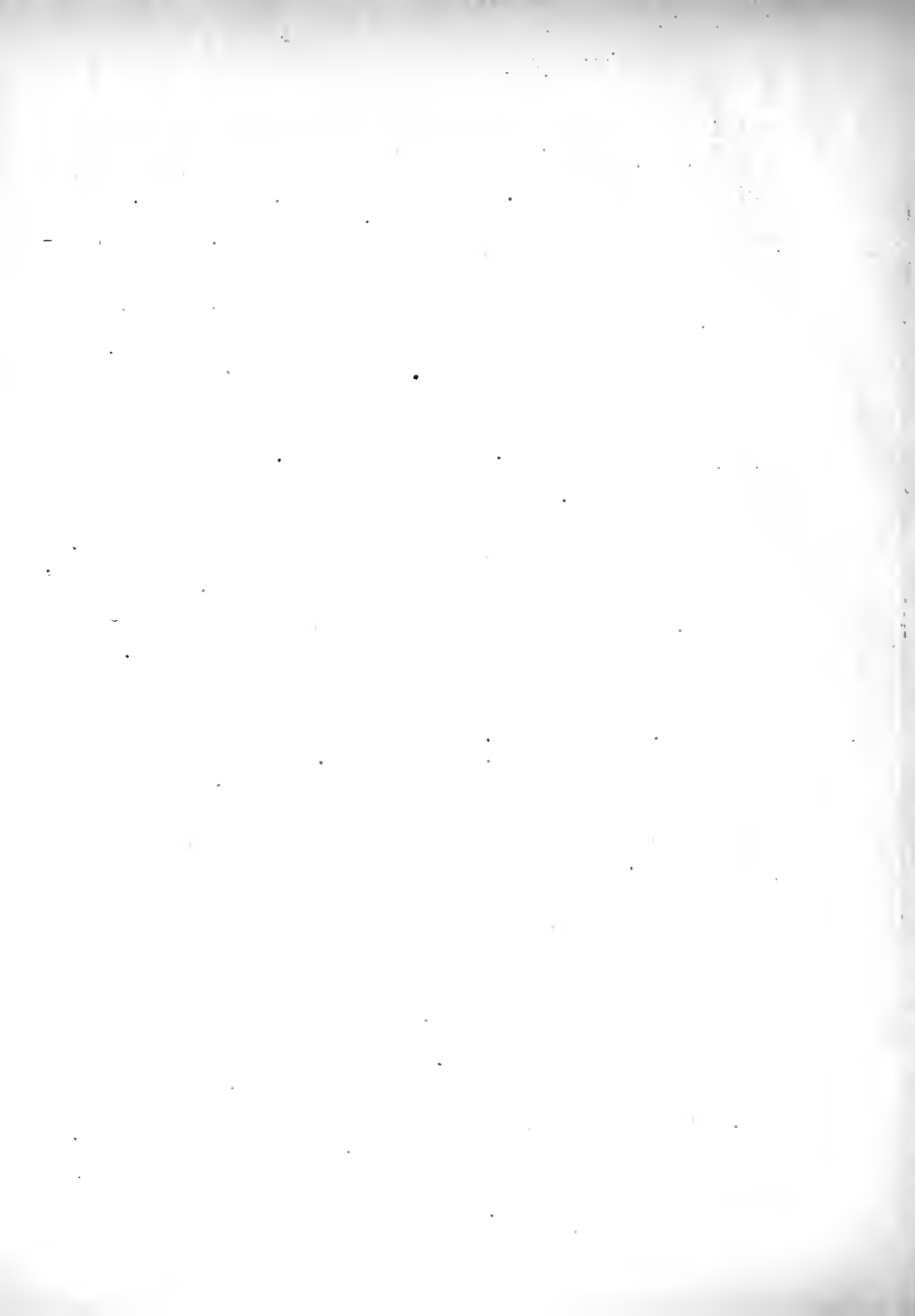
building was the additional heat required in the Winter due to the very large roof area and also the large amount of ventilation required to keep the building comfortable during the hot months. Roof insulation, of course, would help this condition considerably, but nevertheless these two points would always be important factors. Another objection is that when future expansion is considered it is easily seen that it would be necessary to move every department in order to increase the floor area. This, of course, would cause a great deal of disturbance in the manufacturing processes at the time of future expansion, inasmuch as all departments would be affected.

Having disposed of the single story building the next arrangement that would naturally suggest itself was the two story building. Layouts of a U, E and O shape building were all considered and were discarded for one reason or another. For instance in the U type, the wings were too long for proper routing of materials and the problem of future expansion was rendered very difficult. While in the E shape building future expansion was simple, the departments did not group themselves well. In the O shape building the present layout of departments was nearly ideal, but future expansion was practically impossible without a complete rearrangement of all departments.

Finally an H shape building was decided upon as most nearly fulfilling all the requirements of the present and future. Exhibit No.4 shows the layout upon which all calculations were based. Exhibit No.5 shows how easily this layout lended itself to a 50% expansion. In this layout the departments handling the heavy castings and heavy finished product were kept on the first floor and the lighter manufacturing departments were placed on the second floor. This layout also pointed out that a three story building was not practical.

ELEVATION OF FLOOR:

Having decided on a two story building with the first floor at ground level, it was necessary to establish the grade of the first floor. The survey showed that the natural ground level was approximately 15" below the established grade of the curb. To reduce the amount of fill required in the building to a minimum there, of course, was only one elevation at which to establish the first floor line. Other factors, however, were to be considered among them the grade of the switch track, the approach grade to the shipping platform and the proper height of the floor above sidewalk to prevent water from melting snow to find its way on to the floor.



A grade of 25 feet above city datum was established for the first floor line. This brought the sidewalk about 15 inches below the first floor level and required a cut of about 3 feet for the switch track. It also required a 4% grade to the shipping platform. The various driveway grades considered are shown in Exhibit No.6. The 4% grade was finally determined upon in order that horse drawn trucks would be able to leave the platform with a full load. 6% grades are in use in Chicago at bridge approaches but they are not desirable as records of horse fallings show.

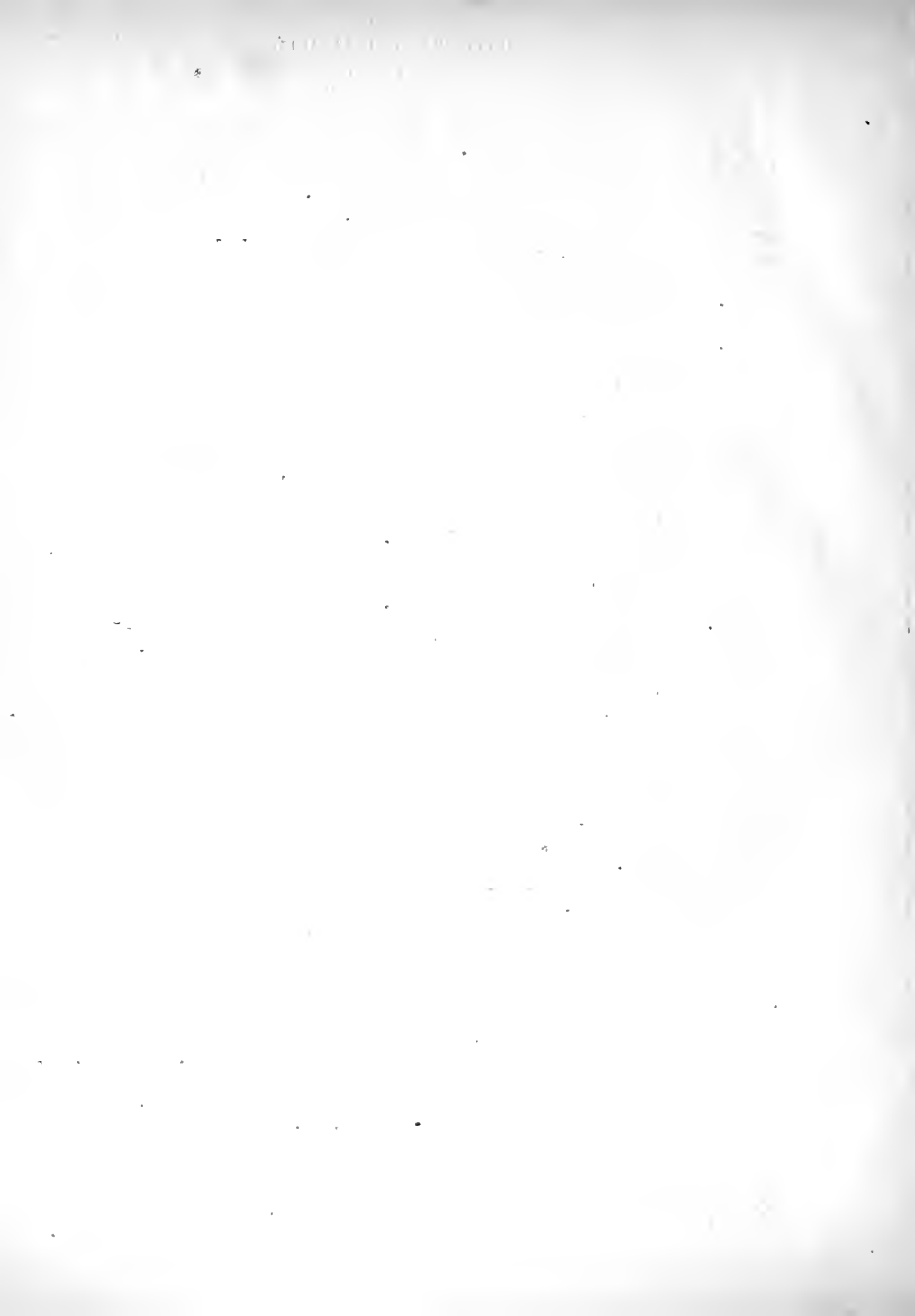
SWITCH TRACK:

The layout of the building showed that the switch track to serve the Company should be located along the south end of the building. Exhibit No.7 shows the layout of the industry tracks serving both the Ilg and Seng Companies. The main switch track was an extension of an existing siding of the railway. Immediately upon leaving the railway property the Seng track branches from the main industry track. The tracks swing into the property on about a $9\frac{3}{4}$ degree curve and a .6% down grade until elevation of 19.5 city datum was reached for the top of rail. This grade was then maintained to the end of the track. As stated before, the elevation of this track entailed a cut of 3 feet. Approximately 5500 cubic yards of material had to be removed. The top 9" was loam and the remainder clay. The loam was scraped off with scrapers and saved for grading around the front of the building. Where a cut was not over 18" in depth the excavating was done with scrapers and for greater depths a steam shovel working in conjunction with wagons was used. The material was spoiled in a more or less even manner over an area of about 100 feet each side of the track. By handling this excavating as a separate contract 35¢ per sq.yd. was saved over the Railroad Company's figure.

BUILDING DETAILS:

After a survey of the machinery which will be located on the second floor and also a study of the floor loadings in possible stock rooms, it was decided that the second floor should be designed for a load of 250 lbs. per sq.ft. The boiler room of the building being located in the basement with the Punch Press department immediately above, required a floor loading of 300 lbs. per sq.ft. for the boiler room ceiling.

In order to eliminate as many posts as possible a 20 foot bay was established as standard. This meant that the wings of the building should be either 60 or 80 feet.



Using high ceilings, 16 feet on the first floor on account of manufacturing operations and 12 feet on the second floor sufficient light would reach the interior of an 80 foot wing, consequently the design was made for 80 foot wings.

A preliminary design both in reinforced concrete and heavy timber construction was made and prices on both layouts secured. By this time the structural steel market was in such condition that the question of using structural steel for the general construction of the building was given up. On account of the extremely high price of lumber at the time that our estimates were completed it showed that a concrete building could be built for about 5% more than a heavy timber constructed building. Consequently final plans were made for a reinforced concrete building.

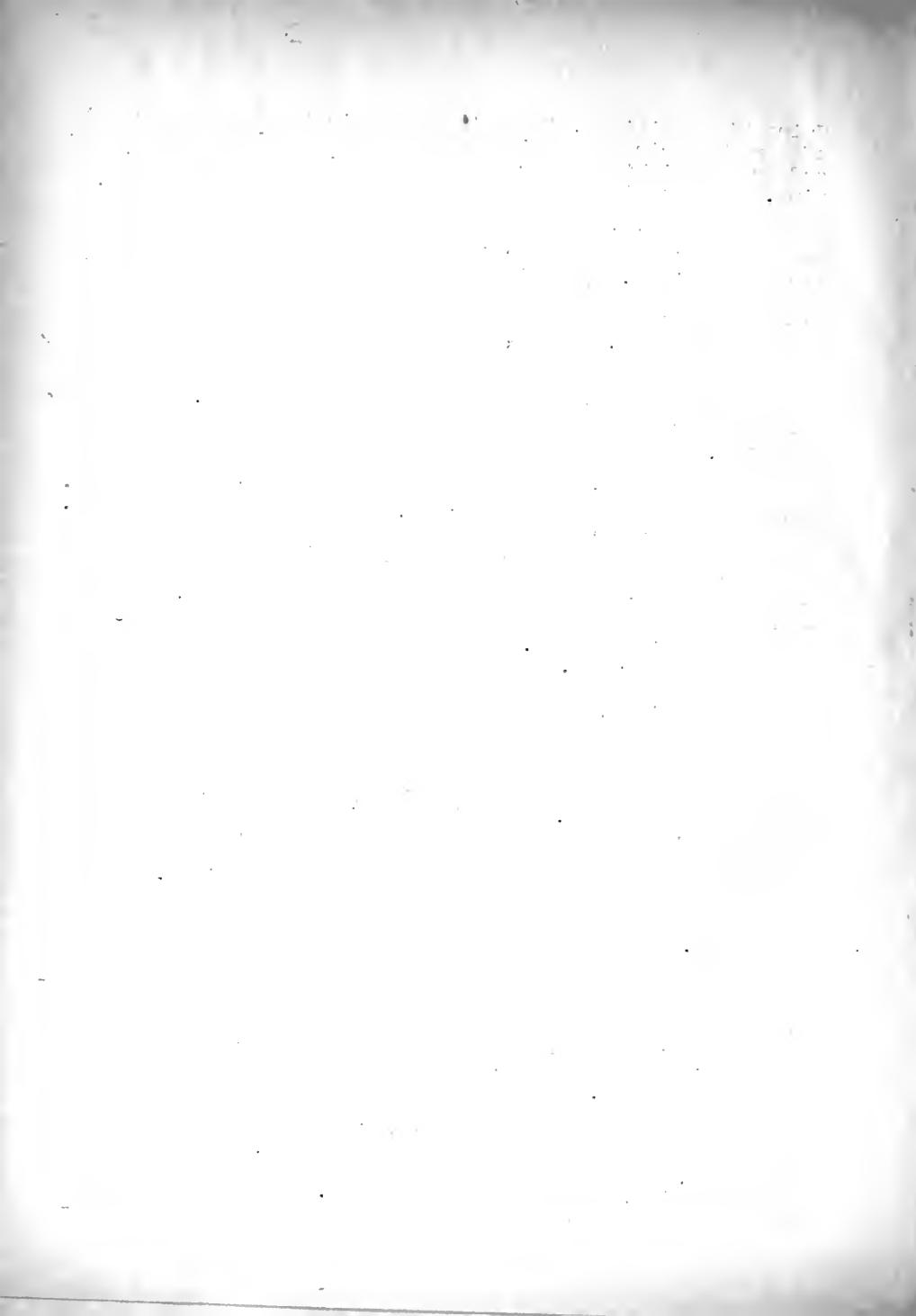
The building was laid out as a flat slab with 7 ft. drop panels over the column caps. The column cap was 4 ft. 6 inches in diameter at the top and sloped down on a 45 degree angle to the column proper which in most cases was 20 inches in diameter for the second floor columns and 22 inches in diameter for the first floor columns. The spandrel beams were left exposed and came about 14 inches below the ceiling line. The spandrel beam acted as lintel over the steel sash. Brick curtain walls were built up 3 feet 6 inches above the floor line and were capped off with stone sills.

Concrete slotted inserts were provided at 4 foot centers in both directions in both the roof and second floor slabs in order to permit the hanging of line shafting and motors at any point. Two rings of inserts were also provided on every interior column at 6 and 9 foot heights respectively in order that platforms could be built on any column to carry motors or other machinery required.

The inserts in all cases were large enough to take a 3/4" bolt.

In order to eliminate excessive chopping of the concrete slabs which always entails the cutting of reinforcing bars when the hole is placed near the columns 4" sleeves were placed on every fifth column in order to provide for any future piping which it may be necessary to run from one floor to another.

Special features involved in the design of this plant consisted in the driving of a 300 ft. well for drinking water, the installation of oil burners for heating, and the use of automatic house telephones. By means of the well it will be possible to get all the drinking water re-



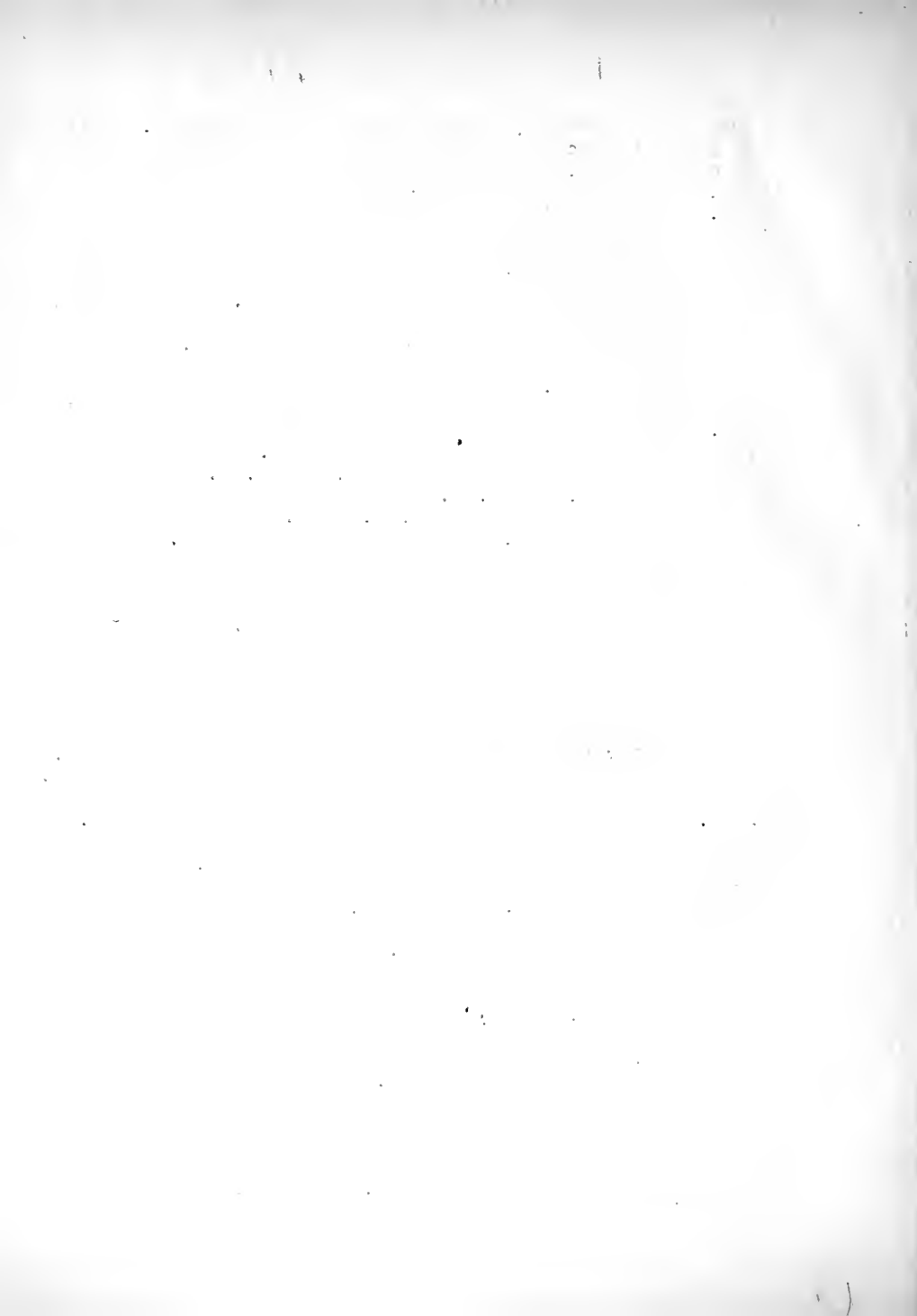
quired at a year around temperature of 52 degrees. This not only lends to health of the employes due to a perfectly pure clear water, but also on account of a uniform temperature, cool enough to be refreshing but not as cold as iced water. By connecting up the three 75 Horse Power boilers with which the plant is being equipped, with oil burners the Company has eliminated the soot and dirt which always accompany the combustion of coal and have also eliminated the trouble of proper disposition of ashes. Furthermore, it will be possible to get up steam in a far shorter time than had chain grates been used and coal burnt.

Exhibit No.8 shows a floor plan together with the overall dimensions of the building as it is actually being built. The photograph immediately proceeding the exhibits gives a birdseye drawing of the building. This building calls for a first floor area of 48,000 sq.ft. and a second floor area of 42,000 sq.ft. The area of the two extra floors in the tower is 560 sq.ft. each. In the top of the tower is located a 60,000 gallon sprinkler tank. The tank is carried on a concrete floor which frames into the concrete columns at a point 73 feet above the sidewalk. The tank which is of steel construction is to be set on cement grout so as to bring it to an even bearing.

CONSTRUCTION:

Construction on the building was started in October 1919 and was greatly hampered through failure of the Railway Company to lay the industry track as per their agreement. Another delay was caused by a strike of the sewer diggers. The result of these two delays was that approximately 6000 cu.yds. of concrete was poured during freezing weather. Approximately 550 yards of this were poured when the thermometer did not rise above the 10 degree mark. Due to the extreme care taken when placing the concrete none was affected by the frost. All water, sand and stone was heated before going into the mixer and a steam jet continually played into the mixer. Immediately before placing concrete any ice adhering to the reinforcing steel form work was melted with a blow torch and the forms heated with a steam jet. The space beneath the floor which was being poured was protected with tarplins and heated with salamanders. Immediately upon completion of a pouring the concrete was protected with hay.

On account of the first floor being on the ground the contractor had intended pouring the first floor slab first so as to keep uniform lengths on the struts used to carry the second floor form work. However, on account of the inability of the sewer contractor to complete his underground work this method had to be abandoned, and the



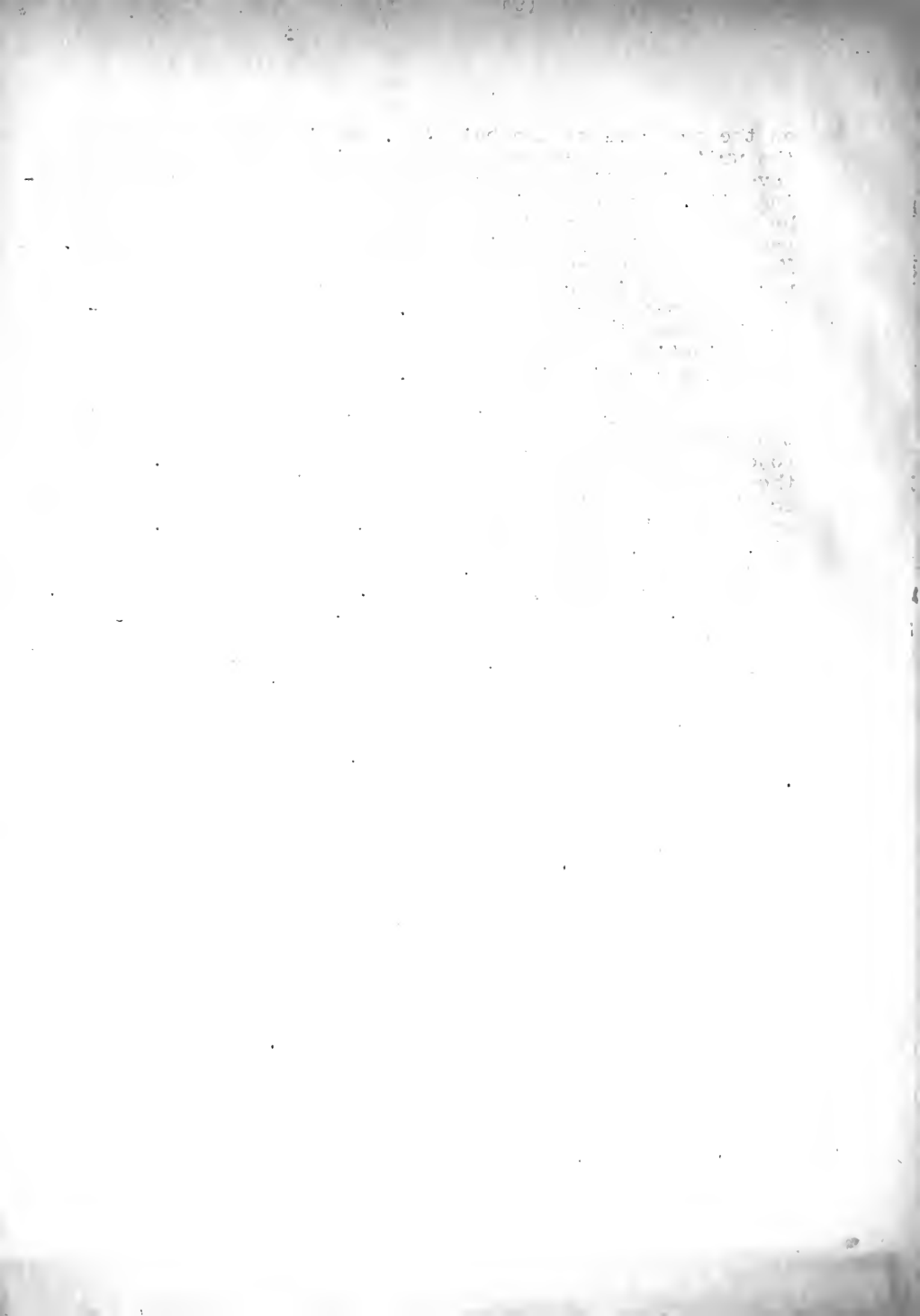
contractor placed mud sills on which to carry his struts. At this point the contractor made a grave mistake inasmuch as he insisted on placing 48,000 sq.ft. of form work before doing any concreting. No amount of persuasion on the part of the writer to have the contractor complete both floors of a small section of the building and then proceed to another section could divert him from his original idea of finishing all of the form work involved on one floor. As a consequence of his method of erecting this building, he found that his lumber bill was extremely high and that in order to start pouring the roof slab it was necessary for him to buy additional lumber inasmuch as he could not remove the form work from the second floor slab, until after the roof had been poured. The result of the whole arrangement was that the contractor has only used his form lumber twice whereas he should have used it four times in order to reduce expenses and also that the building was delayed fully a month and a half through this procedure. The principles of progressive manufacturing and the lesson learned on this building would indicate that it is not advisable to take a large area and expect to complete the form work on the entire area before proceeding to the next floor. It would be far better to take an area say 100 x 200 sq.ft. and after completing the form work pour the concrete, while pouring the concrete start erection of forms for the next section. Then as soon as the concrete has set proceed with the roof framing and while doing this pour the concrete on the first floor of the second section.

Another point which was brought home much to the financial regret of the contractor was the failure to take advantage of the frozen ground around the boiler room excavation. As stated before the soil at the building site was clay and as soon as the excavation was completed for the boiler room there was practically no end to the amount of water which flowed into the cut. By constant pumping the contractor had been able to place his footings and side-walls so as to proceed with the rest of the structure. Cold weather set in at this point freezing the sides of the excavation and preventing the inflow of any water. The contractor could not be persuaded to take advantage of this condition and waited until Spring to place his boiler room floor. As a consequence he has found that up to date it has been impossible to keep the boiler room dry enough to warrant the placing of the concrete floor at this time. Pumps have been operated practically continuously night and day without making much of an impression upon the inflow of water.

In the erection of a building of any size the value of progress photographs should not be overlooked. By taking photographs at a regular interval it has been possible not only to keep the directors of the Ilg Company posted

on the progress of the building, but it has also enabled the writer to check up on some details which he could not have done had it been necessary to make a trip to the building site. One small item which the writer recalls is that he noticed that the form work on one particular column had been built without providing a bracket for a future beam. The mistake was easily remedied inasmuch as it was only necessary to inform the carpenter foreman and have him make the necessary corrections. By studying the photographs made at various intervals the engineer is assisted in estimating the probable amount of work which will be done in a certain time to come.

Another point which was borne out on this job is the advisability of building the form work and concreting towers strong enough to take care of severe winds. During the time that the form work on this building was being erected we had winds of 45 miles an hour on three occasions and at no time was any of the form work destroyed. We did, however, after every storm run levels in order to check the form elevations, but found that in no case were they off more than $1/8$ of an inch. This slight variation, of course, was easily taken care of.

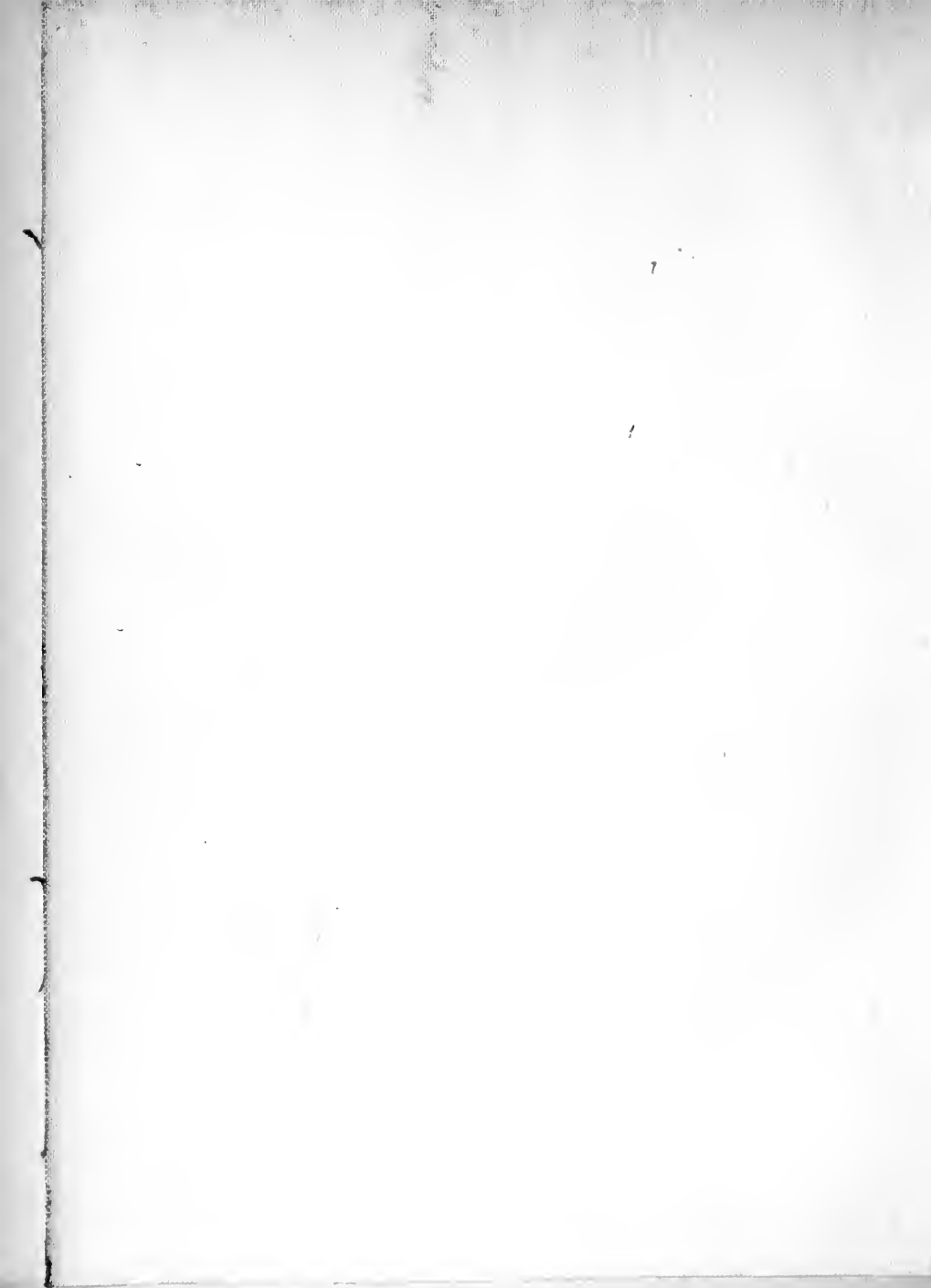




73689







PLAT OF SURVEY

The following described tract of land with 1/2 of the ... and described as follows:
 Beginning at a point on the W line of N Crawford Av. 340.78' ...
 ... and ending at the same place of beginning.



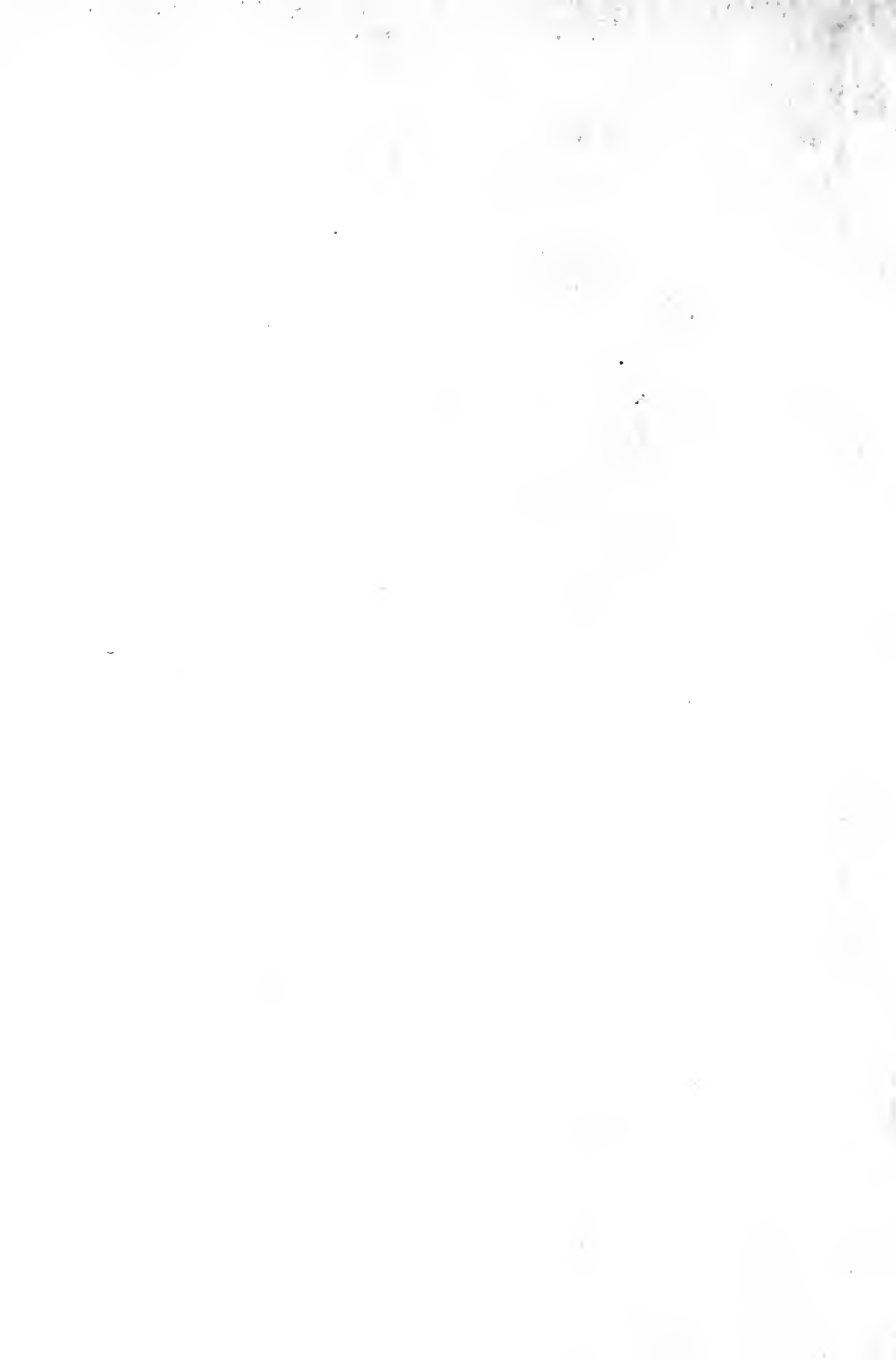
- 15. Corner of George St. Crawford Av. in ...
- 16. Corner of George St. Crawford Av. in ...
- 17. Watermark on N Crawford Av. 205' from W line of Crawford Av. ...
- 18. Watermark on N Crawford Av. 205' from W line of Crawford Av. ...

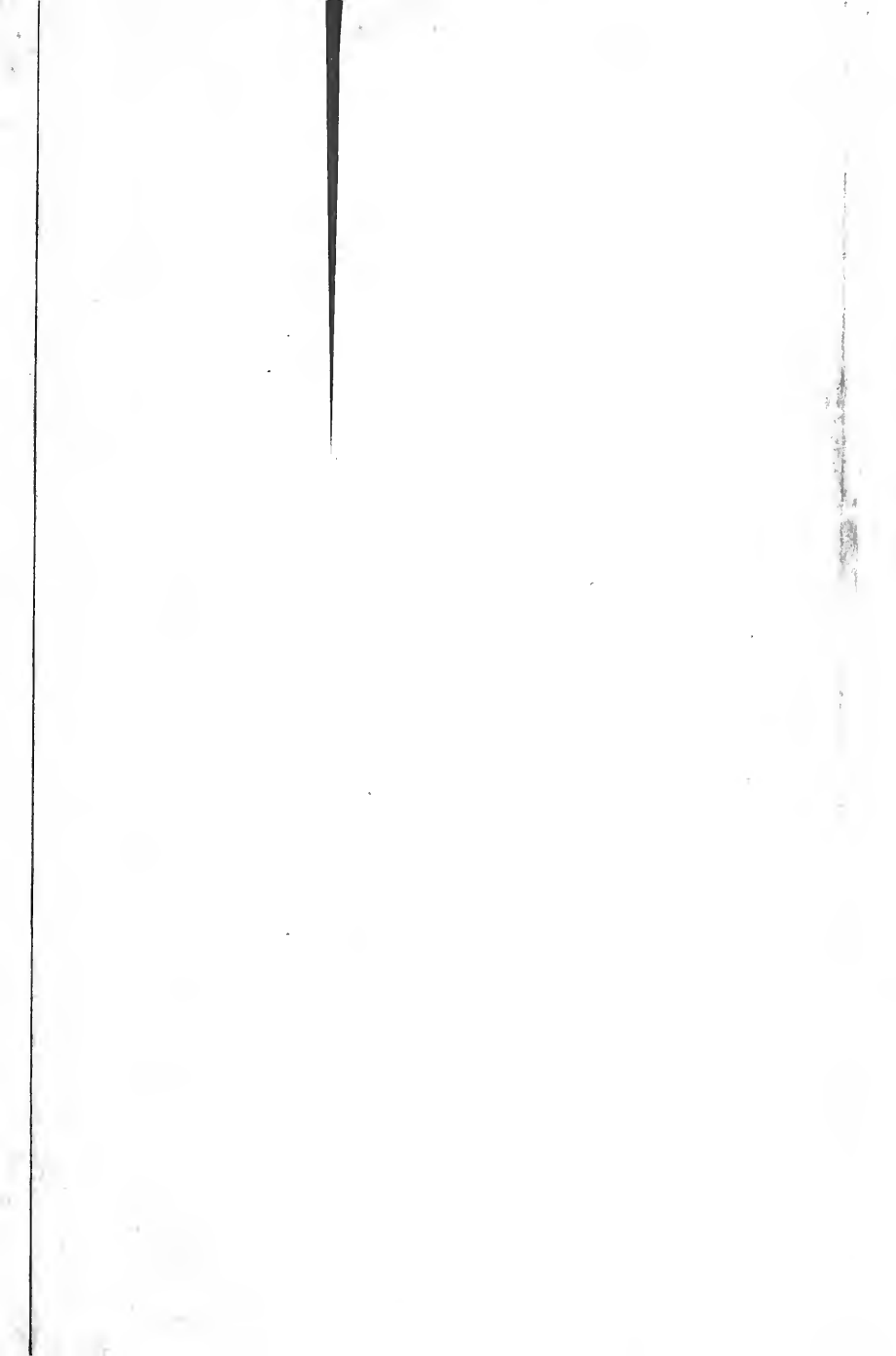
Elevations

Point	Elevation
Corner of George St. Crawford Av.	21.76
Watermark on N Crawford Av.	21.80
Watermark on N Crawford Av.	21.82
Watermark on N Crawford Av.	21.84
Watermark on N Crawford Av.	21.86
Watermark on N Crawford Av.	21.88
Watermark on N Crawford Av.	21.90
Watermark on N Crawford Av.	21.92
Watermark on N Crawford Av.	21.94
Watermark on N Crawford Av.	21.96
Watermark on N Crawford Av.	21.98
Watermark on N Crawford Av.	22.00
Watermark on N Crawford Av.	22.02
Watermark on N Crawford Av.	22.04
Watermark on N Crawford Av.	22.06
Watermark on N Crawford Av.	22.08
Watermark on N Crawford Av.	22.10
Watermark on N Crawford Av.	22.12
Watermark on N Crawford Av.	22.14
Watermark on N Crawford Av.	22.16
Watermark on N Crawford Av.	22.18
Watermark on N Crawford Av.	22.20
Watermark on N Crawford Av.	22.22
Watermark on N Crawford Av.	22.24
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Watermark on N Crawford Av.	22.60
Watermark on N Crawford Av.	22.62
Watermark on N Crawford Av.	22.64
Watermark on N Crawford Av.	22.66
Watermark on N Crawford Av.	22.68
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Watermark on N Crawford Av.	22.72
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Watermark on N Crawford Av.	22.90
Watermark on N Crawford Av.	22.92
Watermark on N Crawford Av.	22.94
Watermark on N Crawford Av.	22.96
Watermark on N Crawford Av.	22.98
Watermark on N Crawford Av.	23.00

This is the original and true plat of survey ...
 Chicago, August 10, 1899
Wm. H. ...
 Surveyor

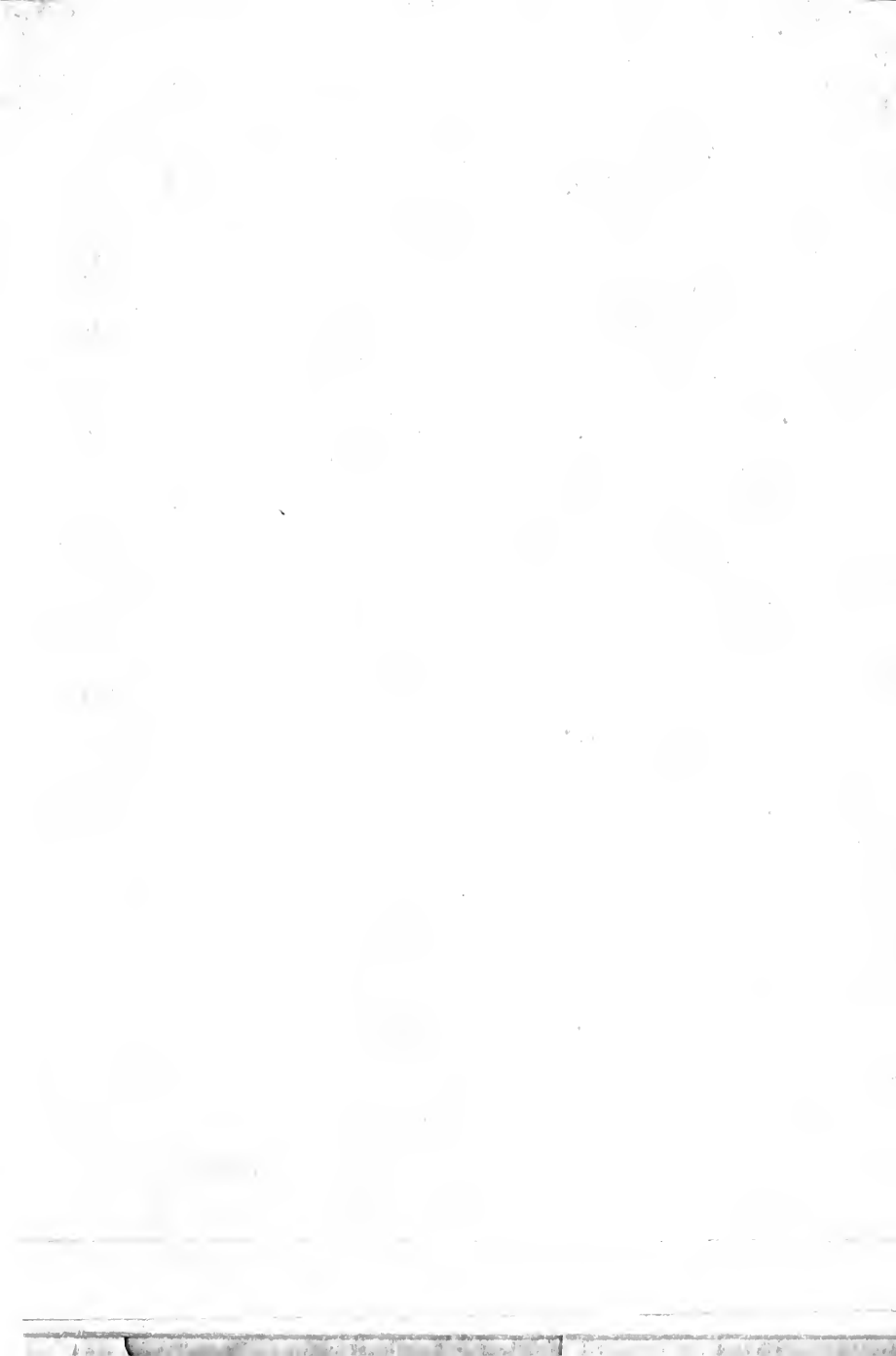
3700













→ Z



450' 0"

315' 0"

400' 0"

SCALE 1/8" = 1'

CRAWFORD AVE.
295 OF

300' 0"

400' 0"

600' 0"

EXHIBIT-3

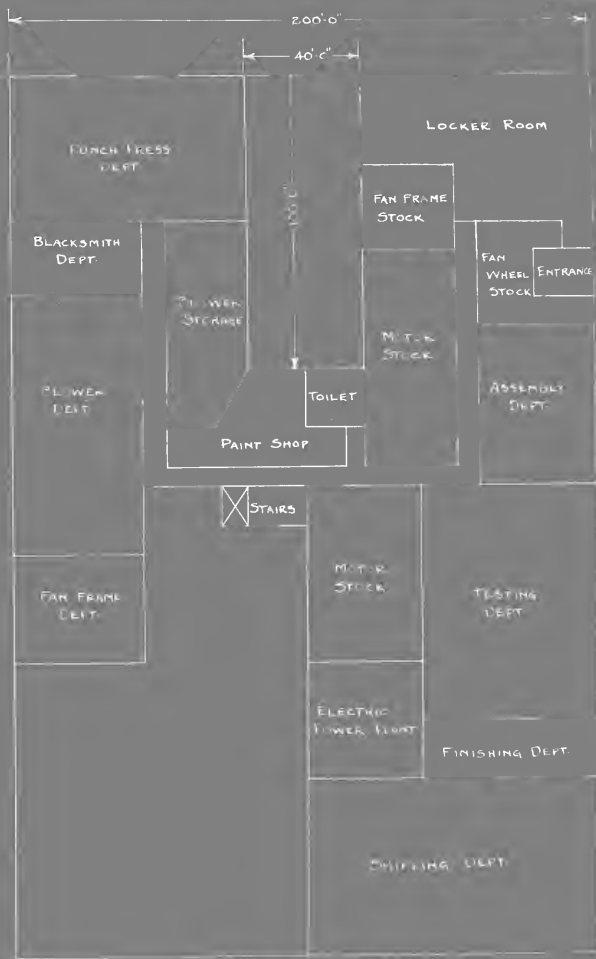








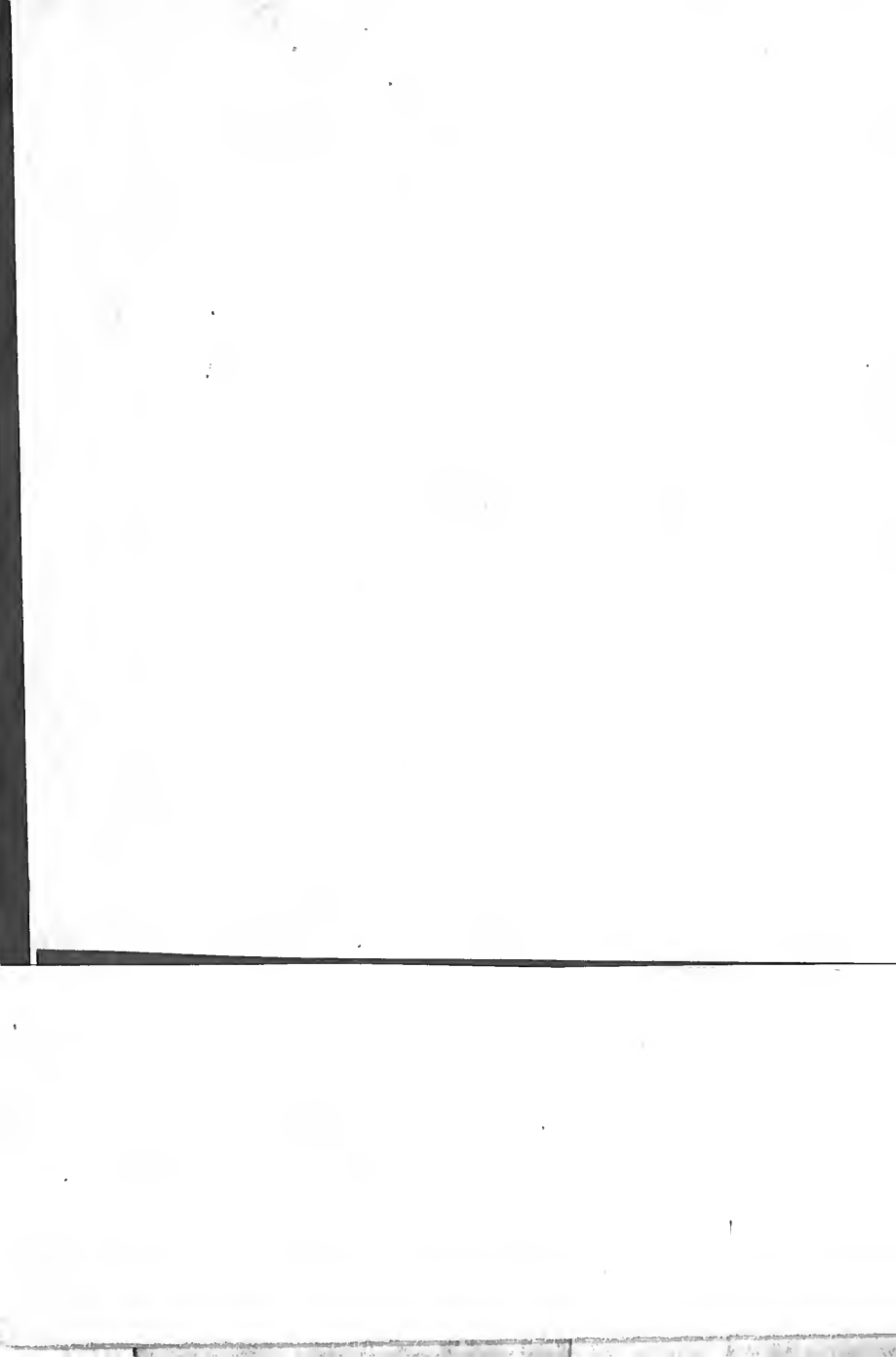
SECOND FLOOR



FIRST FLOOR

Scale 1/8" = 1'-0"





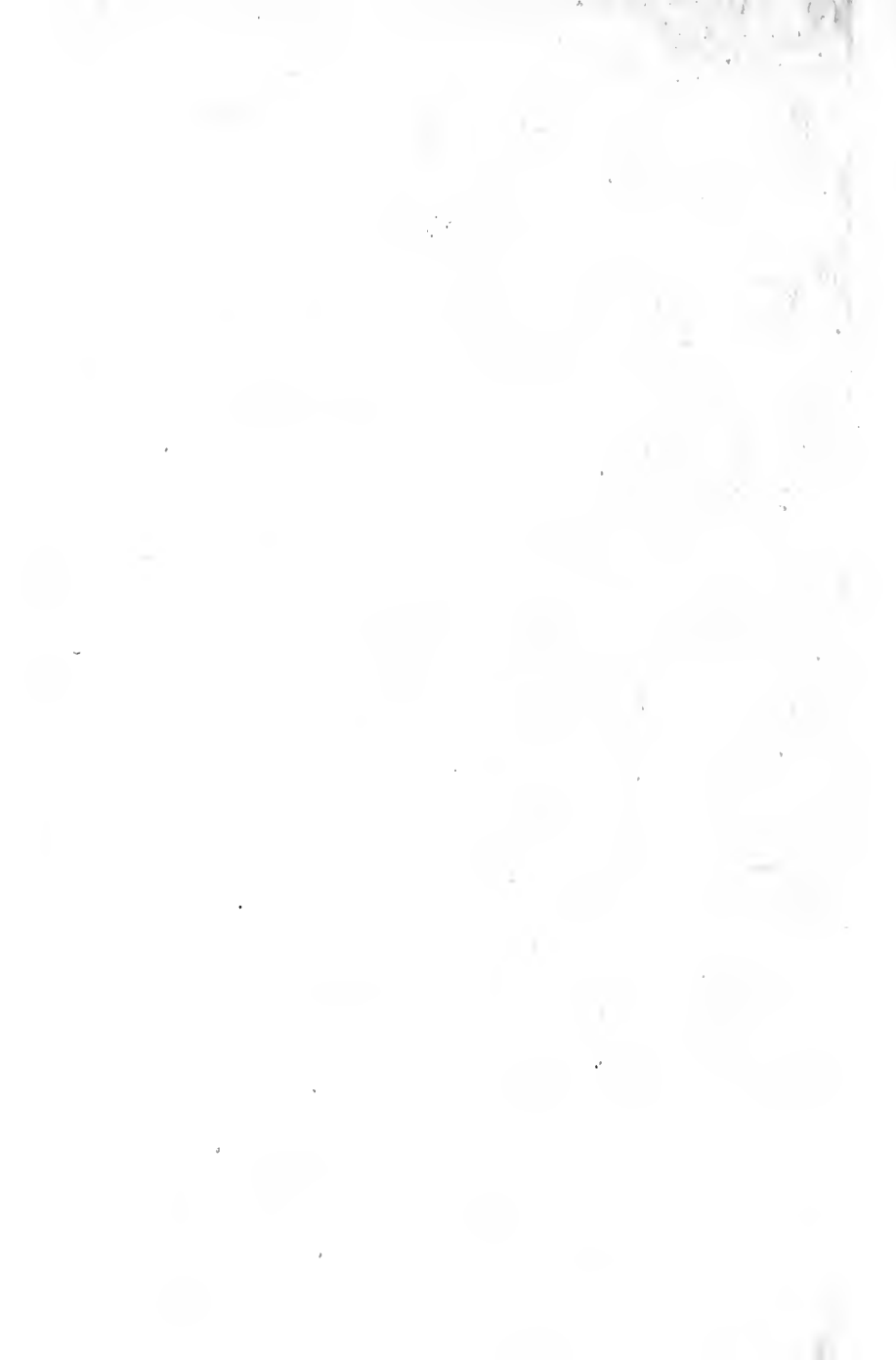




SECOND FLOOR



FIRST FLOOR





LEG BUILDING

31

EXIST. LINE

PROPOSED

EL. 215

EXIST. LINE

LEG TRUCK

SERVICE TRUCK

SENG TRUCK

DRIVE WAY

34'-0"

CRAWFORD AVE

SENG BUILDING

SCALE: 1/8" = 1'-0"

FLOOR ELEV. #250

EL. 215

4.74%

50'

EL. 237.3

EL. 23.00

EL. 23.0

LEVEL A

15'-0"

24'-0"

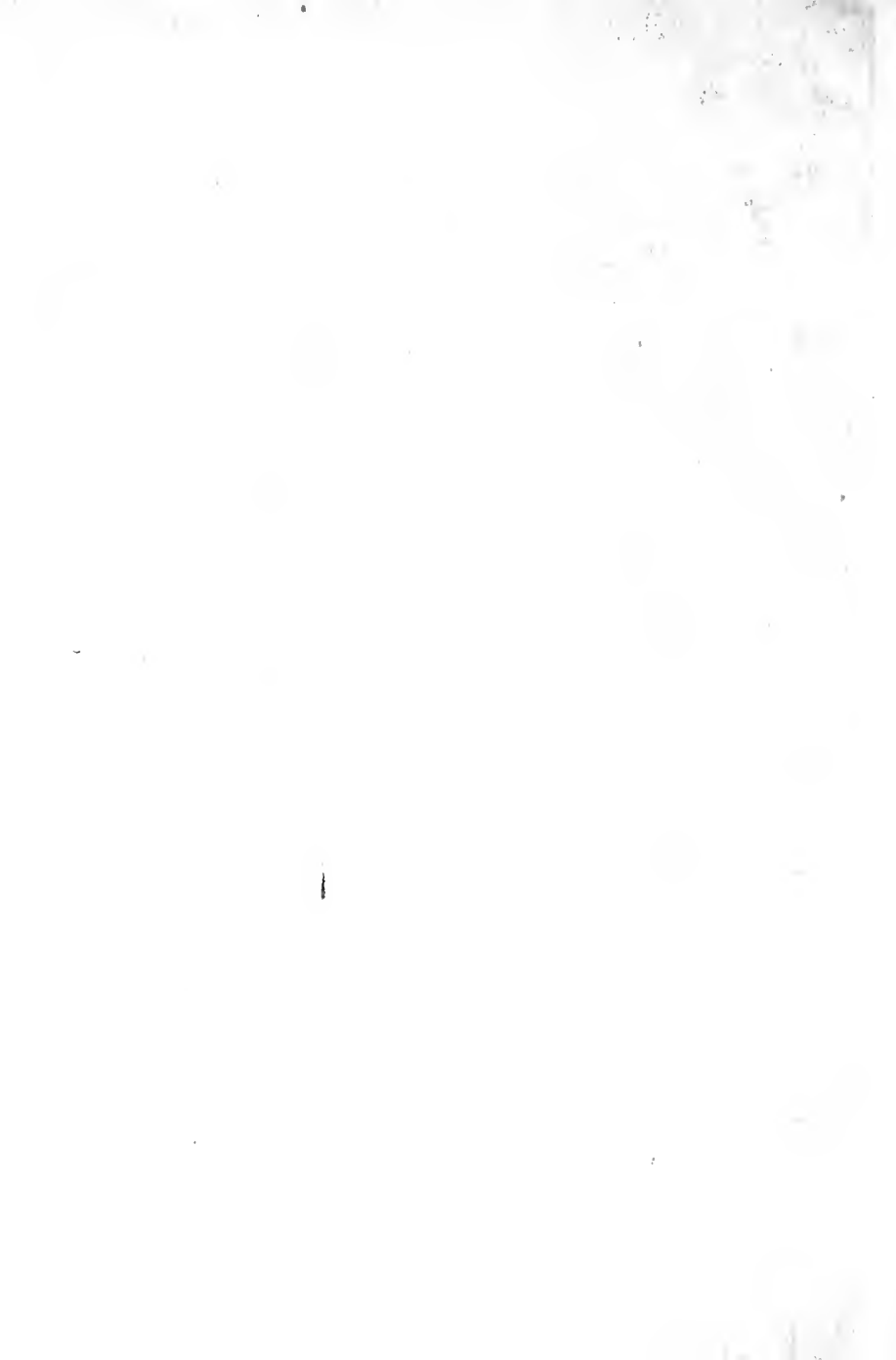
8.25%

47'-0"

100'

4'-0"

EXHIBIT-6



8
7
1

HEA

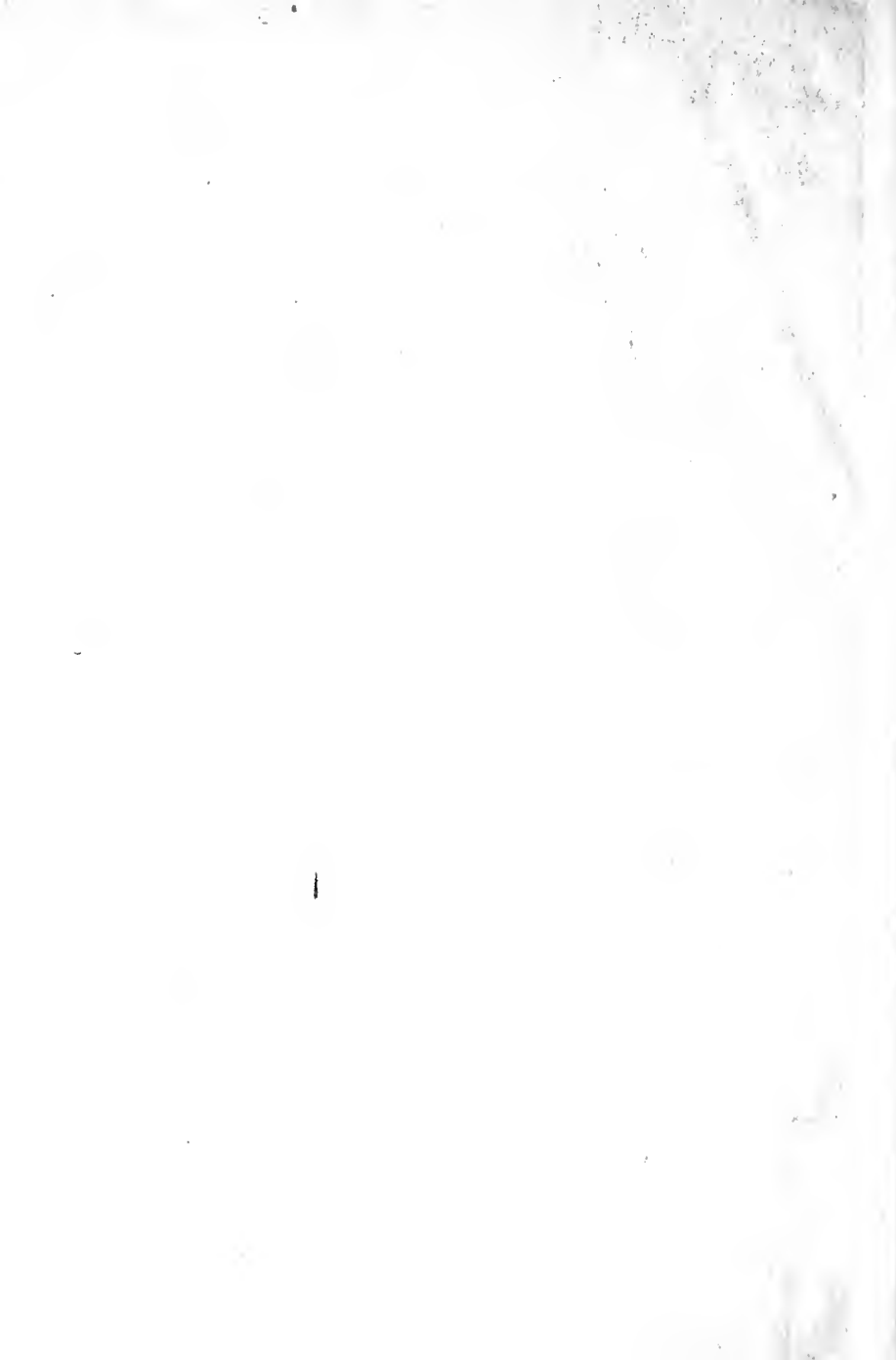


KILBON R. 13E.
CO., ILL.
11/19
OFFICE CHICAGO

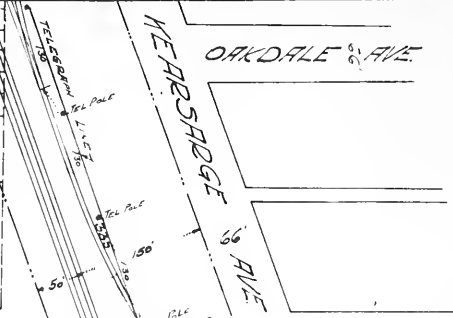


EXHIBIT-7¹⁵

C.M. & ST. P. R. R.
LINED TRACKS TO SERVE
L. A. T. CO. &



WILDHIRE ST AVE
 PART OF
 SUBDIVISION
 10



ILG ELECTRIC VENTILATING CO.

THE SENG CO.



NE 1/4 SEC 27

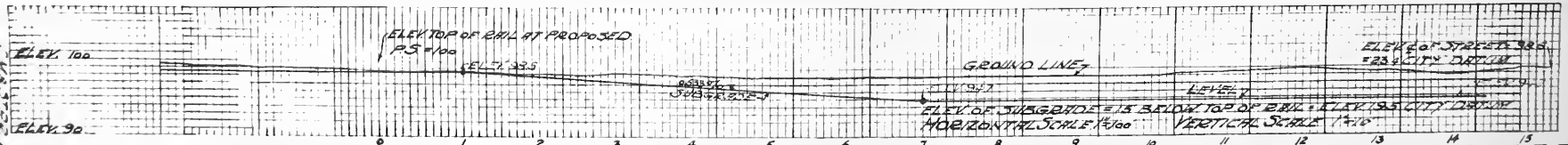
T 40 N 13 E

DIVERSEY

SUBWAY 66 FT WIDE

1/4 SEC LINE

AVE

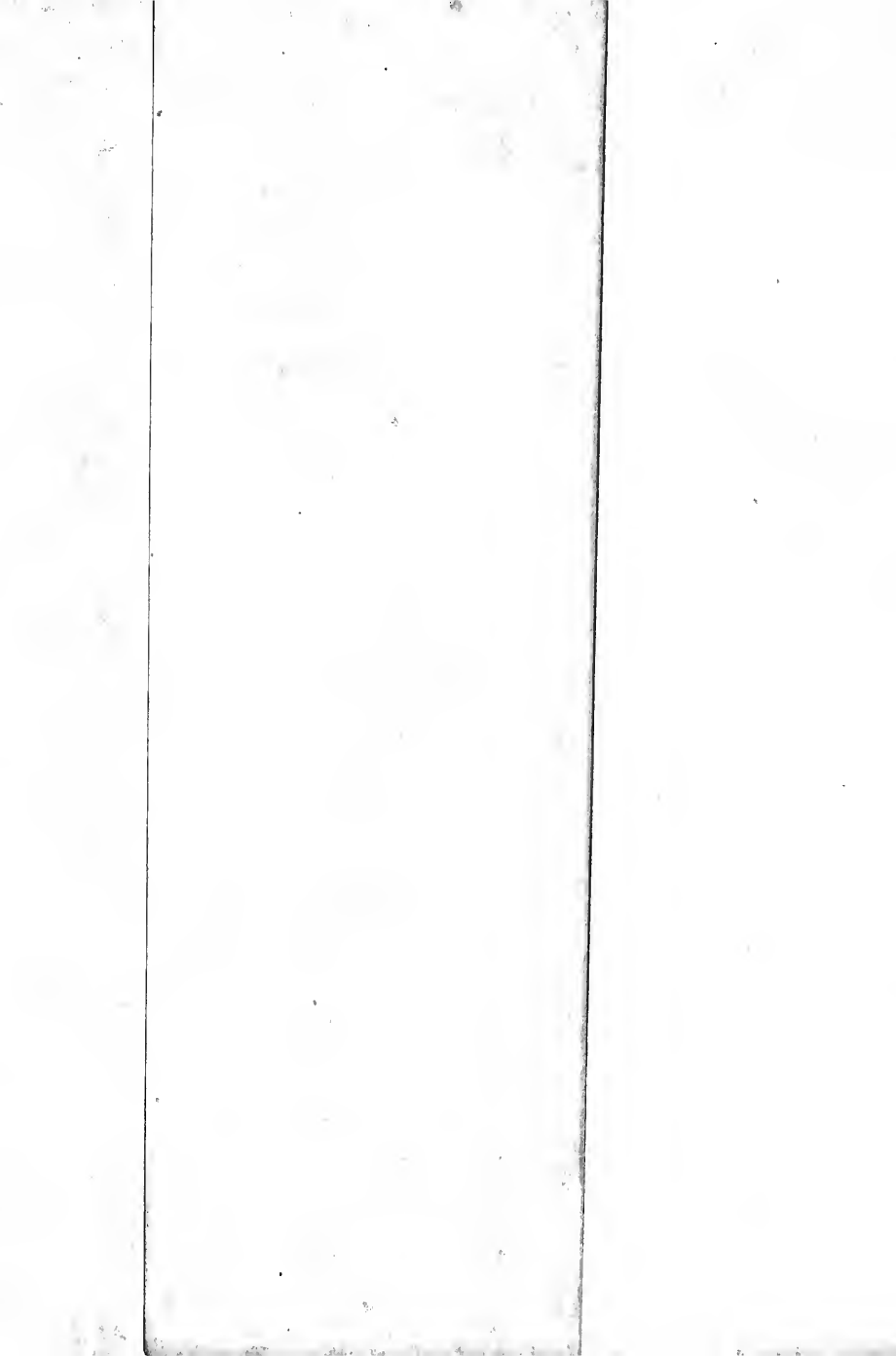


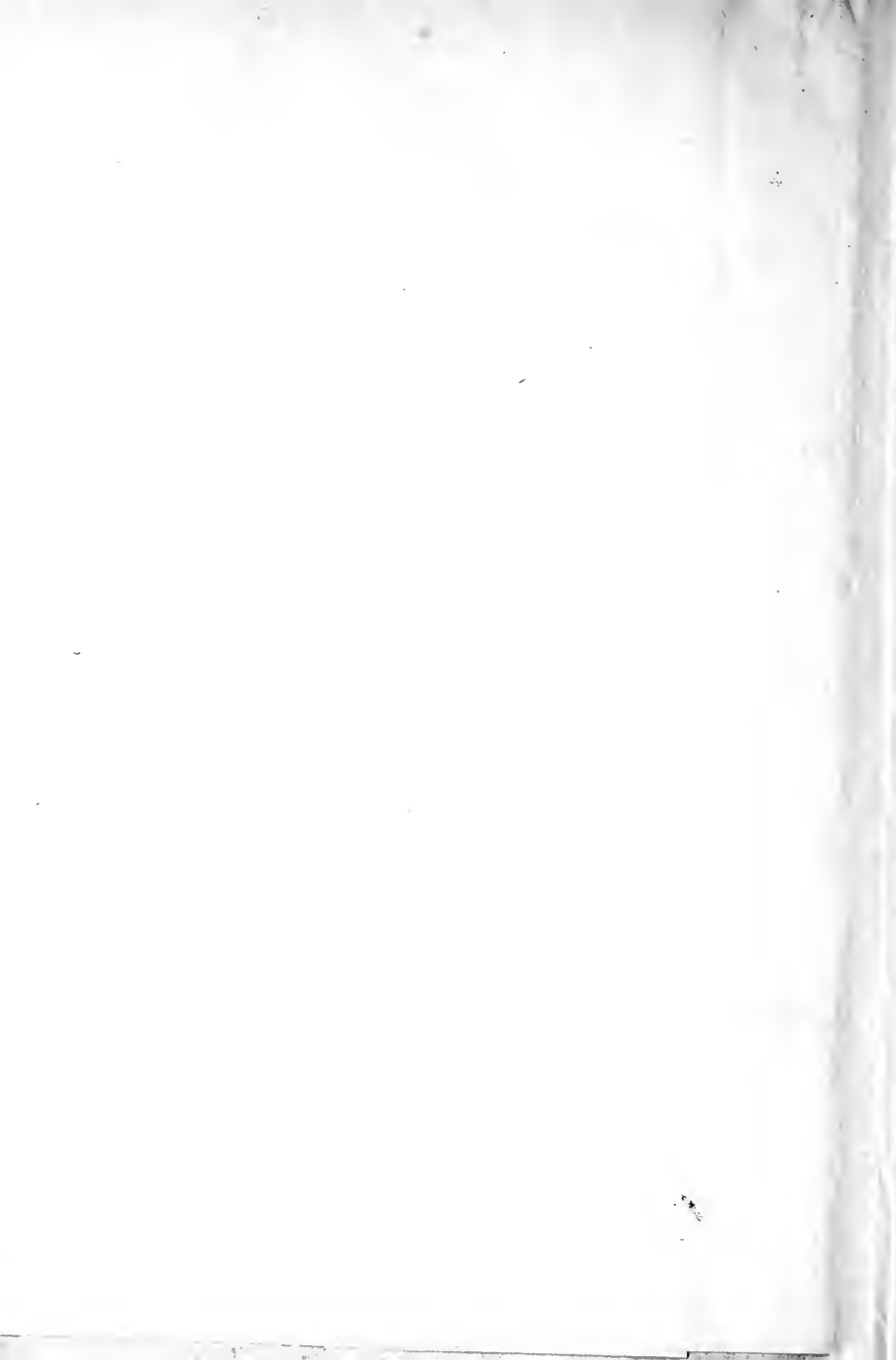
ENGINEER
 PLAN SHOWING PROPOSED RAILROAD CITY STREET
 ILG ELECTRIC VENTILATING CO. AND THE SENG CO.
 IN THE NE 1/4 SEC 27 T 40 N 13 E
 IN THE CHICAGO DISTRICT OF ILL.
 OFFICE OF THE CHIEF ENGINEER

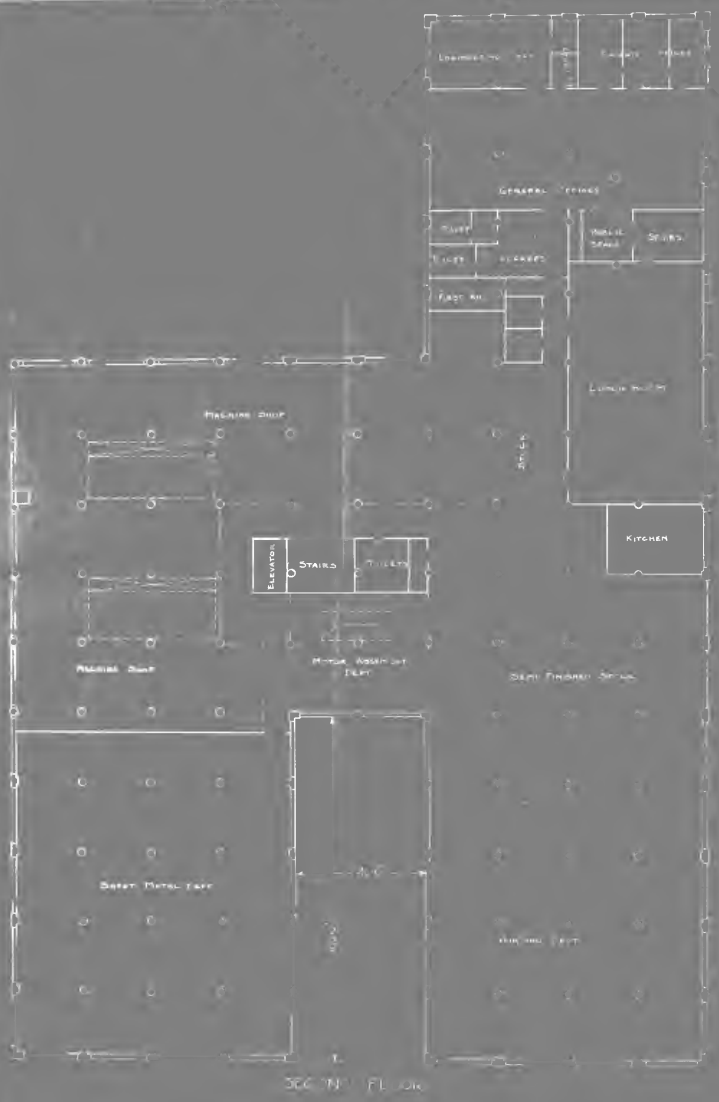
EXHIBIT-7

GROUP 206 ENGINEERS, ELEC. MECH. CO. 140 W. WABASH CO. CHICAGO

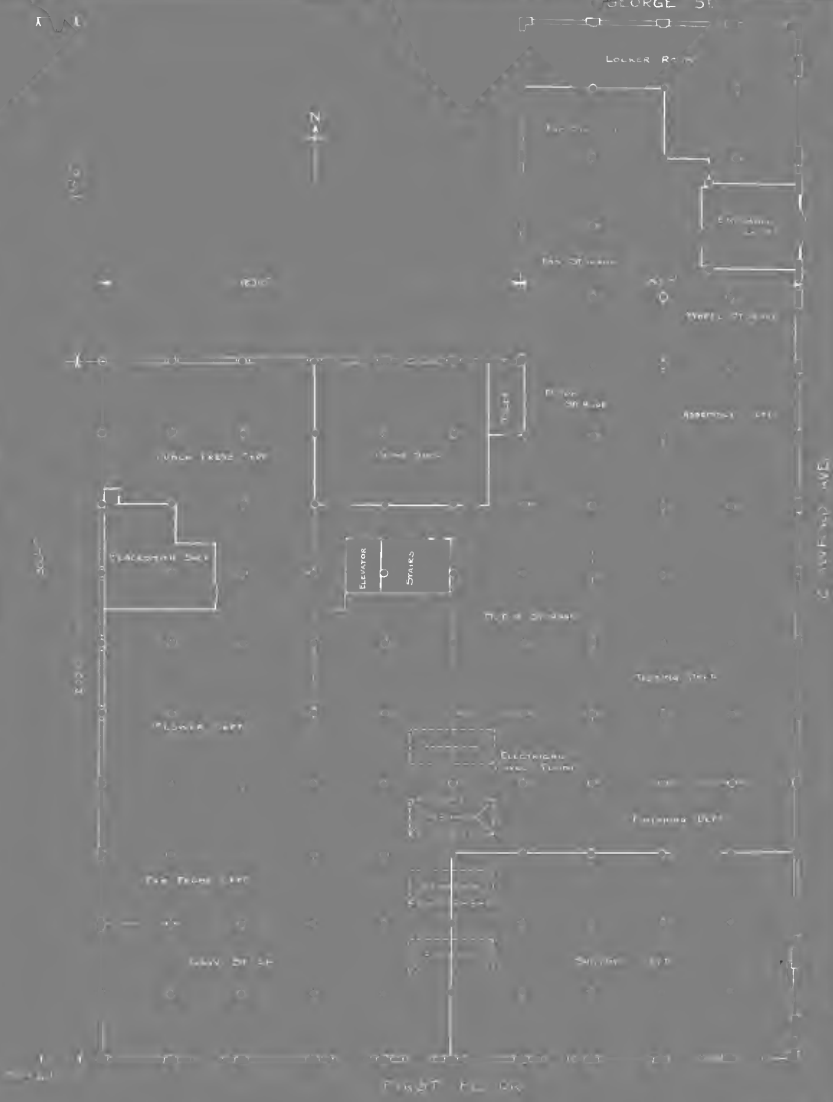








SECOND FLOOR



FIRST FLOOR

