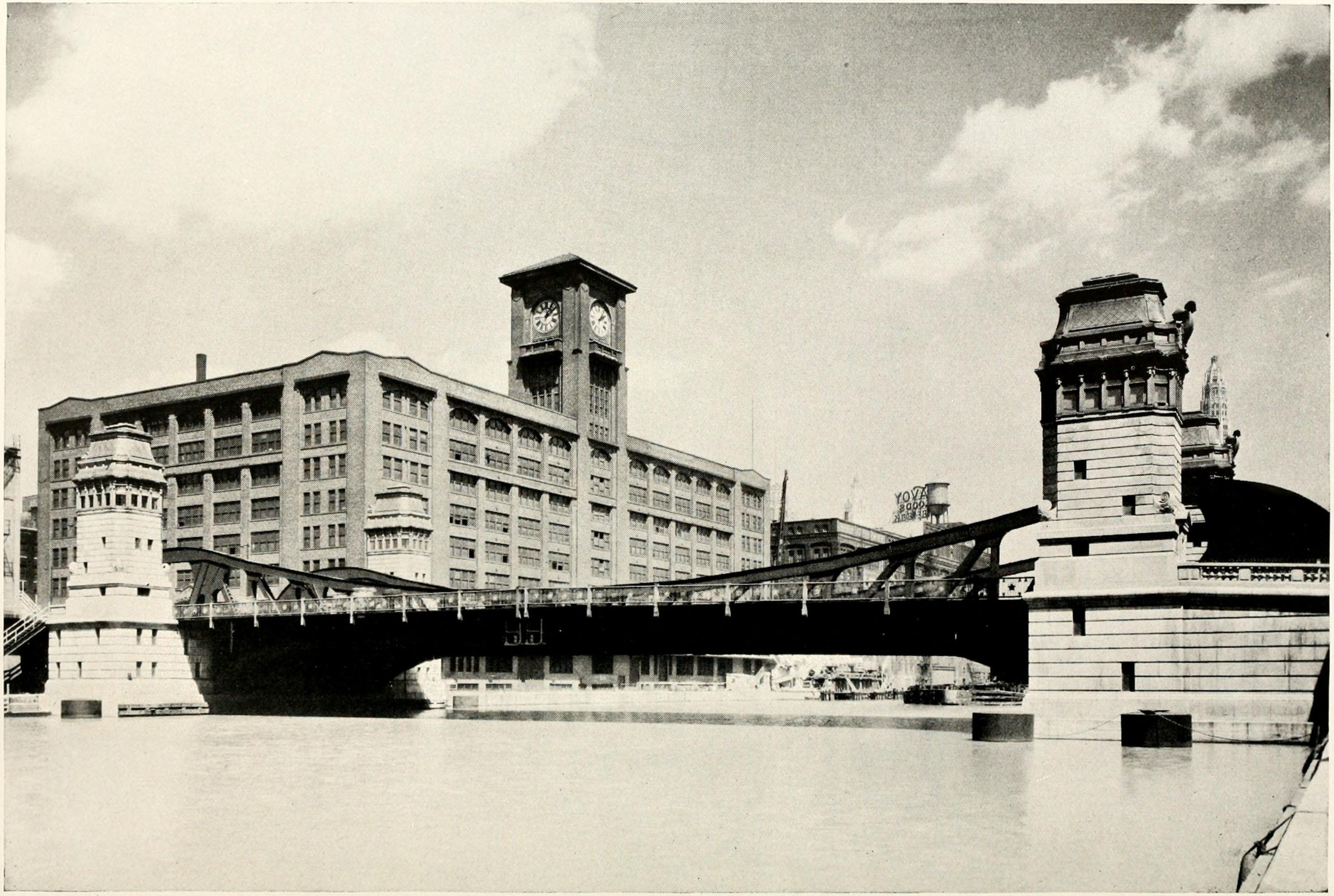

The La Salle Street Bridge — One of the Latest Types of Bascules

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The Development of the Chicago Type Bascule Bridge

By **Earle G. Benson, '25**

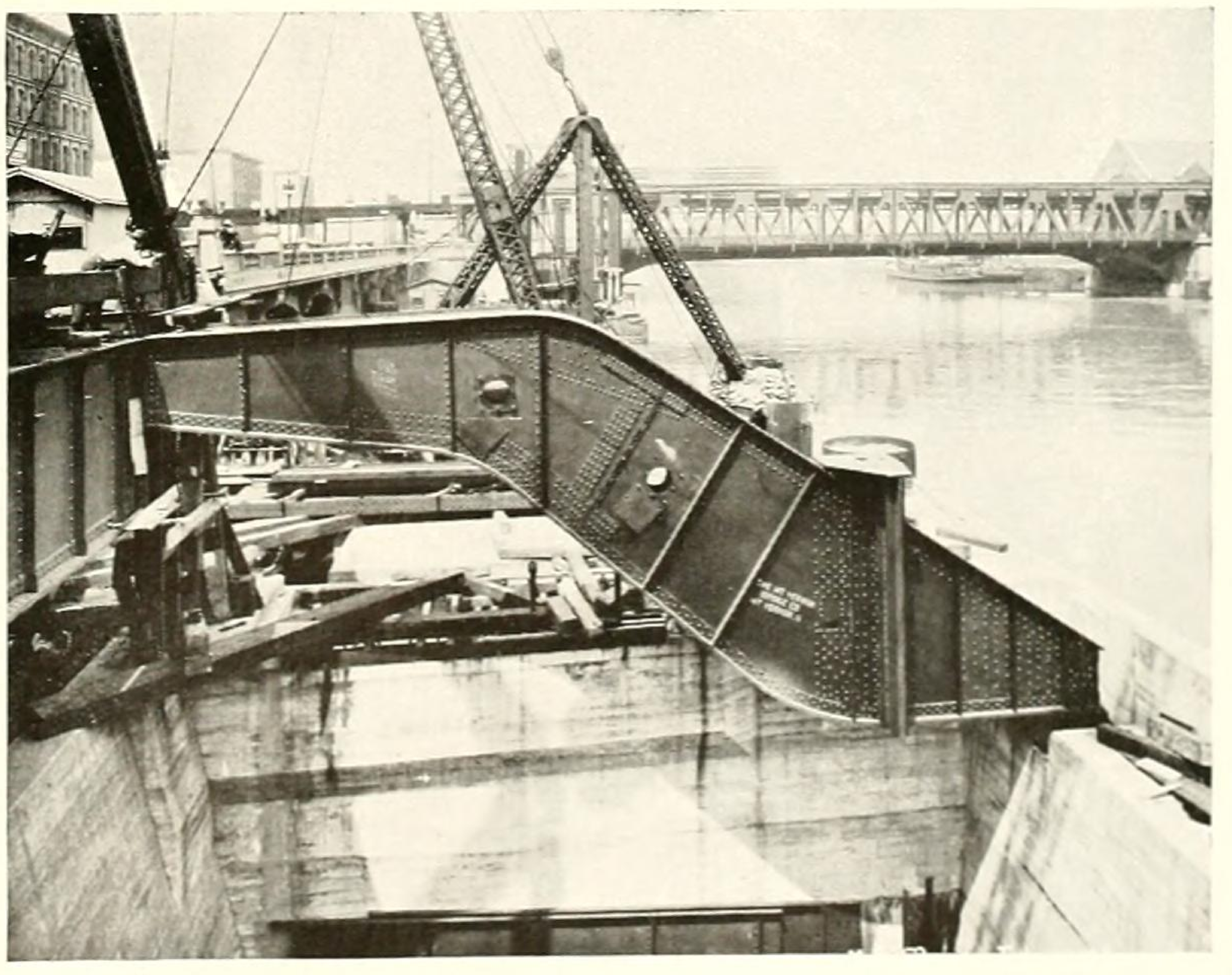
Bridge Design Engineer for the City of Chicago

WHEN one considers that the forerunner of our present mighty lift bridge was a simple hinged leaf over a castle moat,—a means of defense against an invader,—it would appear that the evolution to the present high perfection had been a very gradual process. However, such was not the case for it soon became apparent to those early engineers that any type of lift bridge, counterweighted or not, could not be made any appreciable span with the materials then known or the operating power available. Consequently attention was turned to the self-balanced more easily constructed and operated center pier swing bridge. At the end of the nineteenth century the swing bridge had attained a high degree of development, progressing through the earlier stages of all timber construction to an all-iron structure operated usually by steam power.

The last few years of the nineteenth century saw the beginning of the practical application of electric power and the use of steel instead of wrought iron for construction purposes. These two elements, electric power and steel, made it possible to meet the demand for much bigger and better movable bridges.

The field for development was ready and, what was more important, it was now centralized. Ordinarily bridge installations were at comparatively large intervals on the more traveled rivers of the country, and the total number was few. However, the new metropolis of the prairies offered an entirely different situation. Chicago had grown up on a comparatively narrow river that ran a crooked course through the busiest section of the city and sharply divided it into three distinct portions, a north, south, and west side. So effective had been this division that the early settlers soon recognized that many crossings would be necessary to prevent any breach. Consequently, as early as 1829 rude log and pontoon bridges spanned the river at various points, and by 1834 a simple hinged span had been built at Dearborn Street. Later, all important streets were spanned by swing bridges. At the beginning of the twentieth century these were the prevailing type.

It might be well at this point to give a clear definition of what is meant by a bascule bridge, inasmuch as one so frequently hears this type referred to as "folding" or "jack-knife" bridge. The word "bascule" itself comes from the French, meaning "see-saw"; hence a Bascule Bridge means a balanced structure where the balance or counterpoise lowers as the roadway rises. Such is truly the case with the present day bascules for they are balanced in all positions and revolve about trunnions or pins located near the center of gravity, the counterweight sinking into a tailpit as the roadway swings into the air. There are now many types of leaf bridges having patented features with varying degrees of merit. To describe them all and point out the advantages or defects of each would



The concrete substructure of the bridge rests on massive concrete piers that are built down to bed rock.

be beyond the scope of this article.

It has been said that the Chicago River lent itself admirably to the development of bascule type bridges rather than swing bridges. The reason for this can readily be seen by considering the local conditions. To begin with it is well to recall the character of the Chicago River. Its main branch cuts through a portion of the business district; hence hundreds of thousands of people daily must pass over it to reach homes or places of business. Its north and south branches reach miles out into the industrial sections of the city and there great manufacturies have their docks and loading slips. Consequently, the largest lake steamers must ply almost its entire length. Furthermore, the concentration of business in the comparatively small area of the loop has made land so valuable that every foot of ground up to the river's edge must be utilized, and so the river has become bound in by docks to a width of approximately 200 feet for the greater part of its length.

In view of these conditions, it is simple to list the advantages of the bascule type bridge as against the swing bridge for this district:

(1) No center pier to obstruct navigation — the full width of the river being available for boat passage.

(2) Minimum space is required and approaches are easily built.

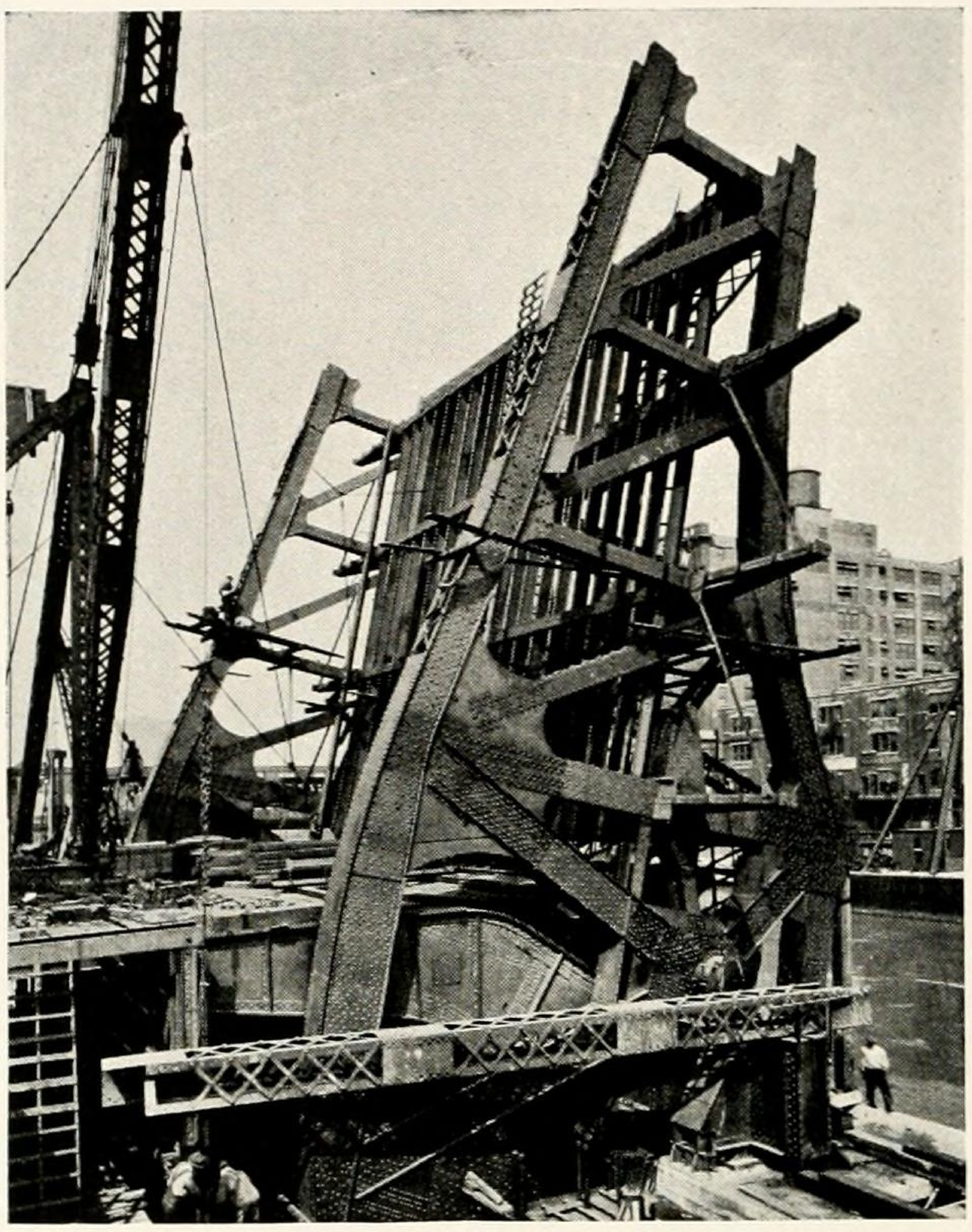
(3) Need not be fully opened for passage of small vessels; swing bridge must always be fully opened.

(4) Bascules have a shorter time of operation.

(5) In cities like Chicago where wide roadways are necessary, a swing bridge of considerable roadwidth narrows the channel when open.

(6) Bascules may be built side by side for railroad use without interference.

Appreciating these advantages and spurred on by the fact that many old swing bridges were beyond practical repair, the City of Chicago in 1900 decided to adopt a policy of replacing existing swing bridges with bascules. To obtain the best design possible, the Commissioner of Public Works, Mr. L. E. McGann, in May, 1900, invited competitive designs for a bascule bridge at 95th Street over the Calumet River where conditions similar to those on the Chicago River prevailed. The competition resulted in the submission of eight designs, three of which were prepared by the city's own engineers and the others by outside bidders. A committee of three prominent bridge engineers, consisting of Messrs. E. L. Cooley, Ralph Modjeski, and Byron B. Carter, were retained to judge the designs. They selected one of the city's own designs on which they recommended several modifications. This general design with some changes and improvements is the type used today not only in Chicago but in several other cities and is generally known as the "Chicago Type Bascule."



The movable leaf is kept in the upright position during its installation. Not until the machinery is put in place and the flooring ready to be laid, is it lowered.

It is interesting to note that in design this bascule follows the famous Tower Bridge of London, which was one of the first of large trunnion bascule bridges. The design accepted was a double leaf structure, each leaf having three trusses which were pivoted about three trunnions. The span was 128 feet from center to center of the trunnion bearings with a clear waterway of 100 feet between protections. To the rear of the trunnions the trusses extended back about 26 feet through slots in the fixed approach floor, under which was carried the cast iron counterweights. This design was of a semi-through type, having portal bracing at the trunnion end. Trusses were set 21 feet center to center and the outer two carried brackets for the sidewalk. The sub-structure consisted of a front and rear pier connected by walls so as to form watertight pockets into which the counterweights were to swing. Plate girders between the front and rear piers carried the trunnion bearings and also the fixed approach. Operating mechanism consisted of two gear trains below the street level driven by two 38 H.P. electric motors for each leaf. The main pinions of the gear train meshed with cast steel racks fastened to the curved heels of the three trusses, and the rack teeth were provided with openings to prevent dirt or ice from clogging the teeth. At the center the two leaves when closed were connected by shear locks consisting of longitudinally sliding lock bolts engaging in sockets in the opposite leaf.

Among the other designs submitted were several rolling lift bridges in which the curved heel of the truss rolled back on a track or revolved on rollers in a track of large radius. Several of the former type had then been built for the city and are in use today, the oldest being at the Van Buren Street crossing. However, the committee's reasons for favoring the trunnion type of bascule are given in their report as follows:

(1) "Constant point and direction of application of load on the foundation whether the bridge is in motion or is stationary." (On a rolling lift bridge the load moves back as the bridge opens and may cause unstability of foundations.)

(2) "Reduction of the number of moving parts to a minimum."

(3) "— the trunnion type of bridge is an old and tried one and is not covered by patents."

"The bascule design permits the placing of the center of gravity of the moving bridge in the trunnion axis on its proximity. The placing of the center of gravity a short distance from the axis of the trunnions toward the draw opening and the arrangement, as designed, by which the fixed approach floor relieves the tail end from any possible live load have the advantage that they tend to hold the bascule firmly in position when closed without absolute necessity for heel locks. There is no tilting effect due to the action of live load coming on the bridge."

Thirty-one years later it is interesting to note that the recommendations made by the Board of Engineers at that time, which were not all then accepted, have now been for the greater part incorporated in present design. Several of the suggestions were:

"—that adjustable resting blocks be placed in front of and near the trunnion so that when the draw closes, the load may be transferred from the trunnions to the resting blocks. This will facilitate lubrication—"

"—for future and more important structures, warranting additional expense, foundations should be carried to bed rock."

"The design of the piers is not satisfactory,—the proposed modification consists of making one counterweight pit by disposing of the partitions—"

How this first early design and the valuable suggestions of the committee have been developed into Chicago's modern type Bascule can be best seen by a description of any of the large bridges designed by the city in the last decade. This period has seen more intensified activity in bridge building than any other, and, while the evolution of each improvement is in itself interesting, the important thing is the composite result of these improvements.

The modern bascule consists essentially of three separate parts: (1) the substructure or foundations, (2) the superstructure, consisting of the leaves themselves and the operating machinery, and (3) the houses and enclosures which serve to protect the operating equipment.

The substructure of today is in reality a huge concrete box with walls four to five feet thick and resting on about six massive concrete piers reaching in most cases to bed rock. This usually means a depth of 50 to 100 feet below lake level. The top of the substructure is usually five or six feet above water level, while the bottom may be from 20 to 30 feet below water level, necessitating of course a water tight pit. On this substructure or "bridge pit" is mounted the pedestals and girders for the trunnion bearings, the river pier or "live load bearings," the anchor columns which secure the tail end of the leaf, the gear trains, and all the columns for the operating houses. The immense concentrated loads together with the earth and water pressure of the submerged parts call for a high degree of engineering skill in the design of reinforced concrete structures.

New types of bridge covering have been developed since the advent of heavy automobile traffic. This particular kind is made up of asphalt planks laid diagonally.

The superstructure consists of the movable leaf and its supports and the fixed approaches. Usually where conditions do not call for roadways of extreme width only two trusses are used. Depending on the approach elevations and conditions, they may be a pony truss, railing height truss, or deck bridge. The pony truss so commonly used in Chicago is a sort of low through truss with all portal bracing omitted. A rigid system of lateral bracing with deep floor beams and solid counterweight box serves to keep the trusses aligned.

The appearance of the trusses has changed vastly from the early bascules. Formerly, designed in accordance with the then existing loads and traffic, they were open, angular, and apparently spindly structures. Today instead, one sees a graceful curved arch in which even the gusset plates have radii. There is now beauty in the strength and massiveness of the structure. So great have the stresses become from the ever increasing design loads that today some cases require the use of nickel steel in the portions of the truss close to the trunnion. The magnitude of these loads can be appreciated when it is realized that although an arch in appearance, each leaf is but a cantilever with an arm of over a hundred feet.

Uniting the trusses, behind the trunnions and under the approach floor, is the counterweight box. These days the counterweight instead of being cast iron is concrete mixed with steel punchings where greater weight is required. Provision is also made for removable blocks of concrete in order that changes of balance can be adjusted and so that a condition of near balance can be maintained during the different stages of construction. It is perhaps needless to say that the bridge is erected in the open position and is not lowered until machinery is installed and the floor ready to be laid. This leaves the river open for traffic and all work can be done from derricks on the shore. The roadway is applied with the leaves horizontal.

The roadway of the bascule bridge offers an entirely different problem than the ordinary fixed highway bridge. On the latter type it is possible to use ordinary roadway paving such as brick or concrete slab. But with a bascule the roadway must remain in place when the leaf is vertical and must also be light in weight, yet need infrequent repairs or replacements. The earlier bridges used oak planking laid on oak or fir subplanking on stringers, the top surface of which later was changed to creosoted wood blocks laid with the end grain up. When the motor vehicular traffic became heavy, a rubber block paving was tried and gave excellent wearing surface. It was more skid proof than wood blocks and more easily repaired. This flooring is used on the Michigan Avenue link bridge on the up-

(*Continued on page 105*)

Development of the Chicago Type Bascule Bridge

(Continued from page 83)

per deck which carries motor vehicles entirely. Later, on the new La Salle Street bridge, a flooring of asphalt planks laid diagonally was used. A new development consisted of using pre-cast light concrete slabs which are fastened to the supporting stringers by lugs imbedded in the slab and welded to the steel beam. This type is used on the recently opened Wabash Avenue bridge.

There has also been a steady improvement in the mechanism to operate the bridge. Earlier designs consisted of complicated gear trains with bearings mounted on built up steel girders which in time, due to their lack of rigidity, showed the need for a more solid alignment of shafts and gears. It was at first thought necessary to tie together with shafting the two or three gear trains operating the rack pinions, in order that one might not run ahead of the other. However, now with the more rigid superstructure, each gear train, with an individual electric motor of from 80 to 100 H.P., operates on a rack, usually of the internal type, in the heel of the truss. In spite of the development in recent years of compact planetary speed reducers, experience in bridge operation has shown that the simple three or four shaft spur gear train is best. The loads imposed are so great and freedom from breakdown so essential that great ruggedness of design is necessary. Heavy cast steel bearing frames carrying alloy steel shafts and cut tooth steel gears throughout are now standard practice. The rack gear teeth now needed to carry the loads imposed are over five inches thick with an eighteen inch face and are of special section. Gear wheels run to six foot and seven foot diameters and are carried by twelve to eighteen inch shafts. A service hand brake is provided in addition to an automatic motor shaft brake. The trunnions that carry the leaf are keyed to the trusses and revolve in bearings mounted on each side of each truss. The outer bearing is carried on a pedestal, while the inner is carried on a curved longitudinal girder running from the river pier to the anchor pier in the rear. Present day bridges require trunnions varying from two to three feet in diameter and nine feet long.

Around this machinery must be built the enclosures and a building to house the control apparatus. Formerly these were but wooden shelters and at the best were unsightly. Today beautiful limestone towers flank the approaches and harmonize with the surrounding architecture. The columns supporting the houses rest directly on the substructure and from these is framed the steelwork carrying the sidewalks and house floors. Usually a bridge house is made with from three to five floors. The lowest floor is the dock level on top of the bridge pit. On this floor the heating equipment for the enclosures and house is placed. Midway between the dock level and the side walk level is located the lower mezzanine floor which houses all the electric control apparatus. The house entrance is at the sidewalk level floor and here is located the locker and general utility space. Above this may be one or two floors depending on the requirements of visibility for the operator for a deck or pony truss type bridge. The top floor is the operator's room, commanding a view of both river and street traffic in all directions from the windows on all sides.

To give in any detail the procedure of the design of the modern Chicago Type Bascule would be a long and involved discussion. Suffice is it to say that today the magnitude of the work requires many individuals, each highly specialized in the design of some particular phase of the work. Only a brief description of the determination of the loads involved can be given here. In the first place, a bascule differs radically from a fixed bridge in that it receives loads in two planes, vertical and horizontal. The vertical loads are the usual ones of dead load, live load, and impact or vibration. The live load through various systems of wheel applications approximates 200 pounds per squae foot. Horizontal load is due to wind pressure against the leaf and must be resisted through the rack and pinion of the gear train and its brakes. The bridge machinery is designed to hold the leaf against a pressure of 20 pounds per square foot of projected area, and to operate against a wind maximum pressure of 10 pounds per square foot. Against a 2 pound wind the leaf must be opened in approximately 45 seconds. The amount of the rack tooth pressure can be appreciated when it is realized that the area of the leaf exposed to wind is at least 65 to 70 feet wide and about 100 feet high, and has a moment arm of perhaps 60 feet to a rack radius of approximately 20 feet. These horizontal loads combined with the dead loads must be carried down through the supporting girders to substucture and piers. Trunnions must be designed to carry and revolve with this resultant load of over 1,500,000 pounds, and the trunnion bearings transmit this concentrated load to a longitudinal girder approximately 50 feet long. Besides this, calculations must be made for shear lock loads transmitted from leaf to leaf, also traction loads and various possible combinations of different loadings.

To say that the ultimate had been reached in bascule design would be short sighted. Each new design shows some new improvement, longer distances spanned, wider roadways provided, and modern structural beauty incorporated. Each bridge built stands as an engineering achievement whose useful life is now only measured by the requirements of a city's traffic 30 to 40 years hence. The only limiting factors of design are the materials available for economic construction. As alloy steels are cheapened and made in structural shapes it will be possible to increase the loadings or decrease the sections. It perhaps is not even hazarding too much to say that eventually the new art of welded fabrication can be adapted to bridge erection and the section-destroying rivet hole abandoned. It should be added that the thing that has made this present achievement in design of Chicago Type Bascule bridges possible has been not only a river requiring many crossings, but the power of a city always to fulfill its needs.

Tawny

These are the tawny days; your face comes back.

The grapes take on purple; the sunsets redden early on the trellis.

The bashful mornings hurl gray mist on the stripes of sunrise.

Creep, silver on fields, the frost is welcome.

Run on, yellow balls on the hills, and you tawny pumpkin flowers, chasing your lines of orange.

Tawny days, and your face again.

—*Carl Sandburg*

CHICAGO'S BRIDGES

By

OTTO W. HANSEN

HISTORY

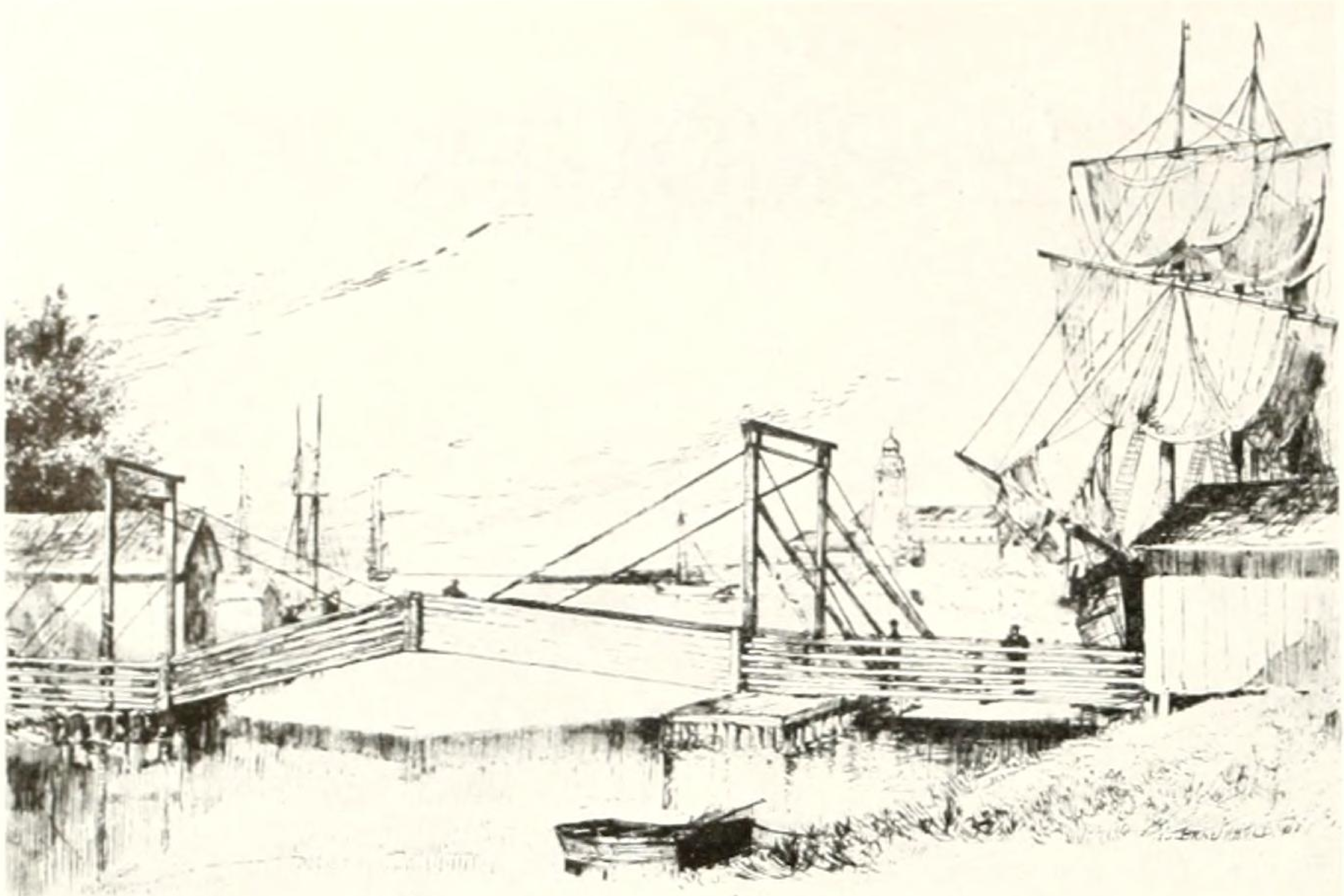
Chicago's site was built during the glacial period. When the ice retreated it left the St. Lawrence River, the Great Lakes and the streams which flow into them.

This system of waterways extends from the Atlantic Ocean to within a few miles of the Des Plaines River. Along this natural route of travel came explorers, traders and settlers who peopled the Mississippi Valley.

Before the advent of the railroad, however, the waterways formed an avenue of communication so important that we of today can hardly appreciate it. The idea of connecting the Chicago River with the Des Plaines River by means of a canal was advanced by the first white explorer who visited the site of Chi-

The Chicago River. A Few of Chicago's Fifty-Six Movable Bridges.

Chicago Tribune Photo



The Chicago River. A Century Ago.

cago. The two streams are only a few miles apart, and the water-shed which separates them is only a few feet high.

These two waterways were connected with each other, first by the Illinois and Michigan Canal in 1848, and a second time by the Sanitary Canal in 1900. Now the projected development of the St. Lawrence Seaway and the Lakes-to-Gulf Waterway maintains this question as a matter of prime importance to Chicago's future.

As Chicago's topography is flat, and only a few feet above water, it became necessary from the very beginning to provide movable bridges to permit the passage of vessels.

With the movable-bridge policy early established it becomes evident that the story of these bridges is the story of Chicago, as it has been closely interwoven in the fabric of this metropolis which in 100 years has developed from a frontier post to a great city of 4,000,000. The important part Chicago's bridges have played in the consolidation of the sections of the city, separated as it is by its rivers, into one homogeneous community is manifest to anyone after a little thought.

The first pedestrian bridge was constructed at Kinzie Street in 1832. The first swing bridge for vehicles and pedestrians was built at Dearborn Street in 1834. All early bridges were of timber; their costs were defrayed from subscription funds. The first municipally built bridge was constructed in 1857 at Madison Street, costing $30,000. The first iron bridge in the west was built in 1856 at Rush Street, Chicago.

With but a few exceptions up to 1890 all bridges were of the horizontal-swing type, supported by a pier in the center of the river and in most cases were manually operated. This type reached a high degree of perfection. One objectionable feature was the restricted use of the river caused by the center pier which made the most desirable part of the waterway useless.

In 1894 a vertical-lift bridge was built at South Halsted Street. It operated as an elevator, with steam power. It did not meet with favor, being costly in construction, unsightly and uneconomical in operation and providing poor operating visibility. In view of the dissatisfaction with this type other designs were developed to meet the demands for increased and unobstructed waterways.

From 1892 to 1900 the construction of the drainage canal was in progress. The proposed flow requirements affected bridge design to the extent that proper waterway had to be furnished to avoid currents which might be detrimental to navigation. Water diversion through the Chicago River was regulated by order of the Secretary of War for many years. After January 1, 1940 this flow was materially reduced so that at the present time provisions for water flow are inconsequential.

Early Bascules

Going back to the conditions in the early nineties, after the Halsted Street lift bridge had been in operation, a rolling-lift bascule bridge was developed by Mr. Wm. Scherzer and was constructed at Van Buren Street in 1895. Its movable leaves are integrally supported on a vertical circular girder the circumference of which rolls, when the bridge is to be raised, on a horizontal foundation a distance of twenty to thirty feet, much as a rocking chair rolls on a floor.

As replacement of many of the bridges was imperative between 1894 and 1907, twelve of these rolling-lift bridges, and six trunnion-bascules were built, mainly at locations where the old bridges impeded the flow of water for sanitary purposes.

Bascule means "see-saw", a double-arm cantilever mounted and balanced on a shaft, the trunnion, on which it my rotate. This principle was used in the construction of the ancient portcullis bridging the moats around castles and forts. Its application to large structures which can be raised and lowered, and of sufficient strength and capacity to meet the traffic requirements of a large city involves considerable engineering ingenuity.

The famous Tower Bridge of London was one of the first large trunnion-bascule bridges to be built, being completed in 1894. Chicago's Van Buren Street rolling-lift bridge was completed in 1895. It naturally followed that local engineers would observe their performance to determine their relative merits.

After several years experience with rolling-lift bascule bridges, it was decided that the trunnion-bascule appeared to be more suitable for local conditions. As a result, competitive designs for a bascule bridge at 95th Street over the Calumet River were invited in May, 1900. A committee of three bridge engineers selected one of the City's own designs, with modifications. This design fundamentally is the type used today not only in Chicago but in several other cities and is known as the "Chicago Type Bascule".

The 95th Street bridge is double-leaf with three trusses 21'-0" c. to c. pivoted about three trunnions. The span is 128 feet c. to c. of trunnion bearings with cast-iron counterweights under the fixed approach. The substructure consists of a front and rear pier connected by walls so as to form watertight counterweight pits. Girders parallel to the movable trusses supported on the front and rear piers carry the trunnion bearings. The main operating pinions for operating the bridge mesh with racks fastened to the curved heels of the three trusses. At the center the leaves when closed are connected by motor-driven shear-locks.

The committee's reasons for favoring the trunnion type of bascule are given in their report as follows:

(1) "Constant point and direction of application of load on the foundation whether the bridge is in motion or is stationary." (On a rolling-lift bridge the load moves back as the bridge opens and may cause instability of foundations.)

(2) "Reduction of the number of moving parts to a minimum."

"The bascule design permits the placing of the center of gravity of the moving bridge in the trunnion axis or its proximity. The placing of the center of gravity a short distance from the axis of the trunnions toward the draw opening and the arrangement by which the tail end is relieved from any possible live load has the advantage of holding the bascule firmly in position when closed without absolute necessity for heel-locks. There is no tilting effect due to the action of live load coming on the bridge."

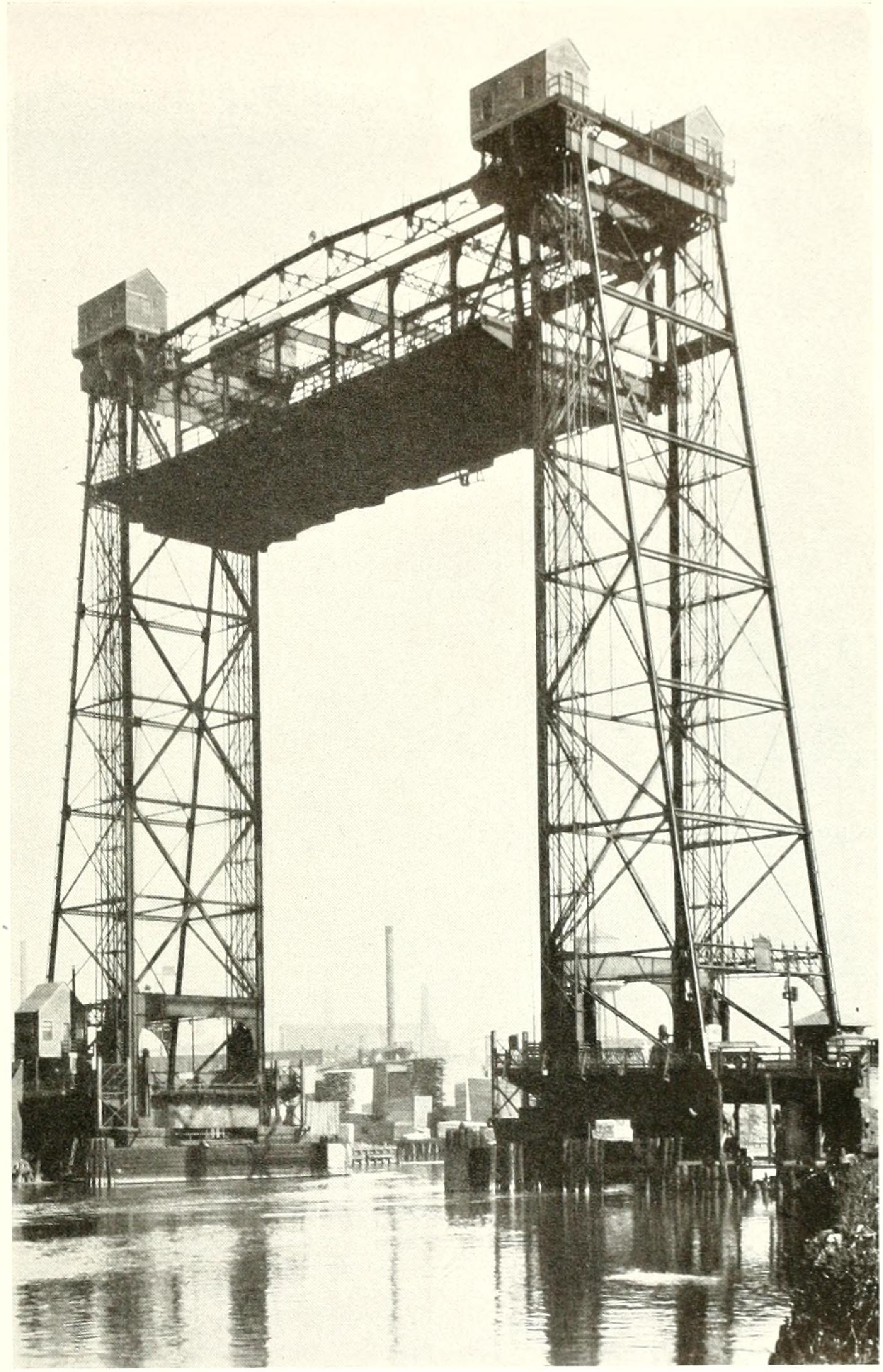
Forty years later and after about $50,000,000 worth of local bascule bridge construction, we note that these early recommendations, which were not all then accepted, have been incorporated in present design. Several of the suggestions were:

"—that adjustable resting blocks be placed in front of and near the trunnion so that when the draw closes, the load may be transferred from the trunnions to the resting blocks."

"—for future and more important structures, warranting additional expense, foundations should be carried to bed rock."

"The design of the piers is not satisfactory, — make one counterweight pit by disposing of the partitions—"

In the main the above description of the 95th Street bridge is an excerpt from an article by Mr. Earle G. Benson, Mechanical Designing Engineer for the Bridge Division, which appeared in THE ARMOUR ENGINEER of March, 1931.



The Halsted Street Lift Bridge
Built in 1894.

MODERN TRUNNION BASCULE

A fundamental departure from the above recommendations and one embodied in practically all the later designs is the distribution of the weights of the movable leaf in such manner as to have the center of gravity of the entire leaf coincide with the center of the trunnions. This feature results in balanced equilibrium of the leaf, exclusive of applied loads, as snow and wind, in all positions of the arc of travel.

In cooperation with the Chicago Plan it was imperative to consider the aesthetic features of the bascule bridges. While the fundamental principle of design which placed the counterweights below the roadway was established in the 95th Street type of bridge, further improvement in appearance was obtained through relocation of the operating rack. This was built into the truss internally. An internal operating pinion was provided and the machinery was placed alongside the trusses. This construction permitted greater latitude in the design of the movable leaves so that variations in appearance could be obtained when so desired.

Abnormal operating conditions require, as insurance against breakdown, great ruggedness and conserva-

Ninety-Fifth Street Bridge: 1905.

3-Truss, External-Rack Trunnion Bascule.

tive design. With the increase in loads, widening of roadways and greater length of spans it followed that the size of the component parts of the bridge naturally developed into a greater massiveness. The combination of engineering functions together with features of beauty, sometimes termed "functional beauty" developed ultimately to such a point that the bascule bridge at Wabash Avenue in 1930 won the first award of the American Institute of Steel Construction for the most beautiful steel bridge constructed during that year.

The modern bascule may be described substantially as follows:

The foundation, a watertight massive-walled concrete box, provides support for the trunnions and accommodates the rear part of the movable leaves and counterweight box. It rests on caissons of 6 to 8 ft. diameter reaching down to the rock from about 60 to 107 ft. below City Datum. The vertical loads run up to 1000 tons. The pit floor is about 20 ft. below water level and thus the resulting uplift and sidewise earth and water pressure must be duly considered. The counterweight must be free of buoyant effects from water and therefore the pits must be watertight.

The superstructure consists of two movable leaves and their supports, the fixed approaches, the machinery and the houses. Each leaf is a huge cantilever arm of over a hundred feet; in closed position the effect is that of a flat arch; in open position the roadway serves as a barrier protecting traffic. Uniting the trusses, behind the trunnions and under the approach floor, is the counterweight box.

The superstructure is designed for dead and live loads. Fifty-ton street cars, 24-ton trucks, 100 lbs. per square ft. uniform moving load and 20 lbs. per sq. ft. wind load are assumed. Proper allowances are made for impact and vibration. Closed and open positions are considered and change in the character of the stresses is taken into account.

The roadway of the bascule bridge offers a different problem from that of the ordinary fixed bridge. It must remain in place when the leaf is vertical; it must be light in weight, yet substantial.

Equipment

One operator's house is provided for each leaf, on opposite sides of the river, with a bridge operator for each leaf. Proper visibility is of importance in the design of these houses. Usually a bridge house is from three to five floors high with suitable architectural treatment. It houses heating equipment, electrical resistances, relays, and controllers, sanitary facilities and operating supplies. The operating room occupies the entire top floor with a commanding view in all directions of river and street traffic. This is possible through the provision of windows all around. The operator regulates the bridge from this station through the controllers on the brakes, motors, gate-signals, center and heel-locks, in a definitely prescribed order. Neon "Stop" signs, electric bells, and one locomotive bell on each house are provided. These signals are interlocked with the center shearlock and the power circuit used for moving the structure, so that before the operator can move the bridge it is necessary that all the signals be in their proper position and on display to traffic. If for any reason trouble is experienced in this primary circuit, he is then required to resort to the use of a secondary auxiliary circuit which is not governed by the interlocking features.

In the event of failure of both these systems, the operator is required to signal the oncoming vessel to stop by means of a red flag by day and electric light by night. Ordinances limit the speed of vessels so that such an emergency can be met.

The control of a heavy bascule bridge in every position, and safe and quick operation, require efficient machinery. The almost perfect balance attained today necessitates motive power only to overcome inertia, friction of moving parts, wind and snow loads.

In the design of the machinery many factors are considered. In addition to static conditions, the stresses from the kinetic energy of the moving masses are transferred to the gear train; in case of failure, to the bumpers and live-load pedestals. Trouble may develop in the machinery, or expansion castings may bind, necessitating extraordinary force to move the bridge and putting heavy pull on the machinery. The most unfavorable condition is assumed to be covered by the 20 lb. per sq. ft. unbalanced load on the leaf. This is the design criterion for the machinery.

Ordinarily carbon-steel forgings and castings are used for machinery parts but with the increase in the size of the newer bridges its use would result in machinery too bulky and impractical. As for example, with trunnions often three feet in diameter and nine feet long, the tendency is towards use of high-strength alloy steels. The machinery is mounted on bed-plate steel castings, although welded construction is resorted to on occasion. The driving power for the larger bridges is two 100 H. P. 600-volt D.C. motors per leaf.

In some instances compressed air and hydraulic devices are used for operating signals, brakes or other appurtenances.

Miscellaneous

On several occasions the use of vertical-lift bridges as means of meeting extraordinary conditions have been considered but invariably these studies reverted to the acceptance of a bascule design. However, skewed river conditions encountered at the Torrence Avenue crossing over the Calumet River, together with the long span, indicated the advisability of the use of the vertical-lift bridge, which was completed in 1937.

Besides the fifty odd movable bridges built by the local governments, railroads have built eight bascule and four lift bridges over the Chicago and Calumet rivers within the City Limits.

Wabash Avenue Bridge. Trunnion Bascule Type.

Award by American Institute of Steel Construction for Most Beautiful Bridge Erected in 1930.

CONSTRUCTION

The scope of this article does not permit of proper discussion of construction methods used in the erection of a bascule bridge. It may be of interest to note that eighteen months are required to complete the construction. Also that during that time traffic is diverted over a temporary bridge, or sometimes over the existing swing bridge. The change-over from the old to the new bridge is generally accomplished with only a few days inconvenience to traffic.

A short time ago bids were taken for the substructure portion of a new bridge at State Street to replace a thirty-five-year-old rolling-lift bascule. The replacement of this bridge resulted from the construction of the State Street subway.

Another rolling-lift bridge, also about thirty-five years old, at Canal Street near Cermak Road is to be replaced shortly with a modern bascule.

From these instances, some idea of the "life" of a bascule bridge in Chicago is obtained.

MAINTENANCE

With forty years assumed life of a bascule and with a system of fifty-six movable bridges, it follows that replacements should be at the rate of about three bridges every two years. From 1900 to 1927, rapid and wide change in traffic requirements, together with periods of economic stress, gave rise to many complex maintenance problems.

After 1922 the depression stopped new bridge construction and lowered the standard of maintenance. Conditions reached such a stage that in 1928 a bond issue of $1,000,000 was passed by the voters for the modernization of nine bridges for which rebuilding was not required and for which funds were not available. The main factor in this situation was the light floor system, designed for the lighter and slower horse-drawn vehicles and not able to cope with the modern heavy and fast-moving traffic. The new floors were stronger and heavier, entailing additional counterweight, all of which added about 100 tons to each leaf. This, together with the increased loadings and the fact that some of these structures were thirty or more years old, and badly

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PHOTOELASTIC ANALYSIS

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further discussion of this important matter. The following references are offered:

"Correlation Between Metallography and Mechanical Testing," H. F. Moore, Reprint No. 9, University of Illinois Engineering Experiment Station.

"Methods of Correlating Data from Fatigue Tests of Stress Concentration Specimens," R. E. Peterson, Timoshenko 60th Anniversary Volume.

Letter by the writer to MACHINE DESIGN, Professional Viewpoints Section, August, 1940.

It has been the intention of this paper to bring to the design engineer an appreciation for the commercial value of the application of photoelastic analysis, and a realization of the simplicity of its application. The writer recommends that a careful investigation be made in each individual case to determine the value of equipping the engineering department with photoelastic apparatus.

Acknowledgment to MACHINE DESIGN is made for permission to use the cuts of Figs. 3 to 9 inclusive and Fig. 12.

CHICAGO'S BRIDGES

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deteriorated, necessitated extensive reinforcements and renewal of component parts.

Many different types of bridge floors have been used since 1890. Considerable study has been given this subject. For observation purposes and to clarify differences of opinion as to the efficiency of various types of construction, typical bridge pavements were installed on the south roadway of Lake Street bridge in 1930, establishing a sort of "roadway laboratory". Of about fifteen types of construction and wearing surfaces, a few proved unsatisfactory. In other samples, weight, cost, wearing qualities, or maintenance costs were factors against them, with the result that today only six different types of bridge pavement are used, the specific type depending on the particular problem at hand.

For example, in 1939 it became necessary to redeck the upper level of the Michigan Avenue bridge to replace a worn rubber-tile pavement installed in 1927. This bridge is a two-level structure with the lower level accommodating trucks, while the upper level serves boulevard and bus traffic. This construction establishes a distance of twenty-one feet from the trunnion to the upper roadway level. Material change in weights of this decking would necessitate a large amount of additional counterweight to prevent the bridge from "falling backwards" when the bridge was raised and to otherwise maintain the horizontal and vertical moment balance. Consequently a comparatively light deck of timber and asphalt planking was adhered to with aluminum curbs and center strip. Back of the trunnions a combination wearing-surface of cast iron and concrete 1½" thick was provided, mainly for added stopping and traction advantages to autos.

In this instance, due to the lower-level traffic, the upper deck had to be waterproofed. With the wear of 40,000 autos and busses daily on this upper level some idea of a few of the elements entering into bridge-floor design are brought to light.

In the maintenance and operation of this bridge system, damages to various parts of the structure and its equipment may result from collisions with vehicles. The more serious of these is from collision of large steamboats with the movable leaves or the foundations of the bridge. In the instance of the sandboat collision with the old Clark Street swing bridge, this was of such a serious nature as to require removal of the old bridge, but ordinarily repairs can be made. These repairs are generally made under difficult conditions in that it is essential to keep traffic going over the structure while repairs are in progress and also to keep the bridge in operating condition so as not to impede vessel movements.

With apologies for this personal reference, the writer as a native Chicagoan recalls the bridges of the early nineties over which nearly every crossing was a precarious one. In his connection with the Bridge Division since 1913 it has been his privilege to be closely associated with the engineers and the many skilled mechanics who put forth tremendous mental and physical efforts, and in many cases gave their lives in the endeavor, which carried the development of these structures from the frail structures of the early nineties to those of the present. Space does not permit naming the many city officials, civic bodies and others who cooperated with the engineer in the solution and coordination of the political and economic problems.

In closing we feel that some parts of this story might well be omitted, rather than not to include a word of tribute to two men, the late Alexander von Babo, Engineer of Bridge Design, and Thomas G. Pihlfeldt, Engineer of Bridges, who passed on recently after more than fifty years in this service and under whose direction the bridge system of Chicago attained its position as one of the world's great achievements.

This article is submitted with the approval of Oscar E. Hewitt, Commissioner of Public Works; W. W. DeBerard, City Engineer; and S. J. Michuda, Engineer of Bridges.

BEHIND DEFENSE

(From page 26)

duties of this unique institution, to keep the whole machine operating smoothly with no stops or breakdowns, requires a staff of no less than seventy-seven persons, including trained librarians, clerks, stenographers, typists, printers, book binders, engineers, janitors and pages.

While books and libraries are being burned and destroyed in Europe, in America we still have the freedom to enjoy unmolested one of the most democratic of institutions—the free public library. Sensing our strength and knowing our value, we feel grateful for the privilege of serving to build a constructive defense as opposed to the useless vocal vituperations so common in many quarters today.

CO-OPS

(From page 30)

tries are interested in directing their students toward this field, which may mean the directing of human beings rather than the engineering of materials.

The success indicated above is not universal. There have been difficulties in carrying the program forward. One company spent time and energy trying to hire other engineering graduates, although they had four co-operative students about to graduate from their own plants. Although their attention had been called to these men, they lost them to other companies which were quick to take the men that the original employer was too busy to follow up. Another company expected the co-operative students to work five years at the starting wage. Still another would grant a two-cent-an-hour raise if the students kicked hard enough. One works manager, although he had received reports of the students' grades at the end of each college term, never talked to students during their five years in his plant.

Some student problems have been interesting. A student after six months experience asked for a transfer to another company because he had learned all there was to know with the first company. Another pair after two months in a stock room in which some fifty thousand different parts were kept wanted to be transferred to a place where they could learn something.

Many calls have come to the Armour College of Engineering for students to work in industries outside the Chicago area. Many of the companies co-operating select from the apprentices in their own plant those who were high-ranking students in high school and who show unusual ability. Still other companies ask for Chicago students to work outside of Chicago.

All candidates are given a battery of tests before being accepted by the college and are required to be in the upper quarter of their high school class.

TABLE II

Dept.	*Location*	*Time Spent in Dept.*	*Time Spent In School*	*Wages*
—	School		2 months	Starting wage 45c
38	Tool Grinding	1 month		
18	Inspection	1 month		
—	School		2 months	
34	Layout	1 month		
30	Welding	1 month		
—	School		2 months	
9	Gear Cutting	2 months		2nd year 50c 3rd year 55c 4th year 60c
39	Stock Room	1 month		
49	Tracing	1 month	2 months	
—	School			
49	Shop Engineering	2 months	2 months	5th year 65c
—	School			
49	Shop Engineering	2 months		
—	School	2 months	2 months	
49	Shop Engineering			

BETTER MOUSETRAPS

(From page 32)

room was called into play. An inner glass-walled room was erected and fitted with auxiliary blowers as well as a liquid-air evaporator. Full dressed for a jump, the parachutist stepped into the chamber and faced a wind of 200 miles per hour at 67° below zero, while tests were made to assure the safety of each article of apparel and the functioning of each piece of equipment carried. Had anything been defective, the parachutist could have stepped out of danger at once, a feat somewhat more difficult when one is dropping through empty air on a one-way ticket.

FRANCIS W. GODWIN,
Armour Research Foundation.