Erecting 56-Ton Sheaves For Calumet River Bridge

Special equipment set-up required to raise operating sheaves 210 ft. to tops of towers of Torrence Ave. lift bridge in Chicago

FOUR of the largest and heaviest sheaves ever used in a lift bridge are required in the new Torrence Ave. crossing of the Calumet River in Chicago, which will be opened to traffic this summer. Their weight of 56 tons each and their diameter of 15½ ft. provided the contractor with an unusual erection problem, which he met by ingenious combination and revamping of his existing equipment.

The Torrence Ave. bridge is a 276-ft. lift span, weighing 1,600 tons, and lifted at each corner by 20 cables 2¼ in. in diameter and 156 ft. long. The cables pass over the sheaves at the top of the 240-ft. towers to connect with the counterweight which moves up and down inside the rectangular towers. The sheaves 5 ft. wide, are mounted on a shaft 30 in. in diameter and 9½ ft. long, which is in turn mounted on huge roller-bearing pillow blocks weighing 12 tons. The bridge provides a 200-ft. wide channel for shipping, with 21-ft. vertical clearance in closed position and 125 ft. clearance when open.

Erection of each sheave required the lifting of a 60-ton load, (consisting of the 56-ton sheave and shaft and 4 tons of lifting fittings,) a vertical distance of 210 ft., the installation of the roller bearings and the setting of the assembly in final position. After considering a number of methods, it was finally decided to use a steel stiffleg derrick, with a specially designed and reinforced 40-ft. boom, placed at the top of the tower on the top flange of the river-face girder, which was reinforced with stiffening angles under the derrick mast. The sill anchorages of the derrick were lashed to the tower legs with cables.

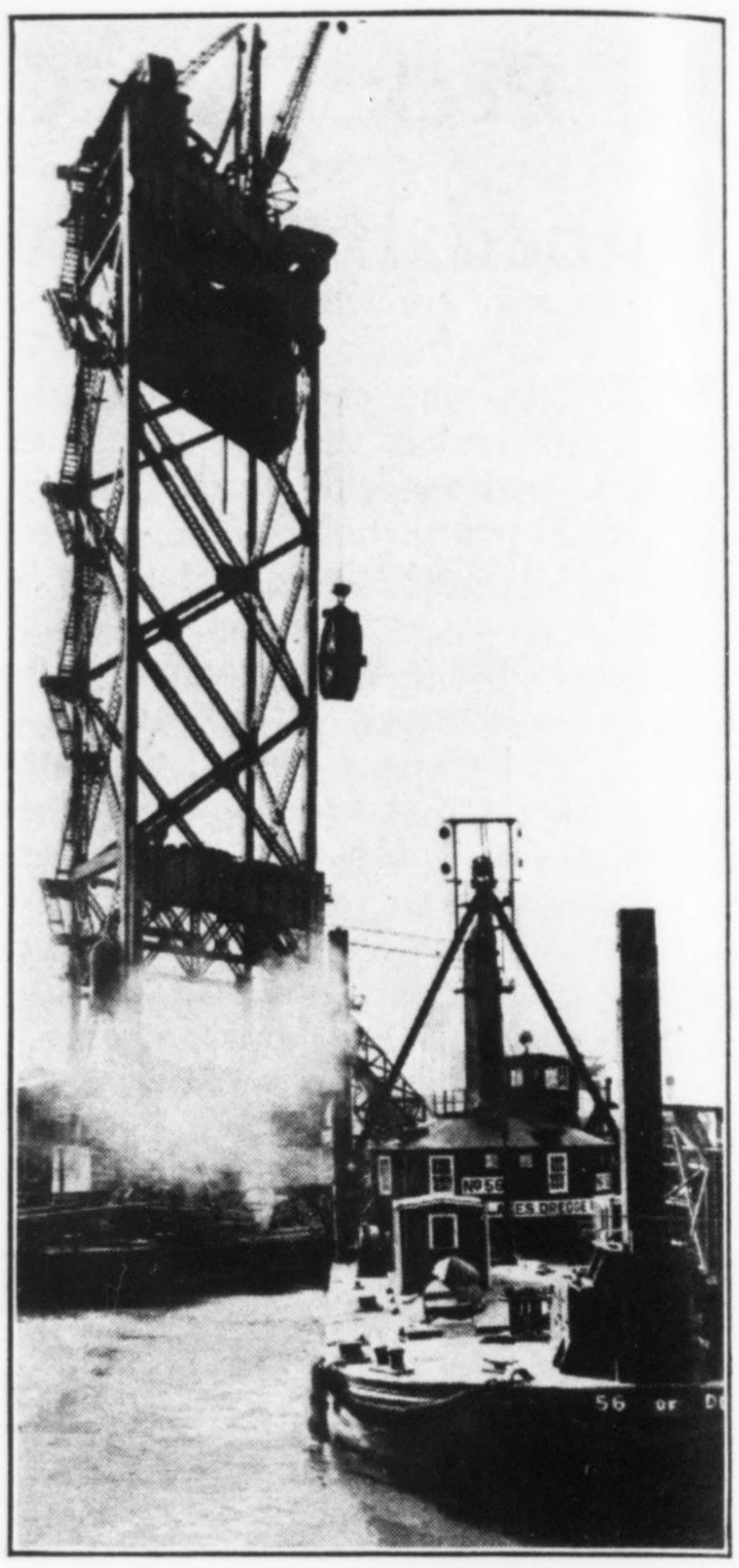

FIG. 2—RAISING A 56-TON SHEAVE onto one of the towers of the Torrence Ave. lift bridge in Chicago using a 9-part line from a hoist on the derrick boat in the foreground

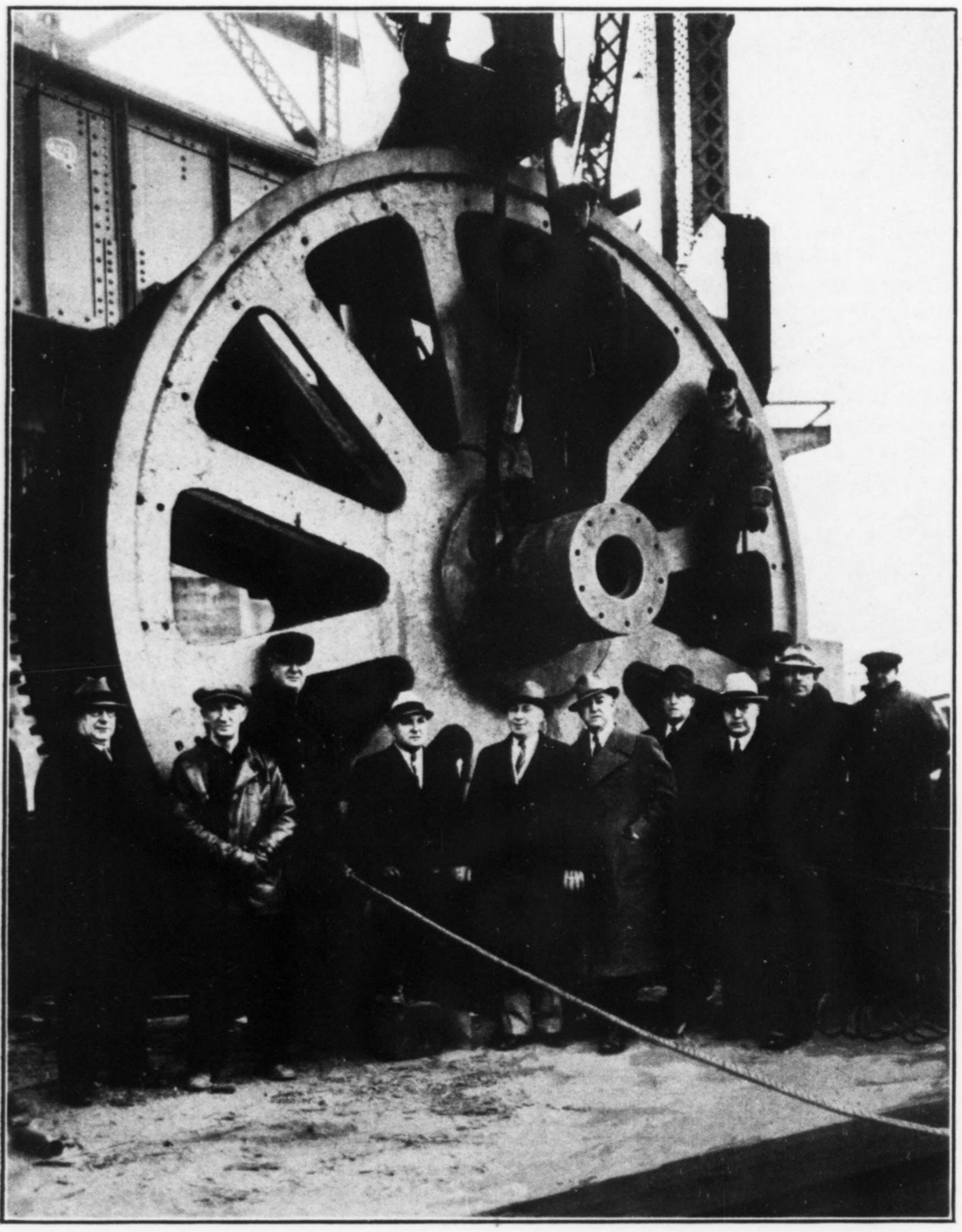

FIG. 1—READY TO RAISE the last sheave using a saddle consisting of stirrups around the shaft connecting to a lifting beam.

Since the existing steam hoists on the steel erecting derrick had neither adequate continuous lifting capacity nor drum capacity for this high and heavy lift, requiring the use of 2,700 lin. ft. of ⅞-in. cable reeved in nine parts, the contractor's 100-ton floating diesel-electric derrick was brought into service. First, the standard hoist cable was removed from the steel erecting derrick, and the special ⅞-in. cable substituted and reeved through special roller bearing blocks to the drum on the floating derrick. Then, since this drum was grooved to accommodate 1⅛-in. cable and in addition could store only about one-third of the amount of cable required, it was necessary to remodel it. This was done by welding a new drum outside of the existing drum and building up the sides of this addition to a height of 7¼ in., to hold the nine layers of cable required. Ample lifting power thus was available from the floating plant, and the other movements of the steel erecting derrick, such as swinging, lowering and raising the boom, were handled by the hoist on shore.

A special lifting saddle was designed

for handling the sheaves, consisting of two stirrups made from $1\frac{3}{4}$-in. square steel bars bent to conform to the circumference of the shaft and extending upward to a steel lifting beam placed across the top of the sheave as shown in Fig. 1. This beam was made up of two 15-in. channels between which are inserted a triangular plate 1-in. thick reinforced by two 1-in. pin plates. A $3\frac{1}{2}$-in. diameter pin was used to attach this saddle to the derrick falls.

After careful preparation and tests as to the adequacy of this equipment, the sheaves were raised into place, the lifting operations consuming about ten minutes per sheave. Each sheave was landed at the top of the tower on an I-beam grillage supported by hydraulic jacks, which permitted the removal of the lifting stirrups and the installation of the roller bearing blocks on either end of the shaft. With the bearings in place, the assembly was put in position.

The erection scheme was devised and the equipment designed by the contractor, the Great Lakes Dredge & Dock Co., Chicago.

The unusual size of these sheaves was at the root of another special problem, namely, the insertion of the shafts into the sheaves at the fabricating plant. Usually such shafts are inserted after the sheave hole has been expanded by heating. The large size of these sheaves made this impracticable, and the alternative of shrinking the shaft by cooling was adopted by the fabricator, the American Bridge Co. The cooling medium consisted of a mixture of 459 gallons of alcohol and 9,600 lb. of dry ice, which was placed in a boxlike structure 11 ft. deep into which the shaft was lowered in vertical position. A 6- to 8-hr. exposure to a 90 deg. F. below zero temperature caused a 1/64 in. shrinkage in shaft diameter. The sheave had been made in two vertical halves, and the shaft was quickly removed from the bath and lowered into one of these halves. Then the other half of the sheave was lowered over the shaft, completing the assembly in an elapsed time of about 4 minutes. In 6 hours the shaft had expanded to normal size, providing a satisfactory fit.

The Torrence Ave. bridge will cost $1,150,000, is being financed by a PWA grant and a state gas tax refund to the city. It is being built under the direction of the bureau of engineering of the Chicago department of public works. Loran D. Gayton is city engineer.

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Finding Good Subgrade Materials

EMPLOYING simple apparatus, the Arizona highway department is conducting tests to develop a test measure of the stability of subgrade materials. A description of the apparatus and process with some test results are published by J. W. Powers, engineer of materials, W. G. O'Harra, chemist, and R. J. Shaw, laboratory helper, in *Arizona Highways* for March, 1937. The following description of the apparatus and testing process is taken from that paper.

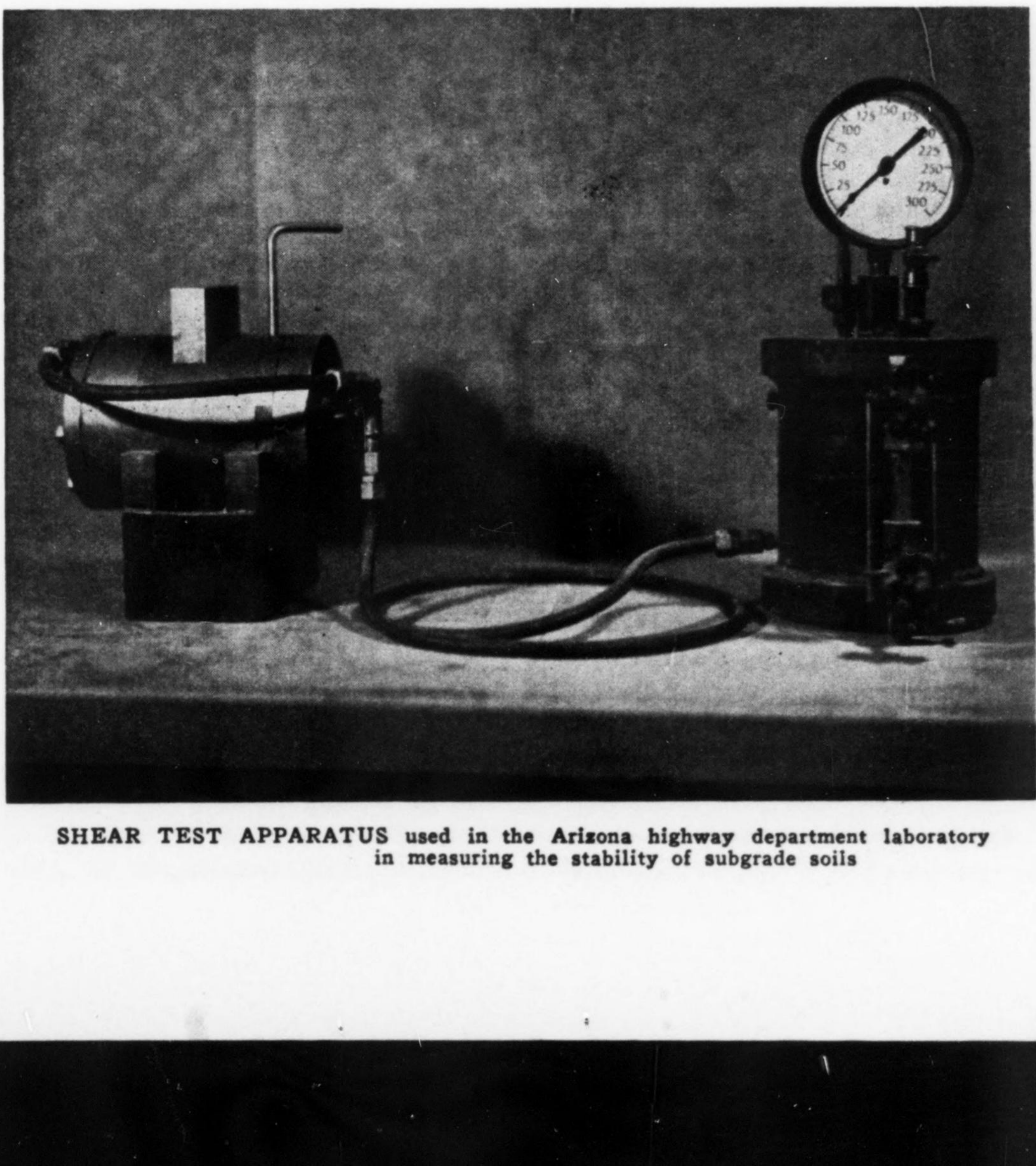
It is found in practice that highway subgrade failures occur in materials that will accumulate sufficient water under actual conditions to cause them to become plastic. The object in this method is to determine the shear strength of the material at moisture contents that are likely to occur under actual conditions.

The apparatus, is essentially the same as that used by Berry, but has been altered to allow the use of compressed air in applying the pressure normal to the shearing force. The material to be tested is first passed through a 3-mesh square sieve. Several 1,000-gr. batches are then made up, using different amounts of water varying from that necessary to produce a nearly dry mix to that necessary to produce a very wet mix. The material is placed in the cylinder in 1-in. layers, and tamped to ultimate compaction; the Hubbard-Field tamping spade having a tamping edge $\frac{1}{4}$x$\frac{15}{16}$ in. is suitable. The top of each layer is roughened before the next layer is added.

Air connections are now made to the air reservoir, the cylinder is placed in the saddle and the aparatus is placed in Hubbard-Field press. The air pressure is run up to 100 lb. per sq.in. for 1 min., then decreased to 75 lb. per sq.in., at which pressure the test is run. The load is then applied at the rate of 0.8 in. (40 turns) per minute; this rate is maintained until the gage indicates a maximum has been passed. The apparatus is then removed and cleaned, a sample of the material from the middle of the cylinder being retained for moisture determination. The test is now repeated, using the remaining batches.

A centrifuge moisture equivalent is then run on the material in the same manner as that used in the Bureau of Public Roads soil constants, but with the following variations: 25 gr. of material passing 3-mesh is used to have the C.M.E. value on the same material as is used in the shear test, thus affording a basis for direct comparison with the moisture content in the shear tests. However, in the case of materials which will almost entirely pass a 40-mesh sieve, the 5 gr., 40-mesh C. M. E. is used.

The shearing loads are plotted against the corresponding moisture contents, and the intersection of the resulting curve with the C.M.E. percentage is noted. Actual correlation between shear values and field observations of subgrade conditions have been made on about 75 materials. This is not deemed a sufficiently large number to warrant any final conclusions, but enough materials have been tested to realize the possibilities of the test.



SHEAR TEST APPARATUS used in the Arizona highway department laboratory in measuring the stability of subgrade soils

Lift Bridge Mechanisms and Controls

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Torrence Ave. lift bridge in Chicago typifies modern installations in general but in addition includes many new mechanical and electrical devices and is operated by its own power plant

WHEN, having standardized for nearly 40 years on bascule bridges, the city of Chicago determined on a vertical lift as the best type for a bridge over the Calumet River at Torrence Ave., it was apparent that a complete redesign of customary motive equipment was necessary. The lack of similarity between the vertical-lift bridge and the bascule led to an unusually thorough study of suitable mechanical and electrical equipment, with consequent engineering development in these items. To add to the problem, the bridge is located in the southeastern part of the city at a considerable distance from customary power facilities. In consequence the design was for a bridge with its own power plant.

The lift span of the Torrence Ave. bridge is a 276-ft. skewed Warren truss with subdivided panels. It is suspended at each corner from twenty 2¼-in. wire ropes, passing over 15-ft. diam. sheaves and attached to steel box counterweights. A 44-ft. roadway and two 8-ft. cantilevered sidewalks are provided. The towers, parallelograms in plan, are 34½ ft. from front to rear to correspond with the panel widths of the trusses. Each tower column is supported by a cylinder pier extending 80 to 90 ft. to rock.

Hoist type selection

Comparative studies, made of several types of span hoist, led to the adoption of a counterweight-sheave drive in which the cables pass up over driving sheaves to balancing counterweights traveling up or down within the two towers, on top of which all driving machinery is located. For obvious structural and architectural reasons this type of design was preferable to a cable-operated design with the machinery supported on the span at the center. A further consideration was safety to roadway traffic. Experience on other Chicago bridges bears out the need of stationing operators at the ends of the bridge where traffic can be observed at all times. On a cable-operated span three attendants, therefore, would be required, whereas one operator in the main tower and a gateman at the opposite end are sufficient for the sheave-drive type.

The sheave-drive type, having independent machinery located in each tower, requires some means to insure that each end of the span will travel at the same rate. A synchro-tie drive is used for this purpose, consisting of 3-phase wound-rotor induction motors in each tower, directly coupled to the same gear-train shaft as the span-driving motors. The rotor circuits of the induction "tie" motors are electrically connected through cables, while their stator circuits are excited from the same power source. When a phase relationship is established between the two tie motors any movement of the rotor of one tie motor will cause a like movement in the other tie motor, varying only by a few electrical degrees, dependent on the resisting torque. Hence any tendency of one tower's drive motor to run ahead will be transmitted through the synchro-tie motors to the far tower and cause a like speed for that end.

To provide the maximum degree of operability, the two tie motors are identical in size and construction with the drive motors. Being identical, the functions of the tie and drive motors can be interchanged, thus permitting operation in case of failure of one tie motor. While it has been proposed for synchro-tie bridge drives that the tie motors might be a fraction of the horsepower of the drive motors, experience on the Torrence Ave. bridge does not verify this; watt-meter readings of power transferred by the tie motors during operation of the span while under construction were at times as great as those shown for the drive motors alone.

The two motors on each tower are coupled to the opposite ends of a high speed shaft of an open gear train located centrally at the tower top as shown in Fig. 2. Cross shafts extend from each side of the gear train to a bevel gear reduction at the outer ends, the bevel gears being necessary because of the skew of the towers. The bevel gears are held in alignment by a unit bearing frame and are totally inclosed. The large bevel-gear shaft carries the main drive-pinion meshing with a circular rack bolted to the side of the counterweight sheave.

The intermediate high speed shaft of the gear train carries a differential provided with a clutch. The differential is so arranged that, with the clutch engaged, the differential gearing revolves as a unit, driving both cross shafts equally; with the clutch released, the differential drives the side with least resistance. Release of the clutches, which are spring set, is effected by 8-in. stroke, 800-lb. thrustors operating through a suitable linkage. The purpose of this feature is to permit lateral seating of the corners of the bridge, as may be necessary should creep or stretch of the ropes occur on the counterweight sheaves, thereby allowing one corner to seat before the other. It is

Fig. 1. Chicago lift bridge, built on a skew, is raised by 80 wire ropes operating over 15 ft. dia. sheaves

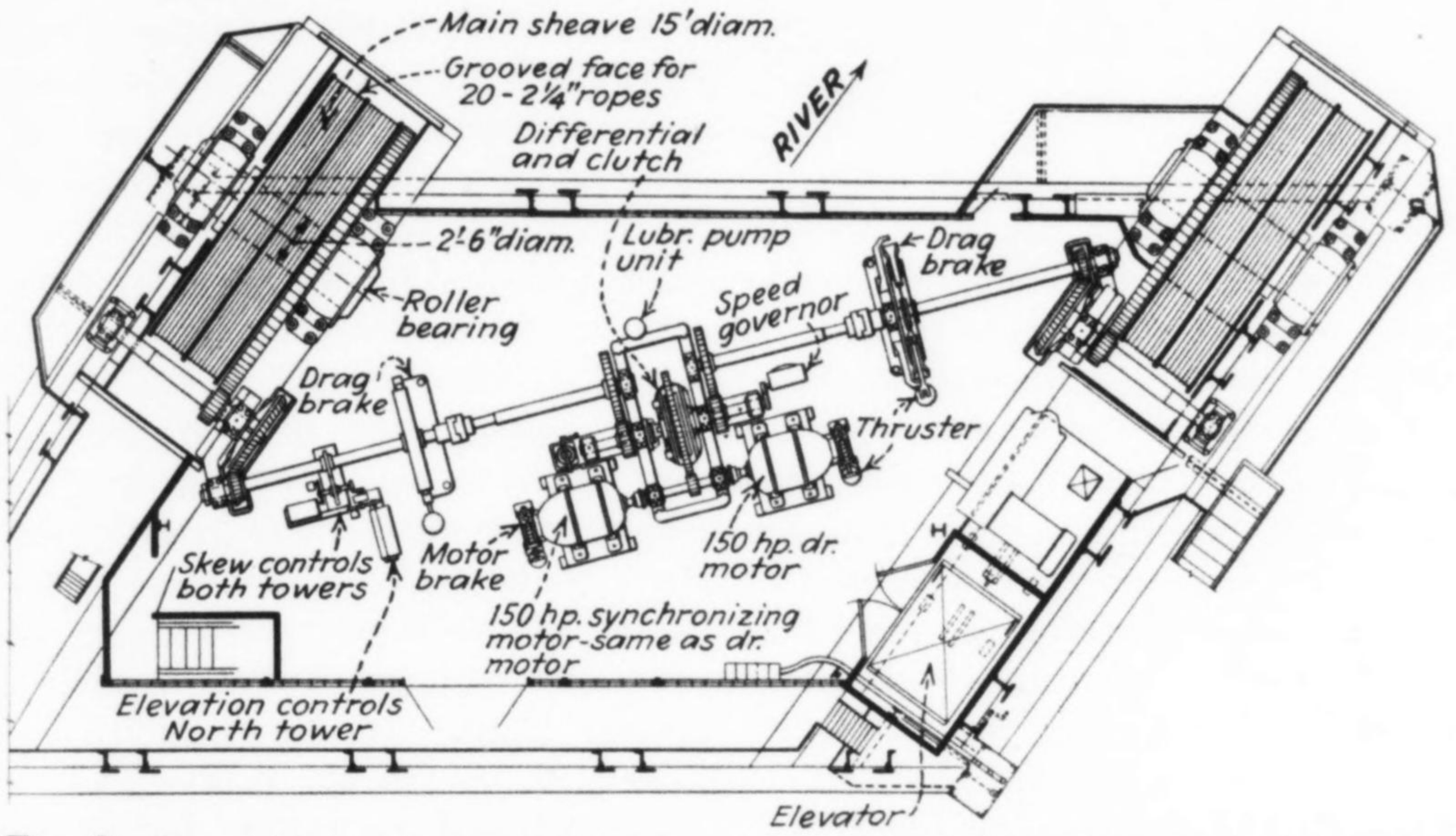

Fig. 2. In machinery rooms at the tower tops are located the drive and synchro-tie motors operating the counterweight sheaves through bevel gears on cross shafts

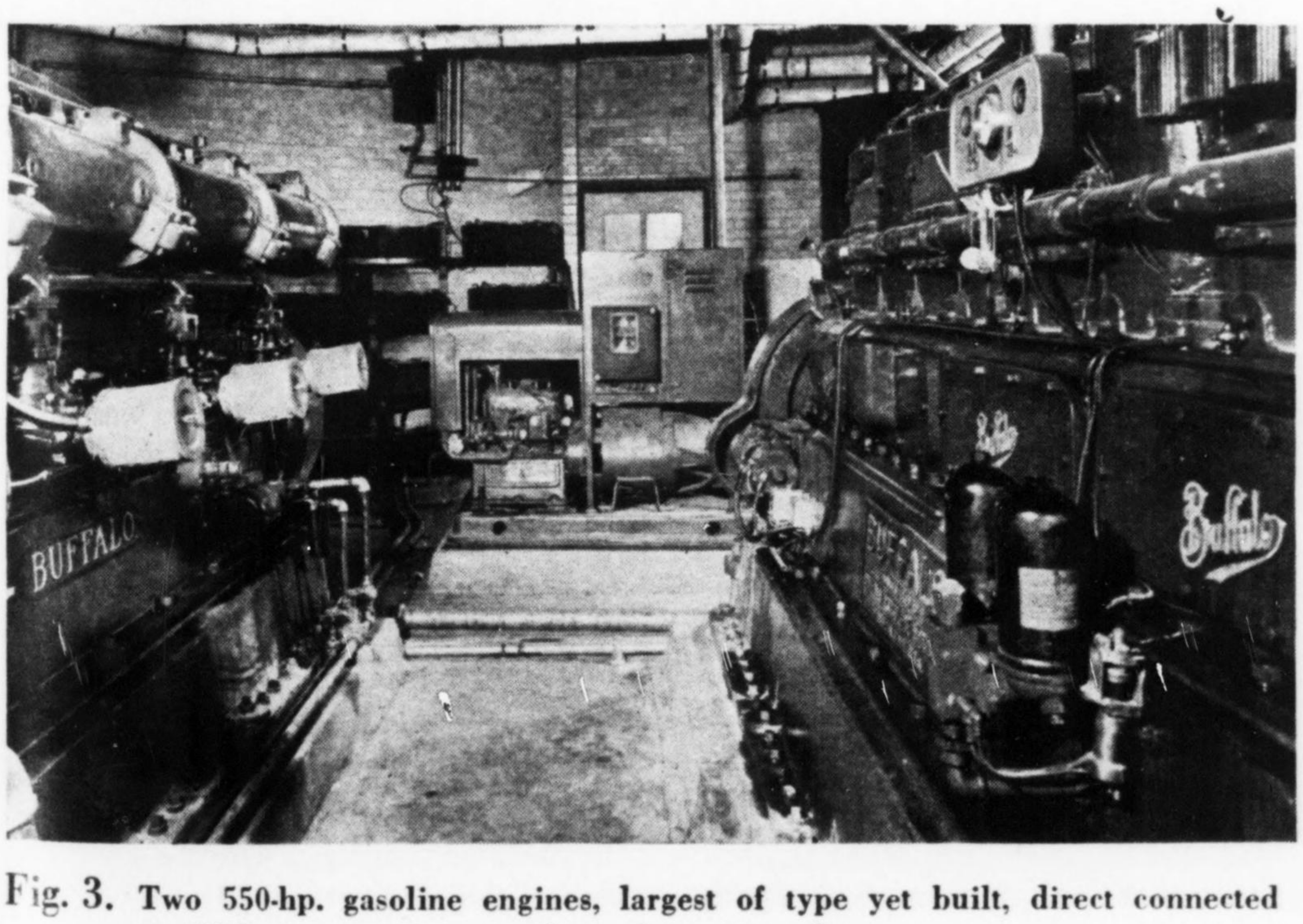

Fig. 3. Two 550-hp. gasoline engines, largest of type yet built, direct connected to 300-kw. generators constitute the power plant

especially important on a wide highway bridge, such as this, that all corners be fully seated to insure matching of the fixed and movable roadway and sidewalks. This seating feature was found particularly valuable for leveling and alignment purposes during construction.

Sheaves

Economy of design of both the lifting girders and the driving machinery, resulting in lessened material and erection costs, was obtained by grouping the counterweight ropes as near the truss connections as possible. This makes necessary a wide sheave face with consequent larger shafts but results in fewer bearings and a simplified drive. The method of shrinking these shafts with dry ice to insert them in the sheaves, as well as the erection of the sheaves, was described in *ENR* May 27, 1937, p. 774.

The sheave shafts rotate in roller bearings, which are the largest ever constructed for this purpose, each bearing carrying a load of 816,000 lb. They are of the fully-hardened straight-roller type, with a bore of 30 in. and an external diameter of the outer race of 47 in. This outer race is carried in a spherical seat to permit of self-alignment under deflection of shaft or carrying girders. A nominal sized roller thrust bearing is also used in each assembly to provide for any lateral load transmitted to the sheaves. The use of roller bearings reduced the required motor horsepower by more than one-half, with attendant reduction in the gearing and shafts and also in the size of electrical equipment and power source, all of which more than offset the increased cost over plain bearings.

Brakes

The braking equipment for the bridge consists of two pair of motor brakes and two pair of drag brakes. These latter brakes are mounted on the cross drive-shafts and consist of 5-ft. cast-steel wheels gripped by floating jaws which are spring set. Release is accomplished by 6-in. stroke, 600-lb. thrustors operated by a variable-speed motor. While their main function is to provide adjustable retarding force when lowering the span with heavy ice loads, these

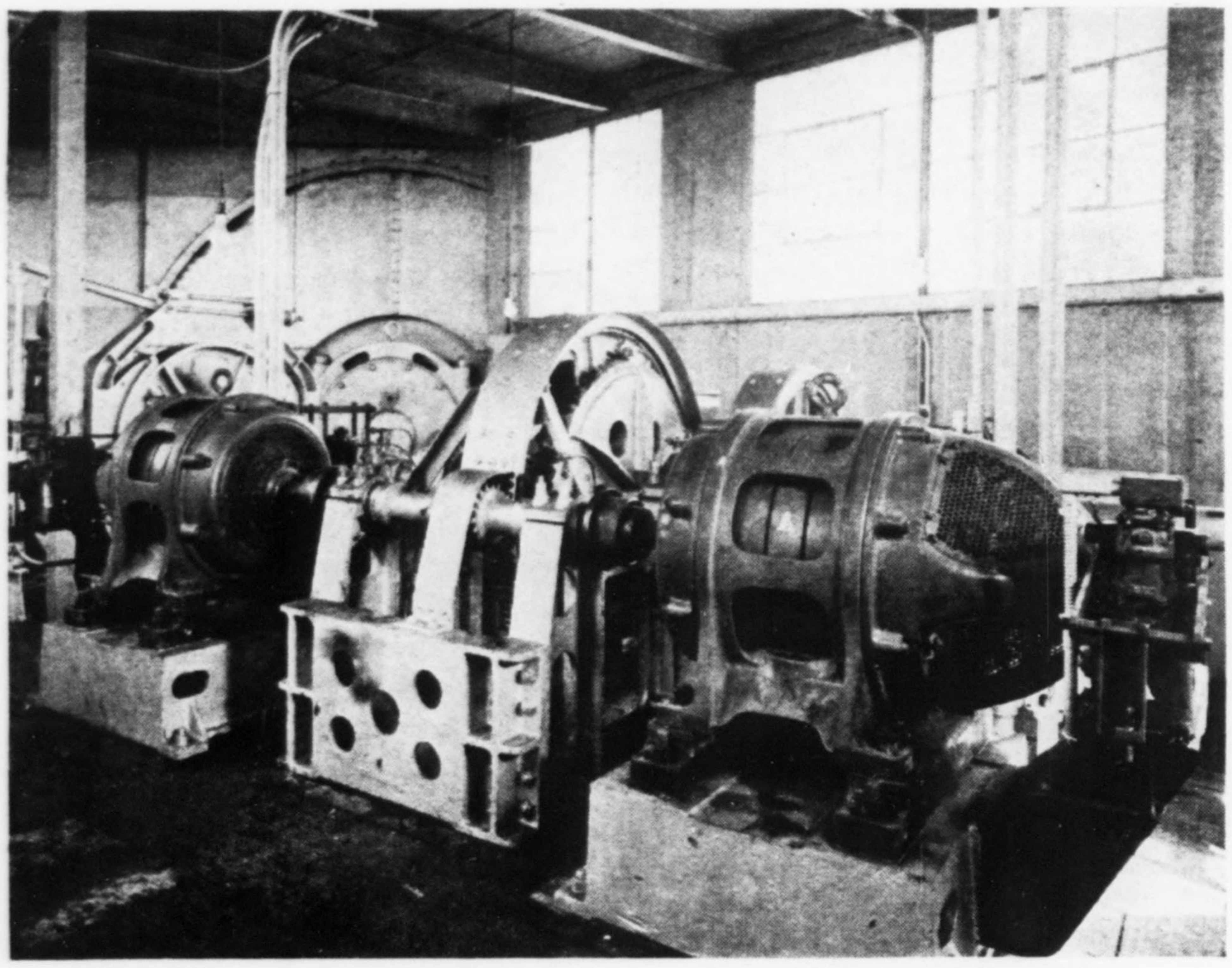

Fig. 4. Machinery on the tower top. The tie motor at the left is electrically connected to a similar motor on the opposite tower assuring that the drive motor at the right will keep in step with the drive motor on the opposite tower

brakes may be adjusted to hold the span in the up-position under an unbalanced condition of 15 lb. per sq.ft. of deck area, or 274,000 lb. The location of these brakes on the cross drive-shafts permits the removal for repair of any portion of the main gear train or the operating motors with the span raised.

Besides the drag brakes, each of the four span motors is provided with a thrustor-released brake. These brakes are arranged to be applied in pairs in two successive steps at the will of the operator. To prevent excessive strains on the machinery in emergency stops, time delays are provided for the stepped application of all brakes.

The use of an independent power plant necessitated special features to provide for regenerative action of the motors. Whenever extreme ice loads are encountered the span may overhaul the motors during lowering, which will reverse the performance of the motors and generators. Under this overhauling condition the motors generate power, functioning as asynchronous generators, and their output is absorbed by the engine-driven generators. The braking effort exerted by the engines is limited and the regenerated power tends to overspeed the generators. This possibility has been forestalled by the use of a regenerative power-absorbing resistor, this being undoubtedly the original application of such a device. This resistor is connected to the generator bus through the medium of a speed governor when the motors reach 105 per cent of synchronous speed. The effect is to permit the engine-driven machines to continue to function as generators while speed, voltage and frequency remain near normal.

Unbalanced loading

For normal operation the gearing was designed to lift the span 104 ft. in 100 sec. of continuous travel with an unbalanced loading (from snow and ice) equal to $2\frac{1}{2}$ lb. per sq.ft. of span roadway and sidewalk area, plus the additional friction of span rollers and counterweight guides due to a lateral wind force of $2\frac{1}{2}$ lb. per sq.ft. on $1\frac{1}{2}$ times the vertical projection of the span and counterweights. This loading required the selection of a motor size that would operate at slightly less than full-load capacity for this condition so that in case of failure of one drive motor the remaining motor's overload capacity would be sufficient to lift the span through the tie motors. The gearing is also designed to have sufficient strength to lift the span under a maximum unbalance of 5 lb. per sq.ft. of span area but at a somewhat reduced speed. In addition to these two specific span loadings the section of gearing extending from the drag brakes outward to the sheaves is designed to carry the stresses due to holding the span with 15 lb. per sq. ft. unbalance.

Final balancing of the span and counterweights was accomplished by observing wattmeter readings for travel in each direction, and shifting counterweight blocks until 5 kw. more power was required for hoisting than for lowering, thus insuring a slightly heavier span for positive seating conditions.

Power plant

Perhaps the most unusual feature of this bridge is its own power plant, located at the north end of the bridge. Investigation indicated that first cost, available room and quick starting ability with unattended operation all favored a gasoline-engine-driven generator set. The main power units selected for operating the span and auxiliary equipment are two 8-cylinder, 550-hp., 1,200-rpm gasoline engines, each direct-connected to a 300-kw., 60-cycle, 480-volt generator and exciter. These units are the largest built in this type. During the acceptance tests a maximum generator output of 357-kw. was developed, a satisfactory margin over the 300-kw. required by the specifications. Either unit has sufficient capacity to operate the bridge, and has demonstrated its ability to lift the span with greater loads than will probably ever be experienced from snow and ice. Power is carried from the north side plant to the south tower through an existing pipe tunnel under the river.

A single smaller gasoline-electric generating unit of 11-kva. capacity is used as a standby for the 110–220-volt single-phase lighting supply line. This set is of the fully automatic type, arranged to start, and come on the line upon the failure of the single-phase utility supply.

Controls

The starting and stopping of the units is controlled electrically from the operator's room, located four stories above the engine room. Indicator lights and warning signals show the functioning of the oil, water and gasoline. The span controls are so located that the operator is required to move to a point of vision, whether it be for road or river traffic. Thus the traffic signals, gates and barriers are controlled from a switch box mounted at a window mullion on the landward end of the house, while the span-operating controllers are at the river end. Span indicators are located at eye-height, requiring no glancing down for observation. Switches, which ordinarily will not be operated with the span in motion, such as engine-starting switches, end-lock switch, high-cutout switch and reversing switch, all having convenient pistol grip handles, are located on a central desk. Also on the desk is the skew limit bypass button and the various sealed interlock release toggle switches. At the back of the desk on a sloping panel is located a voltmeter, ammeter for each drive motor, ammeter for auxiliaries and a differential watt-meter showing tie transfer power. Indicating lamps on the desk show engine operation, while bells within the desk warn of high cooling-water temperature and also of wrong controller-set-up. Within the desk is mounted the automatic rheostatic-leveling controller which comes into use in case of failure of the tie motors.

An innovation in bridge indicating equipment is a panel directly in front of the operator on which is laid out diagrammatically the various parts of the machinery at the tower tops. Indicating lights at the item they represent illuminate an appropriately-lettered colored lens whenever the particular piece of equipment is functioning correctly. Thus the operator can tell at a glance which brakes are released, which motors operating, which corners are seated, etc. Immediately to the right of this, at a convenient angle of vision, is located the level indicator dial showing in inches whether either end of the span is high or low. Below, in the same case, is mounted the height indicator, reading in feet above down position and having a vernier pointer reading in inches for the end points of travel.

The arrangement of controllers is somewhat suggestive of street car practice. The span controller is on the operator's left and controls only the directional and accelerating contactors while, contrary to usual practice on similar bridges, the control of brakes and tie motors is located in a separate controller at the operator's right. This separation of brake control from the span motor is advantageous in permitting individual adjustment of braking effort, resulting in smooth seating and better handling under ice loads.

Rheostat levelers

The rheostatic leveling device, which is to be used in case of failure of the synchro-tie system, consists of a differentially-wound selsyn motor driving cams that are arranged to open or close five steps of motor resistance in conjunction with the span controller. The selsyn motor is electrically connected to selsyn generators driven from the machinery in each tower top. As long as both tower drives rotate at the same speed, the differential selsyn is stationary. Advance of one span end relative to the other will cause the differential selsyn cams to open resistance contactors on that end thus slowing it down. The skewed-end condition of this bridge necessitated close limits of leveling control as binding will occur at about 17 in. out of level. All five steps of leveling control come in within 9 in. out of level. Tests have shown that this leveling controller keeps the span within 2 or 3 in. of level. A hand-leveling controller parallels these same circuits and permits manual leveling in case of selsyn failure.

An additional span-leveling device, an ultimate skew limit switch, is also used. It was developed by Westinghouse for an earlier bridge of this type and has been used on all similar bridges since. Other protective features include the usual overload and undervoltage devices, slow-down and stop at travel limits, overspeed, and the previously described overhauling protection.

A limit switch driven from the north tower gearing stops the span a few feet short of each extreme of travel, requiring the operator to center his controls and restart. It also stops the span at its ultimate upper travel. Interlocking circuits are also controlled through this and other limit switches on the balance of the equipment. The interlocking system is such that the correct sequence must be followed for all operations during a routine lift.

Consistent with regard for safety of roadway traffic, a yielding barrier is placed at each tower across the roadway in addition to the conventional roadway gates. It consists of a net of wire rope arranged to be lowered across the roadway whenever the span is to be raised. Electrical interlocking prevents span operation until all traffic devices are in the closed position. The barriers are designed to yield on impact yet provide sufficient resistance to stop a 4,500-lb. vehicle traveling at 45 mph. in a distance of 18 ft. An electrical drive beneath the roadways performs the raising and lowering operation.

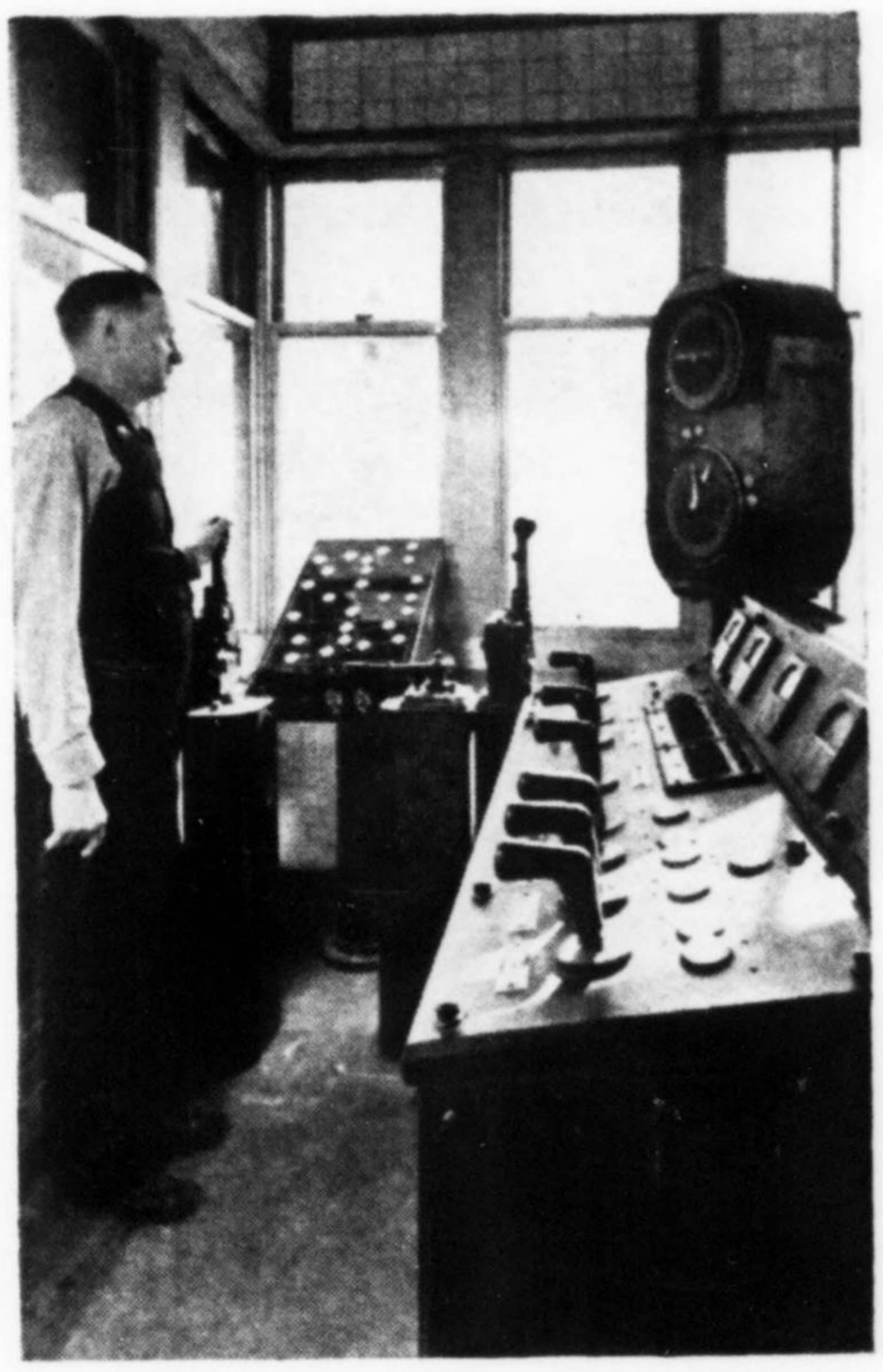

Fig. 5. In the control house the operator is required to move to the window to operate the controls

Miscellaneous equipment

At each end of the bridge, locks are provided to hold the span on its seats. The driving mechanism for each lock is mounted on the tower masonry beneath the roadway and consists of a speed reducer coupled to a crank actuating a connecting rod and lock bolt that engages a socket on the end floorbeam. A 5-hp. line-start induction motor furnishes power, and is supplemented with provision for hand operation.

To cushion the seating of the span, air buffers are provided at each corner. A similar buffer is installed at each corner on the towers for the upper limit of span travel.

The bridge, being gasoline-operated, it was essential that adequate fire protection be provided. To this end a carbon-dioxide gas system is used, having nozzles piped at intervals around the engine room walls and gasoline tank enclosure. Gas is released automatically by heat-actuated valves, or if desired by hand control.

To facilitate rapid access to the tower tops an elevator of 2,500 lb. capacity is installed within the framing of each tower. The elevator is operated from the same 440-volt a.c. as the balance of the equipment.

The total cost of the improvement, including relocation of the old bridge as a temporary crossing, was $1,330,000. It was financed from a grant of $472,500 from the PWA, $740,000 from the city's share of motor fuel funds collected by the state of Illinois and the balance from the city's surplus funds from a previous bridge bond issue.

The bridge was built by the department of public works, Oscar E. Hewitt, commissioner; Loran D. Gayton, city engineer; Thomas G. Philfeldt, engineer of bridges; C. S. Rowe, engineer of bridge construction and the writers. The steel and machinery, in general, were fabricated by the American Bridge Co. and erected by the superstructure contractor, the Great Lakes Dredge & Dock Co. The Westinghouse Electric & Manufacturing Co. supplied the motors and control equipment and co-operated with the city in the details of control design. All electrical work was installed by the Central States Electrical Construction Co. of Chicago.

Railroad Use of Construction Equipment

American Railway Bridge and Building Association discusses increasing use of equipment for construction and maintenance and use of new construction materials

METHODS, materials and machine equipment for railway construction and maintenance were passed in review at the well attended annual meeting of the American Railway Bridge and Building Association, held at Chicago on Oct. 18 to 20. Some of the methods and equipment would apply to work done by contract as well as to that done by railway forces. Pertinent discussion was the strong point of the meeting. Indicative of the railway situation, however, was the fact that for the first time in several years the manufacturers and railway supply houses failed to provide an exhibit of their materials and equipment.

President for 1938–39 is F. H. Masters, assistant chief engineer of the Elgin, Joliet & Eastern R.R. The secretary is C. A. Lichty, of Chicago.

Pile drivers and cranes

Pile driving equipment was made the subject of two reports, one on field methods in the construction of timber trestles and the other on the use of pile driving equipment in modern bridge work. Both pointed to the advantage of high power, self-propelling machines, operated by steam or oil engines. Convertible machines which may be used as grab-bucket excavators, crane or as pile drivers are favored on some roads. A special convertible machine on the Delaware & Hudson has the boiler carried on a separate car, so that there is only a short tail swing for work in restricted spaces or to avoid fouling trains on an adjacent track.

Large cranes are still used for a variety of purposes such as handling materials, rails and bridge girders or structural steel, as well as for excavation and for repair work at washouts. Wrecking cranes of 60 to 200 tons capacity, for use at train and track accidents, are often used for bridge erection and are even loaned to contractors for such work. As much of the steam equipment is said to be obsolete, the report urged the importance of keeping the existing machines in good working order.

For a variety of light work, a small full-revolving self-propelled crane of the type used in rail renewal is a very efficient machine. In a special class of smaller machines are off-track gasoline powered derricks, drag-line excavators, tractors and cranes, many mounted on crawlers. Such machines have advantages for work where rail traffic is heavy, and in some cases have placed the girders of overhead bridges in less time than would have been required to lay temporary track for a locomotive crane. These off-track machines are likely to be used increasingly on bridge and building work, pile driving, ditching, pipe laying and backfilling according to the reports.

Maintenance of movable bridges

Swing, bascule and lift bridges were covered in one report, both as to general substructure and superstructure and the machinery equipment, as well as such details as end rails and end locks. The report noted the importance of operators being thoroughly familiar with the functioning of the various devices involved in the safe and efficient operation of the bridges, and stated that this expert familiarity should be checked occasionally under service conditions.

Operating tests should be made under unfavorable as well as favorable conditions, and tests of brakes, air buffers and other emergency devices should be carried to the point where these devices actually function. Frequent and complete tests are assurance against serious trouble. Auxiliary or stand-by power units need to be operated at intervals, both to insure that they will be ready when needed and to insure that the operators are capable of handling them in case of necessity. Cases of trouble due to neglect of this obvious precaution were cited.

Preframing of timber before preservative treatment, and even for timber that is not to be treated, is in-