AMERICAN CONSULTING ENGINEERS COUNCIL'S

HEAVY MOVABLE STRUCTURES
MOVABLE BRIDGES AFFILIATE

3RD BIENNIAL SYMPOSIUM

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SESSION
WORKSHOP NOTES

Session (6-3)
"State Street ... Bridge Over The Root River, Wi." W.Grinstead, Harrington & Cortelyou, Kansas City, Mo.

ABSTRACT

The project began with an inspection and evaluation of a double–leaf bascule bridge to determine the feasibility and economic justification for major rehabilitation. Subsequent studies were conducted to determine the most suitable and economical type of replacement structure. A major consideration was the elimination of a deep counterweight pit and related pumping requirements, which caused problems in the existing structure due to frequent flooding and freezing.

The new structure is a single leaf, rolling–lift type bascule span, with prestressed concrete girder, fixed approach spans. The bridge is operated by an electro–mechanical drive system with programmable computerized controls. Torque meters provide digital readout of operating torques at the control panel. A traffic barrier was provided at the leaf tip, which automatically raises and lowers with operation of the bascule span. The bridge is in an historic district of the City of Racine, which influenced the architectural treatment of the operator's house, sidewalk railing, bascule girder geometry and other features of the design. Construction was completed in 1989.

STATE STREET BASCULE BRIDGE

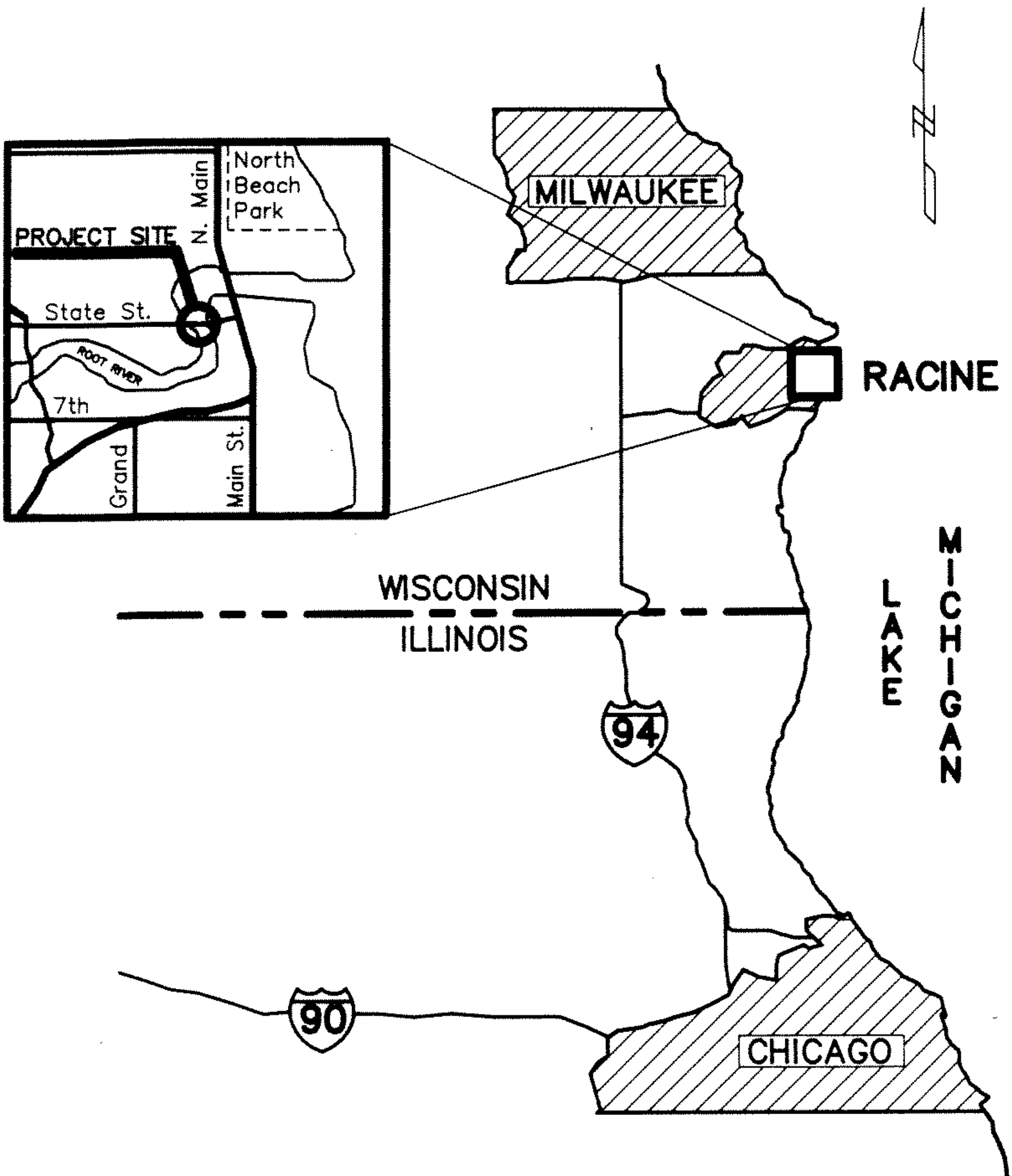
A Single Leaf Span
Over the Root River in Racine, Wisconsin

INTRODUCTION

The City of Racine, Wisconsin is situated on Lake Michigan, approximately 25 miles south of Milwaukee, and 70 miles north of Chicago, Illinois. Project Site and Vicinity Maps are shown on Figure 1. Population of the City exceeds 85,000. The Root River winds through the City and is crossed by Wisconsin S.T.H. 38 at the second bridge upstream of Lake Michigan. This is also State Street in Racine. Navigation on the river is almost entirely of recreational type, consisting of sailboats and small cruisers with occasional commercial craft for sport fishing on the Lake. The navigational channel is under jurisdiction of the United States Coast Guard, Ninth District, Cleveland, Ohio.

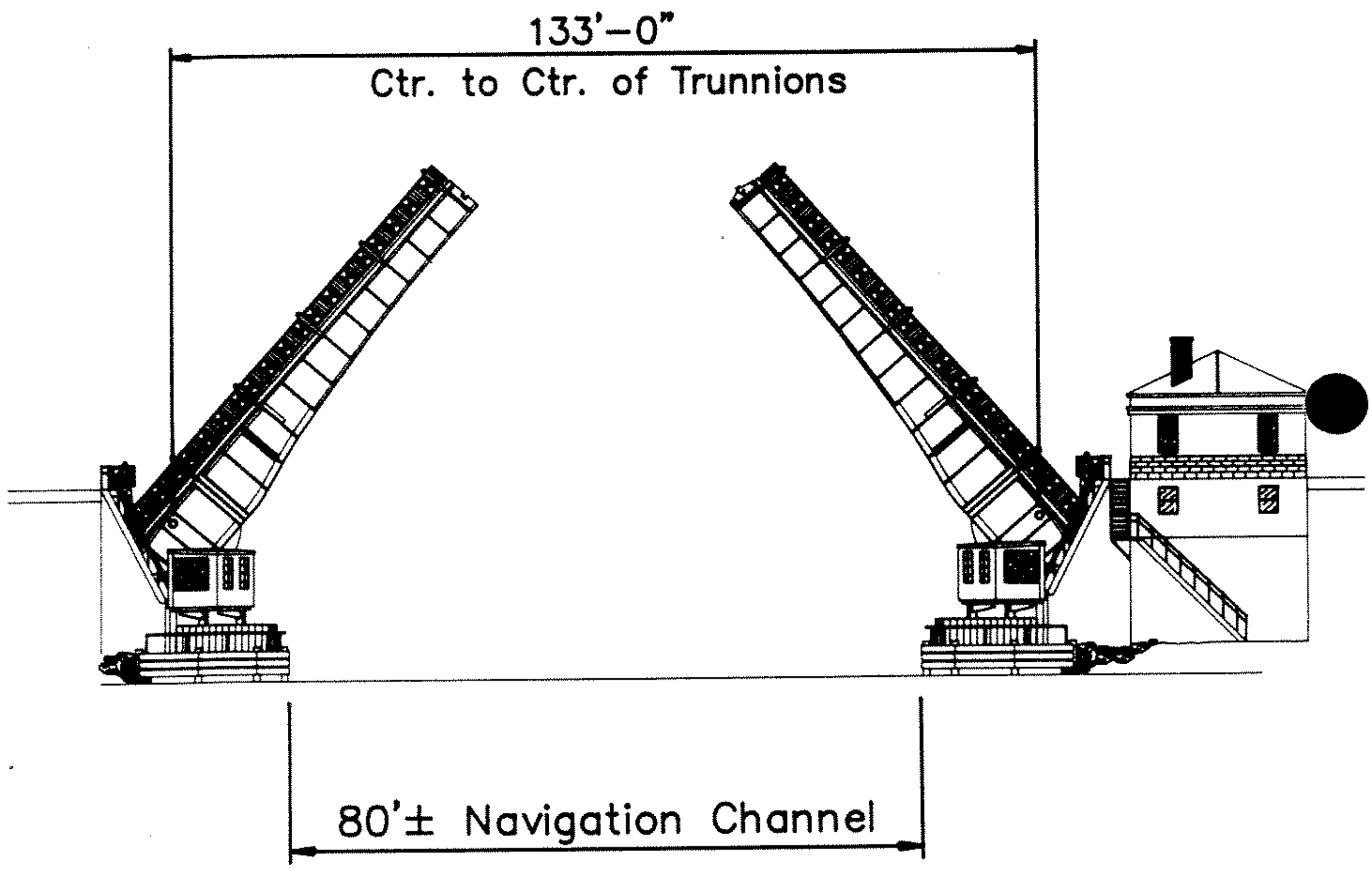
The original bridge at the State Street Crossing of the Root River was constructed in 1921. It was a double-leaf, trunnion type bascule span with a 40 foot clear roadway width, and 10 foot wide sidewalks on each side. The distance center to center of trunnions was 133 feet, as shown on Figure 2. The leaves and trunnion support tower members were essentially identical. Operating power was provided at each of the four trunnions. These sets of machinery were also identical and raising and lowering of the bascule leaves was accomplished by rack and pinion drives. The original machinery layout is shown on Figure 3. The bridge was designed to carry trolley traffic in addition to vehicular traffic. At the time the Wisconsin Department of Transportation began consideration of rehabilitation or replacement in 1982, their records indicated approximately 3,100 openings per year, to pass about 4,400 boats. The bridge had a Federal Highway Administration Sufficiency Rating of 12.

In 1983, Ayres Associates of Eau Claire, Wisconsin, was awarded a contract as prime consultant to conduct preliminary engineering studies for a rehabilitation or replacement project. The project scope included the fixed approach spans to the bascule unit, and substantial approach roadway and street reconstruction. Harrington & Cortelyou, Inc. of Kansas City, Missouri were consultants to Ayres Associates for engineering investigations involving the movable span and the bridge drive system. An inspection and report on the bascule spans was completed by Harrington & Cortelyou in 1983.



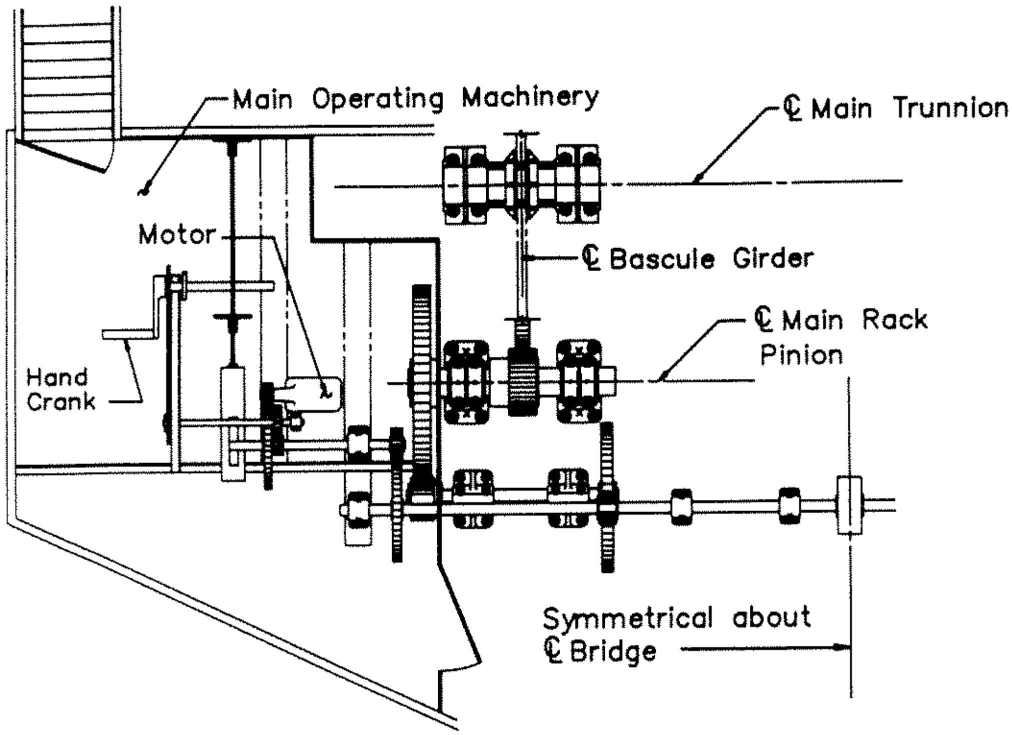
PROJECT SITE AND VICINITY MAPS

FIGURE 1



ORIGINAL BASCULE SPAN

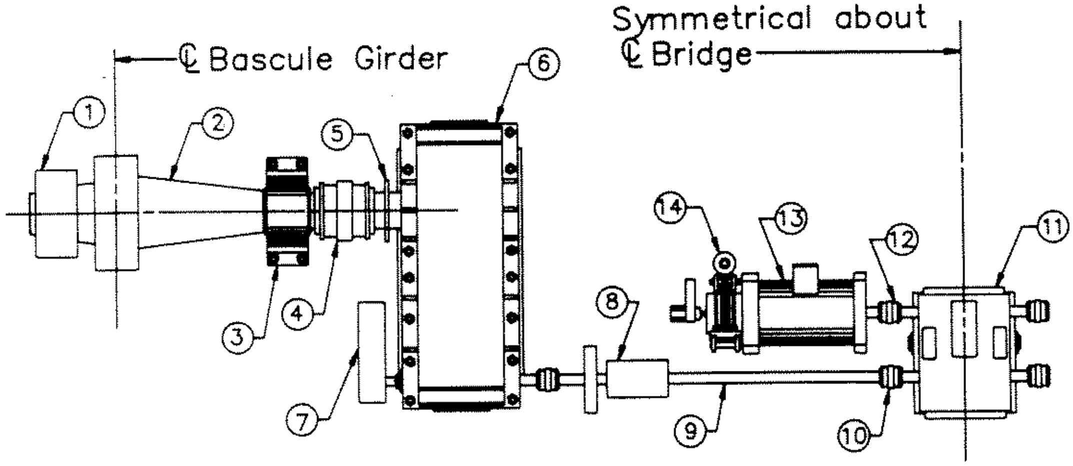
FIGURE 2



ORIGINAL MACHINERY LAYOUT

FIGURE 3

1. Drive Pinion
2. Pinion Shaft
3. Pinion Shaft Bearing
4. Pinion Shaft Coupling
5. Torque Meter
6. Outboard Reducer
7. Machinery Brake
8. Selsyn Transmitter
9. Drive Shaft
10. Drive Shaft Coupling
11. Central Reducer
12. Motor Coupling
13. Electric Motor
14. Motor Brake



NEW MACHINERY LAYOUT

FIGURE 4

INSPECTION OF THE EXISTING BRIDGE

An inspection of the bridge and site was conducted on August 22 through 26, 1983. Except for a few short periods of time, the bridge was kept operable to accommodate both boat and vehicular traffic throughout the inspection. The Department of Public Works of the City of Racine provided maintenance personnel to assist throughout the inspection. They also provided maintenance repair records, and other available data pertaining to the operation of the bridge.

The inspection was conducted in general accordance with pre-prepared checklist forms and schedules. A thorough visual inspection was made of all elements however, it was not possible to remove the caps and open the larger bearings for inspection. The cap bolts had deteriorated to the extent that any attempt at removal would have destroyed them. Deficiencies noted in previous reports were compared with the present condition of the structure to assist in assessing additional deterioration or needed repairs.

Based on results of the field investigation and inspection, review of previous inspection reports, review of available maintenance records, and discussions with maintenance personnel, it was most apparent that an extensive rehabilitation of the structure was necessary if its useful service life was to be appreciably extended. In the meantime, considerable expense to maintain the bridge in a safe and operable condition would be incurred.

The cost for thorough rehabilitation of the bascule leaves and the bridge drive system was estimated to be in excess of $1,000,000 as shown below in Table No. 1. This amount represented the cost for rehabilitation only, and did not include major replacement or upgrading of elements in the drive system.

TABLE NO. 1

Estimated Cost of Rehabilitation
1983 Price Levels

Bascule Girder Repairs	$ 101,000
Floorbeam Repairs	70,000
Counterweight Repairs	56,000
Trunnion Tower Repairs	119,000
Machinery Repairs	376,000
Electrical Modifications and Repairs	35,000
Painting	100,000
Miscellaneous Repairs (15%±)	143,000
Subtotal	$1,000,000
Contingencies (10%±)	100,000
Total Estimated Rehabilitation Cost	$1,100,000

The cost for replacement of the bascule bridge with a new double-leaf bascule structure was estimated to be as shown below in Table No. 2. The new structure as recommended would provide comparable navigation clearances, and would be constructed with a 12 foot wider roadway, ie. 52 feet curb to curb. Five foot sidewalks would be provided on each side.

TABLE NO. 2

Estimated Replacement Cost
1983 Price Levels

Removal of old Bridge	1	Lump Sum	@	$200,000.00	$ 200,000
Excavation for Structures	2,000	Cu. Yd.	@	30.00	60,000
Cofferdams	1	Lump Sum	@	125,000.00	125,000
Steel Piles HP 12 x 53	3,760	Lin. Ft.	@	25.00	94,000
Concrete Masonry-Bridges	1,300	Cu. Yd.	@	300.00	390,000
Reinforcing Steel	130,000	Lb.	@	0.50	65,000
Structural Steel	310,000	Lb.	@	1.60	496,000
Fender System	1	Lump Sum	@	30,000.00	30,000
Bridge Railing	280	Lin. Ft.	@	75.00	21,000
Open Grid Roadway Grating	140,000	Lb.	@	1.40	196,000
Concrete Filled Sidewalk Grating	40,000	Lb.	@	0.70	28,000
Counterweight Concrete	320	Cu. Yd.	@	150.00	48,000
Operating Machinery	1	Lump Sum	@	275,000.00	275,000
Electrical Work	1	Lump Sum	@	520,000.00	520,000
Operators House	1	Lump Sum	@	40,000.00	40,000
		Total Estimated Replacement Cost			$2,588,000

As shown by the estimates in Table Nos. 1 and 2, repair and rehabilitation of the existing structure represented the lowest first cost by a substantial margin when compared to the replacement alternative. However, the structure was approximately 60 years old and had fulfilled all reasonable expectation of useful service life. Repair and rehabilitation would have extended the life of the structure, however many elements that had no apparent defects at the time could have been approaching the end of their service life and could have failed at any time through fatigue. Thus, no assurance could be given the owner that restoration of the bridge and equipment would extend the useful life of the bridge for any appreciable amount of time. Maintenance and repair costs would continue to be high and little improvement in conditions at the site would be realized.

The Wisconsin Department of Transportation subsequently approved a Design Study Report recommending replacement of the structure. A double-leaf bascule was recommended by the consultants, and was the preferred type by the DOT and City. However, the Federal Highway Administration concluded that a single-leaf type would be constructed because of a nominal savings in project cost that was indicated in further cost estimate refinements.

FINAL DESIGN AND CONSTRUCTION PLANS

General

In 1985, the Wisconsin Department of Transportation authorized Ayres Associates and Harrington & Cortelyou to prepare final design and construction plans for the replacement project. The initial tasks included preparation of final design criteria for the movable structure, and determination of owner preferences and requirements that would be incorporated into the completed bridge and drive system.

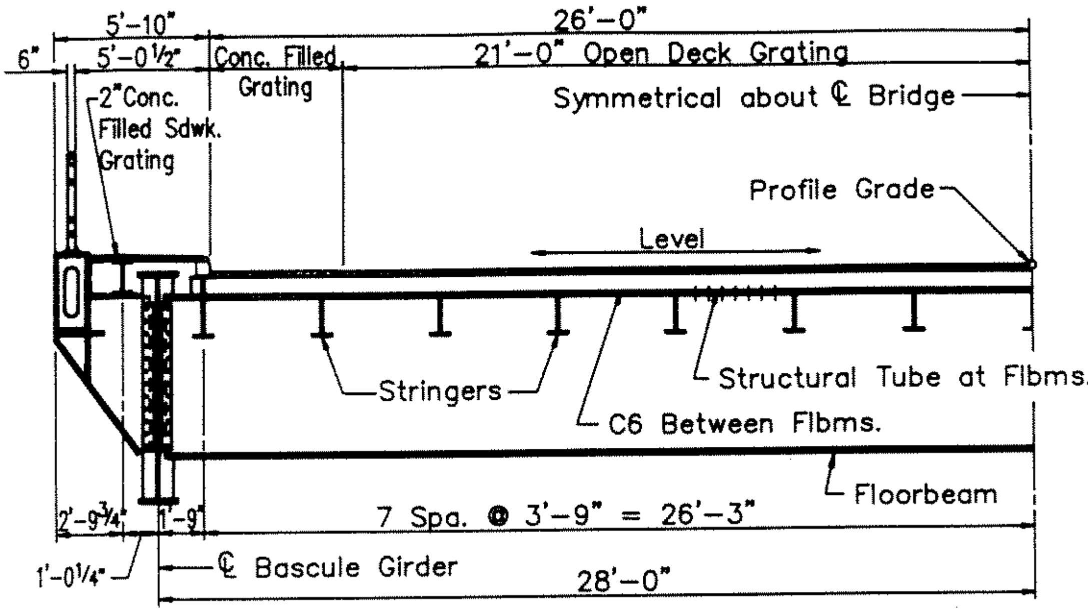
Existing grades at each end of the improvement dictated a low-level structure rather than a medium or high-level grade for the new alignment. This necessitates frequent openings for nearly all types of craft that navigate the river. Available structure depth was also restricted by the level of the river which is less than 20 feet below profile grade. These factors combined to provide an unusually short counterweight arm distance to balance the bascule leaf. These factors, and the design of the bascule pier, which avoided the troublesome counterweight pit, that was a maintenance problem in the original bridge, are further discussed in subsequent sections of this paper.

Bascule Type

Owner preference was for a rolling lift type of bascule span. Also, owner preference was for an electro-mechanical drive system, rather than hydraulic power. This preference was primarily influenced by future maintenance considerations, in that City maintenance personnel were already trained in operating and servicing comparable electro-mechanical drive systems in the original bridge and in the nearby Main Street bascule bridge. However, preliminary studies were prepared for a trunnion type bascule, and for a hydraulic drive system for purposes of comparison. These studies did not indicate significant cost differences with either type of span or drive system.

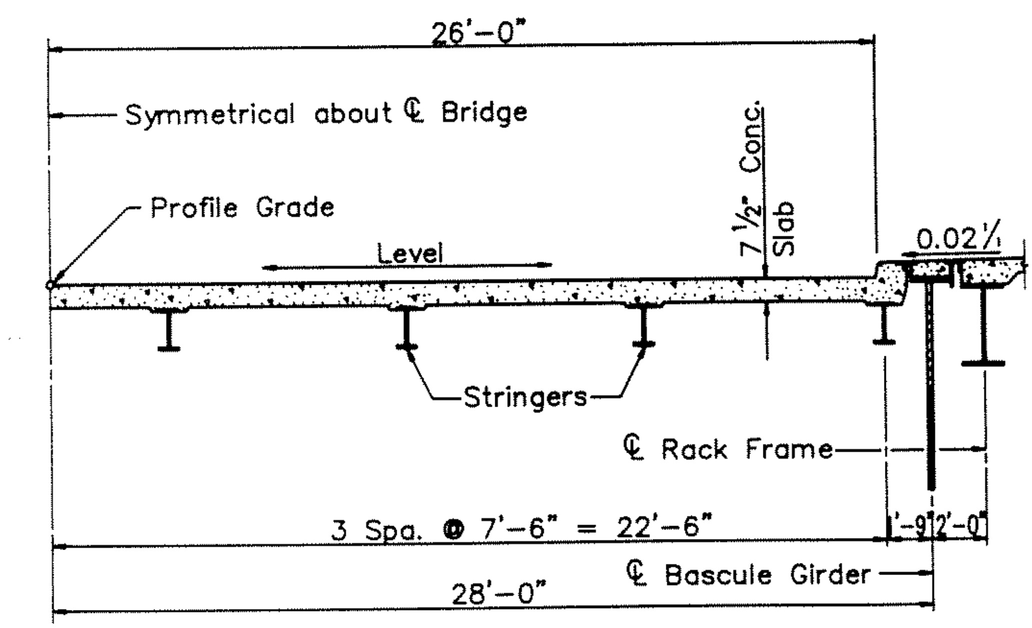
Movable Span Description

The single leaf spans 82 feet from centerline of pinion to centerline of bearing on the rest pier with the bridge is in the closed position. Total width of the bridge is 63.7 feet which provides for a 52 foot clear roadway and 5 foot wide sidewalks on each side. The roadway carries four 10.5 foot traffic lanes and two 5 foot shoulders. The floor system consists of open steel grating on steel stringers with concrete filled steel grating at the shoulders to accommodate bicycle traffic. A portion of the span over the machinery room is constructed of reinforced concrete slab on steel stringers. Typical roadway cross sections are as shown on Figures 5 and 6.



TYPICAL SECTION

FIGURE 5



SECTION AT MACHINERY ROOM

FIGURE

Navigation Clearances

When the span is in the closed position, a minimum vertical underclearance of 10.6 feet above high water is provided near the bascule pier. Vertical underclearance near the rest pier at the shallow end of the girder is 14.5 feet. Water elevation is considered to be the 100 year high water surface elevation of Lake Michigan. When the span is fully open at 76°, a clear horizontal opening of 65 feet with unlimited vertical clearance for navigation is provided. Due to the skewed alignment of the 40 foot wide navigation channel, the horizontal clearance between fenders was established at 69 feet.

Architectural Considerations

The bridge is located in an historic district of the City of Racine. Several prominent historical buildings are located adjacent to the project. Consideration of the surrounding architecture influenced the appearance of several visible features of the design, including the operator's house, sidewalk railing, sidewalk edge beam and street lighting. Brick siding was used for the operator's house which provided compatibility with the surrounding old industrial type buildings, and reflected the typical type of construction for their period. The house is roomy and substantial in appearance partly for architectural reasons and partly because it was designed to also house an operator's console and bridge control equipment for another nearby movable bridge. It was intended that both bridges could ultimately be operated from this same location. The configuration and details of the original sidewalk railing and roadway lighting fixtures were duplicated in the new construction. This required special steel casting for the picket-type pedestrian railing, and special construction methods for the arm and globe type roadway lighting fixtures. The local historical society participated in the final selection of these features. A smooth, continuous edge beam was used to provide clear delineation of the railing features. As discussed in another section of this paper, a below-deck traffic barrier was designed, to avoid the trusswork construction necessary for an overhead type. This selection was also influenced by the local historical society of Racine.

Mechanical Bridge Drive

The design for the mechanical bridge drive system was prepared in accordance with the current American Association of State Highway and Transportation Officials Standard Specifications for Movable Highway Bridges. The time for rotating the span through the normal 76° raise or lower cycle was set at 1-minute. A maximum amount of rotation of 80° was provided as permissible span overtravel.

BASCULE LEAF DESIGN

Primary support of the bascule leaf consists of two bascule girders spaced 56 foot center to center. Transverse floorbeams on 14.5 foot centers, spanning between the bascule girders, support the open grating and steel stringer floor system.

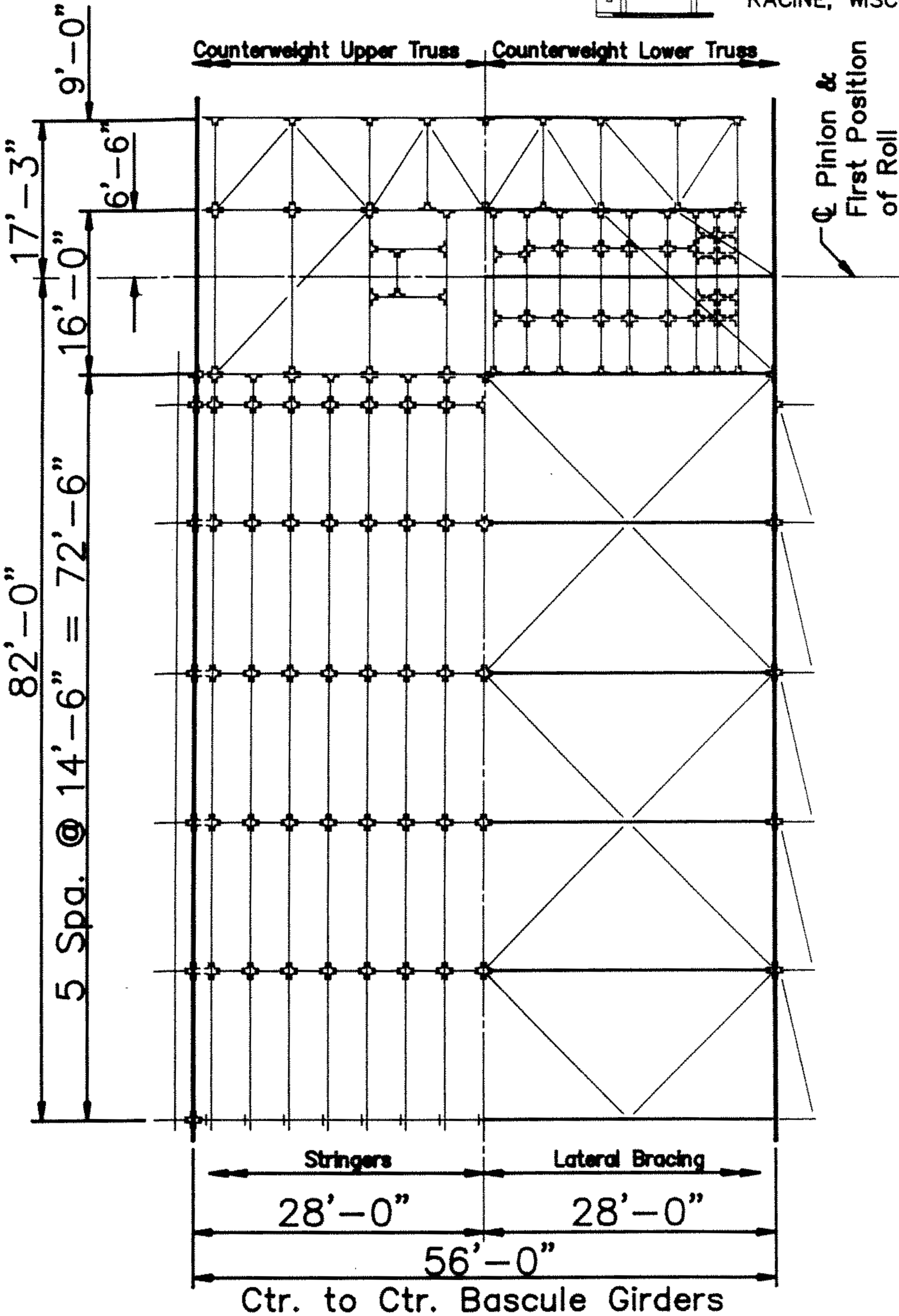
Tee-shaped lateral bracing, cut from wide flange sections, is provided to adequately transfer loads to the girders when the span is in the fully open position. Cantilevered sidewalk brackets support the concrete filled sidewalk grating, boxed edge beam and decorative railing. A layout of the framing plan showing the various components of the bascule leaf is shown on Figure 7.

Several combinations of loading and span position are considered in the design of bascule girders. In a balanced condition, the counterweight nearly balances the weight of the span about the first position of roll, leaving only a small dead load reaction at the tip of the girder. Therefore, the bascule girder is designed as a cantilevered girder when subject to dead loads only. The cantilever effect of the counterweight on the span can be seen in the Dead Load Deflection Diagram shown on Figure 8. When the structure is subjected to live load, the river arm acts as a simply supported girder, spanning between the rest pier and the first position of roll. The combined effect of dead load, live load and impact results in a stress reversal condition on 60% of the girder span. These and other fatigue effects caused from reversing direction of span movement, are addressed in the design. All web and flange plates in the bascule girder are designed as fracture critical members.

The high combined moments and shears in the bascule girder near the first position of roll required the use of a 12 foot web depth in this area. The naturally decreasing cantilever moments and shears toward the tip of the girder permitted transitioning of the web depth to 4.5 feet while maintaining allowable design stresses. A third degree curve was used to define a portion of the bottom of the web profile in order to fit the geometrics and underclearance requirements of the site, and to provide a more aesthetically pleasing girder appearance from the channel vantage point. An elevation view of the bascule girder is shown on Figure 9.

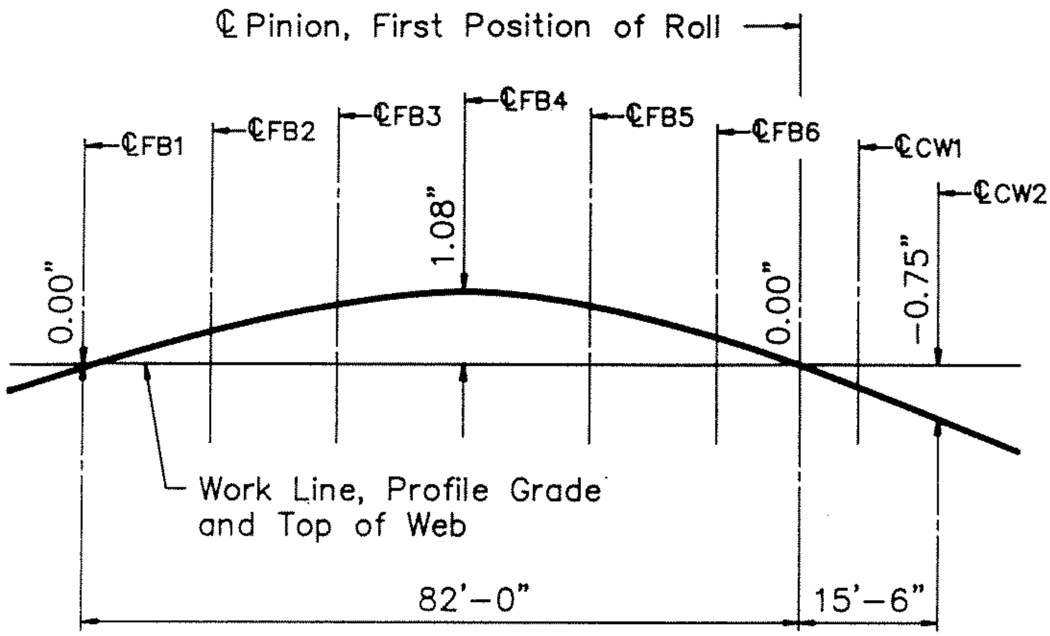
A short counterweight arm was required to keep the counterweight from dipping into the water when the span was raised. Billet steel was added to the counterweight during construction to permit the use of ordinary weight concrete in the counterweight. The concrete counterweight is supported by two embedded steel trussed floorbeams spanning between the bascule girders.

A SINGLE LEAF SPAN
RACINE, WISCONSIN



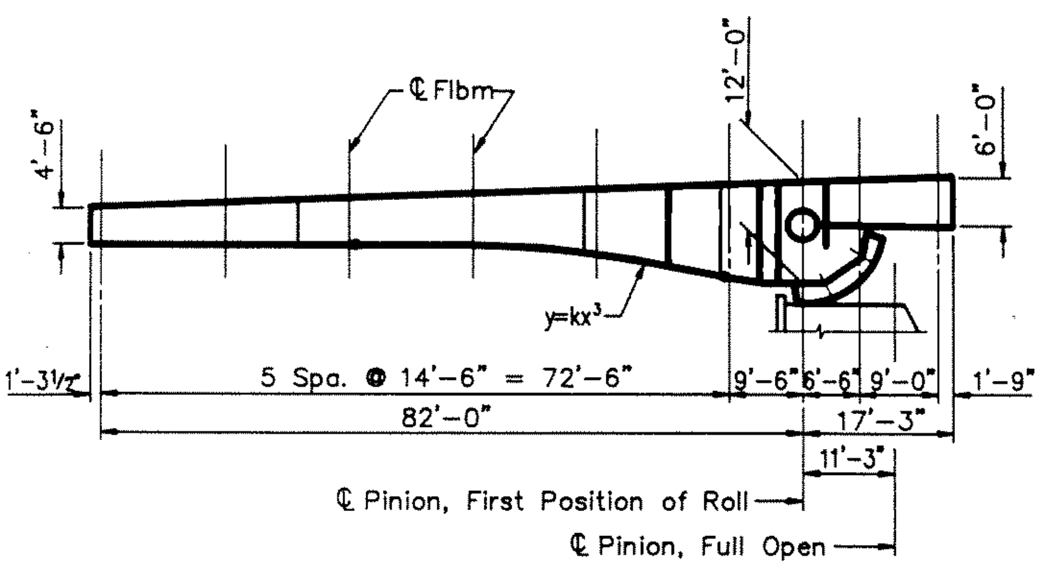
FRAMING PLAN

FIGURE 7



DEAD LOAD DEFLECTIONS

FIGURE 8



GIRDER ELEVATION

FIGURE 9

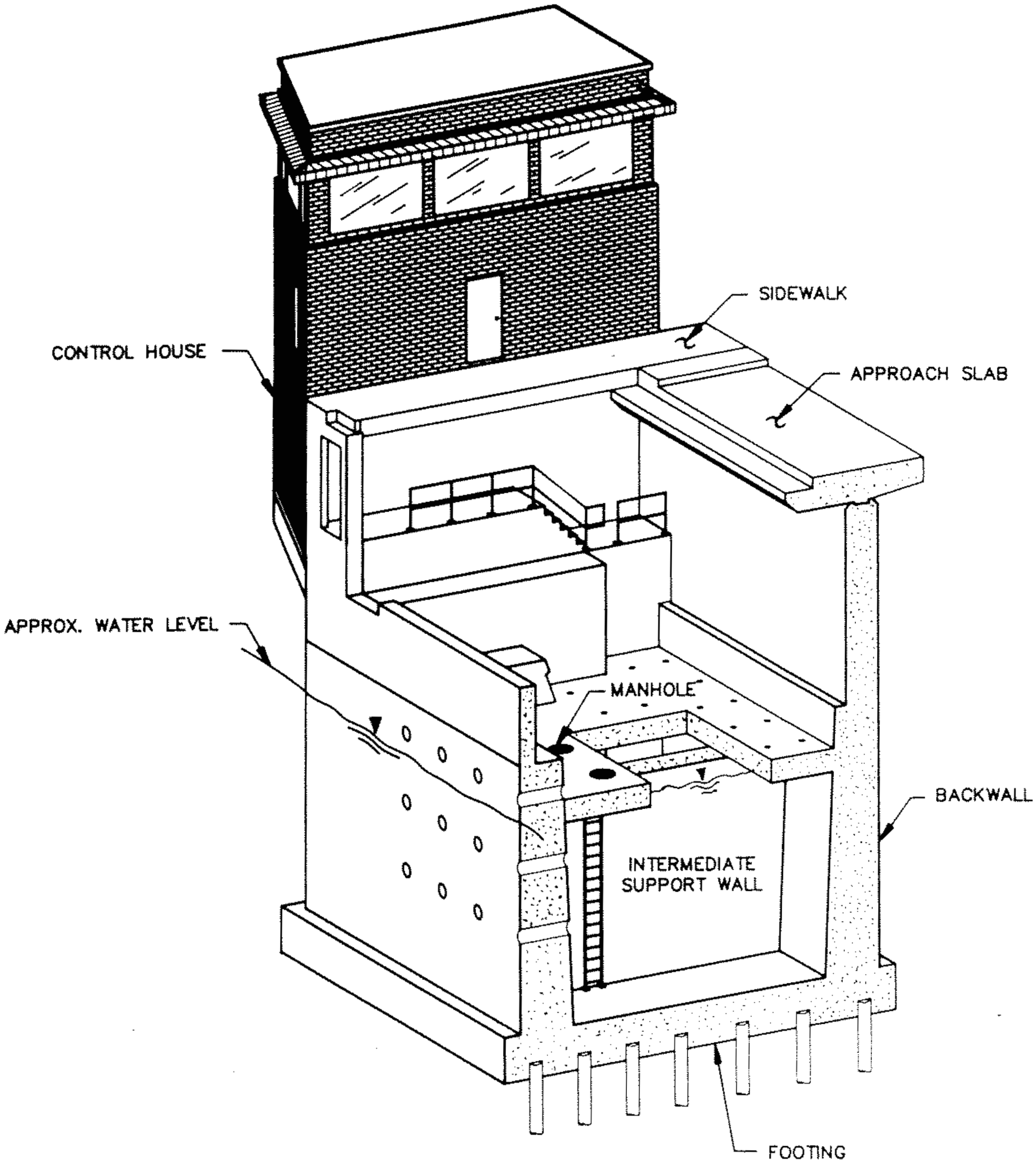
BASCULE PIER DESIGN

The bascule pier supports the movable bascule span and the approach span, and resists the design loadings applied to the pier and bascule leaf for all positions of span movement. Dead load considerations include the weight of water in the pier well and the 915 kip operator's control house cantilevered from the south end of the pier. AASHTO Group II loading with wind load applied to the fully open leaf controlled the design of the foundation piling.

Subsurface investigations performed during the preliminary phase of the project indicated steel end bearing piling was desirable for this location. A total of 91 - HP 14 x 73 driven to 128 tons per pile were required to meet the design loadings. During construction, gravel filled oil field steel pipe piles, of approximately equal capacity, were substituted for the H-piles on a one to one basis at the contractor's request. Pile lengths of approximately 30 feet were required to penetrate the silty clay subsoil and bear on bedrock.

The bascule pier provides a large open area within the pier to accommodate the counter-weight movement during span openings. The pier is stiffened by intermediate support walls located within the well. A cut-away view showing the major components of the bascule pier is shown on Figure 10.

On the original bridge, as with many other D.O.T. bascule bridges, dewatering of the counterweight pit with a pumping system required constant maintenance and costly servicing. To avoid these long term maintenance costs on the new bridge, 15 inch diameter holes were provided through the bascule wall to allow water into the pier well, eliminating the need for a pumping system. The water level in the pier matches the water level of the river. An intermediate floor is provided above the normal water surface elevation to brace the pier walls and maintain a dry surface area for access to the counterweight pit. Several 4 inch diameter holes in the intermediate floor allow for extreme fluctuations in river level. Additional reinforcing bars were placed across the 15 inch holes to preclude unauthorized entry to the pit for safety reasons. Batter on the inside faces of the pier walls allows for expansion should freezing occur in the well.



SECTION THRU BASCULE PIER

FIGURE 10

POWER REQUIREMENTS

The AASHTO Specifications require that the operating machinery for bascules shall be proportioned and power shall be provided to move the span under the following conditions:

Condition A. In the normal time for opening: against frictional resistances, inertia, unbalanced conditions, and a wind load of 2.5 psf.

Condition B. In not more than 1.5 times the normal time for opening: against the loads specified in Condition A plus an ice load of 2.5 psf.

Condition C. In not more than 2.0 times the normal time for opening: against frictional resistances, inertia, unbalanced conditions, a wind load of 10 psf and an ice load of 2.5 psf.

The power requirements for the State Street Bridge are summarized below:

OPERATING TORQUE (FT-LBS)

Operating Load	SPAN DOWN Start	SPAN DOWN Accelerate	SPAN DOWN Run	SPAN UP Start	SPAN UP Accelerate	SPAN UP Run
Condition A						
Friction	190	126	126	190	126	126
Inertia	–	99	–	–	99	–
Unbalance	410	410	410	99	99	99
Wind	495	495	495	493	493	493
Condition A Total	1,095	1,130	1,031	782	817	718
Condition B						
Friction	190	126	126	190	126	126
Inertia	–	66	–	–	66	–
Unbalance	410	410	410	99	99	99
Wind	495	495	495	493	493	493
Ice	495	495	495	119	119	119
Condition B Total	1,590	1,592	1,526	901	903	837
Condition C						
Friction	190	126	126	190	126	126
Inertia	–	49	–	–	49	–
Unbalance	410	410	410	99	99	99
Wind	266	266	266	1,856	1,856	1,856
Ice	495	495	495	119	119	119
Condition C Total	1,361	1,346	1,297	2,264	2,249	2,200

The required motor size is controlled by Load Condition C, *Starting : 2,264 Ft. Lbs. Torque, measured at the center of roll.*

In accordance with AASHTO Specifications, 2 - 900 Rpm, 50 Hp, electric motors were used.

OPERATING MACHINERY

The AASHTO specifications require the operating machinery to be designed at normal allowable unit stresses for 150% of the full-load rated torque of the electric motor prime mover. In addition, the machinery is to be designed to be capable of holding the span in the open position against a wind load of 20 psf at 150% of the normal allowable unit stresses. Accordingly, the following mechanical elements were selected, with manufacturers suitable equipment and alternate suppliers denoted on the plans as shown below. A layout of the main drive machinery is shown on Figure 4.

OPERATING MACHINERY SCHEDULE			
ITEM	NO. REQ'D.	DESIGN REQUIREMENTS	SUITABLE EQUIPMENT
MOTOR COUPLING	2	FLEXIBLE COUPLING - CAPACITY 30 HP @ 100 RPM	FALK TAPERED GRID STEELFLEX COUPLING NO. 1090T20 SIER BATH HORSBURGH & SCOTT
CENTRAL REDUCER	1	PARALLEL SHAFT HORIZONTAL HELICAL GEAR REDUCER WITH INTEGRAL DIFFERENTIAL AND DOUBLE EXTENDED HIGH AND LOW SPEED SHAFTS. APPROXIMATE RATIO 9.2:1. TORQUE CAPACITY 51,000 IN. LB. SERVICE FACTOR 1.0 DURABILITY AND 1.5 STRENGTH AT THE LOW SPEED SHAFT.	PHILADELPHIA GEAR CORP. SPECIAL NO. 51KHPD HORSBURGH & SCOTT FALK
DRIVE SHAFT COUPLING	4	FLEX-RIGID GEAR COUPLINGS. DOUBLE PILOTED FLOATING SHAFT ASSEMBLIES. COUPLING CAPACITY OF 140 H.P. @ 100 RPM. TWO SQUARE KEYS PER COUPLING.	PHILADELPHIA GEAR NO. 3H-ER, OR SIER BATH F-3-1/25, OR FALK 1035G
DRIVE SHAFT	2	HOT ROLLED STEEL SHAFT - 3-15/16 IN. DIA.	ASTM A675 GR75
OUTBOARD REDUCER	2	PARALLEL SHAFT HORIZONTAL HELICAL GEAR REDUCER WITH DOUBLE EXTENDED INPUT SHAFTS AND SINGLE EXTENDED OUTPUT SHAFTS. OUTPUT SHAFT EXTENSION SHALL ACCOMMODATE THE TORQUE METERS. APPROXIMATE RATIO 70:1 TRIPLE REDUCTION. TORQUE CAPACITY 3,500,000 IN. LBS. SERVICE FACTOR 1.0 DURABILITY AND 1.5 STRENGTH AT THE LOW SPEED SHAFT.	PHILADELPHIA GEAR CORP. SPECIAL NO. 195HPX-3 HORSBURGH & SCOTT FALK
PINION SHAFT COUPLING	2	DOUBLE ENGAGEMENT GEAR COUPLINGS. COUPLING CAPACITY OF 5,500 HP. @ 100 RPM. TWO SQUARE KEYS PER COUPLING.	PHILADELPHIA GEAR NO. 12 ERD, OR SIER BATH F-11, OR HORSBURGH SCOTT 12HS
PINION SHAFT BEARING	2	PILLOW BLOCK WITH SELF-ALIGNING SPHERICAL ROLLER BEARING FOR 14 IN. SHAFT DIA. FOUR BOLT CAST STEEL BASE. INSTALL WITH TURNED BOLTS TO COMPLY WITH MANUFACTURER'S RECOMMENDATIONS. RADIAL CAPACITY SHALL BE 100,000 LBS. @ 1.33 RPM MINIMUM.	TORRINGTON COMPANY SDAFS 23076 A x 140CO OR, SKF INDUSTRIES SDAF 23076 KA14
PINION FLANGE BEARING	2	FLANGE MOUNTED PILLOW BLOCK WITH SELF-ALIGNING SPHERICAL ROLLER BEARING. RADIAL CAPACITY SHALL BE 250,000 LBS. @ 1.33 RPM MINIMUM.	TORRINGTON COMPANY No. H-2170-A DETAILED ON PLANS
RACK, PINION AND PINION SHAFT	2 EACH	REQUIREMENTS SHOWN ON PLANS AND IN SPECIFICATIONS.	DETAILED ON PLANS
MACHINERY BRAKE	2	BRAKE WHEEL MOUNTED ON OUTBOARD REDUCER EXTENDED INPUT SHAFT. BRAKE TO BE MOUNTED ROTATED APPROXIMATELY 40° WITH THE SPAN DOWN AND AS RECOMMENDED BY THE BRAKE MANUFACTURER. BRAKE AND BRAKE WHEEL ARE INCLUDED FOR PAYMENT WITH ELECTRICAL EQUIPMENT. BRAKES SHALL BE SET FOR 390 FT. LBS. TORQUE.	GENERAL ELECTRIC 464 THRUSTOR BRAKE
MOTORS, MOTOR BRAKES, SPAN CONTROL EQUIPMENT AND TORQUE METERS	-	REQUIREMENTS SHOWN ON PLANS AND IN SPECIFICATIONS. MOTOR BRAKES SHALL BE SET FOR 390 FT. LBS. TORQUE.	DETAILED WITH ELECTRICAL PLANS

TRAFFIC BARRIER

The AASHTO Specifications state that two traffic gates shall generally be provided on each approach roadway to a movable span bridge. The first gate is to act as a warning device and the second is to be a physical barrier. Energy absorbing systems may be utilized for the physical barrier type. The Specifications further state that when bascule leaves effectively block the roadway, the physical barrier gates may be omitted. With a single-leaf type of bascule installation, it is most desirable, if not necessary, to provide a barrier for the protection of vehicular traffic on the side of the channel opposing the open leaf. The barrier is highly susceptible to collision and must be structurally adequate to provide a good degree of resistance. The barrier is therefore substantial, and consequently develops a significant amount of weight.

Several types of barriers and operating mechanisms were proposed to the owner. The proposals included a type of barrier that would be supported by overhead framework and lowered to roadway level prior to opening the span. An energy absorbing feature was included in the system. The owners however, were particularly concerned about aesthetics in the bridge's historical site, and thought the overhead supports, trusses, etc., would be unsightly. The use of this type of barrier was therefore rejected.

The traffic barrier considered acceptable by the owner consists of a counterweighted barrier on a movable support frame which is supported on the bascule tip rest pier. Structural steel construction was used throughout. The barrier is under-counterweighted in order that it will rise when the leaf tip is raised for a bridge opening. The process is reversed when the tip is lowered and the barrier mechanism is depressed below roadway level. The system thus functions by gravity without the application of external power. While being simple in principle, the details and installation of the system became quite complicated and congested.

When the span is closed, the barrier is not visible at roadway level, which is desirable from the standpoint of aesthetics. However, should the barrier be damaged and/or distorted by collision, there may be a lengthy delay to traffic while the mechanism is repaired or removed. This delay would likely be longer than removal of a barrier from overhead supports. Also, the bridge raise cycle has been initiated, prior to the barrier being raised and in place to protect traffic.

ELECTRIC POWER AND CONTROL SYSTEMS

The AASHTO Specifications state that if the total power necessary at the motor shaft to move the bridge under Condition A at the required speed exceeds 50 Hp, consideration shall be given to the use of two identical span-driving motors, with provision for operation of the bridge by one motor. One motor operation is to be at reduced speed as further defined in the Specifications.

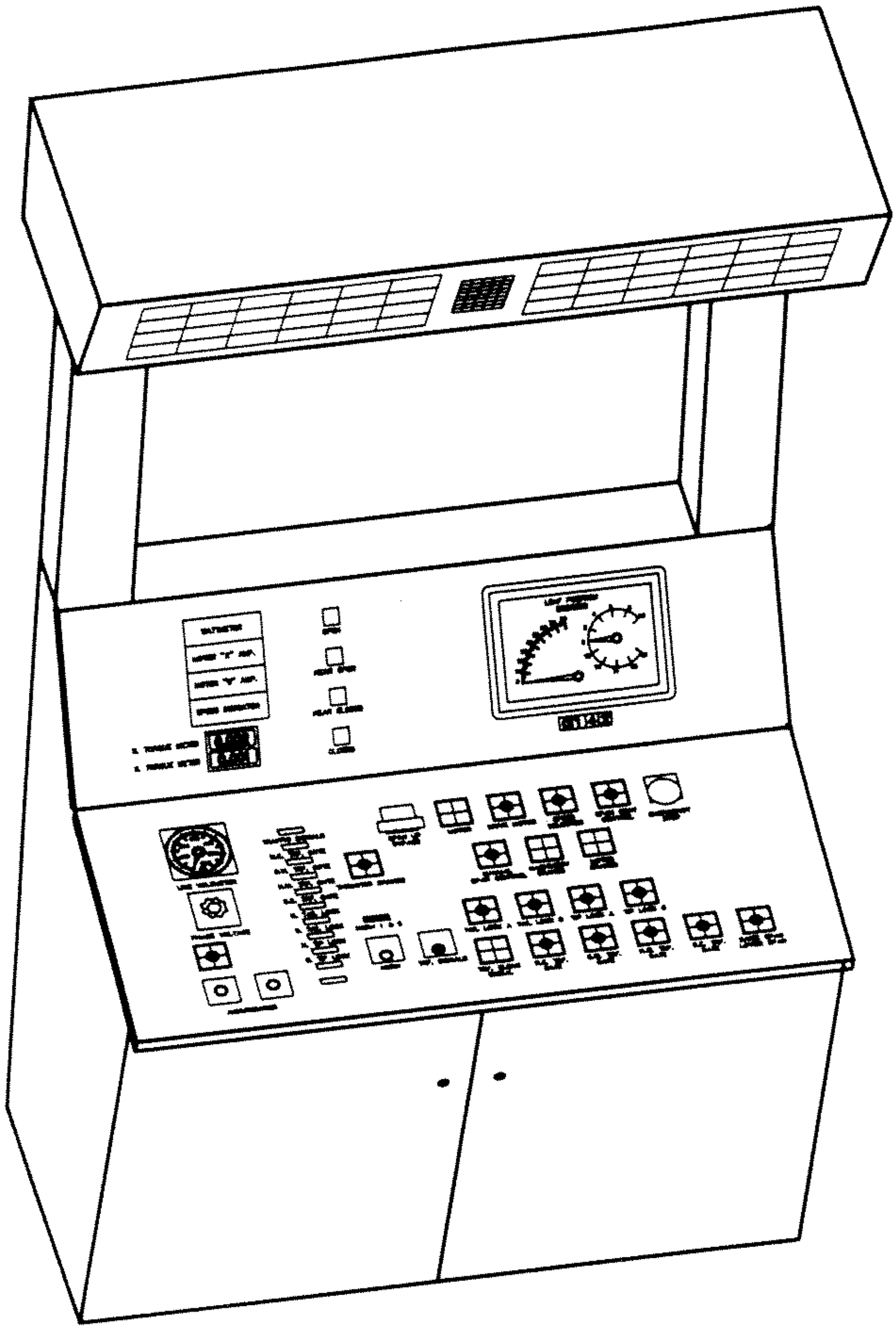
Accordingly, two 50 Hp motors were provided, each supplied with a separate and identical power system for maximum flexibility and simplified maintenance. Both motors may be used simultaneously for normal operating speed, or either of the motors may be used individually, operating at reduced speed. Selection of the operating mode may be originated at the operator's station. The span drive motors are direct current type, mill duty, totally enclosed, and suitable for regenerative braking. The motors are rated 900 RPM.

Electrical service is supplied by the utility distribution system serving the area of the bridge site. A standby diesel engine-generator set is located in the operator's house on the bascule span. It was necessary to install a submarine cable across the channel for the structure lighting, span tip lock motors and controls.

The electric bridge drive system is a fully-automatic static DC regenerative drive system, providing stepless speed control. The control provides motor countertorque for overhauling load conditions and slow down. The operator initiates the raise sequence, the span rises, and then stops automatically at the normal open position of 76° rotation, without further operator action. The lowering sequence is similar. At the nearly-open and nearly-closed positions, the speed of the span is automatically reduced. A stop switch on the control console permits stopping the span at any time with normal deceleration, using drive motor countertorque and mechanical braking. Programmable controllers, primary and backup, were installed in the system.

Torque metering was provided on each of the two main drive pinion shafts, with a digital readout for each meter at the operator's console. Measurement of the torque being delivered to each of the main rack and pinion drives can thus be measured. The systems were used for final balancing checks, and as permanent installations, will be available for future monitoring of the operating torque.

The bridge control console, programmable controllers, and standby diesel engine-generator set are housed in a three-level operator's house supported by the main bascule span pier. A diagram of the operator's control console is shown on Figure 11.



CONTROL CONSOLE

FIGURE 11

OPERATIONAL CONSIDERATIONS

On a single leaf bascule girder, it is necessary to hold the tip of the river arm down when the counterweight arm is subjected to live loading. This was accomplished on the State Street Bridge by use of a 3 inch square lockbar at each girder. The lockbar is driven through a rectangular socket attached to the pier and a beveled tongue attached to the tip of the girder, after the span is seated. The beveled tongue acts as a centering device as the span is seated.

Some difficulties were experienced with the tip lock on the south bascule girder. On days when the bottom flange of this girder was exposed to early morning sun, a situation which occurred only in the fall of the year, the tip lock could not always be driven during seating operations. A vertical upward displacement of 7/8 inch was measured at the tip of the girder.

To eliminate binding between the tongue and socket, 1/4 inch of metal was removed from each side of the tongue. It was believed that the differential drive provided with the machinery would drive the south tip lock if no binding was present. Although the machinery was capable of driving the girder down, it was unable to hold the girder tip down long enough to allow the lockbar to be driven.

The driving difficulties were eliminated by modifying the bevel at the end of the lockbar. The original bevel of 3/4 inch in 3-1/2 inches was changed to 2 inches in 6-1/2 inches, allowing the end of the lockbar to engage the tongue. The thrust of the lockbar operator is adequate to drive the girder tip down and attain proper seating on those days it is necessary.

During the time those modifications were made, the north tip lock remained in place and was kept operational. This allowed the bascule span to be kept operational and open to traffic since the locks are not designed to provide bearing for the girders.

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The project organization and lines of responsibility for the new State Street Bascule Bridge Over the Root River in Racine, Wisconsin, is shown by the charts on the following pages.

Acknowledgment is finally made to the Officers and Committee personnel of Heavy Movable Structures - Movable Bridges for the opportunity to present this paper at the 3rd Biennial Symposium, held from November 12-15, 1990 in St. Petersburg, Florida.

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