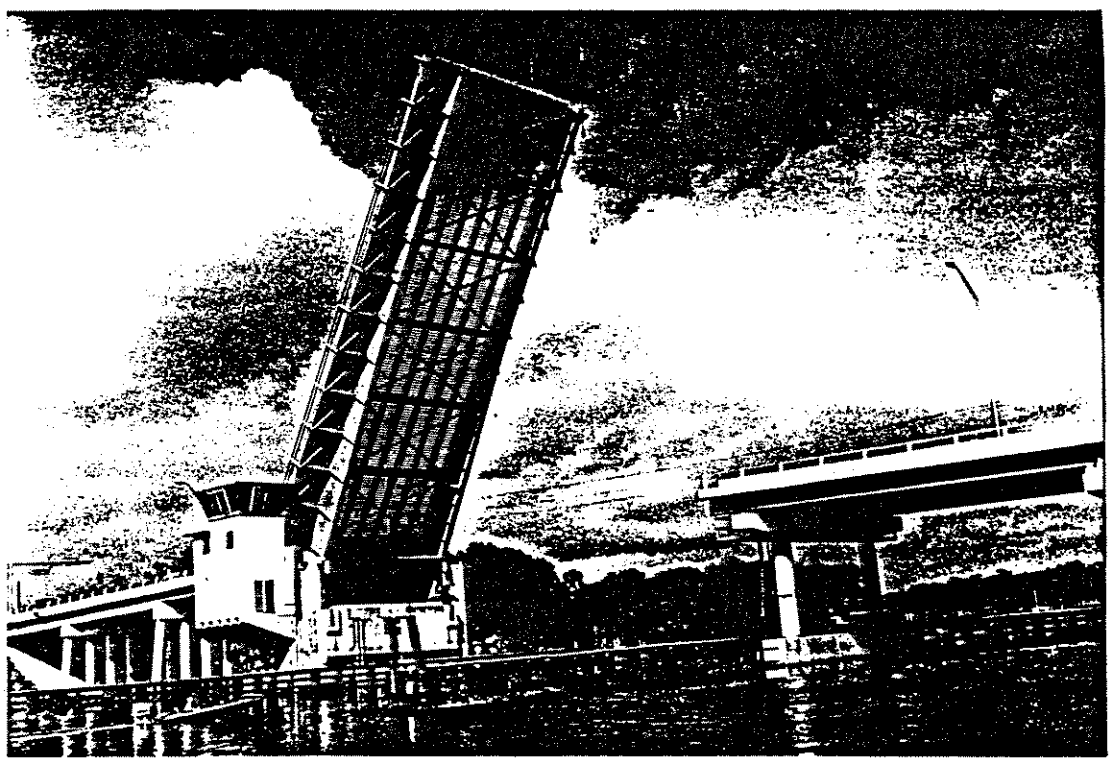
SINGLE LEAF BASCULE SPAN

ON

SR 40

AT

ASTOR, FLORIDA



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Introduction

By 1977 the low level swing bridge on State Road 40 over the St. Johns River at Astor, Florida, had become functionally obsolete and structurally deficient. Replacing this bridge posed the interesting engineering problems of what type of movable span to build, how to maintain vehicular and river traffic during construction, and designing a pleasing serviceable structure using the latest engineering practices, techniques and materials. How a single leaf bascule span, 131'-6" long from center of trunnion to end of leaf, was selected; the structural and mechanical design of the bridge; how the bridge has operated since its opening; and what might be done differently to improve the design if it were being done now is described here in the interest of bridge designers who might be faced with a similar project today.

Existing Bridge

The existing bridge which had been built by the county as a toll bridge provided a roadway width of 20 feet between trusses with no safety curb or sidewalk. The trusses supporting the swing span were 112 feet long from the center of the pivot point to each end. The bridge tender had to walk out and climb down to the pivot pier to operate the bridge and on his way out he would have to climb up on one of the trusses whenever a passing car went by. At the west end of the bridge was an operator's house that spanned across the roadway to a small room used as a toll booth when the bridge was first built. The tolls were discontinued when the state assumed the ownership and maintenance of the bridge. Understandably, some of the local residents were reluctant to see such a picturesque remnant of the past destroyed. At the time the bridge was replaced, the bridge tenders no longer lived in the house, but it did give them a place out of the weather when they were not operating the bridge.

Site Description

State Road 40 is a major east-west highway crossing North Central Florida from Ormond Beach on the east coast to Yankeetown on the west coast. It connects the north-south routes of I-95 and U.S. 1 near the east coast and U.S. 19 near the west coast with Ocala and the Silver Springs area in the center of the state. During the construction of I-95, trucks bringing limerock and fill from the vicinity of Ocala put a heavy strain on the existing bridge. In 1977, the 1995 ADT of SR 40 was estimated at 2700.

SR 40 crosses the St. Johns River about halfway from where it rises near Melbourne to where it turns east at Jacksonville and flows into the Atlantic Ocean. It is one of the large rivers of the world that flows north and is fed by a large flat drainage basin and several streams, including the Oklawaha. The height of fall from where it rises to where it empties into the ocean is small. At Astor the elevation of the water surface varies about four feet during the course of a year. The elevation of the water surface is affected by the amount of rainfall and by the tides during periods of low rainfall. At the bridge the river is about 400 feet wide and ranges up to 40 feet in depth. Some of the best bass and bream fishing in Florida is found in the St. Johns River up and down stream from Astor. Water traffic consists mostly of pleasure craft, fishing boats and towed barges transporting fuel to several large power plants south of Astor.

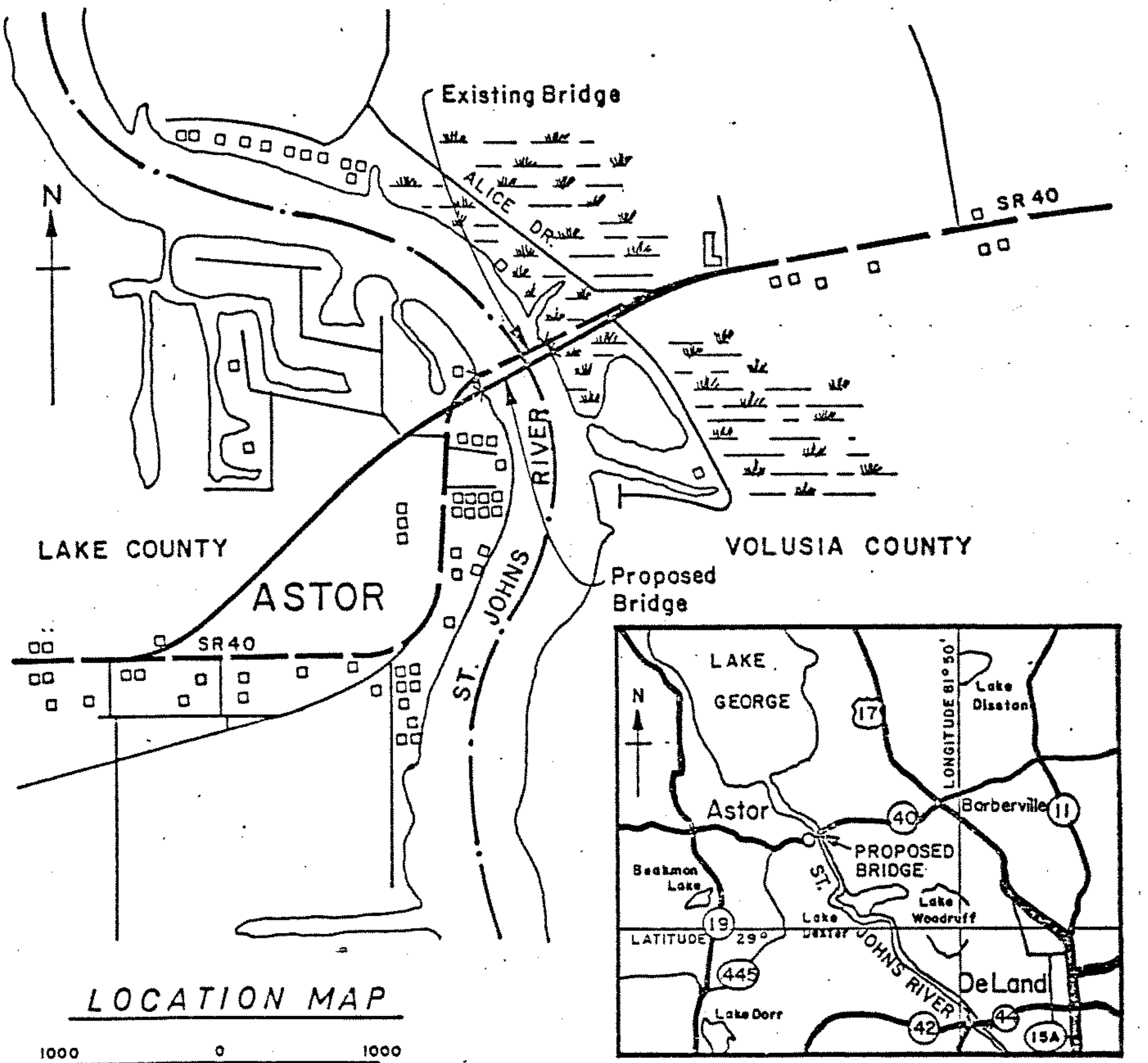
Requirements During Construction

The new bridge had to be constructed without interferring with highway or marine traffic. Curves in the existing road on each side of the river made it possible to realign the road to be parallel to the existing road and 64 feet to the south. The center of the new channel was to be located 15 feet east of the center of the west channel of the existing swing span. To maintain marine traffic during construction the existing bridge would have to swing underneath the superstructure of the proposed bridge and clear the piers on each side when the bridge was being opened. Ninety feet horizontal clearance and unlimited vertical clearance had to be provided at all times during construction. These requirements would affect the designer's grades, depth of structure and pier locations of the channel. The contractor would be permitted to reverse the direction of movement of the swing span if he desired. Location of the old bridge and realignment of the roadway is shown on Figure 1.

Selection of Bridge Type

The primary question facing the designer was what type of movable span should be built. The clear span of 115 feet between fenders required by the permit was well within the economical range of a bascule span and not long enough for the economical range of a vertical lift bridge. One channel opening was sufficient so the two channel openings provided by a swing bridge were not necessary. The question then reduced to whether to build a double leaf or a single leaf bascule span.

The Florida Department of Transportation had traditionally built double leaf bascule spans for openings of this length, but in recent years there was a belief that a single leaf bridge could be more economical with its one movable leaf, one set of drive machinery and one bascule pier to resist the large overturning forces when the leaf is in the open position.



LOCATION MAP

1000 0 1000
(IN FEET)

VICINITY MAP

OFFICIAL FLORIDA 1976 BICENTENNIAL MAP

0 5 10 20
(IN MILES)

Proposed Bridge

over S.R. 40 - ST. JOHNS RIVER

at ASTOR

County of LAKE & VOLUSIA State FLORIDA

Application by FLORIDA DEPARTMENT OF TRANSPORTATION

FIGURE 1

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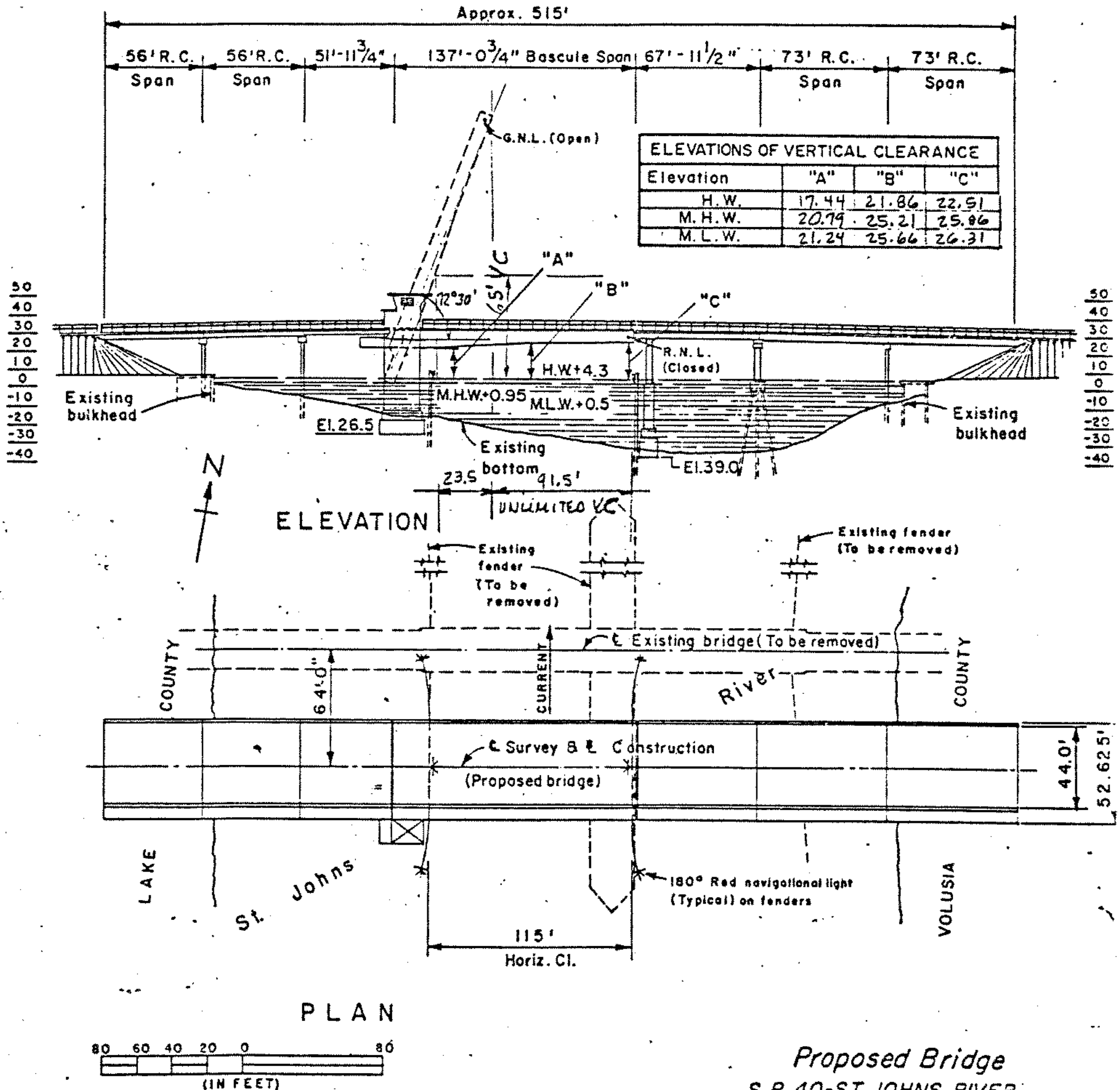
The single leaf span also has the advantage that when the bridge is closed the leaf girders have a positive support at each end when resisting the live load moments. In the case of the double leaf bascule the leaf girders are cantilevered from the live load shoes at the piers when resisting the traffic loads and can transfer shear but cannot transfer moments where they meet in the center of the span. This requires a greater depth of girder at the trunnion and greater relative weight of steel in the girders. With two leaves to span the opening the girders will be shorter, the components of the drive machinery smaller and the power requirement less for each of the two leaves. One advantage of the double leaf bascule bridge is that, when the bridge is open, the bascule leaves provide a positive barrier on each side of the channel to prevent vehicles that might crash through the barrier arms from going into the water. The single leaf span does not have such a barrier on the side of the channel opposite to the leaf and some other positive barrier must be furnished.

A truly satisfactory barrier is not easy to design and is another moving element to be maintained and repaired. Preliminary design and cost estimates were made for the movable spans and flanking spans for both a single leaf and a double leaf concept that would satisfy the required conditions. It was estimated that the single leaf concept would cost about $250,000 or 11.7% less than the double leaf concept. One condition that made the single leaf span more economical at this location was the water depth on one side of the channel was 40 feet. The cost of a bascule pier on this side of the channel which would have to resist the large overturning moments of the wind on the open leaf as would be required for a double span was considerably more than the cost of a rest pier for the single leaf span.

The cost of the single leaf concept was increased by the requirement for the positive resistance barrier on the side of the channel away from the leaf. Providing for the existing movable span to swing under the proposed bridge during construction permitted a lower grade and shorter opening width with the single leaf concept because the girder depth would be less at critical locations and space required by the rest bent would be less than space required by a bascule pier for a double leaf span. Based on the estimated cost and site conditions, the single leaf concept was selected to be built.

General Description

As shown on Figure 2, the single leaf bascule span would have a length of 137 feet from centerline of trunnion to centerline of rest pier. In order to shorten the movable leaf and reduce the overturning forces, the loads on the machinery and the power requirement, the flanking span was cantilevered six feet beyond the rest pier and designed to support the end of the bascule leaf when in the closed position. The cantilevered end was stopped outside the face of the fender so it would not encroach on the horizontal clearance.



ELEVATIONS OF VERTICAL CLEARANCE			
Elevation	"A"	"B"	"C"
H.W.	17.44	21.86	22.51
M.H.W.	20.79	25.21	25.86
M.L.W.	21.24	25.66	26.31

FIGURE 2

Proposed Bridge

over S.R. 40-ST. JOHNS RIVER

at ASTOR

County of LAKE & VOLUSIA State FLORIDA

Application by FLORIDA DEPARTMENT OF TRANSPORTATION

Sheet 2 of 3 Date 11-7

Total width of the bridge is 52'-7½" which provides for a 44 foot roadway (two 12 foot lanes and two 10 foot shoulders) and a five foot sidewalk on the south side. When the span is fully open at 74°, it provides a clear horizontal opening of 95 feet with unlimited vertical clearance and 115 feet with a vertical clearance of 72.25 feet. When the span is in the closed position it provides a vertical clearance above high water of 21.9 feet at the center of the channel; 17.4 feet at the west fender and 22.5 feet at the east fender. The size and location of the bascule pier and rest pier are such that the existing movable span could swing open in a counterclockwise direction without hitting them.

It would be required that construction of the rest pier be delayed as long as possible because a portion of the center fender of the existing bridge would have to be removed to make room to build the foundations. The east side of the river is on the outside of a fairly sharp bend which has caused the bottom to scour in this area. The bascule pier on the west side of the channel is founded in about 20 feet of water and the rest pier on the east side of the channel is founded in about 40 feet of water.

Foundation Design

The bridge boring program indicated a relatively uniform soil profile: a layer of loose sand on top of a layer of muck to Elevation -10; loose to compact sand to Elevation -38; soft to stiff clay and sandy clay to Elevation -55, and very dense to hard white limerock below approximate Elevation -55. The soil report recommended pre-stressed concrete piles as being safe for the proposed bridge. It provided an analysis that showed the safe bearing value that could be achieved with 24" square and 18" square piles at various depths. 18" square concrete piles driven to 70 tons would have a tip elevation of about -60 in the limerock.

As an alternative, 14" steel piles could achieve 70 tons bearing at a tip elevation of about -65. The bridge has end bents on the land with the piles fully embedded, a bascule pier and rest pier founded on the river bottom with the piles fully embedded, pile bents in the water with fairly long unsupported pile lengths and one pier in the water with piles extending to the water surface. It was decided to use 18" square concrete piles in the end bents and the pier with the piles extending to the water surface driven to 45 tons; 14 BP73 steel piles in the bascule pier driven to 70 tons and in the rest pier driven to 60 tons; and 20" square concrete piles in the pile bents driven to 70 tons. 45 tons was all that was required for the end bent and pier piles because of the number of piles required to resist lateral loads and maintain the minimum spacing. 20" square concrete piles were used in the pile bents because of the unsupported length and because there was a single row to resist the lateral forces.

It is common practice of the Florida DOT to use steel piles where a cofferdam is required as was the case with the bascule pier and rest pier because driving a large number of displacement piles, such as concrete piles, can exert large lateral forces on the sides of the cofferdam. The bascule pier required a large number of piles to resist the vertical loads and the wind force on the pier and open leaf. When fully open the end of the leaf reaches to about Elevation 155.

Structural Design of the Bascule Leaf

The shape of the bascule leaf as seen in Figure 6 illustrates the difference in the forces acting on a fixed span and a single leaf movable span. The geometry of the span is shown by the framing plan on Figure 3.

The leaf consists of two main girders 38 feet apart connected by floor beams at 19'-11" on center with brackets at each floor beam cantilevering six feet on one side to support a continuation of the roadway and the rail and cantilevering 7'-7" on the other side to support the sidewalk and rail. The leaf is 131'-6½" from center of trunnion to centerline of the joint at the end and 23'-10" from the center of the trunnion to the end of the counterweight.

The counterweight arm could not be made longer without its end dipping into the water when the bridge is opened. It was found to be less expensive to design a short counterweight arm even though it would require special heavy concrete than raise the grade or build a closed pit bascule pier which would provide a dry space below the water level for the counterweight to swing into when the leaf is opened.

The leaf is supported by and pivots around the trunnion bearings and is proportioned to be balanced in any position. To accomplish this, the weight of the river arm times the distance from its center of gravity to the center of the trunnion must equal the weight of the counterweight arm times the distance from its center of gravity to the center of the trunnion and a straight line connecting the two centers of gravity must pass through the center of the trunnion. In a balanced condition all of the dead load reaction is supported by the trunnion; however, bascule leaves are always designed to have a small positive reaction at the end of the river arm so that gravity will tend to keep the span closed and there will be no strain on the end locks.

When the span is closed and carrying traffic the live load reactions will be supported by the trunnion on the bascule pier and the end of the flanking span which cantilevers beyond the rest pier. A live load shoe at the edge of the bascule pier was not used because of the difficulty of providing and maintaining the correct bearing on three points. The positive live load moments are reduced by the negative dead load moments and are not large enough to warrant shortening the span by introducing a third support.

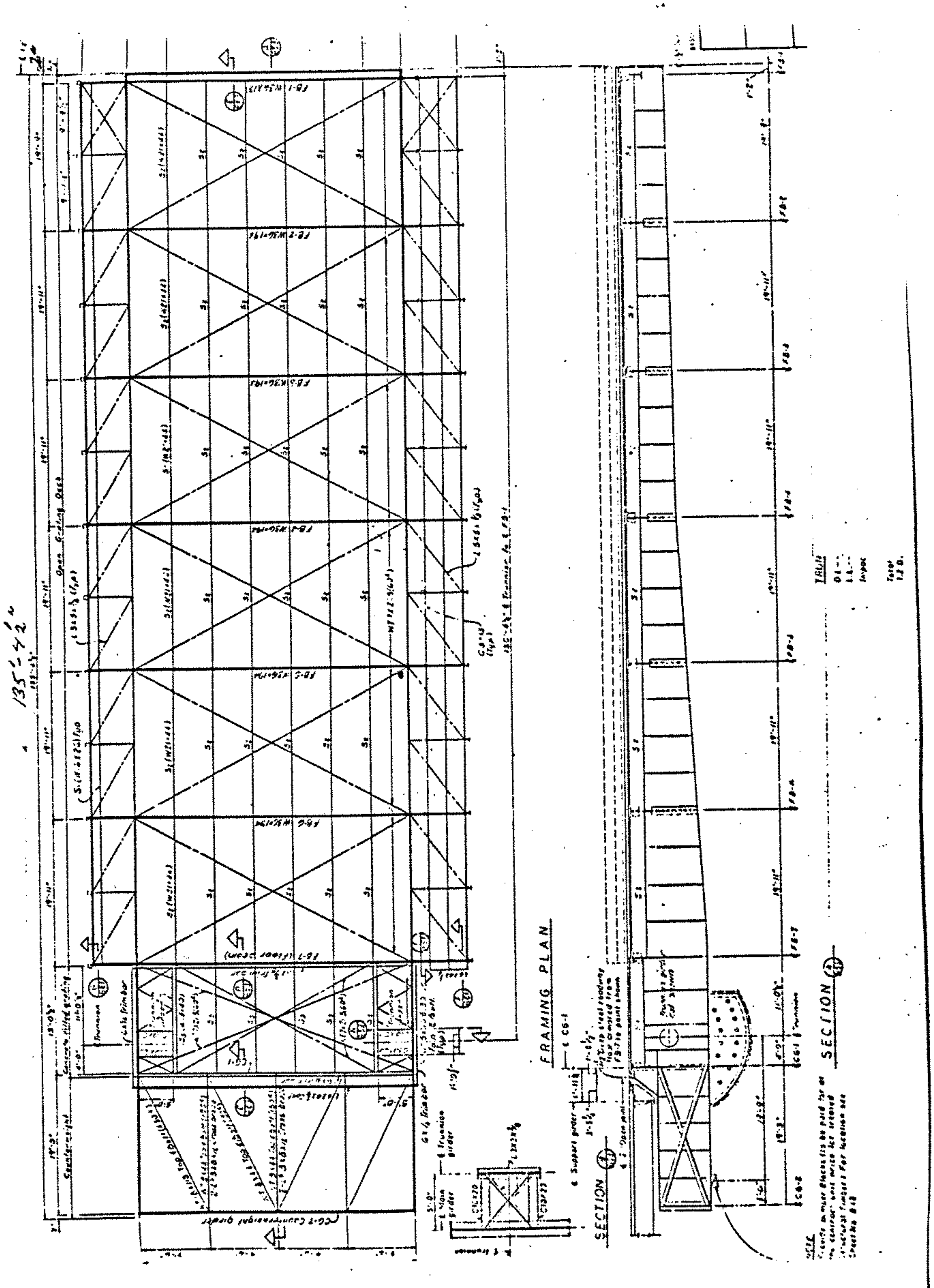


FIGURE 3

The Movable Bridge Code requires that the leaf be proportioned to resist the following load combinations:

(a) Dead load from the span in any open position plus 20% impact caused by the moving span.

(b) Dead load with the bridge closed plus live load plus impact.

(c) Dead load with the bridge closed and with the counterweight independently supported plus live load plus impact.

The moment diagram in Figure No. 4 indicates that dead load plus 20% impact governs from the center of the trunnion to beyond Floor Beam 4 and dead load plus live load plus impact governs from there to the end of the girder.

There is a reversal of stress in the girder from Floor Beam 5 to its end so fatigue limitations are important in this area. The shear diagram in Figure No. 5 shows that dead load plus live load plus impact governs for the entire length of the girder, except for a short section between Floor Beams 4 and 3.

Because of the large forces on the girders compared to the other structural elements in the leaf, it was decided to specify 588 steel for them and A-36 steel for the floor beams, stringers and bracing. The girders were proportioned as shown in Figure No. 6 to have a depth of 10'-6" at the trunnion, 5'-0" at the end and 7'-2" at the counterweight.

The length, width and depth of the counterweight was limited by the geometry of the bridge. The volume of concrete in the counterweight deducting 5% for pockets for balancing blocks and including buildups on top between the stringers of the flanking span was only sufficient to balance the leaf by using special concrete weighing 275 pounds per cubic foot. The maximum weight of heavy concrete allowed by the bridge code is 315 but preferably not more than 275 pounds per cubic foot. The contractor elected to provide the necessary weight in the counterweight by the use of steel billets cast in the concrete and supported by the counterweight girders.

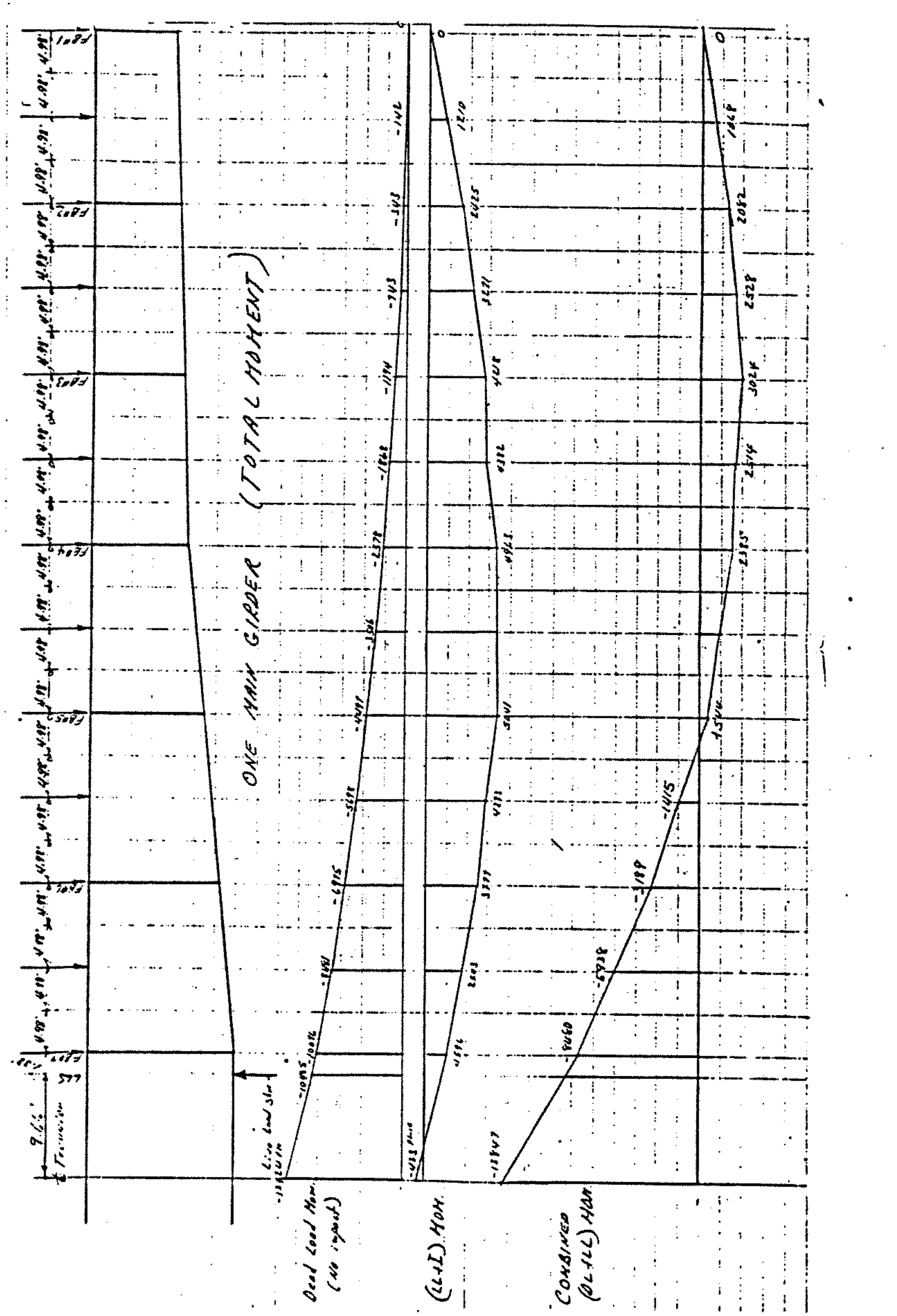

ONE MAIN GIRDER (TOTAL MOMENT)
Dead Load Mom. (No impact)
(LL+I) MOM.
COMBINED (DL+LL) MOM.

FIGURE 4

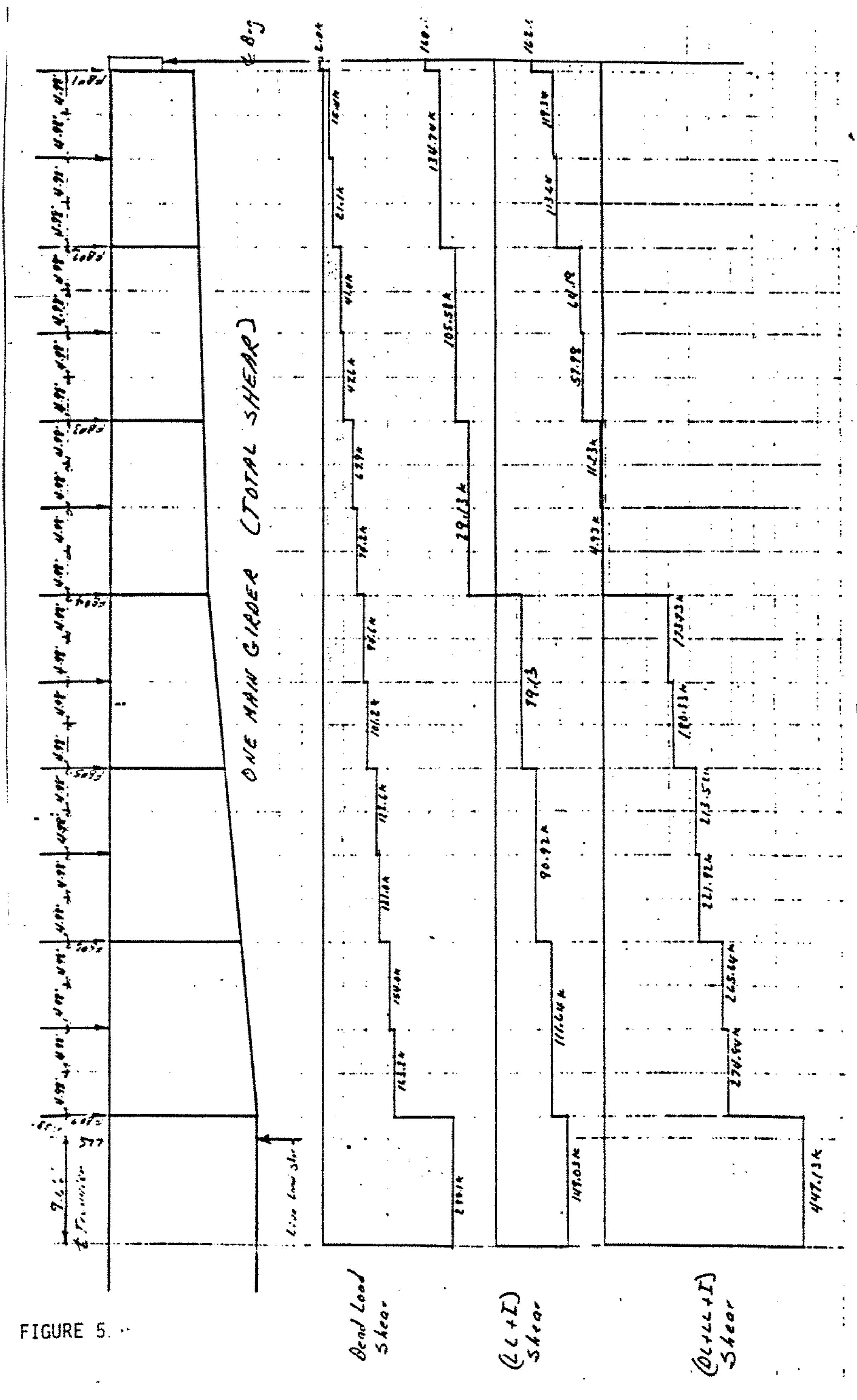
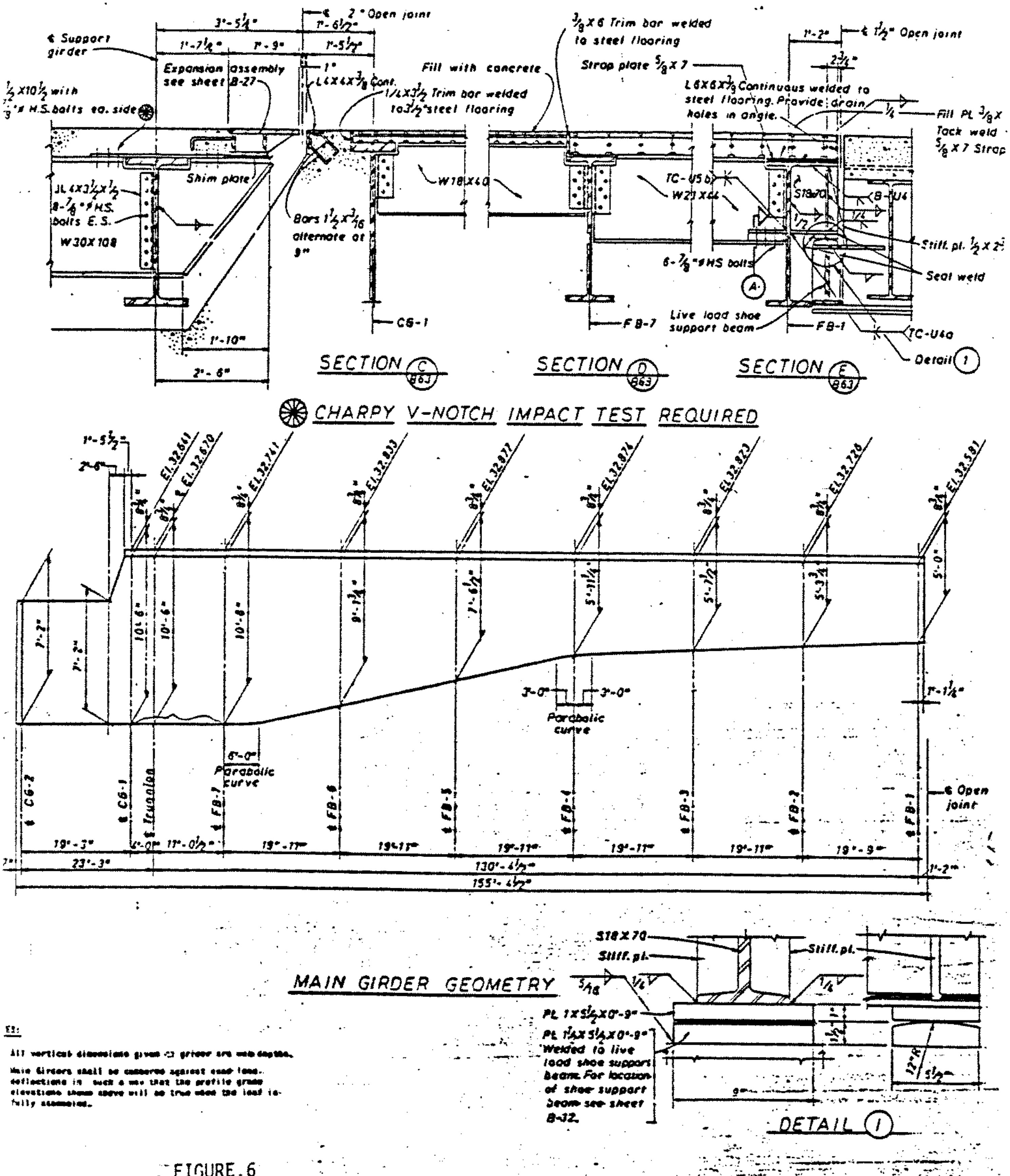

ONE MAIN GIRDER (TOTAL SHEAR)
Dead Load Shear
(LL+I) Shear
(DL+LL+I) Shear
447.13k
149.03k
298.1k

FIGURE 5



ES:

All vertical dimensions given on girder are web depths.

Main Girders shall be cambered against dead load deflections in such a way that the profile grade elevations shown above will be true when the leaf is fully assembled.

FIGURE. 6

Power Requirements and Machinery Design

Power requirements for the Astor Bridge are extra large to overcome the wind torque resulting from the long moment arm of the long leaf and trunnion friction loss and mass inertia resulting from the heaviness of the leaf. The short counterweight arm required a heavy counterweight to balance the span resulting in an extra heavy weight of the span.

The time for rotating the leaf 74^{o} to the fully open position or to close the leaf was selected as approximately one minute, which is the normal time of opening used for bridges of this type.

The Movable Bridge Code requires that sufficient power be supplied to open or close the span under the following conditions:

A. In normal time of opening against frictional resistance in the trunnion bearing, mass inertia of the leaf, the unbalanced condition with the river arm slightly heavier and a wind force of 2½ pounds per square foot acting normal to the floor. The area of open grating flooring is permitted to be calculated as 85% of the actual area.

B. In one and one-half times the normal time of opening for the same loads as in condition A, plus an ice load of 2½ PSF. This condition, of course, does not apply in north central Florida.

C. In twice the normal time of opening against the same forces in Condition A plus an ice load of 2½ PSF, when applicable, except that the wind load is 10 PSF.

For each of the conditions the power requirements must be calculated for starting the leaf, accelerating to running speed and running speed because the resistances to overcome during each state of motion differ as follows:

1. Starting: The dead load of the span is not increased 20% for impact because the span is not moving. The friction resistance at the trunnion is greater when starting than when moving and is specified by the Code to have a coefficient of 0.18. The mass inertia of the leaf is not considered since it is not yet moving. The Code states that the starting torque must not be greater than 125% of the rated full load torque of the motor.

2. Accelerating to Running Speed: The dead load reaction of the leaf includes 20% impact for motion. The frictional resistance at the trunnion has a specified coefficient of 0.12 since the leaf is in motion. The mass inertia of the

leaf has to be overcome to accelerate the span to running speed. The Code requires that the torque to accelerate the span be not greater than 180% of the rated full load torque of the motor.

3. Running Speed: The dead load of the leaf includes 20% for impact from motion. The frictional resistance at the trunnion has a coefficient of 0.12 for motion. The running torque must not be greater than 100% of the rated full load motor torque.

The requirements for accelerating the leaf did not govern because the torque was permitted to be as high as 180% of rated full load motor torque.

An electric motor with a speed of 580 RPM was selected to supply the power through a series of reduction gears to rotate the leaf on the trunnion 74^{o} at approximately 0.2 RPM to open the span in one minute. As shown in Figure 7, the reduction is accomplished through a fully enclosed speed reducer with a ratio of 50:1 for motor speed to low speed shafts; two sets of pinnions and span gears each with a ratio of 2.5333:1 and the main pinnion and the rack mounted on the bottom of the main girder and concentric with the trunnion having a ratio of 8.8619:1. The overall reduction is 2844:1. The velocity of the rack is 14.72 feet per minute.

The total weight of the moving leaf of the Astor Bridge applies a load of 1165 Kips through each main girder to each trunnion. The river arm weighs 272 Kips and the counterweight arm weighs 893 Kips. Total dead load on each trunnion, plus 20% impact for the leaf in motion, is 1398 Kips. The force on each main pinnion from the rack on the girder is 43,700 pounds from a 2½ PSF wind on the open leaf, 175,000 pounds from a 10 PSF wind force and 350,000 pounds from a 20 PSF wind force.

The torque at the motor is calculated as the torque at the main pinnion from the rack resulting from the forces in the conditions described above and increased by the friction losses in the shaft bearings and the efficiency losses in the gear train between the rack and the motor. The motor is sized to operate against the applied torque to open or close the bridge in the specified time.

The Movable Bridge Code states that, if the total power necessary at the motor shaft to move the bridge under condition A at the required speed exceeds 50 horsepower, consideration shall be given to the use of two identical span driving motors with provisions for operation of the bridge by one motor at not more than 1.5 times the time of openings specified for conditions A and C.

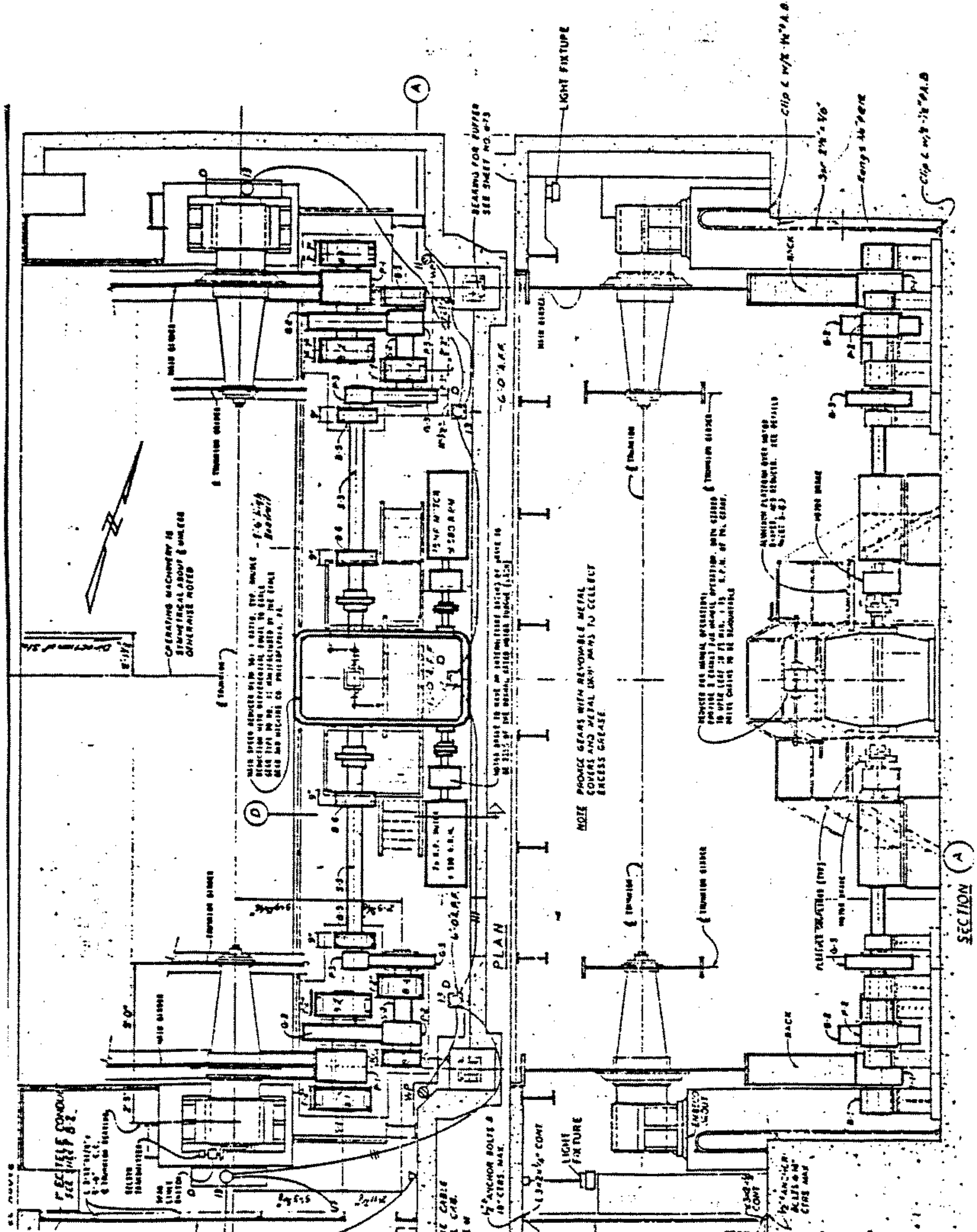

LIGHT FIXTURE
PLAN
SECTION
NOTE PROVIDE GEARS WITH REMOVABLE METAL COVERS AND METAL DRIP PANS TO COLLECT EXCESS GREASE

FIGURE 7

A summary of the power requirements for Astor Bridge follows:

Case	Phase	Opening Time	Motor RPM	Motor Torque in - K	Req'd HP	% Normal HP	Normal HP
Two Motors:							
A	Starting	1 min.	580	9.37	86	125	69
	Running	1 min.	580	8.74	81	100	81
C	Starting	2 min.	290	27.33	126	125	101
	Running	2 min.	290	26.65	123	100	123
One Motor:							
A	Running	1½ min.	387	8.74	54	100	54
C	Running	3 min.	188	26.65	80	100	80

Based on the above power requirements, two identical motors of 75 HP were selected.

The Code also says that, when specified by the engineer, the determination of the size of the motor may be for conditions less severe than the maximum conditions specified. This permits the design engineer to consider the conditions at the site such as the frequency of opening and the chance of vessels operating in strong winds and to size the motor in accordance with his judgment.

The Code requires that the machinery be proportioned to resist forces from 150% of the rated full load motor torque and to hold the span in a fully open position against a wind load of 20 PSF. The machinery parts for the Astor Bridge, such as the width of the gear teeth and diameter of the shafts, were sized to resist the governing forces which were from the wind load of 20 PSF on the leaf.

The ideal machinery system has the least number of elements exposed to the weather and the least number requiring field lubrication. The Earle Gear Company was given the torque requirements at the rack and motor and the horsepower requirements and asked if it were feasible to provide a fully enclosed machinery system to drive the bridge. They said the requirements were well within an enclosed system and recommended the following units:

A. One primary balanced herring bone gear reducer with a differential mechanism rated 155 horsepower and having a ratio of 10:1.

B. Two secondary helical gear reducers, one located at each rack rated at 2800 inch kips output torque and having a ratio of 28.8:1.

The overall reduction from motor to span using this system would be (10)(28.8)(9.71) or 2796.48.

This system would make all the machinery elements fully enclosed and self-lubricated, except for the main pinnion and rack.

The specification for the Astor Bridge permitted an alternative system such as the one described above, but the low bidder chose to provide the machinery as shown in Figure 7.

Resistance Barrier

Several types of movable roadway barriers to stop vehicular traffic on the side of the channel opposite to the leaf were considered. The barrier had to be strong enough, operate freely and not be too difficult to repair when hit. The Florida Department of Transportation had problems with the type of barrier that is depressed below the roadway and raised to block traffic when the bridge is opened. They found that, when this type of barrier was hit, it would usually be distorted and could not be lowered back in the slot in the roadway. Traffic would be blocked until the barrier could be removed and the slot in the roadway temporarily covered.

It was decided to design a barrier that is supported overhead when traffic is crossing the bridge and lowered to the roadway level between concrete buttresses to block traffic when the bridge is opened. Details of the barrier are shown in Figure 8.

The barrier consists of two W 14x78 steel beams positioned with the webs horizontal and stacked one on top of the other with the flanges welded together to form a flat surface, 24 inches high and long enough to span the roadway. The barrier is located to be lowered into a gap in the end bent wing walls. The wing walls are reinforced concrete, supported on piles and designed to resist the horizontal force from a vehicle striking the barrier. When lowered, the barrier bears against rubber bumper blocks built into the gap in the wing walls. Energy from a vehicle striking the barrier is partially dissipated by the flexing of the barrier beams and by the compression of the rubber bumper blocks. The gap in the end bent wing walls is closed by a steel plate when the barrier is in the overhead position. The plate swings down out of the way when the barrier is lowered.

An aluminum space frame founded on the end bent wing walls and spanning the roadway supports the barrier above the roadway when traffic is crossing the bridge. The barrier beam weighs about 8000 pounds and is raised and lowered by two electric hoists with 9/6 inch wire ropes complete with gear motors, brakes limit switches, grooved drums and hand cranks. A separate barrier arm swings into a position to block the sidewalk when the barrier is lowered.

In the sequence of events when the bascule leaf is opened the barrier arm is lowered following the closing of the cantilevered arms.

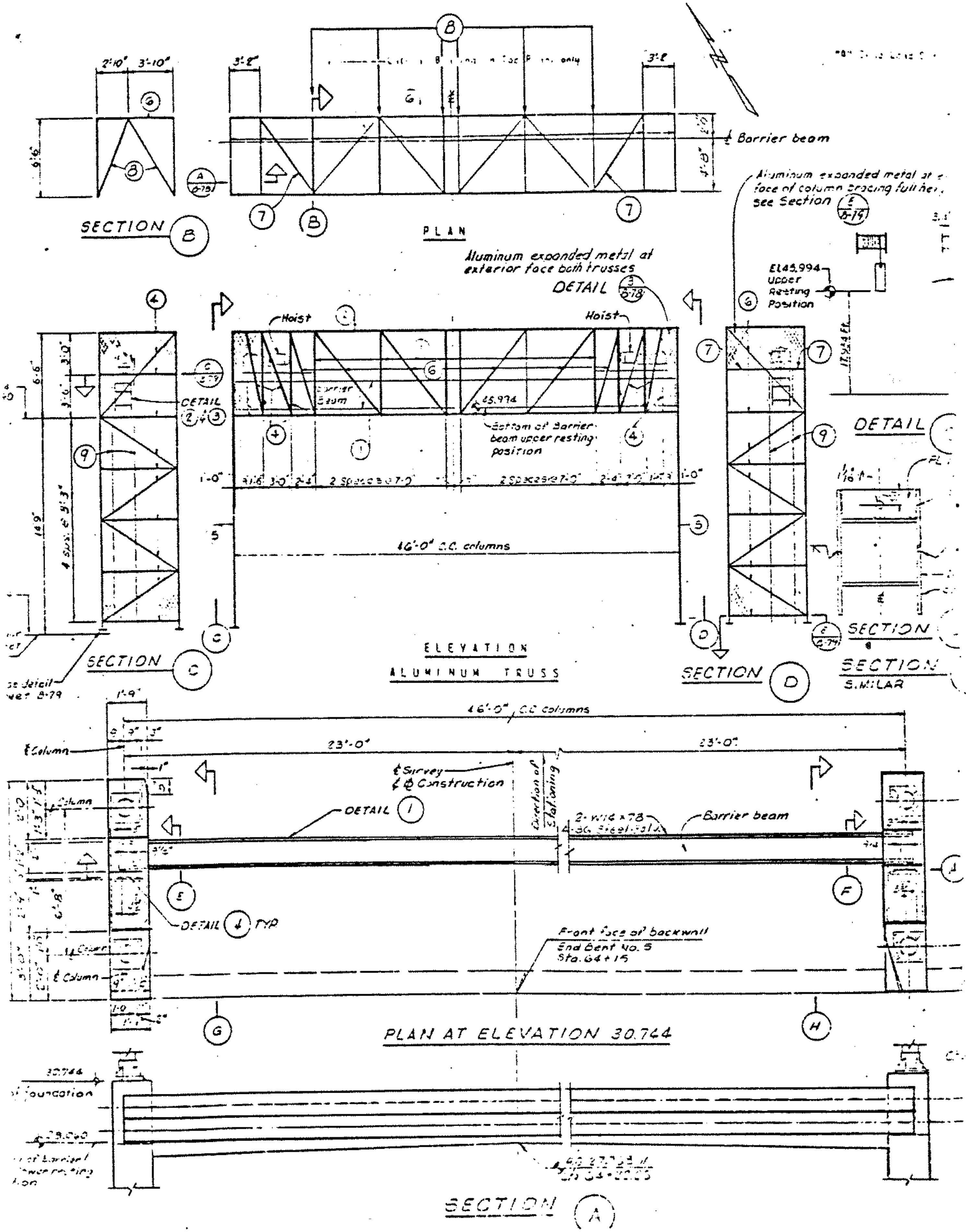

SECTION B
PLAN
Barrier beam
Aluminum expanded metal at exterior face both trusses
DETAIL
Hoist
Bottom of Barrier beam upper resting position
46'-0" C.C. columns
ELEVATION
ALUMINUM TRUSS
SECTION C
SECTION D
SECTION
SIMILAR
DETAIL
EL45.994 Upper Resting Position
℄ Column
℄ Survey
℄ & Construction
DETAIL 1
2-W14x78
Barrier beam
DETAIL 4 TYP
Front face of backwall
End Bent No. 5
Sta. 64+15
PLAN AT ELEVATION 30.744
SECTION A

FIGURE 8

Operation and Maintenance

Since its opening in 1979, the bridge has operated well with only minor problems. One of the electric motors failed while under warranty and had to be replaced. During the several months required to replace the failed motor, the bascule span was opened and closed by one motor with no delays or problems from an overload on the motor. Although the amount of power furnished was in accordance with the Movable Bridge Code, it was more than adequate to operate the bridge.

Several times after the bridge was opened to traffic the FDOT maintenance people were called in the middle of the night because the barrier beam would not seat properly when lowered and permit the opening sequence to continue. Collecting trash was somehow preventing the sidewalk portion of the barrier from closing. The Department removed the sidewalk barrier which was not really needed since the cantilevered barriers block the sidewalk and the barrier has operated freely since that time.

The bridge tenders noted that the time of lowering and raising the resistance barrier increased noticeably the total time that traffic is stopped during a span opening. Although the bascule leaf was opening or closing in little more than a minute, it was taking longer for the resistance barrier to be lowered or raised. Since all of the bridge opening events, i.e.: warning bell, lights, cantilevered barrier arm, positive resistance barrier, span locks and leaf opening or closing, must occur in sequence the several minutes added by the resistance barrier was significant to waiting motorists.

Routine maintenance has kept the machinery, structural steel and concrete elements of the bridge in excellent condition. The environment at Astor is only mildly corrosive. The open gearing is protected by metal covers and the paint on the structural steel shows very little wear or fading.

Summary and Conclusions

The bridge on S.R. 40 over the St. Johns River at Astor, Florida, is a pleasing looking structure that has operated smoothly with very few problems since its opening in 1979. The decision to build a single-leaf rather than a double-leaf span at this location has proved to be sound. The initial cost was less and the savings to be realized by servicing one set of machinery instead of two will continue throughout the life of the bridge.

A drawback to the single-leaf span is that the time required to complete a bridge opening is increased by the time required to raise and lower the resistance barrier which, for this bridge, is significant.

The new bridge provides vertical clearance in the closed position of more than three times that of the old bridge and has reduced the number of openings to less than one third of what it had been.

The design power requirements might have been reduced by the engineer's determination that the conditions at the site were less severe than those specified in the AASHTO Code. A 2½ PSF wind force equates to a wind speed of over 25 MPH and a 10 PSF wind equates to a wind speed of 55 MPH. It is very unlikely that the bridge would ever be called upon to be opened during a 55 MPH wind.

Using recent state-of-the-art equipment and techniques a drive system might be designed today which would provide a constant speed electric motor that supplies power through a visious drive clutch to a single primary differential gear reducer with a 290:1 ratio whose two low speed shafts turn the main pinnions that move the span to the open or closed position. In this type of system all of the elements of the drive machinery are fully enclosed and self-lubricated, except the main pinnions and racks. A schematic drawing of such a system is shown in Figure 9.

The speed of lowering and raising the resistance barrier could also be safely increased to lessen the total time the bridge is closed to traffic during an opening.

The bridge was designed by Reynolds, Smith and Hills for the Florida Department of Transportation. It was constructed by the Houdialle-Duval-Wright Contracting Company of Jacksonville. The structural steel and machinery was fabricated by the Bristol Steel Company of Bristol, Virginia.

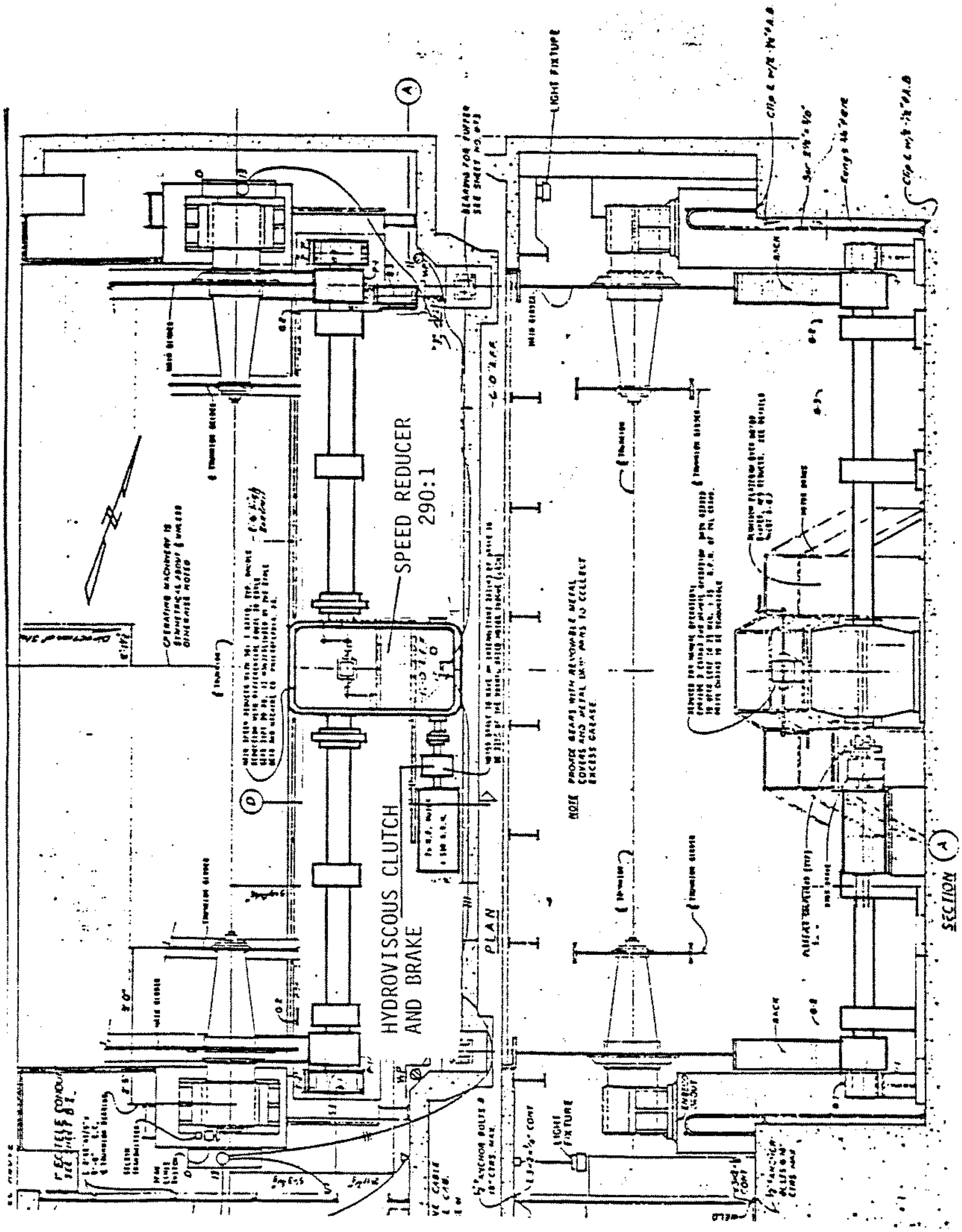

SPEED REDUCER
290:1
HYDROVISCOUS CLUTCH
AND BRAKE
PLAN
SECTION
LIGHT FIXTURE

FIGURE 9