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"Rehabilitation of the 1st Avenue South Bascule Bridge"

by

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REHABILITATION OF THE 1ST AVE. SOUTH BASCULE BRIDGE SEATTLE, WASHINGTON

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Parsons Brinckerhoff Quade & Douglas, Inc.

Introduction

The original 1st Ave. South Bridge is a Chicago type trunnion bascule which carriers S.R. 99 over the Duwamish River between Burien and Seattle Washington. Since the mid 1970's the Washington State Department of Transportation has envisioned building a new bridge as local traffic and the accident rate increased. In 1996 the construction of a new twin double leaf bascule structure was completed to the west of the existing bridge. The plan was to open the new bridge to traffic and close the existing bridge for a major rehabilitation including new approaches, bascule span decking, bridge control system and machinery updates. The final twin bridge configuration will provide double the capacity of the original structure.

In 1995, the Washington State Department of Transportation retained Parsons Brinckerhoff Quade & Douglas, Inc. to provide a design package for the machinery and electrical work for the rehabilitation. The State performed the majority of the structure design for the rehabilitation.

The major features of the electrical and mechanical work include the installation of a new PLC based DC bridge control system, refurbishment of the existing electric drive motors, electrical connections of the original bridge to the new bridge control house, installation of an electric prelube pump on the existing main drive speed reducers, the addition of hydraulic span buffer cylinders, replacement of motor and machinery brakes, and replacement of the span lock system.

This paper will discuss the unique design and decision making process involved in the mechanical and electrical aspects of this bridge rehabilitation project.

Electrical System Design

Each leaf on the existing bridge is driven by two 45 horse power wound rotor electric drive motors. The existing drive was an amplidyne motor/generator system. This system provided many years of service but was obsolete and in need of replacement.

Motors

Inspection of the existing drive motor found them to be in excellent condition. Motors of this vintage are very well constructed, having heavy cast steel casings and heavy windings. These motors are capable of producing up to 300% full load torque. Scraping these stout units, which have really seen very little service (in terms of total running hours), seemed foolish. It was decided that the original motors would be refurbished and reused with a modern electronic drive. Also, reuse of the original motors eliminates costly modifications to the motor supports which would most probably be required if the motors were replaced (new motor would most likely be larger to provide the same torque as the original).

The motor refurbishment consisted of:

- Complete disassembly, stripping of paint, and steam clean
- Bake dry
- Testing of windings and replacement as necessary
- Bearing replacement
- Polishing of commutators, replacement of brushes
- Seal and gasket replacement
- Dynamic balancing of rotors
- Re-assembly and shop test
- Shop paint

Drive System and Control

An SCR (silicon controlled rectifier) four quadrant regenerative drive with PLC (programmable logic controller) was selected for the new electronic drive system. This system will provide excellent speed and torque control required for the large bascule leaves, especially in dynamic braking. The use of the PLC system wound eliminate a considerable amount of field wiring. The new system would use only 25% of the space as the original system.

Power Supply and Wiring

Each bascule leaf receives primary electrical power from both sides of the river, thereby eliminating the need for large power transmission submarine cables (see Figure 1). A small group of control wires was passed through a existing utilidor under the channel bottom to provide communications to the far side bascule. This includes the data bus for the PLC, fire alarm and public address system wiring.

Back up power for emergency operation is by hard wire connections to the new diesel powered generators provided for in the construction of the new bridge (one on each side of the channel).

In the final configuration, both structures will be operated from control desks location in the control house on the new bridge. Therefore, control wire from the rehabilitated bridge was run southward down the west approach, then underground beneath an off ramp, and then run northward along the new bridge's approach into the new control house (see Figure 1).

The cavernous bascule piers provided ample space for all motor control centers and leaf drives to be placed on the machinery platforms in close proximity to the drive motors and drive machinery.

Machinery Considerations

Prelube Pumps

The existing machinery consists of an independent rack and pinion drive on each main truss of the bascule leaves (2 drives per leaf). Each has a large right angle enclosed gear speed reducer. The main drive pinions are mounted to the output shaft of each reducer. Incorporated into the original design of each speed reducer is a shaft driven lubrication pump, which provides oil flow to all the internal shaft bearings and upper gearing. However, these pumps would only operate during operation of the bridge.

Due to long periods of inactivity, the lubricating oil drains from the internal bearings down into the sump. The State recently had several speed reducer failures on another of its bridges. The cause of this failure is thought to be partly due to oil starved upper shaft bearings at the start of bridge operations.

Since an internal lubrication system already existed on the original 1st Ave. South Bridge, it was decided to add an electric motor and oil pump to the system. The pump would be run for several minutes prior to a bridge operation in order to be certain that all the speed reducer's critical internal components are adequately lubricated prior to a bridge operation.

The original shaft driven pump was still in good condition and fully operational. It was left in place and operates as originally designed, as the bridge rotates. The new electric pump is turned on by the PLC at the start of the operating sequence and is shut down just before operation of the drive machinery.

Modifications to the existing piping were very simple. Connections were made in the systems supply and pressure sides on the existing piping. Check valves were installed to isolate the two independent system (see Figure 2).

The specifications for the pumps were as follows:

- Electric Motor - 2 HP, 1800 RPM
- Pump Flow - 8 gallons/minute
- Viscosity Rating of 10,000 SSU
- Maximum Pressure of 100 psi
- Built in pressure relief feature
- Oil pressure switch for PLC monitoring
- Piping - Schedule 40 Standard Weight Steel Piping

Buffer Cylinders

The newly constructed bridge had been fitted with hydraulic type buffer cylinders. Although the existing bridge had been operating for over 40 years without any type of span seating aid, it was decided that hydraulic buffer cylinders would be installed on the original bridge in this rehabilitation. Sizing the buffers and their placement would prove to be the difficult part.

The following design assumptions were made in sizing the hydraulic buffer cylinders for the 1st Ave. South Bascule rehabilitation:

- Worst Case Loading - Control system malfunction and the bridge hits the buffers at full speed including AASHTO Condition "C" ice and wind loadings
- the machinery continues to drive the bridge closed against the buffers after initial impact

Position of the buffer cylinders is important because the further away they are from the centerline trunnion, the smaller the impact force will be. Although space was limited, the buffers were placed at the very rear of the counterweight. At this location the horizontal distance from the trunnion centerline to the buffer impact would be 33.75 feet (see Figure 3), a much greater distance than to the front face of the bascule pier wall.

Using formulas from Taylor Devices Inc., the following was calculated and specified:

Kinetic Energy to be Absorbed = 1,500,000 in-lbs

Maximum Output Force = 135,500 lbs

Stroke = 25 inches

Impact Velocity = 8 in/sec.

The conceptual design drawing of the buffer cylinder is shown in Figure 4. The use of hydraulic buffer cylinders on movable bridges is an excellent application of these devices. The output force supplied by the buffer is proportional to the square of the impact velocity. Normally, the control system will have slowed the bridge down to 10% of full speed well before the bascule leaf impacts the buffer. Under these conditions the buffers will provide a only a nominal output force. In fact it would be difficult to even notice that the buffers are there at all. Only under uncontrolled bridge seating will the buffer cylinders function.

On the 1st Ave. South Bascule Bridge the fully extended buffers contact the bascule at approximately 3.5 degrees from the fully closed position.

Finding a structural member to mount the buffers to which could withstand the 135,500 lbs maximum output force was difficult. There was just enough space to hang the buffer cylinders vertically in the bascule pier under the sidewalk. The sidewalk slab itself could not sustain the load. It was desirable to keep the buffers as close to the side pier access as possible as well as have the buffers impact on the bascule's main truss members.

The existing bascule pier wall was quite thin. Attachment of the buffers to the pier wall was the obvious choice for mounting the buffers. Figure 5 shows the structural work required to adequately strengthen the pier wall to handle the maximum buffer cylinder forces.

A dish shaped striker plate was mounted to each truss near the rear counterweight girder connection (see Figure 6). The strike plates were grouted level and bolted into the back end of the bascule truss.

A series of factory tests was specified to ensure that the buffer cylinders would perform as intended after installation. The testing included:

- Full Stroke Tests: Each unit was fully stroked at 10% and 50% of the maximum design velocity. Three tests of each unit.
- Partial Stroke Tests: Each unit was push tested using a hydraulic actuator to verify the output force at 100%, 50% and 10% rated velocity over six points along the full stroke. A minimum of three tests on each unit.
- Life Cycle Tests: Each unit was fully compressed for the full 25 inches of stroke with a minimum load of 30,000 lbs driving force for 150 cycles.

Motor and Machinery Brake Replacement

Although still functional, the existing brakes were also replaced primarily due to there age and the lack of spare parts. Also, it was desired to incorporate brake position sensing limit switches into the new bridge control system with indicator lights on the control desk as required by current the AASHTO code. Limit switches were incorporated to sense brake set, brake released and brake "manually" released.

One interesting note was that a braking requirement analysis was performed for the bridge completely independent of the original design. The calculated required braking capacity requirements were within 3% of the originally installed brakes.

Clearly, the designer of the past were just as accurate with a slide rule as we are with our Pentiums.

Span Lock System Replacement

It was desired by the owner to replace the existing span lock system with a hydraulically actuated clamping jaw system, similar to that utilized on the new twin structure. This was logical from a maintenance stand point to have similar systems on both structures.

However, we were faced with the existing truss geometry which could not be changed very much. In order to accommodate the jaw lock the following structural modifications were necessary (see Figures 7 & 8):

- An opening in the forward end post vertical truss member on the near span has to be cut for the jaws to pass through and the cut section required strengthening.
- A stub out protuberance had to be added to the forward end post vertical truss member on the far side to provide something for the jaws to clamp onto and transfer to shear between the spans.
- Steel plates were added to the vertical end post truss member on the near side to provide locations to mount the jaw pivoting pins.
- The diagonal truss member on the near side required strengthening for the mounting of the hydraulic actuating cylinder.
- The manual pin locking device had to be relocated.

A constant hydraulic cylinder force of 65,000 lbs is required to provide the required clamping force between the jaws. A 7 inch diameter bore hydraulic cylinder was chosen and would provide the necessary clamping force at approximately 1600 psi. The time to retract the locks was set at 7 seconds. This would require a fluid flow of approximately 9.5 gallons per minute. A 10 horse power reversing electric motor drives a bi-directional fixed displacement hydraulic pump.

The span lock hydraulic system schematic is shown in Figure 9. Another noteworthy feature is the accumulator. The accumulator functions to store fluid under pressure and aids the system in maintaining the constant 1600 psi pressure on the blind end of the cylinder to maintain the clamping force. Two pressure switches are used to monitor the pressure on the back side of the cylinder. When the jaws are clamped, if the pressure falls below 1400 psi, the PLC will automatically run the pumps and build the pressure back to 1600 psi.

A separate hydraulic power unit was used for each span lock. The power units were located below deck on the span lock access platform and the hydraulic cylinders were connected by high pressure hoses. Removal of the existing gear driven span lock system left ample space for the swap over. This was a variation from the new bridge which has its span lock power units on the bascule pier and the cylinders are connected by piping runs.

Shims are provided between the protuberance wear plates and the jaw clamping plates to allow for field adjustments for even clamping. Hardened steel and bronze is used for the jaw and protuberance wear plates, respectively.

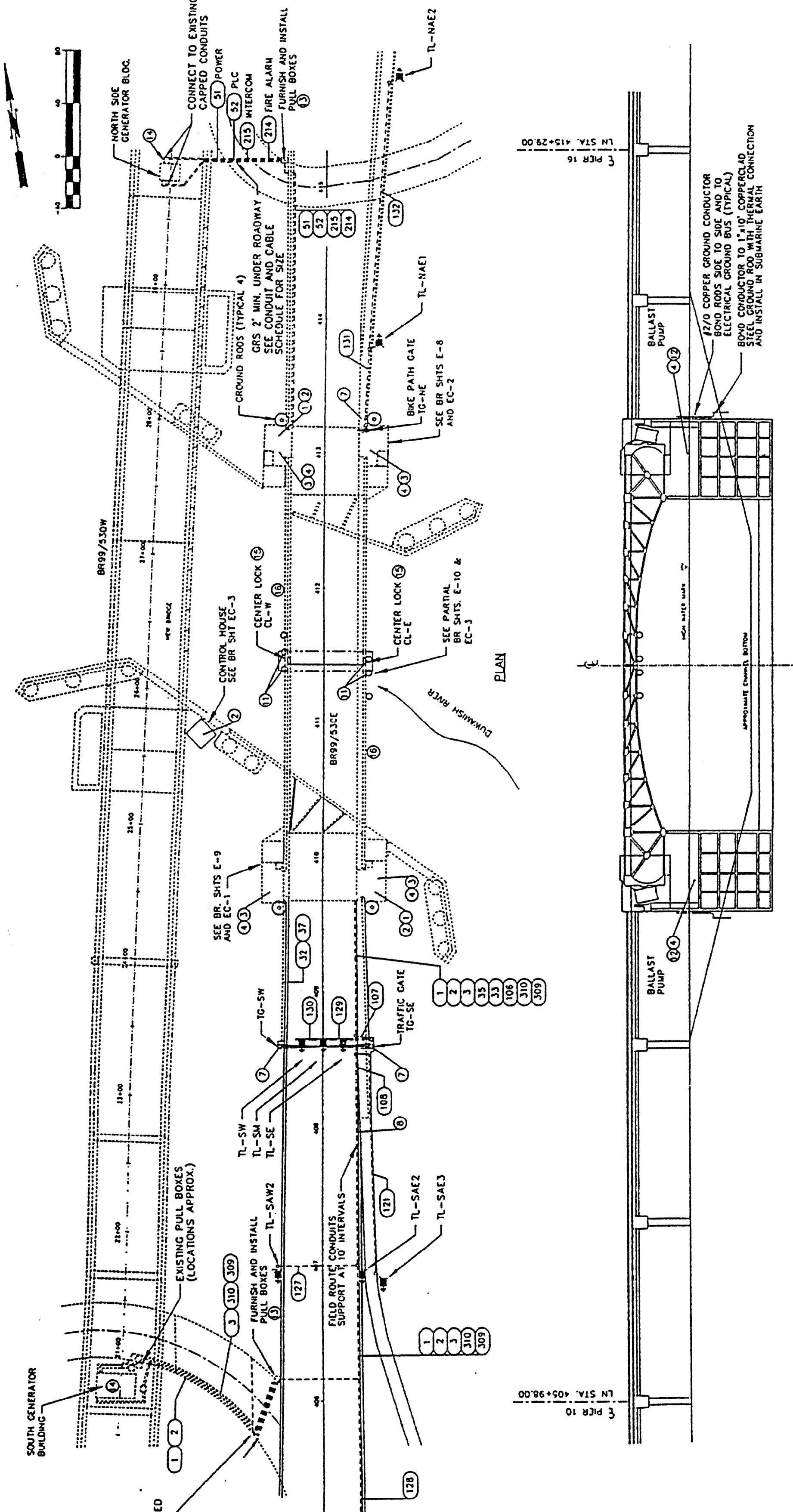
High strength forged steel pins are used for the jaw pivots and all connections utilize high strength bolts.

The installation of the only jaw lock machinery and the removal of the existing system resulted in less than 1000 pounds of additional weight. However, the required steel modifications resulted in the addition of over 10,000 pounds of additional weight. Therefore, the additional weight was counterbalanced by the addition of steel blocks to the counterweight pits.

Summary

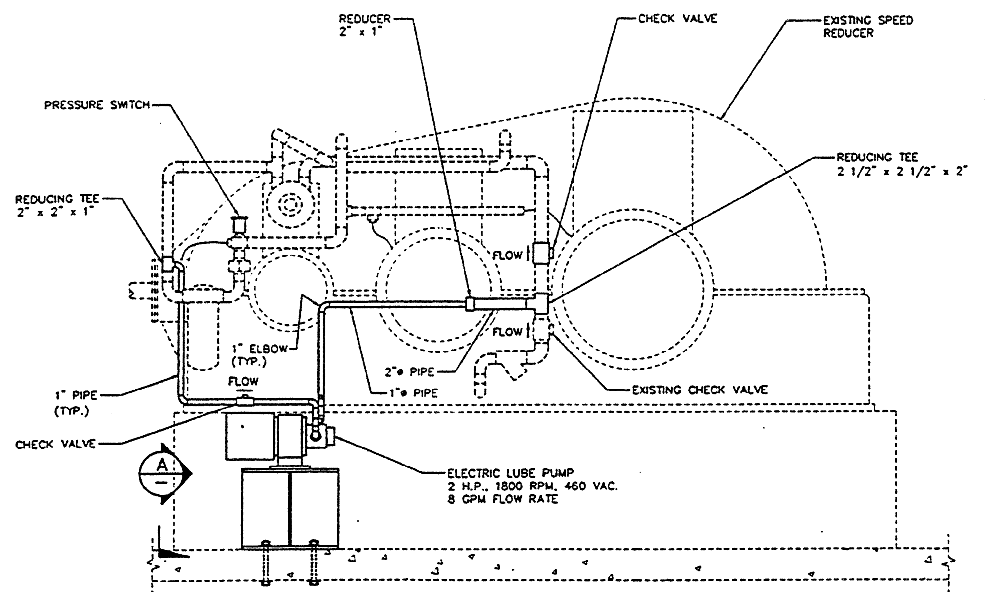
The installation of the new mechanical equipment and bridge control system was completed in late summer 1998, with commissioning and start up testing shortly after. The result is a fully updated vintage bridge which should provide the Washington State Department of Transportation with many additional years of continued service.

FIGURES



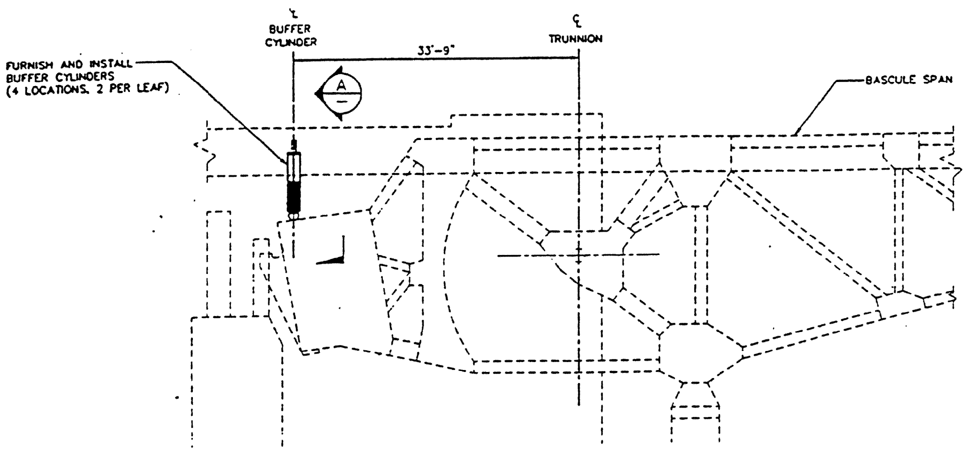
NORTH SIDE GENERATOR BLDG.
CONNECT TO EXISTING CAPPED CONDUITS
POWER
PLC
INTERCOM
FIRE ALARM
FURNISH AND INSTALL PULL BOXES
TL-NAE2
GRS 2" MIN. UNDER ROADWAY SEE CONDUIT AND CABLE SCHEDULE FOR SIZE
GROUND RODS (TYPICAL 4)
TL-NAE1
BIKE PATH GATE TG-NE
SEE BR SHTS E-8 AND EC-2
BR99/530W
CENTER LOCK CL-W
CENTER LOCK CL-E
SEE PARTIAL BR SHTS. E-10 & EC-3
CONTROL HOUSE SEE BR SHT EC-3
DUWAMISH RIVER
PLAN
BR99/53CE
SEE BR. SHTS E-9 AND EC-1
TG-SW
TRAFFIC GATE TG-SE
TL-SW
TL-SM
TL-SE
TL-SAW2
TL-SAE2
TL-SAE3
FIELD ROUTE CONDUITS SUPPORT AT 10' INTERVALS
EXISTING PULL BOXES (LOCATIONS APPROX.)
SOUTH GENERATOR BUILDING
CONNECT TO EXISTING CAPPED CONDUITS
℄ PIER 16
LN STA. 415+29.00
#2/0 COPPER GROUND CONDUCTOR BOND RODS SIDE TO SIDE AND TO ELECTRICAL GROUND BUS (TYPICAL)
BOND CONDUCTOR TO 1"x10' COPPERCLAD STEEL GROUND ROD WITH THERMAL CONNECTION AND INSTALL IN SUBMARINE EARTH
BALLAST PUMP
ELEVATION
℄ PIER 10
LN STA. 405+98.00

FIGURE 1

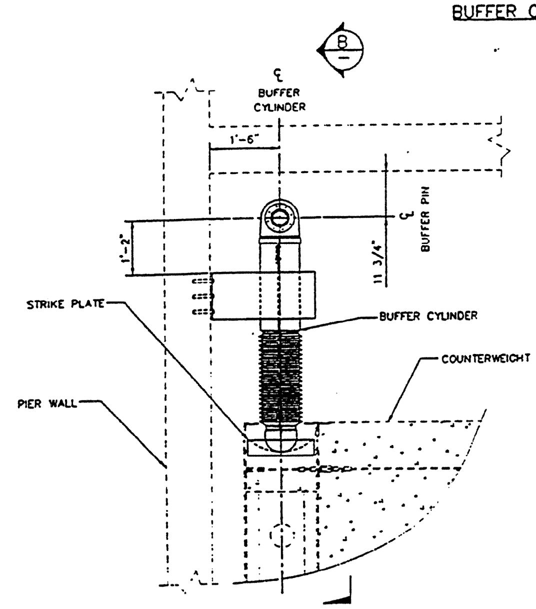


DRIVE MACHINERY – ELEVATION

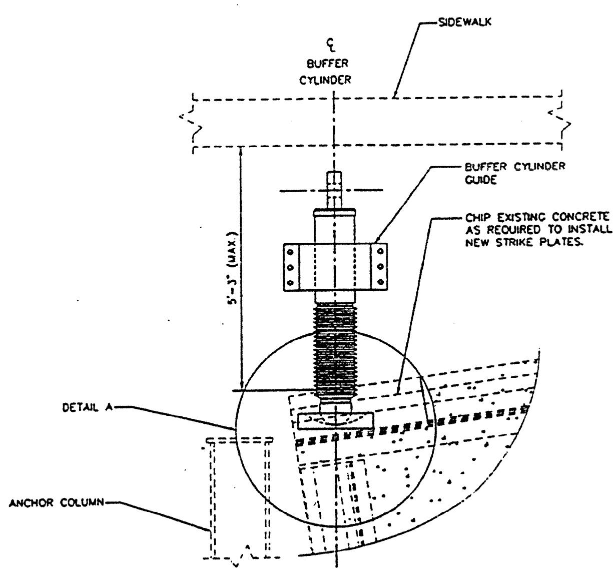
FIGURE 2



BUFFER CYLINDER LOCATION – ELEVATION

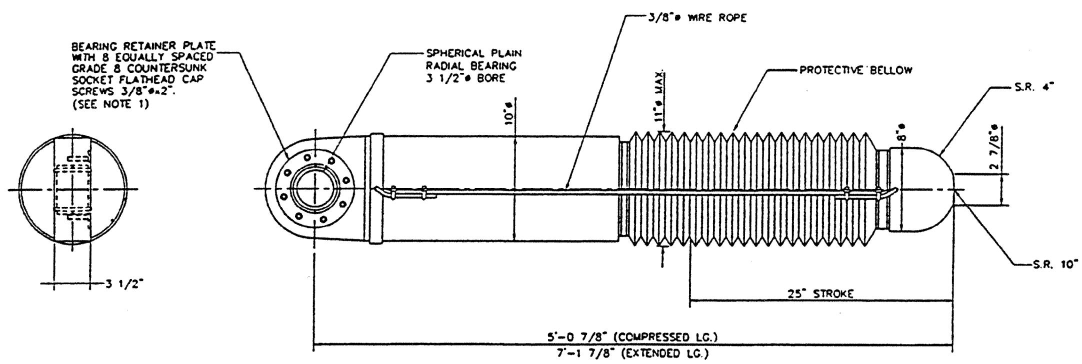


SECTION A



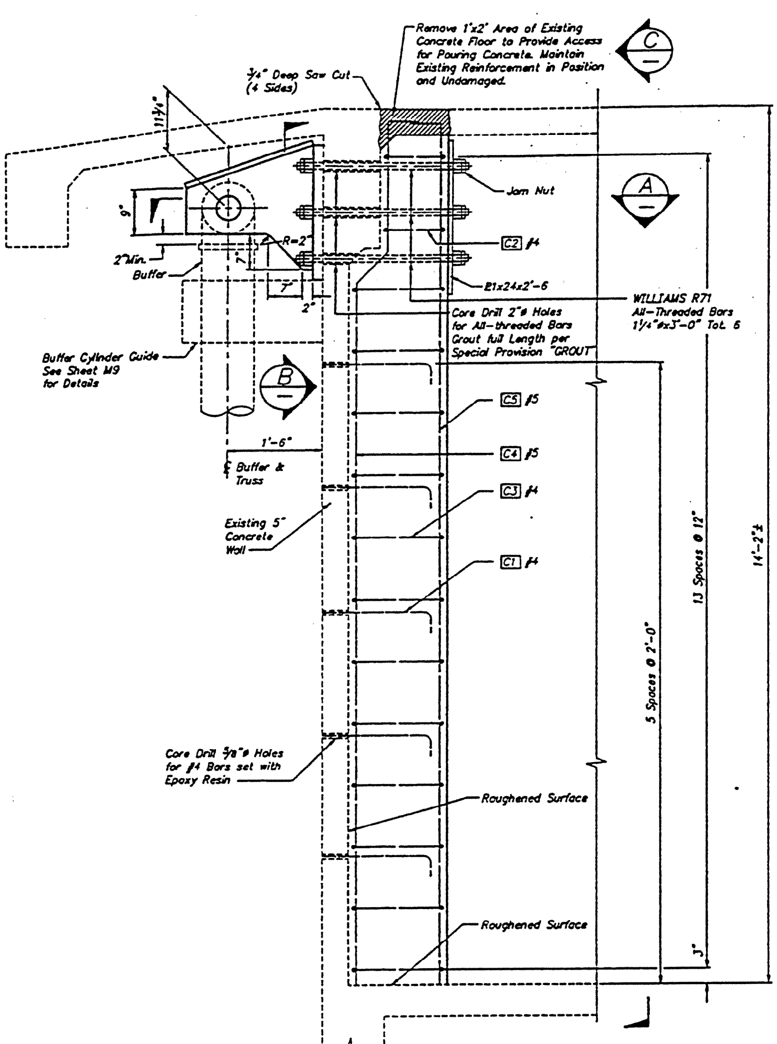
SECTION B

FIGURE 3



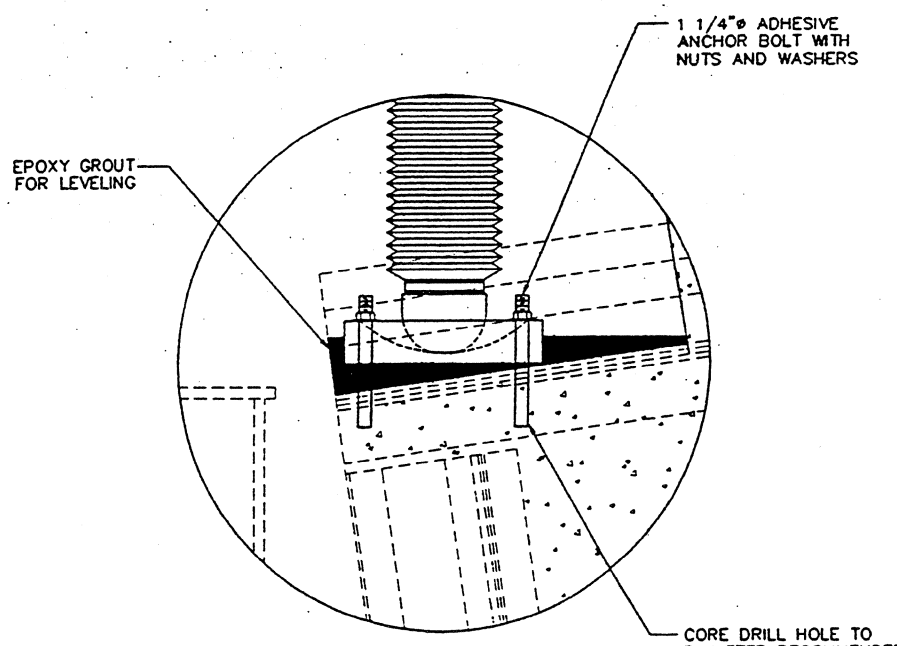
BUFFER CYLINDER

FIGURE 4



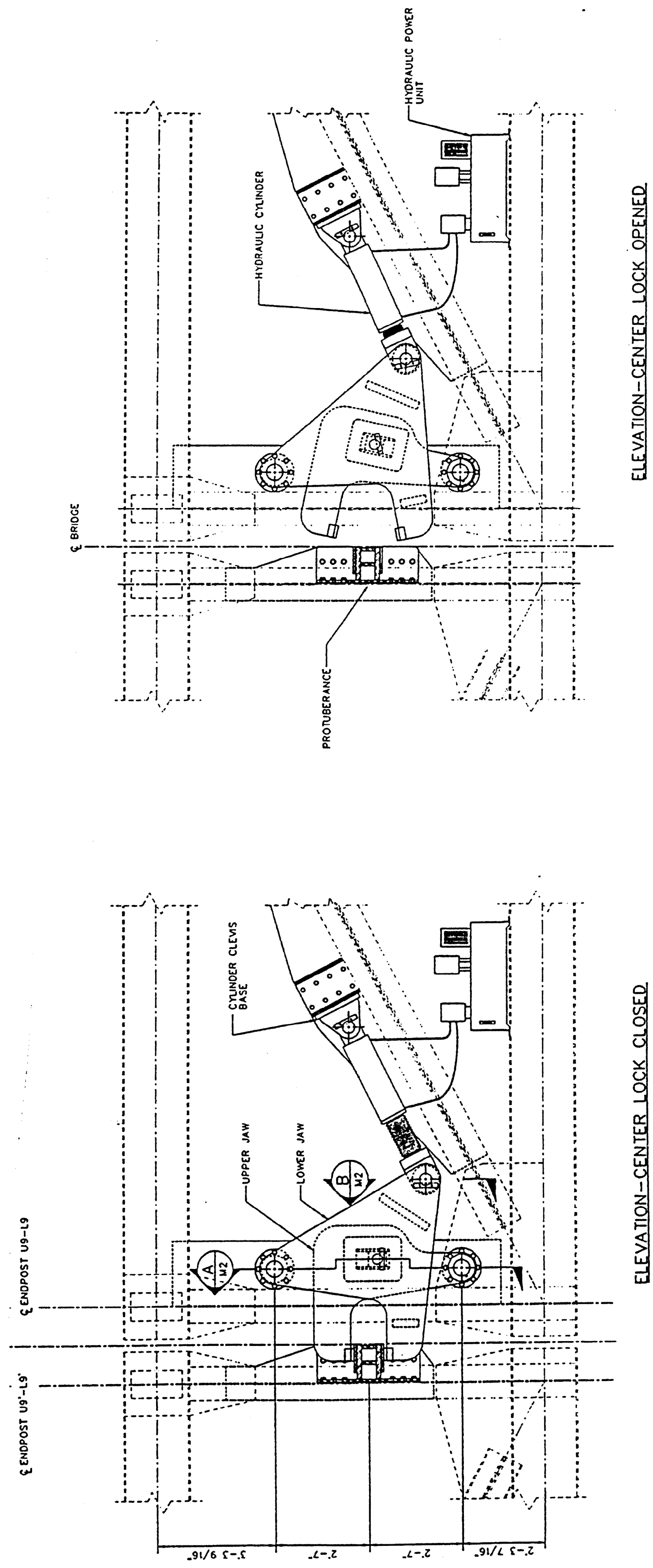
BUFFER SUPPORT DETAIL

FIGURE 5



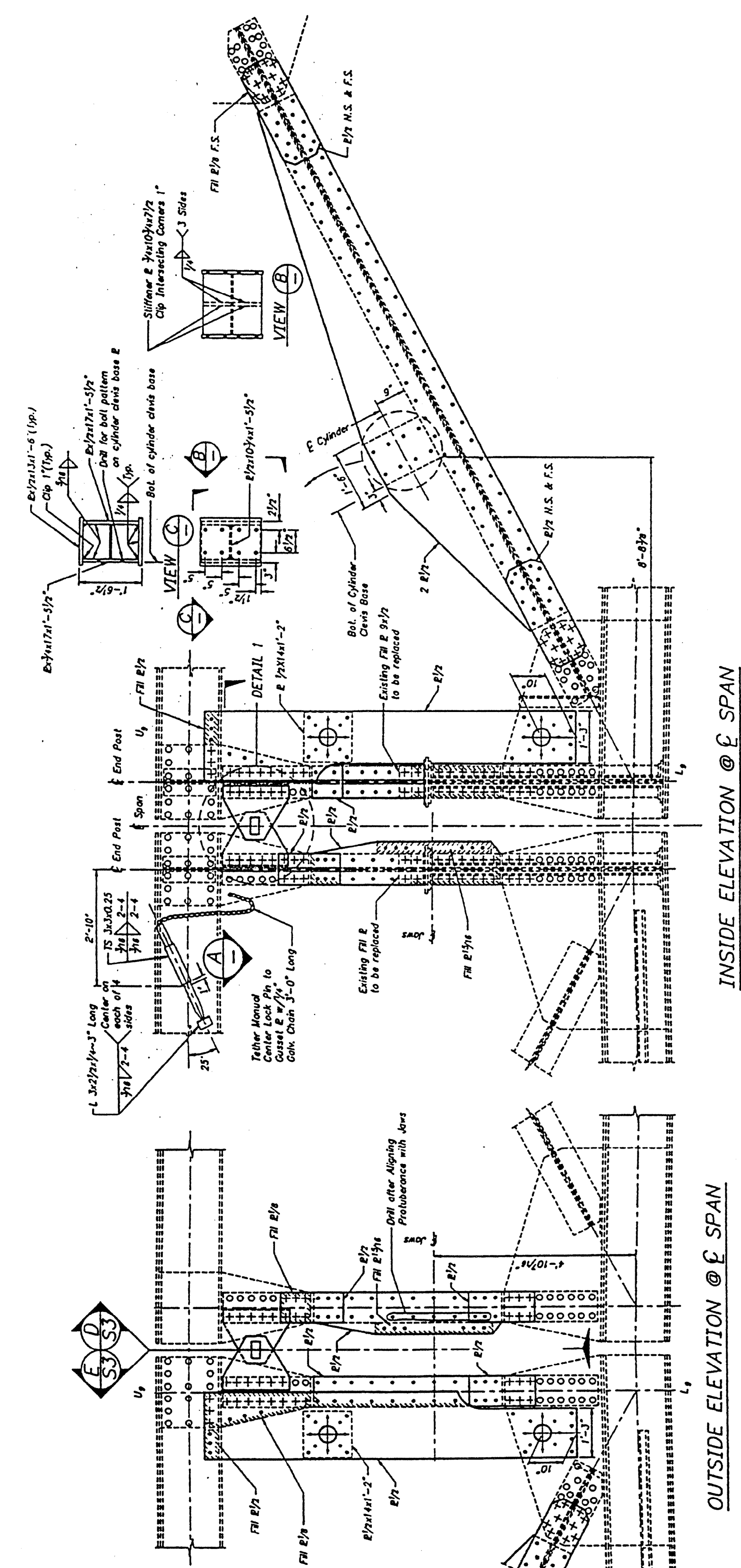
DETAIL A

FIGURE 6



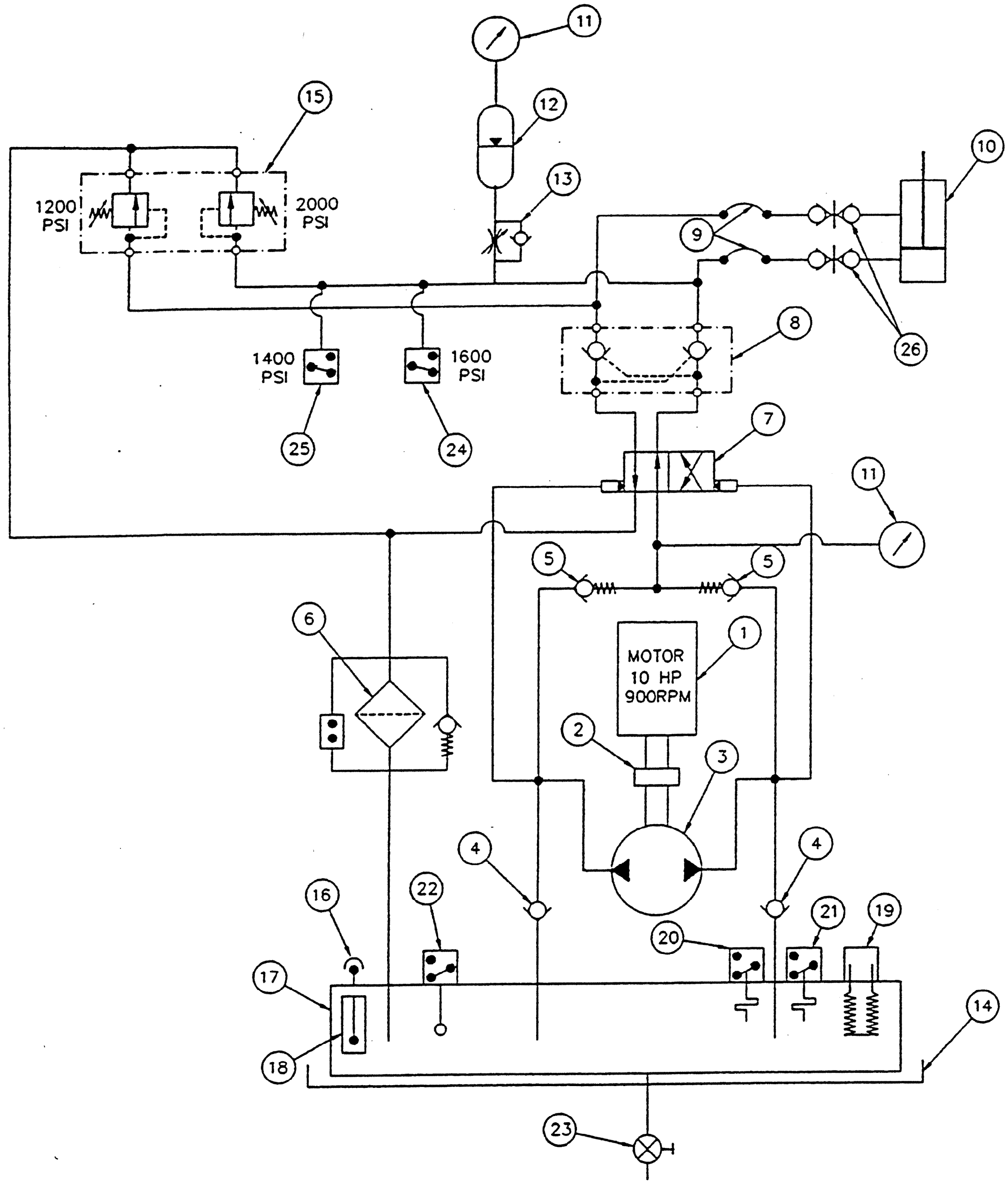
HYDRAULIC POWER UNIT
HYDRAULIC CYLINDER
℄ BRIDGE
PROTUBERANCE
ELEVATION-CENTER LOCK OPENED
℄ ENDPOST U9-L9
℄ ENDPOST U9'-L9'
CYLINDER CLEVIS BASE
UPPER JAW
LOWER JAW
A
M2
B
M2
2'-3 9/16"
2'-7"
2'-7"
2'-3 7/16"
ELEVATION-CENTER LOCK CLOSED

FIGURE 7



INSIDE ELEVATION @ ℄ SPAN
OUTSIDE ELEVATION @ ℄ SPAN
DETAIL 1
VIEW B
VIEW C

FIGURE 8



CENTER LOCK HYDRAULIC SCHEMATIC

FIGURE 9