AMERICAN CONSULTING ENGINEERS COUNCIL'S

HEAVY MOVABLE STRUCTURES
MOVABLE BRIDGES AFFILIATE

3RD BIENNIAL SYMPOSIUM

NOVEMBER 12TH - 15TH, 1990

ST. PETERSBURG HILTON & TOWERS
ST. PETERSBURG, FLORIDA

SESSION
WORKSHOP NOTES

Session (4-2)
"Seabreeze Bridge Emergency Repairs",
James M. Phillips, Parsons Brinckerhoff
Quade & Douglas, Tampa, Fl.

Seabreeze Bridge - Emergency Repairs

Project Summary:

Project Type:	emergency drive system replacement
Bridge Type:	double leaf bascule bridge
Cost:	$720,000
Drive System:	frame mounted hydraulic motors
Designer:	Parsons Brinckerhoff Quade & Douglas, Inc.
Contractor:	J.B. Hagler & Sons Panama City, FL
Owner:	Florida Department of Transportation

Introduction: The movable bridge industry in the United States continues to focus more and more on the maintenance and rehabilitation of existing bridges as the rate of new movable bridge construction remains low. As a direct consequence of this trend, the focus in new and rehabilitated structures is on reliability and maintainability. On the construction side, responsible agencies place great emphasis on timely construction and in particular its effects on the ever mobile public. This paper presents the development of a new bascule bridge drive system which evolved from the response of this writer and others to these current needs.

Background: In the spring of 1988, the Florida Department of Transportation (FDOT) discovered that the Seabreeze Bascule Bridge (State Road 430 over the Intracoastal Waterway) in Daytona Beach, Florida had several mechanical deficiencies which severely jeopardized the reliability of the bridge. The main span of the bridge is a double leaf bascule with each leaf spanning 65 feet (19.8m) from trunnion to tip. The bridge's problems included improper trunnion alignment, deteriorated speed reducers, and recognized deficiencies in the Hopkins Frame drive system.

To correct the problems as quickly as possible, and hopefully before the bridge failed during operation, the FDOT opted to undertake an emergency design/build rehabilitation of the bridge. As defined by the FDOT in the bid package, the scope for the design/build repair project included structural, electrical, and mechanical tasks. The scope for the electrical work included replacement of the entire control system and most of the wiring. Replacement of the machinery support frames (2) was the major structural task. Mechanical tasks included reworking of the trunnions and replacement of the drive system with a frame mounted hydraulic system utilizing hydraulic motors. This paper focuses only on these last two tasks.

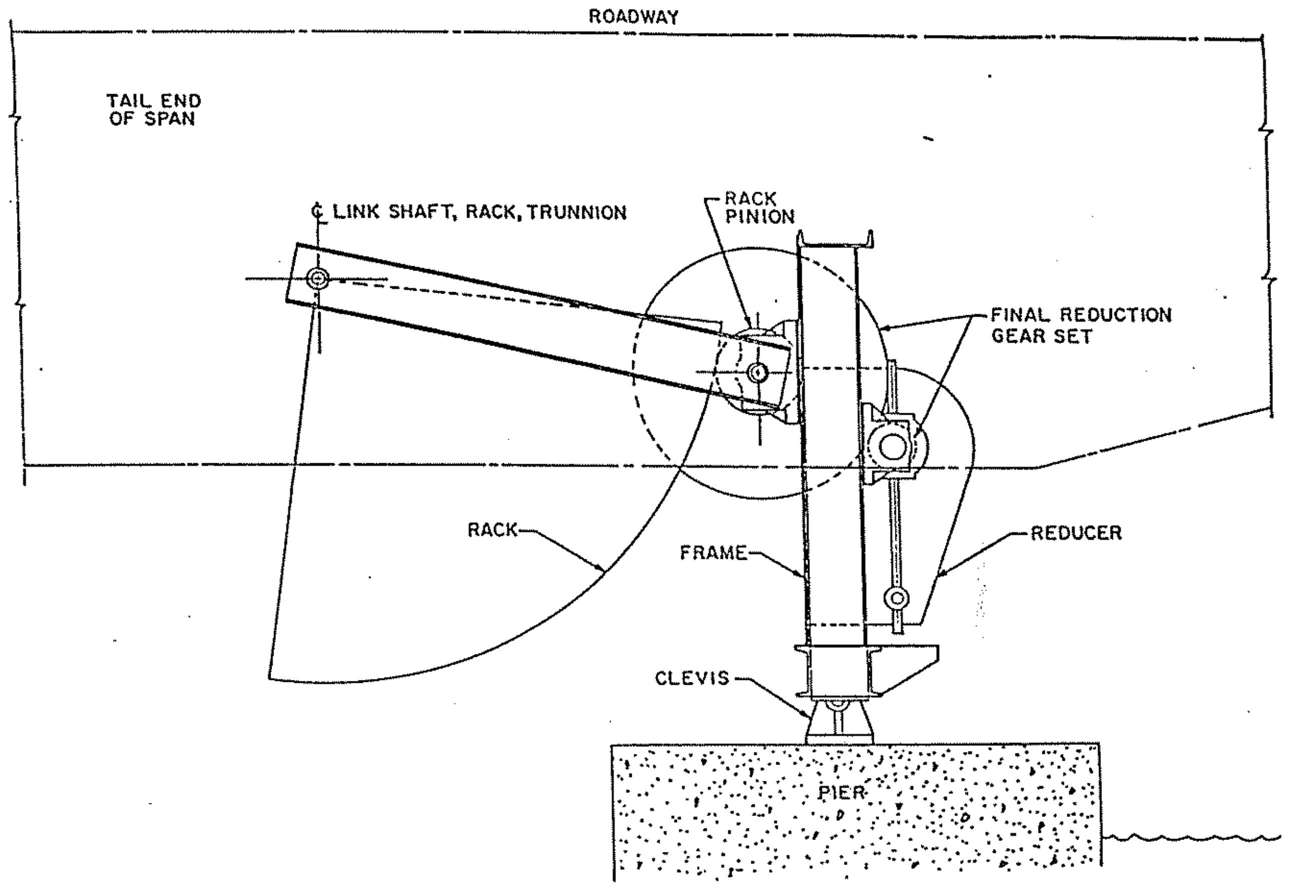
The concept of a frame mounted hydraulic system for movable bridges was not conceived exclusively for this project. Instead, it is one that had been discussed by several people during the preceding years and was in fact derived with many bridges in mind. In addition to this writer, Mike Hanley of Circuit Engineering and the FDOT's mechanical engineering group deserve credit for the concept's development. The discussions prompting the idea occurred during the course of previous FDOT repair projects as it became apparent that a reliable replacement had to be found for the numerous aging and deficient Hopkins Frames. This replacement also had to fit into the unique schedule and constructability requirements of a movable bridge rehabilitation.

Hopkins frame: To understand the factors which lead to the new designs development, we must first review the concept of the original design. Leonard O. Hopkins patented the Hopkins Frame in 1936 as a proprietary drive system for trunnion type bascule bridges. The system offered several advantages over the original designs which were mostly conventional floor mounted machinery. Not only was the machinery mounted on a common frame so that it could be shop aligned and tested, but the frame was ingeniously pinned at the bottom to the bascule pier and at the top to the bascule span by way of links so that alignment of the pinion with the rack and the frame with the trunnions could be quickly obtained and accurately maintained (see Figure 1).

Despite the Hopkins Frame design's advantages, many of the frames have not endured well because of other shortcomings. Most notably, the frame supporting the machinery was not adequately designed and detailed to withstand the cyclic and eccentric loading it was to be subjected to. As can be seen in Figure 1, the loads applied to the pinions during span operation resulted in both axial and bending loads in the main vertical members of the frame. Over time, the vertical members have developed fatigue cracks on many of these structures.

In the course of several previous projects involving the repair, analysis, and design of replacements for Hopkins Frames, this writer has developed insight as to the nature and magnitude of the original design's deficiencies. Three of these deficiencies, which are of major concern, became guidelines for improvements in the development of the new replacement frame. They are summarized as follows:

> The vertical members which are typically W12x27 wide flange sections are inadequate for the bending moments for which they are subjected. If the original geometry is to be maintained, these members need to be replaced with much larger members, such as W12x65 to reduce fatigue stresses to a level acceptable under the current AASHTO code.
>
> The bearings are located on the opposite side of the frame from the center of the trunnions. This results in eccentric loads on the vertical members and excessive tension on the pillow block cap and base bolts.
>
> The pinions are cantilevered outside the pinion shaft bearings and inside of the link arm bearings. Since the shaft bearings and link arm do not provide restraint in the same plane this configuration results in torsion in the supporting frame.



SEABREEZE BRIDGE
EMERGENCY REPAIRS

TYPICAL HOPKINS FRAME

Figure 1

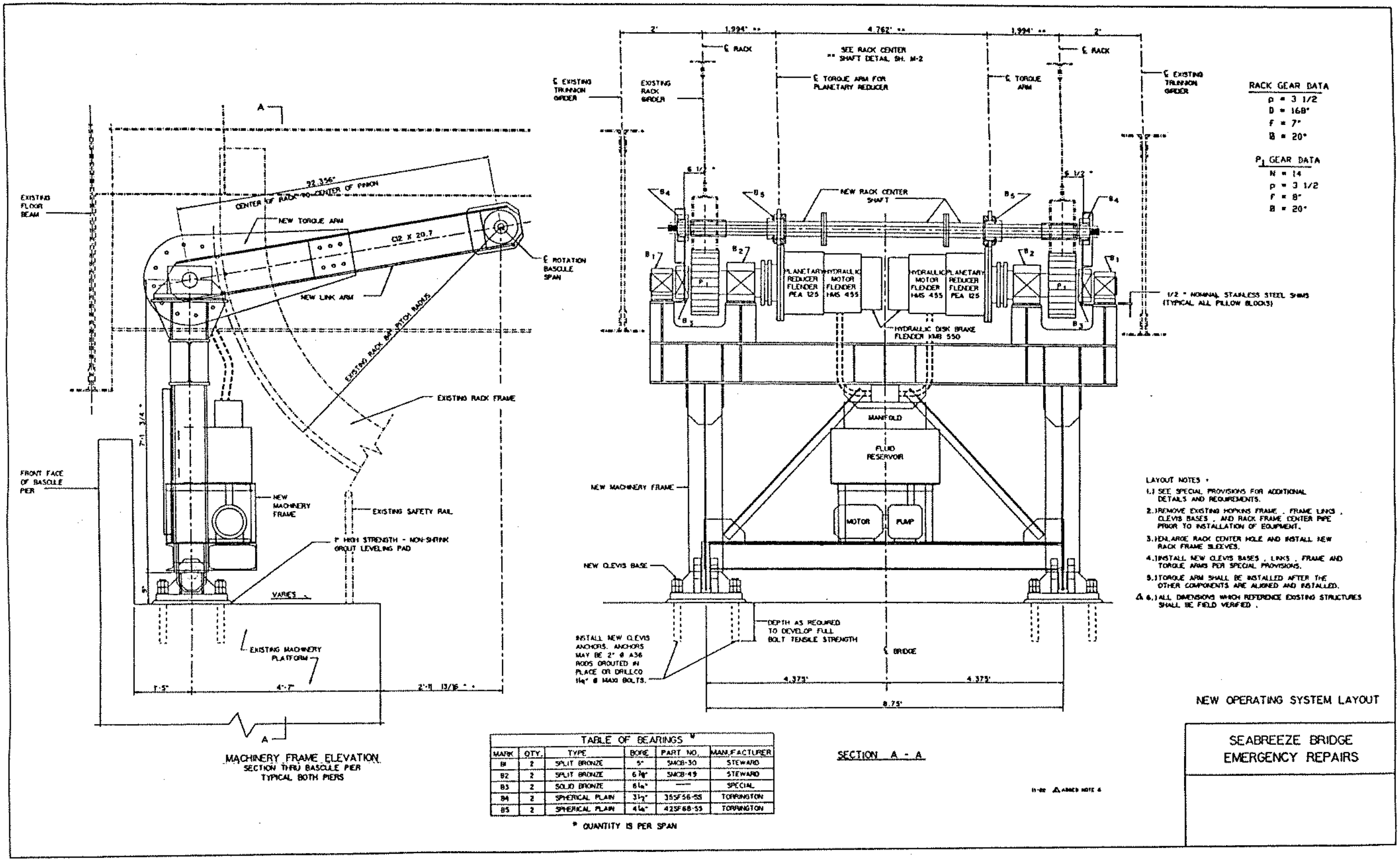
Project Development: As with any rehabilitation project this one had several significant constraints imposed by the existing design and site conditions. · Any new design had to be capable of implementation with minimal disruption to the operation of the bridge as this would impact vehicular traffic accessing Daytona Beach from the mainland and marine traffic traveling the Intracoastal Waterway. After assessing the schedule it was determined the new drive system had to be designed so that it could be put in place in a matter of hours and become functional within two weeks. In addition to the constraints of the Seabreeze site, consideration was also given to adaptability to other similar bridges where the design could be reused with minor modification. Another alternative use considered in the design is the possibility of reuse of a frame mounted hydraulic system on more than one bridge. For example, since the Seabreeze Bridge is scheduled for replacement in the next 5 to 10 years, the drives could be removed and installed on a similar bridge requiring repair at that time.

Although the drive components selected for the new design could be substantially different in size and shape from the existing gears and reducers, the pinions had to line up with the existing racks, and the new frame had to sit on the existing machinery platform. As it turned out these geometric constraints were not very accommodating. Not only is the space on the platform somewhat limited, but consideration had to be given to placing anchorages for the new frame while the old frame was still in place.

As a result of the situation described above, a new concept in movable bridge drive systems was developed and implemented. As requested by the FDOT, the system utilizes a frame mounted hydraulic system. The final solution however, is more than just a hydraulic Hopkins Frame, it is a modern hydraulic system mounted on an improved frame designed to replace existing systems and their inherent deficiencies. It is a new drive system which can be shop assembled and tested before replacing an existing system in a matter of days. It is also a replacement system designed as a permanent system, to last the life of the bridge.

In the new design the typical existing system of electric motors, thrustor brakes, open gears, pillow blocks, and reducers is replaced by a modern hydraulic power unit, low speed-high torque hydraulic motor, planetary reducer, and hydraulic disk brake (see Figure 2). A new frame with concentrically loaded columns replaces the old frame. The existing pinions are reused, but are now strategically mounted between a pair of bearings, oriented to limit tension in the cap bolts and reduce torsion in the frame.

Hydraulic Motors: There are several reasons a hydraulic motor was considered for use in the new drive system. First of all, motors are more like the existing electrical motors in size shape and mounting configuration than hydraulic cylinders would be. Secondly, as a bridge actuator, a motor offers less exposure (as in the extended rod) to corrosive elements and gritty debris than a



RACK GEAR DATA
p = 3 1/2
D = 168"
F = 7"
β = 20°

P1 GEAR DATA
N = 14
p = 3 1/2
F = 8"
β = 20°

LAYOUT NOTES :

1.) SEE SPECIAL PROVISIONS FOR ADDITIONAL DETAILS AND REQUIREMENTS.
2.) REMOVE EXISTING HOPKINS FRAME, FRAME LINKS, CLEVIS BASES, AND RACK FRAME CENTER PIPE PRIOR TO INSTALLATION OF EQUIPMENT.
3.) ENLARGE RACK CENTER HOLE AND INSTALL NEW RACK FRAME SLEEVES.
4.) INSTALL NEW CLEVIS BASES, LINKS, FRAME AND TORQUE ARMS PER SPECIAL PROVISIONS.
5.) TORQUE ARM SHALL BE INSTALLED AFTER THE OTHER COMPONENTS ARE ALIGNED AND INSTALLED.
△ 6.) ALL DIMENSIONS WHICH REFERENCE EXISTING STRUCTURES SHALL BE FIELD VERIFIED.

MACHINERY FRAME ELEVATION
SECTION THRU BASCULE PIER
TYPICAL BOTH PIERS

TABLE OF BEARINGS *

MARK	QTY.	TYPE	BORE	PART NO.	MANUFACTURER
B1	2	SPLIT BRONZE	5"	SMCB-30	STEWARD
B2	2	SPLIT BRONZE	6 7/8"	SMCB-49	STEWARD
B3	2	SOLID BRONZE	6 1/4"	——	SPECIAL
B4	2	SPHERICAL PLAIN	3 1/2"	35SF56-SS	TORRINGTON
B5	2	SPHERICAL PLAIN	4 1/4"	42SF68-SS	TORRINGTON

* QUANTITY IS PER SPAN

SECTION A - A

NEW OPERATING SYSTEM LAYOUT

SEABREEZE BRIDGE
EMERGENCY REPAIRS

Figure 2

cylinder. Third, hydraulic systems in general offer advantages over electric motor systems in particular movable bridge applications, such as those requiring delivery of high torque without space for extensive gear reduction.

The first step in the design was the sizing and selection of the hydraulic system components including pumps, LSHT (Low Speed High Torque) hydraulic motors, brakes, and reducers. Not only was this a priority for design reasons, but for construction reasons. Within the design/build schedule, the long lead time items had to be selected and ordered within a few months after the award of the contract.

The existing drive system was powered by a 15 horsepower (11.2 kW) electric motor operating at 870 rpm. A reducer and open gear set provided a 408.6:1 reduction ratio between the motor and the pinions. The design requirements for the replacement system were established to provide pinion torque and speed equal to or greater than that provided by the existing system in accordance with the 1988 AASHTO design guidelines. In addition, the power requirements were checked against the guideline requirements for loads due to approximated span weights plus live loads. Care was taken not to exceed the design capacity of the existing racks or pinions. Brake loads were determined in a similar manner.

As a result of the power requirement analysis, a 20 horsepower (14.9 kW) motor/pump unit was selected to drive the new system. This was the smallest unit which provided adequate flow and pressure to drive the bridge under all load cases.

Planetary Reducer: The combination of a planetary reducer and hydraulic motor was selected over a motor alone for several reasons. First of all, past experience indicated that speed control, starting, and stopping the bridge would be smoother due to the presence of a reducer which would increase motor speed by a factor of about 20. Secondly, the additional reduction would substantially reduce the size of the brake required to hold the span. This is most important considering the potential for large dynamic loads resulting from oversized or improperly applied brakes. Finally, preliminary calculations revealed that the combination unit was actually smaller and lighter than the motor required to handle the loads by itself.

To eliminate transfer of torsion from the hydraulic motor units to the frame, the units were designed for shrink disk, shaft mounting and torque arm restraint with the torque arms restrained by the bascule span. This was made possible by replacement of the rack center pipe with a sectional shaft having bearings to accept the ends of the torque arms (see Figure 3). Each motor unit and pinion are mounted on independent shafts and are not physically connected. Torque in each pinion is equalized by the use of a common fluid supply (main proportional valve) for both hydraulic motors. Based on the pressure, power (20 hp), and torque (33,300 ft-lbs operating

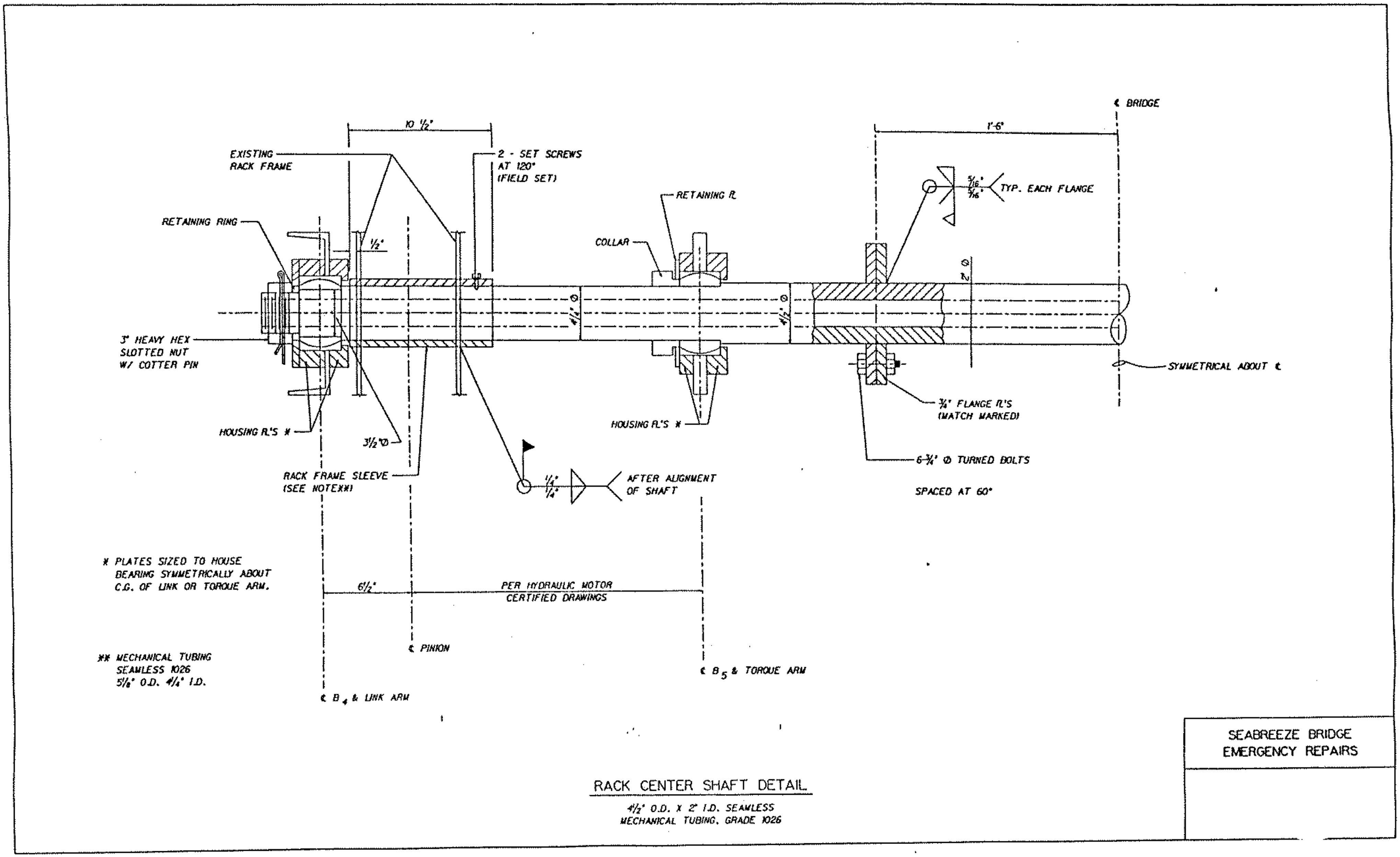

¢ BRIDGE
10 1/2"
1'-6"
EXISTING RACK FRAME
2 - SET SCREWS AT 120° (FIELD SET)
RETAINING ℞
5/16" 5/16" TYP. EACH FLANGE
RETAINING RING
COLLAR
1/2"
Ø 2"
4 1/2" Ø
4 1/2" Ø
3" HEAVY HEX SLOTTED NUT W/ COTTER PIN
SYMMETRICAL ABOUT ¢
3/4" FLANGE ℞'S (MATCH MARKED)
HOUSING ℞'S *
HOUSING ℞'S *
3 1/2"Ø
6-3/4" Ø TURNED BOLTS
SPACED AT 60°
RACK FRAME SLEEVE (SEE NOTE**)
1/4" 1/4"
AFTER ALIGNMENT OF SHAFT
* PLATES SIZED TO HOUSE BEARING SYMMETRICALLY ABOUT C.G. OF LINK OR TORQUE ARM.
6 1/2"
PER HYDRAULIC MOTOR CERTIFIED DRAWINGS
¢ PINION
** MECHANICAL TUBING SEAMLESS 1026 5 1/8" O.D. 4 1/4" I.D.
¢ B5 & TORQUE ARM
¢ B4 & LINK ARM
SEABREEZE BRIDGE
EMERGENCY REPAIRS
RACK CENTER SHAFT DETAIL
4 1/2" O.D. X 2" I.D. SEAMLESS MECHANICAL TUBING, GRADE 1026

Figure 3

(45,155 Nm), 53,700 ft-lbs (72,817 Nm) braking) requirements a Flender PEA 125/ HMS 455/ KMB 550 unit was selected to drive each pinion. This unit provides sufficient torque at acceptable pressure levels, namely, 1750 psi (12,066 kPa) under normal operation and 2950 psi (20,340 kPa) under maximum conditions.

Structural Frame: Design of the frame involved the development of several generations of computer models. Each model was built around the geometry of the span, the bascule pier, the hydraulic motor unit, and the power unit. The model was generated and graphically checked using the frame analysis module of LARSA, a three dimensional structural design/analysis program. Refinements were made in the location of members and bearings until the goal of concentric loading was achieved. To insure that this criteria was truly met, the models were subjected to all the load cases defined in the 1988 ASSHTO Design Specifications, including cases for single pinion operation or braking.

The final frame consists of two pairs of bearing supports, one on either side of each pinion, mounted on a common horizontal member (W12X65), which is in turn supported by two main vertical members (W10X49) (see Figure 4). As with the old Hopkins Frames, these vertical elements are pinned at the bottom to the machinery platform by way of a reinforced clevis. In addition to the main members, there are secondary members to support the hydraulic power unit and bracing members to stabilize the frame, especially under single pinion operation.

To simplify construction and allow the new clevis bases to be installed while the existing frame was still in service, the new frame was located up against the front wall of the pier. The relationship of the new and old frames is demonstrated in Figure 2.

Installation: Several features of the new design were developed with installation and adjustment in mind, based on the following construction sequence.

1. Core new holes in the machinery platform for the new clevis bases.

2. Remove the existing frame, drive machinery (except racks), and rack center pipe. Remove the existing pinions and place them on the new pinion shafts.

3. Enlarge the rack center hole (torch and grind) and install new sleeves for new rack center shaft. Install the center shaft and torque arm extensions.

4. Place new clevis bases, frame assembly, and link arms in position. Attach and align link arms.

5. Align frame and grout clevis bases in place.

6. Align and connect torque arms with torque arm extensions.

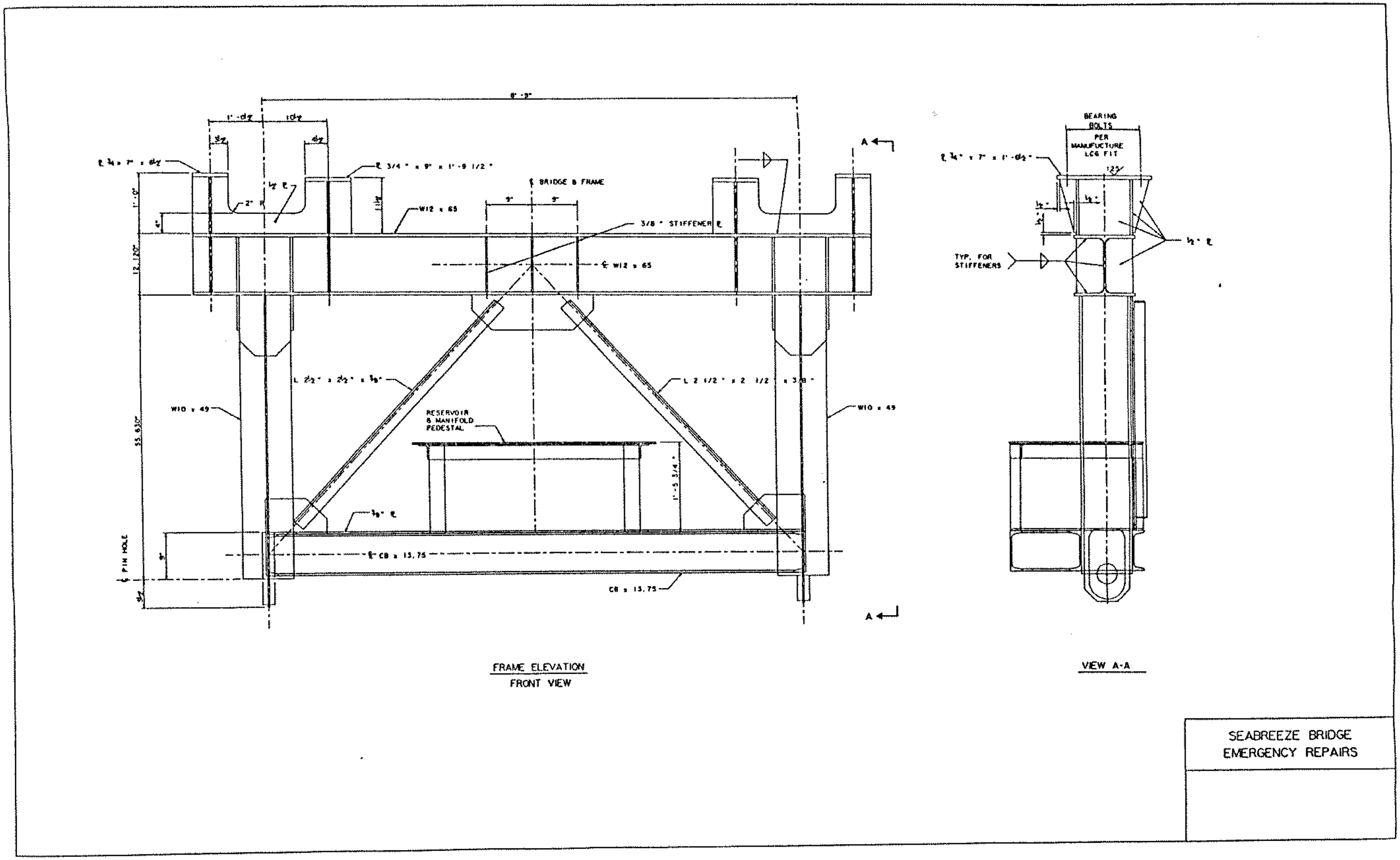

8'-9"
1'-6½"
10½"
3½"
4½"
℄ ¾ x 7" x 6½"
℄ 3/4" x 9" x 1'-9 1/2"
½ ℄
2" R
4"
1'-0"
12.120"
W12 x 65
℄ BRIDGE & FRAME
9"
9"
3/8" STIFFENER ℄
℄ W12 x 65
L 2½" x 2½" x ⅜"
L 2 1/2" x 2 1/2" x 3/8"
W10 x 49
W10 x 49
55.630"
RESERVOIR
& MANIFOLD
PEDESTAL
1'-5 3/4"
⅜" ℄
℄ CB x 13.75
CB x 13.75
℄ PIN HOLE
9"
3½"
A
A
FRAME ELEVATION
FRONT VIEW
BEARING
BOLTS
PER
MANUFACTURE
LCG FIT
℄ ¾" x 7" x 1'-6½"
.125
½"
½"
½"
TYP. FOR
STIFFENERS
½" ℄
VIEW A-A
SEABREEZE BRIDGE
EMERGENCY REPAIRS

Figure 4

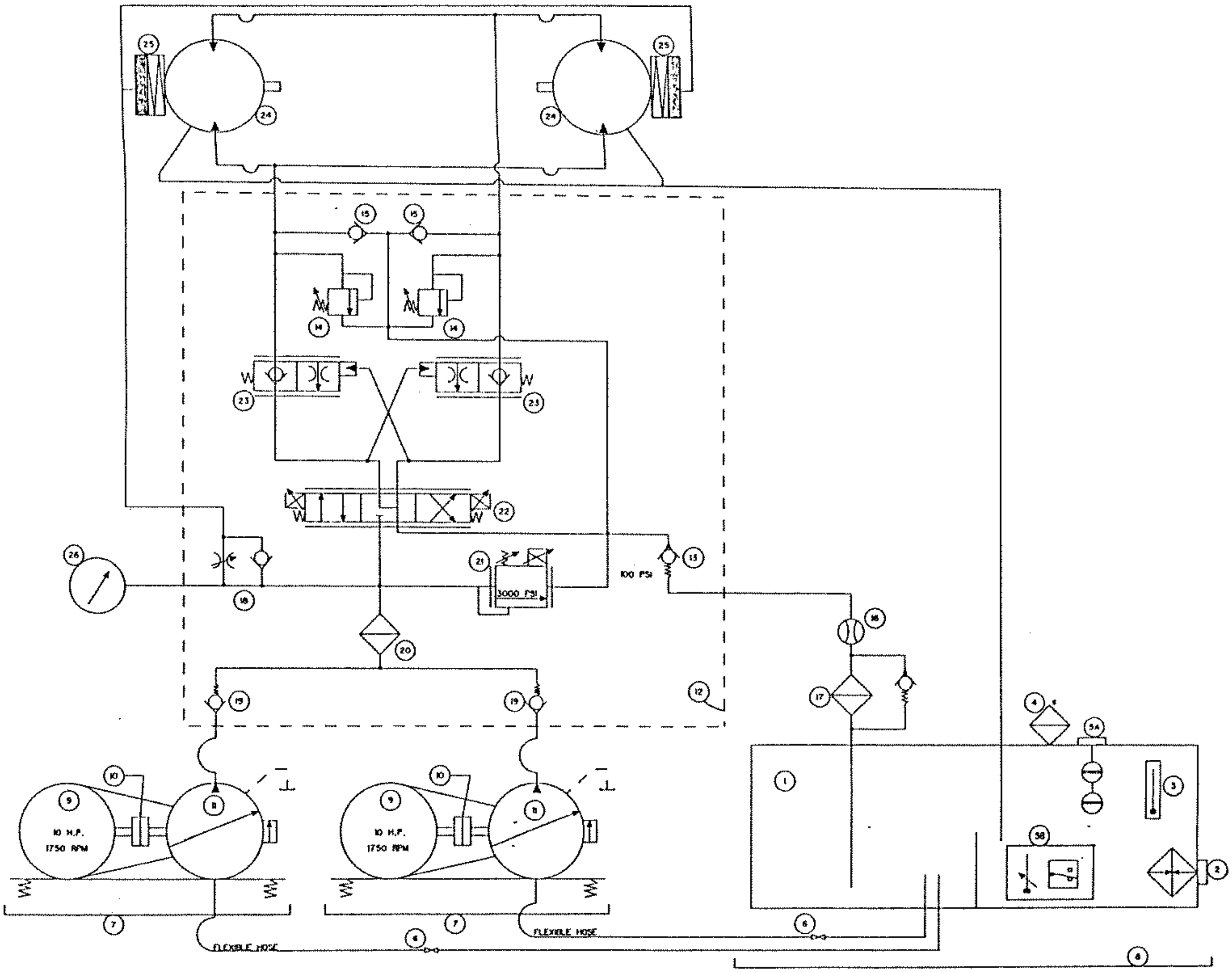
The most notable design adaptations for installation are in the new rack center shaft and the torque arms. In order to provide torque arm bearings at intermediate locations along the rack center shaft between the rack frames, the shaft was designed in three sections joined by bolted, flanged splices. This sectional shaft allows the end pieces to be inserted through the torque arm extension and rack frame from between the racks. The end sections are then joined together with the center section. Each end section fits into a spherical plain bearing in the link just outside of the rack frame.

Like the center shaft, the torque arms are sectionalized. The torque arms consist of two sections; the torque arm and the torque arm extension. The torque arm is a variable depth plate element bolted directly to the planetary reducer housing by 16 high strength bolts. The torque arm extension, comprised of two channels, is mounted on the rack center shaft with a spherical plain bearing housed in the end of the extension. To facilitate accurate alignment of the torque arm relative to the link, frame, and center shaft, the to sections are joined together by a field splice which is partially field drilled.

Power Unit: The hydraulic power unit for the Seabreeze Bridge is represented schematically in Figure 5. It is an open loop system free of unnecessary complexity. Power is derived from two 10 horsepower squirrel cage electric motors which operate at 1750 rpm and drive two variable axial piston, swashplate design pumps. The pumps are horsepower limited, that is, they operate at constant power while flow and pressure vary. The pressure in the system is energized by a single solenoid actuated proportional relief valve. Flow through the motors is controlled by a single 4-way proportional valve. Both of these valves are controlled through a programmable controller by electronic ramp cards. A pair of counterbalance valves and cross-port relief valves serve to provide back pressure for smooth operation and control of overrunning loads.

Summary: This new frame mounted hydraulic drive system was installed by the contractor as planned in a matter of several days per span. The cost for installing the new system, including control system, frames (2), power units (2), and a new control console was approximately $720,000. Since the installation, the system has run virtually error free up to the time of this writing.

The frame mounted hydraulic system is a new concept designed to replace aging and deteriorated bascule bridge drive systems, particularly Hopkins frame systems. It offers improvements over the previous Hopkins drive system, while maintaining the advantages sought in the original design. Most importantly, this new drive system offers bridge owners a replacement option which is aimed at meeting the requirements of a rehabilitation program. Unlike many rehabilitation options, this one provides a system which can be fully tested before installation and is designed as a permanent system, to last the life of the bridge.



BASCULE SPAN HYDRAULIC SCHEMATIC

(2 REQUIRED - 1 PER SPAN)

TABLE OF HYDRAULIC EQUIPMENT

ITEM NO.	QTY	DESCRIPTION
1	1	RESERVOIR ASSEMBLY (20 GAL)
2	1	IMMERSION HEATER 120V
3	1	TEMPERATURE GAUGE/SIGHT GLASS
4	1	DESSICANT BREATHER
5	2	TEMP FLOAT SWITCH ASSEMBLY (5A & 5B)
6	2	SUCTION BUTTERFLY VALVE
7	2	PUMP/MOTOR DRIPTRAY
8	1	RESERVOIR DRIPTRAY
9	2	ELECTRIC MOTOR 10HP @ 1750 RPM
10	2	FLEXIBLE COUPLING
11	2	PUMP (VARIABLE DISPLACEMENT PISTON TYPE)
12	1	VALVE MANIFOLD
13	1	BACK PRESSURE CHECK VALVE 100 PSI
14	2	CROSS-PORT RELIEF VALVE
15	2	ANTICAVITATION CHECK VALVE
16	1	FLOWMETER
17	1	RETURN FILTER W/ELECT. + VISUAL INDICATOR
18	1	BRAKE RELEASE FLOW CONTROL
19	2	CHECK VALVE
20	1	PRESSURE FILTER W/ELECT. + VISUAL INDICATOR
21	1	SOLENOID RELIEF VALVE
22	1	4 - WAY PROPORTIONAL VALVE
23	2	COUNTERBALANCE VALVE
24	2	HYDRAULIC MOTOR (RADIAL PISTON LSHT)
25	2	HYDRAULIC DISC BRAKE
26	1	PRESSURE GAUGE

EQUIPMENT SHOWN IS FOR ONE SPAN. TWO SYSTEMS ARE REQUIRED

HYDRAULIC SYSTEM NOTES

1. THE CONTRACTOR SHALL SUPPLY TWO HYDRAULIC SYSTEMS DESIGNED IN ACCORDANCE WITH THE SPECIAL PROVISIONS AND MEETING THE REQUIREMENTS OF THIS SHEET.
2. THE SYSTEM SHALL DELIVER TO EACH PINION SHAFT 16,500 FT-LBS OF TORQUE AT 2.13 RPM (NORMAL OPERATING SPEED) OR 33,300 FT-LBS OF TORQUE AT 1.10 RPM (ONE HALF NORMAL SPEED). FOR THESE CONDITIONS, THE MAXIMUM PRESSURE SHALL NOT EXCEED THE 3000 PSI OF THE RELIEF VALVE.
3. THE BRAKE SHALL BE ADJUSTED TO DELIVER TO THE PINION SHAFT 51,400 FT-LBS STATIC BRAKING FORCE ±5%. BRAKES SHALL BE FULLY RELEASED AT 280 PSI.
4. PROVISION SHALL BE MADE FOR NORMAL OPERATION BY BOTH MOTORS AND PUMPS AND EMERGENCY OPERATION WITH EITHER MOTOR/PUMP SET WHILE THE OTHER IS OUT OF SERVICE.
5. PROVISION SHALL BE MADE FOR GRADUAL MANUAL RELEASE OF THE BRAKES IN THE EVENT OF A POWER FAILURE.

SEABREEZE BRIDGE
EMERGENCY REPAIRS

Figure 5