Paper No. 51

Hydraulics/Fluid Power

Hydraulic Drive for Great Bridge

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TENTH BIENNIAL SYMPOSIUM

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GREAT BRIDGE MOVABLE BRIDGE REPLACEMENT
Great Bridge, Virginia.
2004

Virginia's newest state of the art bridge crossing the Atlantic Intracoastal Waterway is unique both in its design and features as well as being the first in the Commonwealth of Virginia to be fully hydraulically operated. Nonetheless, its uniqueness due to its features is not surpassed by its special place in the span of more than 228 years of American history. It is the site of the first land battle of the Revolutionary War fought in Virginia, the Battle of Great Bridge.

In November 1775, opposing forces began gathering at the Town of Great Bridge, a thriving commercial village located south of Norfolk a distance of some 12 miles by water or 18 miles if measured by land. The village served as a port for the shipment of naval stores and agricultural products, including tobacco, bound for Norfolk and beyond from North Carolina.

At Great Bridge, a series of causeways and bridges crossing the Southern Branch of the Elizabeth River and its marshy environs afforded the only landward approach to Norfolk. The "greater" of the bridges, first constructed in 1685, crossed the headwaters of the River and was called the Great Bridge. It was the only bridge that crossed any branch of the Elizabeth River, thus providing the only land passage open to Norfolk. This made it an important and strategic military location.

After 12 days of intense fighting from both sides of the bridge, the British retreated to Norfolk. The results of this battle were many but perhaps most importantly; it lifted the spirits of the patriots and demoralized those of the loyalists. This prompted the Fourth Virginia Convention to begin the first open public debate on a declaration of independence from England. The site of the new bridge construction is registered as a Historic Site and the name of the roadway crossing the bridge is Battlefield Blvd.

The next bridge to be built across this important waterway was a swing bridge in 1895. In 1917 the Army Corps of Engineers built a bascule type movable bridge there. Then in 1943 the Corps built a two-lane double swing bridge. Now completed in 2004 the Army Corps has replaced the old span with a double leaf five lane rolling Bascule Bridge. The bridge spans the Intracoastal Waterway over the Albermarle and Chesapeake Canal. This part of the Intracoastal Waterway is a very important and active route for both commercial and recreational marine traffic. The roadway Battlefield Blvd, Virginia Route 168 is a major North-South route connecting Virginia and North Carolina.

Tidewater-Skanska was the successful bidder for the new bridge project in 2001. The challenges of construction were many. The contract called for construction of a new low level, five lane, double leaf, overhead counterweight, hydraulically driven, rolling through truss Bascule Bridge with no disruption to vehicular or marine traffic. This area is so busy that 30,000 cars cross the old bridge every day and the existing swing span opens once an hour for a line up of waiting boats. To make it more difficult, all this had to be done within 10 feet of the old bridge that would swing over the new construction every time it opened and was often stuck in the open position. The entire project had to be accomplished with only four 72 hour channel closures.

The design called for an overhead counterweight in order to maintain a low level roadway profile and avoid deep cofferdams. Tidewater's project team decided to erect the 1500 ton counterweights shored in closed position and preassemble the 270 ton leaf portions offsite. Each counterweight contains 270 tons of structural steel (including two 56.5 ton segmental rolling girders) and 680 cubic yards of concrete. Each of the four segmental rolling girders are seated on a 42 ton, double web, concrete filled, embedded track girder with a 9" thick machined casting attached which forms the rolling surface. Track girders were required to be set to 0.03" tolerance for horizontal and vertical alignment with a 0.006" per foot level tolerance. This was achieved using precision survey equipment and machinist's levels

The leaves (or deck sections) were fully assembled two miles west of the jobsite on the waterway at Tidewater Skanska's equipment yard. These were subsequently floated in and fully connected to the counterweight in the horizontal position during two of the 72 hour channel closures using "Samson" a 350 ton stiff leg derrick type barge crane owned by Tidewater-Skanska. During the same period, the hydraulic cylinders were attached and the bridge leaves opened for the first time. With most of the 72-hour closure dedicated to the attachment of the span to the counterweight, there was little time left for refinement of the hydraulic system. It had to work the first try.

A third and fourth 72 hour shutdown was used to place deck and remaining counterweight concrete which brought the bridge into balance, allowing temporary balancing weights to be removed. Each channel closure was required to be scheduled to the precise hour, 90 days in advance with the US Coastguard.

The August 18, 2003 edition of Engineering News Record reported "New Virginia Span Is Built Like A 5,000 Ton Watch". This was a good analogy as the bascule structures were specified to be erected to very fine tolerances, especially the components forming the rolling surfaces. Tidewater Skanska chose to have the toothed castings, which form the rolling surfaces, shop attached, to avoid making a machine tolerance fit under field conditions. Therefore, precise positioning and alignment of the pairs of embedded track girders on either side of the waterway was critical, as was controlling the overall dimensions of the assembled structural steel. Another important design criteria was for the bridge deck and roadway to end up with a _" warp so that upon engagement of the noselocks into their sockets, a positive force raises the opposing leaf to eliminate "bounce" under traffic conditions. All requirements were met and exceeded. When both leaves were closed and mated for the first time, they were within 1/8" of the 110' plan length, and longitudinally aligned within _". After the hydraulic cylinders were hooked up the bridge leaves operated flawlessly, first time.

The hydraulic system power was provided by two hydraulic cylinders per leaf 450mm(17.7 inch) bore X 4500mm(177 inch) stroke X 280mm(11 inch) rod. The cylinders were heavy-duty mill type with ceramic-coated piston rods. Cylinders were built to operate at 3000 psi and had an integral steel manifold with all the necessary valving.

Oil supply for the cylinders came from a 400hp hydraulic power unit on each leaf. There are three major components to each hydraulic power unit, the pump-motor skid, the reservoir assembly, and the stainless piping system.

The HPU pump motor skid has four pump-motor groups. Each one consists of a 100hp 1200rpm electric motor direct coupled to a 500cc axial piston type hydraulic pump capable of delivering 150gpm. The entire pump assembly is mounted on vibration isolation mounts to attenuate the movement and sound. Filtration is provided for each pump by way of a suction strainer at the inlet and a high-pressure filter at each outlet. All four pumps draw from a common 8" suction line and discharge into a large steel manifold, which contains all the necessary valving.

Dimensions for the manifold are 36" square with the assembly weighing almost 3000 pounds. Unusually high fluid flows of over 400gpm required directional control and counterbalance valves to be large poppet type logic elements rather than spool valves. Electronic proportional valves were used for the relief and counterbalance functions. The total weight of the HPU skid was 26,000 pounds.

The stainless steel reservoir assembly was fabricated separately from the HPU skid with a full capacity of 1750 gallons of ISO grade 32 mineral oil hydraulic fluid. Each reservoir has two large desiccant type breathers and two large return line filters.

Hydraulic stainless steel piping was prefabricated during HPU assembly so that all critical fits and welds could be pretested prior to field installation. The piping was butt welded for minimum flow restriction. Critical 4" high-pressure schedule 160 welds were X-ray inspected. Coordination of the piping prefabrication was critical since the requirement was to fabricate two 40-foot long assemblies per leaf that could be craned into place. This was further complicated by three of the pipes to be fit through a predetermined hole in the machinery room wall to the outside while still being in perfect alignment at the HPU inside the machinery room.

The challenges of the hydraulic system were many. The large sizes of the equipment and high flows required experienced designers, fabricators, and installers. Beginning with the load, the hydraulic cylinders are almost 40 feet long when fully extended. Design calculations were done to ensure that the cylinders would adequately hold the load under all AASHTO conditions. Rod bearing loads were also taken into consideration to minimize any loads being transferred from the bridge to the two cylinder wearing surfaces, piston and rod gland. Using spherical bearings at each end of the cylinders helps to minimize the affects of small changes in alignment as the bridge rolls into the open position.

Large hydraulic cylinders require large hydraulic flows. Just getting the oil in and out required four 2-inch high-pressure hoses at each cylinder. Large steel manifolds were fabricated directly to the cylinder base with the necessary hydraulic valves to hold the load and also to relieve it if need be.

The next challenge to be met was to handle the large fluid flows through the control manifold. The custom steel manifold weighed over 4000 pounds. Logic type cartridge check valves were used instead of multiple spool type valves ganged together to handle the flow. This becomes critical when designing the counterbalance function for a movable bridge since the natural frequency for a bridge is so low that even small changes in counterbalance backpressure can cause wide fluctuations in the leaf movement. For this reason electronically controlled logic valves were selected to control the backpressure of the cylinder load in each direction. An electronic pressure transducer monitors pressure. The electronically controlled logic valve with an integral position feedback provides a calculated logic valve opening very accurately. This process is known as "Electronic Counterbalance Valve" and is sometimes preferred over having multiple spool type valves that can sometimes interact with each other as the load changes.

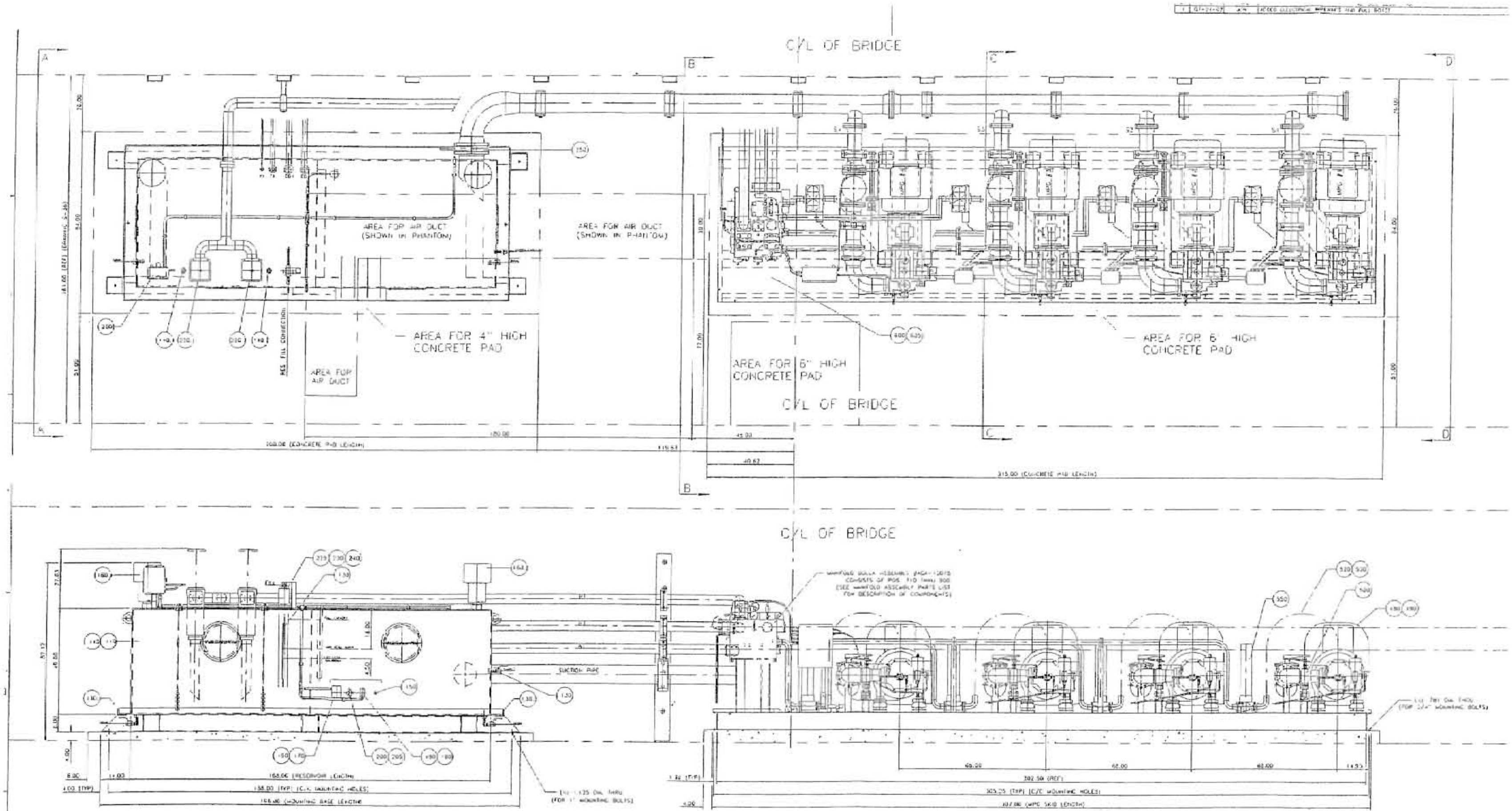
An electronic control over the output of the pumps was another decision made to handle the gradual increase and decrease of a high flow hydraulic system. Each 500cc pump was capable of 150gpm and had to be ramped up to full flow over a ten second time frame. In addition to the electronic proportional control was a pressure limiter on each pump to limit the maximum pressure output to 1900psi.

Reservoir design was simple with two large return filters and two large desiccant type breathers. The reservoir was fabricated from 304-type stainless steel and held 1750 gallons of fluid. Fluid heaters and heat exchangers were not used due to the climate controlled machinery room. The entire reservoir assembly weighed approximately 24000 pounds when full.

All hydraulic equipment except the cylinders was housed inside the machinery room, which was built as an integral part of the bridge foundation. This made for an underground type design that required sealing from water intrusion on all sides. Scheduling of the installation was such that all the stainless piping on the back wall had to be installed prior to the HPU skid and reservoir. Then the concrete roof was poured over top of the entire assembly.

The electrical control system was split into three parts. A single PLC control rack was used in each machinery room to control the HPU and MCC for each leaf. A master control PLC was mounted inside the operator's control console. Both of the machinery room PLC's were connected top the operators control PLC through fiber optic cables. This minimized the number of conductors required for the submarine cable.

Using a PLC for the control of the bridge allowed many advantages. Constant monitoring of the bridge angle inclinometer and speed insured that proper operation was performed as an additional safety to operator input. A touch screen monitor provided a good visual reference for all bridge functions as they happened. In addition, this screen was used to display any fault condition and served as a troubleshooting guide should any problems occur.



NOTES

1) ALL PIPING FROM THE RESERVOIR TO THE MOTOR PUMP GROUP SKID SHOWN ON THIS DRAWING IS FOR REFERENCE ONLY. SEE DRAWING [illegible] FOR EXACT LAYOUT, DIMENSIONS AND CALL-OUTS OF ALL PIPING SUPPLIED BY BOSCH REXROTH.

2) FILL CAPACITY = 1334 GALLONS (APPROX) W/ 10% AIR SPACE
LOW LEVEL = 1284 GALLONS REMAINING
LOW LEVEL SHUTDOWN = 1075 GALLONS REMAINING

3) [illegible] CONNECTIONS ON RESERVOIR TO BE SUPPLIED W/SAE-4 TAP IN SIDE OF FLANGE FOR [illegible]

4) SCHEMATIC NO'S FOR PROJECT
RESERVOIR HYDRAULIC = HS43-43-0705-0
RESERVOIR WIRING = WD-43-48-0734-0
MPC SKID HYDRAULIC = HS43-48-0706-0
MPC SKID WIRING = WD-43-48-0733-0

System Pressure	1200 PSI (MAX)	Project No	07/97 6530/02
Cust. Name	JOURTAIN CHIEF [illegible] SERVICES	Customer PO	
Ref. Hydraulic Schematic	SEE NOTE-4	Ref. Elec./Wiring Diagram	SEE NOTE-4
Project No	07/97 6530/02		

ALL DIMENSIONS IN INCHES PER TOLERANCES SHOWN UNLESS OTHERWISE NOTED

THIRD ANGLE PROJECTION

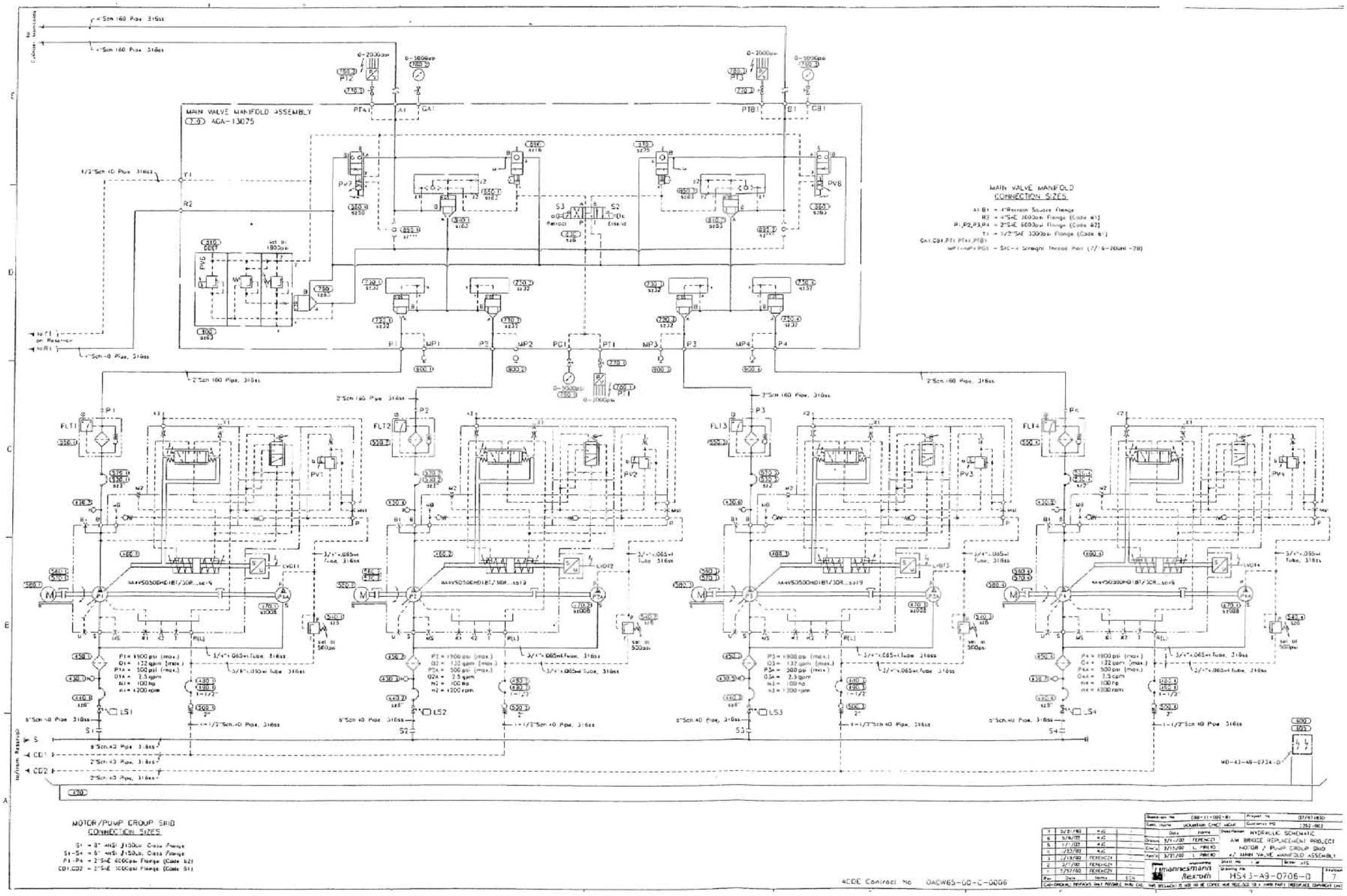
	Date	Name
Drawn	03-19-03	JOH
Chk'd	03-19-03	JOH
App'd	03-19-03	LP

Description: HYDRAULIC POWER UNIT ASSEMBLY AW BRIDGE REPLACEMENT PROJECT RESERVOIR W/MPC SKID

Mannesmann Rexroth

Sheet No. 1 of 2 Scale 1:20

Drawing No. 43AHAC-12337-0-D Revision 1



MAIN VALVE MANIFOLD ASSEMBLY
AGA-13075
MAIN VALVE MANIFOLD
CONNECTION SIZES
A1 B1 = 4"Rexroth Square Flange
R2 = 4"SAE 3000psi Flange (Code 61)
P1,P2,P3,P4 = 2"SAE 6000psi Flange (Code 62)
MOTOR/PUMP GROUP SKID
CONNECTION SIZES
LS1
LS2
LS3
LS4
PV1
PV2
PV3
PV4
PV7
PV8
FLT1
FLT2
FLT3
FLT4
MD-43-A9-0734-D
ACOE Contract No. DACW65-00-C-0066
HYDRAULIC SCHEMATIC
AIW BRIDGE REPLACEMENT PROJECT
MOTOR / PUMP GROUP SKID
w/ MAIN VALVE MANIFOLD ASSEMBLY
mannesmann
Rexroth
HS43-A9-0706-D
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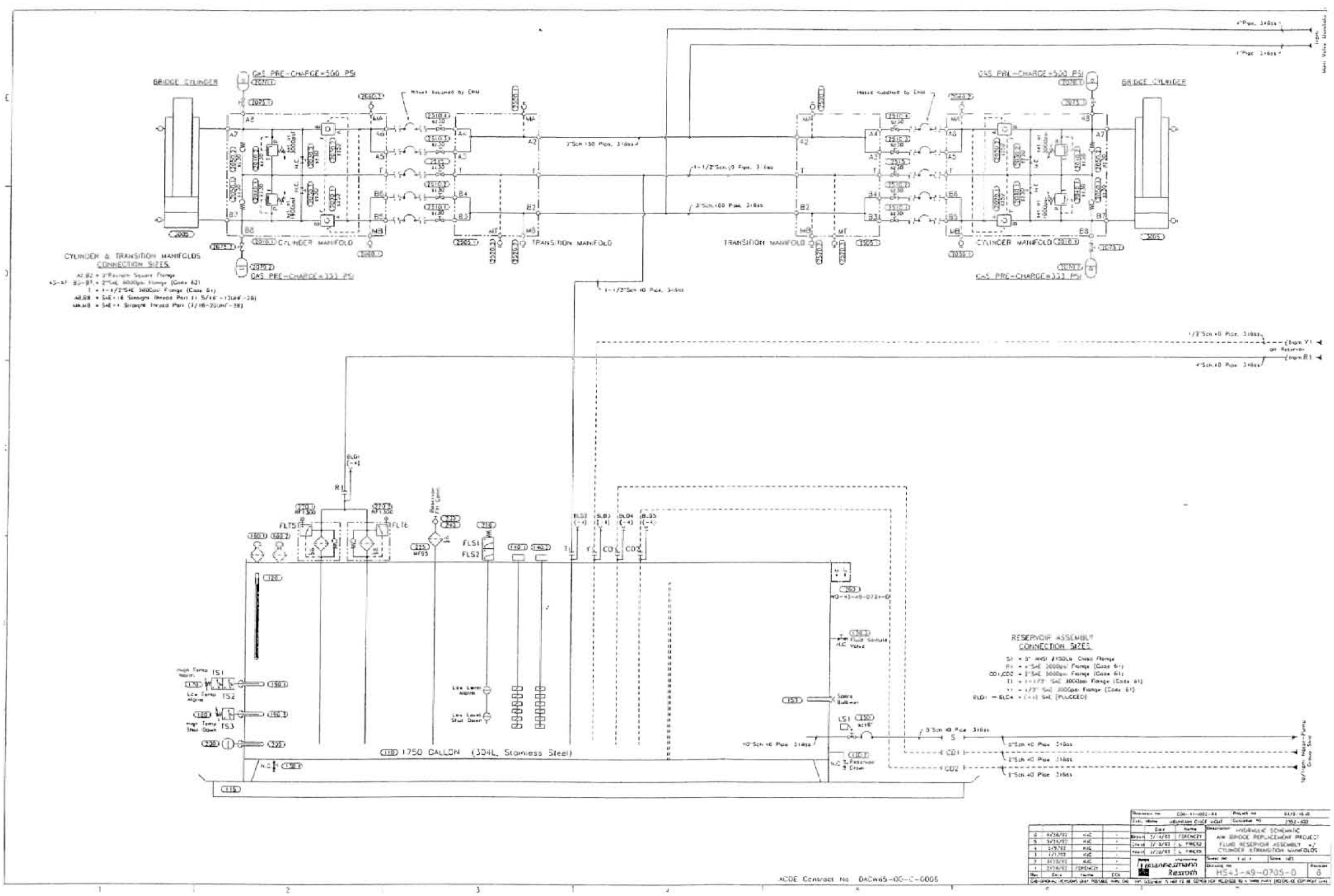
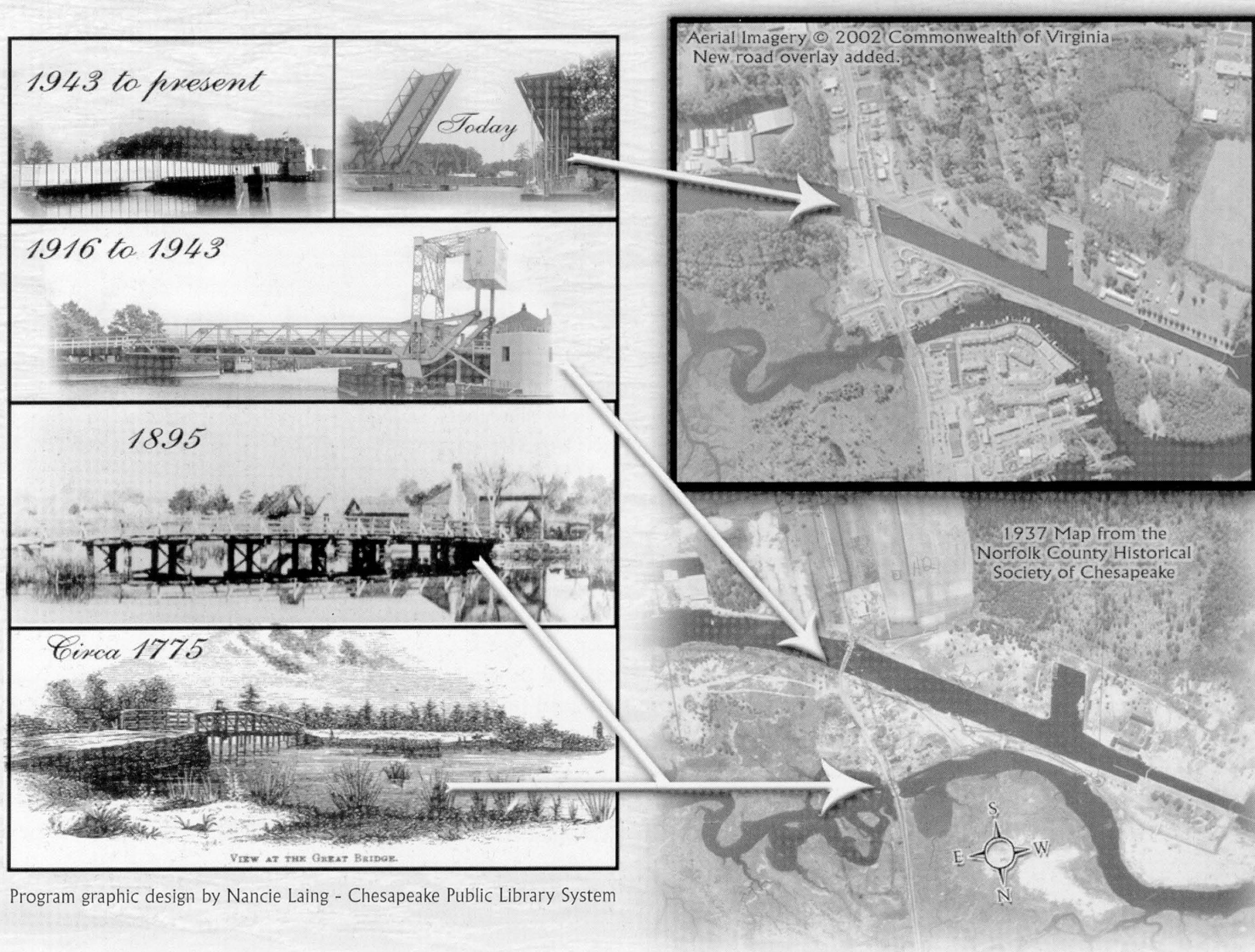


BRIDGE CYLINDER
GAS PRE-CHARGE=500 PSI
GAS PRE-CHARGE=333 PSI
CYLINDER MANIFOLD
TRANSITION MANIFOLD
CYLINDER & TRANSITION MANIFOLDS
CONNECTION SIZES
RESERVOIR ASSEMBLY
CONNECTION SIZES
1750 GALLON (304L Stainless Steel)
FLS1
FLS2
TS1
TS2
TS3
LS1
HYDRAULIC SCHEMATIC
FLUID RESERVOIR ASSEMBLY w/
CYLINDER & TRANSITION MANIFOLDS
Mannesmann Rexroth
HS43-A9-0705-0
ACOE Contract No. DACW65-00-C-0005



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