Rehabilitation of the Fremont Bridge in Seattle, Washington

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HISTORY

- Construction of a Ship Canal to link Lake Washington and Puget Sound began on November 10, 1911.
- The canal required digging cuts between Salmon Bay and Lake Union at Fremont and between Lake Union and Lake Washington at Montlake.
- Locks were constructed linking Puget Sound and Salmon Bay at Ballard.

HISTORY

Construction of the Fremont Bridge, Circa 1916
Seattle Municipal Archives Photograph Collection

- Four Chicago Style, trunnion bascule bridges were built by the City of Seattle at Fremont, Ballard, the University District, and Montlake from 1916-1925.
- The Locks officially opened on July 4, 1917, but the canal was not declared complete until 1934.

HISTORY

Fremont Bridge, Circa 1917
Seattle Municipal Archives Photograph Collection

- The Fremont Bridge was opened on Friday June 15, 1917 at a cost of $410,000.

HISTORY

Fremont Bridge, Original Span Drive Machinery Circa 1936
Seattle Municipal Archives Photograph Collection

- The Fremont Bridge currently opens an average of 35 times per day or almost 13,000 times per year
- When the Fremont Bridge celebrated its' 566,000th opening in January, nearly all of the span drive machinery was original.

HISTORY

- All four of the bascule bridges built by the city are still in operation today, although ownership of the Montlake Bridge has been transferred to the Washington State Department of Transportation.

HISTORY

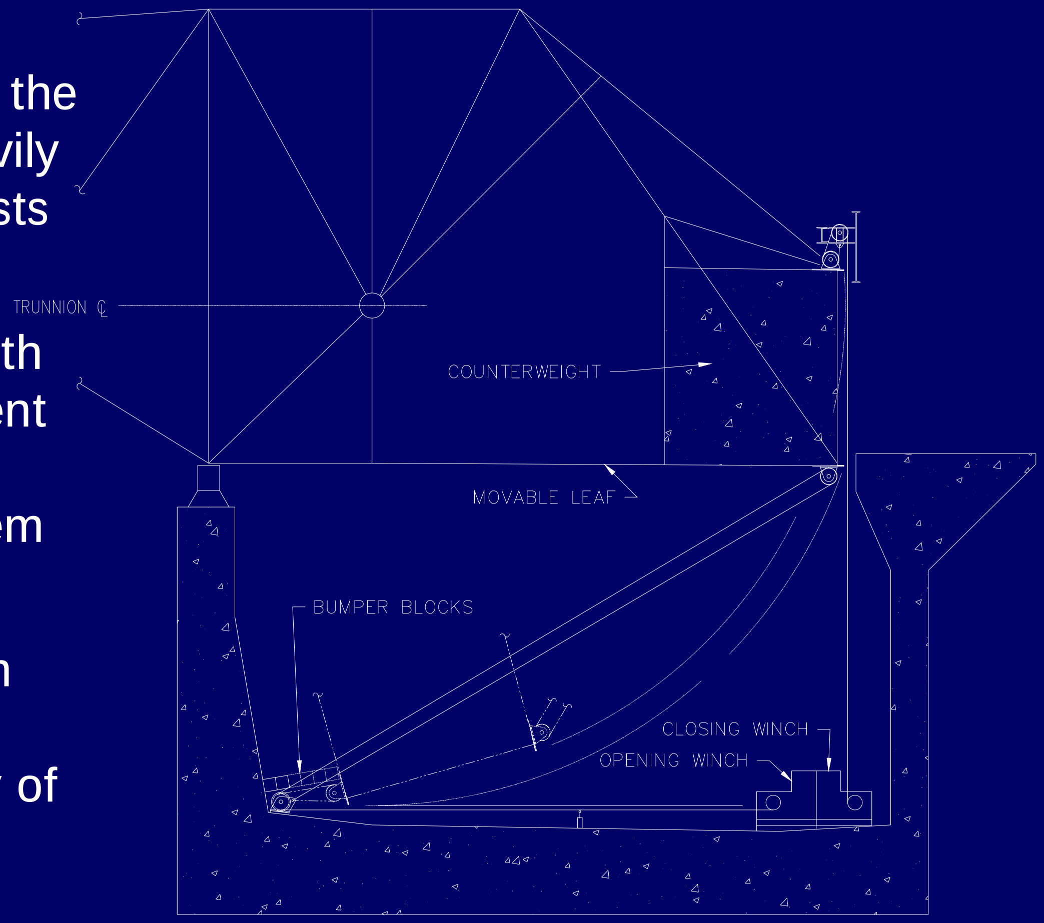
- In the mid 1980's, the City undertook a program to rehabilitate and modernize the structural, mechanical and electrical systems of the three remaining, City owned movable bridges over the Lake Washington Ship Canal.
- Rehabilitation of the University Bridge was completed in 1988.

HISTORY

- Due to funding limitations, the rehabilitation of the Ballard and Fremont bridges was delayed, and in the case of the Ballard Bridge, was completed in phases.
- The mechanical and electrical rehabilitation of the Ballard Bridge was completed in 2001.

TEMPORARY WINCH OPERATING SYSTEM

- All three of the movable brides over the Lake Washington Ship Canal are heavily used by vehicles, pedestrians, bicyclists and marine vessels.
- In order to maintain operation of both movable leaves during the replacement of the span drive machinery, a temporary span drive operating system was required.
- A temporary winch operating system was selected for use on the basis of simplicity, low cost, and the flexibility of the system to be used during the rehabilitation all three of the City's bascule bridges.

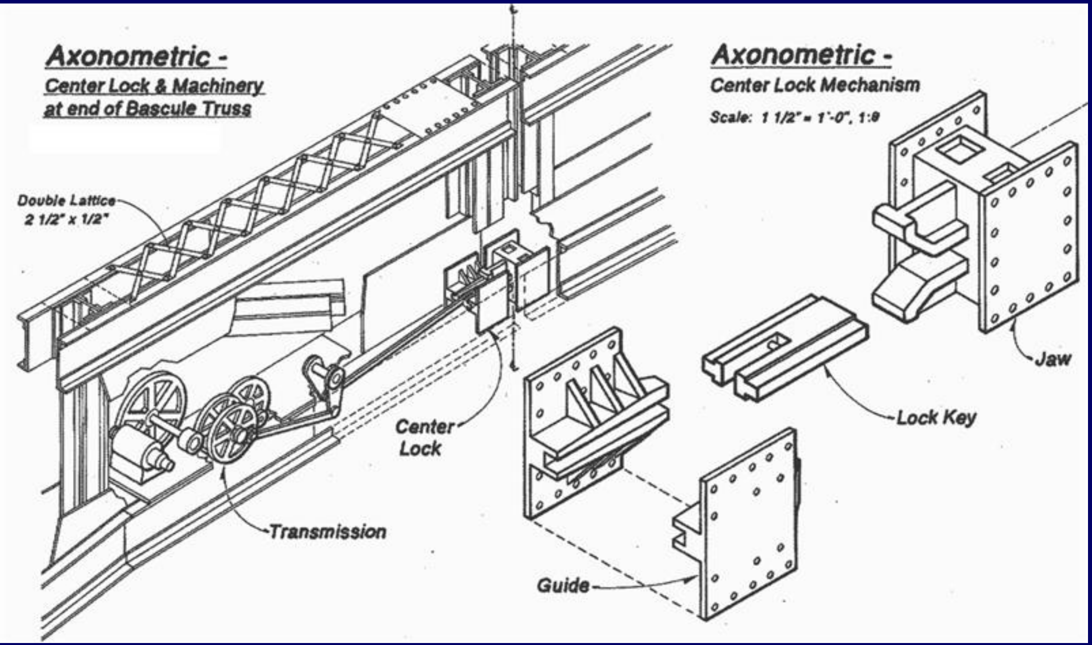


- A temporary winch system designed by SBE was built for use on the University Bridge rehabilitation.
- The winch system was loaned to Multnomah County, Oregon for use during a rehabilitation of the Broadway Bridge in the 90's.
- The winch system was returned to Seattle and used at the Ballard Bridge rehabilitation before utilizing it for the Fremont rehabilitation project.
- The time of opening for the temporary winch system is approximately 3 ½ minutes.

TEMPORARY WINCH OPERATING SYSTEM

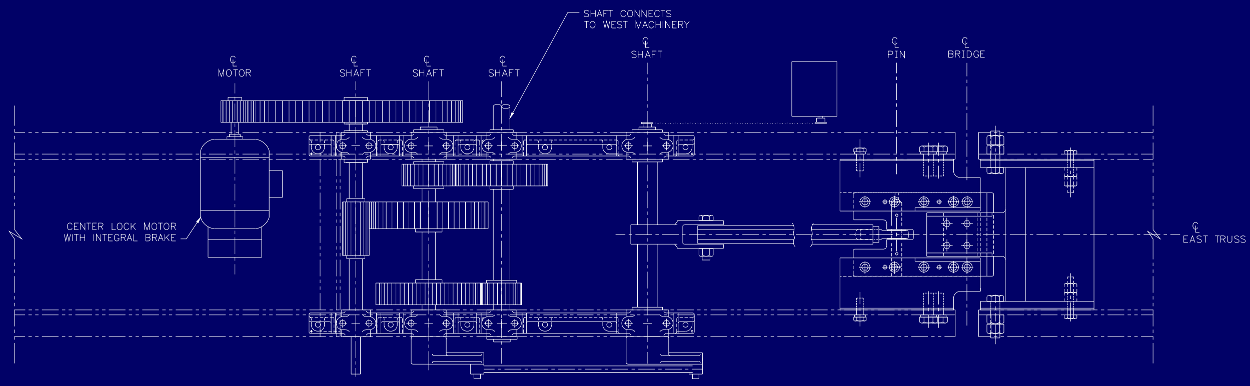
SPAN LOCK REHABILITATION

- The Fremont Bridge utilizes a novel center lock that was developed by the City of Seattle Engineering Department and utilized at all of the City-owned bascule bridges.
- The design features an overlapping jaw and guide design that virtually eliminates bending stresses from the lock key, allowing for a relatively compact lock key.



General Arrangement of the Original Span Lock Machinery, Historic American Engineering Record

SPAN LOCK REHABILITATION



PLAN OF CENTER LOCK
ENGAGED

- The center lock machinery utilizes an electric motor driving open gearing and cross shafting located under the roadway. Cranks drive the lock keys via connecting rods to drive and pull the lock keys upon rotation of the motors.
- The original lock operating machinery was rehabilitated as follows:
  - The bearing journals were polished
  - The bearings were re-babbitted and re-bored
  - The cross shafts were replaced.
  - The brake-motors and motor pinions were replaced.

REHABILITATED SPAN LOCK OPERATING MACHINERY

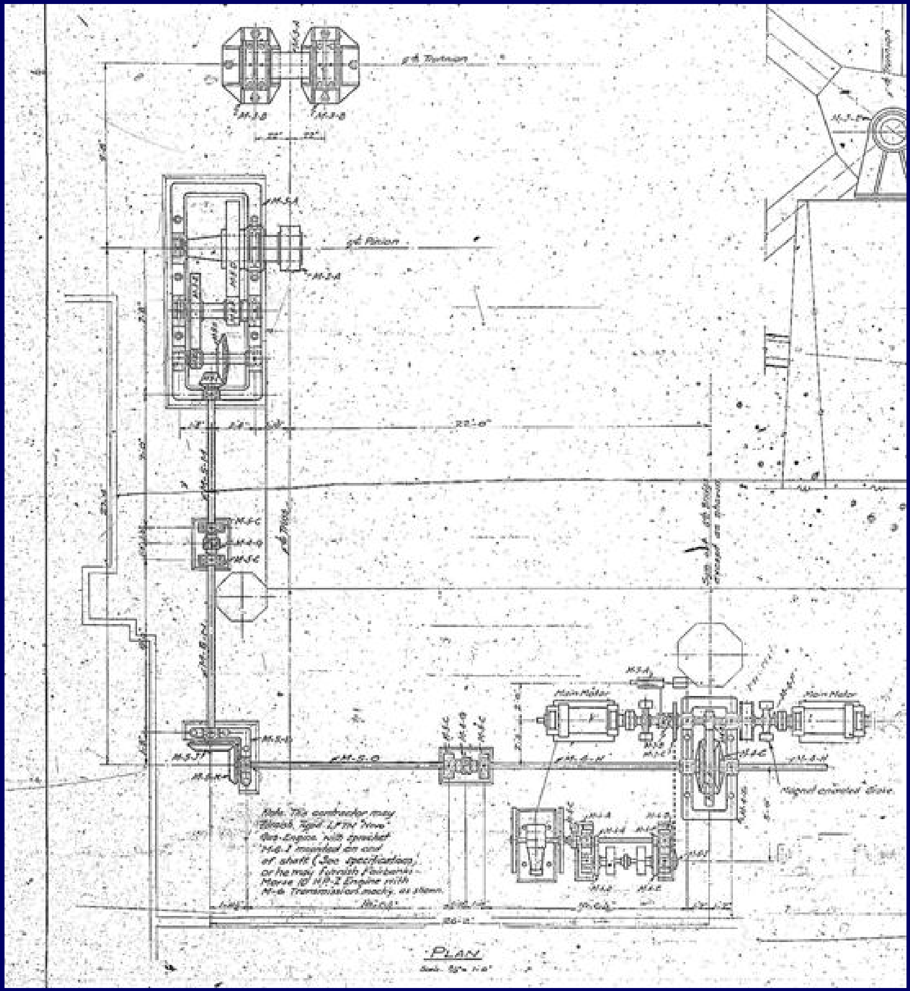
REHABILITATED SPAN LOCK JAWS AND GUIDES

- The original design had no provision to adjust the clearances in the jaw and guides.
- During the current rehabilitation, the guides and jaws were replaced with a new design that included bronze wear shoes.
- A similar design was used at the retrofit of the University Bridge and the feedback from the City after 20 years of service was that that design was performing well.

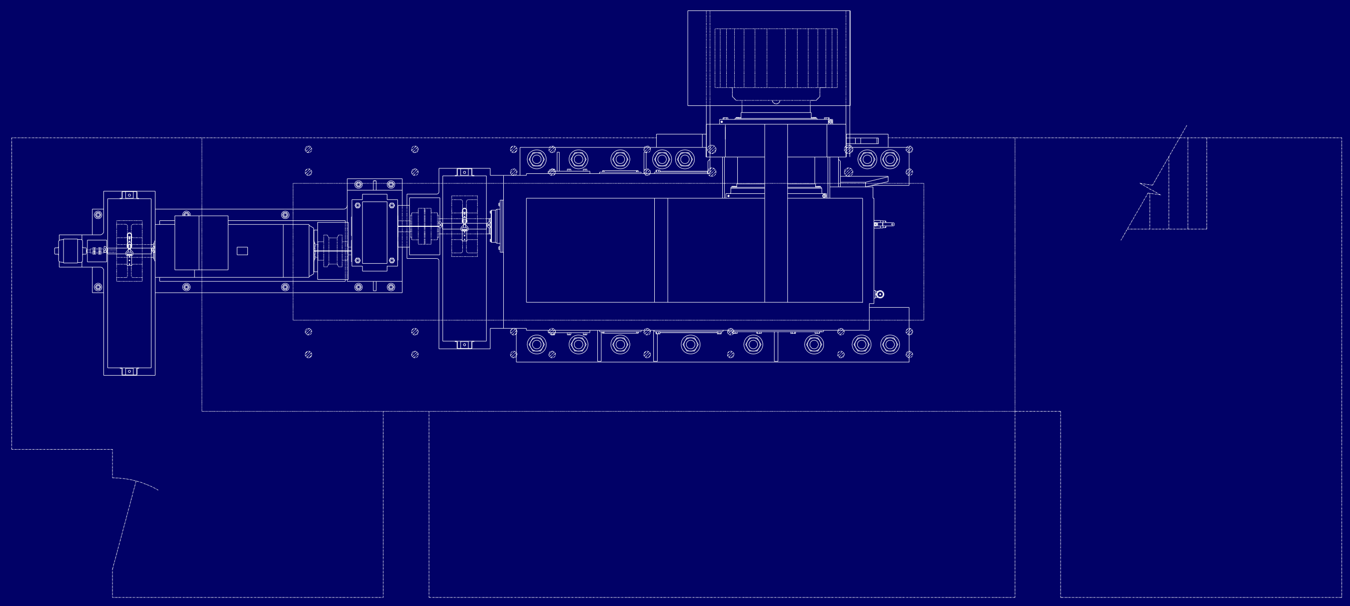
New Span Lock Connecting Rod, Lock Key And Guide With Bronze Wear Shoes, Shown Disengaged

SPAN DRIVE MACHINERY REHABILITATION

- The arrangement of the original machinery placed the 100 HP electric motor, brakes and an open bevel gear type differential in a machinery room enclosure to the rear of the counterweight at the bridge centerline.
- Line shafting extended from the differential to bevel gear sets. The bevel gear sets are connected to open gear frames located outboard of the bascule trusses by additional line shafting.
- Rack pinions are on the final shafts. The rack pinions drive 5 ½" circular pitch internal curved racks mounted on the bascule trusses.

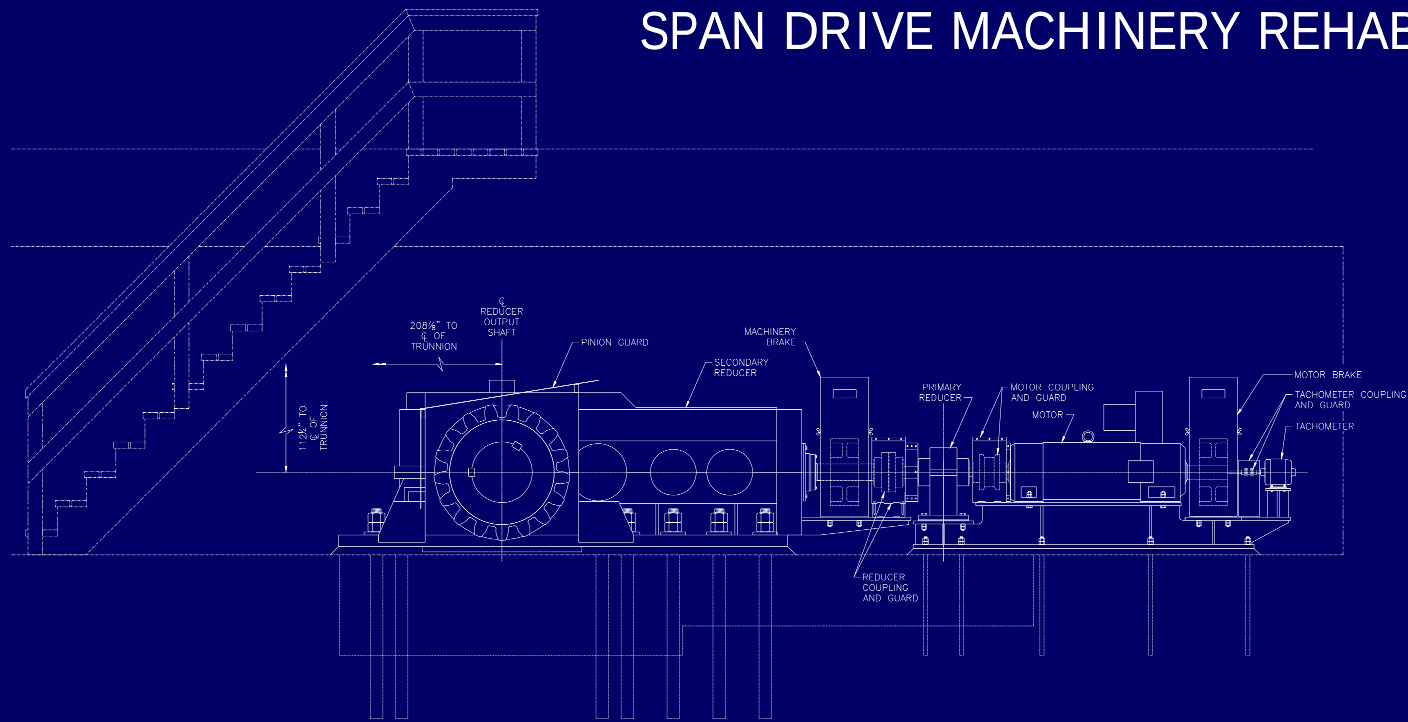


SPAN DRIVE MACHINERY REHABILITATION



- Mechanically independent drives were utilized at each quadrant of the bridge.
- The elimination of the differential allowed that space to be used for electrical equipment and avoided the need for additional electrical room space.
- Each leaf can be operated using one drive at normal speed. The only limitation is the maximum acceptable wind speed for operation is reduced.

SPAN DRIVE MACHINERY REHABILITATION



- Each drive is provided with one 75 HP motor.
- The number of teeth on the rack pinions was increased by one from 16 to 17.
- Time of operation is 76 seconds.

CONSTRUCTION

- The rehabilitation contract was awarded in September, 2005.
- The project was staged so that the approach span replacement work was started immediately.

North Approach Replacement Under Construction

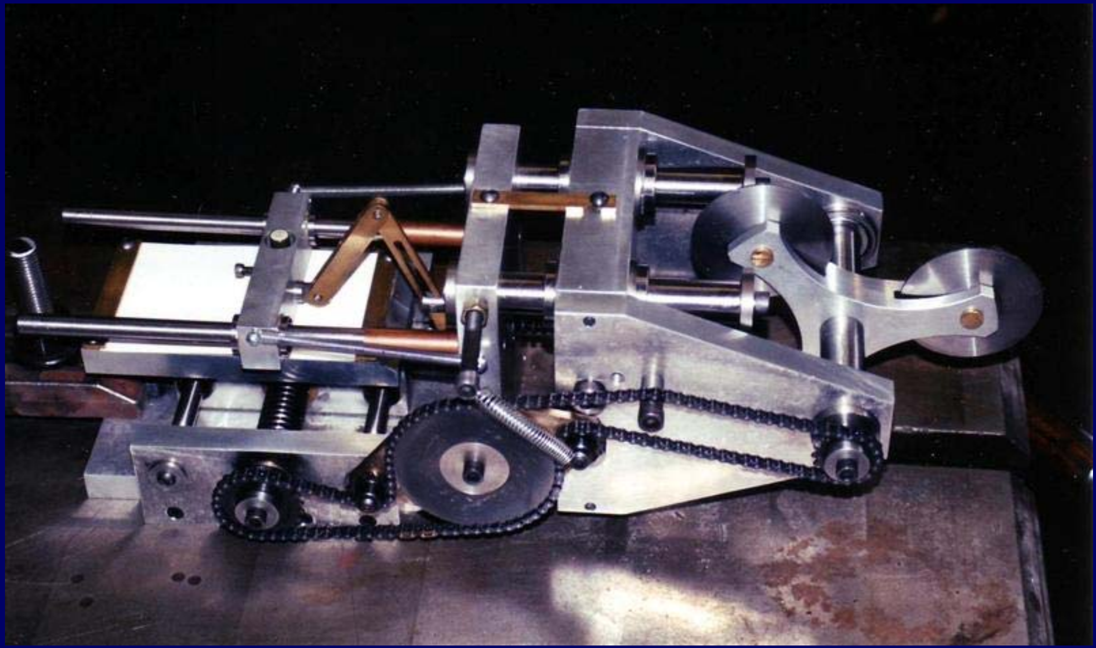
CONSTRUCTION

- While the approach replacement work was underway, the shop drawings were developed and fabrication, testing and shop inspection of the machinery was completed. The replacement of the approaches was completed in May 2007.
- Pedestrian, vehicle and bicycle traffic was maintained throughout construction.

South Approach Replacement Under Construction

CONSTRUCTION

- The span drive machinery sub-contractor was The Gear Works, located in Seattle.
- Field measurements of each existing gear rack were taken to ascertain the point of tightest mesh with the new output pinions. This required the use of a unique portable composite tester specially built for the project (nicknamed the "slinky"). The slinky accounted for the uneven wear of the existing cast steel rack teeth.



The "Slinky" Portable Composite Tester Built By The Gear Works

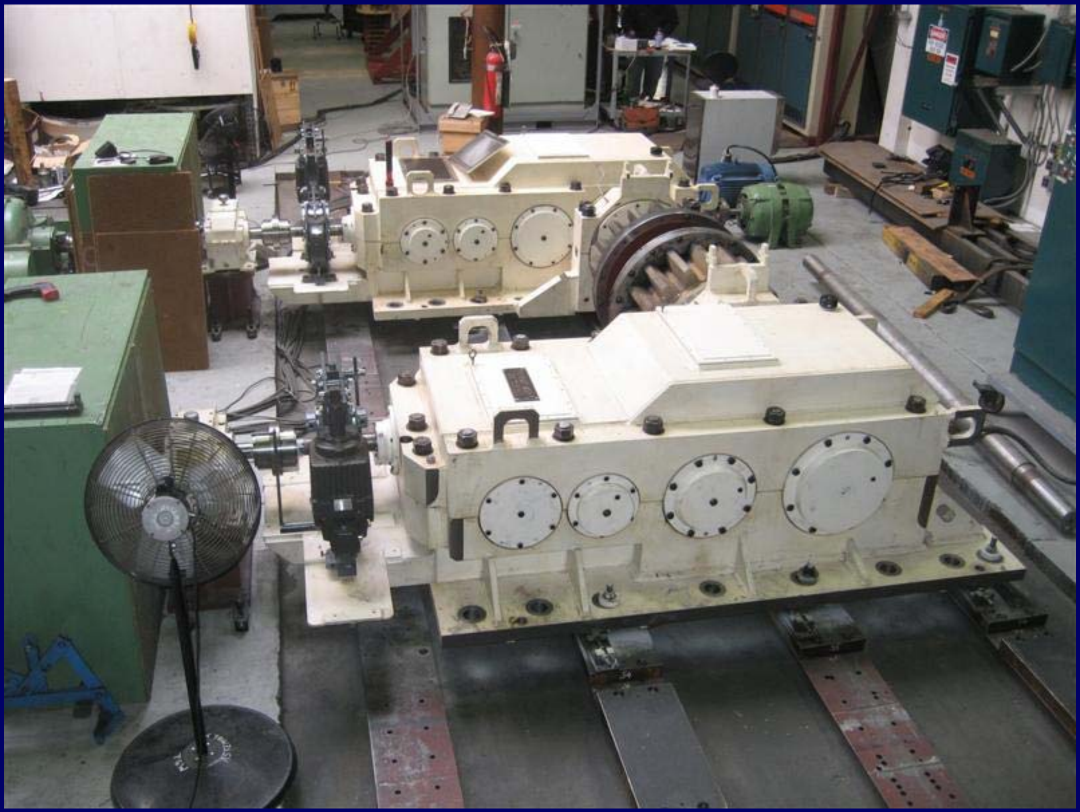
CONSTRUCTION

- Based on the “slinky” measurements, each pinion was custom manufactured with a special modified tooth form to optimize the strength of the teeth and ensure that the desired backlash could be achieved without the risk of tip interference.

Assembly Of The Output Pinion Shaft Into The Reducer At The Gear Works, Seattle

CONSTRUCTION

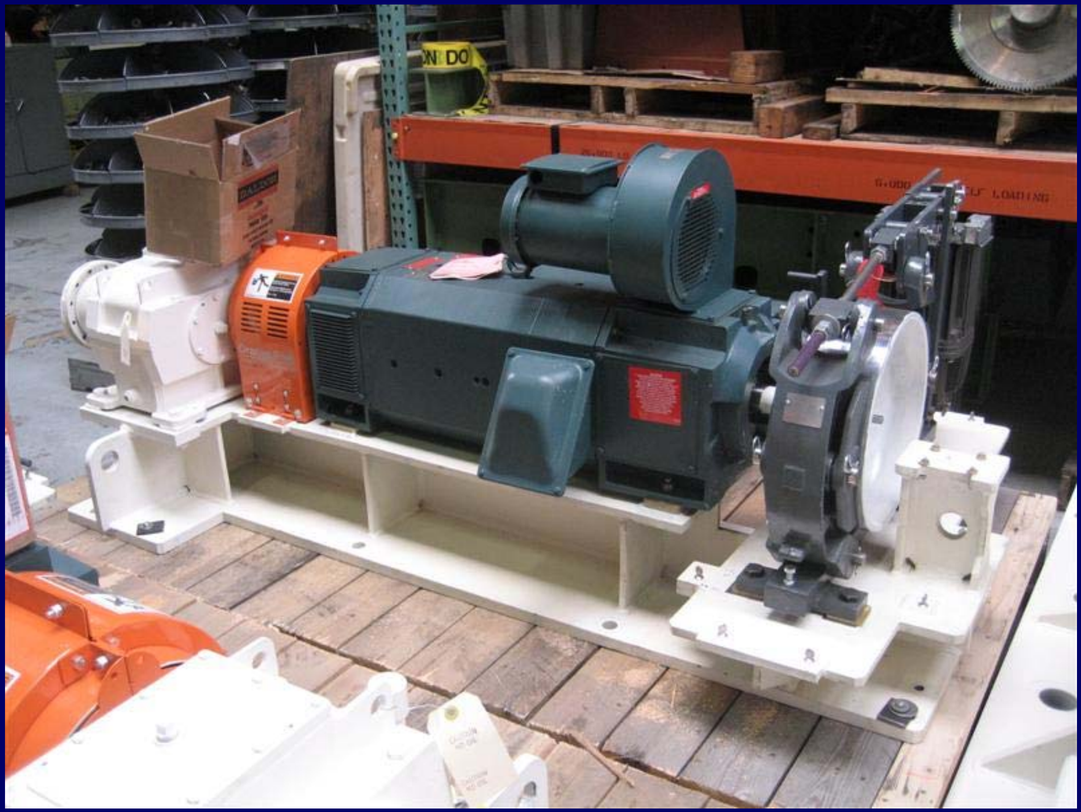
- A 200% load test was applied to the gearboxes by using an electrical regenerative method. Over 2,500,000 lb./in. of torque was applied to the low speed shafts in both directions.
- The load tests were conducted at The Gear Works manufacturing facility in Seattle. The gearboxes were assembled back to back on an 18" thick concrete foundation to allow for rigid load test positioning.



Reducer 200% Load Test Arrangement at The Gear Works, Seattle

CONSTRUCTION

- The machinery brakes were mounted and aligned in the shop on supports integral to the secondary reducers.
- All other machinery was mounted and aligned in the shop on a common machinery support.
- Bedding of the brake shoes was completed in the shop prior to delivery of the equipment to the field.



Machinery Support Assembly Completed And Ready For Delivery

CONSTRUCTION

- Following acceptance of the load tests and other shop inspection, the temporary winch drive system was installed at the north leaf.
- The winch system was commissioned during a nighttime closure of the bridge to vehicular traffic.
- The existing span drive machinery and electrical systems for the north leaf were then removed and the piers were prepared for installation of the new machinery.

Preparation Of The Pier For The New Machinery

CONSTRUCTION

- Rigging was then installed to lift the reducers and machinery support assemblies up to the machinery level

CONSTRUCTION

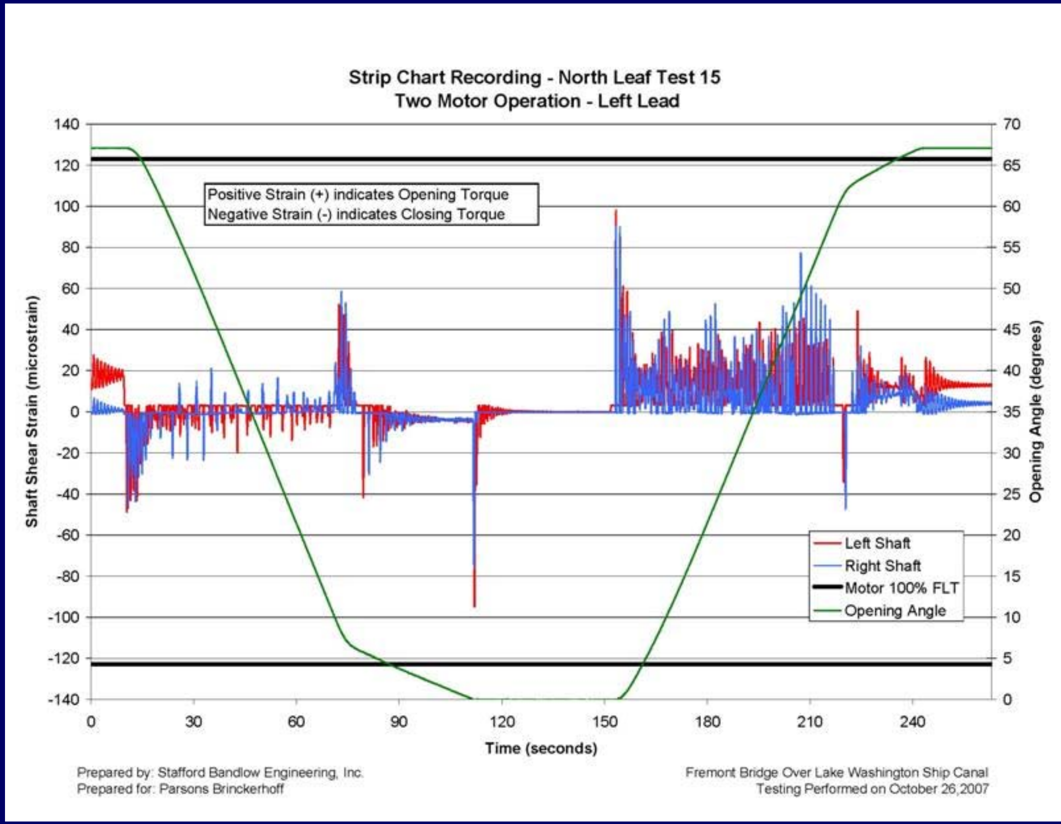
CONSTRUCTION

- The secondary reducers were lowered into position so that the rack pinion engaged the rack during a nighttime closure to vehicular traffic.
- The leaf position corresponding to the minimum backlash had been previously established based on the "slinky" measurements.
- The leaf was opened using the winch to establish the contact pattern on the new pinion and existing rack.

Evaluating Rack Pinion Tooth Contact During Installation Of The Secondary Reducers

CONSTRUCTION

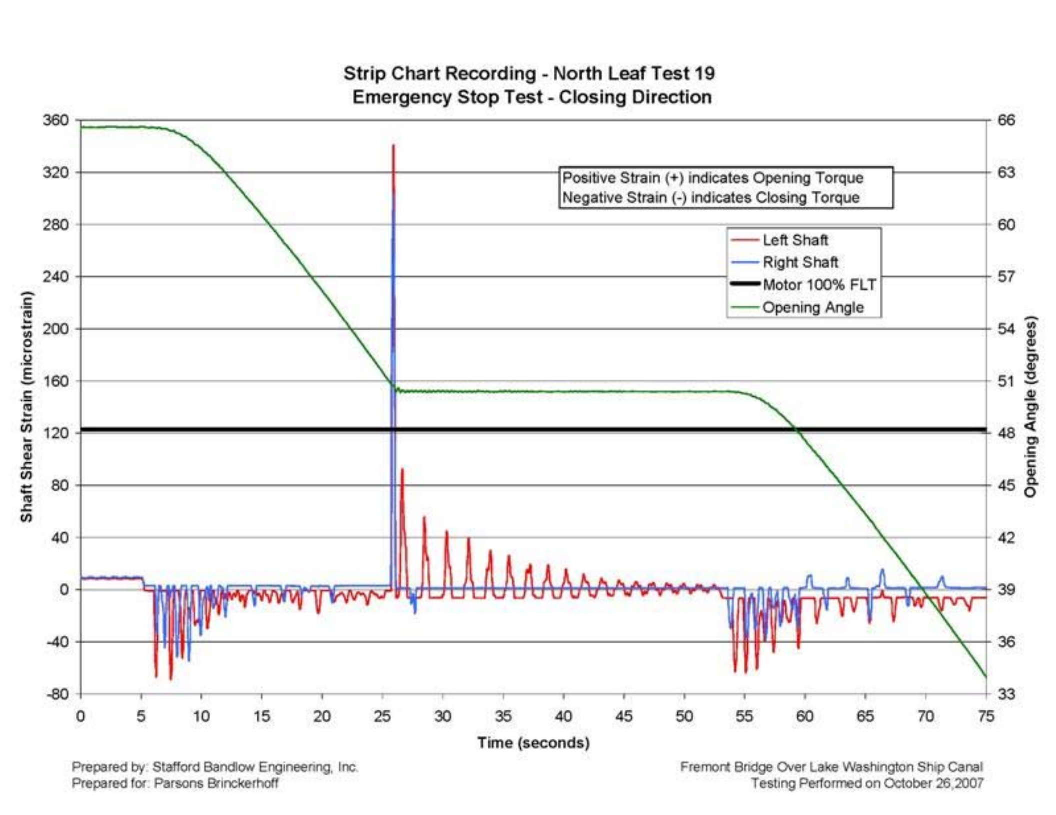
- SBE performed dynamic strain gage measurements during the commissioning tests for the dual purposes of verifying the electronic load sharing functions of the drives and also for determination of span balance.



Operational Testing Of New Span Drive Machinery

CONSTRUCTION

- Emergency stop tests were performed during commissioning
- Brake torque was verified with a torque wrench (equivalent to ~95% FLT of the motor) using the breakaway method
- With the motor brakes set for no time delay the peak braking torque was nearly 300% FLT of the motor.
- With a 2 second time delay for the motor brakes, peak braking torque was reduced by 50%.



Emergency Stop Testing Of New Span Drive Machinery With No Motor Brake Time Delay

CONSTRUCTION ISSUES

- Large voids and poor quality concrete were discovered within the counterweight. It was not possible to anchor the winch sheave brackets and it was necessary to weld them to the counterweight box.
- Unsound concrete was also discovered during modifications to the machinery floor that the secondary reducers were anchored to. In order to ensure the integrity of the reducer anchorage, the unsound concrete was chipped out and reinforcing was added.

Machinery Anchorage Modifications

COMPLETED MACHINERY

- Commissioning of the new span drive machinery and functional testing of the electrical control system was completed in February 2008
- Rehabilitation of the span locks was completed in April 2008

The Rack, New Pinion And Machinery Shield Viewed From Inside The Bascule Leaf

New Span Drive Motor, Primary Reducer, Motor And Machinery Brakes Viewed From The Machinery Room

PROJECT SUMMARY

Owner: Seattle Department of Transportation

Prime Consultant: Parsons Brinckerhoff

Mechanical Sub-Consultant: Stafford Bandlow Engineering

The Prime Contractor: Mowat Construction Company.

Mechanical Machinery Sub-Contractor: The Gear Works, Seattle

Control System Sub-Contractor: Electro Hydraulic Machinery Co.

Total Construction Cost: $36.3 million.

Approach Replacement Construction Cost: $28.8 million

Mechanical and Electrical Construction Cost: $7.5 million