CHICAGO HARBOR LOCK GATES

Replacement, Lessons Learned, Repairs & Successes

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US Army Corps of Engineers

BUILDING STRONG®

Lock Construction in 1936-38

Chicago Lock Overview

- Construction was done by MWRD between 1936 – 1938, sheet pile cells were driven to dewater a small portion of the lake for construction.
- The concrete gate blocks were cast within the dewatered sheet pile cells and anchored to the lake floor on timber piles
- The concrete lock walls were cast directly on top of the sheet pile cells and extend halfway down the wall
- The lock chamber floor was mud up until the mid 50s when precast concrete slabs were placed on the floor and anchored in.
- Because the lock chamber floor is mud below the precast floor slabs, the chamber itself cannot be dewatered.

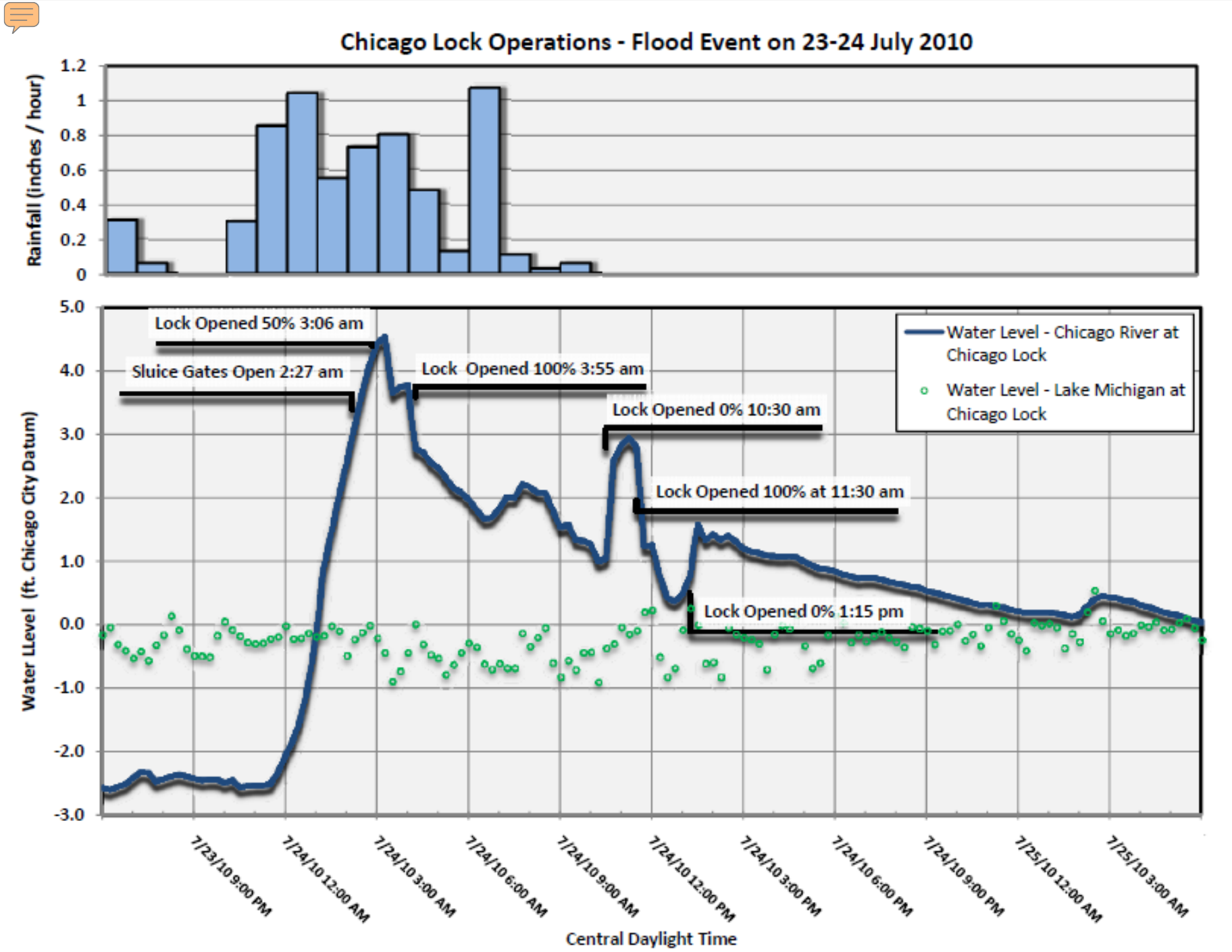
Chicago Lock Overview

Heavy Summertime Recreational and Tour Boat Traffic

Flood Risk – Backflow through Lock Gates

July 2010 Rain Event

- 7 inches of rain fell in 12 hours when 3 inches was forecasted
- Top of the lock wall is +7’0”. The water nearly hit +5’0” and HPUs were wetted
- The Lock Gates were opened and the river was allowed to drain into Lake Michigan to keep the city from flooding.
- Along with carrying rainwater out into the Lake, the river also has the potential to carry sewage with it.
- This event did cause minimal flooding in low lying structures within the city including the train station and condo building basements
- **ONLY Two weeks** after the event a failure and emergency repairs shut the lock down – if these events coincide, the City could experience catastrophic flooding


Chicago Lock Operations - Flood Event on 23-24 July 2010
Rainfall (inches / hour)
1.2
1
0.8
0.6
0.4
0.2
0
Water LLevel (ft. Chicago City Datum)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Lock Opened 50% 3:06 am
Sluice Gates Open 2:27 am
Lock Opened 100% 3:55 am
Lock Opened 0% 10:30 am
Lock Opened 100% at 11:30 am
Lock Opened 0% 1:15 pm
Water Level - Chicago River at Chicago Lock
Water Level - Lake Michigan at Chicago Lock
7/23/10 9:00 PM
7/24/10 12:00 AM
7/24/10 3:00 AM
7/24/10 6:00 AM
7/24/10 9:00 AM
7/24/10 12:00 PM
7/24/10 3:00 PM
7/24/10 6:00 PM
7/24/10 9:00 PM
7/25/10 12:00 AM
7/25/10 3:00 AM
Central Daylight Time

Flood Risk – Backflow through Lock Gates

- The Chicago Lock is used for flood control and navigation
- The Lock can be closed to traffic during the winter without a large impacts (Barges, Fire & Police Boats)
- If a large rain event or snow thaw occurs, the gates must be opened, regardless of the impact on construction
- The Contractor in 2010 was on call 24 hours a day should the stop logs need removal

Original Sector Gate Design

- **Characteristics**
  - Built and installed in 1936
  - Constructed of a series of 6 horizontal frames.
  - Constructed using 36ksi plate and W-sections riveted together
  - Each gate leaf weighed 265,000 lbs

- **Operation**
  - The old sector gates pivoted on a non-adjustable upper hinge and lower pintle ball. The gate leafs were also supported on two pairs of rollers which rode on a lower track.
  - 4 point contact was maintained through the entire range of motion
  - Operated by pulling on a hinge strut arm that slid into recess on a track
  - Operation was by high voltage electric motors
  - Great idea on paper – maintenance difficulties over time

Sector Gate Strut Arm

Original Sector Gate Condition

- The original sector gates had sustained quite a bit of damage and corrosion over their 75 year life span

The Need for new Sector Gates

- Old gates in poor condition with extensive corrosion
- Water diversion through lock due to incomplete seal closure
- Maintaining contact & operation of the lower and upper tracks was becoming increasingly difficult and costly
- Debris on the track or roller damage required divers which can take days
- If something got stuck on the track or the bushings failed, the gates could not be opened in an emergency and a key flood control device was not operational

Lock Gate Replacement Project

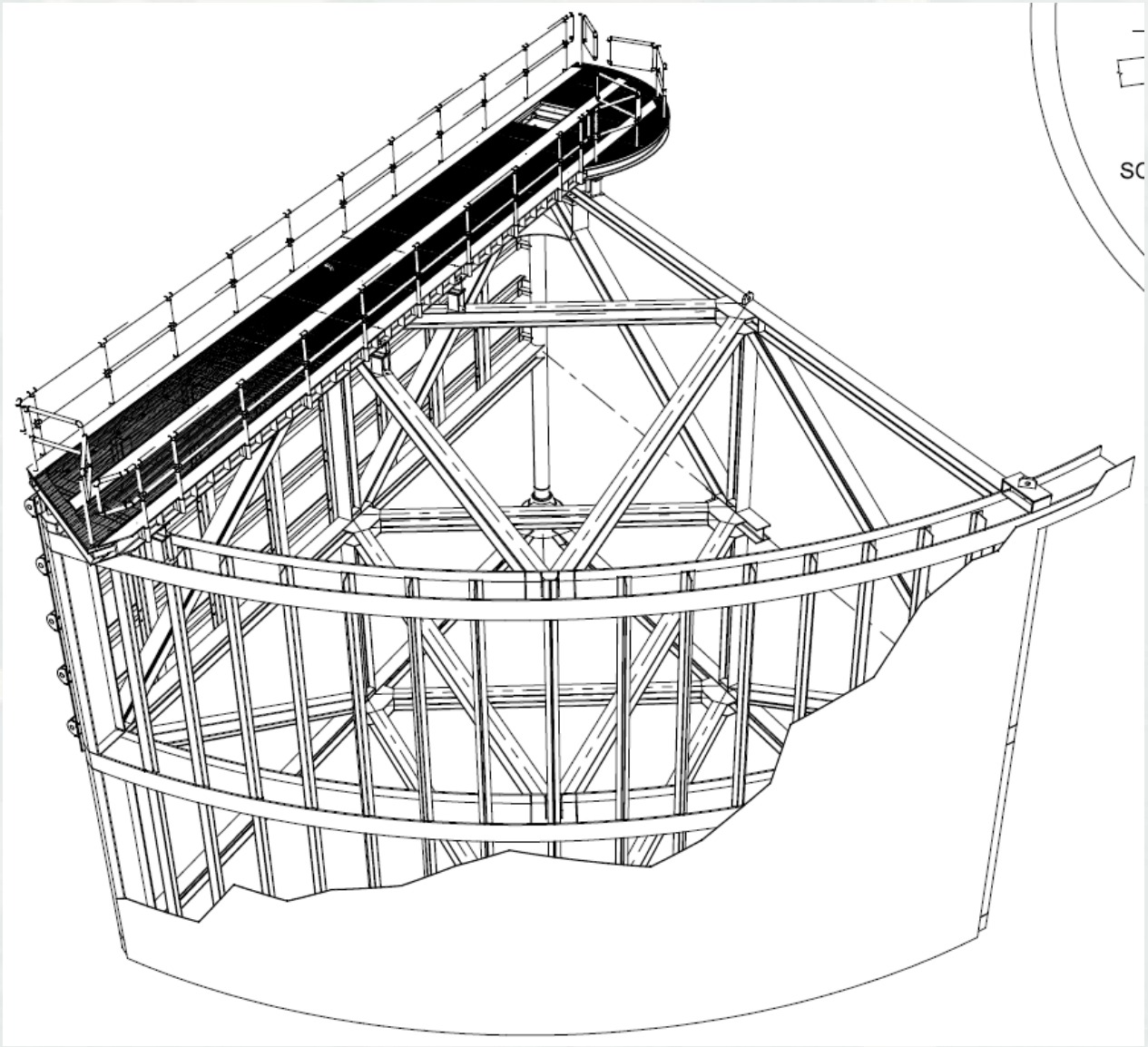
01 NOVEMBER 2010 – 15 APRIL 2011

- Original Gates from 1938 still installed
- Chicago Sanitary District operation until 1985
- Project originally planned for only two gates
- ARRA Funding changed project to four gates
- Old plans used, with no time to improve design
- No improvements to controls were in the plans
- Many small oversights????

New Sector Gate Design

- Layout
  - 3 Horizontal Frames, Curved Skin Plate, two vertical K-brace frames at the lock chamber and recess sides
  - 50 KSI steel fully welded; not riveted or bolted except for hinges & racks
  - Designed per AISC LRFD design and computer modeled with StaadPro
  - Designed between 2001 and 2003 in accordance with Corp Ems
  - Used Greased Bronze Bushing instead of greaseless bushing
- Operation
  - Supported by pintle and upper hinge
  - Operated by skin plate mounted rack and pinion gear
  - New hydraulic HPUs replaced the electric motors
  - Lock Gate walkways able to support BobCat and heavy loads

New Sector Gate Design



Stop Log Storage Problems

Poor Blocking Design Used

Storage Site Under Water

Moving Stop Logs to Lock

Preliminary Weld Inspection in Dansville, NY

Gate Fabrication

Skin Plate Fabrication Jig

Test fitting Walkway Assemblies

Test fitting Fender Assemblies

Gates Erected in Chicago

Completing Gates at Chicago Site

Welding Lessons Learned: Sector Gate QA vs. QC

- Per contract, the fabricator, LMC hired a QC firm to test and inspect all the fracture critical welds.
- The General Contractor hired their own QA to verify the fabricator's QC before "buying" the gates.
- There were a lot of discrepancies between the fabricator's QC and the contractor's QC.
- USACE had originally planned to hire QA to check 5% of the welds on the gates.
- Due to the discrepancies and the inability of the GC to rectify the differences between their own QA and the fabricator's QC, we expanded the scope of our QA.
- Our QA's new scope grew to include 100% visual inspection and 50% NDT on all fracture critical members.
- In two days the weld inspector was able to completely assess all four gates.
- For a minimal expense, we gained a much greater confidence in the final product.
- If we could do it again, we would have involved our weld inspector earlier in the process to reduce the lost time due to conflicting QC/QA reports and due to having to repaint areas of each gate

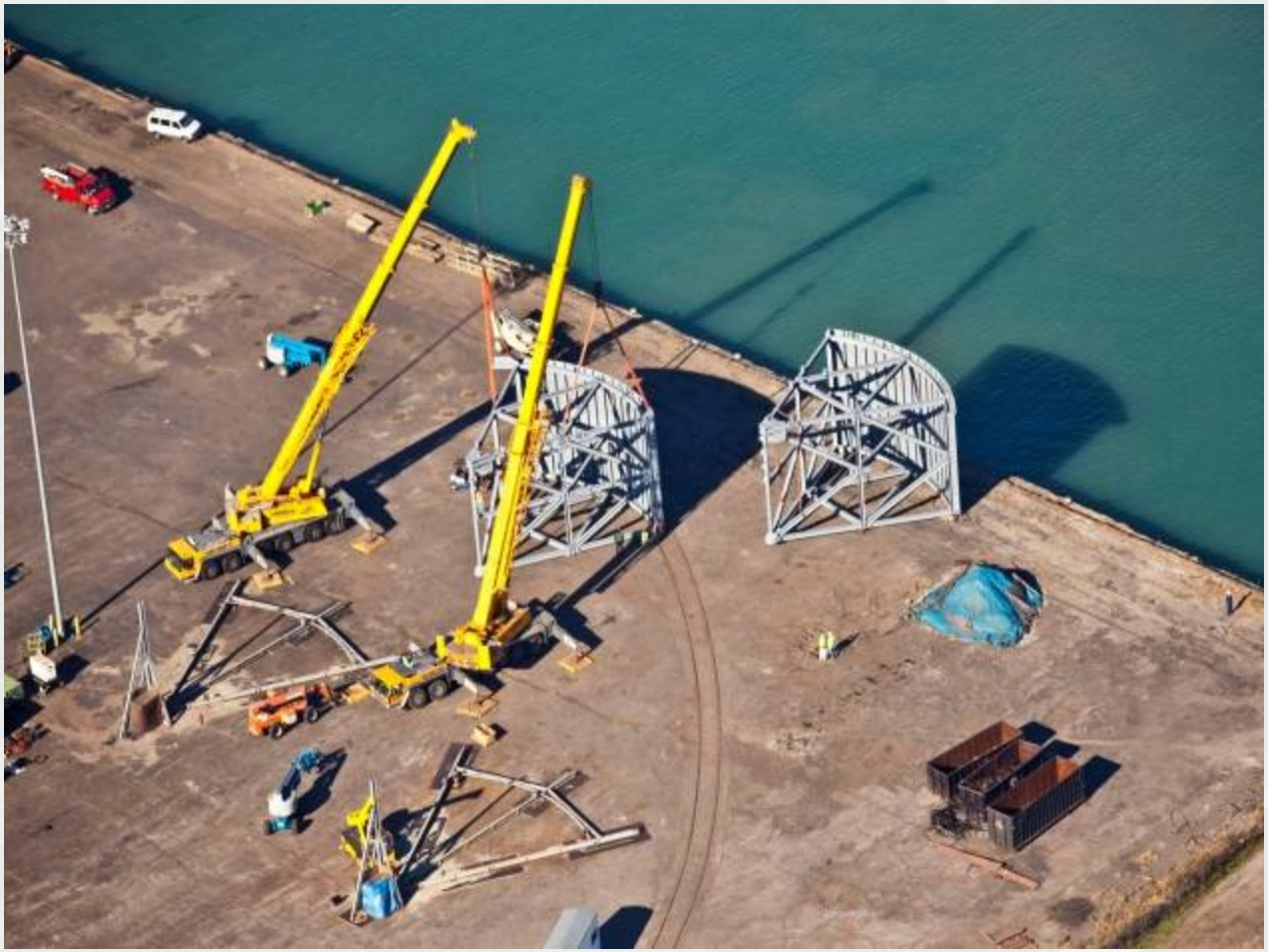
Pintle Built-up section size inconsistencies

Mismatched Member flanges

Solution DevisedDuring Assembly

Poor Fit-Up & Alignment

Moving Gates Into Position for Loading onto Barge



Lake Move of Gates Required Fair Weather Permit

Stop Logs Delivered to Lock

New Lock Gates Delivered

Two Gates Stored in Parking Lot

Lock Gate Installation

- Removal and installation of all 4 gates performed during one 6.5 month winter shut-down period.

  01 NOVEMBER 2010 – 15 APRIL 2011

- The Construction schedule was very compressed and necessitated working 10 hours days, 6 or 7 days a week.

- If a reverse back flow event occurred, the bulkheads would have to be removed and the gate blocks re-watered regardless of construction impact

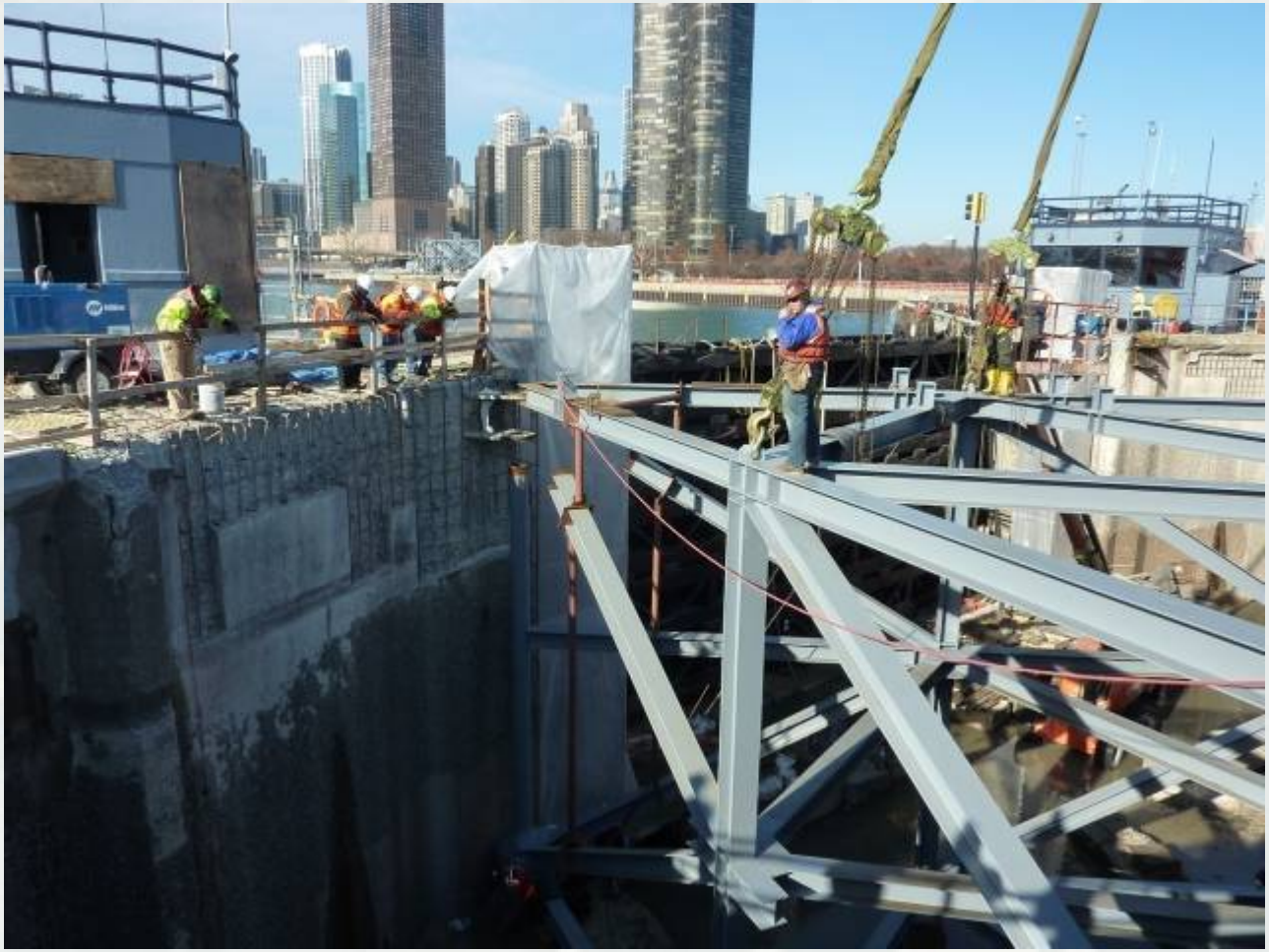
Demolition Begins

Gate Installation: Installation in two pieces

Gate without upper hinge

- The decision to retain the existing hinge plates created some installation challenges
- The solution was to separate the upper hinge from the gate and to install the gate only on the pintle and temporary blocking
- The upper hinges and fabricated filler plates were installed afterwards
- Following bolt up, all cut members were welded and fully UTed

Gate Installation



New Gate without Upper Hinge in Place

Upper Hinge Installation

Upper Hinge installed with temporary supports cut

New Gates Installed

New Seals Being Installed

Operating Machinery Installed

Flooding After Gates Installed

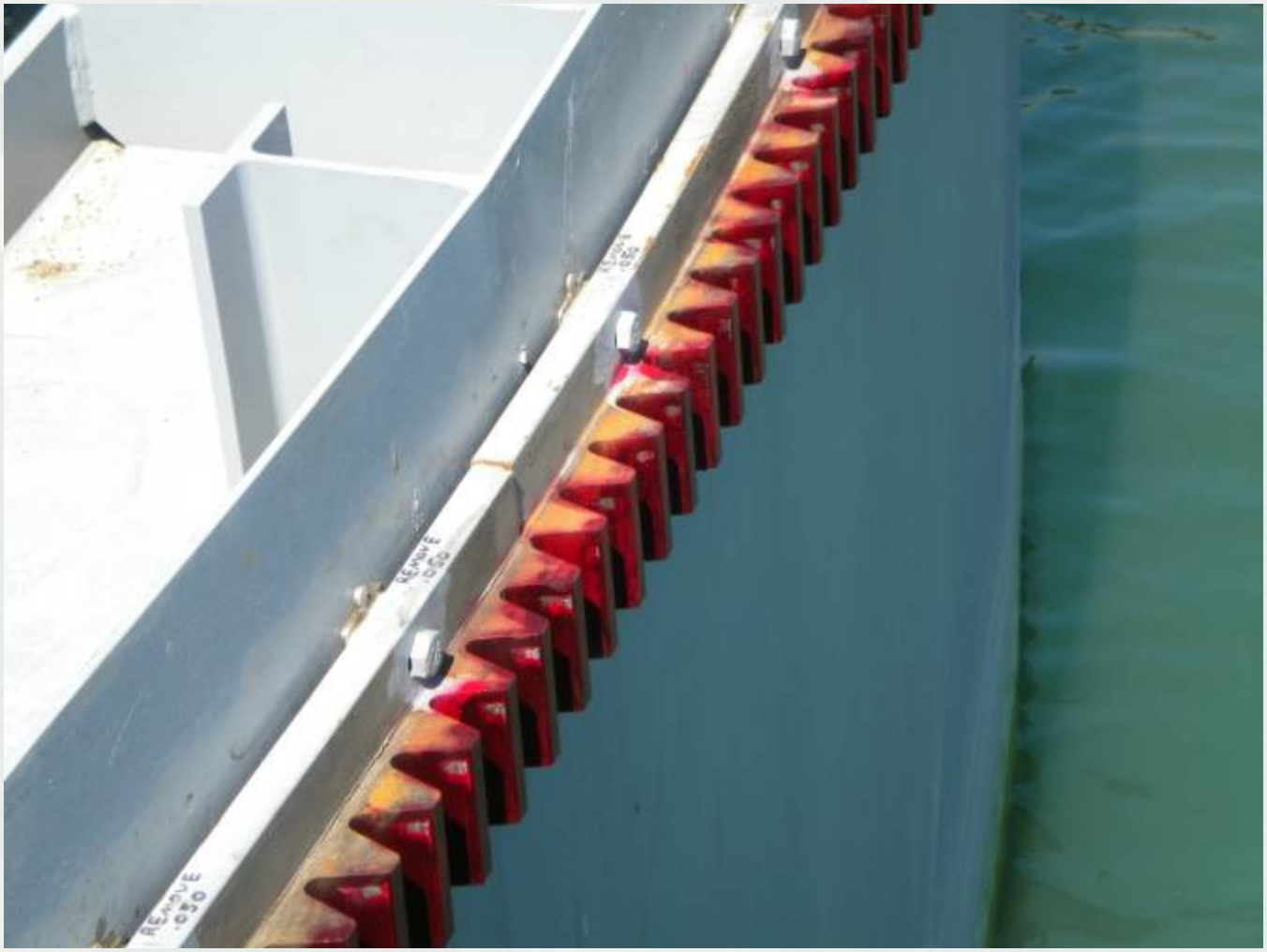
Project Status as of 15 April 2011

- The Project was completed on time and under budget
- All 4 sector gates are installed and fully operational
- Considering relocating the HPUs further away from the gates to alleviate the pitchline overlap and potential for gate binding
- The project was nominated for an LRD excellence award

Problems Develop During Operations

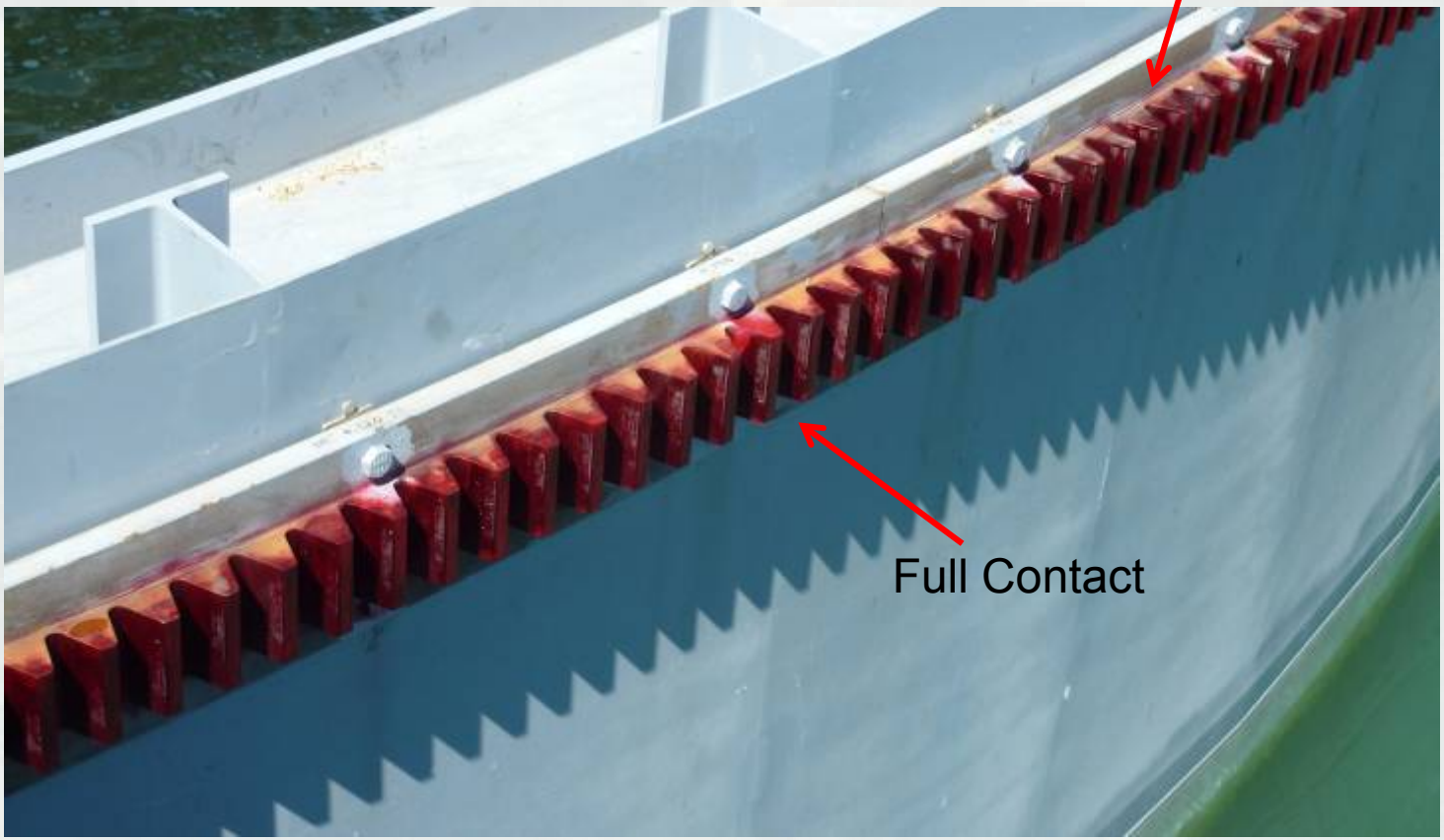
- Mechanical limit switch failures (17/24)
- Brake failures during back-flow event
- Control relays & Touch Screen problems
- Bottom seal squeak & shudder
- Hinge & pintle noise
- Numerous and large leaks on HPUs
- Damage to HPU Pinion shaft during Hot Weather

Poor Tooth Contact Pattern Discovered



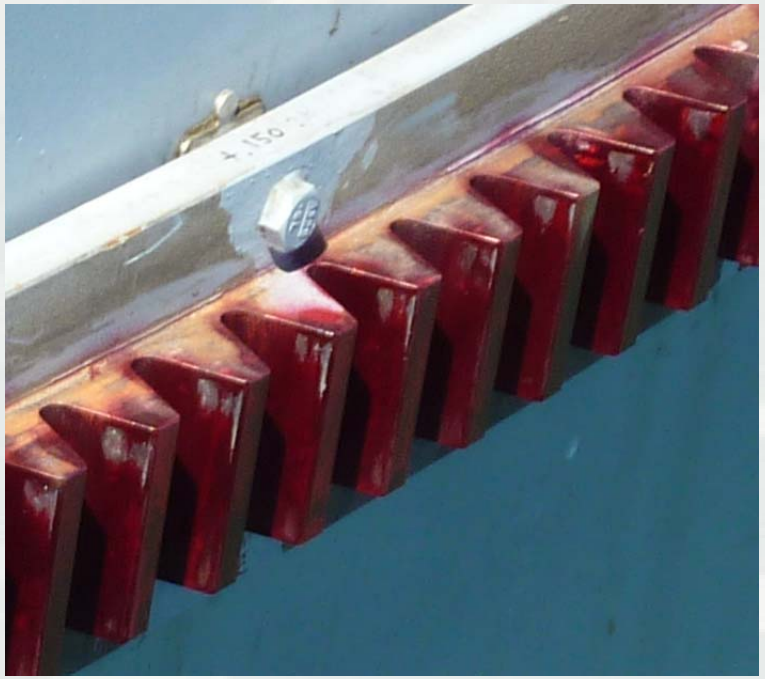
Lessons Learned - Rack Installation

- Dykem Fluid test to determine points of contact



Lessons Learned - Rack Installation

Full Contact at center of rack tooth



Minimal Contact at top of rack tooth

This rack misalignment will cause:

- Variable/ Premature wear
- Rounding of Pinion Teeth
- Potential for gate binding

Lessons Learned - Rack Installation

- Large variation in individual rack section installation

Racks not level, plumb, or well aligned at joints

Lessons Learned - Rack Installation

- Large variation in rack pitch

Lessons Learned - Rack Installation

- The plans and specs should have required that field drilling and installation of racks was required. Slotting the holes for field adjustability was also necessary at the worst areas

  (Louisville Crew made these repairs)

- Our plans should have specified a tolerance over the entire length of the rack, not just individual sections

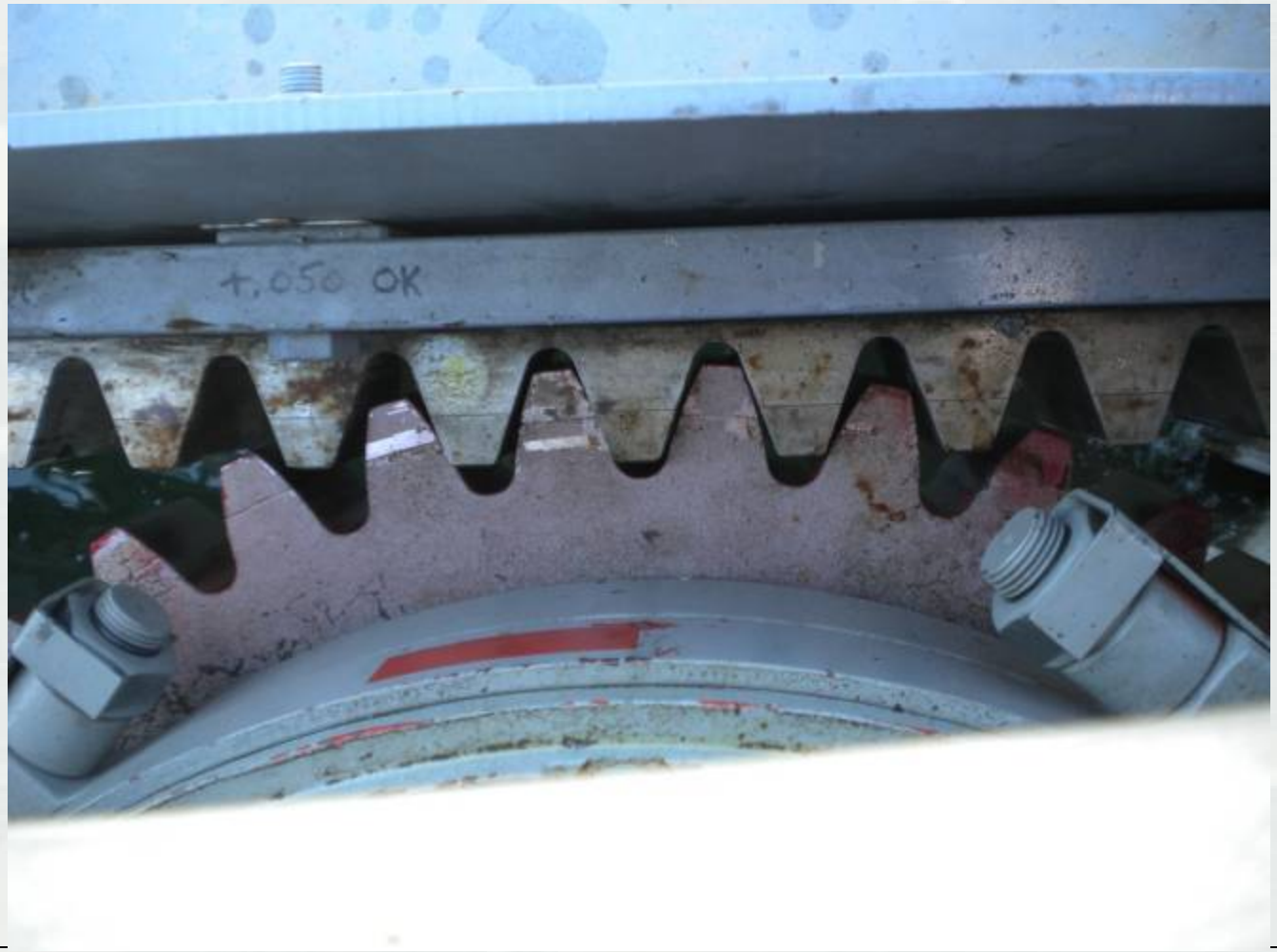
- Specs should have required a dye test be performed as a performance test before accepting the gates

Louisville Crew Working in January Chicago Weather

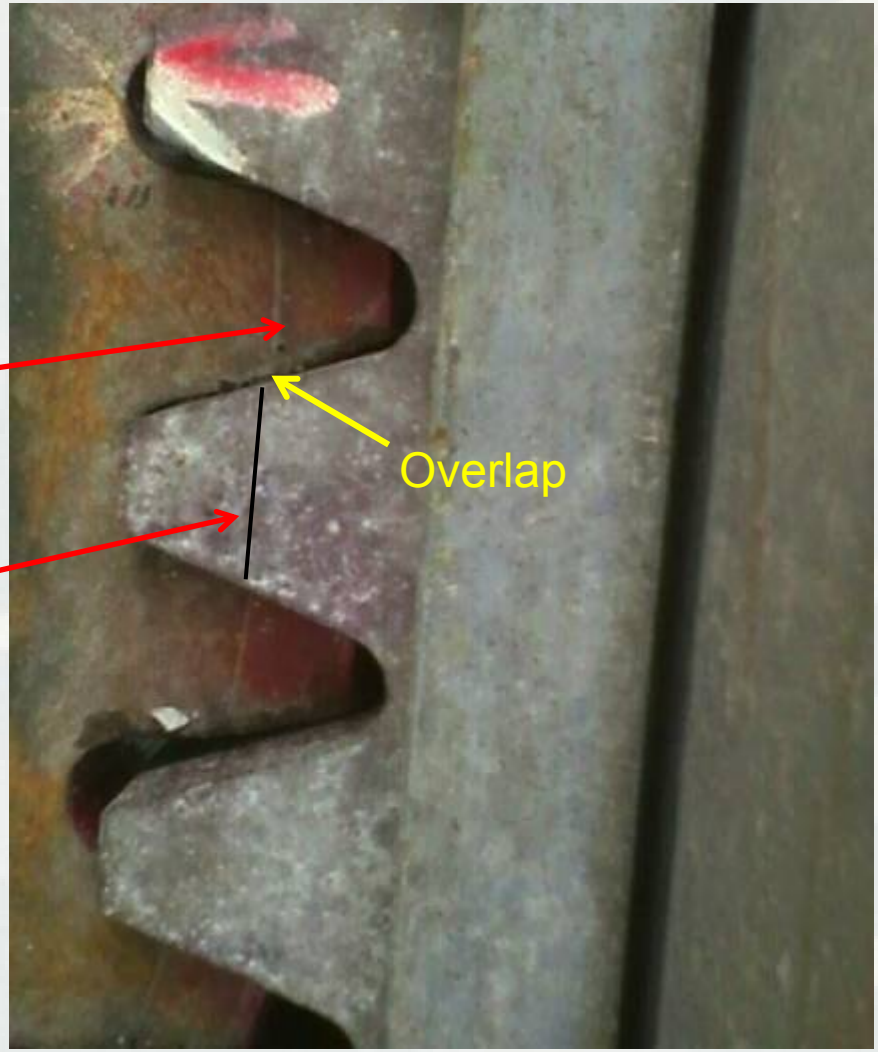
Lessons Learned – HPU Installation/ Pitch-line Separation

Pinion and Rack interface

Original Pitch Line Separation



Lessons Learned – HPU Installation/ Pitchline Separation in HOT WEATHER

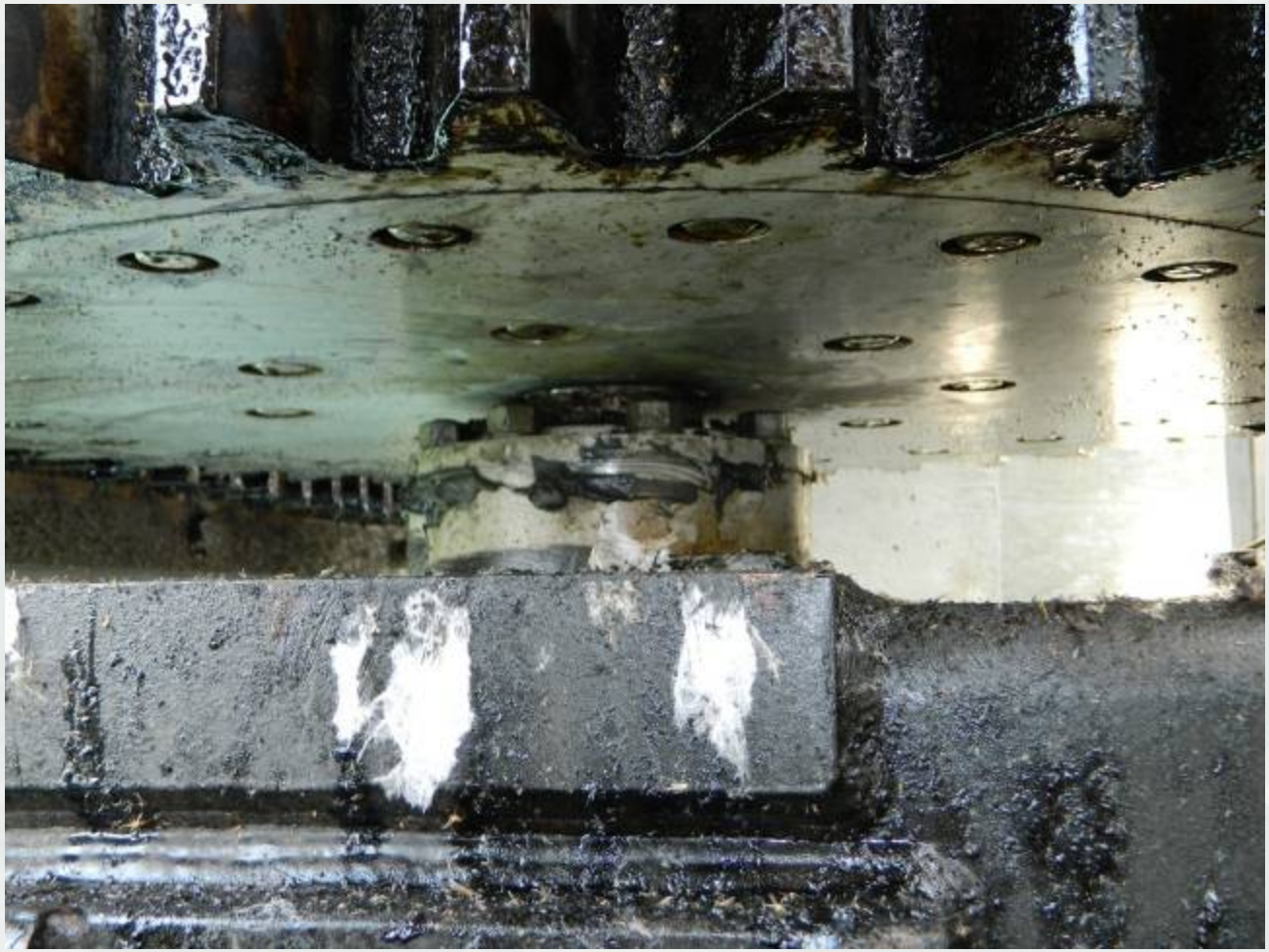


- Per our plans and specs these pitch lines are to coincide at 140 degrees
- The pitch lines were past overlapping at 80 degrees ambient temperature and low water temperature
- Temperatures reached 97 degrees during the summer of 2011 in Chicago
- **Potential for Binding!**

Rigged Cooling System to Relieve Heat Expansion

Reduced Radiant heating of structure from 127 deg. in 97 deg. ambient to less than 80 deg. using PVC water soaking system.

Damage to Pinion Gear Shaft Discovered During High Temperatures



Shaft Weld Broken & Bolts Loose

Visit to Calcacieux Lock, Louisiana - Greater Pitch Line Separation Noted

Repetitive, Large Oil Leaks

Hose & Fitting Variations Between the four HPUs

HPUs Modified to have Lower Profile and Identical Hoses

Limit Switch Failures

Bent Mounting Brackets and Broken Limit Switches Resulted

Limit Switches hung on walkway structure, causing unwanted movement.

Thermal expansion Caused Racking of Lock Gate Structure and Walkway Supports

Limit Switches struck by Target, and 17 of 24 switches failed in first season

Conversion to Proximity Switches

Eliminated Physical Contact

Bottom Seal Too Tight when Structure Racked in Hot Weather

Divers removed the vertical leg of the stainless angle to reduce pressure on the bottom seals

Lower Seal Stainless Angle Iron showed severe pitting and corrosion after less than one year of service.

PLC Controls are Actually used to turn old controls OFF & ON and need to be updated to eliminate problematic failures of timers and relays left over from the old system.

Walkway Pinch Points around Gates Discovered During Construction

Access Pinch Points Created

#1 – Contractor made partial repair

#3 Moved Railing

#2 – Problem remains

#4 - Removed obsolete building

Icing in Old Lock Gates

Eliminated by High Volume Bubbler System

New Bubbler System Installed

- Air compressors are indoor units, installed outdoors, resulting in oil temperature problems, rusting, etc. Plans in process to build a heated enclosure for them.
- Piping system was over-complicated for this application, using 12 remotely operated valves for each of the two compressors. Plans to simplify the piping when enclosure is built.

Improved Stop Log Storage to Eliminate Standing Water

Improved Blocking for Stop Log Storage, Where Needed

General Lessons Learned

- Operations must be involved earlier in the Design Process
- Better Weld Inspection required
- Better design of controls and better electrical inspection required from Construction
- Consult with other similar Locks (don't try to reinvent the wheel)

Future Problems???

Pintle Greasing Adequate?

Emergency Operations Adequate?


Any Questions?
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