



# Diagonals Tensioning System





# Diagonals Tensioning System



**Implantation & Expertise  
on**

## **A New Tensioning Design for Mitre Gates Diagonals**

**M4/134-47/022 (2014-2015)**

**Prepared by: Pierre ROBY ing./P.Eng.**



# Diagonals Tensioning System



## The Great Lakes St. Lawrence Seaway System





# Diagonals Tensioning System



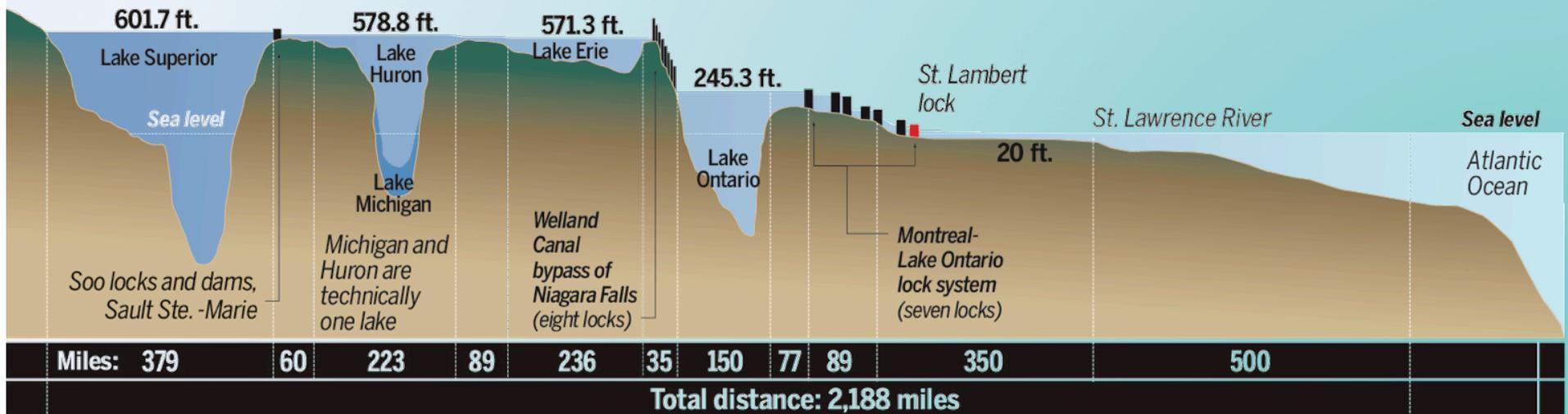
## Maisonneuve region

- Lock N°:1 St-Lambert
- Lock N°:2 Côte-Ste-Catherine
- Lock N°:3 Lower Beauharnois
- Lock N°:4 Upper Beauharnois
- Lock N°:7 Iroquois (Ont)



## Navigating the St. Lawrence Seaway

Drawing not to scale. Vertical elevations are exaggerated.

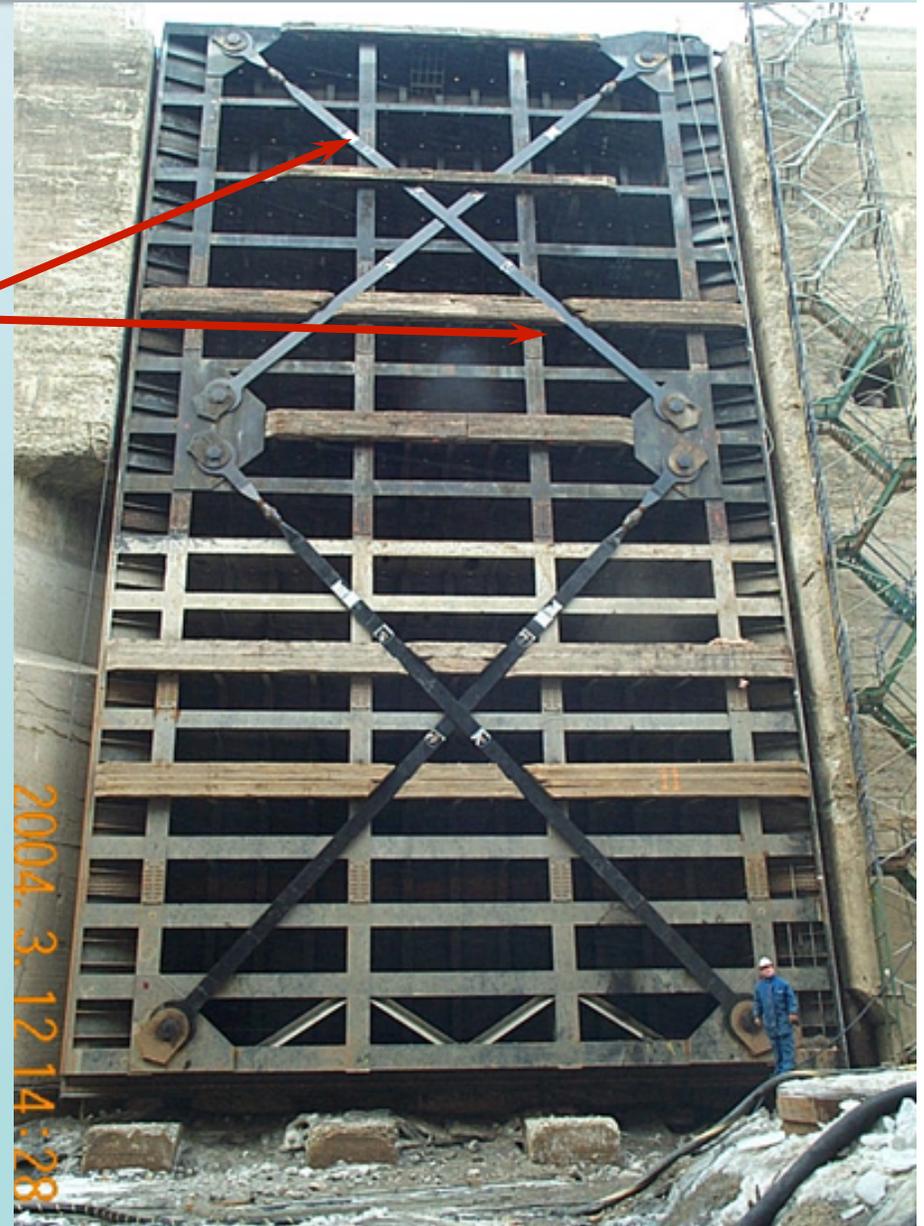




# Diagonals Tensioning System

## Diagonals

- ❖ Diagonals are structural bracing required for open leaf mitre gates
- ❖ Canadian Seaway locks, Maisonneuve region has 26 open leaf mitre gates for a total 72 diagonals

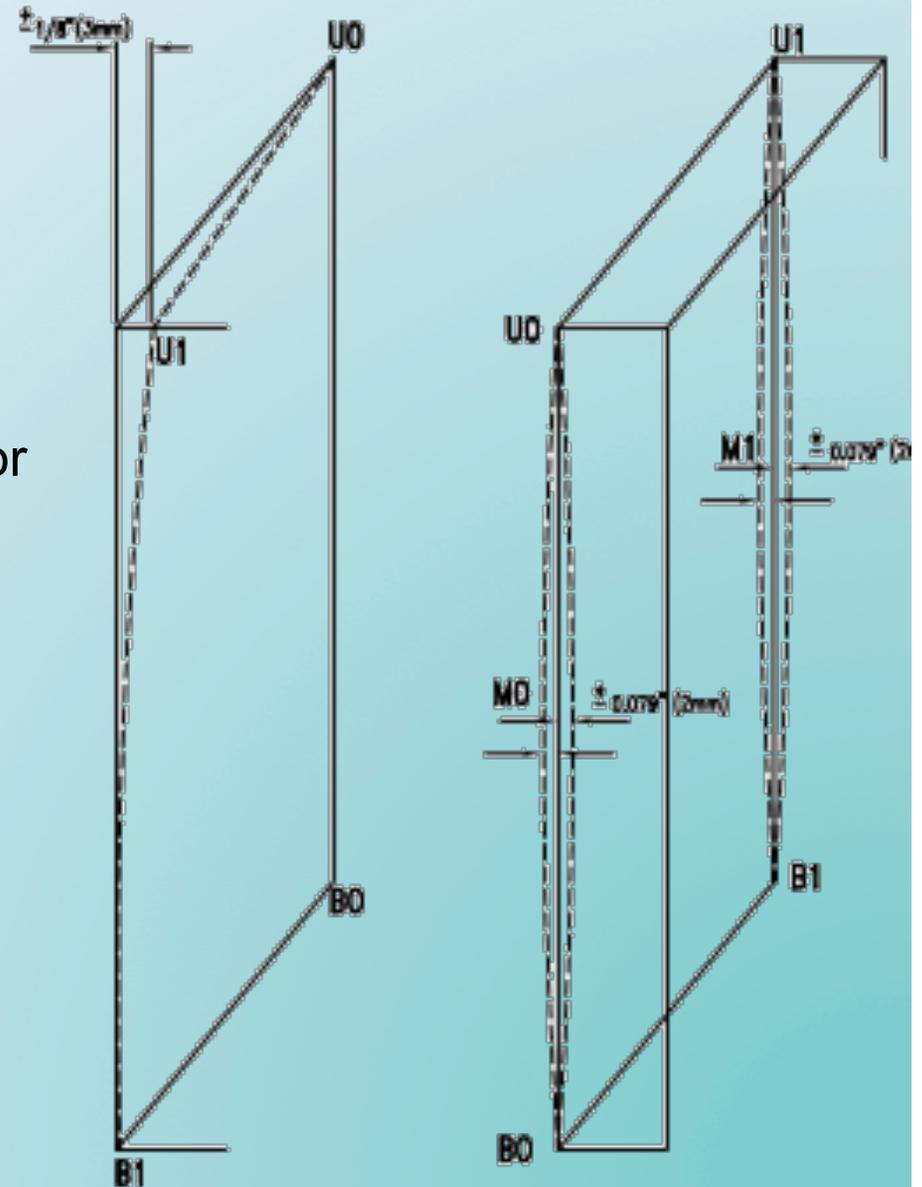




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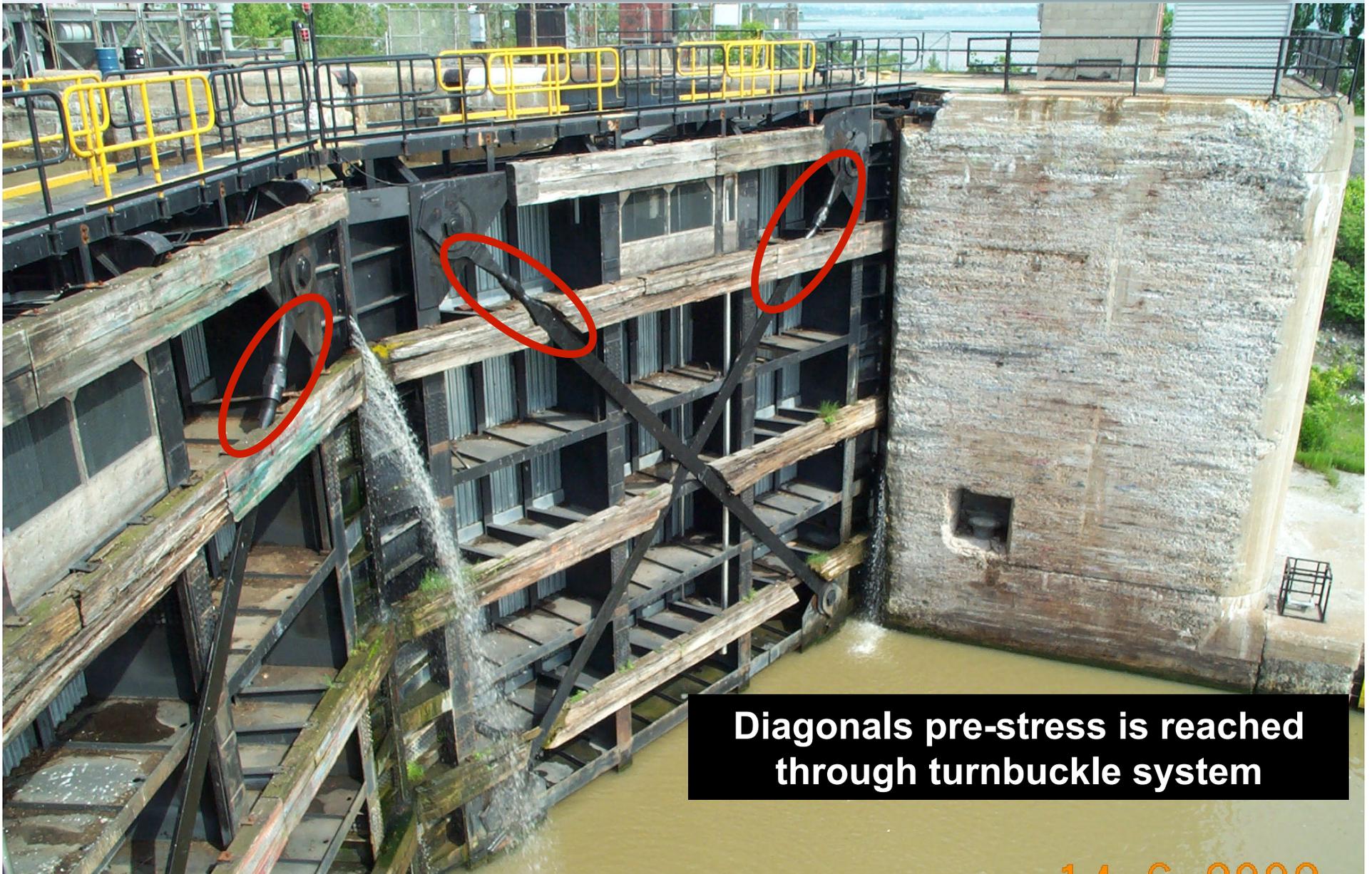
## Diagonals pre-stress

- ❖ Provide stiffness for mitering and during motions of gates
- ❖ Maintain flatness or straightness for mitre and coin blocks fits





# Diagonals Tensioning System



**Diagonals pre-stress is reached through turnbuckle system**



# Diagonals Tensioning System

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## ENCOUNTERED PROBLEMS



# Diagonals Tensioning System

**N<sup>o</sup> 1 DURABILITY: Threads maintenance vs corrosion & loss of functionality**





# Diagonals Tensioning System



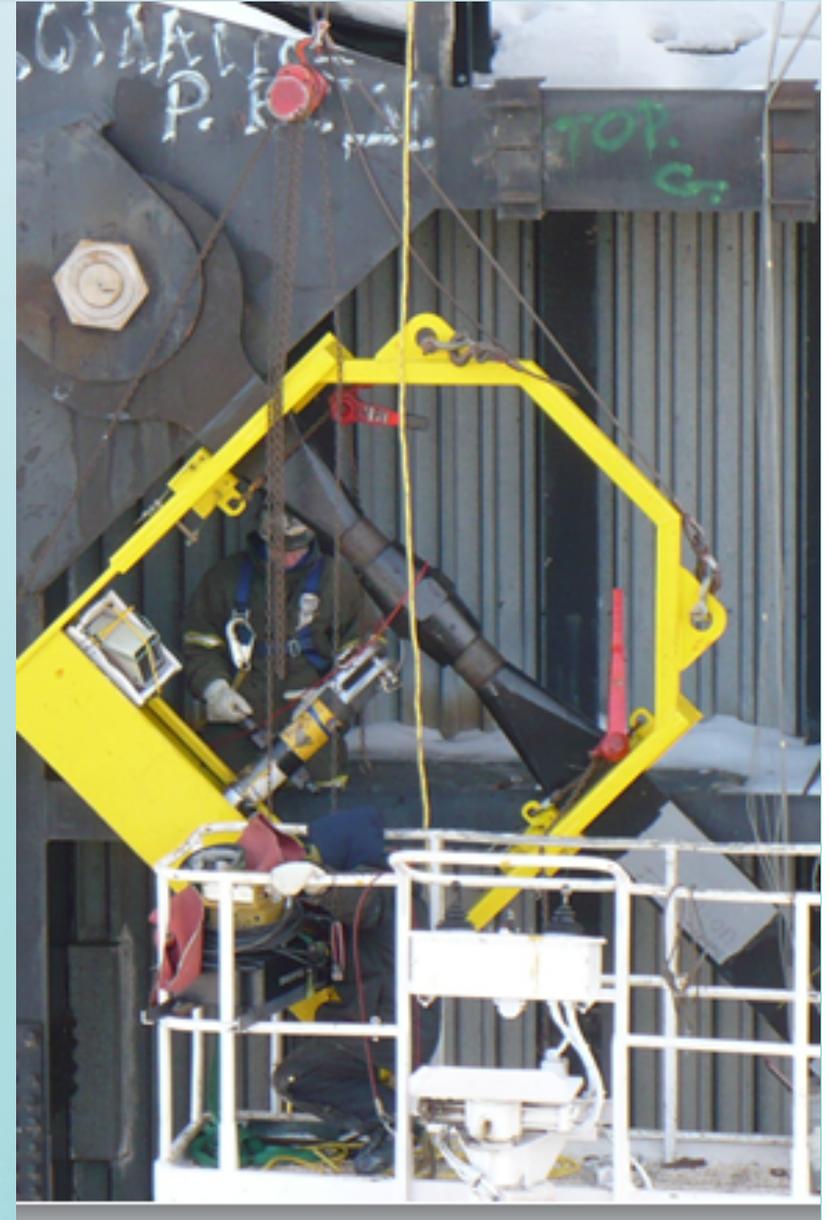
**Nº 2 COSTLY REPLACEMENT: Forged parts are costly and long to produce**





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**N<sup>o</sup> 3 COMPLEXITY:** Applying torque, torque retaking (recapturing), tooling and nut damaging.



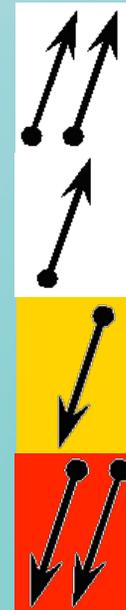


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**N° 4 INACCURATE EVALUATION:** Tension in diagonals has to be evaluated to rate its performance as part of the asset



**Tensions are qualified according to their behaviour when stimulated**





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**N° 5 ZEROING GAUGE:** Instrument required to measure the real pre-stress in bars has to be zeroed at some point, since turnbuckle is at least partially out of order, we only work with stress increments and flatness survey.

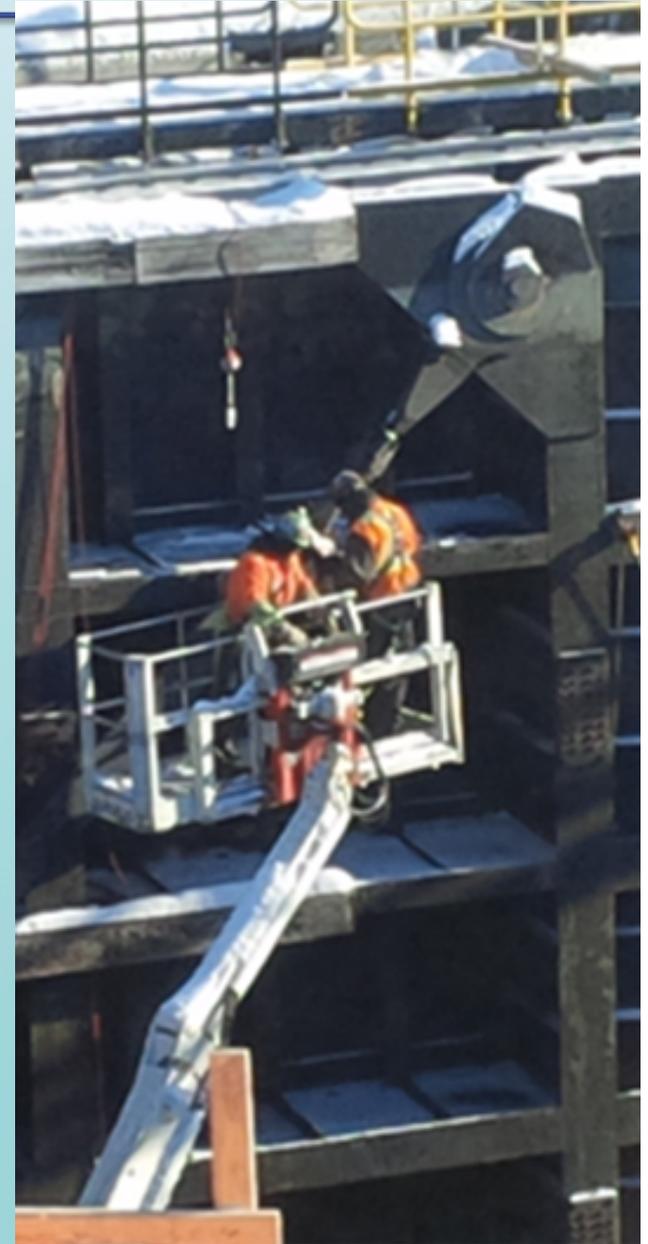




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**N<sup>o</sup> 6 SAFETY HAZARDS : Working-at-height  
with multiple lifting devices**





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**BENCHMARK**



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**NOT ADJUSTABLE DIAGONALS:** For miter gates with few or no straightness problems usually small gates.

France

Russian

Ukraine





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## NOT ADJUSTABLE DIAGONALS:

**SLSMC's gates need to be trended for straightness of alignment**

- ❖ **Lost tension**
- ❖ **AAR (Alkali-Aggregate Reaction)**
- ❖ **Bent structures**

**Welded beams concept will not fit with our assets**



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**ADJUSTABLE DIAGONALS:** Adjustments on miter gates all required exposed threads (turnbuckles or threaded bar & nuts)

**SLSMC's gates turnbuckles are inoperative because of thread inadequate maintenance**

**Messina**

**Soo Locks Detroit**

**Upper Mississippi  
& Illinois River  
Lock**





# Diagonals Tensioning System

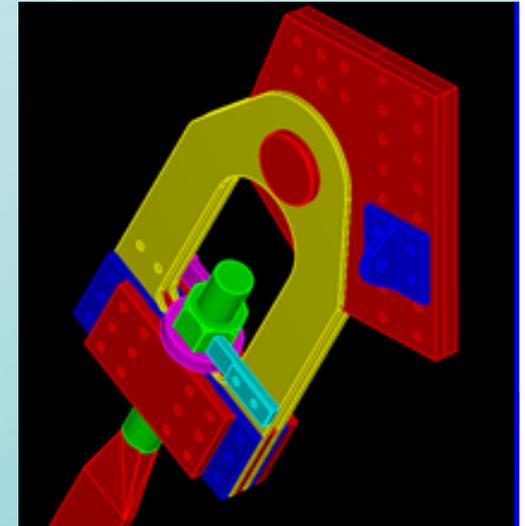


## ADJUSTABLE DIAGONALS



Louisville

### USACE Modification



Three Gorges river  
China





# Diagonals Tensioning System

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## NEW DESIGN OBJECTIVES



# Diagonals Tensioning System



## Objectives

**IF WE HAVE TO REPLACE DIAGONALS, WHAT CAN WE REASONABLY IMPROVE?**

## Conceptual Ambitions

- ❖ Reliable / LOW or NO Maintenance
- ❖ Easy to readjust the tension
- ❖ Adaptable to each of the six (6) different diagonals types
- ❖ As much as possible, NO strain gages installation
- ❖ As much as possible, NO costly forged parts & quick to produce
- ❖ As much as possible, NO torque retaking (recapturing)
- ❖ Easy to repair in case of vessel collision
- ❖ Reversible «if practicable»



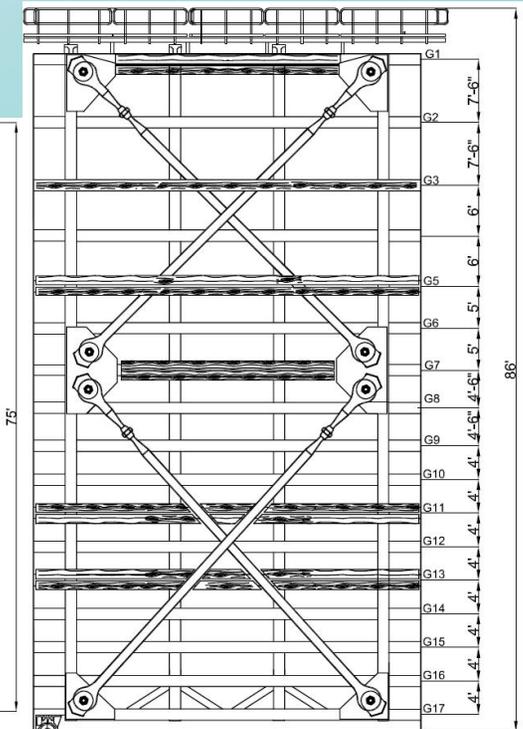
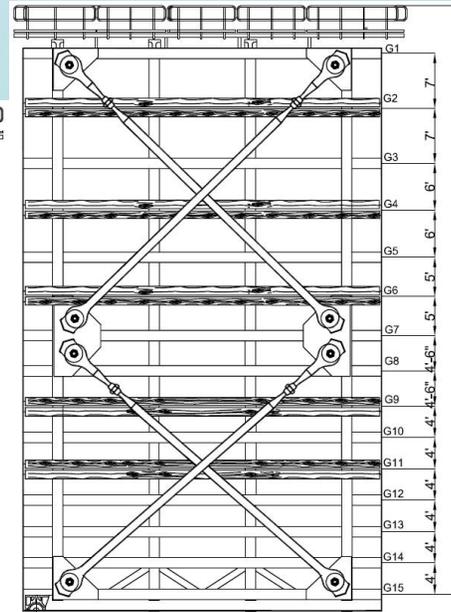
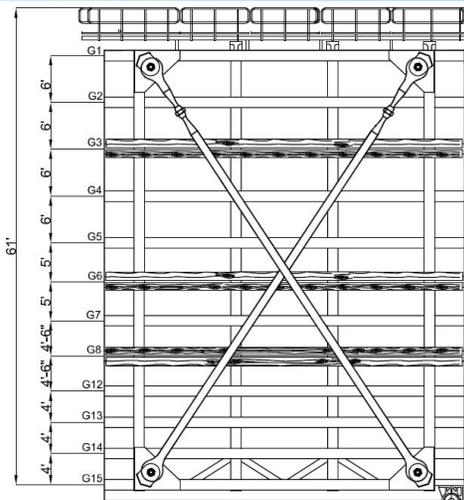
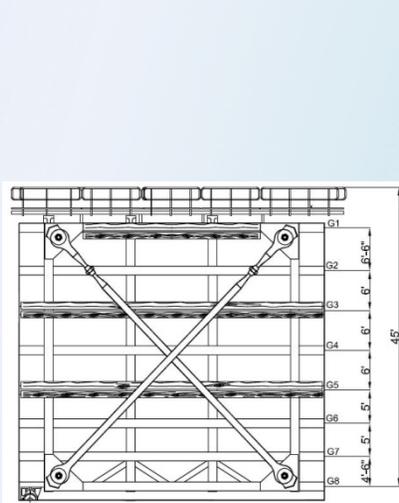
# Diagonals Tensioning System



Six (6) different length of diagonals  
Different pre-stress in each type

**ASSEMBLAGE SOUDÉ**  
EHELLE 1 / 16

ÉCLUSE	A	B	C	D	E
PORTES AMONT (UPPER)	48' - 7"	42' - 5 8/8"	51' - 6 1/2"	S/O	5' - 0"
ST. LABMERT	60' - 5 5/16"	53' - 10 15/16"	63' - 4 13/16"	S/O	4' - 2"
PORTES AVAL (LOWER)					
COTE STE CATHERINE SECTION SUPERIEURE	45' - 7 3/8"	39' - 1"	48' - 6 7/8"	4' - 10"	S/O
COTE STE CATHERINE SECTION INFÉRIEUR	43' - 4 13/16"	36' - 10 7/16"	46' - 4 5/16"	5' - 10"	S/O
BEAUHARNOIS SECTION SUPERIEURE	46' - 3 3/4"	39' - 9 3/8"	49' - 3 1/4"	4' - 10"	S/O
BEAUHARNOIS SECTION INFÉRIEUR	49' - 9 1/16"	42' - 6 3/16"	52' - 1 1/16"	5' - 5"	S/O





# Diagonals Tensioning System



**Standardized the profile to fit to the highest pre-stress**

«Uper gates» Portes busquées 45 pieds	Diagonale $U_0L_1$	Diagonale $L_0U_1$
Pré-tension (lb)	193 000	107 000

St-Lambert~Écluse № 1 Portes busquées «Lower Gates», 61 pieds	Diagonale $U_0L_1$	Diagonale $L_0U_1$
Pré-tension (lb)	234 000	141 000

PRÉ-TENSIONS REQUISES POUR LES MISES SOUS TENSION DES DIAGONALES				
C-St-C~Écluse № 2 Portes busquées «Lower Gates», 75 pieds	Diagonales			
	$U_0M_1$	$M_0L_1$	$M_0U_1$	$L_0M_1$
Pré-tension (lbs)	272 000	245 000	134 200	141 000

PRÉ-TENSIONS REQUISES POUR LES MISES SOUS TENSION DES DIAGONALES (RÉVISION 2014)				
Beauharnois~Écluse № 3 & 4 Portes busquées «Lower Gates», 86 pieds	Diagonales			
	$U_0M_1$	$M_0L_1$	$M_0U_1$	$L_0M_1$
Pré-tension (lbs)	292 000	285 000	153 000	160 000



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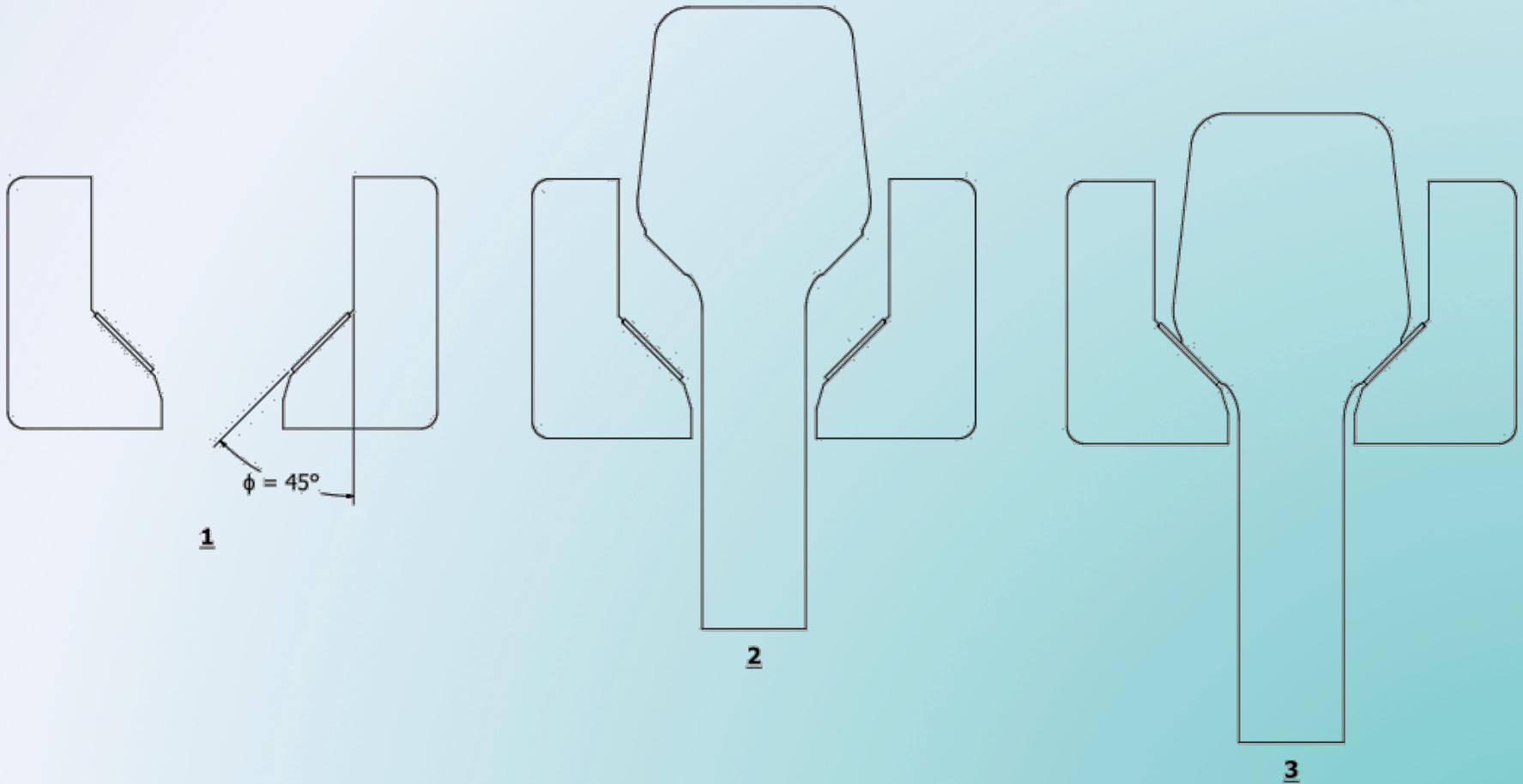
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## PROPOSED PRINCIPLE

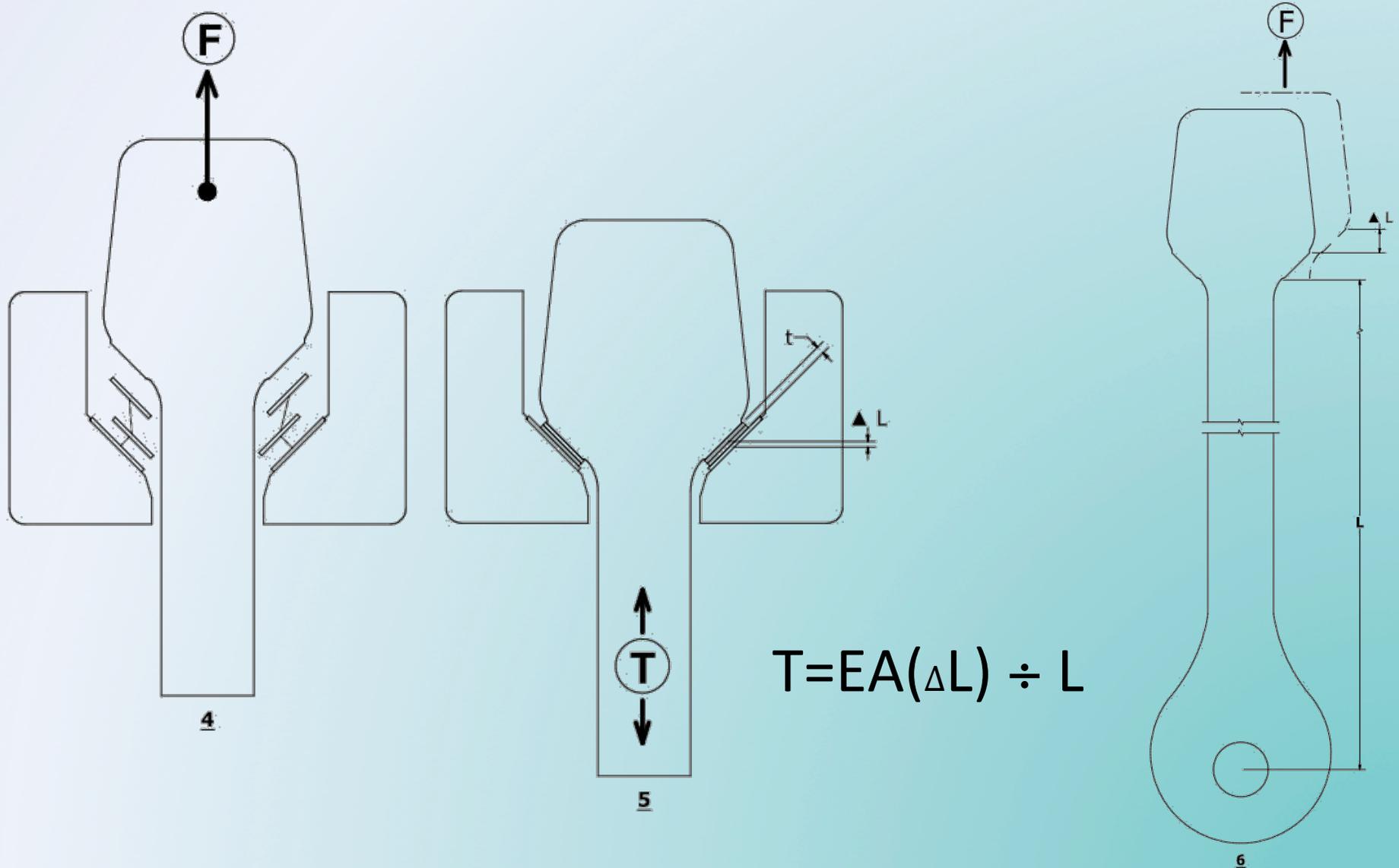


# Diagonals Tensioning System



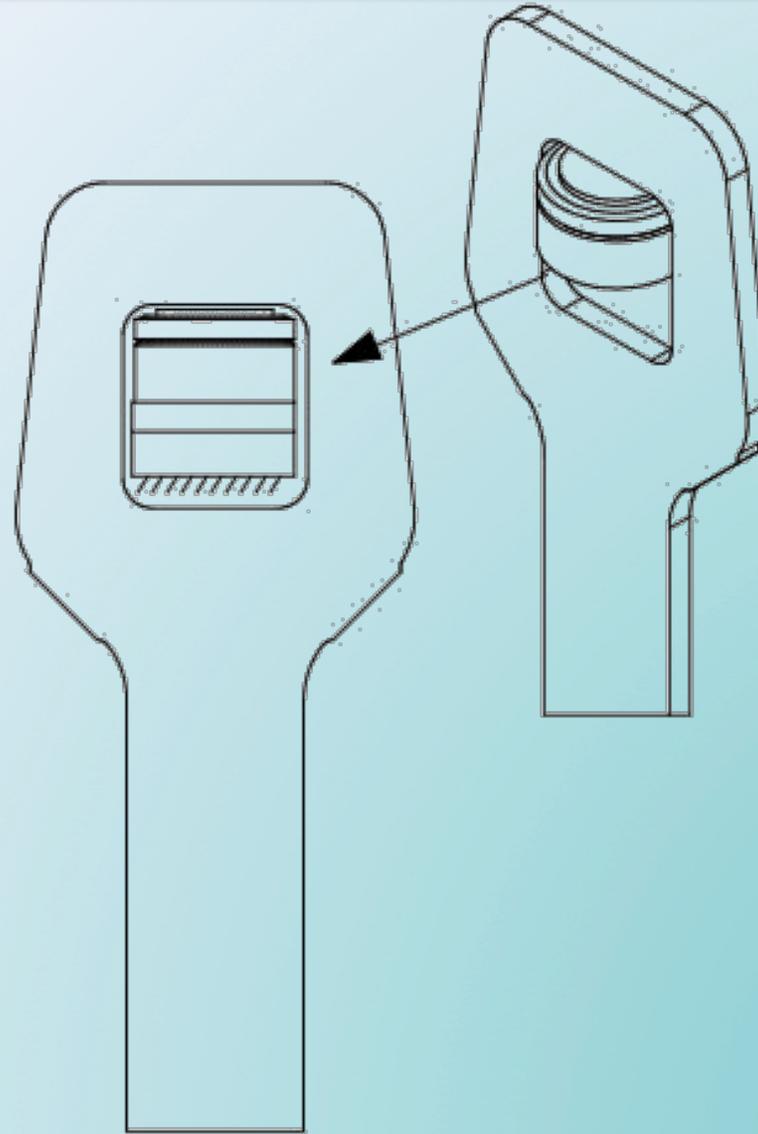


# Diagonals Tensioning System





# Diagonals Tensioning System



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# Diagonals Tensioning System

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**NEW DIAGONALS FORMING**

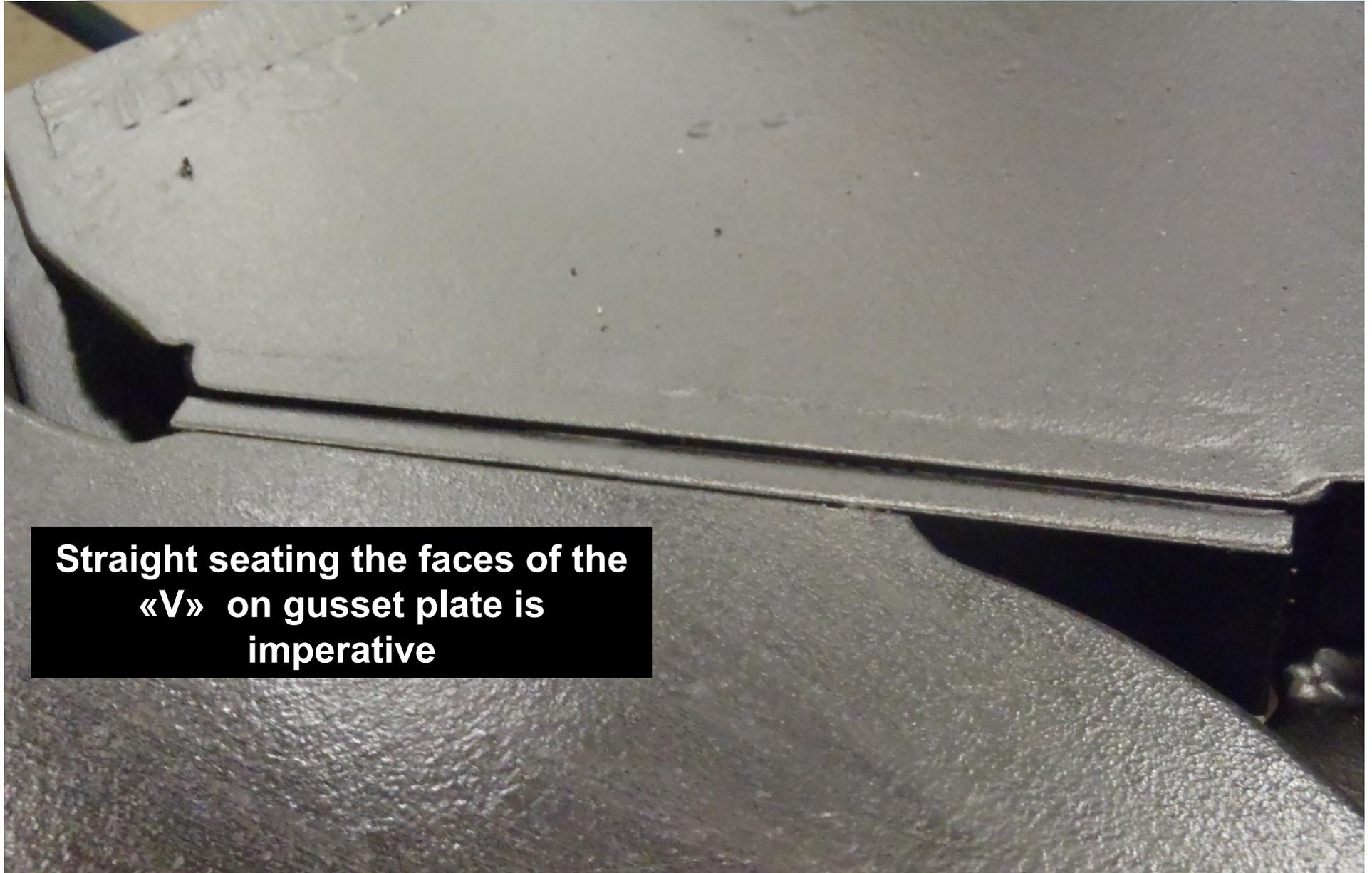


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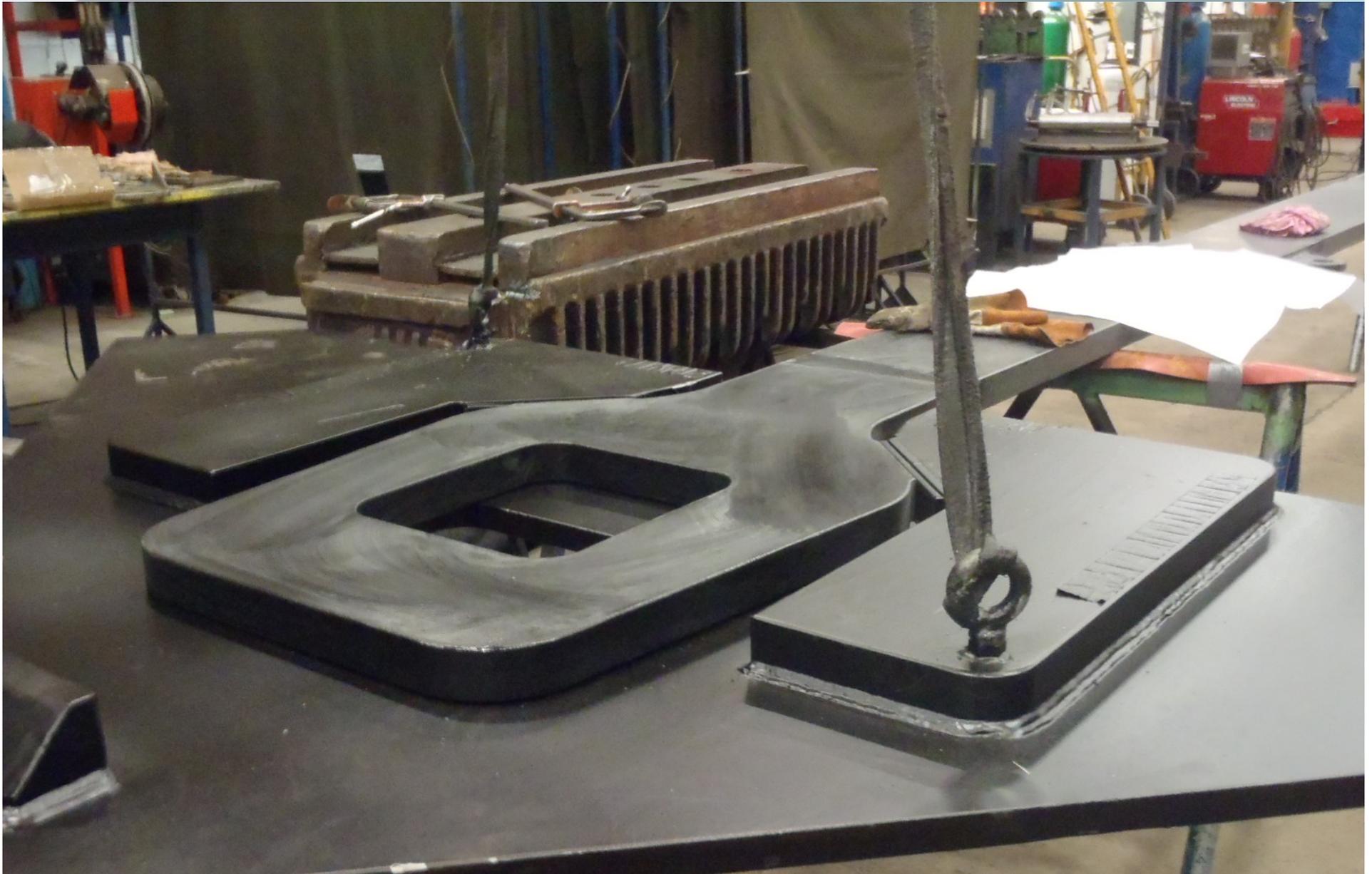
**Straight seating the faces of the  
«V» on gusset plate is  
imperative**



# Diagonals Tensioning System

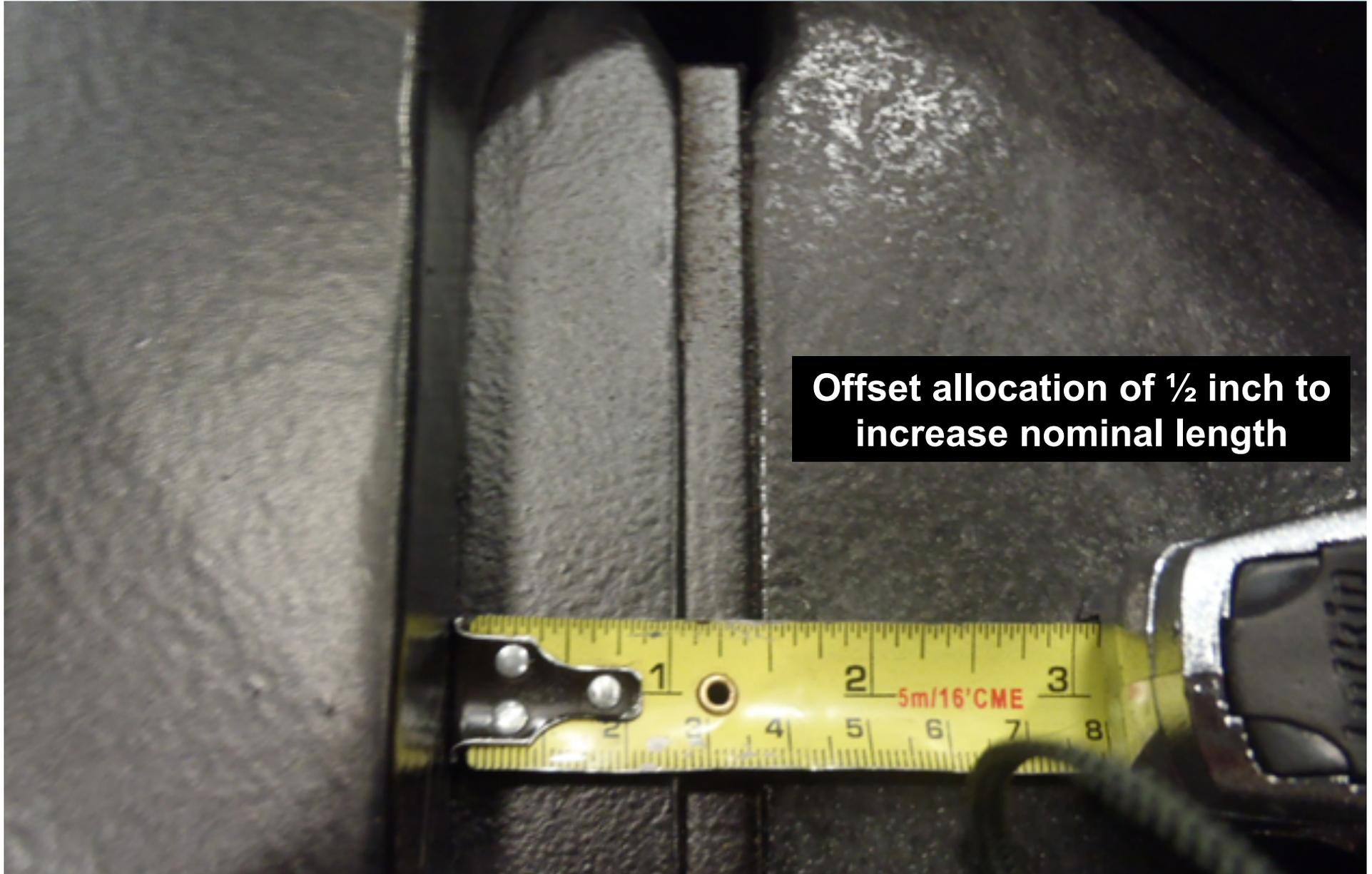


Transports  
Canada





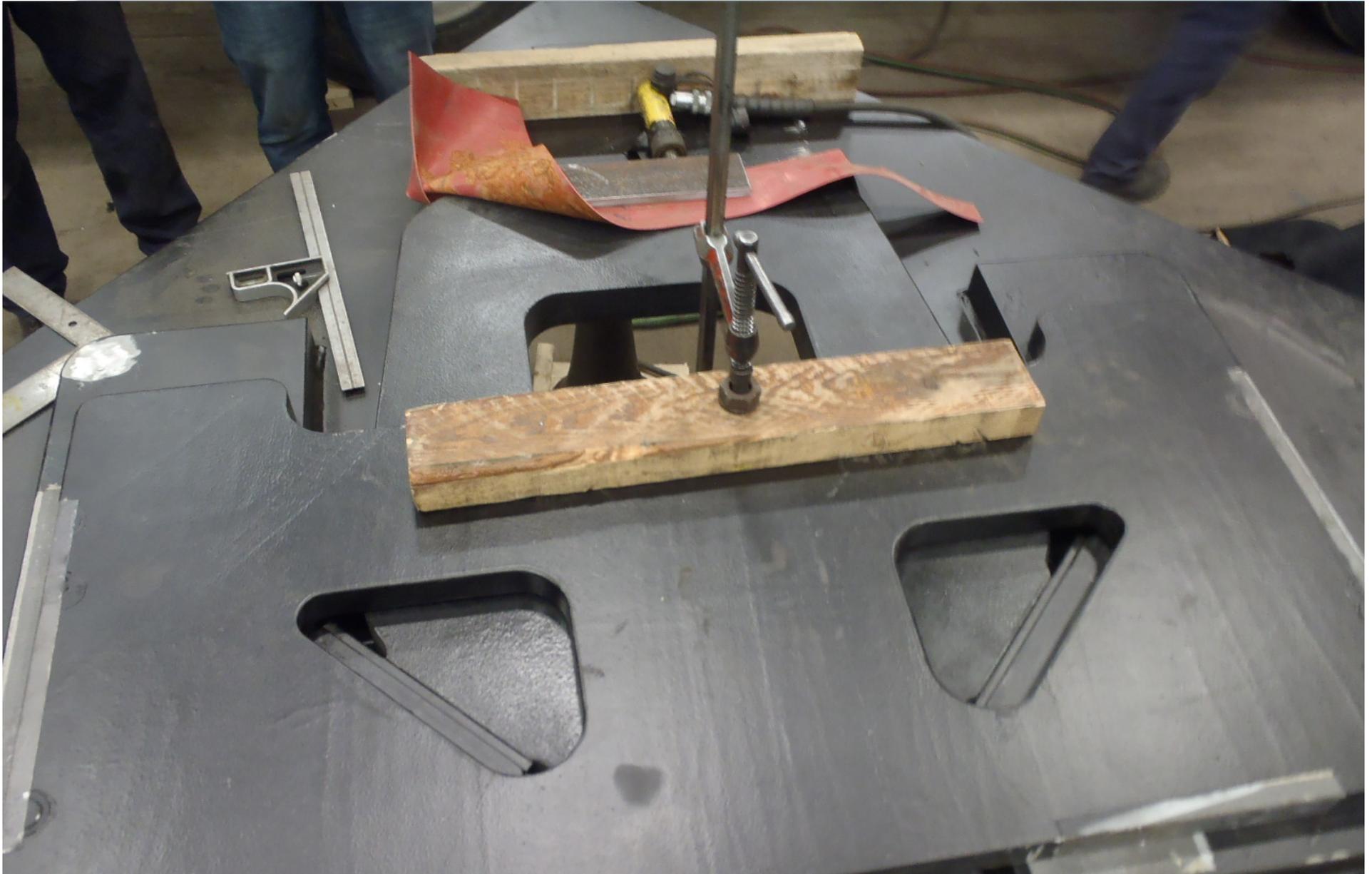
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**Offset allocation of  $\frac{1}{2}$  inch to increase nominal length**



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# Diagonals Tensioning System

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## SITE IMPLEMENTATION



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**With straight seating maintain,  
gusset is adjusted to the gate  
frame with the shims and rotate  
at top pin**



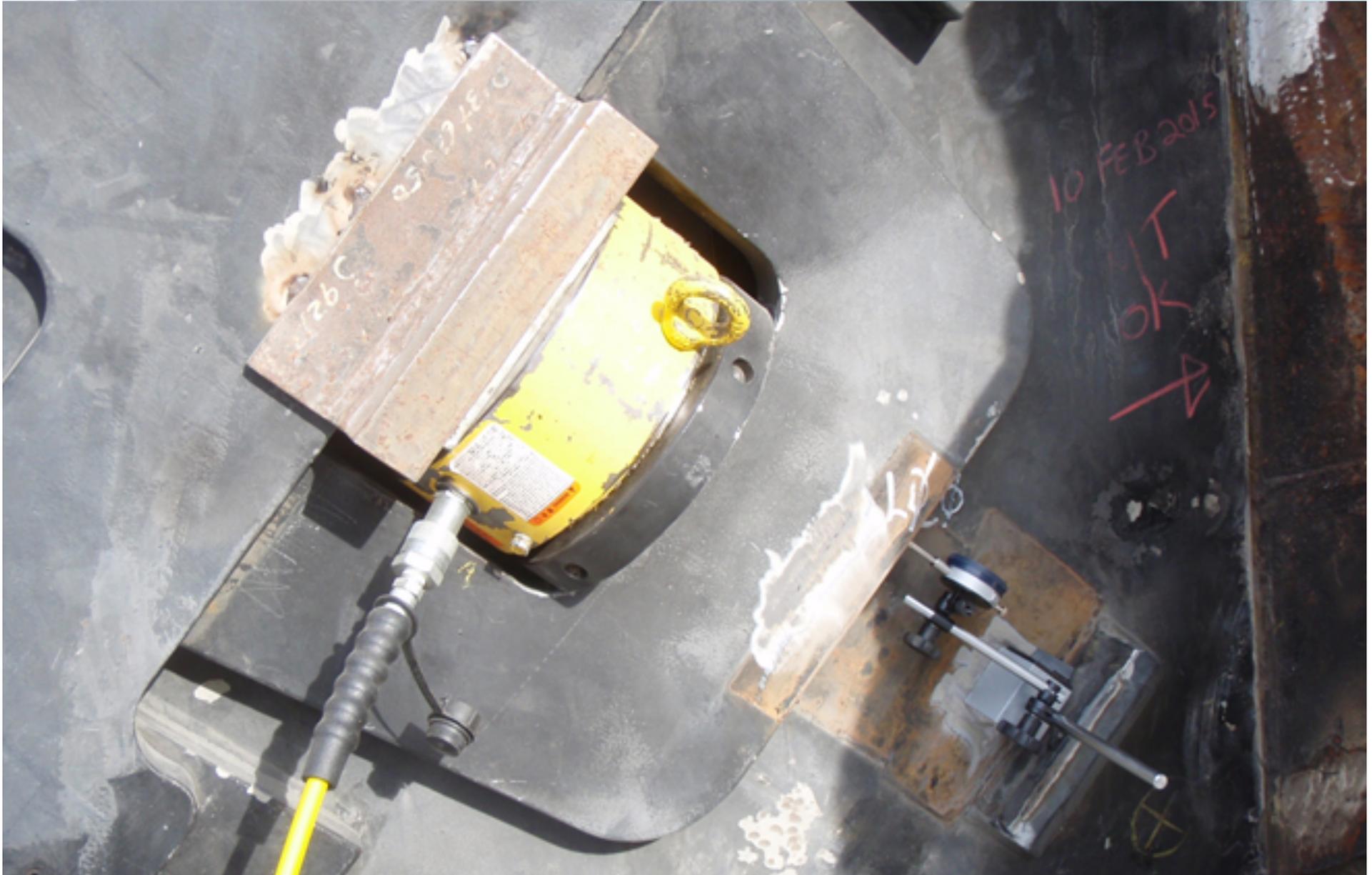


# Diagonals Tensioning System





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**DATA RECORDED**



# Diagonals Tensioning System



## DATA RECORDED

Since we are installing load cells to capture pre-stress in bars, we set the objective to built relation charts for maintenance

- ❖ Stress in bar (load cells) Tension ~vs~ Hydraulic Pressure
- ❖ Stress in bar (load cells) Tension ~vs~ Natural frequency of bars



# Diagonals Tensioning System



## DATA RECORDED

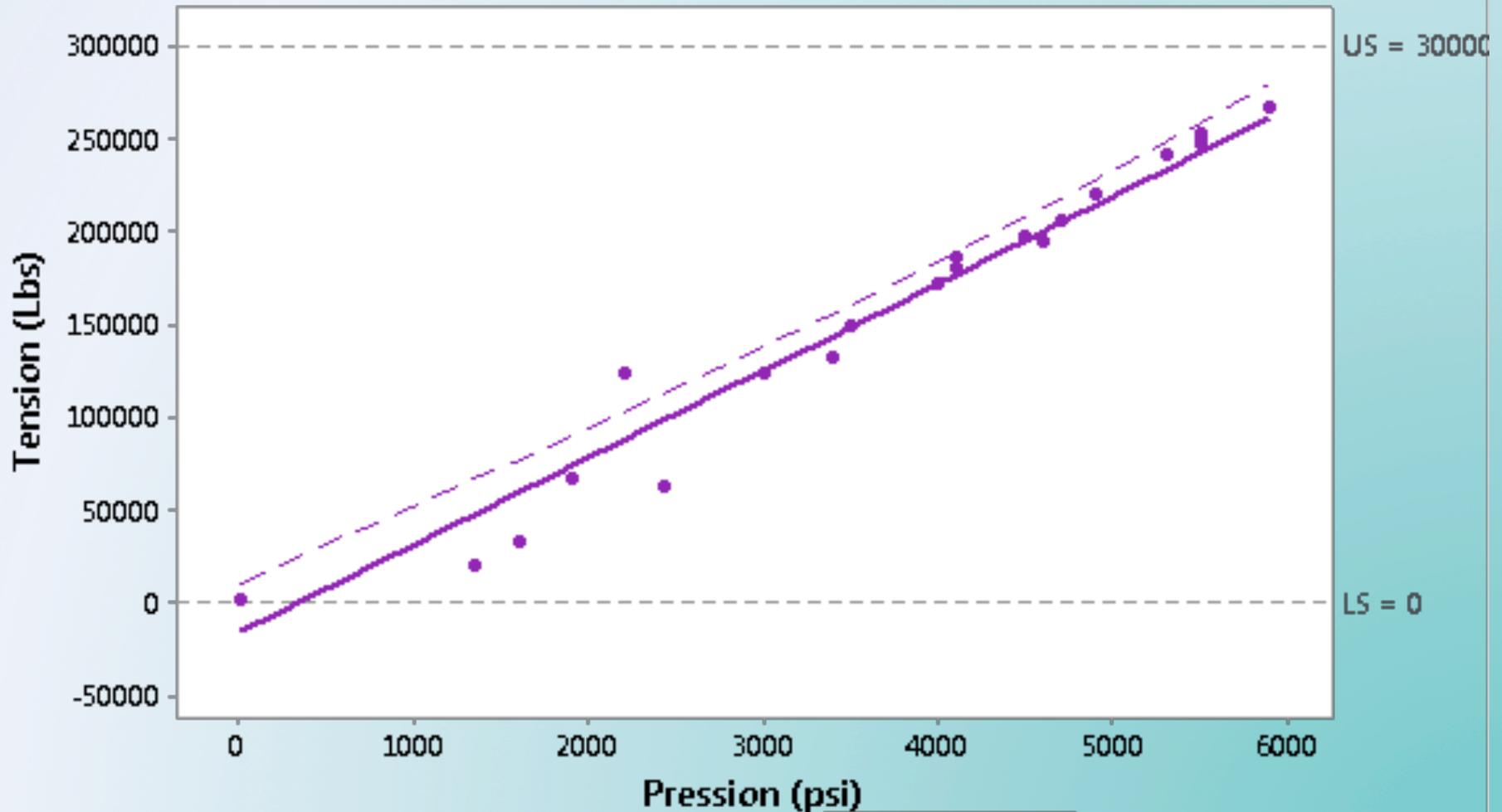
- ❖ Stress in bar (load cells) Tension
- ❖ Hydraulic Pressure
- ❖ Leaf deflection
- ❖ Natural frequency of bars
- ❖ Elongation at stapes (traction bow) end



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P4-U0L1



LS = Lower Specification, US = Upper Specification

Equation for fitted line:  $Tension (Lbs) = -14874 + 46.9 Pressure (psi)$

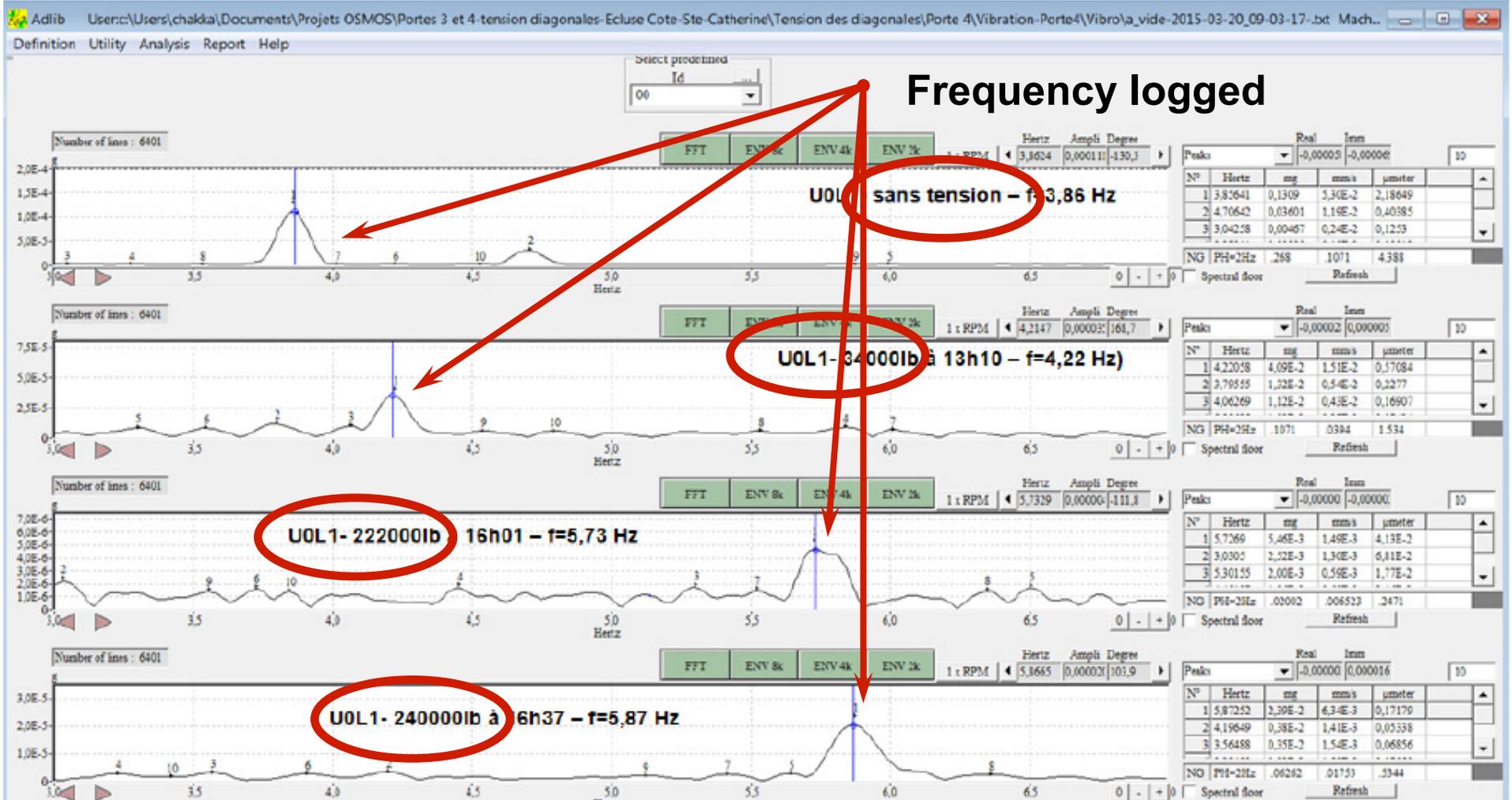
— Fitted Line  
- - - 95% CI



# Diagonals Tensioning System



## Building the Natural Frequency Response to Tension Chart

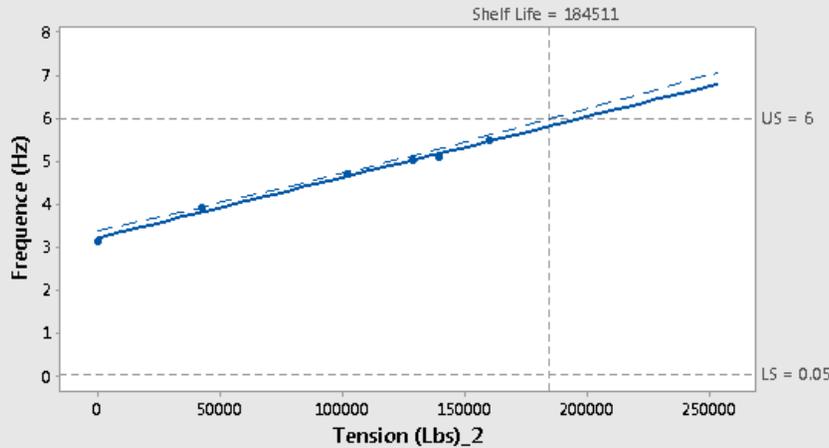




# Diagonals Tensioning System

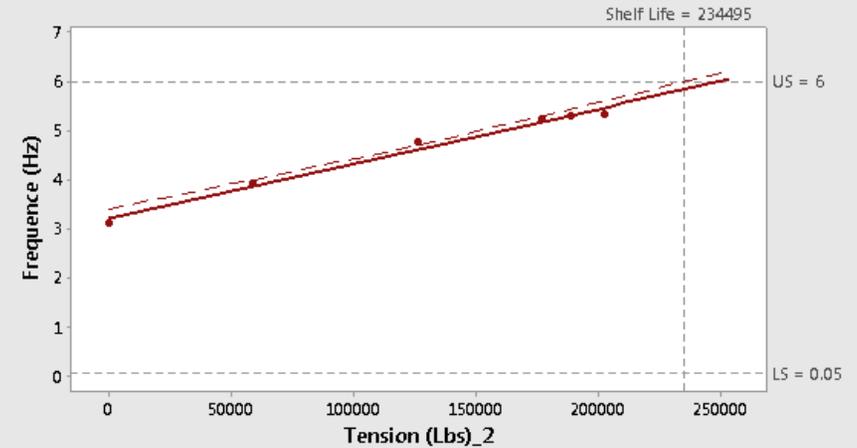


### Shelf Life Plot for Batch P3-LOU1



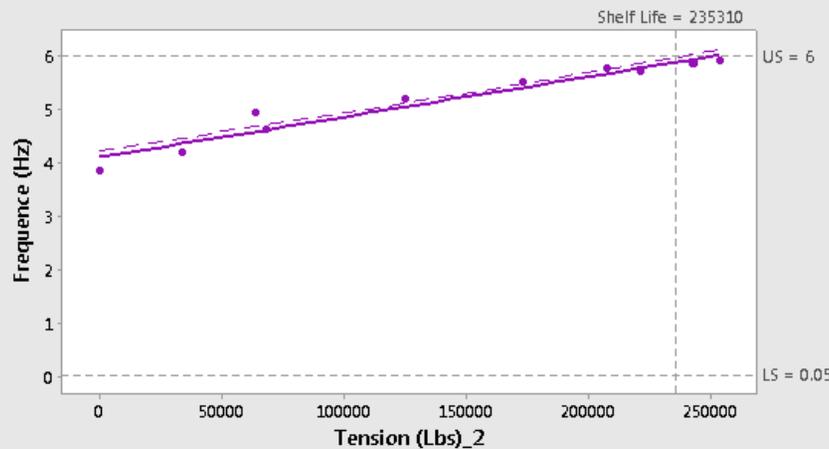
LS = Lower Specification, US = Upper Specification  
Equation for fitted line:  $Frequency (Hz) = 3.21 + 0.000014 Tension (Lbs)_2$

### Shelf Life Plot for Batch P3-UOL1



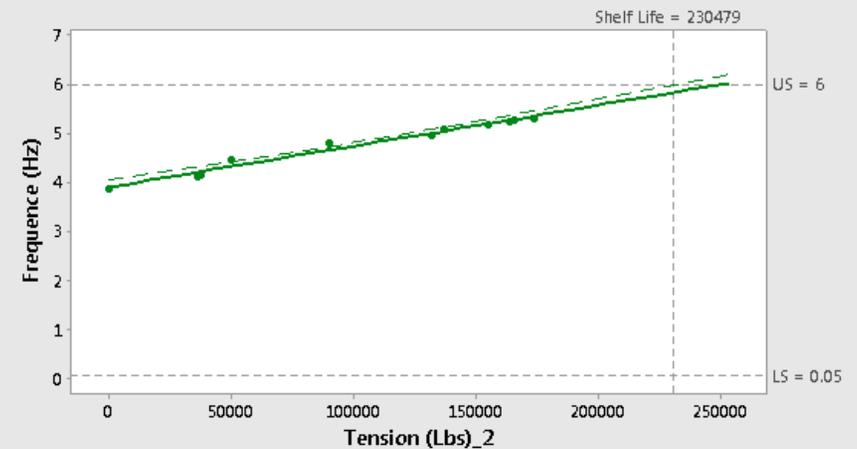
LS = Lower Specification, US = Upper Specification  
Equation for fitted line:  $Frequency (Hz) = 3.22 + 0.000011 Tension (Lbs)_2$

### Shelf Life Plot for Batch P4-UOL1



LS = Lower Specification, US = Upper Specification  
Equation for fitted line:  $Frequency (Hz) = 4.12 + 0.000008 Tension (Lbs)_2$

### Shelf Life Plot for Batch P4-LOU1



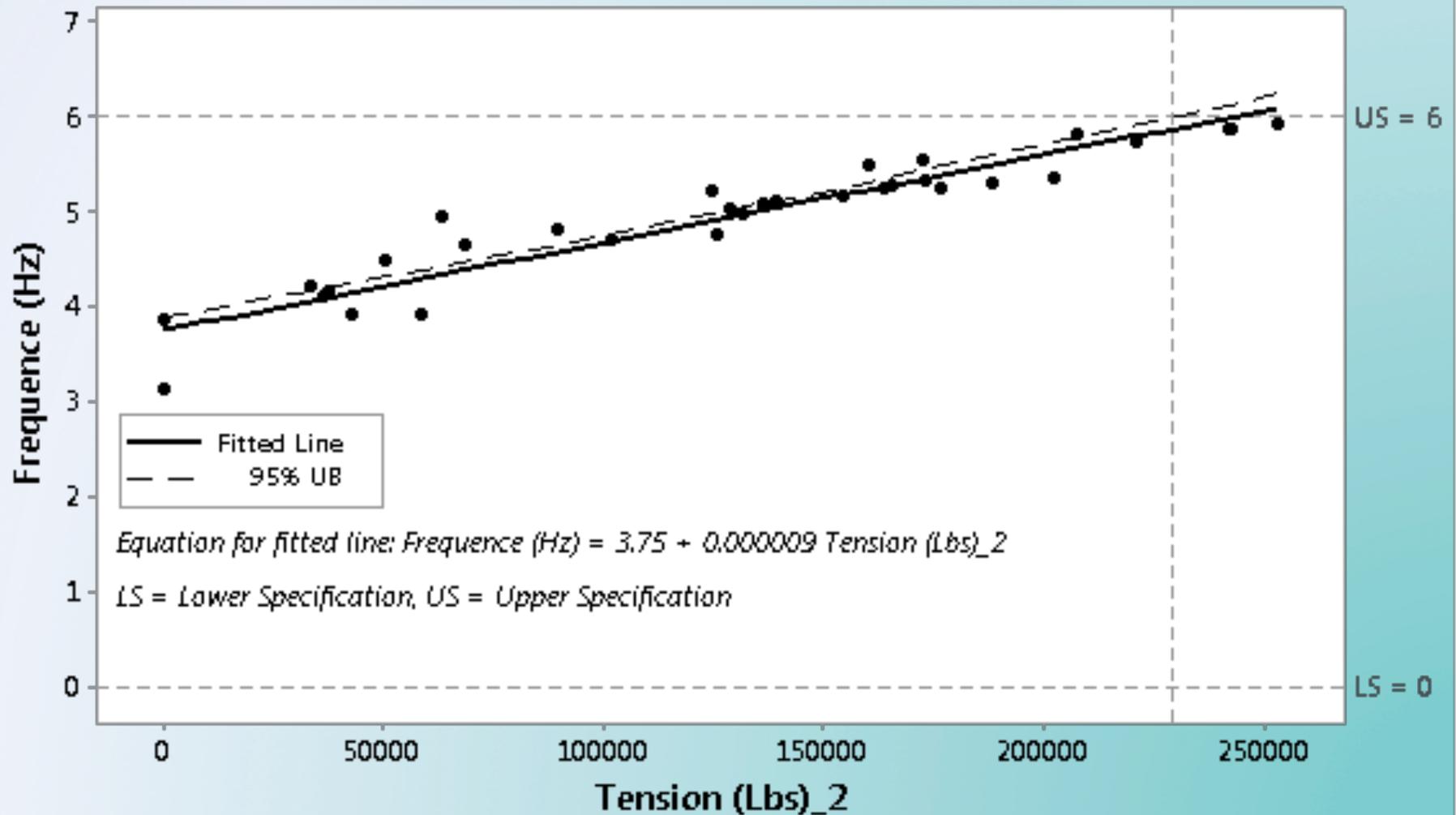
LS = Lower Specification, US = Upper Specification  
Equation for fitted line:  $Frequency (Hz) = 3.91 + 0.000008 Tension (Lbs)_2$



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## UPER GATE ~ Frequency response to various tensions





# Diagonals Tensioning System



## CONCRETE APPLICATION

We are now in possession of technical data and modified assets where:

- ❖ Pre-stress in diagonals can be quickly estimate through natural frequency response of bars
- ❖ Pre-stressing adjustment in diagonals can be quickly reach through hydraulic cylinder and measure with pressure
- ❖ Any damages to diagonals can be repair by plates working



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## PROJECT ASSESSMENT



# Diagonals Tensioning System



## Project Assessment (Went well)

- ❖ Simplicity of the design is definitely a success
- ❖ Simplicity to evaluate pre-stress in bar with natural frequency chart
- ❖ Time to raise or lower tension with hydraulic pump & charts
- ❖ Straight and linear relation between pressure and pre-load
- ❖ Security – few work in height
- ❖ Very low cost to pretension the bars (crane/boom truck/tooling/man power) count in hours.



# Diagonals Tensioning System



## Project Assessment (To Improve)

- ❖ Some nominal extra shims are needed to compensate curvature due to vessel damages
- ❖ Increase Welded joint to fit wavy beam flange
- ❖ Alignment risks (Procedure) & Archimedes' buoyancy recapturing
- ❖ Precision of Measurement for charts
- ❖ 520 ton Cap. Enerpac pancake lock nut cylinders seal rupture
- ❖ Enerpac cylinders CLP-5002 weight (190 kg - 5° deg. Tilt)
- ❖ Needle valve sensitivity





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## PROJECT COSTS



# Diagonals Tensioning System



## Project cost ( CAN\$ )

For 2 upper gates

❖ Prototyping the concept (2012-2015)	477 500 \$
❖ Implementation of the concept	427 200 \$
❖ Standard model~forged turnbuckles	403 000 \$
❖ Regular pre-stressing with charts	14 000 \$
❖ Further saving per programmed maintenance	<b>390 000 \$</b>

NB:Accuracy of pricing is subject to winter conditions





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## ADDITIONAL BENEFITS



# Diagonals Tensioning System



## ACKNOWLEDGEMENTS

### Maintenance Review Team

**Yvon Pinard** Mech. Insp.

**Guy Tremblay** Design Draftsman & Mech. Insp

### Engineering

**Alain Laplante** ing. / PEO

**Alain Fafard** ing. / PEO

**Francis Gagnon** ing. / PEO

**Martin Beaudet** Design Draftsman

### Manager

**Stéphane Lépine** ing.



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## QUESTIONS / COMMENTS

Pierre ROBY ing. / PEO

Senior Mechanical Engineer

St. Lawrence Seaway Management Corporation

Phone: (450) 672-4115 ext. : 2407

E-mail: [proby@seaway.ca](mailto:proby@seaway.ca)



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