

# **INNOVATION: A NEVER ENDING JOURNEY**

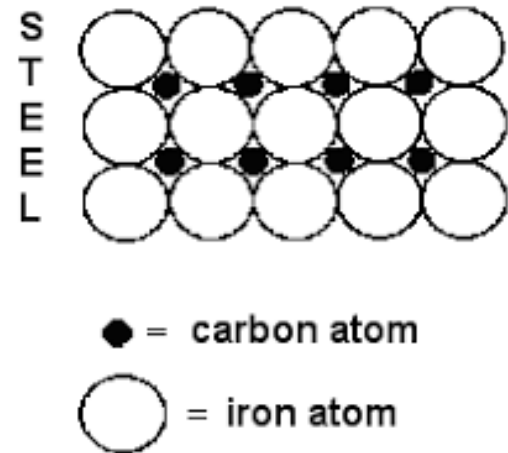


# CHALLENGE EVERYTHING!

- ◆ **How did I get here and who are we?**
- ◆ **Had to reinvent myself and what it means to be the leader of our company**
- ◆ **Surround yourself with people that share your values and vision**
- ◆ **Hold everyone accountable to goals**
- ◆ **Core values are critical**
- ◆ **Still learning and growing, never stop**

# CHALLENGE WHAT A COMPOSITE IS

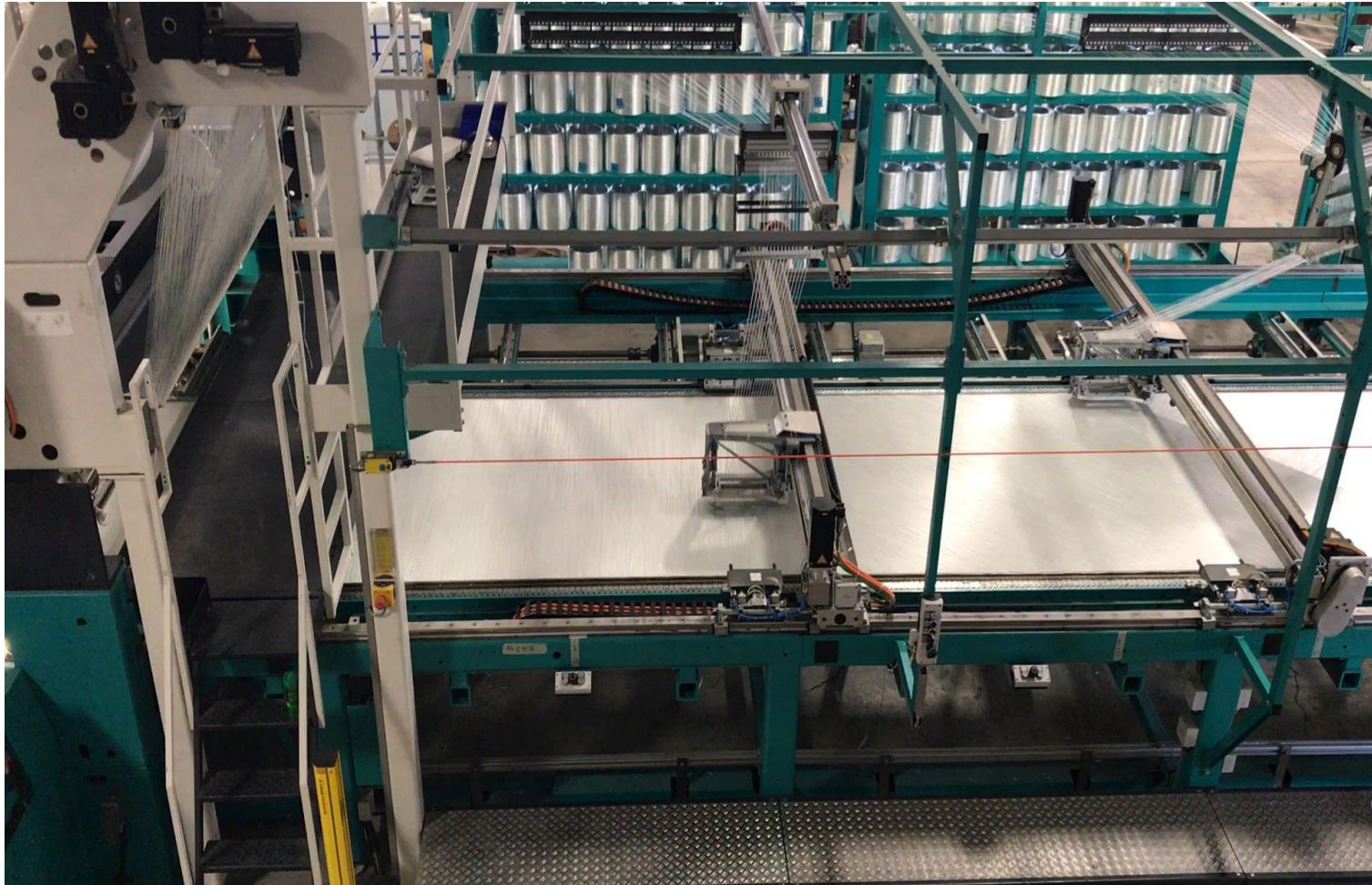
- ◆ **What is a composite?**
- ◆ **So many varieties**
- ◆ **The future of building materials**
- ◆ **Testing and design is key to best technology**
- ◆ **Internal capability speeds innovation**



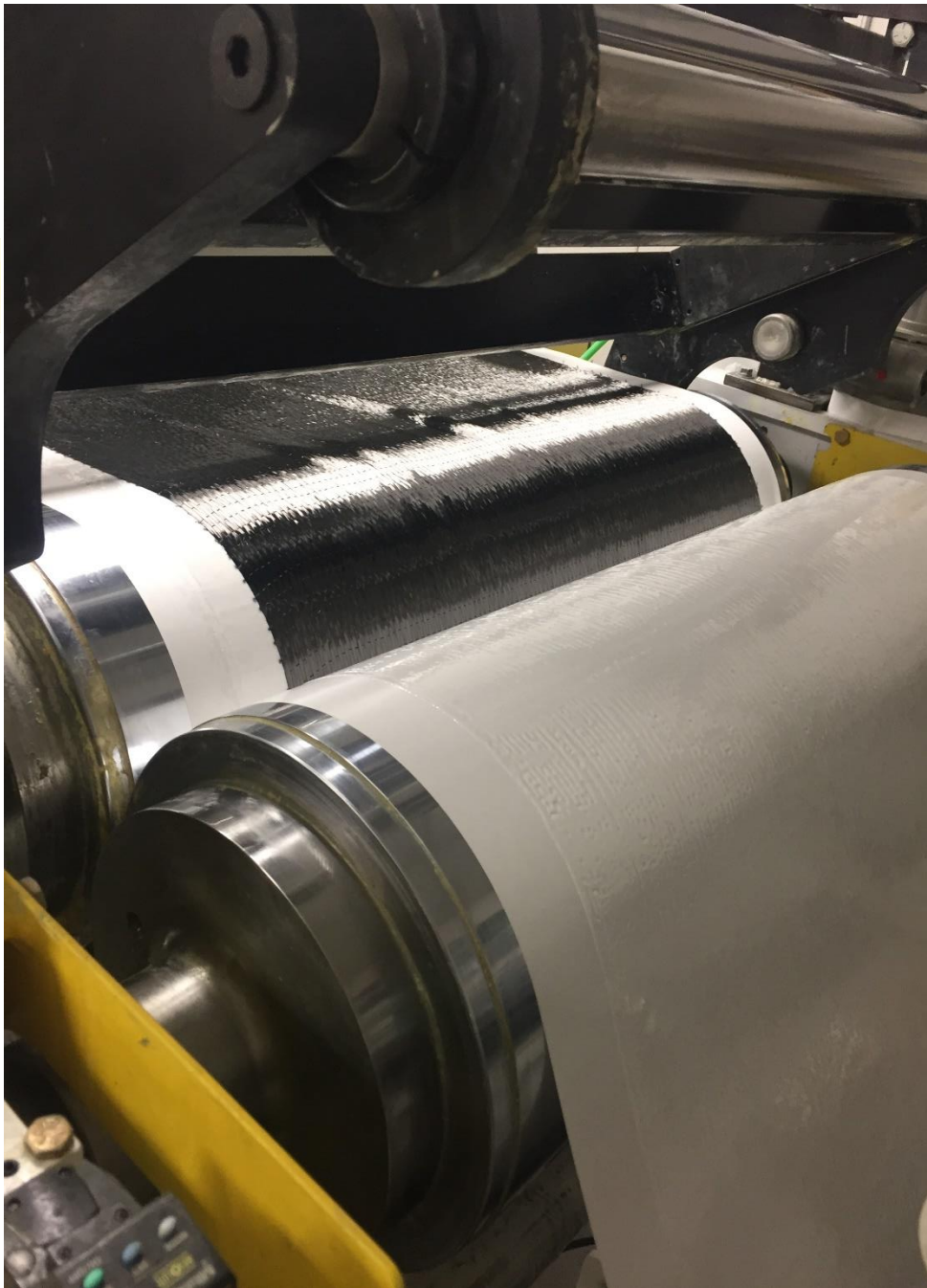
# INNOVATION RESOURCES

- ◆ **Full state of the art composite weaving machinery**
- ◆ **Resin design and characterization laboratory for Epoxy and Polyurethanes**
- ◆ **Testing cyclical capability to determine long term performance and strain characterization (lifespan)**
- ◆ **NRI University to educate and push application ease**
- ◆ **A commitment to never settling and always pushing technology and questioning what is possible**
- ◆ **Manufacturing equipment designed and manufactured on Aerospace prepreg lines**
- ◆ **PEOPLE, Goals and Accountability**

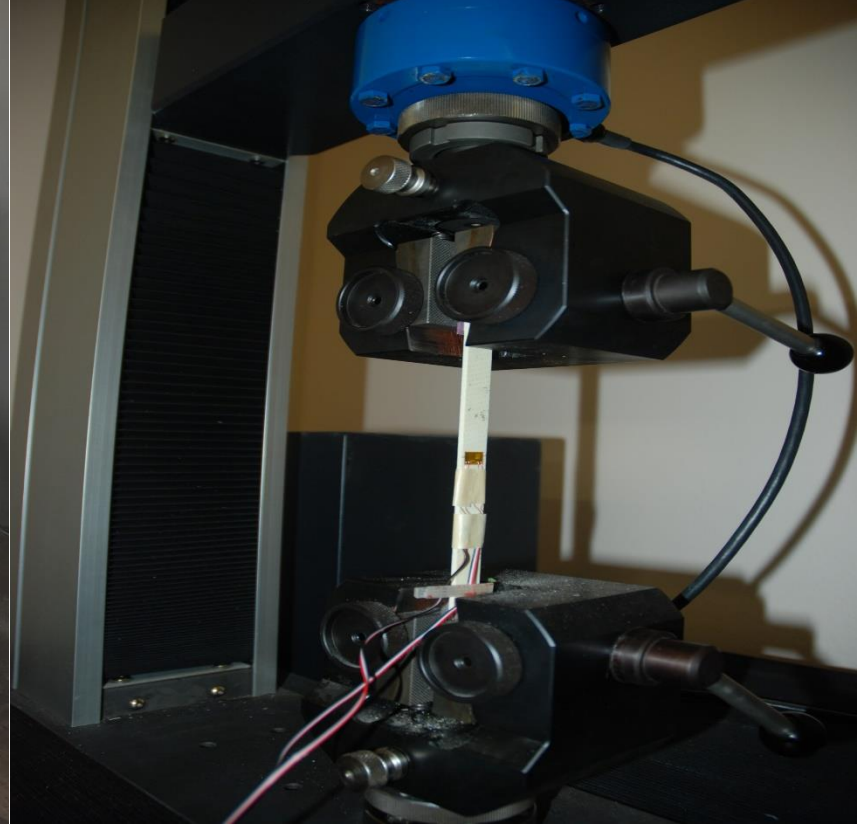
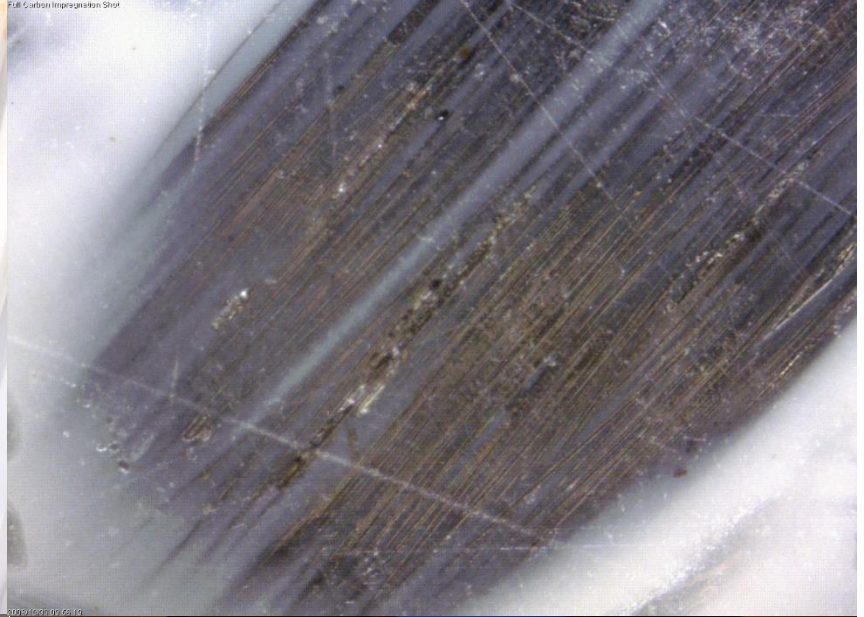
- ◆ **Multi axis weaving for fiber optimization quality control and consistency from lot to lot.**
- ◆ **By controlling our fiber we control and understand the importance of sizing, binders and the value of different performance carbon and glass fibers**







- ◆ **World Class Prepregging machines**
- ◆ **Manufacturing quality standards taken from the aerospace industry**
- ◆ **Repeatable performance in the field**
- ◆ **Core technology proven**
- ◆ **Efficiency of fiber improved**
- ◆ **Innovate where it make sense and take technology and improve upon it**





# CONFIDENCE IS KEY TO COMPOSITE ADOPTION AND FUTURE APPLICATIONS

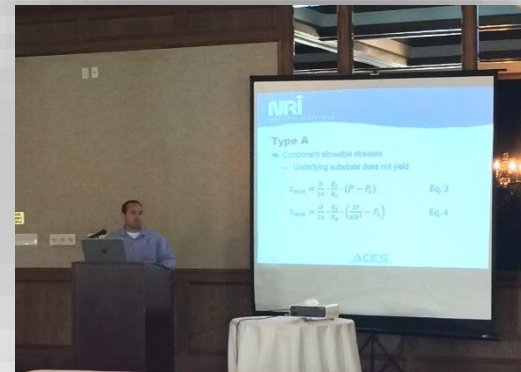
## ◆ Innovate

- ◆ R&D Lab
- ◆ Test, test, test



## ◆ Educate

- ◆ Engineers
- ◆ Applicators



## ◆ Support

- ◆ Training
- ◆ Design
- ◆ Delivery





# **THE ROAD TO OPTIMIZATION OF OUR APEX LINE**

- ◆ **Select a specific application and examine needs**
- ◆ **Select a fiber type**
- ◆ **Design a range of fiber orientations and layup designs**
- ◆ **Lab scale to screen for winners**
- ◆ **Take three options to large scale and determine optimized solution**
- ◆ **Full scale testing of winner**
- ◆ **Long term cyclic testing**
- ◆ **Review the results and present value**

# COUPON TEST DISCOVERIES

## ◆ Tensile Testing

- Elongation to failure tended to increase with addition of chopped fiber (*preferable for long-term cyclic testing*)

## ◆ Flexural Testing

- Failure mode of the 0 and 12 oz/yd<sup>2</sup> samples was primarily fiber breakage
- Failure mode of the 4 and 8 oz/yd<sup>2</sup> samples was primarily delamination (*preferred method of failure*)

## ◆ ILSS Testing

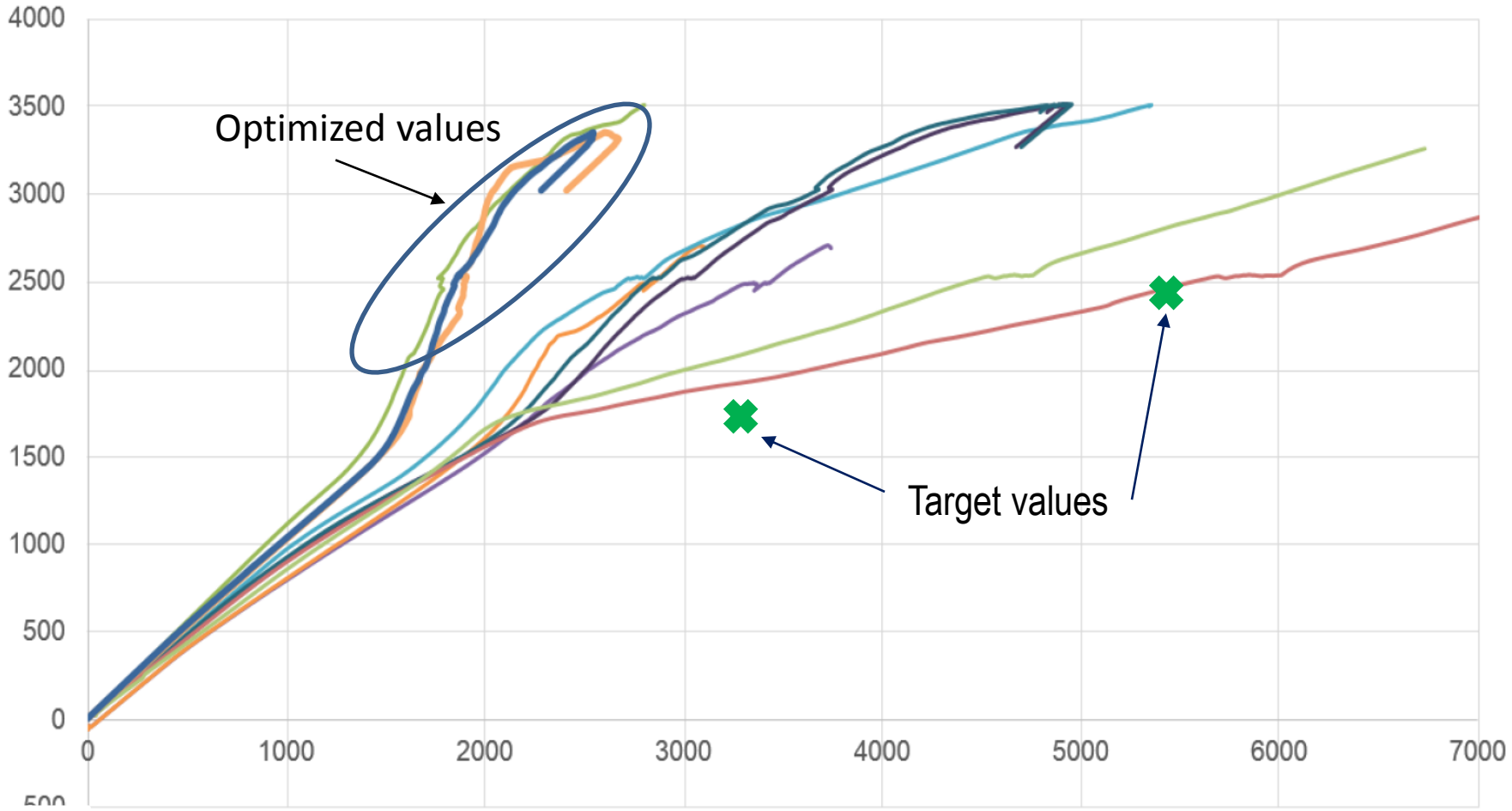
- Not a significant difference with different percentages of reinforcement

# FULL-SCALE PRESSURE TEST

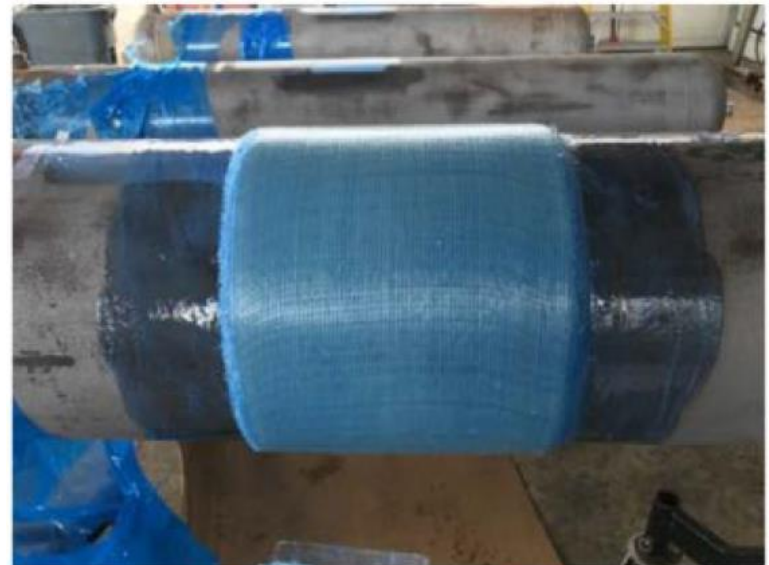
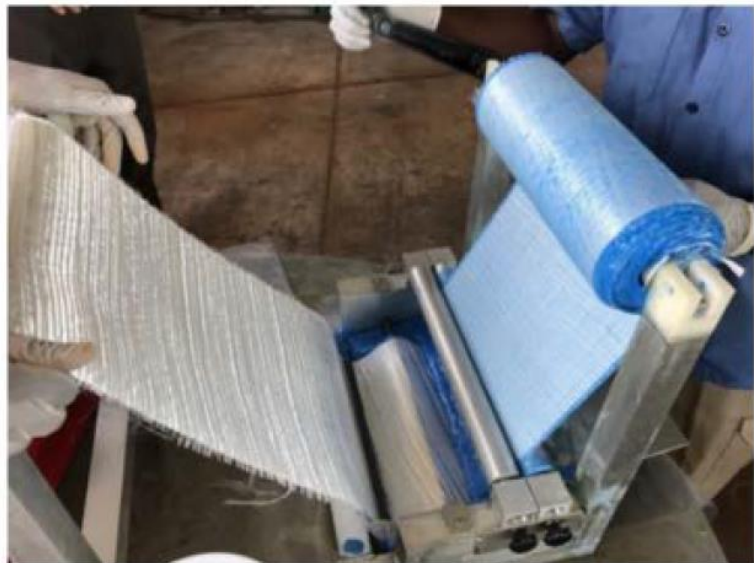
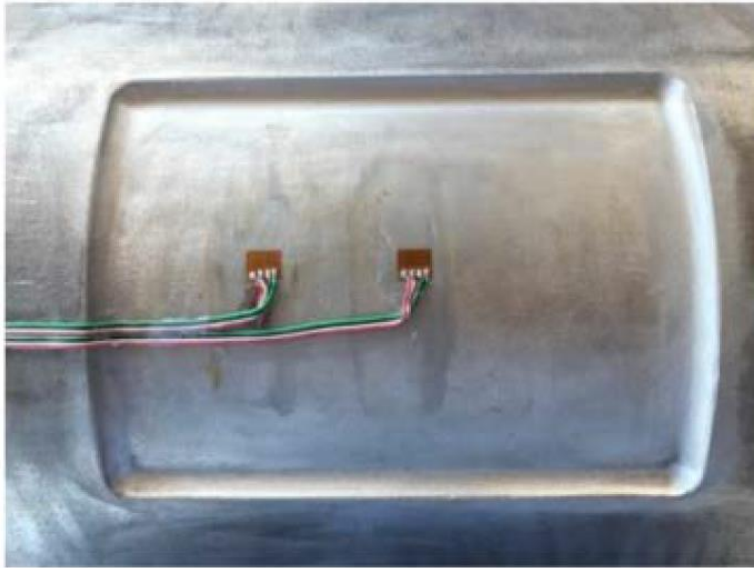
- ◆ Based on results and discoveries in coupon testing:
  - Test group #1 (70:30) was eliminated entirely
  - Test group #s 2.2, 2.3, 3.2, and 3.3 chosen to continue (80:20 and 90:10 with 4 and 8oz/yd<sup>2</sup> of CSM)
  - Test group #3.1 (90:10 with no CSM) was also chosen but only to serve as a baseline comparison for the other test groups
- ◆ Full-scale pressure test conducted on each sample and biaxial strain data collected
- ◆ Pipe sample and defect created according to drawing using a 12.75-inch x 0.375-in, Grade X52 pipe
- ◆ Strain gauges applied at marked areas



# PRESSURE TEST RESULTS



# REPAIR INSTALLATION

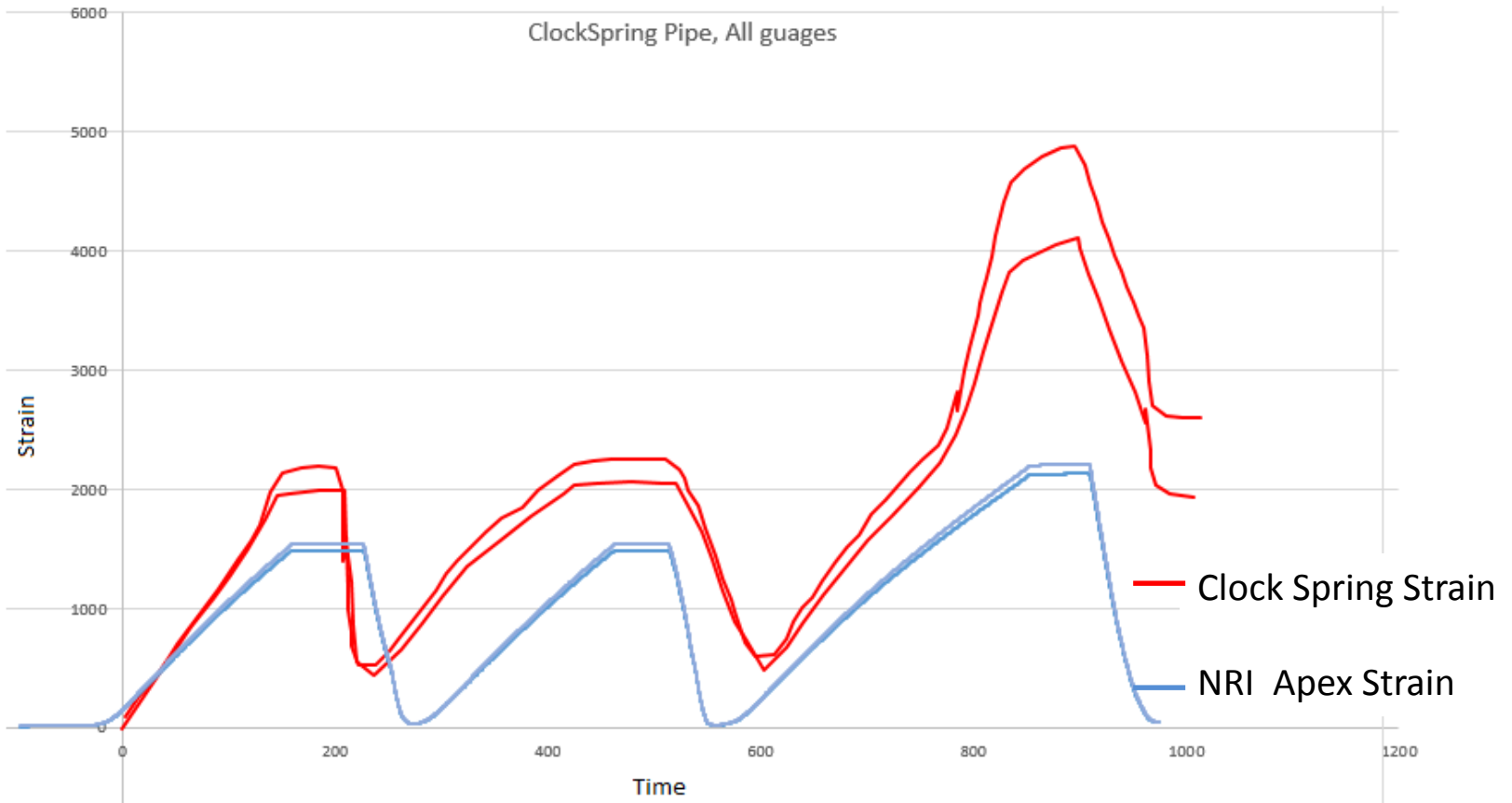


# FULL-SCALE TEST RESULTS

- ◆ Comparing to identical test on a product by GTI in the 1990's:
- ◆ In burst testing, reduced strain in the defect region by 50% at pressures up to 2000 psi and as pressure increased this reduced strain by over 70%.
- ◆ Also, when the pressure was returned to zero the strain went back to zero showing no permanent yielding in the defect zone.
- ◆ In cyclic testing, reduced max strain in defect region by 50%.
  - ◆ Relatively constant strain range over long-term usage



# COMPARISON VS CS DATA



**Optimized system at the same thickness show substantial reduction in strain under repair vs. CS published data.**

**NO residual strain damage to the underlying Steel as all strains return to zero**

# **INNOVATION: THE JOURNEY CONTIUES**

- ◆ **Pushing limits of resins**
- ◆ **Fillers and optimizers composite resins**
- ◆ **Optimizing carbon fiber utilization**
- ◆ **Robotic application**
- ◆ **Simplification of installation**
- ◆ **Growing people and making leaders**