



DEEP CRYOGENICS INTERNATIONAL
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MINING TECHNOLOGY

DEEP CRYOGENICS

MINING INDUSTRY ISSUES



- Short life of ground tools, drills, crushers, mill liners, pumps
- Downtime and maintenance
- Safety risk to miners
- Financial impact



HIGH WEAR COMPONENTS

Excavation
Drilling
Crushing
Grinding
Pumps
Hauling

bucket teeth, links, wear plates
drill bits, pipe, bearings, shafts,
cone crusher liners and mantles
cast mill liners, grates, ball media
impellers, liners, bearings, nozzles,
conveyor parts, suspension, gears



SOLUTION



DEEP CRYOGENIC TREATMENT (DCT)
Reduces Wear and Corrosion 20-70%
Fast - Effective - Low Cost - Green

DCT IS A POST-HEAT TREAT PROCESS

WHY DEEP CRYOGENICS?

Reduce metal-on-metal wear by 20-70%
Reduce corrosion 20-40%

WHICH METALS RESPOND?

Steel, copper, aluminum, tungsten carbide, cast iron, manganese and TRIP steels

WHAT ACTUALLY HAPPENS?

Grain structure densifies and releases stress, voids disappear, carbide particles bind weaker elements, material becomes wear resistant.

IN WHAT FORM CAN ITEMS BE TREATED?

Raw material/castings/forgings; fully machined and finished parts as supplied by OEM's



ADVANTAGES OF DCT

COST/BENEFIT Cost is 10% of the original item to increase wear life 20-60%

DOES DIMENSIONAL SIZE REMAIN CONSTANT? Yes

SAFETY? Uses liquid nitrogen; no chemicals or hazardous waste

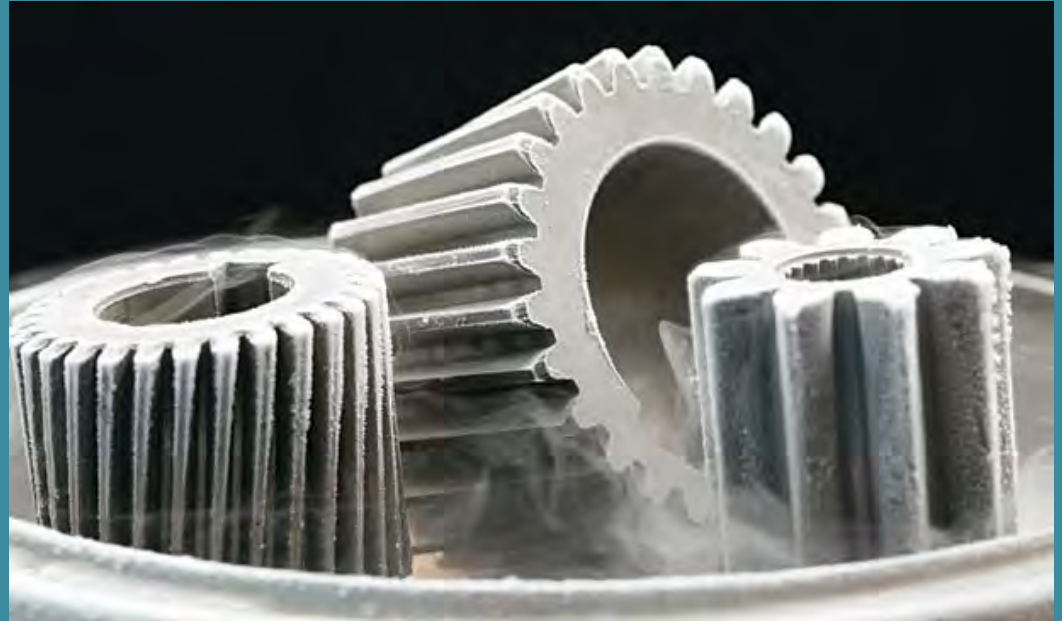
WHERE IS IT USED NOW? Bearings, brake rotors, engines, turbines, machine tools

WHERE COULD IT BE USED NEXT? Mining, marine, wind turbines, transportation

WHY HASN'T THIS TECHNOLOGY BEEN EXPLORED FURTHER?

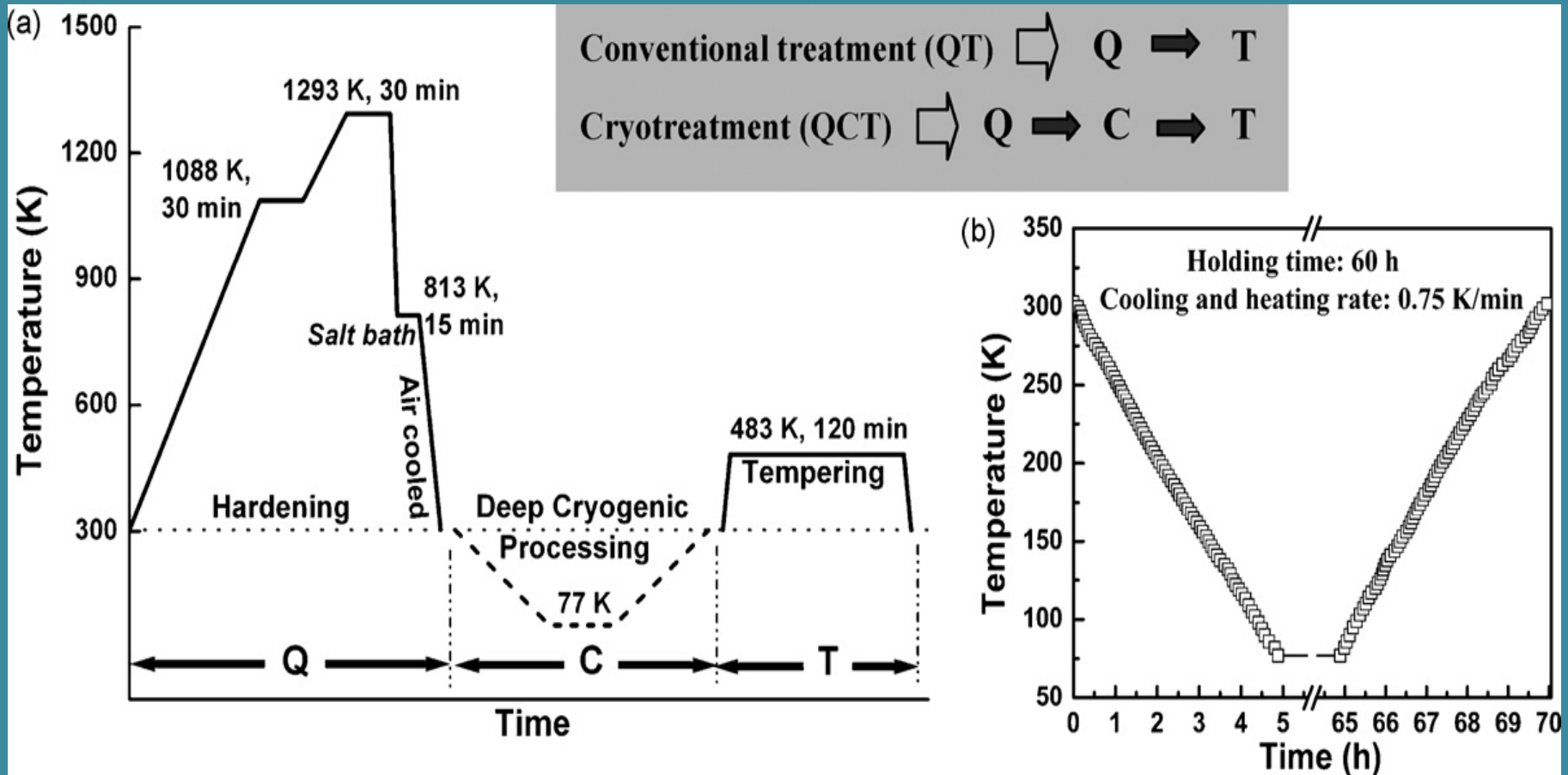
- No test method (*prior to 2018*)
- No industrial prove-out (*prior to 2019*)
- No certification procedure (*prior to 2020*)
- No scale-up equipment for large industrial application (*prior to 2021*)

HOW IT WORKS



- Metal items are slow cooled to -196°C in a special tank
- Items are tested and certified to current ASTM specs
- Thousands of pounds can be treated simultaneously
- Entire process takes three days

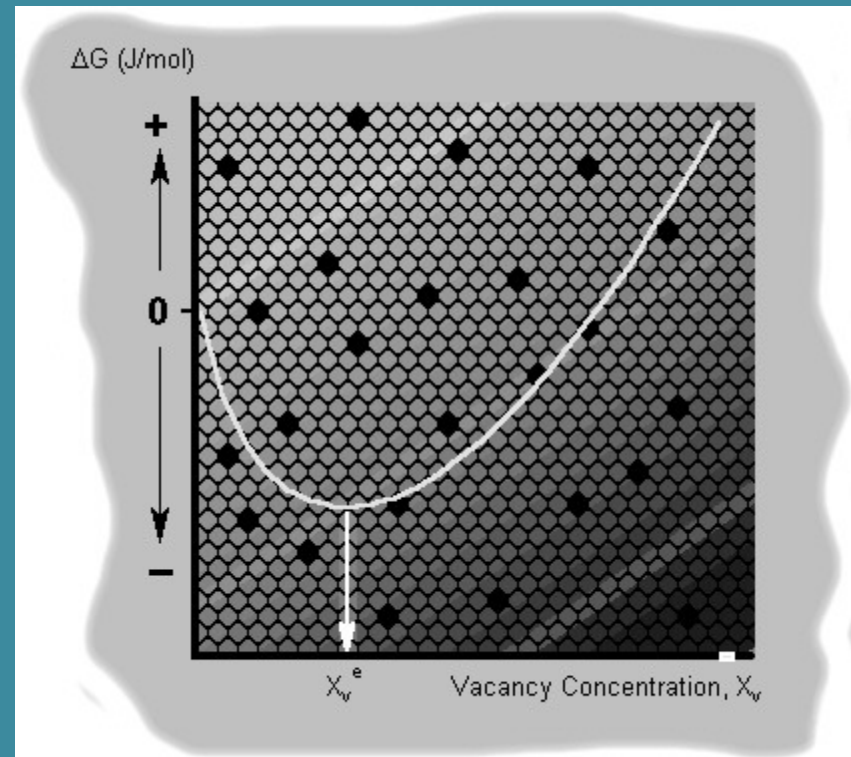
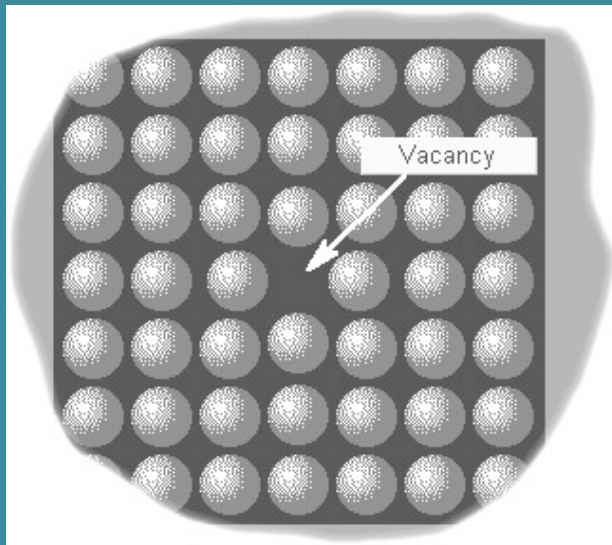
THE PROCESS



HEATTREAT(QT) + DEEP CRYOGENIC TREATMENT(QCT)

METALLURGICAL CHANGES FROM DCT

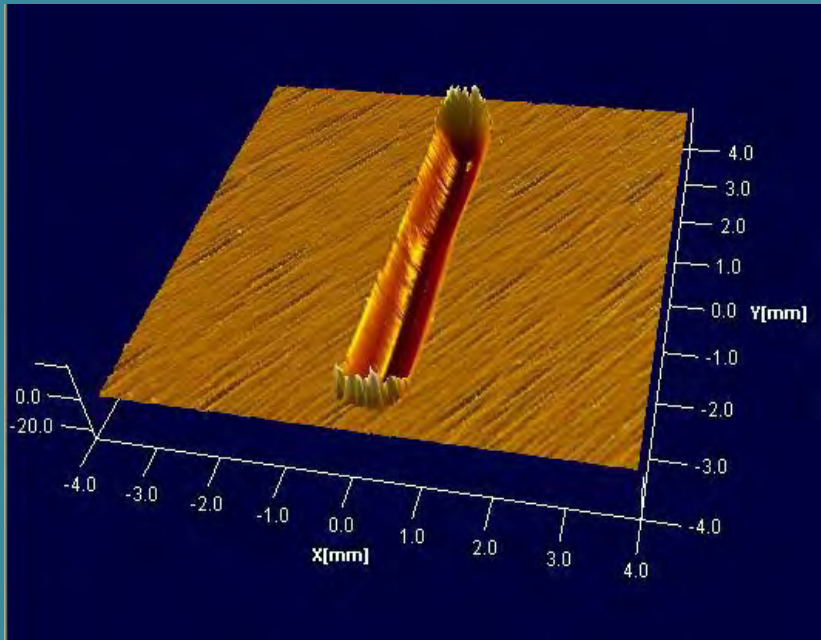
- Austenite to martensite conversion without embrittlement
- Precipitation of fine primary and secondary (η) carbides
- Lattice phase change from face centric to body centric tetragonal
- Material grain refinement; edge and boundary diffusion



G133 PIN ON PLATE TEST

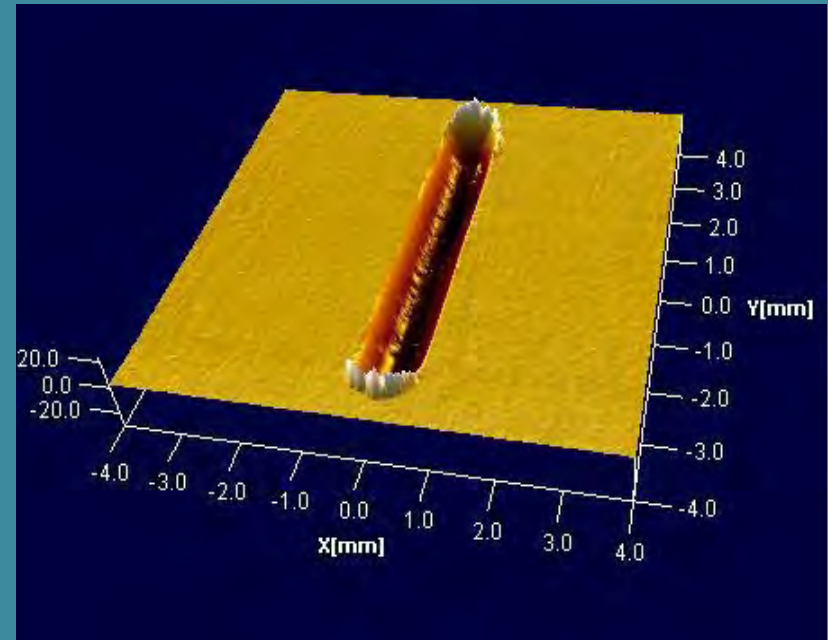
Cryo Processed

Non-Cryo Processed



Material loss = $0.082[\text{mm}^3]$

Width = $1056\mu\text{m}$



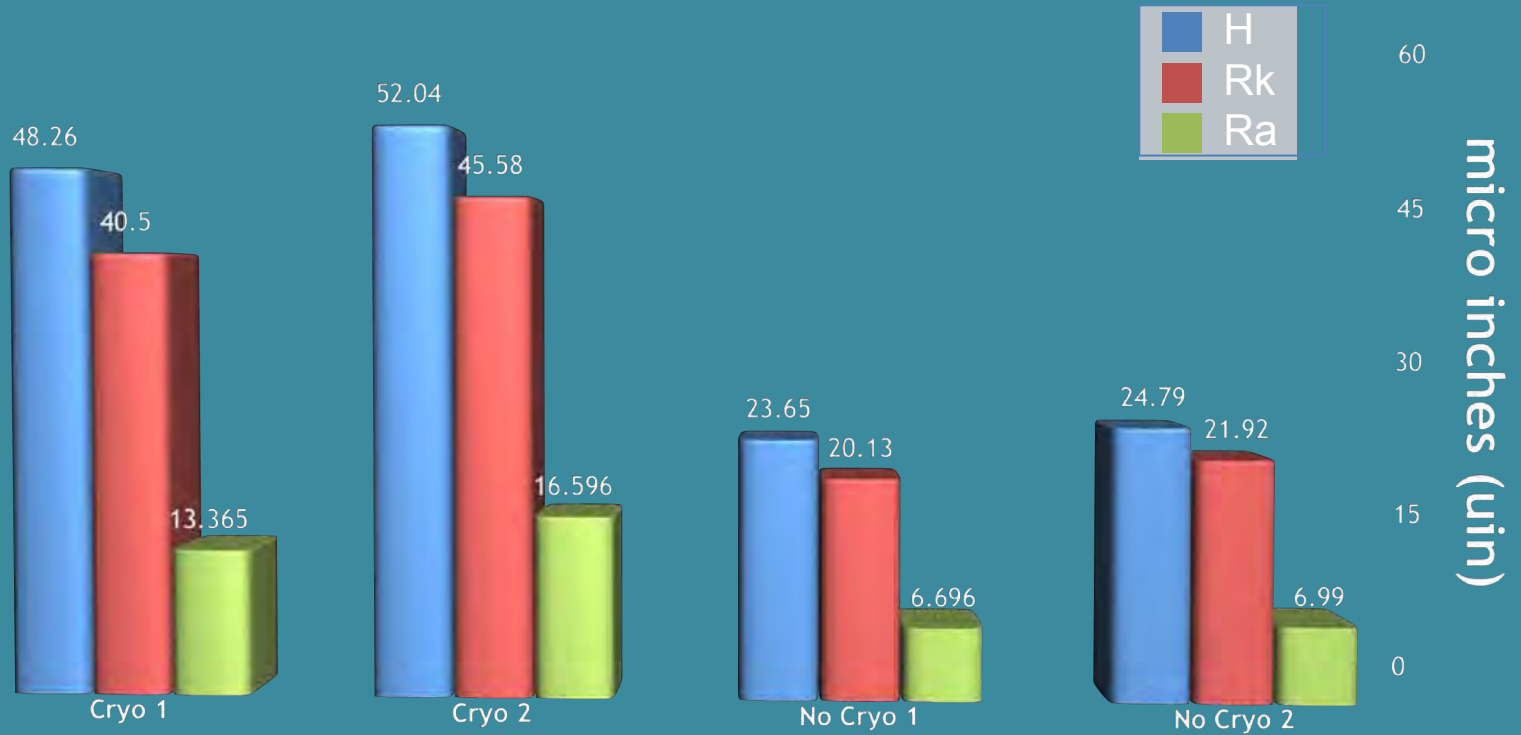
Material loss = $0.128[\text{mm}^3]$

Width = $1098\mu\text{m}$

RESULT: 64% REDUCTION IN EROSIVE WEAR

SURFACE FINISH IMPROVEMENT

DCT versus Non-DCT Surface contact area

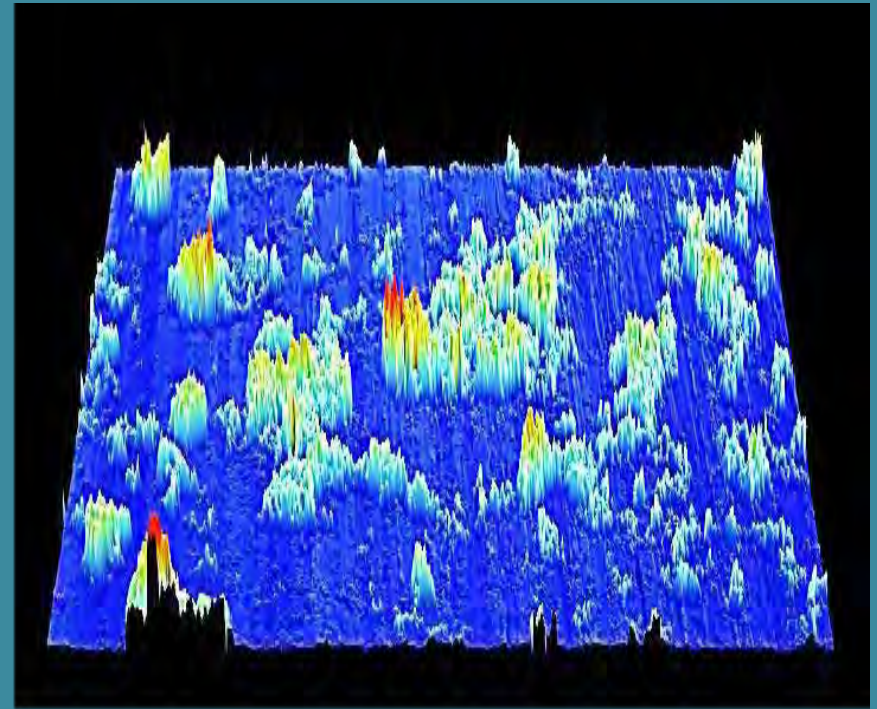
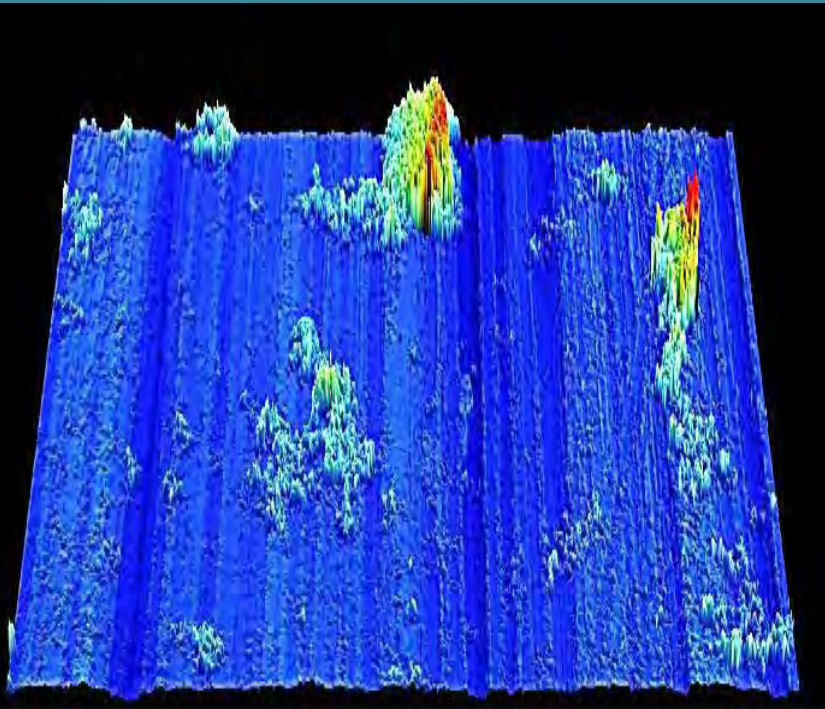


RESULT: 100% IMPROVEMENT IN SURFACE FINISH (Rk) IN 30 MINUTES

4340 STEEL CORROSION TEST #1

Corrosion-18 hrs in 3.5% NaCl
Cryo treated coupon 100 μm

Corrosion-18 hrs in 3.5% NaCl
Non-cryo treated coupon 100 μm



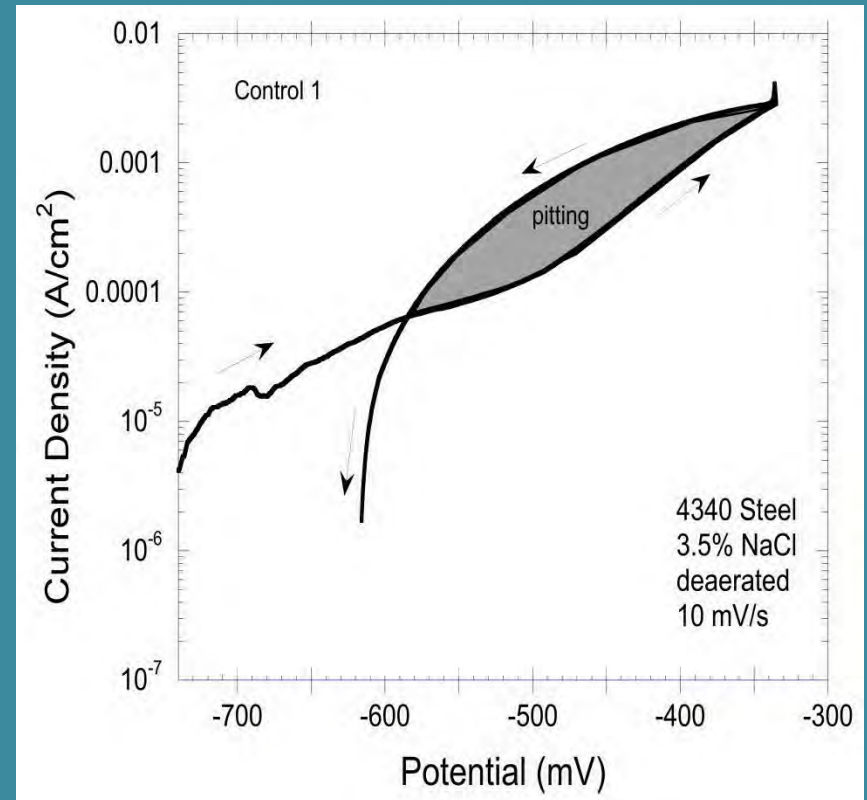
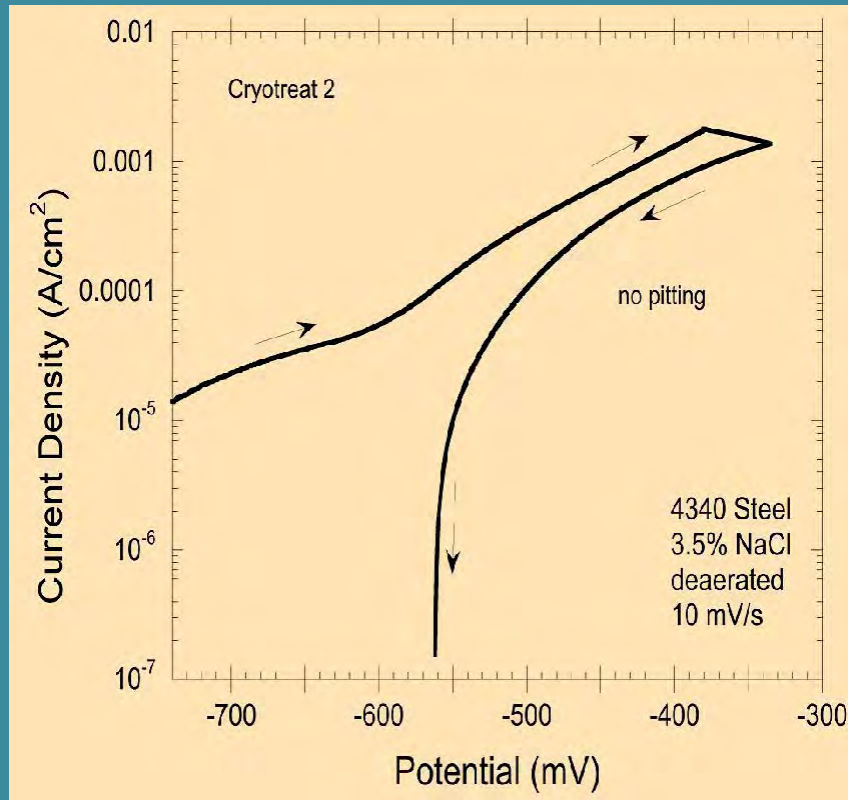
TEST RESULT: 84% REDUCTION IN GENERAL CORROSION (VOLUMETRIC)

4340 STEEL CORROSION TEST #2

Potentiodynamic Test for Pitting Resistance

Corrosion 36 hrs in 3.5% NaCl
3 cryo treated coupon samples

Corrosion 36 hrs in 3.5% NaCl
3 untreated coupon samples



TEST RESULT: 0 PERCENT PITTING DETECTED IN THE DCT COUPONS

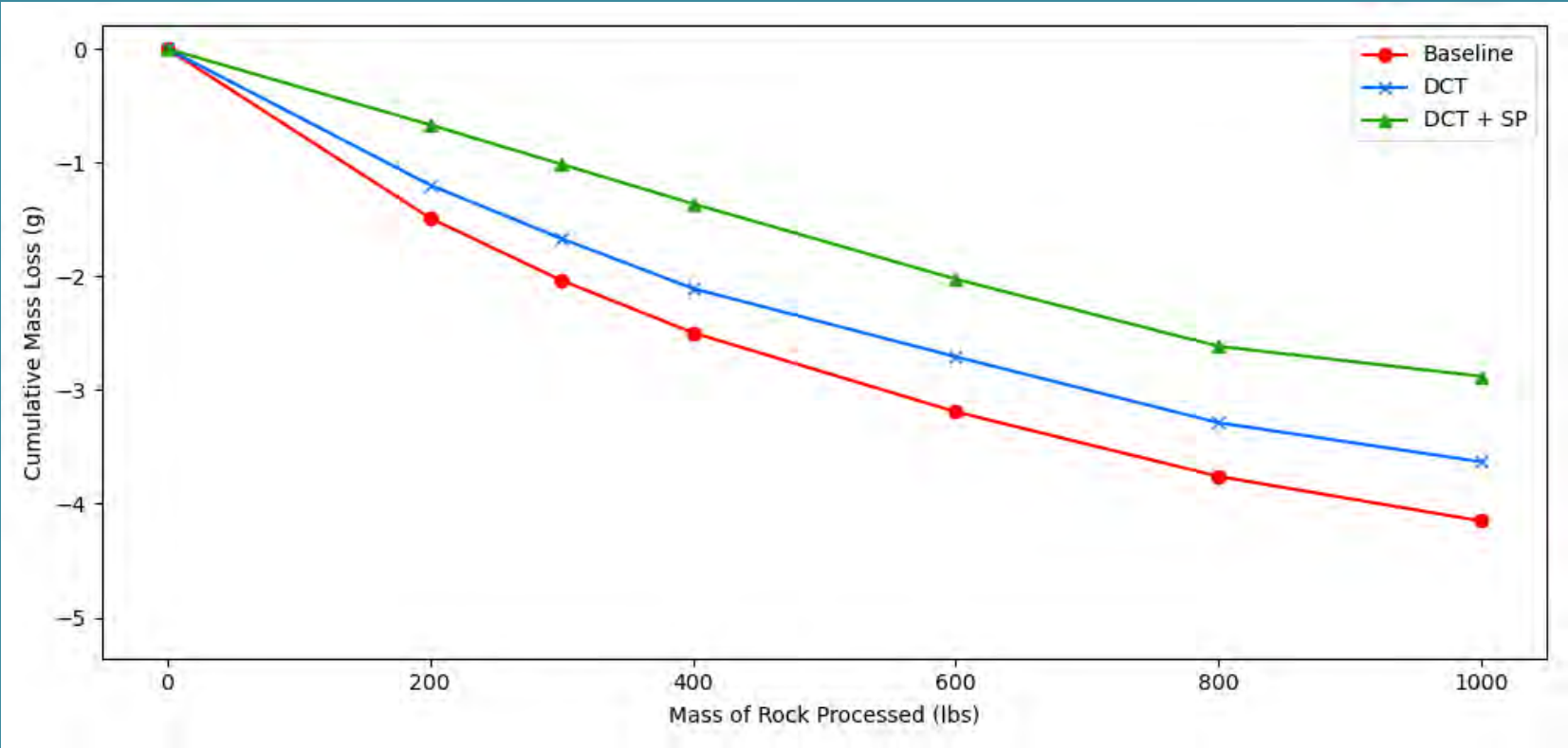
52100 AND 4340 UTS TEST

SUMMARY RESULTS:

	Yield Peak Strength		% Stress.	Strain Elong	Reduction @ Break
	KSI	KSI	%	%	%
No Cryo 52100, Baseline	268	359	2.5	3.9	6
Cryo 52100, Cryo then Tempered	317	382	1.6	3.5	1
Cryo 52100, Tempered then Cryo	320	376	1.8	3.8	4.5
No Cryo 4340, Baseline	221	295	15.3	12.5	51.7
Cryo 4340, Cryo then Tempered	240	300	14.2	11.6	51.3
Cryo 4340, Tempered then Cryo	221	287	15.9	12.3	51.6

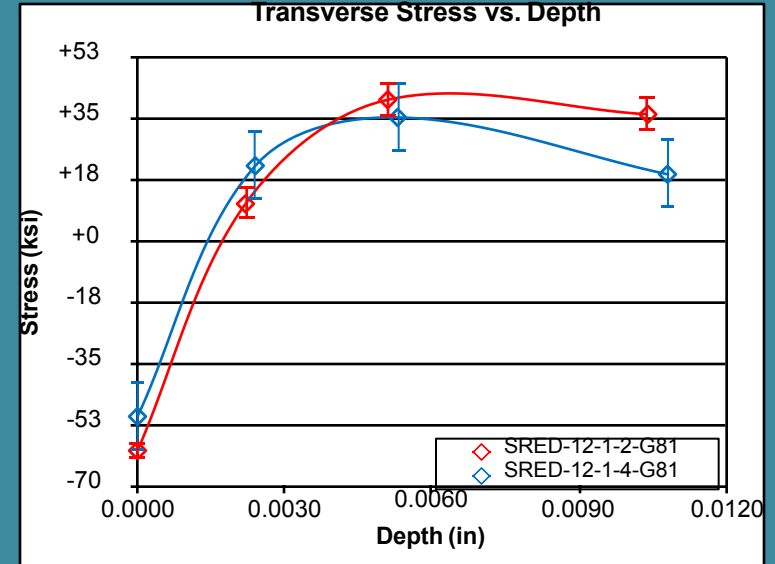
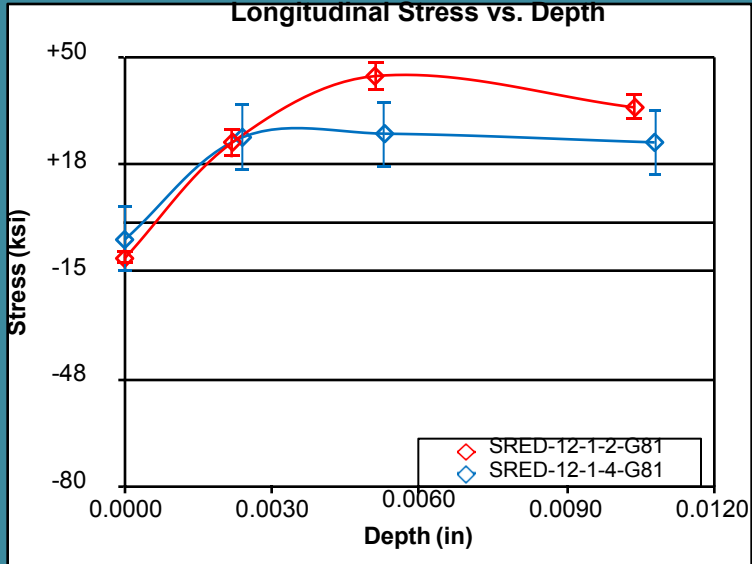
20% improvement to 52100 yield strength
10% improvement to 4340 yield strength

ASTM G81 ABRASIVE WEAR TEST OF MANGANESE



Cone Crusher mantle & liner field test - 1,000 lbs of greenstone granite -13% Mn

2020 XRD RESIDUAL STRESS OF 13% MN

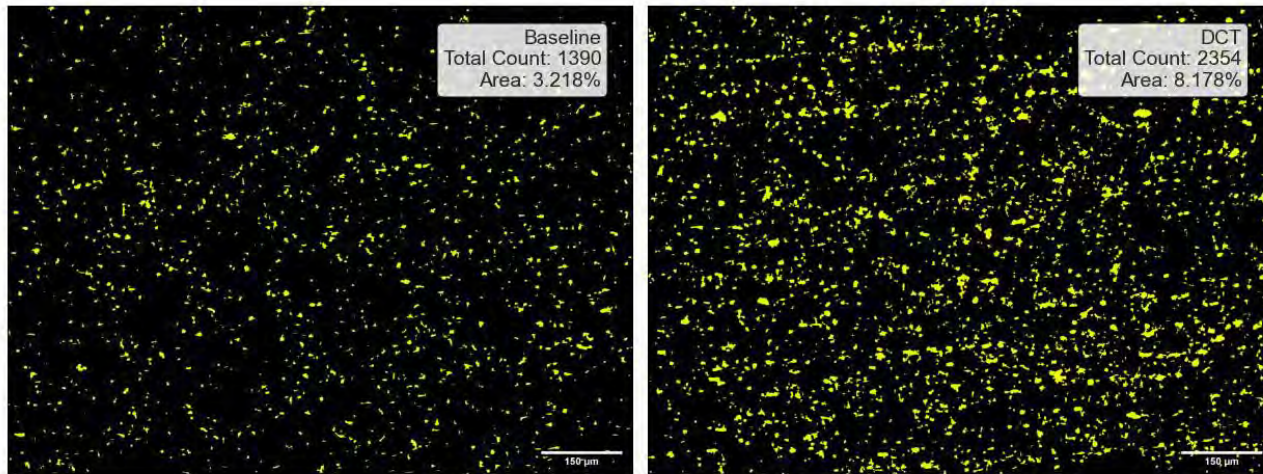


Gradient and Depth Corrected Stress (ksi)	
Baseline	DCT
-11 ± 2	-5 ± 2
+24 ± 4	+26 ± 4
+44 ± 5	+27 ± 5
+35 ± 5	+24 ± 4

Gradient and Depth Corrected Stress (ksi)	
Baseline	DCT
-60 ± 2	-50 ± 2
+11 ± 4	+21 ± 5
+40 ± 5	+35 ± 5
+36 ± 5	+19 ± 5

DCT reduced longitudinal residual stress by 32%
DCT reduced transverse residual stress by 48%

DCT IMPROVEMENT TO MANGANESE TRIP STEEL



Etched micrographs (100x) of carbide precipitation in baseline (left) and after DCT (right)

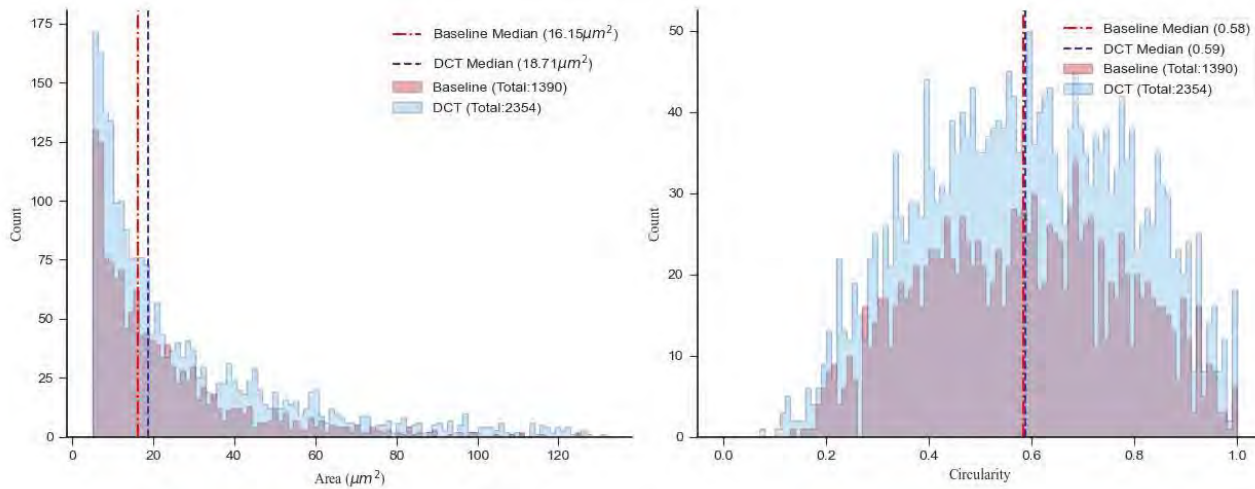
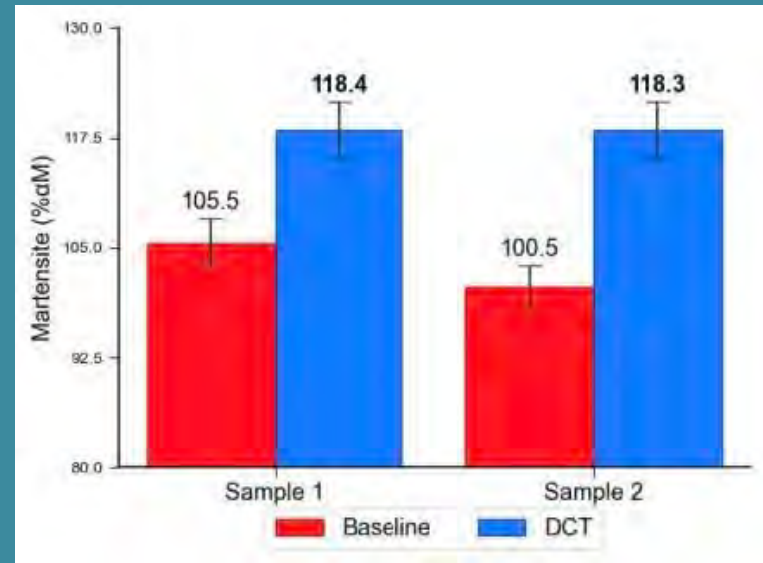
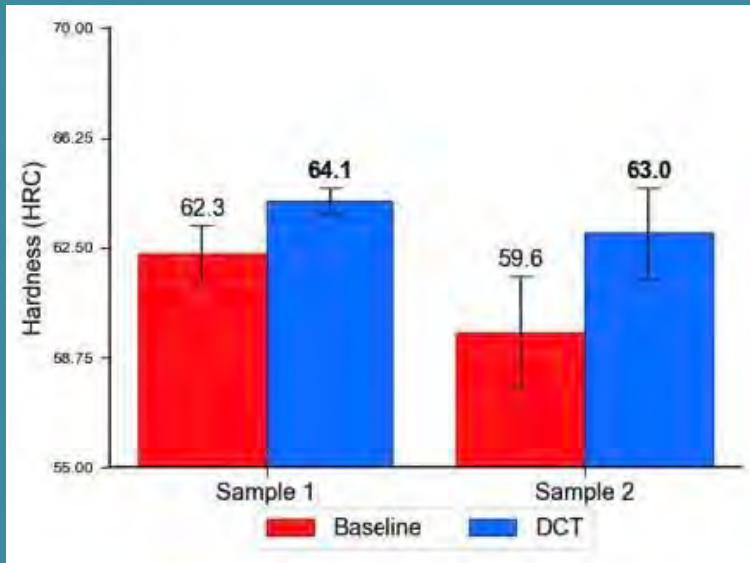


Figure 2: Area (left) and Circularity (right) distributions on both samples

DCT IMPROVEMENT TO SAG MILL BALL WEAR

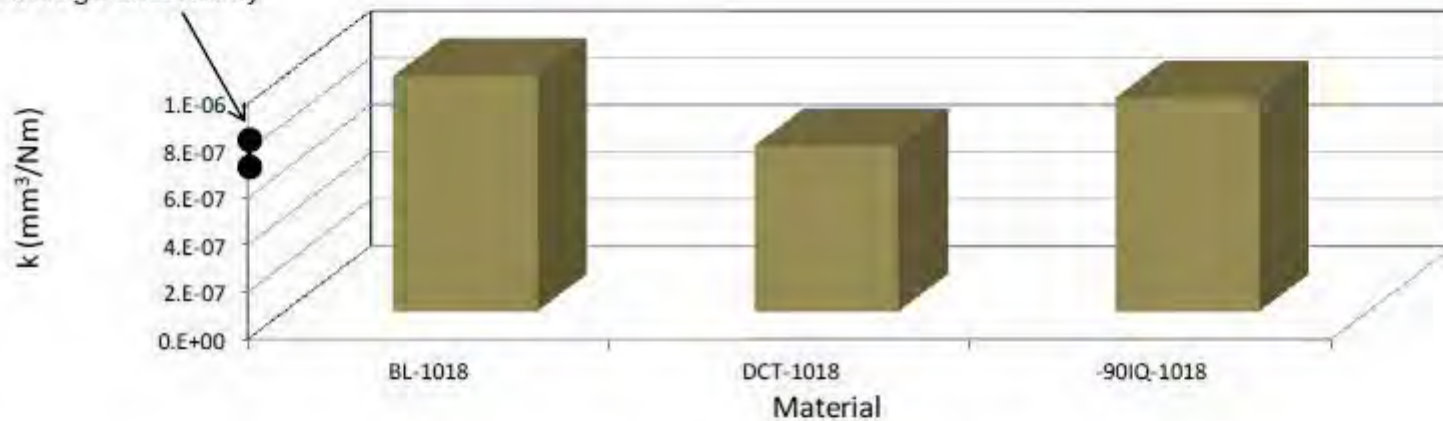


5.5% & 3.0% increase in Rc hardness

12% & 17.5% increase in martensite

- For 1018, the DCT specimens the wear rate is reduced by an average of 30% compared to non-cryo treated specimens, which is well outside the average uncertainty range of $\pm 0.07 \times 10^{-6} \text{ mm}^3/\text{Nm}$.

Average uncertainty



- Similar trends are observed for average wear depth as expected.

Average uncertainty



TECHNOLOGY STEP CHANGE

CURRENT: Heat treat only

- \$90 billion int'l market
- 10-30% improvement
- 14,000 shops worldwide



FUTURE: Heat treat + *DCT*

- \$120 billion int'l market
- 20-70% improvement
- 20 DCT shops worldwide



DCI CAPACITY



Current - 7 cu foot R&D/Prototype tank
22" x 33" - 1,500 lb small volume
Location: Lunenburg, Nova Scotia

Current - 42 cu foot Production tank
40" x 63" - 4,000 lb large volume
Location: North Bay, Ontario



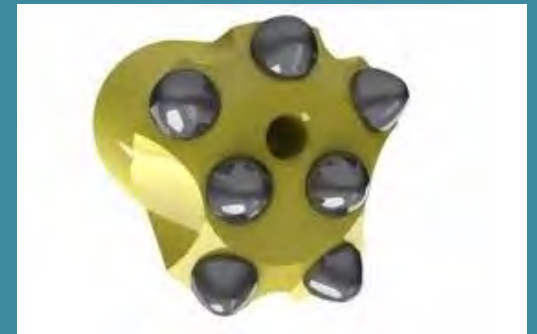
October 2021 - 1,280 cubic feet
8' x 8' x 20' - 30,000 lb capacity
Largest tank in the world
Location: TBA; available for lease

DCI CUSTOMERS AND APPLICATIONS



TARGET MINING PROJECTS

- Paste pump seal plates
- Sag/mill balls
- Rock drills
- Crusher cones/liners/mantles
- Mill liners



TEST METHODS AT DCI



Electrical
Conductivity



Ferrite/welds



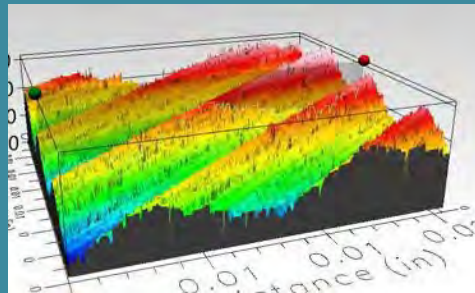
Hardness Testing



Thermal Imaging



Chem - Phys Analysis



Surface finish



Abrasion & Wear



Metallurgical analysis

DCI HISTORY AND IP

- Founded in 2010; Canadian incorporation 2019
- Recommendations; MIT, Rolls Royce, US Army, NIST
- 1 USPTO patent, 4 pending; certifications and trademark



Jack Cahn
President



Linda Williams
Vice President



Dr. Rob Stephens
Advisor



Alistair Ross
Advisor

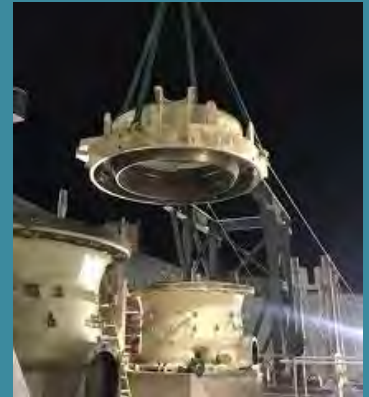


Dr. Hani Henein
Advisor

DEEP CRYOGENICS INTERNATIONAL

Making Things Last Longer ®

- Environment - Lower carbon footprint and use of diesel
- Safety - Reduce risk to miners by extending part life
- Production - Reduce downtime, increase output
- Revenue - Lower annual consumables cost





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