10. APPENDICES

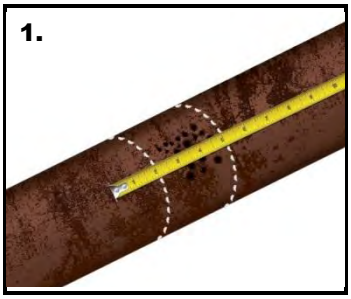
A. Syntho Glass XT Installation Guide
B. Automated control of test setup
C. Material properties used in FEA
D. Syntho Glass XT ASME-PCC2 Article 4.1 & 4.2 Test Requirement Overview
E. Strain development OF1
F. Strain development OF3, trial cycles
G. Strain development OF3
H. Strain development OF4

SYNTHO-GLASS® XT
INSTALLATION GUIDE

For ideal shelf life, store products in a cool, shaded area at ambient temperature: 72°F (23°C). Do not expose materials to temperatures above 110°F (44°C) or below 40°F (5°C).
Do not open bag containing Syntho-Glass XT until you are ready to use it, as XT cures when exposed to water or humidity. Care must be taken when handling the sealed bags to prevent puncturing or scuffing. If the protective foil pouch is punctured, the composite wrap will cure within the sealed foil pouch.

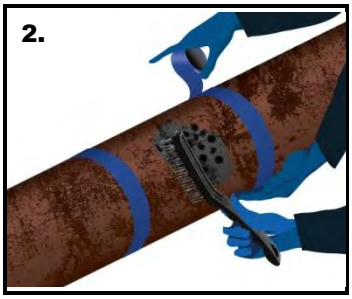
Procedures to be taken in handling and storage.

1.



Measure the total repair length using NRI's engineered calculations. Extend length by 1" (2.54cm) each end, and center repair on defect.

2.



Mark edges of repair area using masking tape. Remove pipe coating, rust, paint and other foreign matter.

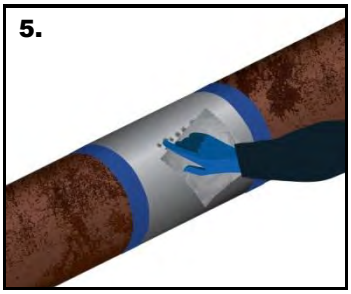
3.

Remove all dirt, grease and oil from pipe surface in accordance with SSPC-SP1 "Solvent Cleaning."

4.

Prepare surface in accordance with SSPC-SP10 / NACE 2 "Near White Blast Cleaning." Smooth any remaining sharp edges by grinding or filing to reduce stress concentrations.

5.

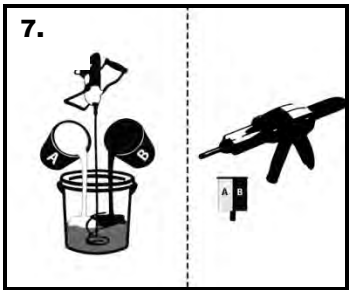


Remove all dirt, grease and oil from pipe surface in accordance with SSPC-SP1 "Solvent Cleaning."

6.

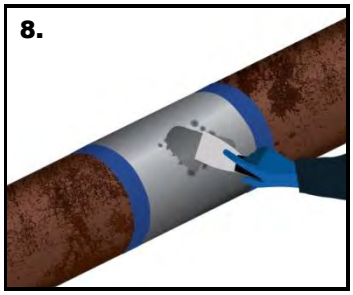
Measure and re-mark edges of repair area using masking tape. Be reminded to extend repair length by 1" (2.54cm) each end for Syntho-Subsea™LV epoxy overlap onto existing mainline coating.

7.



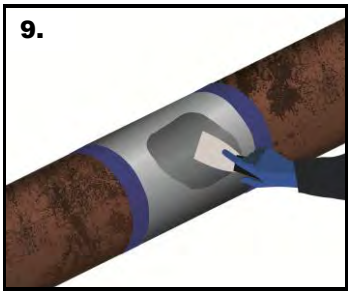
Thoroughly mix Syntho-Poxy™HC, load transfer material, prior to application. A jiffy mixer can be used to mix SPHC cans. Cartridges are mixed using an applicator gun and mixing nozzle(s).

8.



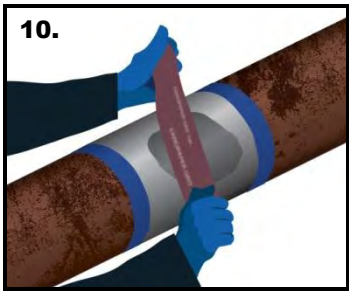
Apply Syntho-Poxy HC into defect(s) using spatula, trowel or putty knife. Work the material into all indentations to assure that no air bubbles remain.

9.



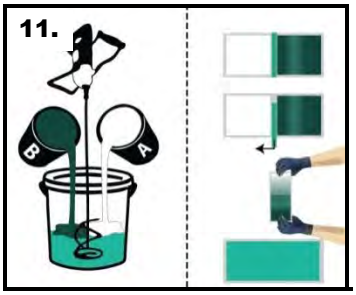
Feather edges of Syntho-Poxy HC to ensure a water-tight seal.

10.



Once the Syntho-Poxy HC has set, it can be sanded it to match the contour of the pipe.

11.



Thoroughly mix Syntho-Subsea LV prior to application. A jiffy mixer can be used to mix LV cans. Manually mix bi-packs within the pouch after removing the divider clip.

SDS and Technical Datasheets available at http://neptuneresearch.com/downloads/ .

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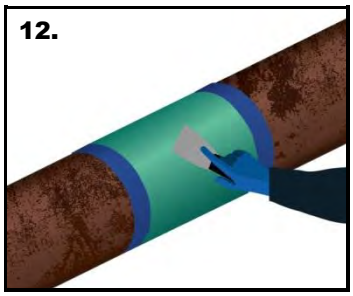
SYNTHO-GLASS® XT
INSTALLATION GUIDE

12.



Apply the mixed Syntho-Subsea LV 360° around the circumference of pipe within the borders of the marked repair area at 30-60mils.

13.

Inspect Syntho-Subsea LV to assure 30-60mil coverage. Confirm that 100% of the pipe surface is coated and that no bare steel remains. Remove masking tape.

14.

Begin Syntho-Glass XT application 1" (2.54cm) inside the borders of Subsea LV, spraying each layer of XT with water as it is applied. Spirally wrap XT using a 50% overlap until you've achieved the # of layers specified by NRI's calculations.

15.

Apply 4 layers of compression film in the same direction the layers of Syntho-Glass XT were applied.

16.

Perforate the compression film.

17.

After initial cure, remove compression film.

18.

Using a Durometer, measure the Shore D of the LV and XT to confirm they've reached full cure before returning the line to service.
Syntho-Subsea LV: 70
Syntho-Glass XT: 70

19a.

Protect the composite repair with a UV coating, such as Syntho-Glass®UV (19a) or Syntho-Coat™ (19b).

19b.

Protect the composite repair with a UV coating, such as Syntho-Coat™ (19b) or Syntho-Glass®UV (19a).

Vertical installations such as offshore risers or jacket legs, XT shall be applied so the last pass is applied upwards, with the wrap terminating at the top of the repair.
Sub-sea and splash zone installations, the last (outer) wrap shall be tied down to ensure the currents will not affect the adhesion of the last layer of fiberglass tape before the resin has reached its initial cure.
Sub-sea installations open bags of XT underwater, at the repair site, after all cleaning is completed and all epoxies have been applied.

Cold weather installations, follow procedures above however, as an additional step, after applying the compression film, use a heating pad over the entire repair area since XT will not cure by itself at temps below 40ºF (5ºC). DO NOT HEAT TO TEMPS ABOVE 150ºF (66ºC)
Hot weather installations, follow procedures above however, use ice water in the sprayer to slow down the curing, thus allowing the installer sufficient working time. Furthermore, store unopened bags of Syntho-Glass XT in an ice chest if possible.

Buried pipeline applications, smart pig detectable marker bands, washers or pipe coupons should be installed at each end of the Syntho-Glass XT repair as per the operators' procedures to identify the repair during future ILI inspections.

SDS and Technical Datasheets available at http://neptuneresearch.com/downloads/ .

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A. AUTOMATED CONTROL OF TEST SETUP

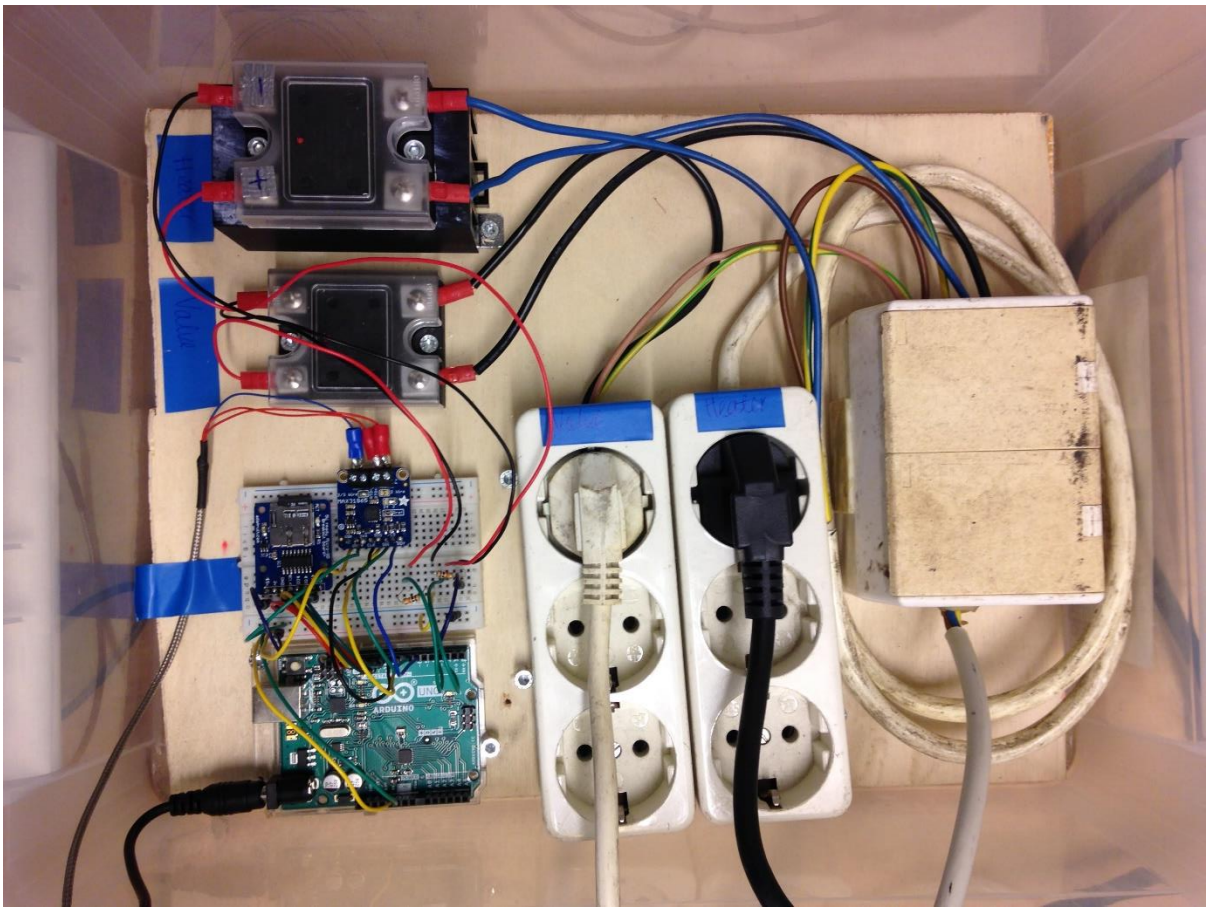
ARDUINO CODE

```
#include <Adafruit_MAX31865.h>
#include <SPI.h>
#include <SD.h>

int valve  = 3;
int heater = 2;
int temp;

unsigned long startMillis;
unsigned long currentMillis;

boolean keepHeating = true;

unsigned long heatDuration = 28800000; //=8 timer i ms
unsigned long coolDuration = 28800000;

unsigned long startHeating;
unsigned long startCooling;

unsigned long prevMillis = 0;

const int chipSelect = 10;

Adafruit_MAX31865 max = Adafruit_MAX31865(6, 7, 8, 9);

#define RREF      430.0     //The value of the Rref resistor
#define RNOMINAL  100.0     //The 'nominal' 0-degrees-C resistance
of the sensor

void setup() {
  Serial.begin(115200);
  pinMode(valve, OUTPUT);
  pinMode(heater, OUTPUT);
  startMillis = millis();
  startHeating = millis();
  max.begin(MAX31865_3WIRE);

  Serial.print("Initializing SD card...");
  // see if the card is present and can be initialized:
  if (!SD.begin(chipSelect)) {
    Serial.println("Card failed, or not present");
    // don't do anything more:
    while (1);
  }
  Serial.println("card initialized.");

}

void loop()
{
    currentMillis=millis();
```

```
    if (currentMillis - prevMillis >= 60000)
    {
        if (keepHeating == true)
        {
            if (currentMillis - startHeating > heatDuration)
            {
                keepHeating = false;
                digitalWrite(heater, LOW);
                startCooling = currentMillis;
                }
            else
            {
              temp = max.temperature(RNOMINAL, RREF);
              if (temp < 90)
              {
                    digitalWrite(heater, HIGH);
              }
              else
              {
                  digitalWrite(heater, LOW);
              }
            }
        }
        else
        {
            if (currentMillis - startCooling > coolDuration)
            {
                keepHeating = true;
                digitalWrite(valve, LOW);
                startHeating = currentMillis;
            }
            else
            {
                digitalWrite(valve, HIGH);
            }
        }
        simplePrint();
        prevMillis = currentMillis;
    }
}

void simplePrint()
{
  uint16_t rtd = max.readRTD();
  //Serial.print("RTD value: "); Serial.println(rtd);
  float ratio = rtd;
  ratio /= 32768;
  //Serial.print("Ratio = "); Serial.println(ratio, 8);
  //Serial.print("Resistance = "); Serial.println(RREF * ratio, 8);
  Serial.print("Temperature = ");
Serial.println(max.temperature(RNOMINAL, RREF));
  temp = max.temperature(RNOMINAL, RREF);
  Serial.print("Time = "); Serial.println(currentMillis / 1000);
  Serial.print("Heater = "); Serial.println(digitalRead(2));
  Serial.print("Cooler = "); Serial.println(digitalRead(3));
  Serial.println(" ");
```

```
  File dataFile = SD.open("datalog.txt", FILE_WRITE);

  if (dataFile) {
    dataFile.print("Temperature = ");
dataFile.println(max.temperature(RNOMINAL, RREF));
    dataFile.print("Time = "); dataFile.println(currentMillis /
1000);
    dataFile.print("Heater = "); dataFile.println(digitalRead(2));
    dataFile.print("Cooler = "); dataFile.println(digitalRead(3));
    dataFile.println(" ");
    dataFile.close();
  }
  else {
    Serial.println("error opening datalog.txt");
  }

  uint8_t fault = max.readFault();
  if (fault)
  {
    Serial.print("Fault 0x"); Serial.println(fault, HEX);
    if (fault & MAX31865_FAULT_HIGHTHRESH) {
      Serial.println("RTD High Threshold");
    }
    if (fault & MAX31865_FAULT_LOWTHRESH) {
      Serial.println("RTD Low Threshold");
    }
    if (fault & MAX31865_FAULT_REFINLOW) {
      Serial.println("REFIN- > 0.85 x Bias");
    }
    if (fault & MAX31865_FAULT_REFINHIGH) {
      Serial.println("REFIN- < 0.85 x Bias - FORCE- open");
    }
    if (fault & MAX31865_FAULT_RTDINLOW) {
      Serial.println("RTDIN- < 0.85 x Bias - FORCE- open");
    }
    if (fault & MAX31865_FAULT_OVUV) {
      Serial.println("Under/Over voltage");
    }
    max.clearFault();
  }
}
```

AUTOMATED CONTROL



C. MATERIAL PROPERTIES USED IN FEA

Model Dimensions	
D_{outer}	254 mm
t_{steel}	7.4 mm
t_{repair}	1.8 mm
l_{steel}	330 mm
l_{repair}	280 mm

Material Properties	
E_1	24 877 MPa
E_2	13 499 MPa
ν_{12}	0.1326
G_{12}	1 827 MPa
E_m[1]	3 550 MPa
α_{11}	1.165E-05
α_{22}	5.22E-05

Assumptions	
E_3	E_m
ν_m	0.4
$\nu_{13} = \nu_{23}$	ν_m
V_f	0.65
$G_{13} = G_{23}$	G_m
α_{33}	1.00E-04

$$G_m = \frac{E_m}{2(1+\nu_m)} = \frac{3550}{2(1+0.4)} = 1268\ MPa$$

[1] Brinson, H. F., & Brinson, L. C. (2015). Characteristics, Applications and Properties of Polymers. In Polymer Engineering Science and Viscoelasticity: An Introduction (pp. 57-100). Boston, MA: Springer US.

SYNTHO-GLASS® XT

ASME-PCC2 ARTICLE 4.1 & 4.2
TEST REQUIREMENT OVERVIEW

Property	Test Methods	Test Type	Results
Per Ply Thickness	Determined from the tensile tests ASTM 3039	Mandatory	0.013" (.33mm)
Tensile Modulus Circumferential 0 Degree	ISO 527-1, ISO 527-2, or ASTM D 3039	Mandatory	3595.23 ksi
Tensile Strain to Failure Circumferential 0 Degree	ISO 527-1, ISO 527-2, or ASTM D 3039	Mandatory	1.50%
Tensile Strength Circumferential 0 Degree	ISO 527-1, ISO 527-2, or ASTM D 3039	Mandatory	54,806.6 psi (3,744.26 bar)
Tensile Modulus Axial 90 Degree	ISO 527-1, ISO 527-2, or ASTM D 3039	Mandatory	1957.88 ksi
Tensile Strain to Failure Axial 90 Degree	ISO 527-1, ISO 527-2, or ASTM D 3039	Mandatory	1.61%
Tensile Strength Axial 90 Degree	ISO 527-1, ISO 527-2, or ASTM D 3039	Mandatory	24,117.2 psi (1,662.8 bar)
Poisson's Ratio Circumferential 0 Degree	ISO 527-1, ISO 527-2, or ASTM D 3039	Mandatory	0.1326 (0.1%-0.3%)
Poisson's Ratio Axial 90 Degree	ISO 527-1, ISO 527-2, or ASTM D 3039	Mandatory	0.0687 (0.1%-0.3%)
Bending Modulus Circumferential 0 Degree	ISO 178, ASTM D 790	Mandatory	5406.8 ksi
Bending Modulus Axial 90 Degree	ISO 178, ASTM D 790	Mandatory	3399.3 ksi
Shear Modulus Circumferential 0 Degree	ASTM D 5379	Mandatory	264.92 ksi
Shear Modulus Axial 90 Degree	ASTM D 5379	Mandatory	310.11 ksi
Shore Hardness Circumferential 0 Degree	ISO 868 or En 59 or ASTM D2583 (ASTM D2240-04)	Mandatory	76
Shore Hardness Axial 90 Degree	ISO 868 or En 59 or ASTM D2583 (ASTM D2240-04)	Mandatory	78
Thermal Expansion Coefficient Axial 90 Degree	ISO 11359-2, ASTM E 831	Mandatory	5.22 E-05 mm/mm/C
Thermal Expansion Coefficient Circumferential 0 Degree	ISO 11359-2, ASTM E 831	Mandatory	1.165 E-05 mm/mm/C
HDT	ISO 75, ASTM D648	Mandatory	383.7°F (194.5°C)
Glass Transition Temperature	ASTM E 1640	Mandatory	313°F (156°C)
Lap Shear Adhesion Strength 1000hr Soak @ 190°F (87°C)	ASTM D 5868	Mandatory	Short Term: 1032 psi (71 bar) Long Term: 714 psi (49 bar)
Short-Term Pipe Spool Survival Test Type A Defect Non-Through Wall (Appendix III)	ASTM D 1599 (Stress Engineering PRCI Test)	Mandatory	80% wall loss passed
Long Term Survival Test (Appendix V)	ASTM D 1598	Optional	99.99% Confidence Long-Term Strength
Energy Release Rate for Through-Wall Defect Calculations (Appendix IV)	ASTM D 1599	Optional	0.525 $in.lb/in^2$

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SYNTHO-GLASS® XT

ASME-PCC2 ARTICLE 4.1 & 4.2
TEST REQUIREMENT OVERVIEW

Property	Test Methods	Test Type	Results
Creep and Creep-Rupture Tests at Room Temperature ~13,500 hours or ~1.5 years	See Test Report	Optional	Creep Rupture 36.7 ksi Avg
Creep and Creep-Rupture Tests at 160°F (71°C), ~13,500 hours or ~1.5 years	See Test Report	Optional	Creep Rupture 27 ksi Avg
Impact Performance	ASTM G14 Modified, ASTM D 1599	Optional	0.524 in.lb/in^2
Cathodic Disbondment Test	ASTM G8	Optional	True disbonded area 0.95 in2
Long Term Pressure Cycle Testing	See Test Report	Optional	>165,000 Pressure Cycles

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