masters of reliability

Rejuvenation Instructions

#341 – Injection Fluids – UPR

This NRI covers the following:

- Understanding the applications of injection fluids for UPR.
- How to calculate fluid volumes using **NRI 301 The Cable Table - UPR**.
- Understanding the best fluid-handling practices for UPR injection fluids.

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WARNING: It is dangerous working around energized high-voltage systems, pressurized systems, and chemicals. Always work in accordance to the Novinium Field Operations Safety Handbook (FOSH) or other local governing safety standards.

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engineering@novinium.com
Revised: September 30, 2015

Novinium, Inc.
22820 Russell Rd Kent, WA 98032
(253) 395-0200

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Types of Fluid

1. Cablecure XL.

Cablecure XL is the primary injection fluid in the UPR process to cure the water tree related problems in small-diameter cables.

a. For cables treated with Cablecure XL, select ‘CC XL – Cablecure XL’ from the ‘Primary’ fluid dropdown found in the ‘Injection’ section of Knomentous.

b. Useful conversion factors for XL fluid are provided in Table 1.

1 lb. fluid	0.131 gallons
1 lb. fluid	2.4 inches of fill (4” feed tank)
1 lb. fluid	4.3 inches of fill (3” feed tank)
1 lb. fluid	0.454 kilograms
1 pail fluid	35 lb.
1 pail fluid	15.9 kilograms
1 vertical ft.	0.42psi

Table 1: Conversion factors for Cablecure XL.

2. Cablecure DMDB.

Cablecure DMDB is the primary injection fluid in the UPR process to cure the water tree related problems in large-diameter cables.

a. For cables treated with Cablecure DMDB, select ‘CC DMDB – Cablecure DMDB’ from the ‘Primary’ fluid dropdown found in the ‘Injection’ section of Knomentous.

b. Useful conversion factors for DMDB fluid are provided in Table 2.

1 lb. fluid	0.143 gallons
1 lb. fluid	2.6 inches of fill (4” feed tank)
1 lb. fluid	4.7 inches of fill (3” feed tank)
1 lb. fluid	0.454 kilograms
1 pail fluid	35 lb.
1 pail fluid	15.9 kilograms
1 vertical ft.	0.36psi

Table 2: Conversion factors for Cablecure DMDB.

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3. Catalyst upgrade packages (CUP).

- The XL-CUP (11840-1) and DMDB-CUP (11842-1) are field-mixable catalyst upgrade packages that increase the performance of the injection fluids and eliminate the need for the soak period in URD cables.
- The CUP contains a patented and highly efficient catalyst that greatly increases the rate of water-reactivity for the injection fluid (Figure 1).

Figure 1: Catalyst upgrade package (CUP).

a. Upon mixing the CUP into XL or DMDB fluid, the fluid is known as Cablecure XLe and Cablecure iDMDB respectively.

- New options have been added to the Knomentous database to document the use of the CUP.

b. Select either Cablecure XLe or Cablecure iDMDB under the ‘Primary’ fluid dropdown inside the ‘Injection’ section of Knomentous (Figure 2).

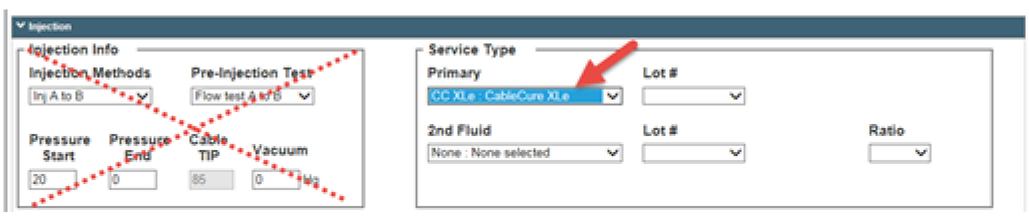

Figure 2: Enter records into Knomentous.

c. After entering the fluid type, select the Lot# found on the original Dow Corning label from the dropdown menu.

d. The timing of the transition to CUP will be managed by Sales and Marketing and be customer-specific.

- The specific timing will be determined by each customer, so crews should wait until directed by their Regional Operations Manager or Area Manager.
- After an agreement is reached with each customer, crews will be directed to start mixing the CUP into their cans of XL or DMDB fluid.

Mixing instructions:

a. Clean the top of the 5 gallon pail to remove dirt.

b. Extend the pour spout, unscrew the cap, and open the quality seal.

c. Pour the contents of the CUP into the pail.

d. Securely fasten the screw cap and compress the spout.

e. Carefully lay the pail on its side on a flat surface.

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f. Rock the pail back and forth for two minutes to mix contents.

g. Affix the red Cablecure XLe or Cablecure iDMDB sticker to the white space on the Dow Corning label signifying that the CUP was added (Figure 3).

h. If not for immediate use, add a nitrogen blanket in the fluid.

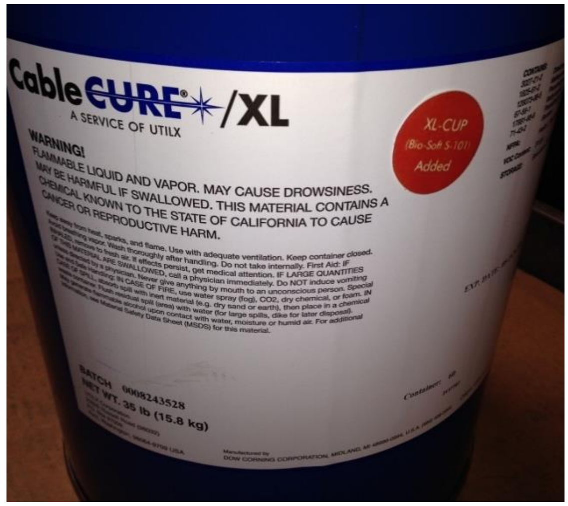

Figure 3: Sticker denoting that the CUP has been added.

Calculating Fluid Volumes

1. Match the cable to the cable table.

a. The cable table for the UPR process is found in **NRI 301** and provides the fluid volumes for all common cable sizes.

Cablecure XL - Small Diameter Cables (URD)

Cable Description		Conductor			Conductor Shield	Insulation		Insulation Shield		Soak	3" Tank (in./1,000ft)			4" Tank (in./1,000ft)			Weight
AWG, Compression	Insulation Rating, %, mils	# of Strands	Diameter	Strand Dia.	Material	Material	Diameter	Material	Diameter	Days	Injection	Soak	Total	Injection	Soak	Total	Total lbs.
#2, Compressed	15kV, 100%, 175mil	7	0.283	0.097	Extruded	XLPE	0.692	Extruded	0.752	60	3.6	20.0	23.6	2.0	11.1	13.1	5.5
#2, Compressed	15kV, 133%, 220mil	7	0.283	0.097	Extruded	XLPE	0.764	Extruded	.864	75	3.6	20.0	23.6	2.0	11.1	13.1	5.5
#2, Compressed	25kV, 100%, 260mil	7	0.283	0.097	Extruded	XLPE	0.844	Extruded	.944	90	3.6	21.8	25.4	2.0	12.1	14.1	5.9
#2, Compressed	35kV, 100%, 345mil	7	0.283	0.097	Extruded	XLPE	1.014	Extruded	1.114	115	3.6	25.6	29.2	2.0	14.2	16.2	6.8
#1, Compressed	15kV, 100%, 175mil	19	0.322	0.066	Extruded	XLPE	0.712	Extruded	0.812	60	15.3	19.3	34.6	8.5	10.7	19.2	8.3

Figure 4: Excerpt from NRI 301 The Cable Table.

b. The cable table is organized by fluid type (XL, DMDB, XLe, or iDMDB) and the application (small or large diameter cables).

c. Under the 'Cable Description' heading, the following subheadings are used to identify a cable.

- **AWG:** Details the conductor size, typically listed as American Wire Gauge (AWG) or thousand-circular mils (kcmil).

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- **Compression:** Identifies the level of strand compression for the cable as compressed, compact and round.
- **Insulation Rating:** Specifies the nominal insulating rating for the cable (15kV, 25kV or 35kV).
- **% Insulation:** Specifies the percent of the insulation thickness for a given cable rating.
- **Mils:** The nominal insulation thickness typically listed in mils (or .001 inch).

d. Under the 'Conductor' heading, the following subheadings detail the conductor.

- **# of Strands:** The number of conductor strands.
- **Diameter:** The measured diameter of the conductor bundle in inches.
- **Strand Dia.:** The measured diameter for a single conductor strand.

e. Under the 'Conductor Shield' heading, the subheading **Material** specifies whether the conductor shield is made of extruded plastic or cloth tape.

f. Under the 'Insulation' heading, the following subheadings detail the cable insulation.

- **Material:** The material of the cable insulation (either XLPE or EPR).
- **Diameter:** The diameter of the cable insulation measured in inches.

g. Under the 'Insulation Shield' heading, the following subheadings detail the cable's shield.

- **Material:** The material of the cable insulation (either extruded or cloth).
- **Diameter:** The diameter of the cable's insulation shield measured in inches.

h. For cables not found in the cable table, it will be necessary to contact Engineering.

i. The 'Soak Days' heading lists the average number of soak days required for the soak fluid to enter the cable.

- This column is not provided on the cable tables where a soak period is not required like XLe.

j. The '3" Feed Tank' heading lists the fluid usage for a given cable in vertical inches per 1,000ft measured in the 3" diameter feed tank.

k. The '4" Feed Tank' heading lists the fluid usage in vertical inches per 1,000ft measured in the 4" diameter feed tank or charge tank.

l. The 'Weight' heading lists the fluid usage in pounds per 1,000ft measured on a scale.

2. Calculations for small diameter cables.

Small diameter cables often require a soak period when treated by the UPR process. The fluid will be calculated in two parts: the total inject volume and the soak volume.

Total Inject Volume:
It is the volume that should be available in the feed tank at the start of the injection and consists of the following:

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- **Interstitial volume:** The volume within the conductor strands calculated by the cable length and the cable table.
- **Safety volume:** The extra volume to accommodate measurement error and the slight inconsistencies in cable construction (typically 0.1 to 0.2 is used). However, this number can be adjusted based on field experience.
- **Equipment volume:** Determined by the equipment used.
- **Splice volume:** Determined by number of splices.
- **Flush volume:** The amount of fluid flushed through the cable.

Soak Volume:

The soak volume is calculated by the cable length and by information contained in the cable table. A worksheet for calculating the fluid volume for small diameter cables is provided below in Table 3.

Interstitial Volume = Cable Table Amount × Footage ÷ 1000	______ Interstitial
Safety Volume = Interstitial Volume × Safety Factor	______ Safety
Equipment Volume: • Add 2” for Charge Tank • Add 0 for all other feed systems	______ Equipment
Splice Volume: • For 3” dia. feed tank, multiply # of splices by 1” • For 4” dia. feed tanks, multiply # of splice by .5” • For pump, multiply # of splices by .2lbs	______ Splice
Flush Volume: • For 3” diameter feed tanks, add 1” • For 4” diameter feed tanks, add .5” • For pump, add.5lbs	______ Flush
TOTAL Inject = Interstitial + Safety + Equipment + Splice + Flush	______ Total Inject
	______
Soak Volume = Cable Table Amount × Footage ÷ 1000	______ Total Soak

Table 3: Calculating fluid volumes for small diameter cables.

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3. Calculations for large diameter cables.

The process is similar but simplified for large-diameter cables. There is no soak volume to consider and using threaded seal kits eliminates the need to consider the additional volume of a splice housing. The fluid will be calculated in one part: the total inject volume.

Total Inject Volume:
It is the volume that should be available in the feed tank at the start of the injection and consists of the following:

- **Interstitial volume:** the volume within the conductor strands calculated by the cable length and by the cable table.
- **Safety volume:** The extra volume to accommodate measurement error and the slight inconsistencies in cable construction (typically 0.1 to 0.2 is used). However, this number can be adjusted based on field experience.
- **Flush volume:** the amount of fluid flushed through the cable.

The process for calculating the fluid volume for large diameter cables is provided below in Table 4.

Interstitial Volume = Cable Table Amount × Footage ÷ 1000	______ Interstitial
Safety Volume = Interstitial Volume × Safety Factor	______ Safety
Flush Volume:	
• For 3” diameter feed tanks, add 2.5”	
• For 4” diameter feed tanks, add .1.3”	
• For pump, add 1.0lbs	______ Flush
TOTAL Inject = Interstitial + Safety + Flush	______ Total Inject

Table 4: Calculating fluid volumes for large diameter cables.

4. Example.

An example fluid calculation is provided on the following page:

- **Cable size:** 1/0awg.
- **Insulation thickness:** 175mils.
- **Shield:** extruded insulation shield.
- **Strands:** 19 conductors.

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- **Circuit length:** 400ft verified by TDR.
- **Splice count:** two at mid-span, tested for flow and pressure.
- **Injection fluid:** XL for small diameter cables.
- **Injection equipment:** 4” diameter feed tank.

Interstitial Volume = Cable Table Amount × Footage ÷ 1000 = 10.5 × 400 ÷ 1000	*4.2”* Interstitial
Safety Volume = Interstitial Volume × Safety Factor = 4.2 × .2	*0.8”* Safety
Equipment Volume: • Add 2” for Charge Tank • Add 0 for all other feed systems	*0”* Equipment
Splice Volume: • For 3” dia. feed tank, multiply # of splices by 1” • For 4” dia. feed tanks, multiply # of splice by .5” = 2 × .5 • For pump, multiply # of splices by .2lbs	*1”* Splice
Flush Volume: • For 3” diameter feed tanks, add 1” • For 4” diameter feed tanks, add .5” • For pump, add.5lbs	*0.5”* Flush
TOTAL Inject = Interstitial + Safety + Equipment + Splice + Flush	*6.5”* Total Inject
Soak Volume = Cable Table Amount × Footage ÷ 1000 = 12.1 × 400 ÷ 1000	*4.8”* Total Soak

Table 5: Example calculation.

Handling Fluids

The UPR process relies on quality craftsmanship, electrical components, fluid delivery systems, and injection fluids to be effective.

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The injection fluid must be clean of physical contamination to flow through and fill the conductor, and it must be clean of chemical contamination to properly diffuse and protect the cable against water-tree related failures. The general process diagram for injection fluids is provided in Figure 4.

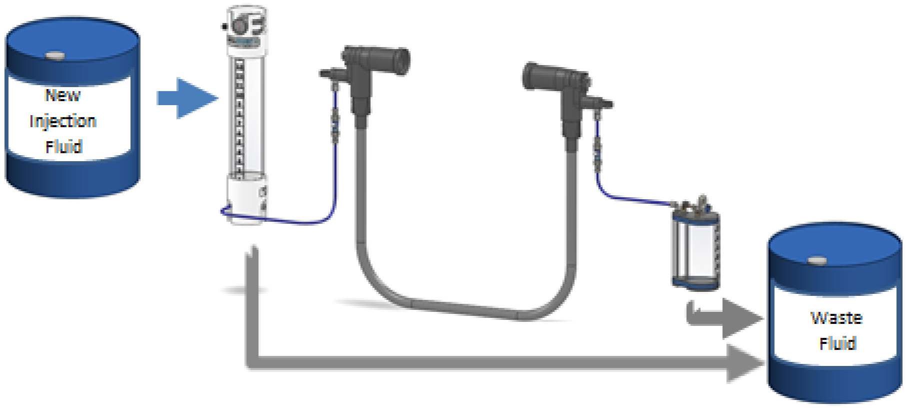

Figure 4: Fluid handling process diagram.

Physical contamination such as dirt particles can be introduced into the injection fluid through a number of poor fluid-handling practices and can affect the long-term reliability of the cable through the following:

- **Blockages** can occur when particles like dirt and grease get introduced into the fluid system. The blockage can occur in either the injection equipment or in the conductor of the cable and can affect the flow rate of fluid moving into the cable during both the initial injection and the soak.

Chemical contamination such as water or other fluids and gasses can occur through a number of poor fluid-handling practices and can alter the chemical properties of the injection fluid. Some key properties that can be altered through contamination and have severe consequences on the long-term reliability of the cable include:

- The **viscosity** of injection fluids can be altered through exposure to moisture and it affects the ability of the fluid to move readily through the cable's conductor strands.
- The **diffusion rate** of Cablecure fluids can be drastically reduced by exposure to moisture and it affects how fast the fluid diffuses into the cable's insulation and reaches the troubled water-tree regions.
- The **water reactivity** of Cablecure fluids can be diminished by exposure to moisture and it affects the ability of the fluid to dry the cable's insulation and semi-conductive shields.

1. Long-term storage.

- **Injection fluid must be stored in the original, sealed and unopened can until needed.** This will limit the exposure of the injection fluid to sources of physical and chemical contamination.
- **Injection fluids should be warehoused or kept in a storage tote until close to the time of use.** Storing injection fluids on the work truck should be kept to a minimum as temperature swings and exposure to the elements can reduce the functional life span of the unopened can.

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- **Injection fluids must only be used prior to their expiration date.** The expiration date is roughly 36 months from the time of manufacturing. It is good practice to make note of the expiration date for each can and arrange them in storage so that the oldest cans are used first.

2. In-use.

- **Opened cans of injection fluids that are used regularly must be sealed with the Dryer Cap Assembly (11416-1).** The dryer cap acts as both a desiccant for removing the atmospheric moisture from the incoming air and a filter to help prevent physical contamination.
- **Opened cans of injection fluid that are used for pumping or that will sit idle for more than one week must be sealed with the manufacturer's cap and a blanket of nitrogen.** Just prior to installing the manufacturer's cap on the opened can, run compressed nitrogen at 10psi and an audible flow rate for the duration provided in Table 6. Nitrogen is a dense gas that will displace the moist atmospheric air within the can and form a blanket of dry gas over the fluid.

Fluid Volume	Duration for Nitrogen
75-100% Full	1 minutes
50-75% Full	2 minutes
25-50% Full	3 minutes
0-25% Full	4 minutes

Table 6: Duration for Nitrogen blanket at 10psi.

- **Use only new injection fluid to treat cables.** New fluid is transferred directly from the new injection-fluid can into the feed tank or measuring cylinder that will be used to treat the cable.
- **Always transfer fluid into feed tanks using a vacuum.** This process removes the dissolved gases from the injection fluid that could otherwise come out of solution in the cable and cause bubbles. See **NRI 411**.
- **Always use a new or clean section of tubing for filling feed tanks, pumping, or injecting cables.** Re-used tubing can be a source of physical and chemical contamination so it is important to ensure that it is clean.
- **Fluid left over in a feed tank after the completing the injection phase may be used in the soak phase or to inject a nearby cable.** The existing fluid volume may be supplemented with new injection fluid to achieve the volume required to treat the cable.

3. Disposal.

- **All discard fluid that is collected on the receiving end of the cable in the discard tank and vacuum tank must be disposed of in the waste-fluid can.** Discard fluid is both physically and chemically contaminated.

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- **Fluid should never be transferred between feed tanks except in instances where feed tanks must be connected in series to treat long spans of cable.** Feed tanks, bladder tanks, and measuring cylinders may become contaminated and it is important to limit the potential for cross contamination.
- **Empty all fluid from feed tanks and measuring cylinders in the waste-fluid can prior to storage or transportation.** This includes all fluid that remains in the feed tank after completing the soak period. Feed tanks are not impervious to moisture or other forms of chemical and physical contamination.

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