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Rejuvenation Instructions Power Cables Sustained Pressure Injection

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- Ultrinium™ sustained pressure injection method (U.S. Patent 7,615,247)
- Ultrinium™ formulation optimization injection method (U.S. Patent 7,611,748)
- Injection Adaptor (U.S. Patents 7,195,504, 7,538,274 and 7,683,260)
- Perfectium™ single visit, single switch injection (U.S. Patent 7,353,601)
- Formulation of Ultrinium™ & Perficio™ components (U.S. Patent 7,658,808, 7,700,871 and other patents pending)
- Predicting performance of Electrical Power cables (U.S. Patent 7,643,977 and 7,848,912)
- N-Rex™ submarine cable injection process (U.S. Patent 7,976,747)
- N-Ter™ injection or Novinium thermally enhanced rejuvenation (patent pending)
- Reticular Flash Preventer (RFP) provides safer operation of conventional injection elbows (patent pending)

Version 20120113

Sustained Pressure Injection

The Ultrinium™ sustained pressure injection process proceeds from an end of a cable subsegment to its other end. A subsegment of cable is a continuous and splice-free piece of cable. A segment of cable is defined as the length of a single cable from termination to termination. If there are no splices the subsegment is the same as the segment. Case 1 subsegments are termination-to-termination.

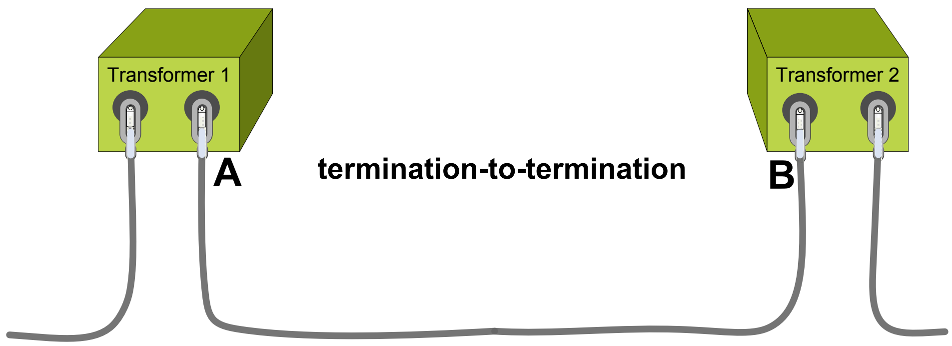


Figure 1. Case 1

If there is one splice location, there are two subsegments. Each subsegment is the length of a single cable from a termination to the splice. Case 2 subsegments are termination-to-splice.

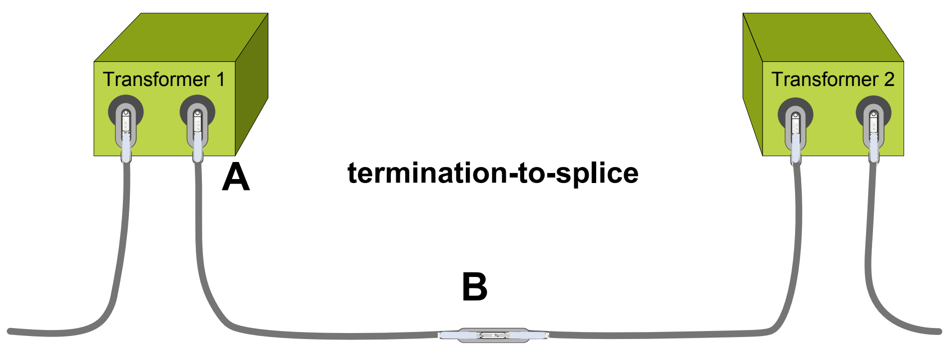


Figure 2. Case 2

If a segment includes more than a single splice location, the segment will contain two termination-to-splice subsegments (Case 2) and a number (the number of splice locations less one) of splice-to-splice subsegments. Case 3 subsegments are splice-to-splice.

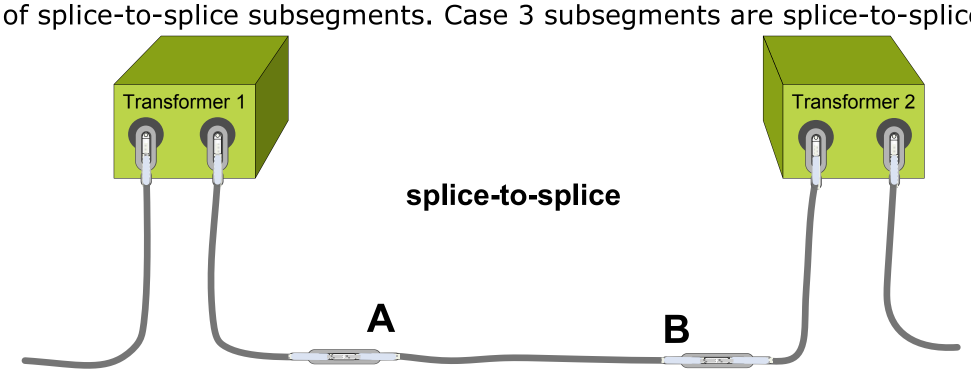


Figure 3. Case 3

The initial choice of the fluid flow direction is designated by the injector as A to B. The injector designation, generally driven by convenience, is arbitrary. The tailored injection overview shows the general Novinium injection process and uses the "A to B" or "B to A" injection directions for each of the three cases described above. Each of the numbered boxes is a step in the injection process, which is described in the correspondingly numbered instructions on subsequent pages.

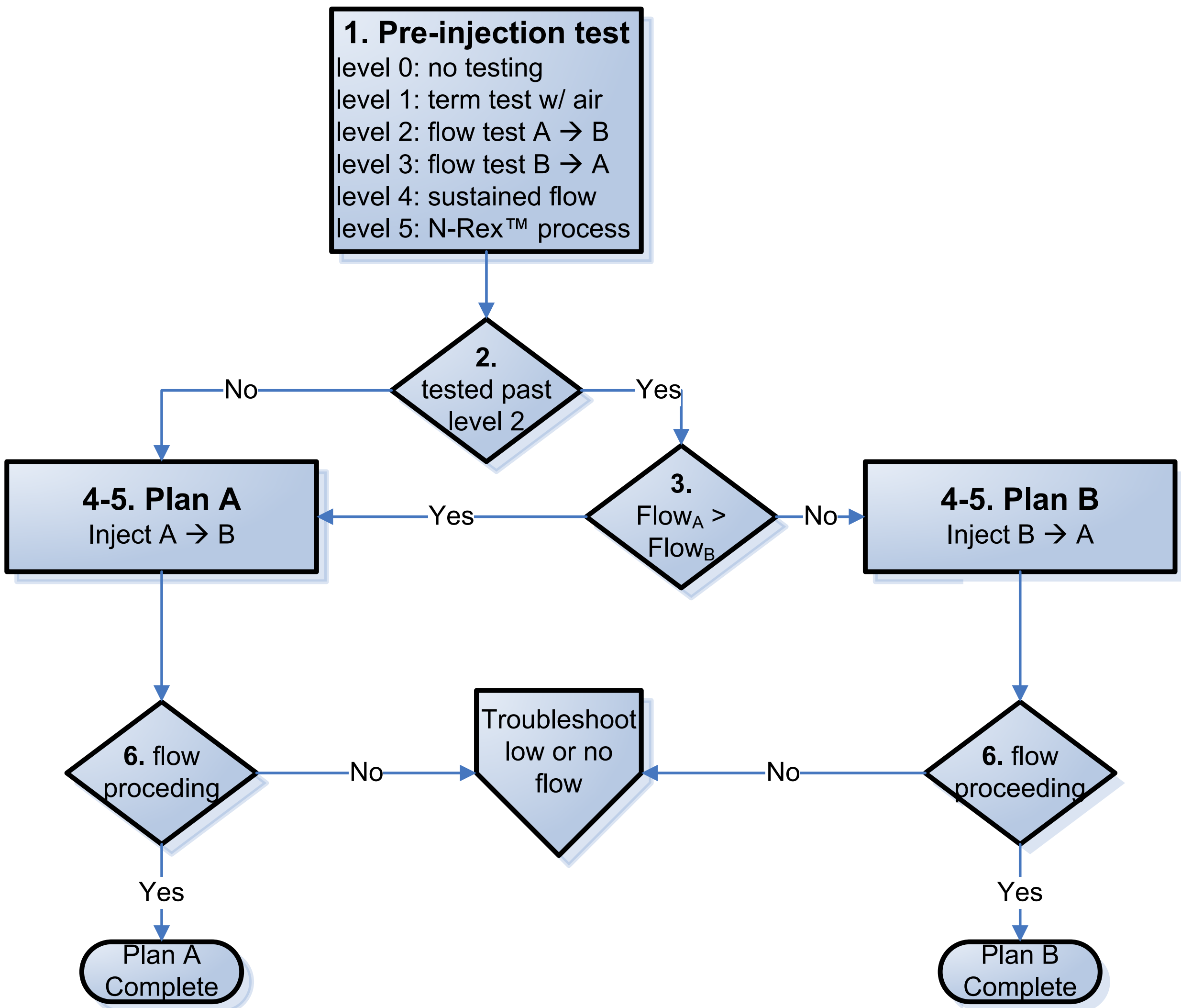


Figure 4. Tailored Injection™ overview

Caution: Working around energized high-voltage systems may cause serious injury or death. The procedures in these instructions should be performed by personnel familiar with good safety practice in handling high-voltage electrical equipment. De-energize, test and ground all electrical systems before proceeding.

1. Inspect and diagnose the cable as instructed in NRI 10 and NRI 12. Select the appropriate components and make any necessary corrections such as use of extended length components, addition of splices and new cable, or, as a last resort, proper sanding of cable insulation.

NRI 10: Visual Inspection & measurement

NRI 12: Electronic Cable Diagnosis & Pinpointing

2. Most cables flow easily and do not require pre-injection testing. Where the cable is extremely long or where there are suspicions that fluid may not readily flow (as illustrated to the right), injection personnel should implement the instructions of NRI-50, "Novinium Rejuvenation Instructions: Power Cable – Flow and Pressure Testing." If a cable shows signs of oxidation, and requires unusual corrective efforts to allow flow, contact engineering.

surface deposits

gunk in the stand interstices

white powder is oxidized aluminum

3. If no pre-injection testing has been performed beyond level 2, skip to step 4. If a level 3 or higher flow test has been performed, inject in the direction in which the cable flows better.

4. Prepare the cable

For Elbows where a standard injection adapter (IA) will be used, follow the steps in NRI 31.

Instructions for use of IAs when a splice is installed are found in NRI 32.

For Live front applications follow the instructions in NRI 34.

Use NRI 69 for Novinium Radial Exclusion (N-REX™) applications using IAs.

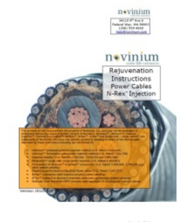
Consult Novinium Engineering at (206) 529-4828 for other applications.

All cable preparation must meet or exceed IEEE® P1816™ requirements.

NRI 31: IA Installation – Dead Front Termination

NRI 32: IA installation – Dead Front Splice

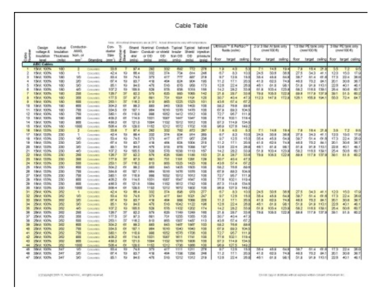
NRI 34: Live Front Termination



NRI 69: Novinium Radial Exclusion (N-REX™)

5. Select the proper type and amount of fluid for the cable which will be injected. Refer to NRI 20 for fluid selection requirements. Use the cable table in NRI 21 to determine the amount of fluid to inject. Note the floor, target, and ceiling amounts. Select appropriate feed and receiver tanks for the fluid amount, and injection situation.

NRI 20: Tailored Formulation™ & Tailored Pressure™

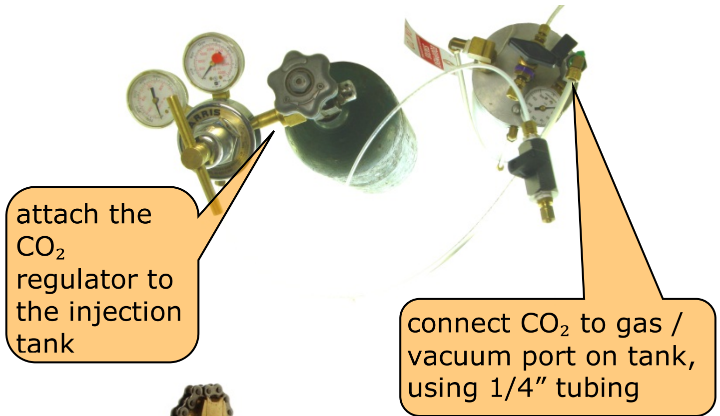

Cable Table

NRI 21: Cable Table

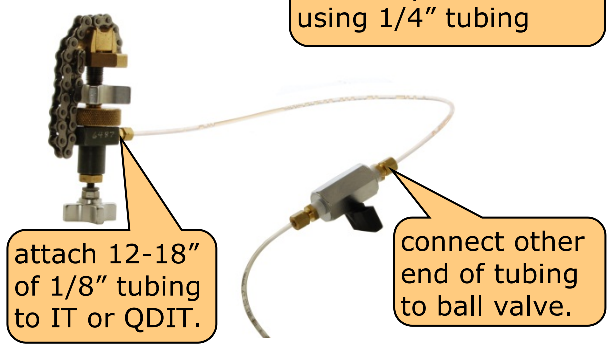
6. Determine the Adjusted Flow Pressure (AFP), and Adjusted Tailored Injection Pressure (ATIP) as instructed in NRI 20. The AFP is the pressure at fluid will be injected through the cable; the ATIP is the pressure which will be left in the cable after injection is complete. Both are effected by the cable construction, as well as factors such as elevation changes, and temperature. Failure to use the proper AFP and ATIP can lead to cable failure.

7. Record the feed tank type, fluid type and feed tank level in NITS.

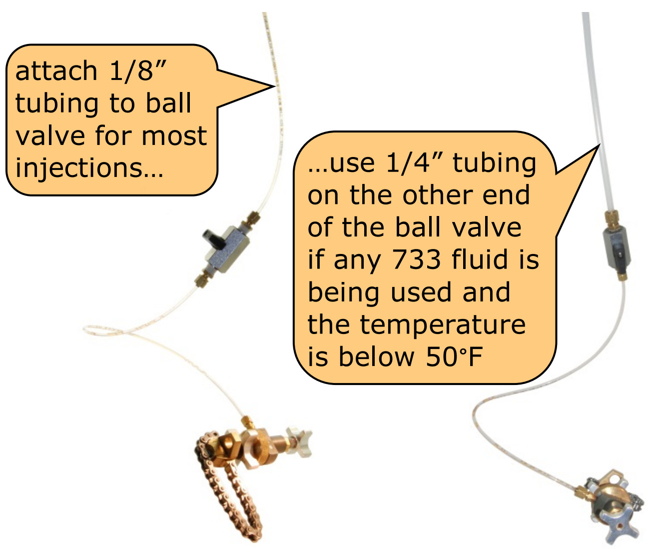
8. Connect the injection hardware and tubing to the feed end of the cable. Use injection tools for Standard IA's or QDIT's live front connections using QDIA's. Connect Tubing and Valves to $C0_2$, injection, and receiver tanks. See NRI 75 for details of tank selection, operation and connections.



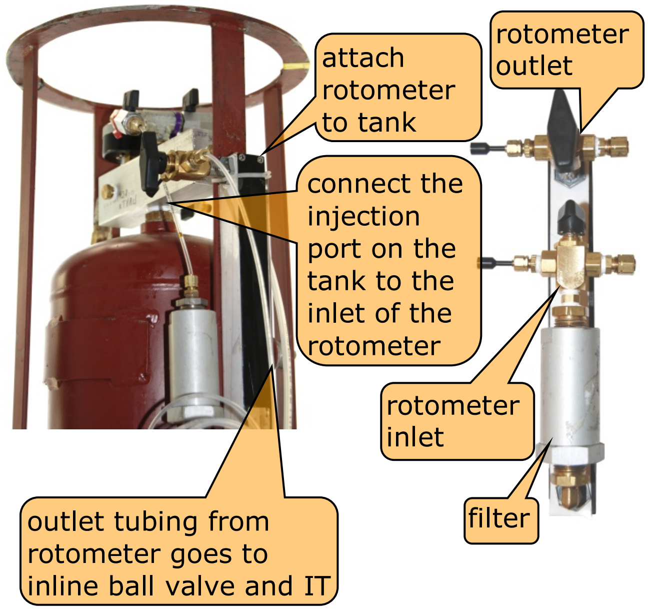
   a. Connect 12-18″ of 1/8″ tubing to the injection tool or QDIT. Attach the other end of the tubing to a ball valve (use 1/8″ X 1/8″ for typical injection or 1/8″ X 1/4″ for long tubing lengths in cold weather, when injecting feeder cables).



   b. Connect to the inline ball valve using 1/8″ tubing for all URD injection (cables smaller than 250mcm), and most feeder injection. If 733 fluid, or an Ultrinium® 733 fluid mixture is being used, and the outside air temperature is below 50°F (10°C), or if the injection calculator shows an improvement in injection time which merits 1/4″ tubing for a faster flow, connect the ball valve using 1/4″ tubing. 733 fluid can thicken severely at low temperatures.

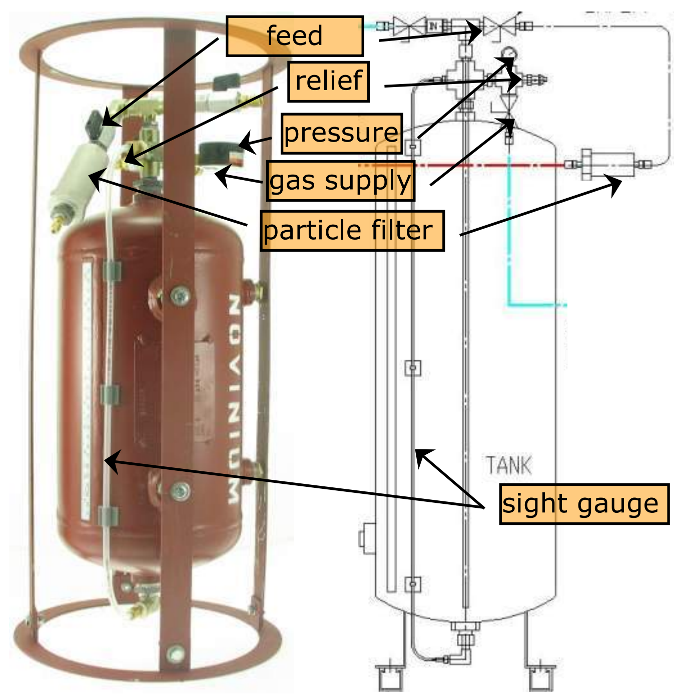


c. Install a rotometer (liquid flow meter): secure the rotometer to the tank, connect the injection port (colored red) on the tank to the inlet port of the rotometer. Connect the 1/8″ or 1/4″ tubing attached to the inline ball valve to the outlet port of the rotometer. See NRI 75 for tank connections and operational details.



use 1/8" connections for 1/8″ tubing or 1/4″ connections for 1/4″ tubing

d. Pressurize the feed tank to the AFP (adjusted flow pressure), as calculated in NRI 20 (plus 10% for attended operations), or the maximum pressure the tank is rated for. Read pressure from the gauge mounted on the tank.



Check tank for any leaks. If any leaks are observed, relieve all pressure immediately and correct.

e. A pressure relief valve assures the hardware is not operated above the design pressure. Do not tamper with the pressure relief valve.

f. Record the fluid meniscus (See Step 11.a) level in mm (millimeters) from the sight gauge.
Open the fluid feed valve. Watch for leaks. **Close the feed valve if any leaks are observed.**

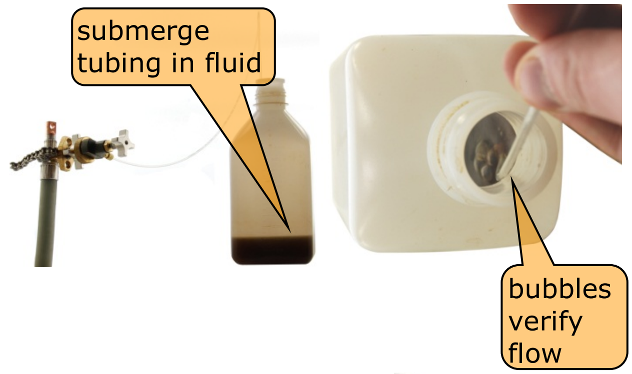
9. On the reciever end of the cable segment or subsegment, install an empty fluid receiving tank or flush bottle connected by 1/8” tubing to an IT/IA or QDIT/QDIA.

    a. Verify flow through the cable by submerging the end of the outlet tubing in fluid left over in a catch bottle from a previous injection. Air flow through the cable will cause bubbles.

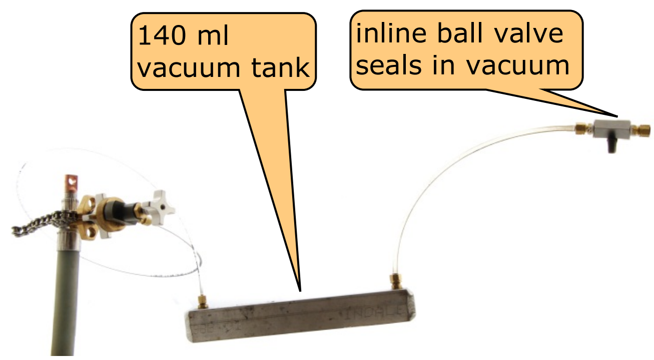
    b. For typical run lengths and monitored injection use a 250 ml liter zero-pressure flush bottle (NPN: O-FH-BTTL-FL0250). If a flush bottle is left unattended, place it in a basin (NPN: O-FH-BASIN) to avoid an accidental spill.

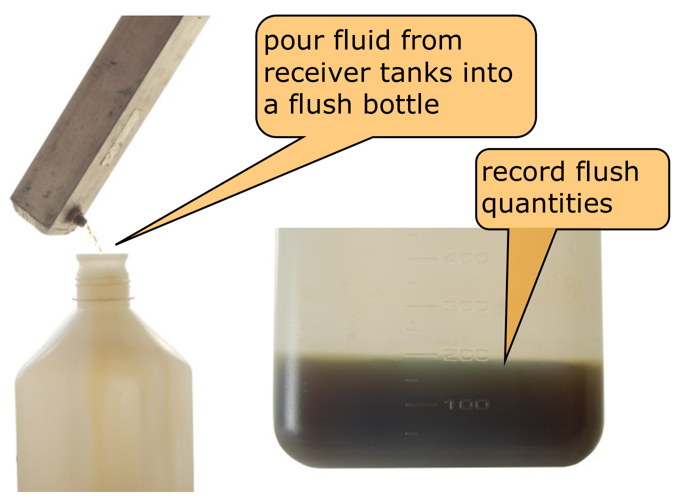
    c. For very long run lengths or for unattended injection, install a vacuum-pressure receiving vessel. The 140ml aluminum pressure / vacuum tank is most commonly used for this application. Periodically vent excess pressure and apply vacuum as desired. Ensure that any vacuum / receiver tank which will be used for injection is empty before being attached to the cable. For continuous vacuum applications contact Novinium Engineering at 206-529-4828.

    d. If there is water in the cable, it may be necessary to empty a vacuum / receiver tank multiple times during injection. To measure the quantity of fluid in a vacuum-pressure receiving vessel, pour the fluid into a flush bottle, and read the graduations from the side. Record all fluid flush; the total flush volume will be recorded in NITS / FDE later.



flush bottle basin

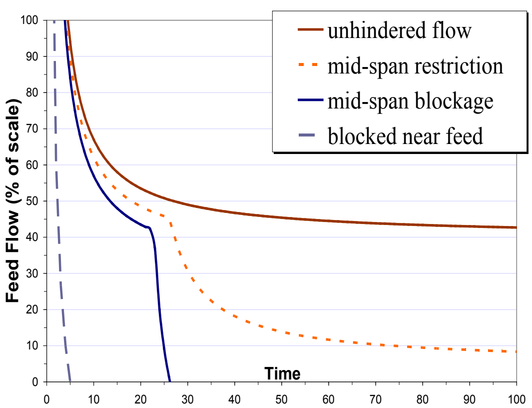




10.

Read the flow rate in cc/min from the liquid rotometer. Use the more sensitive black ball and the right-hand scale if the black ball is not above the scale. If the black ball is above the scale, use the silver ball and the left-hand scale.

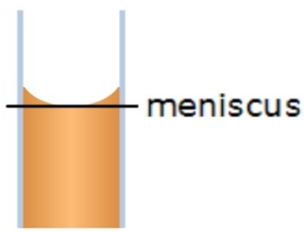
Much can be learned by observation of the flow rate with time. The illustration below shows several common examples:

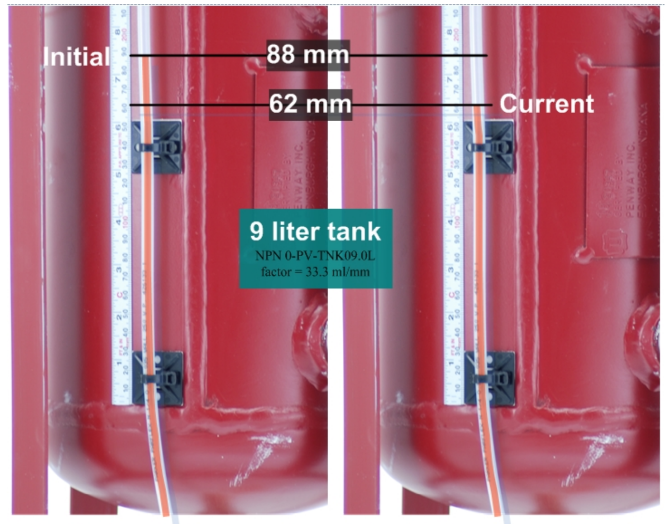


11.

Calculate the ETA (estimated time of arrival) of the fluid at the outlet as follows:

a. Measure and record the fluid level of the tank and the time. Subtract the measured fluid level from the recorded starting fluid level. Multiply the difference in level measurements (mm) by the tank factor (cc/mm) to calculate the volume of fluid injected (cc). Divide the volume of fluid injected by the elapsed time since the injection started to calculate the average fluid flow rate (cc/min). Read the fluid level at the meniscus as shown below.





2 or 3 liter tank	9 liter tank	50 liter tank
0-PV-TNK03.0L & 0-PV-TNK02.0L Factor: 8.33 cc/mm	0-PV-TNK09.0L Factor: 33.3 cc/mm	0-PV-TNK50.0L Factor: 71.4 cc/mm

88mm – 62mm = 26mm x 33.3 cc/mm = 866 cc

866 cc ÷ 180 min = 4.81 cc/min

b. Estimate the remaining fluid requirement for this cable. Starting with the targeted fluid requirement provided in "NRI 21: Cable Table", subtract the fluid supplied so far (step 11a) from the estimate of the fluid required.

Example calculation:

For 328 feet of cable with target$_{u/p}$=12.0 cc/m …

12 cc/m X 328 ft ÷ 3.28 ft/m = 120 cc

If 90 cc had been supplied …

120 cc required – 90 cc supplied ≈ 66 cc remaining

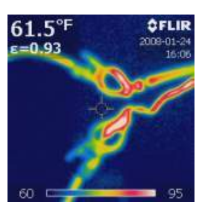
c. Divide the remaining fluid requirement (cc) by the feed flow rate (cc/min) read from the rotometer to estimate remaining injection time. (ETA)

Example calculation:

If corrected flow rate from step 1 is 2 ml/min, time remaining would be approximately …

ETA = 66 cc ÷ 2 cc/min ≈ 33 minutes

d. If the flow rate is too slow or it is likely that the fluid supplied to the cable will fall short of the target, execute NRI-25, Novinium-Thermally Enhanced Rejuvenation.



e. Is the flow proceeding at an acceptable pace?

If yes continue. If no, see NRI-70, "Troubleshooting Cable Flow"

12. Complete the injection

a. Whenever possible configure the injection for unattended operation. See step 9.

b. Flush any contaminants out of the cable. Ensure that the fluid exiting the receiver end of the cable is clear, and free of debris, water, or other visible impurities, and that at least 25cc of clear, clean fluid has exited the cable. Measure the volume of fluid discarded; If there are two fluid phases present record the volume of both phases in NITS. Add all previous flush which was done during the injection to the total.

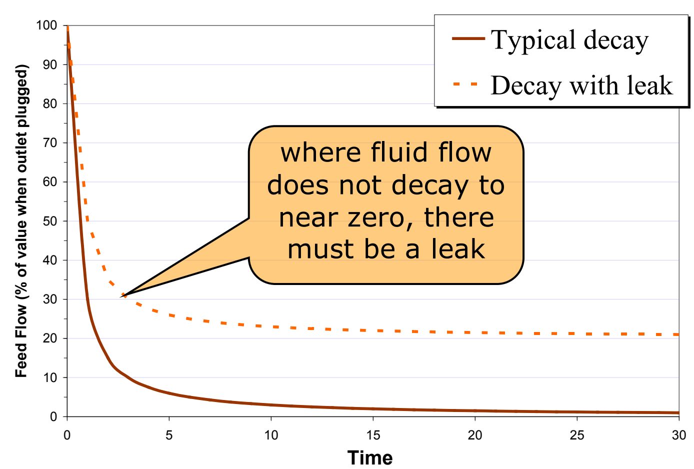
Measure the volume of fluid discard by pouring the contents of this device into a clear, graduated container

Allow at least 25cc of clean fluid flush

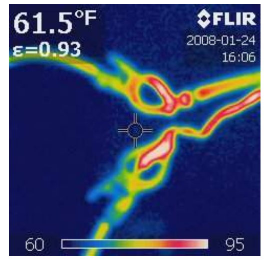
c. Note the inlet fluid feed rate on the inlet rotometer and then install the press pin at the outlet IT as per steps 13-15 of "NRI 40: IT Install & Remove".

d. Reduce the pressure at the inlet end of the cable to the Adjusted Tailored Injection Pressure (ATIP). See NRI 20.

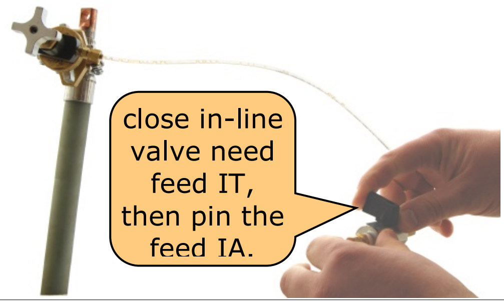
e. After the outlet is pinned, the inlet flow will decay to a very low value. Longer runs take longer to decay. If the flow rate does not decay to a value less than 1 ml/min, there may be a leak somewhere in the system. Look for and repair fluid leaks at both cable ends. If there are no leaks on the cable ends there is either a fault or an undetected splice on the cable. Locate and repair the splice or fault. Re-inject the cable sub-segments.



f. Compare the actual fluid supplied to the cable to the target, floor and ceiling of the NRI-21 Cable Table. Assure that the fluid supplied is near the target and between the floor and ceiling. If not enough fluid has been supplied, execute NRI-25, Novinium-Thermally Enhanced Rejuvenation.

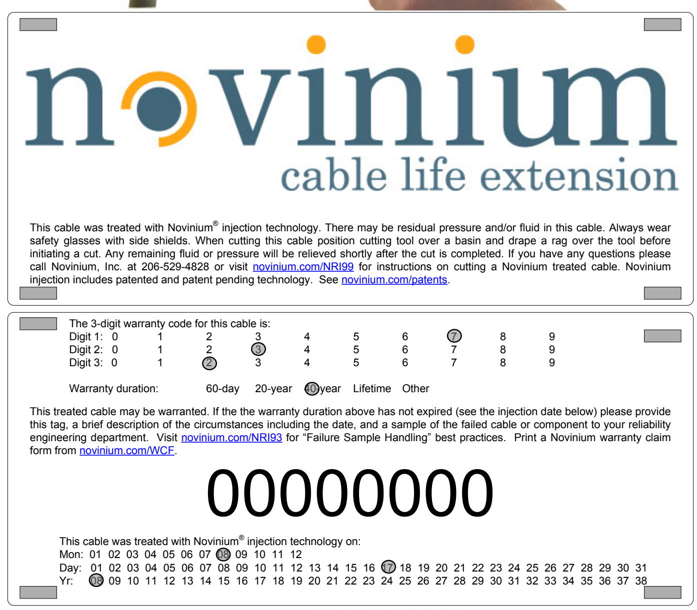


g. Close the inline valve near the inlet injection tool to avoid fluid spray. Install the plug pin at the inlet IT as per steps 13-15 of "NRI 40: IT Install & Remove".



13. Attach a Novinium warranty tag to each end of the cable segment with tie wraps. Use a hole punch to indicate the 3-digit warranty code and the warranty duration from the customer contract. Punch out the injection date near the bottom of the tag. Enter the tag number and injection date in NITS.

   a. For example on segment tag "00000000" to the right, warranty code 732 has been chosen, a warranty duration of 40 years is indicated, and the date was punched to indicate the cable was injected on August 17, 2008.



14. Record the lot number for all fluid and applicable components used in the injection process. Enter the lot number information in the appropriate fields in NITS. See NRI 90: Novinium Injection Tracking System for more information.

   a.