CABLE REJUVENATION AND CABLE CURING

What is cable rejuvenation?

Q: What is cable Rejuvenation?

A: Cable rejuvenation is a method to recover or fix insulation weakness of XLPE cables in the voltage levels between 6 KV to 63 KV

Q: How cables will be rejuvenated?

A: rejuvenation will be done by a chemical reaction and by injecting a chemical material inside the cable conductor.

Q: How long it takes to rejuvenate a cable?

A: It takes maximum 72 hours

Q: What is the maximum length of cable could be rejuvenated?

A: rejuvenation will be done for each 500 meters sections and if cable is longer, then each 500 meters, there should be injection tools to inject the chemical liquid material.

What is the benefit of cable rejuvenation?

Q: What is the benefit of cable Rejuvenation against replacing cables?

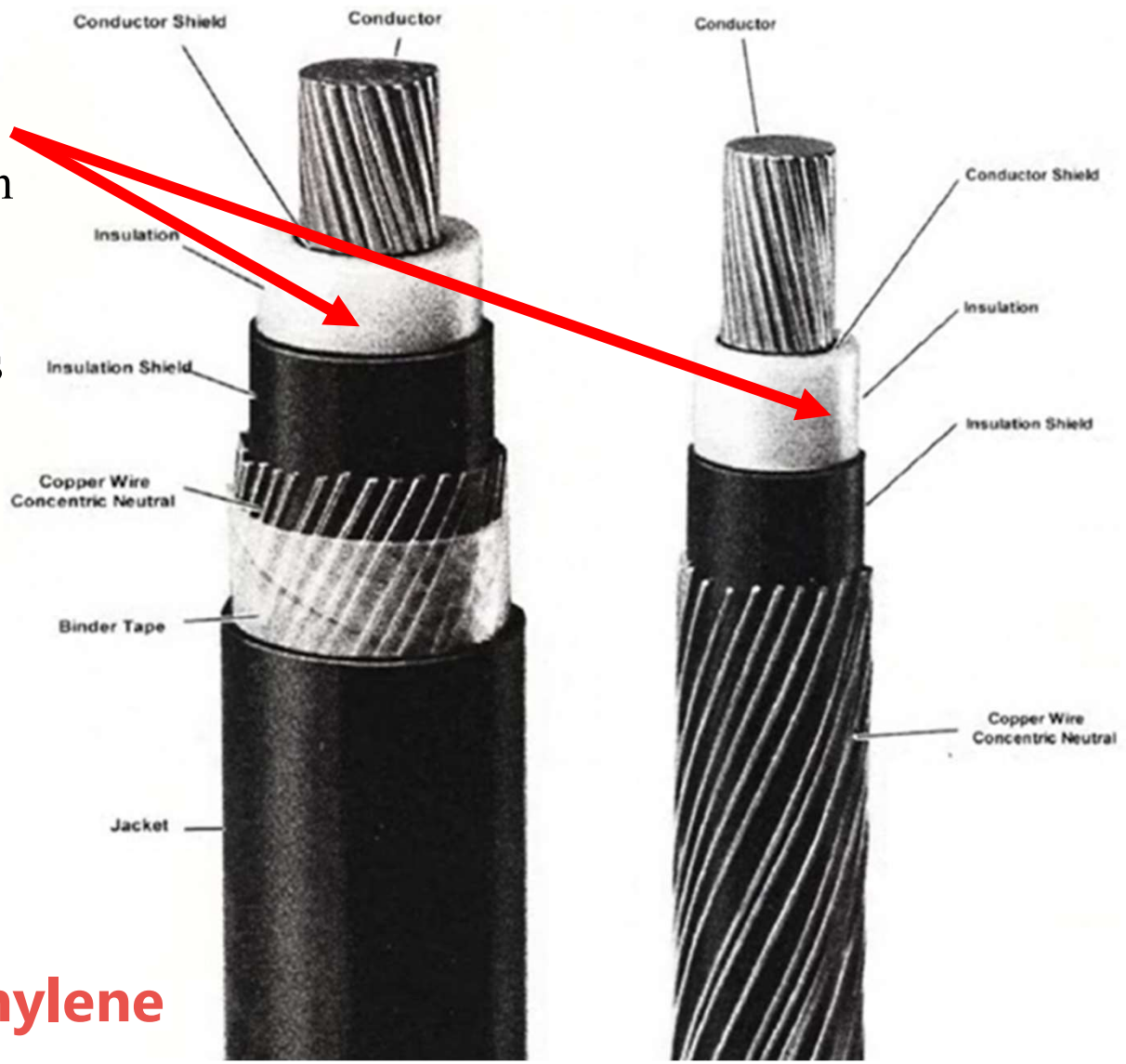
A: the most benefit of cable rejuvenation is cost.

- The costs of rejuvenating one cable is maximum 40 percent of the replacing prices of the same cable.
- Also time is very important, rejuvenation chemical reaction will be done in two steps, first the fast step in the first 72 hours that recover insulation withstand level of old cables up to 90% of insulation withstand level of a brand new cable, and
- second the slow process that recover insulation level till 30 percent better than brand new cables in next 5 years and keep it same in the next 25 years.
- Also by rejuvenating cables, 90% of cables junction issues will be solved

Cable construction details

Insulation thickness of a cable depends on voltage level and level of insulation for each cable.

XLPE Cables normally has insulation level of 15 KV per mm



XLPE:

Cross-linked polyethylene

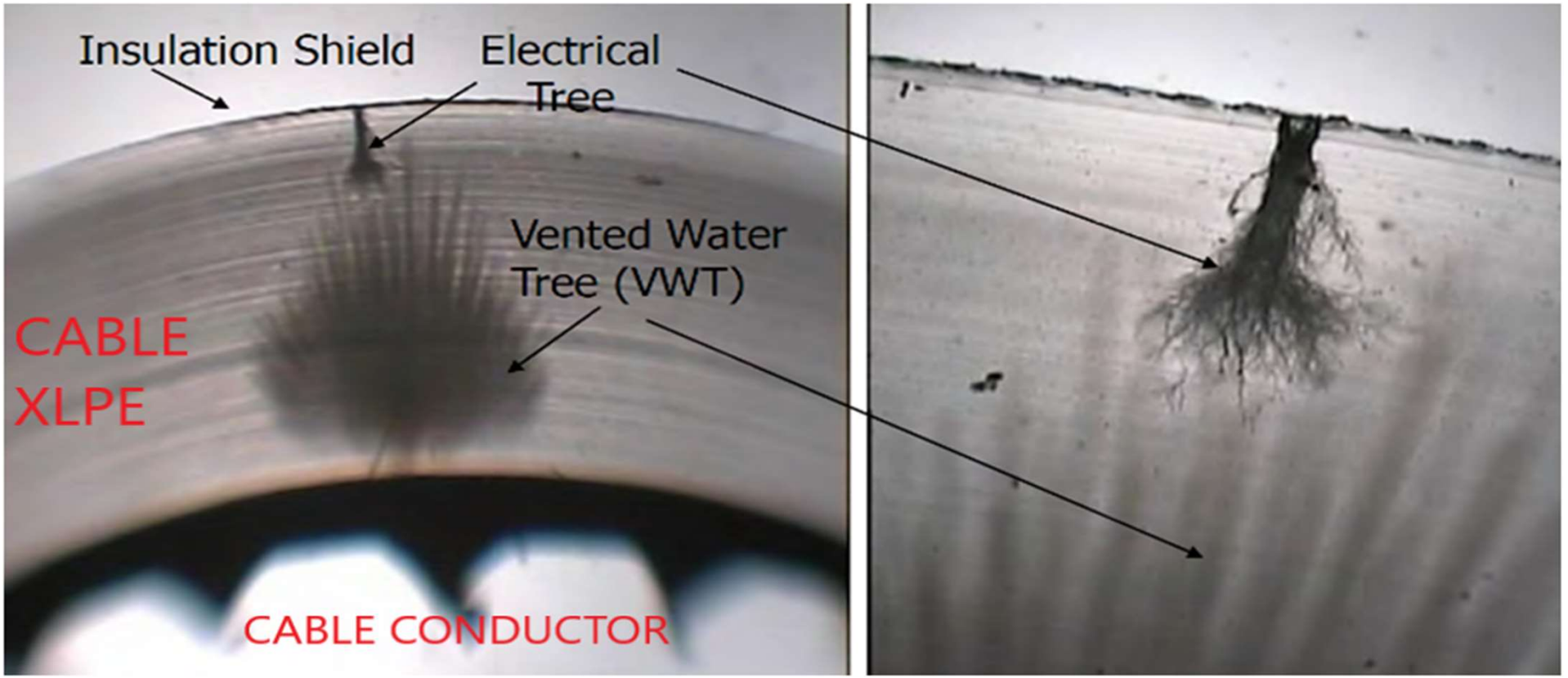
BIL and maximum voltage of cables

Uo (kV)	U (kV)	Um (kV)	BIL (kV)	Insulation Thickness (minimum average)
3.8	6.6	7.2	60	2.5 – 3.2 mm*
6.35	11	12	95	3.4 mm
8.7	15	17.5	120	4.5 mm
12.7	20	24	144	5.5 mm
19	33	36	194	8.0 mm

Insulation levels of cables

Voltage Rating (kV)	Insulation Level (%)	Typical Insulation Thickness	
		mm	mils
5	100	2.29	90
	133	2.92	115
	173	3.56	140
8	100	2.92	115
	133	3.56	140
	173	4.45	175
15	100	4.45	175
	133	5.59	220
	173	6.6	260
25	100	6.6	260
	133	8.13	320
	173	10.67	420
35	100	8.76	345
	133	10.67	420
	173	14.73	580

Defects and issues in the cables



- **Microscope voids inside the cable named “water tree”**
- **A channel consist of integrated water trees has been named “electrical tree”**

Water tree and electrical tree

Water tree: is a defect in the insulation of the extruded cables which can be seen in amorphous and hydrophilic regions of the insulation in the form of water-filled micro voids attached to nanometer-scaled interconnected channels in two different shapes:

1-Bow-tie tree that occurs within the cable insulation

2- vented tree that originates from internal and external semiconductor of cables

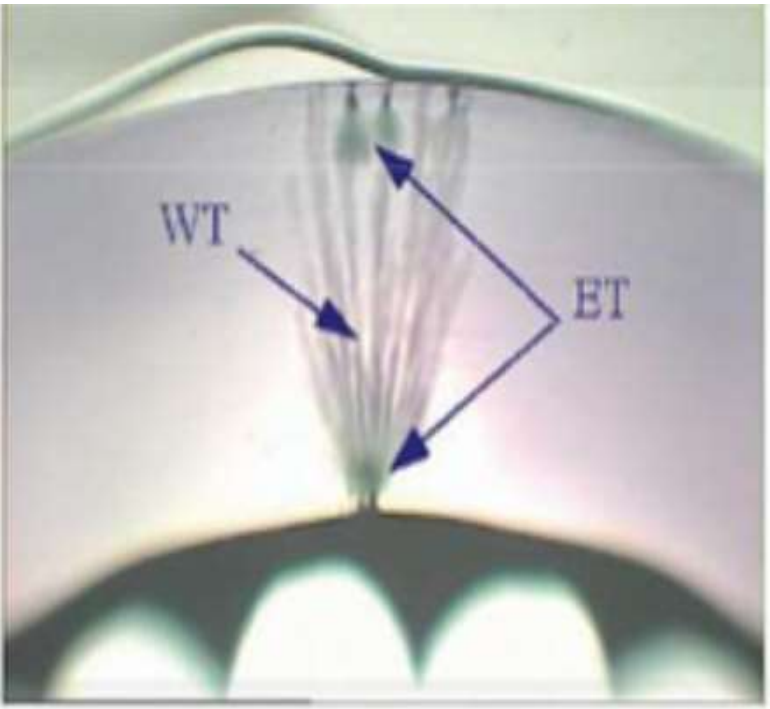
Water tree and electrical tree

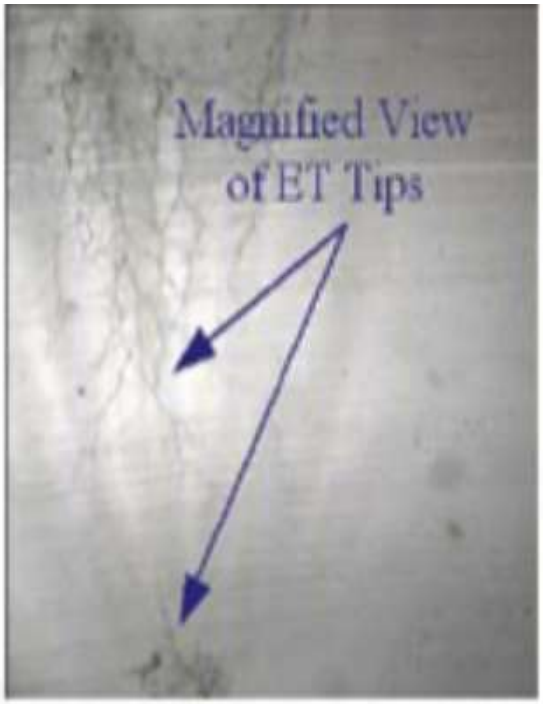
Electrical tree: Electrical tree includes empty voids in a channel format inside the insulation and mostly from conductor to the outer layer of insulation which are considered as the last step of electrical breakdown in cable insulation

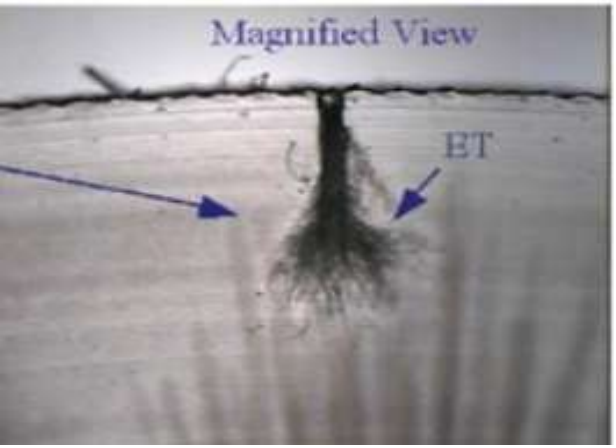
This phenomenon is the result of

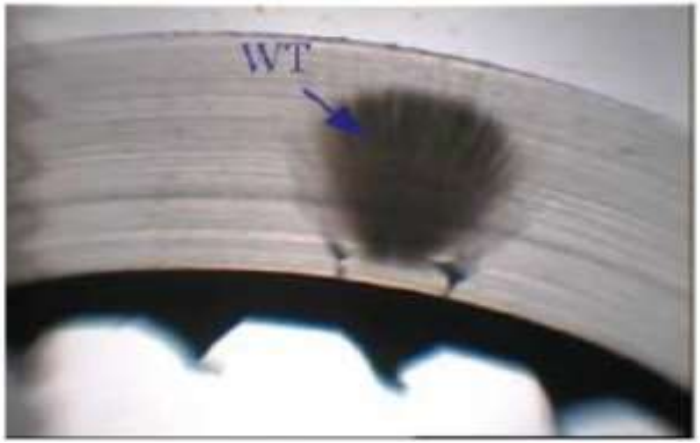
- Surges
- electric impulses
- collision of UV photons to the insulation wall
- extension of hot electrons from water tree growth process
- mechanical-thermal stress

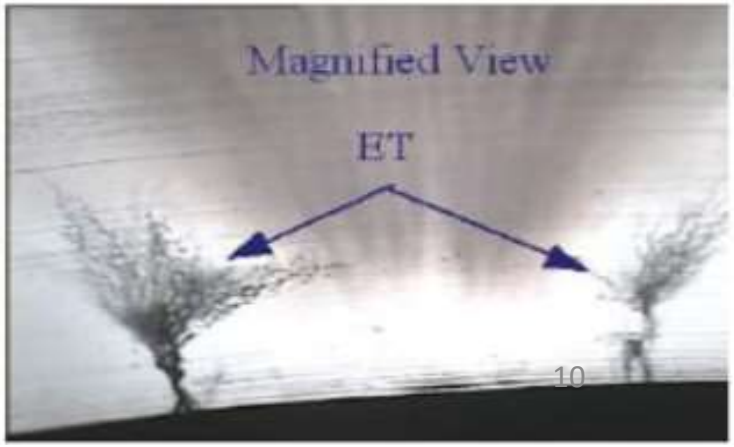
Samples of water tree and electrical tree









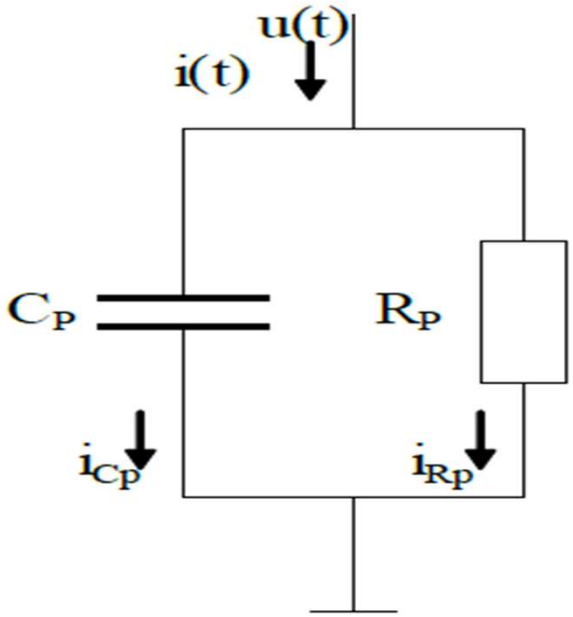


What we name it as cable Aging?

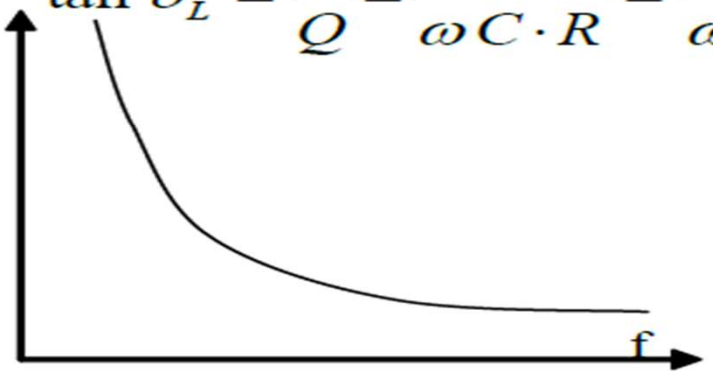
- When the voids inside the cable insulation increases, we could say that the cable is getting aged
- Electrical ages of the cables is different from yearly ages of a the cables
- Electrical age of a cable depends on many factors as operation temperature of cable, duration of operation under high temperature, humidity , the water values or humidity inside conductor of the cable, level of transient voltages that cable faces during operation, frequency of the transient voltages, quality of XLPE, the level of steaming out from the insulation , mechanical stress, and …
- The level of water tree existence in the insulation of the cables can represent electrical age of a cable
- When water trees inside the insulation expands, the electrical tree will be created that is the first step of starting failure in the cables
- Tang delta test of a cable is a standard test method to understand aging of a cable

How to detect quality and aging of a cable? What is Tang delta test method?

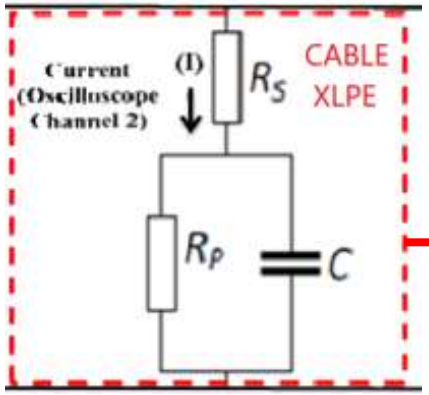
- In the test methods, both sides of the cable and as well metallic sheath of the cable will be open and a voltage with the magnitude between 1.0 to 2.0 P.P. with the frequency of 0.1 HZ will be applied between conductor and metallic sheath
- Tang of angle between voltage and current during test represent quality of insulation
- In fact if the insulation is 100% pure and without any void, it should be a perfect capacitor
- In case there is some voids inside the insulation , there will a resistive current , so the current will not be pure capacitive.

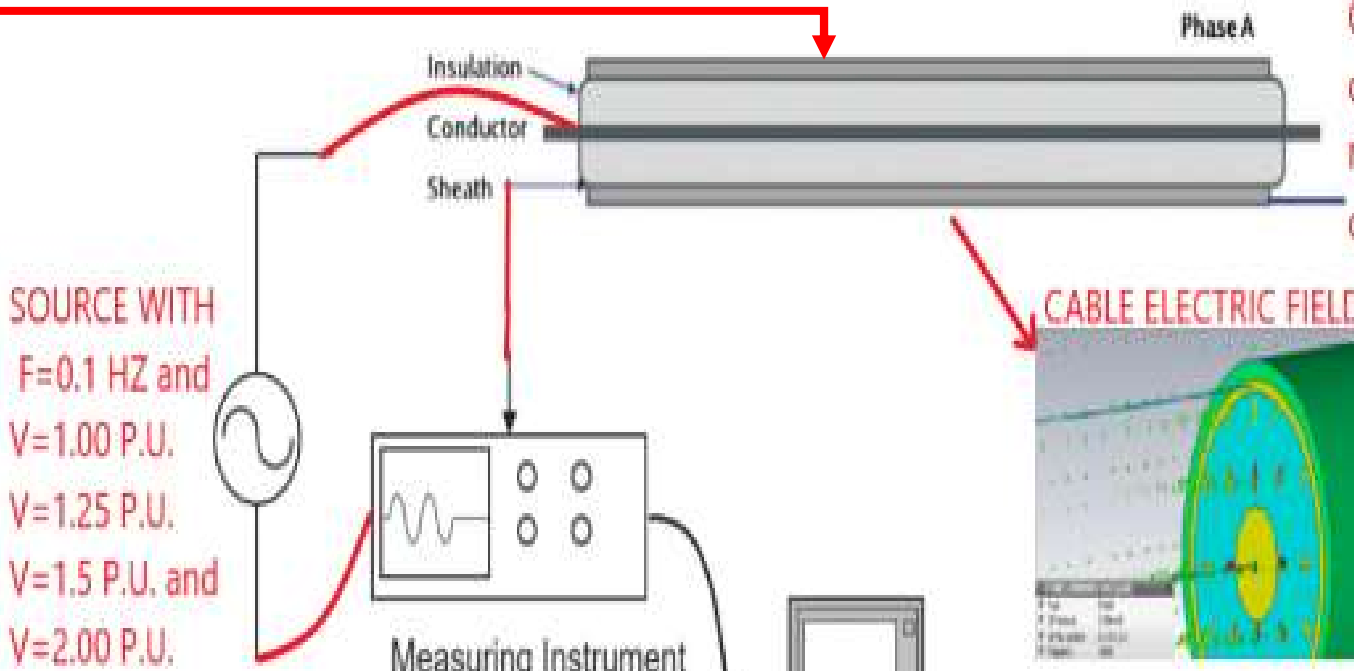


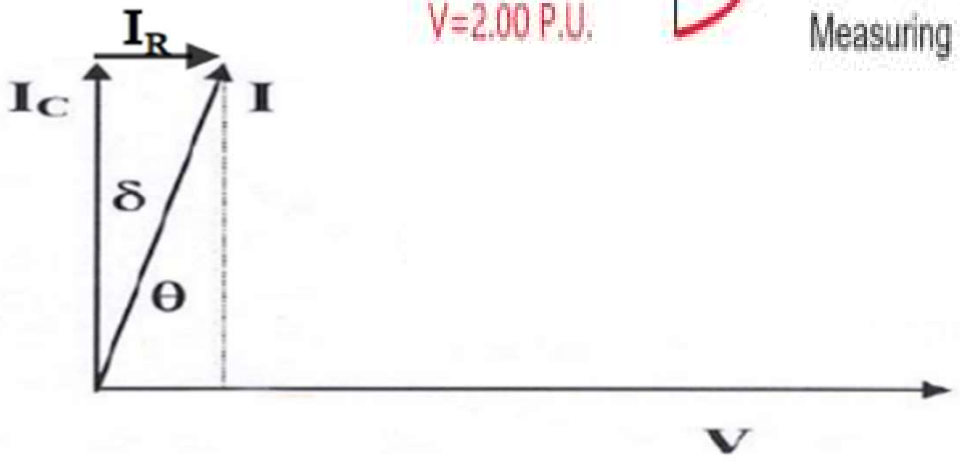
$$\tan \delta_L = \frac{P}{Q} = \frac{1}{\omega C \cdot R} = \frac{\kappa_\infty}{\omega \varepsilon_0 \varepsilon_r}$$



How to detect quality and aging of cable with tang delta test method?

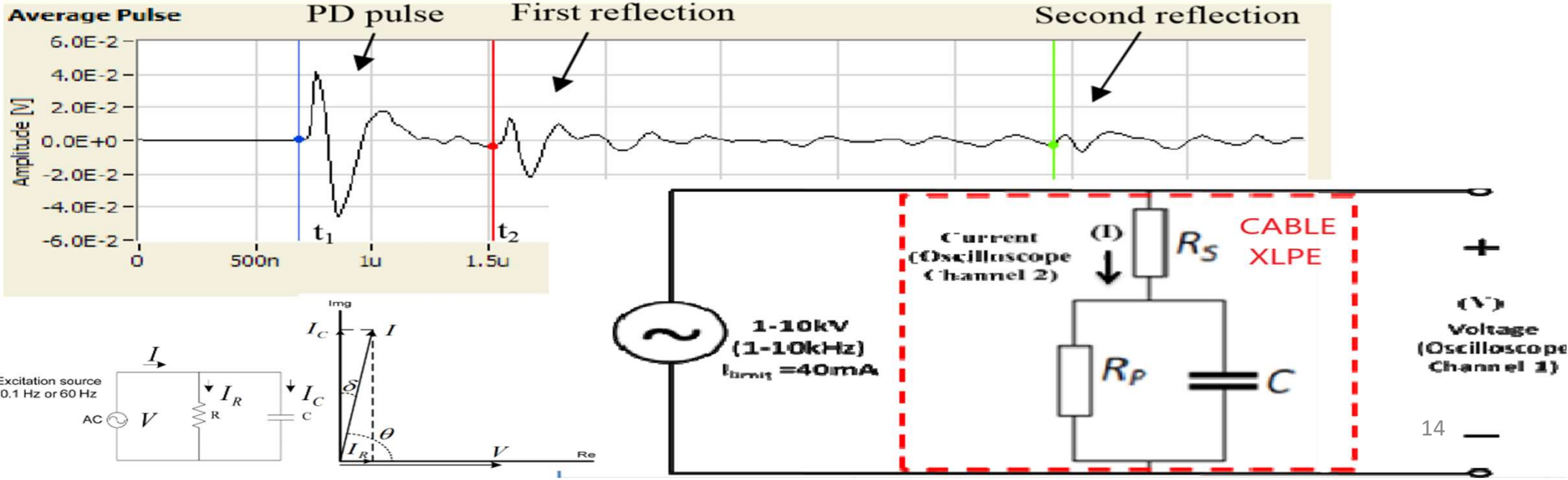






How to detect electrical tree and cables likely to fails?

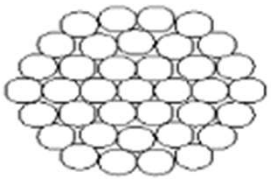
- When tang delta values are more than a specific value, it is recommended apply partial discharge test method to the cables.
- In this method, a very short pulse with magnitude of 3 to 4 P.U. will be applied to the cable and the locations and values of partial discharge will be calculated.
- These locations with high partial discharge values are the weak points of cables
- Insulation of cables with high partial discharge values will be degraded and cable will have fault/failure in the location of high partial discharge



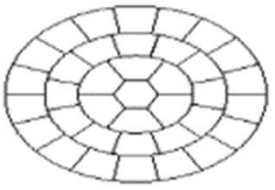
Can rejuvenation method fix Junction ?
Which types of cables can be rejuvenated?

- One of the weak points of the cables are the junction points
- In the junction points , mostly there is high partial discharge values that cause the cable to get fault if quality of junction is not good enough.
- Finding exact location of having partial discharge is very difficult
- Also in junction , may there is a leakage , so water and humidity could go inside the cable from the junction location and make the cable get fault or expedite aging of the cable.
- With rejuvenation, most of the junction issues will be solved.

- Stranded XLPE cables with any types and values of water tree and a limited value of electrical tree can be rejuvenated with the existence technology



Stranded



Compact

Rejuvenation process in simplified steps

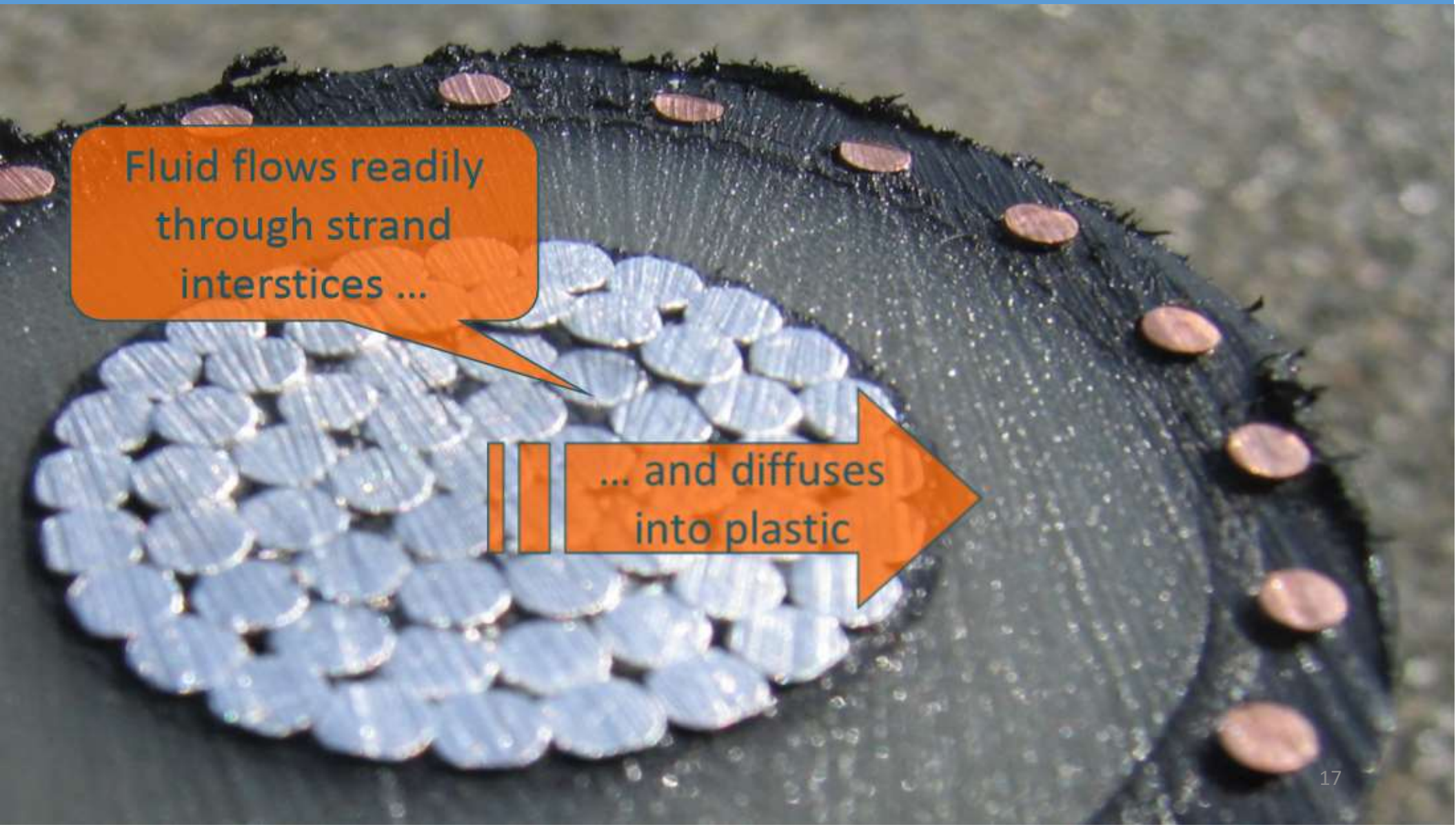
1. Injecting CO2 gas from one side of cable to understand the practical spaces inside the conductor and junctions, possibility of having blockage or leakage in the junction points.

2. Injecting a non flammable gas inside the conductor , so it penetrate inside the microscope voids of the XLPE insulation and start the initial chemical reaction for a duration between 2 to 6 hours

3. Injecting **CIR7**, **CIR18** or **CIC21** liquid materials to the cable conductor to start fast process of chemical reaction for a duration of 48 to 72 hours (the type of injection material will be decided based on tang delta and as well partial discharge test results)

4. Injecting CO2 gas from one side of cable to push material goes out from other side of the cable

Rejuvenation process in simplified steps



Rejuvenation process in simplified steps

1. After injecting the material inside the cable and finishing the rejuvenation process, the material penetrate and diffuse inside the XLPE and makes a chemical reaction with water molecules inside the XLPE voids and create a powerful molecules that has voltage insulation withstand level even more than 10 times of XLPE material insulation level.

2. That means the voids will be filled with a material that got insulation level of over 100 KV to 400 KV per mm.

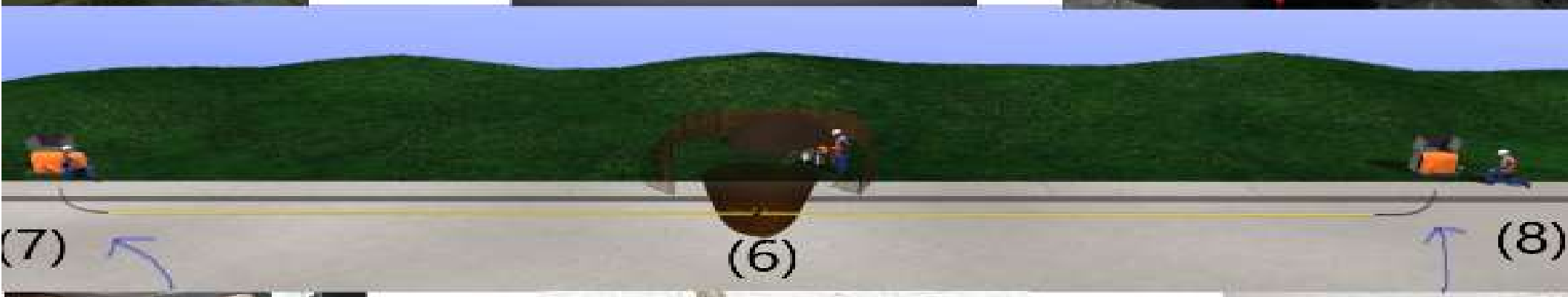
This process could be done only for the cables that has got water tree or limited values of electrical trees.

For understanding that if a cable could be rejuvenated and could be fixed or not, the mentioned tests of tang delta and partial discharge shall be carry out and then based on test results, rejuvenation process or curing process will be decided.

Rejuvenation process in simplified steps

(4)

(5)



(7)

(6)

(8)

(1)

(3)

(2)

Rejuvenation process in simplified steps

(1) Injection tools at the first of the cable

(2) Injection tools at the end of the cable

(3) Injection tools at the middle of the cable

(4) Vacuum tanks

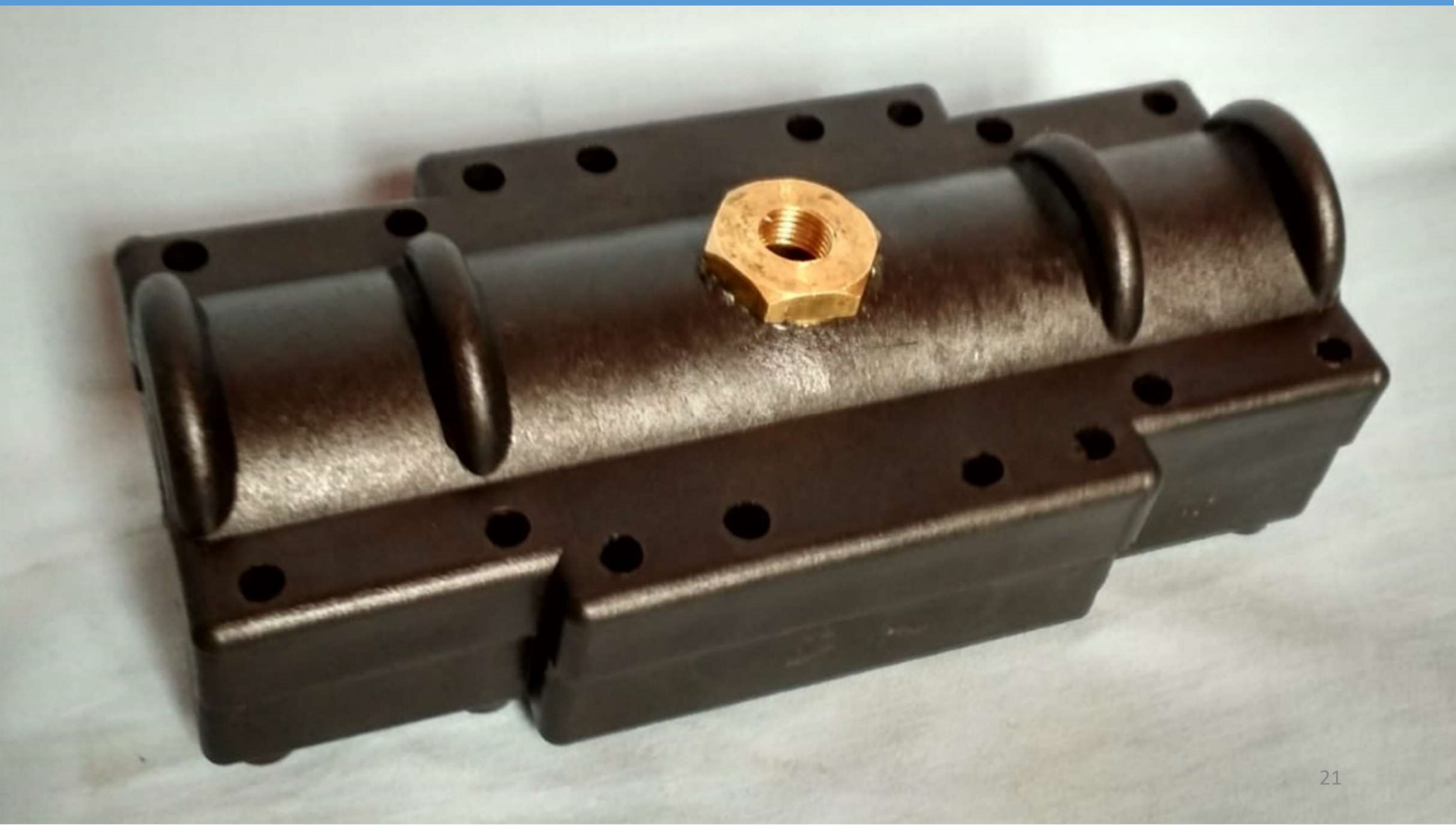
(5) Pressure tanks

(6) Middle point of cable or junction point of cable for cables longer than 500 meters

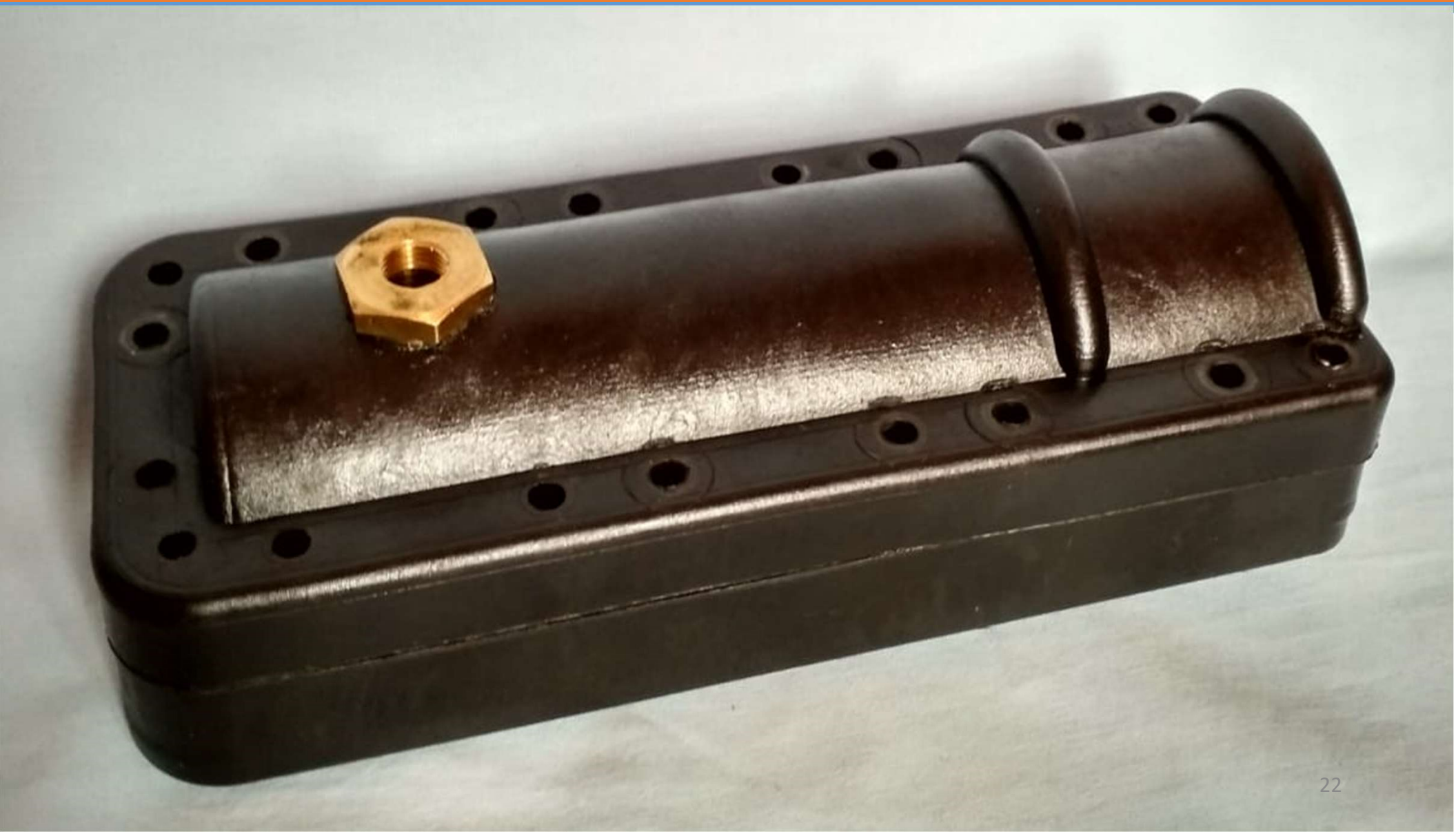
(7) First side of the cable

(8) End of the the cable

Injection Tool for middle of cable(each 500 meters)



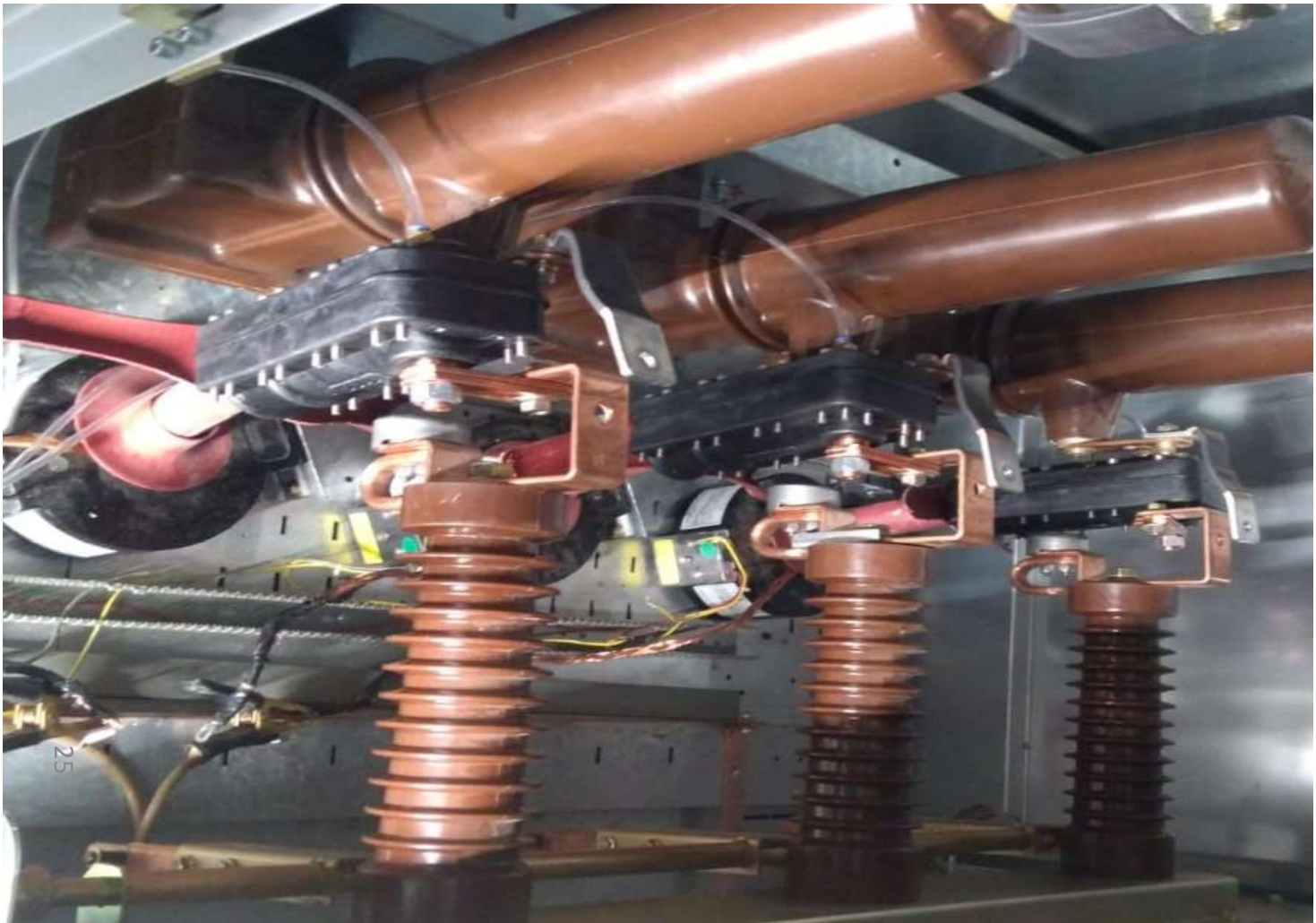
Injection Tool for heads of cables



Vacuum and pressure tanks

Samples of connecting injection tools

Samples of connecting injection tools



Samples of connecting injection tools to cable head

Thank you