From A to Z – Methods, Experiences, and Lessons Learned from the Installation of a Critical MV Power Cable System – Sub F

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Outline

- Background
- Critical Circuits
- From A to Z Methods – Highest Reliability & Case Study
  - Factory Acceptance Test – FAT
  - Site Acceptance Test – SAT
  - Site Overview
  - Installation Acceptance Test - IAT
  - Takeaways
  - Other important steps
- Summary

Background

- Utilities recognize the value of commissioning and condition-based asset management of their distribution cable circuits
- There is ready availability of voltage sources and well-established condition assessment criteria to undertake the condition-based maintenance
- IEEE-PES-ICC Spring 2022 – Sub F – “Considerations when Managing Critical MV Cable Circuits”

Critical Circuits

- The definition would likely change from utility to utility
- Specific cases may require unique parameters
- Circuits are considered critical when the risk and consequences of a failure severely impact the users, system, and/or third parties
- Drivers might include:
  - Critical infrastructure
  - ★ Impact to the end customer
  - SAIFI and SAIDI
  - ★ Circuit Access (Location/Parts)
- Performance requirements remain constant across utilities perspectives, i.e. highest possible reliability
- To ensure the highest possible reliability, methods from cable design to manufacturing and installation are required

★ Case study presented here

From A to Z Methods – Highest Possible Reliability

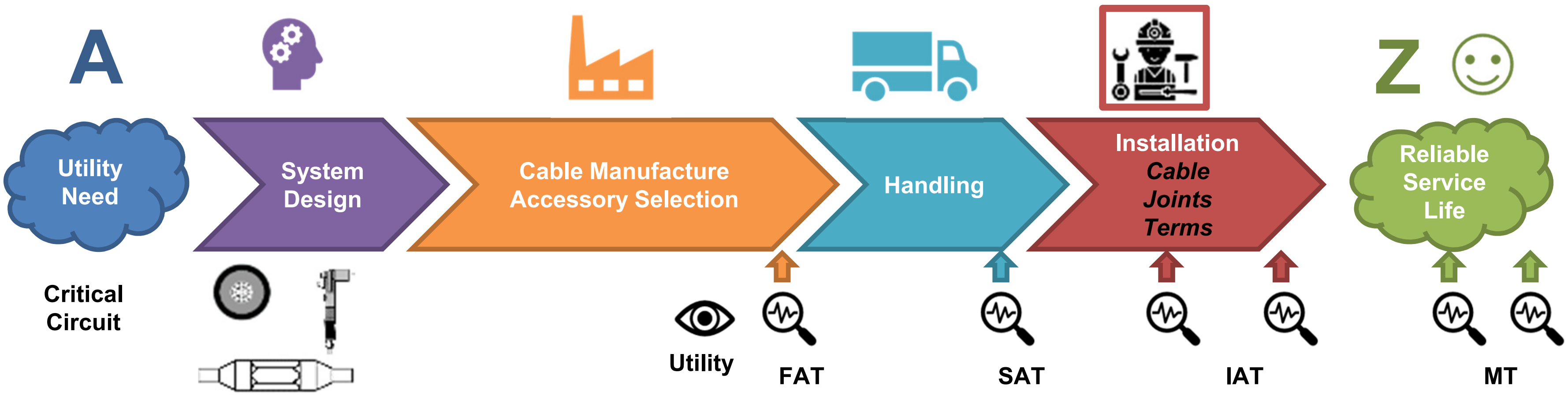
Q: How to get highest reliability?

A: By been involved from the beginning to end – A to Z

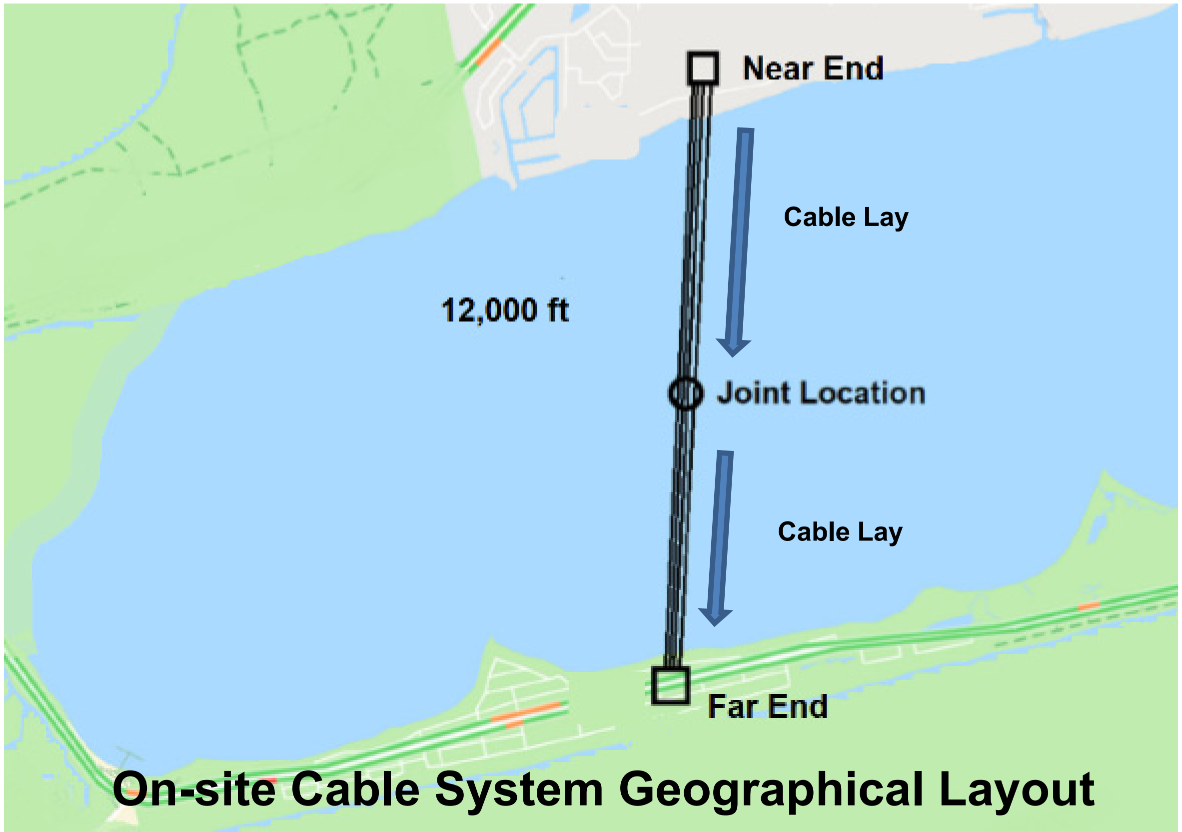
The A to Z process:

Diagnostic Intervention Diverse/Complimentary Set of Diagnostic Technologies

FAT: Factory Acceptance Test
SAT: Site Acceptance Test
IAT: Installation Acceptance Test
MT: Maintenance Test



Critical Circuit – Case Study

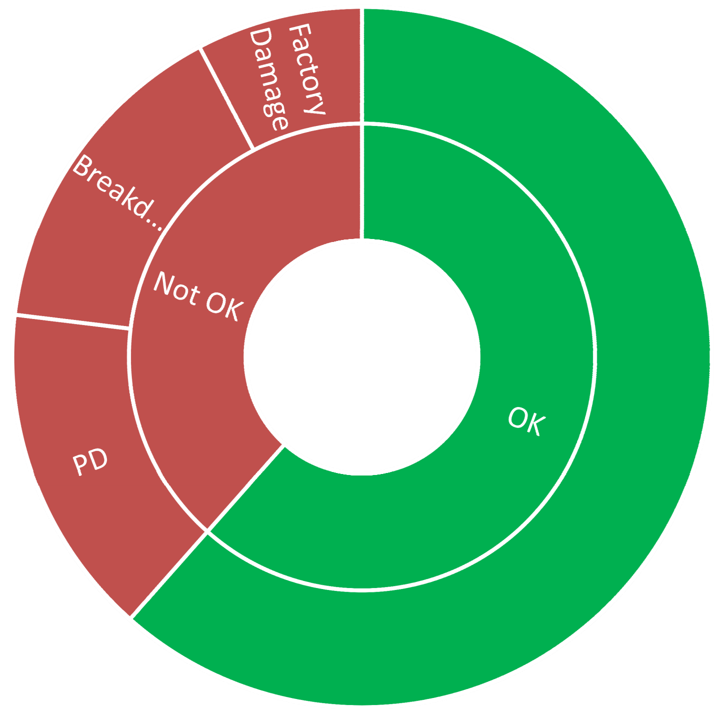


- Feeder Type
- Three-Phase
- Bay Crossing
- One Spare
- 8 Reels (6,000 ft)
- 4 Joints
- 8 Terminations
- 2 cables installed at the time

Factory Acceptance Testing – FAT

- Witness electrical routine test / review quality records for each reel by experienced representative on behalf of the end user
- FAT conducted in addition to standard Routine Test
- Consider augmenting standard test frequencies for critical cases

Case Study



Site Acceptance Test - SAT

Ensure that the cable did not suffer any damage during handling and transportation

- Visual Inspection
- TDR
- VLF Tan δ
- PD with DAC
- PD VLF Monitored Withstand

New cables were OK after factory handling and transportation

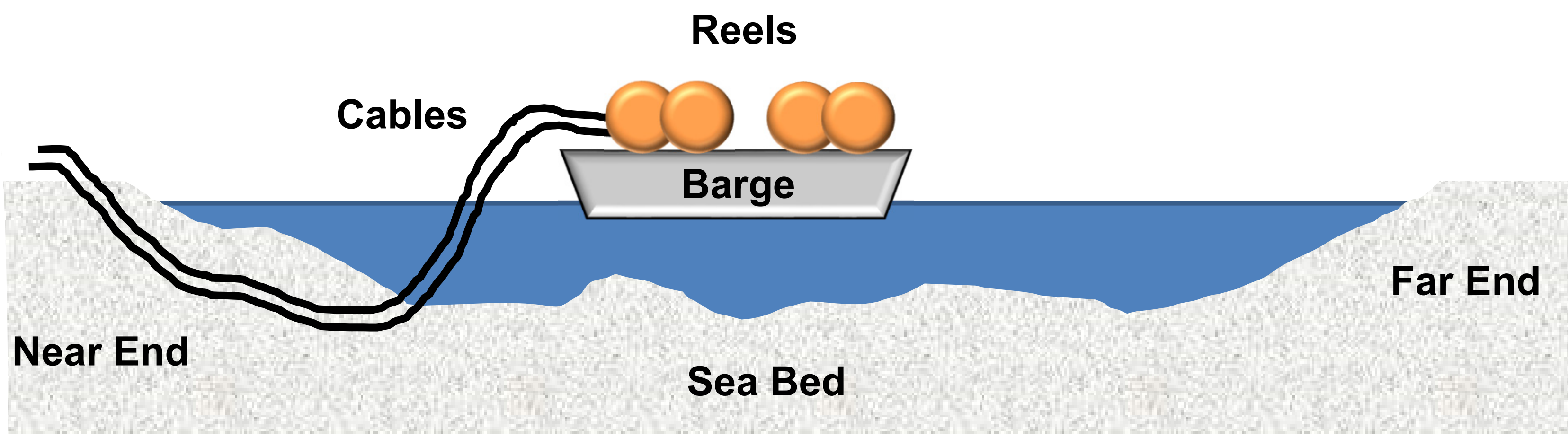
Site Overview (1 of 3)

Site Overview (2 of 3)

Site Overview (3 of 3)

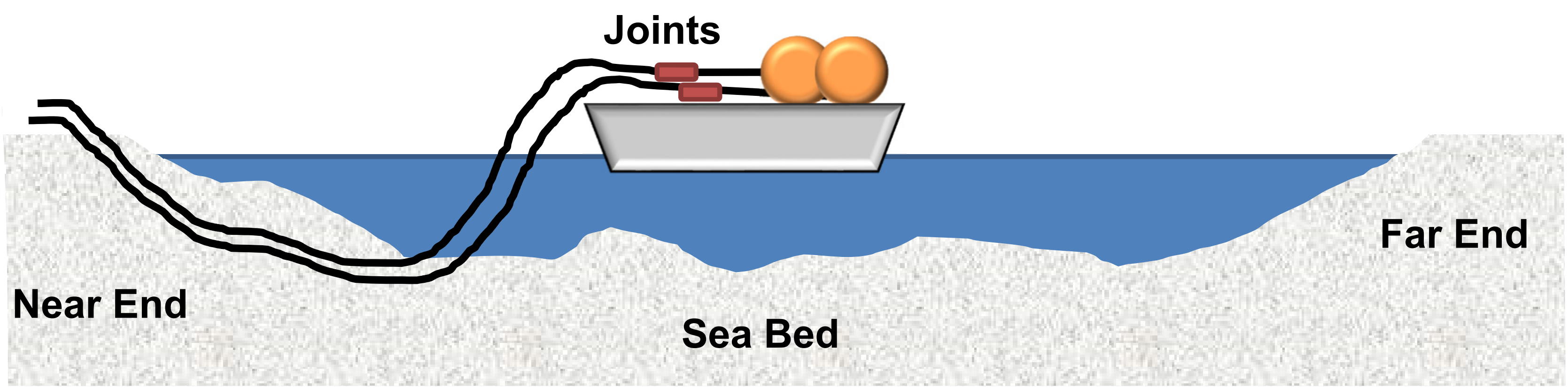
Installation Acceptance Test (IAT) - Stages

Stage 0 – First half of cable installed



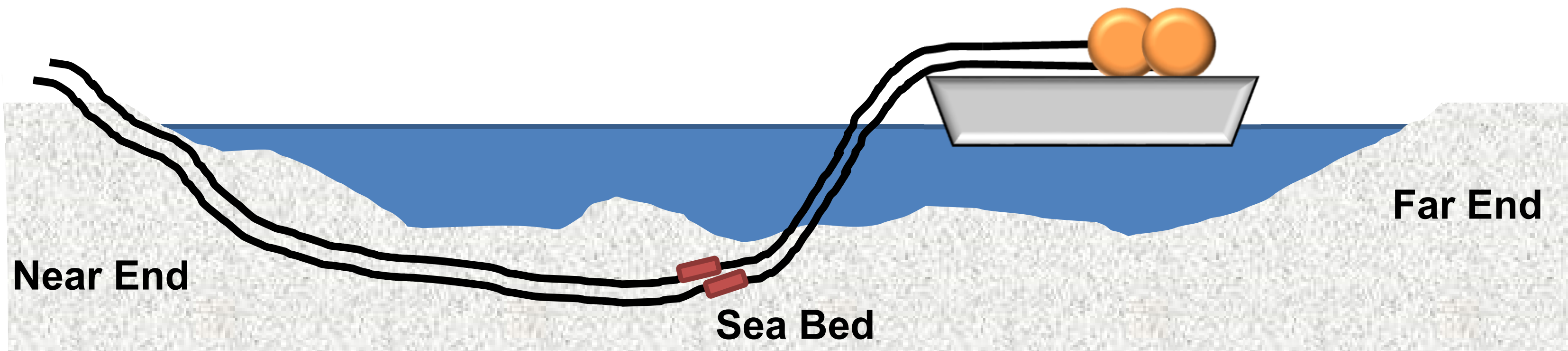
Installation Acceptance Test (IAT) - Stages

Stage 1 – Jointing on barge



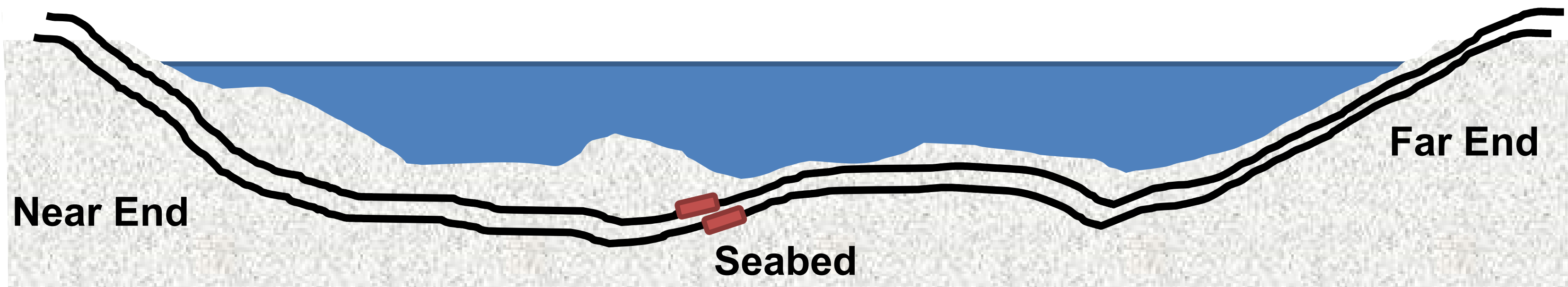
Installation Acceptance Test (IAT) - Stages

Stage 2 – Joints buried in seabed



Installation Acceptance Test (IAT) - Stages

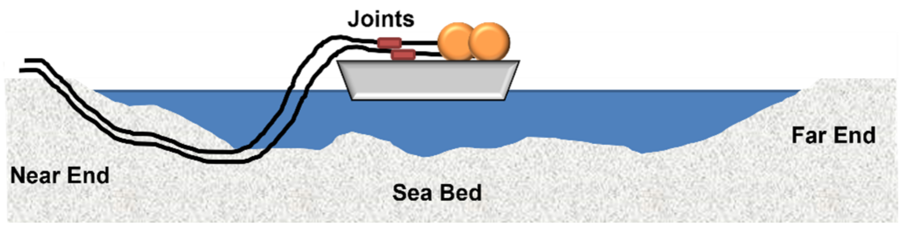
Stage 3 – Installation complete



Installation Acceptance Test - Stage 1

Stage 1 - Joint Acceptance:

- **Completed half crossing**
- **Joint assembly on barge**
- **Test terminations**

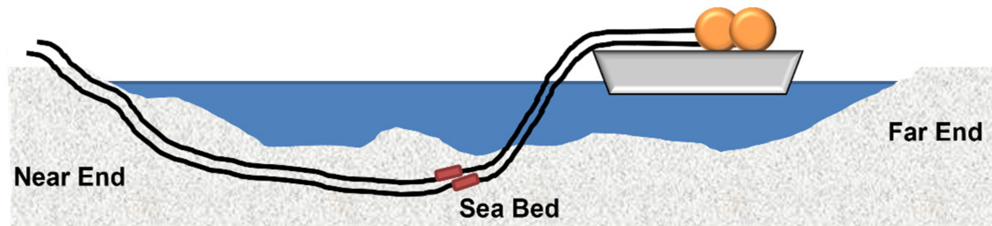


Test Sequence	Test	Test Voltages	Applicable Standards
1	TDR	N/A	IEEE 400
2	PD with DAC	0.5 U_0, U_0, 1.5 U_0, 1.7 U_0	IEEE 400.4
3	MWT PD with VLF	30 min	IEEE 400.2
4	PD with DAC	0.5 U_0, U_0, 1.5 U_0, 1.7 U_0	IEEE 400.4

Installation Acceptance Test - Stage 2

Stage 2 - Joint Submergence:

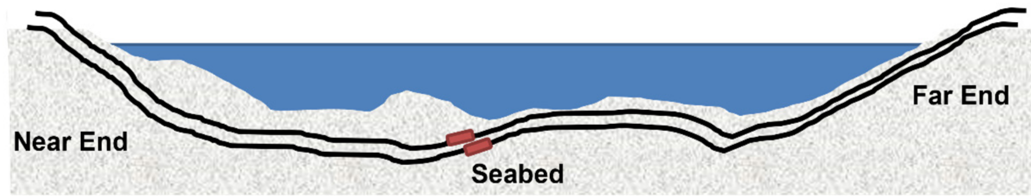
- **Completed half crossing**
- **Joint assembly laid on seabed**
- **Test terminations**



Test Sequence	Test	Test Voltages	Applicable Standards
1	TDR	N/A	IEEE 400
2	PD with DAC	0.5 U_0, U_0, 1.5 U_0, 1.7 U_0	IEEE 400.4
3	MWT PD with VLF	60 min	IEEE 400.2

Installation Acceptance Test - Stage 3

Stage 3 - Final Commissioning:
Completed full crossing
Joint assembly buried
Final pre-molded terminations



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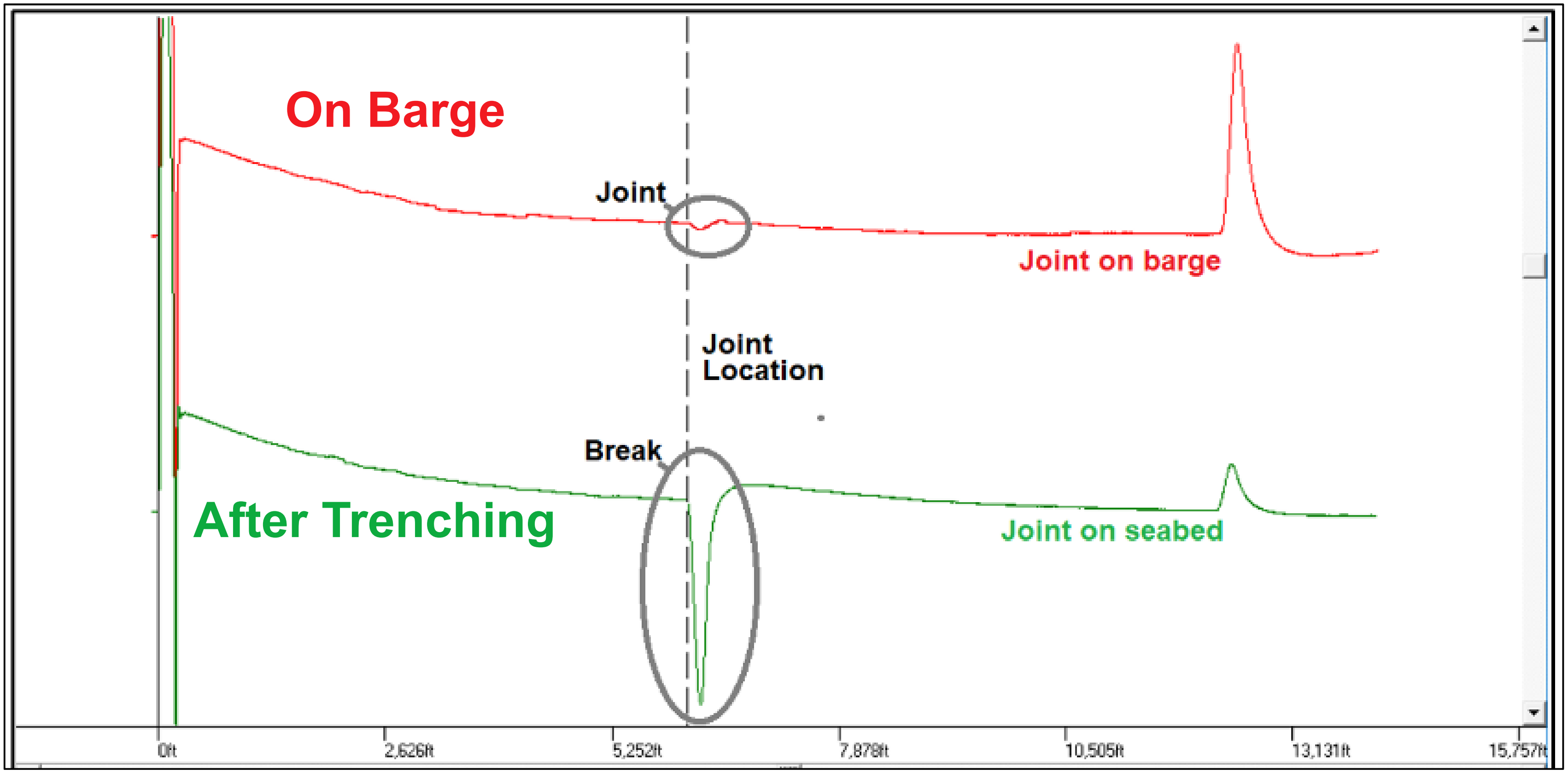
3	VLF Tan δ	0.5 U_0, U_0, 1.5 U_0	IEEE 400.2
4	MWT PD with VLF	30 min	IEEE 400.2

Summary of Test Results by IAT Stage

Feeder Phase	Stage 1 Joint Acceptance	Stage 2 Joint Submergence	Stage 3 Final Commissioning
Cable 1	√	joint mechanical damage	Abandoned

§: Needed because Cable 1 was Abandoned

TDR for Cable 1 (Abandoned)



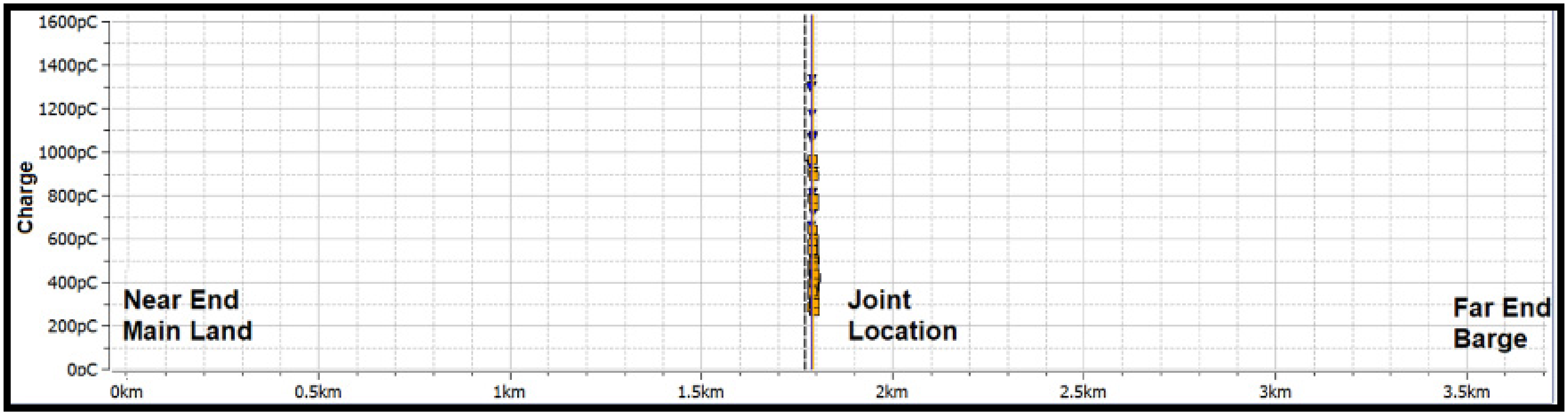
Summary of Test Results by IAT Stage

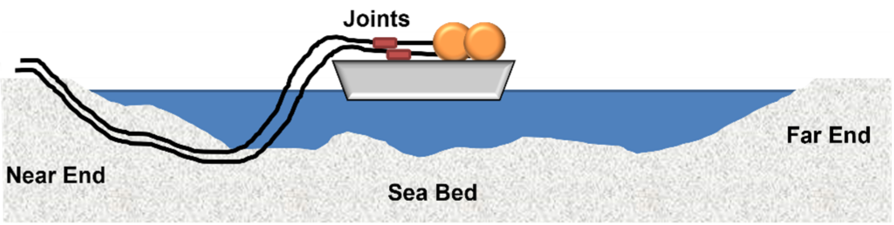
Feeder Phase	Stage 1 Joint Acceptance	Stage 2 Joint Submergence	Stage 3 Final Commissioning
Cable 1	√	joint mechanical damage	Abandoned
Cable 2 Red Phase	√ Rejoint§ PD at Joint – replaced √	√	√
Cable 3 Spare Phase	PD at Joint – replaced √	√	√

§: Needed because Cable 1 was Abandoned

IAT DAC PD Location Tests Results

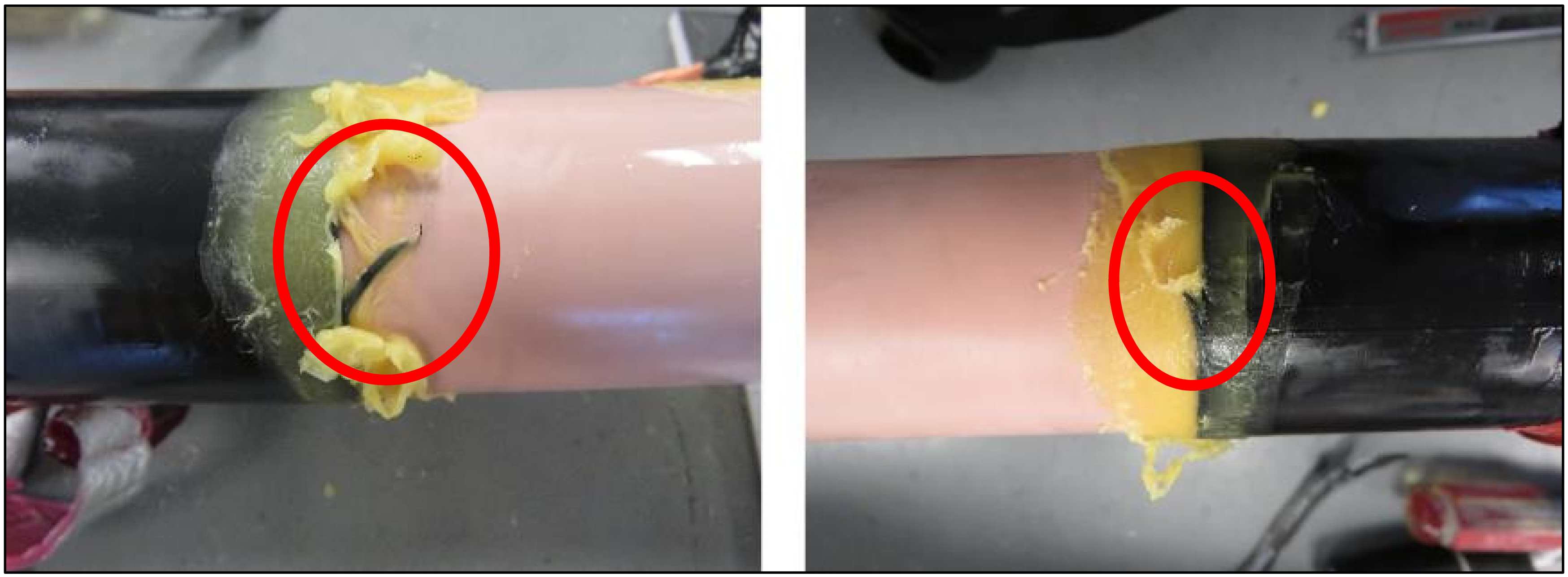
Cable 2 (Red Phase)





Cable 2 (Red Phase) Joint Dissection

Insulation Shield Cutback Defects



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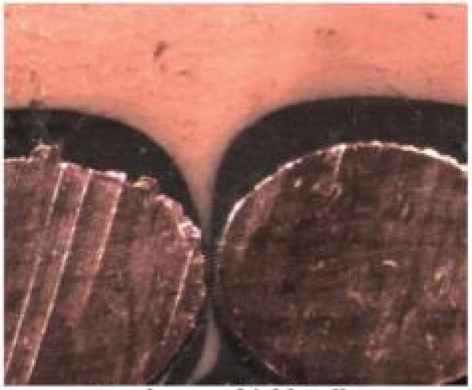
Cable 1	√	joint mechanical damage	Abandoned
Cable 2 Red Phase	√ Rejoint§ PD at Joint – replaced √	√	√
Cable 3 Spare Phase	PD at Joint – replaced √	√	√
Cable 4 Blue Phase	√	√	√
Cable 5 White Phase	√	√	√

§: Needed because Cable 1 was Abandoned

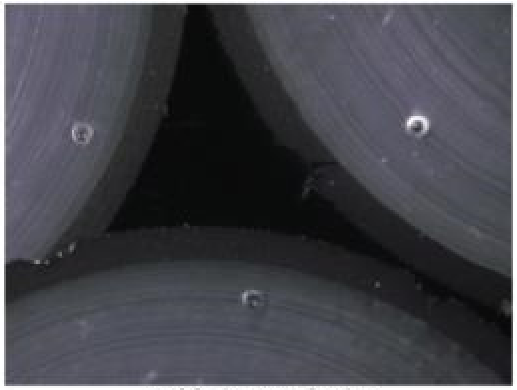
Other Important Steps

Cable Quality Assurance

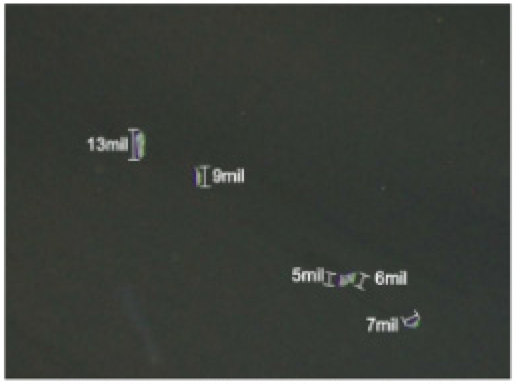
- Perform QA checks on all shipping reels to ensure each reel meets design specifications
- Ensure at least spare reels are available should issues arise



Conductor Shield Full-In



Voids in Insulation



Insulation Material Contaminants

Manufacturer Selection / Qualification to Bid

- Require qualification reports
- Require monthly CV qualification reports > 12 months
- Review experience of production of the design being purchased – has this design been manufactured before?
- Manufacturer may be audited considering quality and technical parameters
- Remember that a factory visit <u>is not</u> a full audit

Cable Design – Case Study

- EPR was the utility choice
- Only MV production plants can be used
- Limits the length to approximately 6,000 ft
- Jointing is required during the crossing
- Water blocked, fully encapsulation, and no armor

Accessory Selection

- Use only qualified joint designs (IEEE 404)
- Request qualification reports
- Use only qualified connectors – consider own experience
- Stick with joint designs and installation practices that utility crews are most familiar with

Summary

- Successfully conducted subsea commissioning program
- Commissioning integrated with the installation
- Designed to detect manufacturing and installation issues as soon as practical avoiding risk
- Multiple and complimentary diagnostic tests / technologies to improve accuracy
- Reduced repair/replacement costs
- The methods and processes can be used as guidance for other critical circuit applications