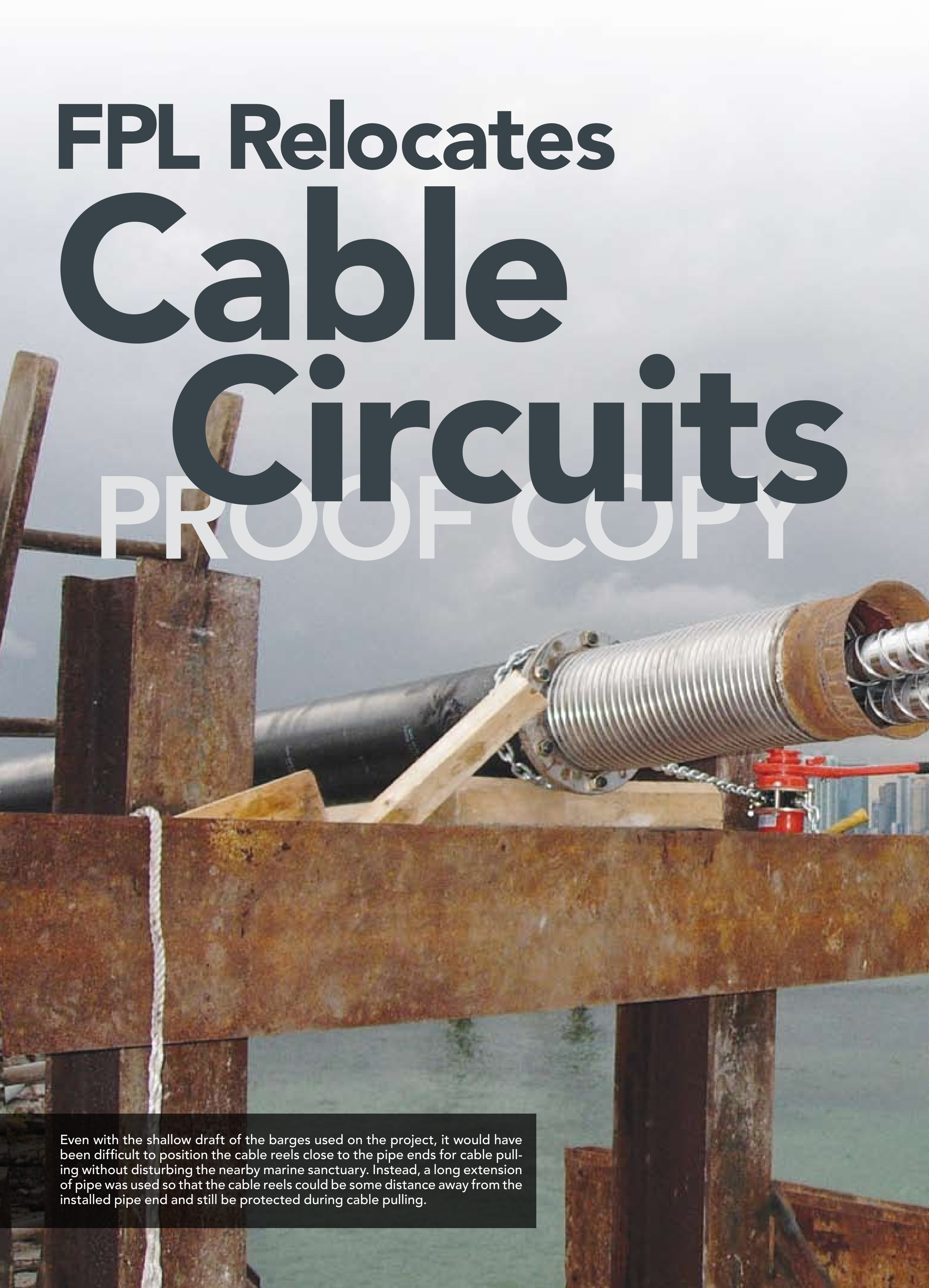
FPL Relocates Cable Circuits



Even with the shallow draft of the barges used on the project, it would have been difficult to position the cable reels close to the pipe ends for cable pulling without disturbing the nearby marine sanctuary. Instead, a long extension of pipe was used so that the cable reels could be some distance away from the installed pipe end and still be protected during cable pulling.

Pipe-type cable circuits are rerouted to allow dredging operations required for Port of Miami expansion.

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MORE THAN 40 YEARS AGO, 138-KV AND 69-KV PIPE-TYPE CABLES WERE INSTALLED FROM MIAMI to Miami Beach and Key Biscayne, Florida, U.S. The cables were initially installed by plowing the pipes in some areas and laying the pipes on the water bottom in others. These circuits pass in the vicinity of Lummus Island, which, in 1980, was surrounded by sheet piles and topped off with fill so the Port of Miami could accommodate container ships.

In the 1970s, the U.S. Army Corps of Engineers approached Florida Power & Light (Juno Beach, Florida) with plans to dredge a major shipping channel near the port in the vicinity of FPL's cables; the Army Corps reinitiated contact with FPL in the late 1990s, stating its intent to move forward with the project. The dredging project would increase the depth of the channel to accommodate large ships, and the expected after dredging channel depth would be below the elevation of the existing pipe-type cables crossing the area.

The 138-kV and 69-kV cable circuits are integral to the utility's extensive underground transmission network, so FPL needed to relocate the portions of the circuits under the water channel before dredging could occur.

Horizontal directional drilling (HDD) was the only viable

A connector is used to accommodate the transition between two different cable conductor sizes.

means to install new sections of cable pipe at the required depth below the channel and to avoid disrupting shipping traffic at the port or disturbing aquatic plant and wildlife preserves in the vicinity. In 2001, FPL contracted with Jacobs Civil Inc. (St. Louis, Missouri, U.S.) to perform the needed design and environmental studies for installing new cable pipes well below the channel along a 2297-ft (700-m) route.

Power Delivery Consultants Inc. (Schenectady, New York, U.S.) worked closely with Jacobs to develop a cable electrical design that was compatible with civil design constraints to meet FPL's desired power transfer. Specifications were prepared for contractors — UTEC Constructors Corp. (Boston, Massachusetts, U.S.) working with directional driller Mears Group Inc. (Rosebush, Michigan, U.S.) — to build the circuit. Many challenges existed during the design stages and construction, which made this an exciting project. Okonite Cable Co. (Paterson, New Jersey, U.S.) supplied the cable for the project, and MAC Products (Kearny, New Jersey) supplied the splice kits.

CABLE DESIGN

The cable system design was done in close coordination with the civil design, because several factors were influential to both. The electrical design — mainly to achieve FPL's desired ampacity — was critical. But in some ways, the requirements of the cable design were counter to the civil design requirements, which made for an interesting project.

No consideration of alternative cable system types was made because the project only involved sections of existing 138-kV and 69-kV pipe-type lines. Completely rebuilding either line would have added significant cost and caused further community and environmental impacts. Thus, the initial step in many cable projects — determining which cable type to use — was predetermined at the onset.

FPL wanted to match the existing pipe-type infrastructure, including installing two cable pipes for each voltage, one containing cables and one a spare. The circuit routing generally traveled south across port property and under water. There, the 138-kV cable circuit continued south to Key Biscayne and the 69-kV cable circuit headed west to Miami. Using directional drilling, the relocated sections would traverse from a point on port property to an area in the water.

Circuit-current rating was a critical design challenge. The utility wanted 970 A on the 138-kV line and 945 A on the 69-kV line. However, there were civil design constraints. Specific depth of sheet piles were unknown, so the civil design required boring well under the piles, increasing the pipe bore depth to about 120 ft (37 m). The thermal resistance to heat leaving the cable would increase with bore depth, so for cable-rating purposes, the cable engineer wanted to maintain as shallow a bore as possible while still satisfying the civil installation requirements.

The required bore depth was hardly shallow. The drill path was carefully considered to minimize the chance for unintended drilling mud returns (often called *frac outs*) and to account for the limestone rock through which some of the directional drilling would be done below the shipping channel.

The fill material used to construct the port on Lummus Island posed another ampacity challenge. Years earlier, sheet piles were placed around the perimeter of the island, and various types of fill material was used to bring the port area up to grade. Geotherm Inc.

(Aurora, Ontario, Canada) conducted thermal testing that showed that much of this material had a very high thermal resistivity, particularly when the material was above the water table.

To mitigate the effect of those poor soils, the design team needed to install a low thermal resistivity grout around the cable pipes below the normal trench depth of about 8 ft (2 m). An outer casing was used for each pair of cable pipes. The interstitial space between the cable pipes and the 24-inch (610-mm) steel casing was then filled with a low thermal resistivity grout.

Various cable designs were considered to maximize ampacity. An 8⅝-inch (219-mm) cable pipe is commonly used for 138-kV cable systems and provided adequate internal clearance for the cables, so this pipe size was considered for the project. The design team specified a ⅜-inch (9.5-mm) wall thickness rather than the more-typical ¼-inch (6.4-mm) wall, because the installation was going to be under water and essentially unavailable for repair if corrosion successfully attacked the cable pipes.

Because an outer casing was being used, an extruded polyethylene cable pipe coating was selected for its better corrosion-protection properties (higher dielectric strength) over the more mechanically robust fusion-bonded epoxy and polymer concrete that is often used in HDD installations. During construction, the casing pipe and cable pipes were assembled together in 400-ft (122-m) sections and then welded together into one long section prior to pull back. These sections of casing pipe were welded together on the water to minimize impact to environmental habitats and to facilitate permitting from the Department of Environmental Protection.

An evaluation of pulling tensions showed that for the

Selecting a work area within the Port of Miami property was a challenge, because every available space is occupied with shipping containers or equipment used to move the containers.

Because of the deep burial depth of the existing cable pipes into the newly installed HDD cable pipes, an extensive pit had to be exacavated and fitted with an elaborate well-point system to keep the area and connected manhole relatively dry while pipe cutting and welding, as well as cable splicing, were completed.

2200-ft (671-m) 138-kV bore and the 2300-ft (701-m) 69-kV bore, a stainless-steel skid wire in a steel pipe would provide acceptable pulling tensions.

Many pipe bends were needed on Lummus Island to align the new pipe with the existing manhole, raising concerns about the cable-pulling direction. The preference is to pull into sharp bends, but this would have meant increasing the anchoring of the barge out in the water, likely affecting the amount of disturbed seabed. Because FPL strives to be a good neighbor in the communities in which it works, pulling was done from the water toward land and found to be within acceptable limits.

The existing cable pipes to which the relocated circuits would be connected contained a variety of cable sizes, including 1500 kcmil, 2000 kcmil and 2500 kcmil, with various insulation wall thicknesses, such as 0.505 inches (12.827 mm) and 0.490 inches (12.446 mm). Since there was uncertainty about where the exact location of the cable tie-in would be in the water and what cable construction would be encountered for both the 138-kV and 69-kV circuits, multiple splice kits were ordered from MAC Products for each joint location. The splice kits included specially made connectors to accommodate all the possible differences in conductor sizes between the new and existing cables.

Laminated paper-polypropylene (LPP) insulation was considered as a cable-insulating material to permit a larger (3500-kcmil) conductor to be used while still maintaining the necessary clearance in the pipe. However, there was uncertainty about the types and relative quantities of dielectric liquids. Some manufacturers expressed concern about the extent of alkylbenzene in the existing cable pipes and the impact of exposing LPP-insulated cables to alkylbenzene.

Ultimately, cable material costs and concerns about possible conflicts with mating a very large LPP cable to the existing cables dictated that a more-standard kraft-paper insulation be used with a 3000-kcmil segmented, copper conductor.

New Cable Construction

Component	Description
Conductor, shield	3000-kcmil segmented, copper with intercalated metalized paper and copper tapes
Insulation	0.490-inch (12.446-mm) kraft paper
Insulation shield	Intercalated metalized paper and copper tapes, Mylar tapes
Skid wires	2-inch to 3-inch (51-mm to 76-mm) lay, D-shaped 0.1-inch by 0.2-inch (2.5-mm by 5-mm) stainless steel
Cable pipe	8.625-inch (219.075-mm) outer diameter, 0.375-inch (9.525-mm) wall thickness
Cable pipe coating	Extruded polyethylene 70 mils
Pipe filling liquid	Polybutene

The team also elected to use identical cable for both the 69-kV and 138-kV circuits to minimize possible spare-parts requirements and also provide for a single manufacturing production run. The table summarizes the basic cable and pipe construction used for the relocation project.

CORROSION PROTECTION

Another challenge of the project was how to implement a cathodic protection system to protect the relocated cable pipe sections. With directly buried cable pipes, a negative rectifier voltage (-0.85 V) is applied to the cable pipe through a polarization cell or solid-state equivalent. The pipe coating is the primary means to protect the cable pipe from corrosion. However, in the event of a holiday in the pipe coating, either during operation from external mechanical damage or during installation, the impressed-current cathodic protection system forces the cable pipe to the cathode in an anode-cathode galvanic cell, protecting the pipe.

With the cable pipes installed within a steel HDD casing pipe, the typical cathodic protection system would essentially be shielded from protecting the cable pipes. One option to overcome this challenge was to pull an anode conductor

An extra-long and redundant pipe freeze, using copper tubing and dewars filled with liquid nitrogen, was applied to the existing cable pipe to freeze the dielectric oil within the pipe. The extra precautions were used to avoid any chance of dielectric oil escaping from the cable pipe into the water.

inside the steel casing pipes along with the cable pipes. However, this was thought to be problematic, because if the anode were to make direct electrical contact with the cable pipes, the cathodic protection system would fail to work and could possibly cause electrolytic corrosion on the cable pipes.

UTEC suggested using plastic spacer rings to protect the cable pipe coating during installation. With the spacer rings in place, the team was reasonably assured the cable pipes would not be in direct contact with the HDD casing pipe. Since the inside of the casing pipe would be grouted for ampacity reasons — making removal of the cable pipes impossible — the outer casing pipe was considered sacrificial anyway.

As such, the design team elected to use the HDD casing pipe as a distributed anode in the cathodic protection system. The 0.5-inch (12.7-mm)-thick steel HDD casing pipe was expected to last more than 50 years given the relatively slow rate of consumption the steel would experience. This was determined to be a workable approach to the cathodic protection system for the relocated cables.

CIVIL ENGINEERING AND CONSTRUCTION

FPL is a leader in clean energy, conservation and environmental stewardship. Therefore, an important consideration for this project was to minimize the environmental impact from any construction work done in the water.

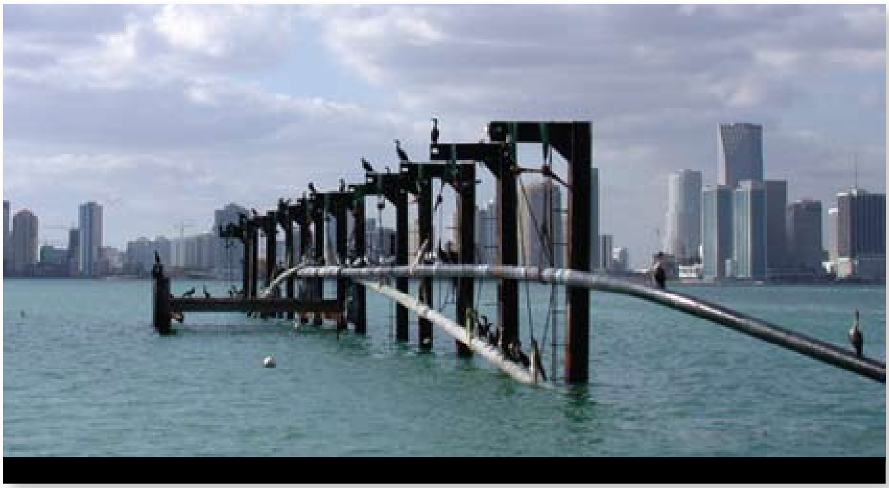
Sea grasses in the area and a manatee habitat were of critical concern, so the locations of pilings and barges used in the water were carefully selected to minimize disturbing the sea bottom and affecting plant life, particularly Johnson's sea grass. Manatees are a protected species, so spotters were used to observe whenever work was going on in the water — such as when setting up barges and floating pipe sections — with the requirement to stop work if a manatee was sighted in the area. The turbidity of the water was a related concern, so turbidity blankets and booms were used to limit the possibility of drilling fluids escaping the work area.

Permitting was a significant part of the overall project schedule, so FPL could demonstrate its contractors had adequately addressed these important environmental issues.

Portions of the work were conducted within Port of Miami property. As such, the port authority's cooperation was critical to the successful execution of the project, including significant coordination for worker access to the secure facility. The port is a very active place, with shipping containers being loaded and unloaded from ships and received and dispatched on trucks at all times.

The project team had to select a work location that met several requirements:

- Sufficient work space to lay down HDD equipment
- Proximity to the existing cable pipes that would be connected to the relocated cable pipes
- Accessibility for project team equipment and personnel to enter and



The existing cable pipes and newly installed cable pipes were brought above the water surface and aligned so that the pipes could be safely cut and the cables spliced.

leave the construction site, and to permit cable jointing and splicing

- Minimal disruption to port operations.

Although a challenge, a suitable site was negotiated with the port authority, which understood the importance of this project to FPL and to the reliability of southern Florida's transmission infrastructure.

Many challenges were encountered during construction and installation of the new cable pipes and cables. Space at the Port of Miami — one of the busiest and largest ports in the United States — is at a premium, and the precise location of the existing cable pipes was not well known, both because the circuits had been installed many years earlier with scarce installation records and because the port had been physically expanded with layers of additional fill added above the original cable elevation. The cables turned out to be well below the water table and were in close proximity to the ocean, requiring an extensive wellpoint dewatering system.

The weather also played an important role during construction. The Miami area sustained four hurricanes during construction that interrupted fabrication of the cable pipes and casings and impacted dewatering and cable pulling. Barge placement was critical, because the locations of cables in the water were not well defined. The contractors wanted to avoid placing a barge in the marine sanctuary that bordered the work area.

Fortunately, the directional drilling work was relatively straightforward, using a combination of Mears' 880,000-lb (399,000-kg) drill rig primarily for the pilot hole boring and a 70,000-lb (31,751-kg) rig to assist with reaming the bore hole. A specialized technique of "forward reaming" from land was used to minimize the possibility of drilling mud escaping at the water exit point. Placement of the new pipes was well configured to tie into the existing pipes when they were raised above the water.

Once above the surface, cable pulling was done in the new pipes and freezes were applied to the existing cable pipes. Extra-long freezes were established for the existing cable sections using copper tubing and liquid nitrogen so that there would be no chance of dielectric oil leaking into the water during cable work.

AN UNEXPECTED HITCH

Work on the 138-kV cable circuit was completed without any major issues. However, the existing 69-kV circuit unexpectedly contained significant gas inside the cable pipe, which was first indicated when there was difficulty establishing a pipe freeze on the 69-kV line.

The source of the gas was unclear, though FPL endeavored to perform dissolved gas-in-oil analysis to determine the nature of the gases present and the source of the gases. The origin of the gases was thought to be related to damage to the 69-kV circuit from a dragged anchor several years earlier when water might have entered the cable pipe and not been completely removed before the cable was put back in service.

FPL used extensive oil degassing and flushing of the cable oil in the 69-kV cable pipe to mitigate the problem. Both the 138-kV and 69-kV circuits were successfully re-energized. The cables and dielectric oil from the older pipes under Fisherman's Channel, near the port, were removed, and the insides of the pipes were swabbed and cleaned to remove any oil residue. The evacuated cable pipes were then removed by the Army Corps' dredging company.

The project was a success for FPL, its contractors, the Port of Miami and the Army Corps of Engineers. Now, with the dredging work complete, much-larger container ships are allowed to deliver goods to Miami. TDW

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