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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of: FLORIDA POWER AND LIGHT COMPANY (St. Lucie Nuclear Power Plant, Unit No. 2)	DOCKET NO. 50-389

AFFIDAVIT OF CLIFFORD S. KENT

I am Clifford S. Kent, Project Manager for Engineering for the St. Lucie nuclear project for Florida Power & Light Company. My educational and professional qualifications appear in the Nuclear Regulatory Commission's record of this proceeding, following Tr. 5184.

The St. Lucie Unit 2 steam generators and secondary system are described in the Attachments to this affidavit. Their design includes provisions to minimize the potential for steam generator tube denting, the corrosion of steam generator tubing, and sludge formation. To help understand the effectiveness of the St. Lucie Unit 2 design, a brief description of the conditions necessary to support the various corrosion processes will be presented, followed by a description of the design provisions and operating procedures utilized to preclude these conditions.

Avoidance of Denting

Based on operating experience and laboratory testing, at least the following conditions must exist simultaneously to produce denting:

a) A region adjacent to the tube capable of concentrating impurities (historically a tube/tube support plate annulus blocked by a porous corrosion product);

b) A rigid carbon steel tube support plate;

c) The ingress of impurities that can produce a local acidic environment.

The removal of any one of these three conditions should preclude denting. The St. Lucie Unit 2 design is such as to eliminate all three.

The exclusive use of non-rigid (egg-crate design) tube support structures throughout the steam generator, as described in Attachment A, removes the first two necessary conditions for denting. The egg-crate tube support structure design eliminates the narrow annular gap adjacent to the steam generator tube that is present in the drilled tube support plate design. In the egg-crate design steam generator fluid passes upward around each steam generator tube, continuously flushing the area between the tube and egg crate support structure, thereby reducing the possibility for a build-up of corrosion products that could block the free flow of fluid around a tube and form a site wherein contaminants could concentrate.

Secondly, the egg-crate support system is also flexibile, i.e., the ligaments of the egg-crate offer significantly less resistance to deformation under in-plane expansion loading than drilled support plate ligaments. Thus, in the extremely unlikely event that non-protective magnetite (Fe_3O_4) began to form at the tube/tube support contact point, the resultant in-plane expansion loading would be absorbed by deflection of the egg-crate support structure before the load could deform (dent) the steam generator tube.

In summary, steam generator tube denting should not occur with egg-crate type tube supports. This conclusion is supported by the operating history of Combustion Engineering (C-E) designed commercial steam generators. Each operating C-E steam generator has egg-crate type support structures to some extent, and denting has never been known to occur at egg-crate supports. This is true even in those steam generators, such as those utilized at Maine Yankee and Millstone Unit 2, where some denting has occurred only at the drilled upper support plates.

Notwithstanding the above, St. Lucie Unit 2 has been designed to minimize the third condition necessary for denting. Historically, the source of dent-producing impurities has been the inleakage of condenser cooling water. Florida Power & Light Company (FPL) believes that this matter has been appropriately addressed within the context of condenser design for St. Lucie Unit 2 instead of including additional hardware such as demineralizers to collect and treat impurities. Although the use of demineralizers is not currently envisioned as either necessary or desirable, they can be accommodated for St. Lucie 2 in the unlikely event they should prove to be needed. FPL has studied the condenser leakage problem extensively in an effort to attain an optimum condenser design that will minimize the ingress of impurities. The final condenser design is described in Attachment B. Some of the more important features worthy of particular note are:

1. The condenser will utilize titanium tubes. Titanium is the most corrosion resistant material currently available in the industry for this application.

2. The tube to tube sheet joint will utilize a roll into a double grooved tube sheet offering excellent pull out strength and leak tightness.

3. The condenser hot well will be compartmentalized to enable the timely recognition and location of condenser inleakage in the event that it does occur.

4. The condenser leak detection system, utilizing on-line cation conductivity monitoring, is capable of detecting inleakage down to 0.001 gpm.

5. The condenser, with individual water box isolation, is designed to facilitate timely removal from service of that section of the condenser in which inleakage has been detected.

6. The condenser is designed with a capability to rapidly drain the affected water box and thereby further minimize the duration of inleakage to the condensate.

To complement the condenser design, FPL will employ strict operating procedures to further limit the input of contaminants into the steam generators. The procedures will require prompt action upon indication of condenser leakage. Operator action will vary as a function of the level of inleakage, ranging from reducing load, isolating the section of the condenser with the leak, and draining the cooling water from the water box;

to shutting down the plant in parallel with isolating the affected section of the condenser, and draining the cooling water from it.

Strict adherence to such procedures, which have been implemented on St. Lucie 1, has been shown to be very successful for chloride contaminant control, as indicated by the following table.

St. Lucie Unit 1 Steam Generator Chloride Operating History

(1)	Hours less than detectable chloride % of total	- 5745 hours - 98.2 %
(2)	Hours greater than detectable, but less than 0.5 PPM % of total	- 58 hours - 1 %
(3)	Hours greater than 0.5 PPM, but less than 1.0 PPM % of total	- 44 hours - 0.75 %
(4)	Hours greater than 1.0 PPM % of total	- 3 hours - 0.05 %

Note: Total Operating Hours: 5850; highest concentration detected in the steam generators: 1.25 PPM chloride.

St. Lucie Unit 2 will also follow the practice of periodically performing hydrostatic tests of the condenser tubes to add further assurance of continued condenser tube integrity. In this manner leaks which are virtually incipient can be detected and located, and such tubes removed from service by plugging.

While it appears that egg-crate support structures alone will preclude denting, FPL is continuing to monitor new developments as additional experience is gained at operating plants. In addition, eddy current testing, capable of detecting denting at an early stage, will be employed routinely at St. Lucie Unit 2.

More generally, to deal with the denting phenomenon, a program comprised of the following elements is being developed within the industry (PWR Steam Generator Owner's Group under Electric Power Research Institute (EPRI) management):

(1) Detection of crevice (support to tube clearance) blockage;

(2) Removal of blockages by chemical cleaning methods;

(3) Introduction of a chemical additive that will arrest the fast linear growth of magnetite.

FP&L is actively supporting this program.

There are also complementary efforts underway in the industry relative to chemical cleaning and the development of chemical additives. FPL is actively participating in some of these efforts and is closely following the others to stay abreast of significant developments.

Through these programs, FPL is assisting in developing a means of coping with denting and maintaining a readiness to implement new preventive measures when developed.

Avoidance of Steam Generator Tube Corrosion

The Inconel 600 tubes used in the St. Lucie Unit 2 steam generators are polished and heat treated as described in Attachment A to enhance their resistance to corrosion. In addition, tube corrosion will be further restricted as a result of the design features and operating procedures discussed above, and the control of steam generator sludge, described below.

Avoidance of Steam Generator Sludge Formation

The general corrosion which can occur in a recirculating steam generator is basically the result of one or both of the following:

a) The ingress of a contaminant in sufficient quantity to cause an aggressive environment in the bulk water within the steam generator;

b) The creation of an environment whereby small amounts of contaminants in the bulk water can concentrate to form an aggressive environment locally.

Item a), and to some extent item b), have been discussed above within the context of denting. However, some additional design features should be mentioned with respect to item b).

FPL believes that it is important to minimize the accumulation of sludge in the steam generators, even though All Volatile Treatment (AVT) chemistry control will be utilized at St. Lucie Unit 2. The development of a local, aggressively corrosive environment has historically involved a crevice and/or sludge accumulation in the steam generator. Accordingly, Florida Power & Light Company has incorporated design features and operating procedures to control the accumulation of sludge in the steam generators. St. Lucie Unit 2 will have a feedwater recirculation-cleanup system as described in Attachment B. The recirculation system will be employed during startup to minimize ingress of feedwater train corrosion products and other impurities into the steam generators. Specifically, a condensate pump will be operated to recirculate condensate to permit a sampling of the water from the feed train and condenser hot well.

A process of "bleed and feed", "dump and refill," or recirculation through the cleanup filter is used to adjust the feedwater chemistry to within acceptable limits prior to introducing feedwater to the steam generators.

To minimize the potential problems associated with the existence of crevices where contaminants can concentrate, the steam generator design will also employ a full depth explosive expansion of the tube in the tube sheet as noted in Attachment A to eliminate potential sites for concentration of contaminants.

Another corrosion limiting design feature is deaeration of the condensate storage tank. Condensate storage tank water is used to fill the feedwater system and steam generator during an extended shutdown and subsequent startup. Water from this condensate storage tank is also fed directly to the steam generators in the event of loss of normal feedwater during operation. Deaerated water minimizes the ingress of oxygen into the secondary system which limits the formation of secondary system corrosion products.

In addition, the following limits and controls will be used to restrict the formation and accumulation of sludge in the steam generators:

(1) Blowdown - High steam generator blowdown is an integral part of the secondary chemistry program. A base blowdown rate will normally be maintained and increased to maximum (125 gpm per generator) on plant startup and when steam generator chemistry parameters such as total solids, chlorides, etc., show an increase above normal levels.

(2) Oxygen/Hydrazine - Hydrazine will be automatically controlled at the last feedwater heater outlet at 10 to 50 ppb; this results in no detectable oxygen entering the steam generators and maintains a slight hydrazine residual in the steam generators. To reduce corrosion levels in the secondary system, oxygen is maintained at less than 10 ppb at the condensate header.

(3) Lay-up - A comprehensive lay-up program will be used during outages, including wet lay-up of the steam generators and a combination of wet lay-up and nitrogen over pressure on the feedwater heaters and hot wells. Hydrazine is used as the corrosion inhibitor.

CLIFFORD S. KENT

STATE OF FLORIDA)
) ss.
COUNTY OF DADE)

Subscribed and sworn to before me this 4th day of November, 1977.

My commission expires: NOTARY PUBLIC STATE OF FLORIDA at LARGE MY COMMISSION EXPIRES AUGUST 24, 1981 BONDED THRU MAYNARD BONDING AGENCY

Lois J. Marino

NOTARY PUBLIC

ATTACHMENT A

STEAM GENERATORS

General

The St. Lucie Unit #2 is supplied with two steam generators (pictured on the last page of this attachment) designed and manufactured by Combustion Engineering (C-E). The steam generators are a vertical U-tube, recirculating design. The steam generators utilize the heat produced by the reactor core to generate steam.

The hot reactor coolant from the reactor enters each steam generator through the primary inlet nozzle into the primary head. A divider plate in the primary head constitutes a boundary so that the reactor coolant is directed from the inlet side of the primary head into one end of the vertical U-tubes where heat is transferred to the secondary water through the tube walls. The reactor coolant discharges from the other end of the U-tubes into the outlet side of the primary head and leaves the steam generator through the outlet nozzles to return to the reactor.

Feedwater enters each steam generator through the feedwater nozzle located in the upper portion of the downcomer section and flows into the distribution ring which distributes the feedwater around the periphery of the downcomer section. The perforated internal feedwater piping is located in the downcomer annulus at the approximate level of the top of the tube bundle. The feedwater is distributed via "J" tubes connected to the distribution ring.

The feedwater discharging from the distribution ring mixes with the recirculating water from the steam drum and flows down the downcomer annulus formed by the vessel shell and the tube wrapper and into the tube bundle at the secondary face of the tubesheet. As the water rises through the tube bundle, heat from the reactor coolant, flowing inside the tubes, heats the water, forming steam. The steam and water mixture rises through the tube bundle to the separator support plate. The steam and water mixture then flows through the steam/water separators where the bulk of the water is separated. The water that has been separated from the steam then drains back into the downcomer annulus to mix with feedwater flow. The steam continues to rise to the steam dryers where the remaining water is removed to produce high quality steam. The water from the dryers collects on the drain plates of the dryers, then drains through piping from the dryer plate to the separator support plate and hence to the downcomer annulus.

The steam leaving the steam dryers rises into the upper dome of the steam drum around the deflector and into the steam outlet nozzle where it exits the steam generator.

Construction

Steam generator design and construction features related to denting, tube corrosion and sludge removal include tube installation and support, secondary side flow velocities during normal operation and blowdown pipe configuration.

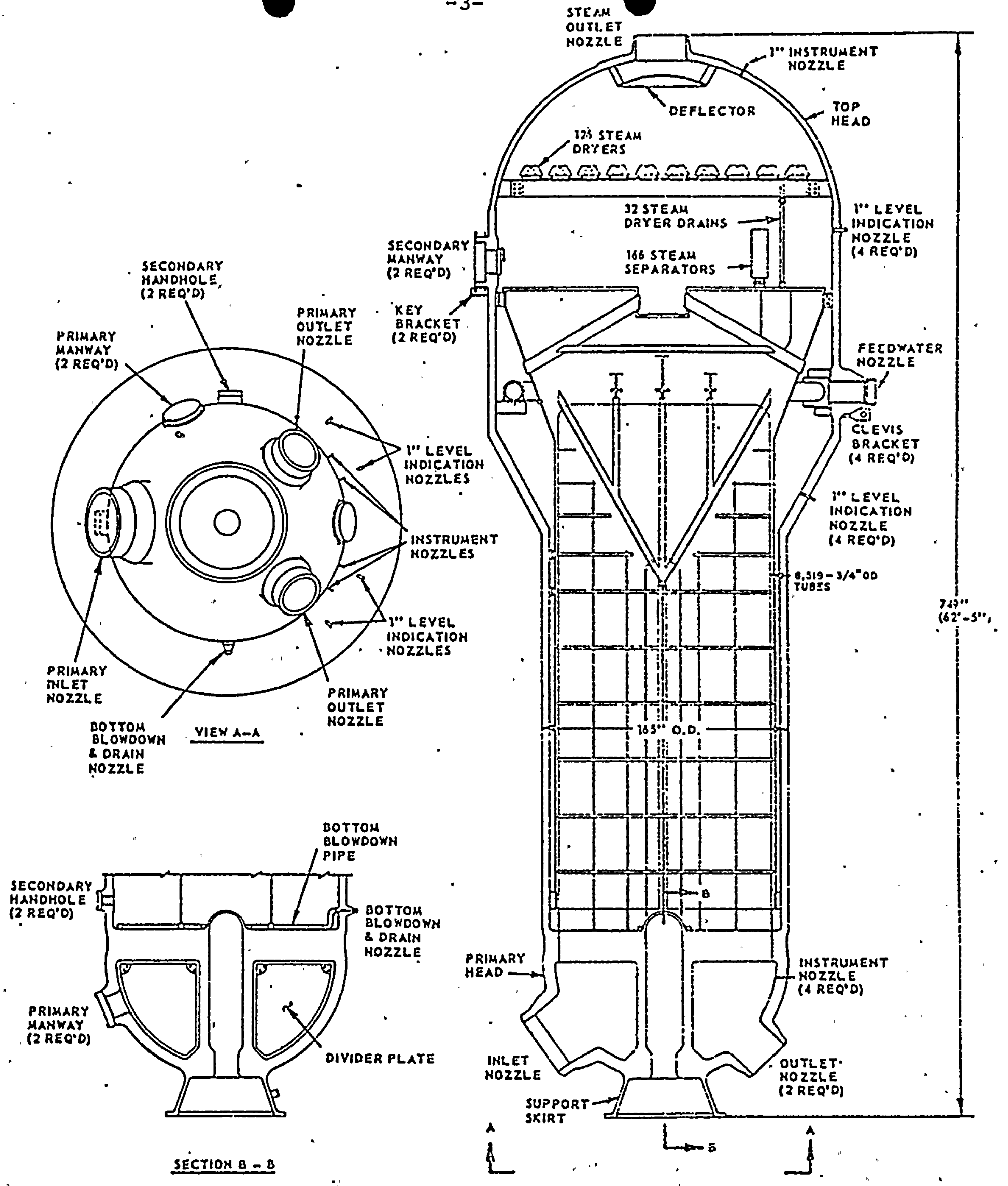
St. Lucie Unit #2 steam generator tubing is constructed from Inconel 600 and is fabricated per specification. This specification invokes ASME-SB-163 and additional quality requirements. These include a belt polished OD surface, four directional ultrasonic tests, and a volumetric eddy current examination. The tubing is supplied in the mill annealed condition; achieved in a moving hearth, hydrogen furnace wherein the tube is heated to 1800°F-1900°F. This temperature provides complete recrystalization of the grain structure after the final tube reduction without permitting excessive grai growth. The tubing is subsequently quenched from the annealing temperature to minimize grain boundary carbide precipitation.

Steam generator tubing is installed in the tubesheet with a primary side weld joint in conjunction with a full depth expansion. The full depth expansion is achieved using an explosive expansion technique. This "explansion" technique eliminates potential sites for the concentration of contaminants and subsequent tube degradation. Possible tube damage due to expansion beyond the tubesheet secondary face is prevented by control of the length and charge size of the explosive plug.

St. Lucie Unit #2 steam generator support design is based on the utilization of "egg crate" support structures as opposed to drilled support plates. The steam generators are provided with seven full suports in the straight portion of the tube bundle. Support in the U-bend region is provided by a system of partial supports (egg crate design), a bat wing support, and four vertical supports. The tube support plate design provides protection from tube damage due to mechanical and flow induced vibration, while offering minimum resistance to steam/water flow in the tube bundle.

The egg crate supports are manufactured from carbon steel strip. The support design provides a large open flow area which avoids the accumulation of water deposits by eliminating local flow eddies. Avoiding the accumulation of corrosion products avoids the concentration of acid producing chloride salts, which are believed to cause accelerated carbon steel support corrosion and subsequent tube denting. Further, if magnetite growth due to chloride salt concentration does occur within the egg crate, the geometry cannot produce the denting phenomena. The thin strips which makeup the support matrix do not have sufficient rigidity to collapse the tube wall.

Blowdown capability is provided by an internal blowdown pipe and a 2" shell nozzle connection. Blowdown capacity is rated as a maximum of 125 gpm per steam generator.



FLORIDA POWER & LIGHT CO. St. Lucie Plant	STEAM GENERATOR	Figure 5.5-7

ATTACHMENT B

FEEDWATER TRAIN

Condensers

The St. Lucie condensers were designed and manufactured by the Westinghouse Condenser Division. They are single pressure, twin shell units having a single cooling water pass. Cooling water is supplied by an ocean intake system and is delivered to the condensers by low head circulating water pumps operating in a siphon system. Design features of the St. Lucie #2 condenser which are directly associated with condenser integrity are the tube material selection, tube installation, and the condenser's mechanical design.

Prior to the placement of the St. Lucie #2 condenser tube order, Florida Power & Light reanalyzed the original selection of aluminum brass condenser tubing. The basis for this decision was the increasing emphasis in the industry concerning condenser in-leakage, the greater restrictions being placed on secondary chemistry, and the continuing decline in the differential cost between copper alloy tubing and titanium tubing. Candidate materials for evaluation included titanium, 90-10 copper-nickel and the originally specified aluminum brass tubing (with 70-30 Cu-Ni in the air cooler). On the basis of a study considering both material considerations and total life economics, Florida Power & Light concluded that the best tubing choice for the St. Lucie #2 condenser would be titanium. FPL subsequently specified titanium tubing for the unit.

Florida Power & Light believes titanium tubing is a good choice for this unit due to both the properties of the metal alloy and to the stringent testing requirements which govern its fabrication. The St. Lucie Unit #2 condenser tubing is fabricated according to ASTM-B-338-73 Grade 2.

The tubing supplied for St. Lucie Unit #2 has successfully completed the following non-destructive examinations as covered in ASTM-B-338.

1) Eddy current testing in accordance with ASTM-E-426-71 of 100% of the tubes. The acceptance test is based on a notch of less than .004 inch or 12.5 percent of wall depth, whichever is less.

2) Ultrasonic testing in accordance with ASTM-E-213-74 of 100% of the tubes. The acceptance criteria is based on a longitudinal notch of less than 10 percent of the nominal tube wall thickness.

3) Pneumatic testing in accordance with ASTM-B-338-73 of 100% of the tubes. This test was performed under water with an internal air pressure of 150 psig. The acceptance criteria is no visible leakage.

Tube installation is another important facet of condenser integrity. Florida Power & Light has specified a tubesheet design based on double grooving to insure adequate pullout strength and leak tightness. While experimental work by Florida Power & Light has shown that tube joints are leak tight without special grooving, grooved joints further enhance the tube joint design.

The mechanical design of the St. Lucie #2 condenser will provide further assurance of overall condenser integrity. The St. Lucie condenser was originally designed for the use of aluminum brass tubes. Following the specification of titanium tubes, Florida Power & Light worked closely with Westinghouse to assure the adequacy of the design in conjunction with the new tubing. On Westinghouse's recommendation, Florida Power & Light installed additional partial tube support plates to ensure adequate tube support would be available. With the addition of these plates, the full advantages of the titanium tube can be utilized without difficulties due to possible vibration failure mechanisms.

<u>Feedwater Heaters</u>

The St. Lucie #2 unit is equipped with 5 stages of feedwater heating arranged in two parallel trains. The tube material used in the first three stages of heating is admiralty manufactured to ASTM-B-395. The tube material used in the 4th stage feedwater heater and its independent drain cooler is 90-10 copper-nickel manufactured to ASTM-B-163. The 5th stage feedwater heaters are tubed with monel tubes manufactured to ASTM-B-111.

<u>Moisture Separator/Reheaters</u>

The St. Lucie Unit #2 is equipped with single stage moisture separation and reheating equipment supplied by Westinghouse. There are four separate MSR's which are tubed with 90-10 Cu-Ni finned tubing.

<u>Secondary System Components: Miscellaneous</u>

The St. Lucie Unit #2 secondary system has been described insofar as the heat transfer apparatus (i.e., steam generator, condenser, feedwater heaters, and moisture separator/reheaters) are concerned. The remainder of the system consisting of a deaerated condensate storage tank, piping, valves, pumps, etc. is constructed of carbon steel and small amounts of stainless steel.

<u>Feedwater Recirculation Line and Filter</u>

The feedwater train is equipped with a recirculation line from the last stage feedwater heater discharge header to the condenser or drains. The purpose of this line is to provide a means of removing feedwater train corrosion products which could form during a system lay-up period. Prior to start-up the system is recirculated. The flow path is from the condenser, through an operating condensate pump, through the low pressure feedwater train, through non-operating boiler feed pumps, through the high pressure heater and through the recirculation line to return to the condenser.

A feedwater recirculation filter is provided in the recirculation line for corrosion product removal. The filter is sized for a flow rate of 25% of the feedwater system flow and is a 5 micron filter.