4 SUMMARY

The following sections summarize the operating experience presented in Section 3. Summaries are provided for each of the three groupings of plants (i.e., model D5, model F, and replacement models). There is also a combined summary. The combined summary includes a discussion on tubes removed for destructive examination, discussion on unscheduled steam generator outages (i.e., forced outages), and observations regarding the results from the inspections.

4.1 Model D5 Summary

There are a total of 73,120 thermally treated tubes in the four plants with model D5 steam generators. Cumulatively, these four plants have operated for 51 calendar years (as of December 2001), and have commercially operated for an average of 13 calendar years (as of December 2001). Of the 73,120 tubes in these steam generators, only 563 tubes (0.8%) have been plugged. This information is summarized in Table 4-1.

Table 4-2 summarizes the number of tubes plugged in the model D5 steam generators as a function of the degradation mechanism. The information in this table is graphically depicted in Figure 4-1. As can be seen from the figure, approximately 53% of the tubes were plugged as a result of tube wear. This wear occurred predominantly at the antivibration bars (AVBs), although some occurred at tube support plates and near loose parts. With only a few tubes being plugged for wear in the preheater region, it appears that the tube expansion at the preheater baffle plates (as discussed in Section 2.2) was successful in mitigating this phenomenon. In addition to tube wear, many (17%) of the tubes were plugged as a result of flaws attributed to manufacturing.

Figures 4-2 and 4-3 depict the number of tubes plugged at each plant as a function of year and refueling outage, respectively. These figures indicate, for the most part, that the four plants are operating similarly. The information in Figure 4-2 is summarized in Tables 4-3 and 4-4. The information in Figure 4-3 is summarized in Table 4-5.

Figure 4-4 depicts the fraction of tubes plugged for a specific mechanism as a function of year. This figure was developed from the data provided in Tables 4-6, 4-7, and 4-8. In this figure, tubes plugged prior to commercial operation were treated as being plugged during the year the plant began commercial operation (in previous tables and figures in this report, tubes plugged prior to operation were treated as a distinct group independent of the actual year/outage in which they were plugged).

Tables 3-1, 3-4, 3-7, and 3-10 indicate that plants with D5 steam generators typically performed bobbin coil inspections in all four steam generators during each refueling outage in the 1990s. In addition, with the exception of Comanche Peak 2, these inspections usually involved a large percentage of the tubes (i.e., greater than 50%). In 2000 and 2001, these plants began reducing the number of steam generators inspected and/or the number of tubes inspected during the refueling outage. For example, in 2000 Comanche Peak 2 only inspected two steam generators, and in 2001 Byron 2 only inspected one steam generator.

4.2 Model F Summary

There are a total of 117,376 thermally treated tubes in the six plants that originally installed model F steam generators in their plants. Cumulatively, these six plants have operated for approximately 88 calendar years as of December 2001, and have commercially operated for an average of 15 calendar years (as of December 2001). Of the 117,376 tubes in these steam generators, only 434 tubes (0.4%) have been plugged. This information is summarized in Table 4-9.

Table 4-10 summarizes the number of tubes plugged in the model F steam generators as a function of degradation mechanism. The information in this table is graphically depicted in Figure 4-5. As can be seen from the figure, approximately 74% of the tubes were plugged as a result of tube wear. This wear occurred predominantly at the AVBs, although some occurred near loose parts. No (or a very limited number of) tubes have been plugged for wear at the tube support plates. In addition to tube wear, many (14%) of the tubes were plugged as a result of manufacturing flaws.

The wear at the AVBs in model F steam generators is primarily observed in the tubes in row 20 and higher on the periphery and row 30 and higher in the middle of the tube bundle. At least one licensee has reported that the AVB wear flaws in the middle of the tube bundle tend to be shallower than those on the periphery. In addition, several licensees reported that the average AVB wear rate generally decreases with time.

Figures 4-6 and 4-7 depict the number of tubes plugged at each plant as a function of year and refueling outage, respectively. These figures indicate, for the most part, that the six plants are operating similarly. The information in Figure 4-6 is summarized in Tables 4-11 and 4-12. The information in Figure 4-7 is summarized in Table 4-13.

Figure 4-8 depicts the fraction of tubes plugged for a specific mechanism as a function of year. This figure was developed from the data provided in Tables 4-14, 4-15, and 4-16. In this figure, tubes plugged prior to commercial operation were treated as being plugged during the year the plant began commercial operation (in previous tables and figures in this report, tubes plugged prior to operation were treated as a distinct group independent of the actual year/outage in which they were plugged).

Tables 3-13, 3-16, 3-19, 3-22, 3-25, and 3-28 indicate that plants with model F steam generators typically inspect 100% of the tubes in two of the four steam generators each refueling outage. Of particular note, however, is that the majority of the tubes at Callaway are mill-annealed.

4.3 Replacement Model Summary

There are a total of 90,766 tubes in the eight plants with replacement steam generators that contain thermally treated Alloy 600 tubes. Cumulatively, these eight plants have operated for approximately 120 calendar years as of December 2001, and have commercially operated for an average of 15 calendar years (as of December 2001). Of the 90,766 tubes in these steam generators, only 400 tubes (0.4%) have been plugged. This information is summarized in Table 4-17.

Table 4-18 summarizes the number of tubes plugged in the replacement model steam generators as a function of degradation mechanism. The information in this table is graphically depicted in Figure 4-9. As can be seen from the figure, approximately 31% of the tubes were plugged as a result of tube wear. This wear occurred predominantly at the AVBs although some occurred near loose parts. No (or a very limited number of) tubes have been plugged for wear at the tube support plates. Replacement steam generators appear to be less susceptible to wear at the AVBs than the model F steam generators as evidenced by operating experience and evaluations. In addition to tube wear, many (33%) of the tubes were plugged as a result of manufacturing flaws.

Figures 4-10 and 4-11 depict the number of tubes plugged at each plant as a function of year and refueling outage, respectively. These figures indicate, for the most part, that the eight plants are operating similarly with the possible exception of Salem 1, which has Model F steam generators, and Turkey Point 3, which has plugged significantly more tubes than the other plants. The information in Figure 4-10 is summarized in Tables 4-19 and 4-20. The information in Figure 4-11 is summarized in Table 4-21.

Figure 4-12 depicts the fraction of tubes plugged for a specific mechanism as a function of year. This figure was developed from the data provided in Tables 4-22, 4-23, and 4-24. In this figure, tubes plugged prior to commercial operation were treated as being plugged during the year the plant began commercial operation (in previous tables and figures in this report, tubes plugged prior to operation were treated as a distinct group independent of the actual year/outage in which they were plugged).

Tables 3-31, 3-34, 3-37, 3-40, 3-43, 3-46, 3-49, and 3-52 indicate that plants with replacement steam generators with thermally treated Alloy 600 tubes have a variety of strategies for inspecting their steam generators. Several plants inspect a subset of steam generators each refueling outage (e.g., one of three steam generators is inspected each outage). This is referred to as "skip steam generator." Others inspect all steam generators every other outage (i.e., no tube inspections are performed during one refueling outage but all steam generators are inspected the next refueling outage). This schedule is referred to as "skip-cycle." Yet others inspect all steam generators every outage. Plants that skip cycles or skip steam generators typically inspect 100% of the tubes in the steam generators inspected.

4.4 Overall Summary

4.4.1 Forced Outages

As of December 2001, the steam generator operating experience of plants with thermally treated Alloy 600 has been favorable. These plants account for approximately 25% of the currently operating PWRs. A historical review identified only six unplanned outages as a result of steam generator issues in plants with thermally treated Alloy 600 tubes: two due to primary-to-secondary leakage and four due to indications of loose parts (e.g., loose parts monitor alarms). These six outages are discussed below. (During the preparation of this report in the first half of 2002, two additional unplanned outages attributed to steam generator issues occurred. One of these was attributed to leakage and one was attributed to an indication of a loose part. These are briefly discussed below.)

Only two plants with thermally treated Alloy 600 tubes have experienced any significant primary-to-secondary leakage. One of these plants, Byron 2, entered a refueling outage early as a result of a 120-gallon-per-day primary-to-secondary leak in 1996. The cause of the leak was a foreign object attributed to thermal-cutting debris from a pipe whose diameter was somewhere between 12 and 18 inches. The foreign object was located on the secondary side of the steam generator. This object damaged four tubes and the tubes were plugged. One tube had a 100% throughwall indication, one had a 56% throughwall indication, and the remaining two tubes were plugged as the result of nonquantifiable volumetric indications found by a rotating pancake coil probe. The other plant, Surry 2, shut down in June 1986 as a result of a leak in an expansion joint on the service water return line from a recirculation spray heat exchanger and to identify the source of a steam generator tube leak. Similar to Byron 2, the source of the Surry 2 leak was a tube affected by a foreign object. One steam generator tube was plugged as a result of this outage. Other plants (e.g., Seabrook) have experienced amounts of leakage (< 5 gallons per day) too small to necessitate a plant shutdown. The sources of such small amounts of leakage are usually never conclusively identified. (As mentioned in the Executive Summary, Byron 2 shut down in June 2002 as a result of a 75- to 80- gpd primary-to-secondary leak. Preliminary investigations indicate the cause of the leak was a loose part.)

In February 2000, the licensee for Point Beach 1 shut down the unit to investigate indications of loose parts in the steam generator. A thorough inspection found no loose parts and the unit was restarted.

In May 1996, Vogtle 1 was shut down in response to a possible loose part on the primary side of steam generator 4. Upon entering the hot-leg channel head, licensee personnel found a support pin nut from a control rod guide tube assembly. The nut's locking device was found wedged into the bottom of a tube and was subsequently removed. Another object, believed to be a fragment of the support pin nut, was found on the cold-leg side of the steam generator. The loose object impacted the lower tubesheet on the hot-leg side and numerous indications were noted. The hot-legs of the other three steam generators did not exhibit any signs of damage. During a subsequent steam generator tube inspection, the shank of the broken support pin was found lodged in a tube. The shank was left in place and the tube was plugged. Damaged tube ends on the tubesheet were rerolled during this outage.

In February 1994, the licensee for Robinson 2 shut down the facility for repairs to an emergency diesel generator. During this shutdown, the licensee also investigated a loose parts monitor alarm. The investigation revealed two strips of metal resting on the tubesheet. Their composition was similar to that of welding electrodes believed to have been used to fabricate the replacement steam generator shell welds. The pieces of metal were removed from the steam generators and two tubes were plugged because of localized wear where the metal objects contacted the tubes. Two nearby tubes had been plugged in prior outages due to either outside diameter wear or manufacturing marks. These indications may have been related to the loose part.

On April 3, 1989, the licensee for Robinson 2 shut down the unit as a result of audio signals indicating a loose part in the hot-leg channel head of steam generator C. When the licensee opened the steam generator manway, a loose part fell out. The part was a split pin nut from a control rod guide tube support. Examination of the tubesheet, tube ends, tube-to-tubesheet welds, and divider plate welds did not reveal conditions that required immediate repair. However, this examination did reveal damage to the tubesheet and tube ends on the hot-leg side of steam generator C. This damage obliterated some of the tubesheet face markings used to identify tubes on the hot leg, complicating the insertion of inspection probes through the hot-leg tube end.

(As briefly discussed in the Executive Summary, Wolf Creek was shut down in May 2002 as a result of a loose part located on the primary side of the steam generator. The part was a control rod guide tube support pin nut and locking device.)

4.4.2 Tube Pulls

To characterize eddy current indications found during steam generator tube inservice inspections, portions of a few tubes have been removed from steam generators with thermally treated Alloy 600 tubes. Based on information supplied to the NRC, tubes have only been removed from two such plants as of December 2001: Surry 1 and Byron 2. The results of these examinations are discussed below. (During the preparation of this report in the first half of 2002, portions of two tubes were removed from Seabrook as discussed below.)

- In 1998, Byron 2 removed portions of three tubes with circumferential indications at the hot-leg expansion transition region for destructive examination. A total of 29 tubes with circumferential indications were identified and plugged and stabilized during this outage. According to the preliminary tube pull results, the circumferential indications were not service-induced cracking or corrosion but shallow grooves that may have been introduced during initial steam generator fabrication or the first few cycles of operation. Burst testing of the indications showed that the indications did not affect the structural integrity of the tubes. Final results from these examinations were not readily available.

- In 1990, portions of two tubes were removed from Surry 1 to examine axial and circumferential anomalies at the top of the tubesheet and were subsequently plugged. The examination found no operationally induced degradation of the tube wall on either of these tubes. Field nondestructive examination results suggested the presence of circumferentially oriented degradation. Upon further review of the nondestructive examination results for one of the pulled tubes, the licensee concluded that the poorly defined rotating pancake coil signal was similar to that of a ding or mechanical deformation. For the other pulled tube, a 70° groove, mechanical in nature, was found on the outside diameter of the tube and attributed to the interaction of the tube with the edge of the tubesheet during the expansion process. Although the hydraulic expansion process used was designed to position the transition slightly below the top of the tubesheet, the licensee concluded that this tube was overexpanded above the top of the tubesheet. In summary, destructive examination of the pulled tube segments detected no corrosion. The nondestructive examination indications were attributed to probe liftoff in the expansion transition and to the tube installation process.

- Portions of one tube were removed from steam generator C at Surry 1 in 1986 to examine an eddy current indication near the uppermost (seventh) tube support plate. The indication was thought to be caused by conductive deposits on the outside surface of the tubes. The tube pull confirmed the absence of degradation where eddy current testing had suggested degradation.

Although tube wear (from support structures and loose parts) is the dominant degradation mechanism, no tubes have been pulled from plants with thermally treated Alloy 600 to characterize these indications.

(As discussed in the Executive Summary, portions of two tubes were pulled from Seabrook in May 2002 to investigate the nature of axial-crack-like indications which were observed at the hot- and cold-leg tube support plates. All of the indications were on the portion of the tube within the thickness of the tube support plate and opposite the broached tube hole lands. In all 15 tubes were found to have indications at 42 tube support plate intersections. The maximum depth of the indications was estimated to be 62% throughwall and the lengths ranged from 0.3 to 0.75 inch. The NRC issued Information Notice 2002-21, "Axial Outside-Diameter Cracking Affecting Thermally Treated Alloy 600 Steam Generator Tubing," on June 25, 2002, describing the nondestructive examination results from Seabrook. The destructive examination confirmed the presence of cracks in these tubes, representing the first confirmed instance of cracking in thermally treated Alloy 600 tubes. The root cause evaluation, including the destructive examination of these two pulled tubes, confirmed that the indications were axially oriented outside diameter stress corrosion cracking, and also identified unusually high levels of residual stress in the straight leg sections of both the hot and cold legs. Nonoptimal tube processing during steam generator manufacturing was strongly suspected to be the primary cause of the high residual stresses and the principal factor increasing the susceptibility of the affected tubes to stress corrosion cracking. The precise processing steps responsible for the adverse stress state could not be conclusively determined from a review of the tube processing records.)

4.4.3 Selected Inspection Findings

Some of the more noteworthy findings from inspections of thermally treated Alloy 600 tubes are summarized below. Except as noted, the tubes discussed below were plugged. In addition, none of these tubes were removed for destructive examination except for two of the tubes at Seabrook (as discussed in Section 4.4.2).

- As briefly discussed in the Executive Summary, axial crack-like indications were detected at 42 tube-to-tube-support-plate intersections in 15 tubes at Seabrook in May 2002. Two tubes were pulled to characterize the nature of the degradation. The destructive examination confirmed the presence of cracks in these tubes, representing the first confirmed instance of cracking in thermally treated Alloy 600 tubes. The root cause evaluation, including the destructive examination of these two pulled tubes, confirmed that the indications were axially oriented outside diameter stress corrosion cracking, and also identified unusually high levels of residual stress in the straight leg sections of both the hot and cold legs. Nonoptimal tube processing during steam generator manufacturing was strongly suspected to be the primary cause of the high residual stresses and the principal factor increasing the susceptibility of the affected tubes to stress corrosion cracking. The precise processing steps responsible for the adverse stress state could not be conclusively determined from a review of the tube processing records.

- At Millstone 3 in February 2001, 29 single volumetric indications at the top of the tubesheet and flow distribution baffle were identified. These indications were attributed to wear due to loose parts and to fabrication-related defects.

- At Turkey Point 3 in 2001, 12 tubes were plugged as a result of indications of mechanical wear at the broached tube support plates. Plugging of tubes for wear at tube support plates is fairly rare in plants with thermally treated Alloy 600 tubes.

- At Turkey Point 3 in the spring of 2000, 41 volumetric pitlike indications, 15 inside-diameter-initiated circumferential indications, and 8 outside-diameter-initiated circumferential indications were identified. Most of these indications were in the hot-leg hydraulic-expansion transition region at the top of the tubesheet. The volumetric and circumferential indications were detected with rotating probes. This was the first time rotating probes were extensively used at Turkey Point 3. As a result of these findings, the licensee began a review of historical data and industry experience, during the outage, to assess the root causes of the tube degradation. Because of the lack of prior rotating probe inspection data for Turkey Point 3 and the limited number of defects identified by the industry in thermally treated Alloy 600 tubes, the results, at the time of the inspection, were inconclusive for the circumferential and volumetric indications. Based on subsequent investigation, the licensee concluded that of the 64 volumetric and circumferential indications originally identified, only 26 tubes contain volumetric or pitlike indications (possibly due to manufacturing and installation artifacts), while the remaining 38 tubes contain no degradation (13 had circumferential geometric anomalies, 23 had dings or dents, and 2 had manufacturing buff marks).

- In an outage at Turkey Point 4 in the fall of 2000, the licensee detected seven tubes with possible corrosion degradation and plugged these tubes since a qualified depth-sizing technique was not available. Based on the eddy current and ultrasonic examination results of this inspection, the licensee reanalyzed the spring 2000 Unit 3 data (discussed above). The licensee's judgment is that the indications at Unit 3 were false positives and caused by manufacturing anomalies or deposits at the top of tubesheet or by the inspection techniques associated with the rotating probe. These results are discussed in NRC Information Notice 2001-016, "Recent Foreign and Domestic Experience With Degradation of Steam Generator Tubes and Internals."

- At Surry 1 in 2000 and 2001, denting of tubes at the sixth and seventh tube supports was detected. These dents corresponded to the quatrefoil lands. The dents are concentrated in the periphery of the tube bundle near the wedge regions and are located at (or near) the edges of the support plate.

- At Braidwood 2 in 1996, one axial indication was detected in a small-radius tube (in row 1). The licensee concluded at that time that the most likely cause for this indication was primary water stress corrosion cracking (PWSCC).

- At Callaway in 1996, axial, circumferential, and volumetric indications were detected at the hot-leg expansion transition. Additional indications were detected near the top of the tubesheet (i.e., the expansion transition region) in subsequent outages.

- At Millstone 3 in August 1993, a tube was deplugged in order to replace the plug with a more corrosion-resistant material. This tube had been plugged in 1989 as a result of a 43% throughwall wear indication at the fifth anti-vibration bar. During the 4 years the tube was plugged, the defect had apparently grown from 43% to 100% throughwall. To prevent the tube from severing at the defect and contacting adjacent tubes, a stabilizer was inserted before the tube was replugged.

- At Callaway in 1992, one undefined indication was detected in a row 2 tube. The indication, located just above the seventh cold-leg support plate, was not identified with the bobbin coil. The licensee concluded that this indication was an anomaly since no degradation mechanism had been identified in this region. In addition, a senior eddy current analyst judged this indication to be a distorted signal caused by its location in the U-bend transition.

- At Surry 2 in the mid-1990s, the licensee began detecting a limited number of pitlike indications above the tubesheet on the cold-leg side of the steam generator. The licensee used the rotating pancake coil terrain plot display as the primary basis for classifying the signals as pitlike indications. The indications were nearly round and were located in the cold leg above the tubesheet expansion transition, where pitting might be expected given the chemistry conditions. Some of these tubes with pitlike indications were initially left in service. The pitting is believed to have initiated before the chemical cleaning which was performed in 1994. New pits are unlikely to initiate in future cycles because the licensee removes copper-rich sludge, the major contributor to pitting, and has improved its chemistry control program. The licensee eventually plugged all 12 tubes with pitlike indications due to the uncertainty in nondestructive sizing estimates.

4.4.4 Summary and Observations

As depicted in Figure 4-13, there were 281,262 thermally treated Alloy 600 tubes placed in service at 18 plants between 1980 and 2001. Cumulatively, these 18 plants have operated for approximately 260 calendar years (as of December 2001) and have commercially operated for an average of 14 calendar years (as of December 2001). Of these 281,262 tubes, only 1397 tubes (0.5%) have been plugged. The number and percentage of tubes plugged at the 18 plants with thermally treated tubes are summarized in Table 4-25. Figure 4-14 depicts the total number and percentage of tubes plugged in plants with thermally treated Alloy 600 tubes as a function of model/grouping (i.e., model D5, model F, replacement models).

Tables 4-26 and 4-27 summarize the causes of tube plugging for Model D5, Model F, and replacement steam generators. In addition, these tables summarize the causes of tube plugging for all steam generators with thermally treated Alloy 600 tubes. The information in these tables is graphically depicted in Figure 4-15. As can be seen from the tables and figure, the dominant degradation mode of thermally treated Alloy 600 tubes is wear. Of the approximately 1400 tubes plugged, approximately 53% of the tubes were plugged as a result of tube wear. Tube wear occurs as a result of contact between the tube and a support structure (e.g., an anti-vibration bar) or a foreign object (e.g., a loose part). Loose parts can be introduced during steam generator fabrication, during maintenance activities, or as a result of corrosion degradation of other components in the primary or secondary side of the steam generator (e.g., a split pin nut). The rate of tube wear from support structures is generally predictable and is readily managed. Wear from loose parts is usually unexpected and can only be detected by inspection, loose parts monitoring systems, or primary-to-secondary leakage. The wear in thermally treated tubes has occurred predominantly at the AVBs although some occurred near loose parts. A very limited number of tubes have been plugged for wear at the tube support plates.

The percentage of tubes plugged for wear is greater for the Model F steam generators than for the Model D5 or replacement model steam generators. Manufacturing flaws also accounted for a significant percentage of tube plugging, accounting for 21% of the tubes plugged. The plugging of 23% of the tubes was attributed to "other" degradation mechanisms. Several tubes have been plugged due to restrictions. The nature and causes of many of these restrictions have not been provided.

Plants with replacement steam generators with thermally treated Alloy 600 tubes have a variety of strategies for inspecting their steam generators. Several plants inspect a subset of steam generators each refueling outage (e.g., one of three steam generators is inspected each outage). This is referred to as "skip steam generator." Others inspect all steam generators every other outage (i.e., no tube inspections are performed during one refueling outage but all steam generators are inspected the next refueling outage). This schedule is referred to as "skip-cycle." Yet others inspect all steam generators every outage. Plants that skip cycles or skip steam generators typically inspect 100% of the tubes in the steam generators inspected. In general, licensees with thermally treated Alloy 600 tubes inspect a subset of the total number of steam generators during an outage (e.g., two of four steam generators are inspected during one outage and the remaining two steam generators are inspected during the next outage). Such inspection programs result in an inspection frequency for thermally treated Alloy 600 tubes of every two cycles. At a few plants, steam generators are inspected every three operating cycles (e.g., at intervals of 48 effective full-power months).

Based on a review of inspection summary reports, tube inspections in plants with thermally treated Alloy 600 have become more comprehensive since the early 1980s. The inspections today focus on ensuring tube integrity for the interval between inspections consistent with Nuclear Energy Institute 97-06, "Steam Generator Program Guidelines." There have been no reported instances in which a thermally treated Alloy 600 tube did not satisfy the structural performance criterion (e.g., three times the normal operating differential pressure).

Figure 4-16 depicts the number of tubes plugged for each type of thermally treated Alloy 600 steam generator (e.g., Model D5) as a function of year. Similarly, Figure 4-17 provides the percentage of tubes plugged for each type of thermally treated Alloy 600 steam generator (e.g., Model D5) as a function of year. The percentage of tubes plugged each year has been relatively constant since the early 1990s. The data used to compile these figures is summarized in Table 4-28.

Figure 4-18 depicts the fraction of tubes plugged for a specific mechanism as a function of year. This figure was developed from the data provided in Tables 4-29, 4-30, and 4-31. In this figure, tubes plugged prior to commercial operation were treated as being plugged during the year the plant began commercial operation (in previous tables and figures in this report, tubes plugged prior to operation were treated as a distinct group independent of the actual year/outage in which they were plugged).

As a result of reviewing the operating experience with thermally treated Alloy 600 steam generator tubes, the following observations are made:

- A number of plants with mill-annealed Alloy 600 tubes stabilize tubes as a result of finding circumferential indications. Stabilization is intended to prevent a plugged tube from contacting neighboring tubes in the event that it severs. A tube could sever as a result of tube degradation that continues to progress following plugging. Some plants assess the need to stabilize forms of degradation (e.g., wear) other than circumferential indications and preventively stabilize tubes when indications reach or are projected to reach certain limits.

- At least one plant identified a tube that continued to wear following plugging. The wear indication proceeded throughwall after being plugged four years earlier with a 43% throughwall indication. The potential for tubes to continue to degrade following plugging raises questions about the need for tube stabilization in the future.

- Plugging of tubes for wear at tube support plates is fairly uncommon in plants with thermally treated Alloy 600 tubes. Recently plants have reported plugging tubes for this form of degradation. In addition, plants have been observing denting at tube supports corresponding to the quatrefoil lands.

- Some plants cut out access ports in the steam generator shell in order to remove loose parts. Plants remove the loose parts to prevent the initiation or continuation of wear degradation to tubes and/or to avoid preventively plugging and stabilizing tubes that may potentially be affected by these loose parts.

- Several plants, if not all, plug stub tubes since these locations are not routinely inspected during the inservice inspection.

- Several plants have reported tube expansion anomalies in the tubesheet. These areas are locations where degradation is likely to occur. These anomalies include tubes that were not expanded, tubes that were not expanded for the full length of the tubesheet, and tubes that were expanded above the top of the secondary face of the tubesheet. For tubes that were not expanded, some plants have plugged these tubes while others have reexpanded the tubes to avoid inspecting these tubes every outage (presumably with a rotating probe). Tubes that were not expanded do not appear to be found until well after the start of operation. When a tube was not fully expanded for the full length of the tubesheet, the expansion transition occurs below the secondary face of the tubesheet, resulting in an open crevice region where sludge deposits can accumulate. The expansion of a tube above the top of the secondary face of the tubesheet is an anomaly which results in an area of higher stress. Some plants inspect all identified expansion anomalies with a rotating probe.

- Performing tube inspections concurrent or after maintenance activities (e.g., sludge lancing) may make it difficult to assess the cause of indications since the maintenance activities may cause the loose parts to move . On the other hand, performing tube inspections before maintenance activities may result in missing indications of degradation induced during these activities and/or result in missing opportunities to find loose parts introduced as a result of these activities.

- Manufacturing buff marks (MBMs) and free span differential (FSD) signals are the result of a light buffing of the tubes to remove small imperfections of the tubing outside diameter. The two types of signals are generally analogous, except that the FSDs are readily discernable in the differential channels of the eddy current data, whereas MBMs are called in the absolute channel. Historical reviews are frequently performed for MBMs and FSD signals to determine if they have changed phase angle and/or voltage since the baseline. If the signal changes, supplemental rotating probe testing is typically performed.

- The few tubes pulled for destructive examination suggest that manufacturing anomalies or some other phenomena are producing eddy current signals indicative of degradation. The ability of the nondestructive examination techniques to distinguish true flaw signals from these anomalous inspection signals may become important as the second-generation steam generators age (and the potential for corrosion increases). Performing comprehensive baseline inspections before the steam generators are placed in service could provide confidence that "anomalous" nondestructive examination signals are truly signals from manufacturing marks rather than from service-induced conditions.

- Plants initially identify manufacturing flaws well after placing the steam generators in service. This is attributed to many factors including more stringent calling criteria, improvements in analyst performance, and improvements in inspection technology.

- Plants have found a number of indications (volumetric and linear) for which no definitive root cause was identified (although plausible explanations for the indications were put forward). The frequency of finding such indications appears to be increasing.

- A number of volumetric indications attributed to tube wear have been detected in the midspan of tubes and/or in the interior of the tube bundle. Material reviewed during the development of this report contained no insights on how a foreign object moves deep into the interior of the tube bundle without damaging other tubes on its path. In addition, no information was available on whether an object was found or retrieved near the location of the tube wear in many of these cases.

- Obstructions to the passage of bobbin coil probes have been identified in a few tubes. These obstructions were often identified only after a number of years of operation. The causal mechanism for these obstructions was not readily ascertainable. Obstructed tubes were reported at Callaway in 1996 (in a tube inspected in 1992), Comanche Peak in 1997, Surry 1 and 2 in the mid-1990s as well as in 1986, Vogtle 1 in 1997, and Robinson 2 in 2001.

- Volumetric indications have been detected at several plants. The cause of these indications has not been determined through removal of tubes for destructive examination. Destructive examination might provide insights on the nature of the indications. Volumetric indications have been reported at a number of plants, including Braidwood 2 in 1996 (1H), Byron 2 in 1996 (2C and 1H), Byron 2 in 2001 (above 2C), and at Wolf Creek in various years.

Far fewer tubes have been plugged in the steam generators with second-generation tube materials (i.e., thermally treated alloy 600) than in earlier steam generators with comparable operating times. Improvements in the design and operation of the second-generation steam generators appear to have increased the corrosion resistance of the tubes, as evidenced by the general lack of any significant amounts of corrosion degradation. The enhanced corrosion resistance is largely due to the thermal treatment process that has superseded the mill annealing process used in earlier steam generator designs.

The relatively good operating experience for plants with thermally treated Alloy 600 steam generator tubes can be attributed to several factors in addition to the heat treatment the tubes received: hydraulic expansion of the tubes into the tubesheet, the quatrefoil design of the tube support plates, and the stainless steel material used to fabricate the plates. The residual stress levels at the expansion transition in tubes hydraulically expanded into the tubesheet are lower than observed in plants whose tubes were expanded mechanically or explosively. Since crack growth rate and time to crack initiation depend, in part, on the stress level, lower stresses may result in lower crack growth rates and/or longer times before crack initiation.

This historical review has identified a number of issues which may warrant additional investigation in the future.

Although the operating experience with thermally treated Alloy 600 tubes has been favorable to date, there is a continued need to monitor the tubes to detect the onset of tube degradation (including cracking) and to assure the structural and leakage integrity of the tubes during the intervals between inspections. A better understanding of the nature of a number of these findings would be useful in determining appropriate intervals for future monitoring of tube degradation.

Table 4-1: Model D5: Total Number and Percentage of Tubes Plugged (12/01)

Plant	Number of Tubes Plugged[1]	Percent Plugged	Operating Time[2]
Braidwood 2	120	0.66	13
Byron 2	223	1.22	14
Catawba 2	183	1.00	15
Comanche Peak 2	37	0.20	8
TOTALS:	563	0.77	

[1]As of 12/31/01
[2]Operating Time = calendar years of operation as of 12/31/01

Table 4-2: Model D5: Number of Tubes Plugged as a Function of Mechanism (Detailed) (12/01)

Cause of Tube Plugging		Tubes Plugged	Percentage of Plugs	Tubes Plugged	Percentage of Plugs
Wear	AVB	258	45.8%	**262**	**46.5%**
	Pre-heater TSP (D5)	2	0.4%		
	TSP	2	0.4%		
Loose Parts	Confirmed	19	3.4%	**38**	**6.7%**
	Not Confirmed, Periphery	16	2.8%		
	Not Confirmed, Not Periphery	3	0.5%		
Obstruction Restriction	From PSI - no progression	0	0.0%	**2**	**0.4%**
	Service Induced	2	0.4%		
Manufacturing Flaws	Preservice	50	8.9%	**94**	**16.7%**
	Other	44	7.8%		
Inspection Issues	Probe Lodged	2	0.4%	**15**	**2.7%**
	Data Quality	2	0.4%		
	Dent/Geometry	4	0.7%		
	Permeability	4	0.7%		
	Not Inspected	3	0.5%		
Other	Top of Tubesheet	18	3.2%	**152**	**27.0%**
	Free Span	80	14.2%		
	TSP	44	7.8%		
	Other/Not Reported	10	1.8%		
SCC	ID	0	0.0%	**0**	**0.0%**
	OD	0	0.0%		
	TOTALS	563	100.0%	563	100.0%

Total Tubes: 73120
Fraction Plugged 0.77%

Table 4-3: Model D5: Cumulative Plugging Per Year

Year	Braidwood 2	Byron 2	Catawba 2	Comanche Peak 2
Pre-Op	6	11	14	20
1986				
1987			14	
1988			21	
1989		22	29	
1990	8	43	48	
1991	19		60	
1992		72		
1993	34	108	103	
1994	40		134	20
1995		137	157	
1996	75	167		20
1997	103		167	28
1998		205	176	
1999	109	219		33
2000	120		183	37
2001		223	183	

Table 4-4: Model D5: Plugging Per Year

Year	Braidwood 2	Byron 2	Catawba 2	Comanche Peak 2	Model D5 Totals
Pre-Op	6	11	14	20	51
1986					0
1987			0		0
1988			7		7
1989		11	8		19
1990	2	21	19		42
1991	11		12		23
1992		29			29
1993	15	36	43		94
1994	6		31	0	37
1995		29	23		52
1996	35	30		0	65
1997	28		10	8	46
1998		38	9		47
1999	6	14		5	25
2000	11		7	4	22
2001		4	0		4
Totals:	120	223	183	37	563

Table 4-5: Model D5: Cumulative Plugging Per RFO

Outage	Braidwood 2	Byron 2	Catawba 2	Comanche Peak 2
Pre-Op	6	11	14	20
RFO 1	8	22	21	20
RFO 2	19	43	29	20
RFO 3	34	72	48	28
RFO 4	40	108	60	33
RFO 5	75	137	103	37
RFO 6	103	167	134	
RFO 7	109	205	157	
RFO 8	120	219	167	
RFO 9		223	176	
RFO 10			183	
RFO 11			183	

Table 4-6: Model D5: Number of Tubes Plugged As a Function of Mechanism Per Year (Detailed)

Cause of Tube Plugging/Outage	Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals	Totals
Wear	AVB										2	35	17	25	51	7	22	48	19	2	15	15		258	262
	Pre-heater TSP (D5)																			1	1			2	
	TSP																			2				2	
Loose Parts	Confirmed									2	4						1	6	2	3			1	19	38
	Not Confirmed, Periphery										1				1		7				5		2	16	
	Not Confirmed, Not Periphery																				1	2		3	
Obstruction Restriction	From PSI - no progression																							0	2
	Service Induced																		1		1			2	
Manufacturing Flaws	Preservice							14	11	6					19									50	94
	Other																		15	29				44	
Inspection Issues	Probe Lodged																					2		2	15
	Data Quality										1								1					2	
	Dent/Geometry										1							1		2				4	
	Permeability																		2	1		1		4	
	Not Inspected																		1			2		3	
Other	Top of Tubesheet										2				3	4	2	1	3	2	1			18	152
	Free Span									3	4	1	1	3	30	20	10	5	2				1	80	
	TSP									2	3	4	5	1	8	6	5	4		5	1			44	
	Not Reported										1	2			2		5							10	
SCC	ID																							0	0
	OD																							0	
	TOTALS	0	0	0	0	0	0	14	11	13	19	42	23	29	114	37	52	65	46	47	25	22	4	563	563
Notes																									

Notes

Table 4-7: Model D5: Number of Tubes Plugged As a Function of Mechanism Per Year (Summary)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
Cause																							
Wear										2	35	17	25	51	7	22	48	19	5	16	15		262
Loose Parts									2	5				1		8	6	2	3	6	2	3	38
Restrictions																		1		1			2
Manufacturing							14	11	6					19				15	29				94
Inspection Issues										2							1	4	3		5		15
Other									5	10	7	6	4	43	30	22	10	5	7	2		1	152
SCC																							0
	0	0	0	0	0	0	14	11	13	19	42	23	29	114	37	52	65	46	47	25	22	4	563
Notes																							

Notes

Table 4-8: Model D5: Fraction of Tubes Plugged As a Function of Mechanism Per Year (Summary)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
Cause																							
Wear										0 11	0 83	0 74	0 86	0 45	0 19	0 42	0 74	0 41	0 11	0 64	0 68		0 47
Loose Parts									0 15	0 26				0 01		0 15	0 09	0 04	0 06	0 24	0 09	0 75	0 07
Restrictions																		0 02		0 04			0 00
Manufacturing							1 00	1 00	0 46					0 17				0 33	0 62				0 17
Inspection Issues										0 11							0 02	0 09	0 06		0 23		0 03
Other									0 38	0 53	0 17	0 26	0 14	0 38	0 81	0 42	0 15	0 11	0 15	0 08		0 25	0 27
SCC																							
	0 00	0 00	0 00	0 00	0 00	0 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00
Notes																							

Notes

Table 4-9: Model F: Total Number and Percentage of Tubes Plugged (12/01)

Plant	Number of Tubes Plugged[1]	Percent Plugged	Operating Time[2]
Callaway[3]	17	0.35	17
Millstone 3	106	0.47	16
Seabrook 1	90	0.40	11
Vogtle 1	48	0.21	15
Vogtle 2	29	0 13	13
Wolf Creek 1	144	0 64	16
TOTALS:	434	0.37	

[1]As of 12/31/01
[2]Operating Time = calendar years of operation as of 12/31/01
[3]Thermally Treated Tubes only

Table 4-10: Model F: Number of Tubes Plugged as a Function of Mechanism (Detailed) (12/01)

Cause of Tube Plugging		Tubes Plugged	Percentage of Plugs	Tubes Plugged	Percentage of Plugs
Wear	AVB	295	68.0%	**295**	**68.0%**
	Pre-heater TSP (D5)	0	0.0%		
	TSP	0	0.0%		
Loose Parts	Confirmed	9	2.1%	**24**	**5.5%**
	Not Confirmed, Periphery	10	2.3%		
	Not Confirmed, Not Periphery	5	1.2%		
Obstruction Restriction	From PSI - no progression	0	0.0%	**2**	**0.5%**
	Service Induced	2	0.5%		
Manufacturing Flaws	Preservice	63	14.5%	**63**	**14.5%**
	Other	0	0.0%		
Inspection Issues	Probe Lodged	0	0.0%	**0**	**0.0%**
	Data Quality	0	0.0%		
	Dent/Geometry	0	0.0%		
	Permeability	0	0.0%		
	Not Inspected	0	0.0%		
Other	Top of Tubesheet	19	4.4%	**50**	**11.5%**
	Free Span	13	3.0%		
	TSP	18	4.1%		
	Other/Not Reported	0	0.0%		
SCC	ID	0	0.0%	**0**	**0.0%**
	OD	0	0.0%		
	TOTALS	434	100.0%	434	100.0%

Total Tubes: 117376
Fraction Plugged 0.37%

Table 4-11: Model F: Cumulative Plugging Per Year

Outage	Callaway	Millstone 3	Seabrook	Vogtle 1	Vogtle 2	Wolf Creek
Pre-Op	4	10	13	6	15	15
1986	4					15
1987	5	12				
1988				7		37
1989	6	16				
1990	6			11	15	39
1991		21	23	11		39
1992	7		23		15	
1993	7	28		15	15	44
1994			24	27		71
1995	11	39	36		18	
1996	16	41		31	24	87
1997			49	46		106
1998	16				24	
1999	16	55	74	46	29	112
2000			90	48		144
2001	17	106			29	

Table 4-12: Model F: Plugging Per Year

Outage	Callaway	Millstone 3	Seabrook	Vogtle 1	Vogtle 2	Wolf Creek	Model F Totals
Pre-Op	4	10	13	6	15	15	63
1986	0					0	0
1987	1	2					3
1988				1		22	23
1989	1	4					5
1990	0			4	0	2	6
1991		5	10	0		0	15
1992	1		0		0		1
1993	0	7		4	0	5	16
1994			1	12		27	40
1995	4	11	12		3		30
1996	5	2		4	6	16	33
1997			13	15		19	47
1998	0				0		0
1999	0	14	25	0	5	6	50
2000			16	2		32	50
2001	1	51			0		52
Totals:	17	106	90	48	29	144	434

Table 4-13: Model F: Cumulative Plugging Per RFO

Outage	Callaway	Millstone 3	Seabrook	Vogtle 1	Vogtle 2	Wolf Creek
Pre-Op	4	10	13	6	15	15
RFO 1	4	12	23	7	15	15
RFO 2	5	16	23	11	15	15
RFO 3	6	21	24	11	15	37
RFO 4	6	28	36	15	18	39
RFO 5	7	39	49	27	24	39
RFO 6	7	55	74	31	24	44
RFO 7	11	106	90	46	29	71
RFO 8	16			46	29	87
RFO 9	16			48		106
RFO 10	16					112
RFO 11	17					144

Table 4-14: Model F: Number of Tubes Plugged As a Function of Mechanism Per Year (Detailed)

Cause of Tube Plugging/Outage	Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals	Totals
Wear	AVB								2	19	3	6	11		16	38	26	28	38		49	44	15	295	295
	Pre-heater TSP (D5)																							0	
	TSP																							0	
Loose Parts	Confirmed												4						5					9	24
	Not Confirmed, Periphery																2				1	1	6	10	
	Not Confirmed, Not Periphery																		2			2	1	5	
Obstruction Restriction	From PSI - no progression																							0	2
	Service Induced																		2					2	
Manufacturing Flaws	Preservice					4	15	10	6		15	13												63	63
	Other																							0	
Inspection Issues	Probe Lodged																							0	0
	Data Quality																							0	
	Dent/Geometry																							0	
	Permeability																							0	
	Not Inspected																							0	
Other	Top of Tubesheet																	3				2	14	19	50
	Free Span									4	1		0	1			2	2					3	13	
	TSP								1		1					2						1	13	18	
	Not Reported																							0	
SCC	ID																							0	0
	OD																							0	
	TOTALS	0	0	0	0	4	15	10	9	23	20	19	15	1	16	40	30	33	47	0	50	50	52	434	434
Notes																									

Notes

Table 4-15: Model F: Number of Tubes Plugged As a Function of Mechanism Per Year (Summary)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
Cause																							
Wear								2	19	3	6	11		16	38	26	28	38		49	44	15	295
Loose Parts												4				2		7		1	3	7	24
Restrictions																		2					2
Manufacturing					4	15	10	6		15	13												63
Inspection Issues																							0
Other								1	4	2			1		2	2	5				3	30	50
SCC																							0
	0	0	0	0	4	15	10	9	23	20	19	15	1	16	40	30	33	47	0	50	50	52	434
Notes:																							

Notes

Table 4-16: Model F: Fraction of Tubes Plugged As a Function of Mechanism Per Year (Summary)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
Cause																							
Wear								0 22	0 83	0 15	0 32	0 73		1 00	0 95	0 87	0 85	0 81		0 98	0 88	0 29	0 68
Loose Parts												0 27				0 07		0 15		0 02	0 06	0 13	0 06
Restrictions																		0 04					0 00
Manufacturing					1 00	1 00	1 00	0 67		0 75	0 68												0 15
Inspection Issues																							
Other								0 11	0 17	0 10			1 00		0 05	0 07	0 15				0 06	0 58	0 12
SCC																							
	0 00	0 00	0 00	0 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	0 00	1 00	1 00	1 00	1 00
Notes																							

Notes

Table 4-17: Replacement Models: Total Number and Percentage of Tubes Plugged (12/01)

Plant	Number of Tubes Plugged[1]	Percent Plugged	Operating Time[2]
Indian Point 2	2	0.02	1
Point Beach 1	10	0.16	18
Robinson 2	39	0.40	17
Salem 1	58	0.26	4
Surry 1	43	0.43	20
Surry 2	39	0.39	21
Turkey Point 3	166	1.72	20
Turkey Point 4	43	0.45	19
TOTALS:	400	0.44	

[1]As of 12/31/01
[2]Operating Time = calendar years of operation as of 12/31/01

Table 4-18: Replacement Models: Number of Tubes Plugged as a Function of Mechanism (Detailed) (12/01)

Cause of Tube Plugging		Tubes Plugged	Percentage of Plugs	Tubes Plugged	Percentage of Plugs
Wear	AVB	93	23.3%	107	26.8%
	Pre-heater TSP (D5)	0	0.0%		
	TSP	14	3.5%		
Loose Parts	Confirmed	3	0.8%	15	3.8%
	Not Confirmed, Periphery	11	2.8%		
	Not Confirmed, Not Periphery	1	0.3%		
Obstruction Restriction	From PSI - no progression	2	0.5%	19	4.8%
	Service Induced	17	4.3%		
Manufacturing Flaws	Preservice	121	30.3%	131	32.8%
	Other	10	2.5%		
Inspection Issues	Probe Lodged	0	0.0%	7	1.8%
	Data Quality	4	1.0%		
	Dent/Geometry	0	0.0%		
	Permeability	3	0.8%		
	Not Inspected	0	0.0%		
Other	Top of Tubesheet	102	25.5%	121	30.3%
	Free Span	12	3.0%		
	TSP	7	1.8%		
	Other/Not Reported	0	0.0%		
SCC	ID	0	0.0%	0	0.0%
	OD	0	0.0%		
	TOTALS	400	100.0%	400	100.0%

Total Tubes: 90766
Fraction Plugged 0.44%

Table 4-19: Replacement Models: Cumulative Plugging Per Year

Outage	Indian Point 2	Point Beach 1	Robinson 2	Salem 1	Surry 1	Surry 2	Turkey Point 3	Turkey Point 4
Pre-Op	2	4	28	13	2	2	39	31
1980								
1981						2		
1982								
1983					2	2	39	
1984		4			6			31
1985		4				2	43	
1986		4	28		10	3		31
1987		4	28				44	
1988		6	29		10	3		32
1989		6	29					
1990		6	30		12		55	
1991		8				3		33
1992		8	31		14		62	
1993		8	32			5		33
1994		8	34		18		66	33
1995		9	34		19	10	68	
1996		9	35			18		33
1997					24	23	82	33
1998		9	35		30		83	
1999		9	35	23		32		33
2000		9			38	39	152	43
2001		10	39	58	43		166	

Table 4-20: Replacement Models: Plugging Per Year

Outage	Indian Point 2	Point Beach 1	Robinson 2	Salem 1	Surry 1	Surry 2	Turkey Point 3	Turkey Point 4	Replacement Totals
Pre-Op	2	4	28	13	2	2	39	31	121
1980									0
1981						0			0
1982									0
1983					0	0	0		0
1984		0			4			0	4
1985		0				0	4		4
1986		0	0		4	1		0	5
1987		0	0				1		1
1988		2	1		0	0		1	4
1989		0	0						0
1990		0	1		2		11		14
1991		2				0		1	3
1992		0	1		2		7		10
1993		0	1			2		0	3
1994		0	2		4		4	0	10
1995		1	0		1	5	2		9
1996		0	1			8		0	9
1997					5	5	14	0	24
1998		0	0		6		1		7
1999		0	0	10		9		0	19
2000		0			8	7	69	10	94
2001		1	4	35	5		14		59
Totals:	2	10	39	58	43	39	166	43	400

Table 4-21: Replacement Models: Cumulative Plugging Per RFO

Outage	Indian Point 2	Point Beach 1	Robinson 2	Salem 1	Surry 1	Surry 2	Turkey Point 3	Turkey Point 4
Pre-Op	2	4	28	13	2	2	39	31
RFO 1		4	28	23	2	2	39	31
RFO 2		4	28	58	6	2	43	31
RFO 3		4	29		10	2	44	32
RFO 4		6	30		10	3	55	33
RFO 5		6	31		12	3	62	33
RFO 6		6	32		14	3	66	33
RFO 7		8	34		18	5	68	33
RFO 8		8	35		19	10	82	33
RFO 9		8	35		24	18	83	33
RFO 10		8	35		30	23	152	43
RFO 11		9	39		38	32	166	
RFO 12		9			43	39		
RFO 13		9						
RFO 14		9						
RFO 15		10						
RFO 16								
RFO 17								
RFO 18								
RFO 19								
RFO 20								
RFO 21								
RFO 22								

Table 4-22: Replacement Models: Number of Tubes Plugged As a Function of Mechanism Per Year (Detailed)

Cause of Tube Plugging/Outage	Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals	Totals
Wear	AVB											7	1	4	2	7	3	3	5	1	8	20	32	93	107
	Pre heater TSP (D5)																							0	
	TSP												1									1	12	14	
Loose Parts	Confirmed							1								2								3	15
	Not Confirmed, Periphery									1		1						1	2	3			3	11	
	Not Confirmed, Not Periphery																						1	1	
Obstruction Restriction	From PSI - no progression													1	1									2	19
	Service Induced							1		1			1				1	2	5	3	1		2	17	
Manufacturing Flaws	Preservice	2	2	39	31	32													13			2		121	131
	Other							1		2		2									2		3	10	
Inspection Issues	Probe Lodged																							0	7
	Data Quality																						4	4	
	Dent/Geometry																							0	
	Permeability																		1			1	1	3	
	Not Inspected																							0	
Other	Top of Tubesheet					1	3		1			2					5	3	8		8	71		102	121
	Free Span							1						5		1			3			1	1	12	
	TSP					3	1	1				2												7	
	Not Reported																							0	
SCC	ID																							0	0
	OD																							0	
	TOTALS	2	2	39	31	36	4	5	1	4	0	14	3	10	3	10	9	9	37	7	19	96	59	400	400
Notes																									

Notes

Table 4-23: Replacment Models: Number of Tubes Plugged As a Function of Mechanism Per Year (Summary)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
Cause																							
Wear											7	2	4	2	7	3	3	5	1	8	21	44	107
Loose Parts							1		1		1				2		1	2	3			4	15
Restrictions							1		1			1	1	1		1	2	5	3	1		2	19
Manufacturing	2	2	39	31	32		1		2		2							13		2	2	3	131
Inspection Issues																		1			1	5	7
Other					4	4	2	1			4		5		1	5	3	11		8	72	1	121
SCC																							0
	2	2	39	31	36	4	5	1	4	0	14	3	10	3	10	9	9	37	7	19	96	59	400
Notes																							

Notes

Table 4-24: Replacement Models: Fraction of Tubes Plugged As a Function of Mechanism Per Year (Summary)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
Cause																							
Wear											0 50	0 67	0 40	0 67	0 70	0 33	0 33	0 14	0 14	0 42	0 22	0 75	0 27
Loose Parts							0 20		0 25		0 07				0 20		0 11	0 05	0 43			0 07	0 04
Restrictions							0 20		0 25			0 33	0 10	0 33		0 11	0 22	0 14	0 43	0 05		0 03	0 05
Manufactunng	1 00	1 00	1 00	1 00	0 89		0 20		0 50		0 14							0 35		0 11	0 02	0 05	0 33
Inspection Issues																		0 03			0 01	0 08	0 02
Other					0 11	1 00	0 40	1 00			0 29		0 50		0 10	0 56	0 33	0 30		0 42	0 75	0 02	0 30
SCC																							
	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	0 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00
Notes																							

Notes

Table 4-25: All Models: Total Number and Percentage of Tubes Plugged (12/01)

Plant	Number of Tubes Plugged[1]	Percent Plugged	Operating Time[2]
Braidwood 2	120	0.66	13
Byron 2	223	1.22	14
Callaway	17	0.35	17
Catawba 2	183	1.00	15
Comanche Peak 2	37	0.20	8
Indian Point 2	2	0.02	1
Millstone 3	106	0.47	16
Point Beach 1	10	0.16	18
Robinson 2	39	0.40	17
Salem 1	58	0.26	4
Seabrook 1	90	0.40	11
Surry 1	43	0.43	20
Surry 2	39	0.39	21
Turkey Point 3	166	1.72	20
Turkey Point 4	43	0.45	19
Vogtle 1	48	0.21	15
Vogtle 2	29	0.13	13
Wolf Creek 1	144	0.64	16
TOTALS:	1397	0.50	

[1]As of 12/31/01
[2]Operating Time = calendar years of operation as of 12/31/01

Table 4-26: All Models: Number of Tubes Plugged As a Function of Mechanism (Detailed) (12/01)

Cause of Tube Plugging		Model D5 Tubes Plugged	Model D5 Percentage of Plugs	Model F Tubes Plugged	Model F Percentage of Plugs	Replacement Models Tubes Plugged	Replacement Models Percentage of Plugs	All Models Tubes Plugged	All Models Percentage of Plugs
Wear	AVB	258	45.8%	295	68.0%	93	23.3%	646	46.2%
	Pre-heater TSP (D5)	2	0.4%	0	0.0%	0	0.0%	2	0.1%
	TSP	2	0.4%	0	0.0%	14	3.5%	16	1.1%
Loose Parts	Confirmed	19	3.4%	9	2.1%	3	0.8%	31	2.2%
	Not Confirmed, Periphery	16	2.8%	10	2.3%	11	2.8%	37	2.6%
	Not Confirmed, Not Periphery	3	0.5%	5	1.2%	1	0.3%	9	0.6%
Obstruction Restriction	From PSI - no progression	0	0.0%	0	0.0%	2	0.5%	2	0.1%
	Service Induced	2	0.4%	2	0.5%	17	4.3%	21	1.5%
Manufacturing Flaws	Preservice	50	8.9%	63	14.5%	121	30.3%	234	16.8%
	Other	44	7.8%	0	0.0%	10	2.5%	54	3.9%
Inspection Issues	Probe Lodged	2	0.4%	0	0.0%	0	0.0%	2	0.1%
	Data Quality	2	0.4%	0	0.0%	4	1.0%	6	0.4%
	Dent/Geometry	4	0.7%	0	0.0%	0	0.0%	4	0.3%
	Permeability	4	0.7%	0	0.0%	3	0.8%	7	0.5%
	Not Inspected	3	0.5%	0	0.0%	0	0.0%	3	0.2%
Other	Top of Tubesheet	18	3.2%	19	4.4%	102	25.5%	139	9.9%
	Free Span	80	14.2%	13	3.0%	12	3.0%	105	7.5%
	TSP	44	7.8%	18	4.1%	7	1.8%	69	4.9%
	Other/Not Reported	10	1.8%	0	0.0%	0	0.0%	10	0.7%
SCC	ID	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	OD	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	TOTALS	563	100.0%	434	100.0%	400	100.0%	1397	100.0%

	Model D5	Model F	Replacement Models	All Models
Total Tubes:	73120	117376	90766	281262
Fraction Plugged:	0.77%	0.37%	0.44%	0.50%
Average Age (years):	12.8	14.6	15.1	14.4

Table 4-27: All Models: Number of Tubes Plugged as a Function of Mechanism (Summary) (12/01)

Cause of Tube Plugging		Model D5		Model F		Replacement Models		All Models	
		Tubes Plugged	Percentage of Plugs	Tubes Plugged	Percentage of Plugs	Tubes Plugged	Percentage of Plugs	Tubes Plugged	Percentage of Plugs
Wear	AVB Pre-heater TSP (D5) TSP	262	46.5%	295	68.0%	107	26.8%	664	47.5%
Loose Parts	Confirmed Not Confirmed, Periphery Not Confirmed, Not Periphery	38	6.7%	24	5.5%	15	3.8%	77	5.5%
Obstruction Restriction	From PSI - no progression Service Induced	2	0.4%	2	0.5%	19	4.8%	23	1.6%
Manufacturing Flaws	Preservice Other	94	16.7%	63	14.5%	131	32.8%	288	20.6%
Inspection Issues	Probe Lodged Data Quality Dent/Geometry Permeability Not Inspected	15	2.7%	0	0.0%	7	1.8%	22	1.6%
Other	Top of Tubesheet Free Span TSP Other/Not Reported	152	27.0%	50	11.5%	121	30.3%	323	23.1%
SCC	ID OD	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	TOTALS	563	100.0%	434	100.0%	400	100.0%	1397	100.0%

	Model D5	Model F	Replacement Models	All Models
Total Tubes:	73120	117376	90766	281262
Fraction Plugged:	0.77%	0.37%	0.44%	0.50%
Average Age (years):	12.8	14.6	15.1	14.4

Table 4-28: All Models: Plugging Per Year

Year	Model D5	Model F	Replacement Models	All Models	Tubes in TT SGs
Pre-Op	51	63	121	235	281262
1980			0	0	10026
1981			0	0	20052
1982			0	0	29694
1983			0	0	39336
1984			4	4	60262
1985			4	4	82766
1986	0	0	5	5	123550
1987	0	3	1	4	164334
1988	7	23	4	34	182614
1989	19	5	0	24	205118
1990	42	6	14	62	227622
1991	23	15	3	41	227622
1992	29	1	10	40	227622
1993	94	16	3	113	245902
1994	37	40	10	87	245902
1995	52	30	9	91	245902
1996	65	33	9	107	245902
1997	46	47	24	117	268406
1998	47	0	7	54	268406
1999	25	50	19	94	268406
2000	22	50	94	166	281262
2001·	4	52	59	115	281262
Totals:	563	434	400	1397	

Table 4-29: All Models: Number of Tubes Plugged As a Function of Mechanism Per Year (Detailed)

Cause of Tube Plugging/Outage	Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals	Totals
Wear	AVB								2	19	5	48	29	29	69	52	51	79	62	3	72	79	47	646	664
	Pre-heater TSP (D5)																			1	1			2	
	TSP												1							2		1	12	16	
Loose Parts	Confirmed							1		2	4		4			2	1	6	7	3			1	31	77
	Not Confirmed, Periphery									1	1	1			1		9	1	2	3	6	1	11	37	
	Not Confirmed, Not Periphery																		2		1	4	2	9	
Obstruction Restriction	From PSI - no progression													1	1									2	23
	Service Induced							1		1			1				1	2	8	3	2		2	21	
Manufacturing Flaws	Preservice	2	2	39	31	36	15	24	17	6	15	13			19				13			2		234	288
	Other							1		2		2							15	29	2		3	54	
Inspection Issues	Probe Lodged																					2		2	22
	Data Quality										1								1				4	6	
	Dent/Geometry										1							1		2				4	
	Permeability																		3	1		2	1	7	
	Not Inspected																		1			2		3	
Other	Top of Tubesheet					1	3		1		2	2			3	4	7	7	11	2	9	73	14	139	323
	Free Span							1		7	5	1	1	9	30	21	12	7	5			1	5	105	
	TSP					3	1	1	1	2	4	6	5	1	8	8	5	4		5	1	1	13	69	
	Not Reported										1	2			2		5							10	
SCC	ID																							0	0
	OD																							0	
	TOTALS	2	2	39	31	40	19	29	21	40	39	75	41	40	133	87	91	107	130	54	94	168	115	1397	1397
Notes																									

Notes

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Table 4-30: All Models: Number of Tubes Plugged As a Function of Mechanism Per Year (Summary)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
Cause																							
Wear								2	19	5	48	30	29	69	52	51	79	62	6	73	80	59	664
Loose Parts							1		3	5	1	4		1	2	10	7	11	6	7	5	14	77
Restrictions							1		1			1	1	1		1	2	8	3	2		2	23
Manufacturing	2	2	39	31	36	15	25	17	8	15	15			19				28	29	2	2	3	288
Inspection Issues										2							1	5	3		6	5	22
Other					4	4	2	2	9	12	11	6	10	43	33	29	18	16	7	10	75	32	323
SCC																							0
	2	2	39	31	40	19	29	21	40	39	75	41	40	133	87	91	107	130	54	94	168	115	1397
Notes·																							

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Table 4-31: All Models: Fraction of Tubes Plugged As a Function of Mechanism Per Year (Summary)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
Cause																							
Wear								0 10	0 48	0 13	0 64	0 73	0 73	0 52	0 60	0 56	0 74	0 48	0 11	0 78	0 48	0 51	0 48
Loose Parts							0 03		0 08	0 13	0 01	0 10		0 01	0 02	0 11	0 07	0 08	0 11	0 07	0 03	0 12	0 06
Restrictions							0 03		0 03			0 02	0 03	0 01		0 01	0 02	0 06	0 06	0 02		0 02	0 02
Manufacturing	1 00	1 00	1 00	1 00	0 90	0 79	0 86	0 81	0 20	0 38	0 20			0 14				0 22	0 54	0 02	0 01	0 03	0 21
Inspection Issues										0 05							0 01	0 04	0 06		0 04	0 04	0 02
Other					0 10	0 21	0 07	0 10	0 23	0 31	0 15	0 15	0 25	0 32	0 38	0 32	0 17	0 12	0 13	0 11	0 45	0 28	0 23
SCC																							
	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00	1 00
Notes:																							

Notes

Figure 4-1: Model D5: Causes of Tube Plugging

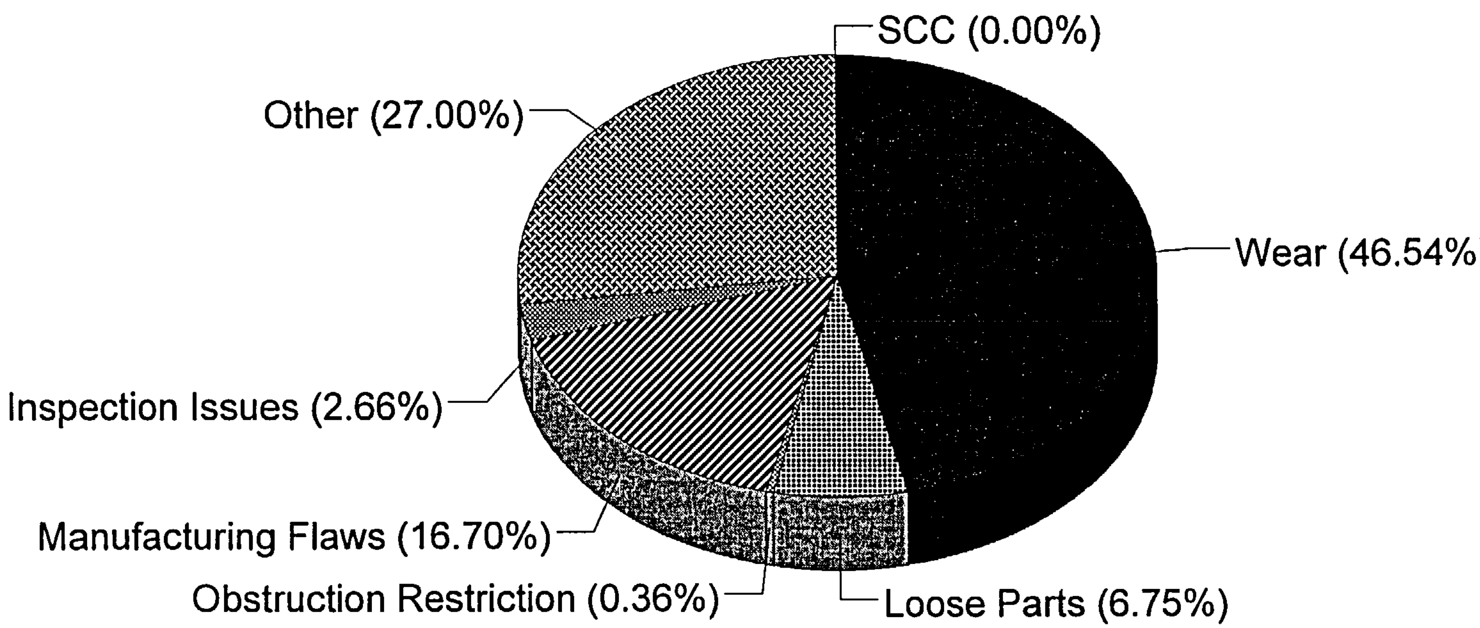


Figure 4-2: Model D5: Plugging Per Year

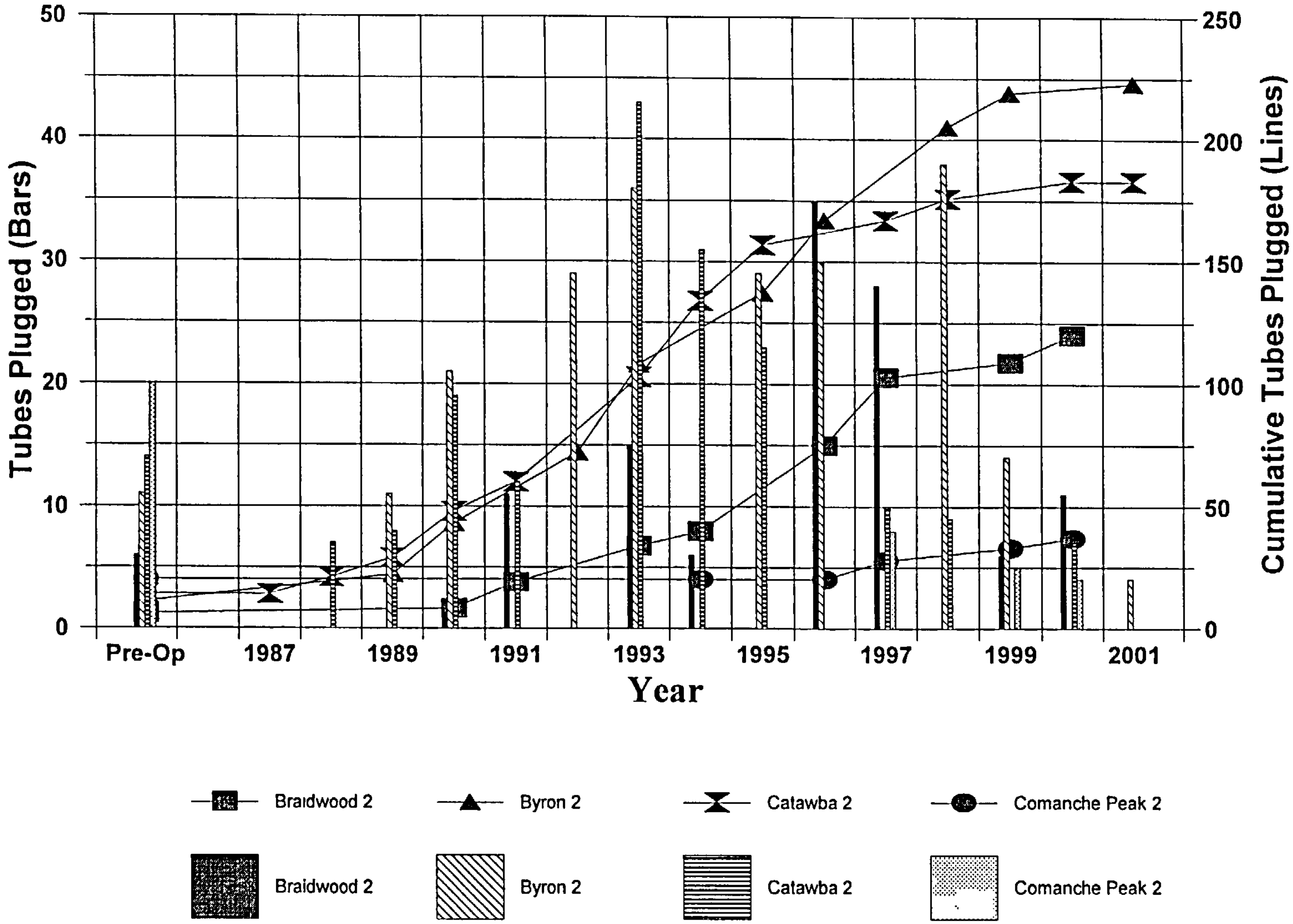


Figure 4-3: Model D5: Cumulative Plugging Per Refueling Outage

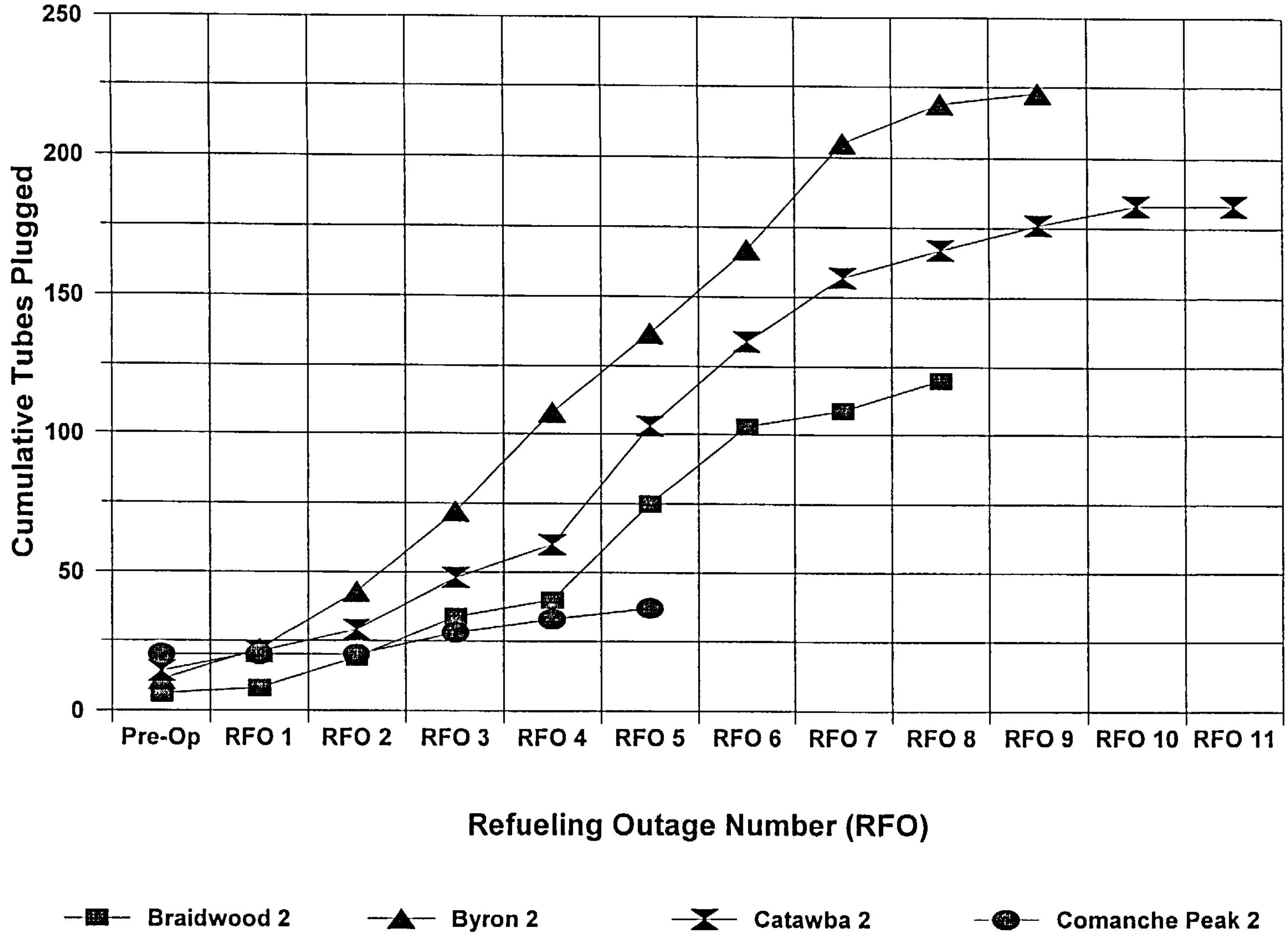


Figure 4-4: Model D5: Causes of Tube Plugging Per Year

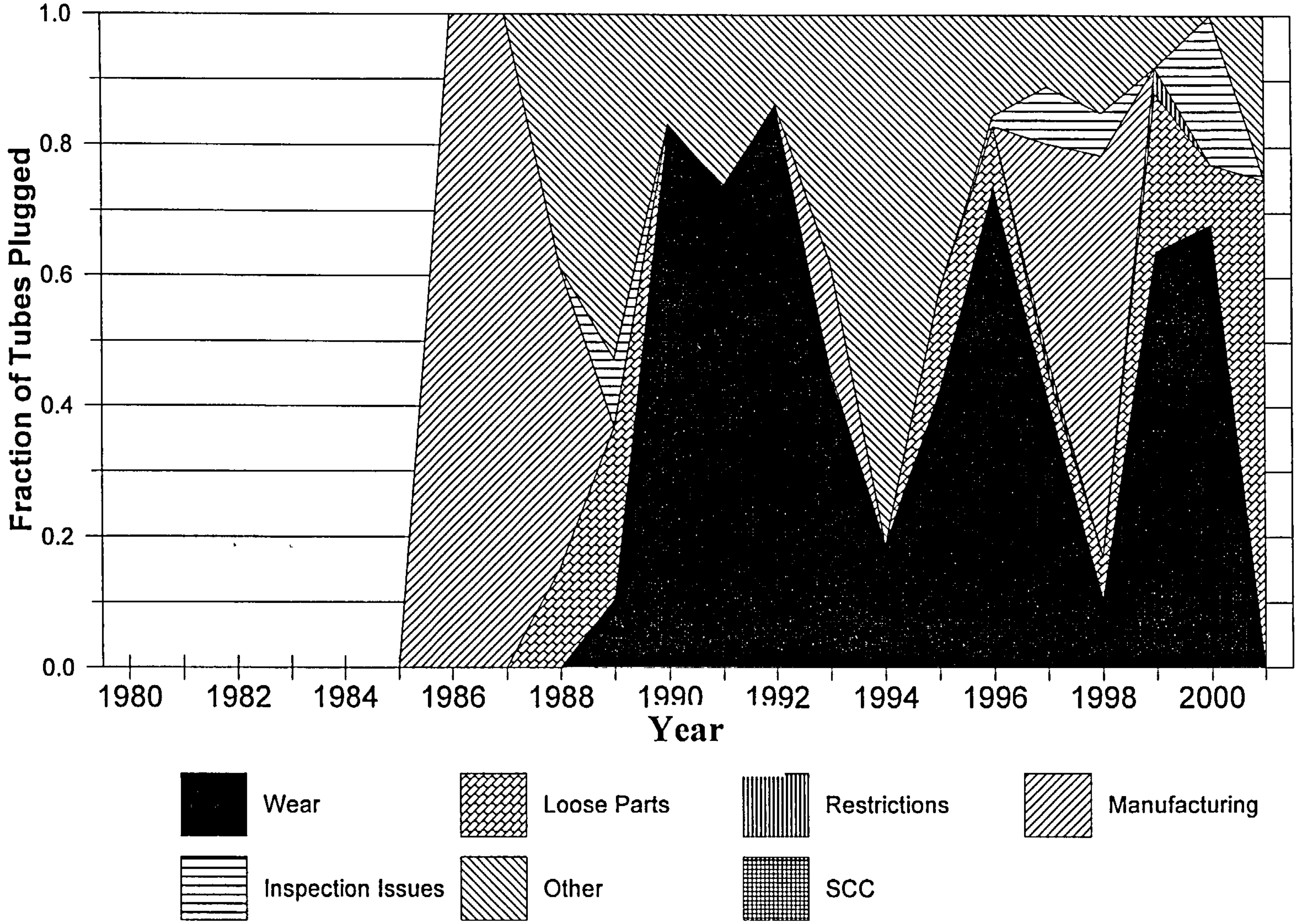


Figure 4-5: Model F: Causes of Tube Plugging (12/01)

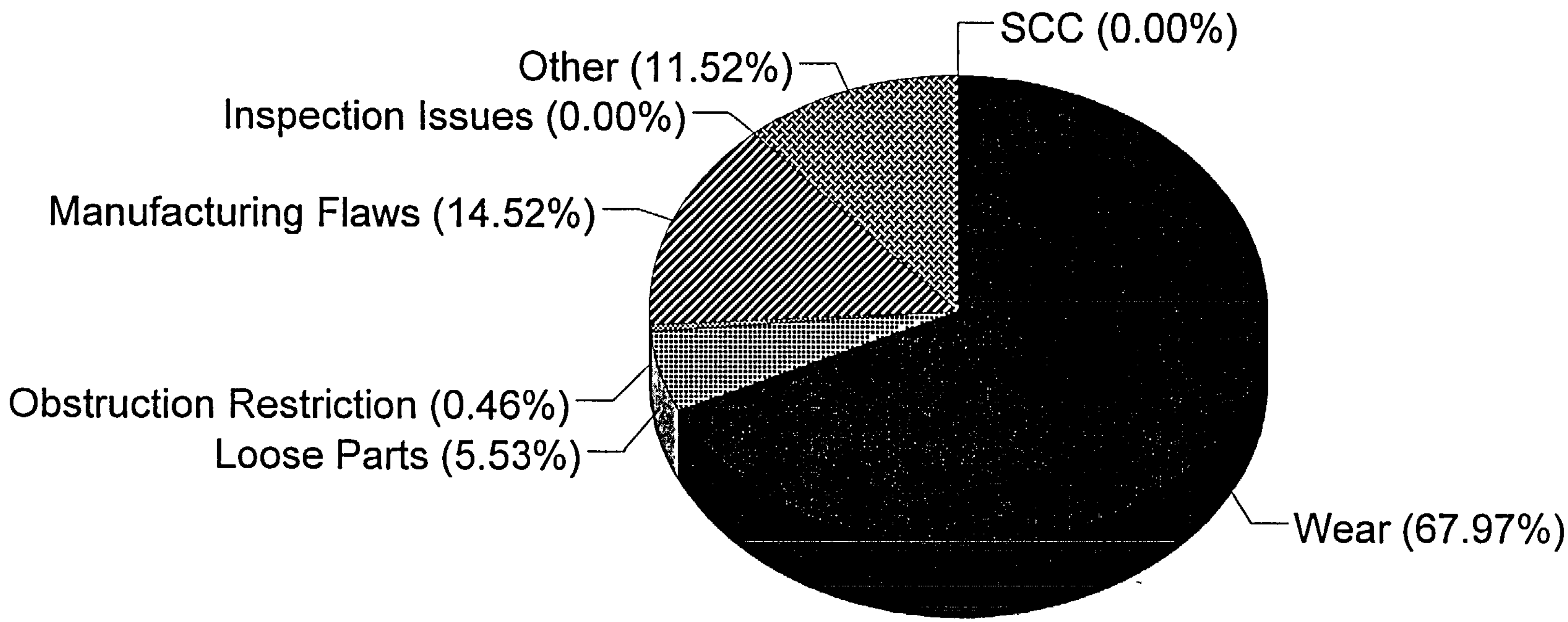


Figure 4-6: Model F: Plugging Per Year

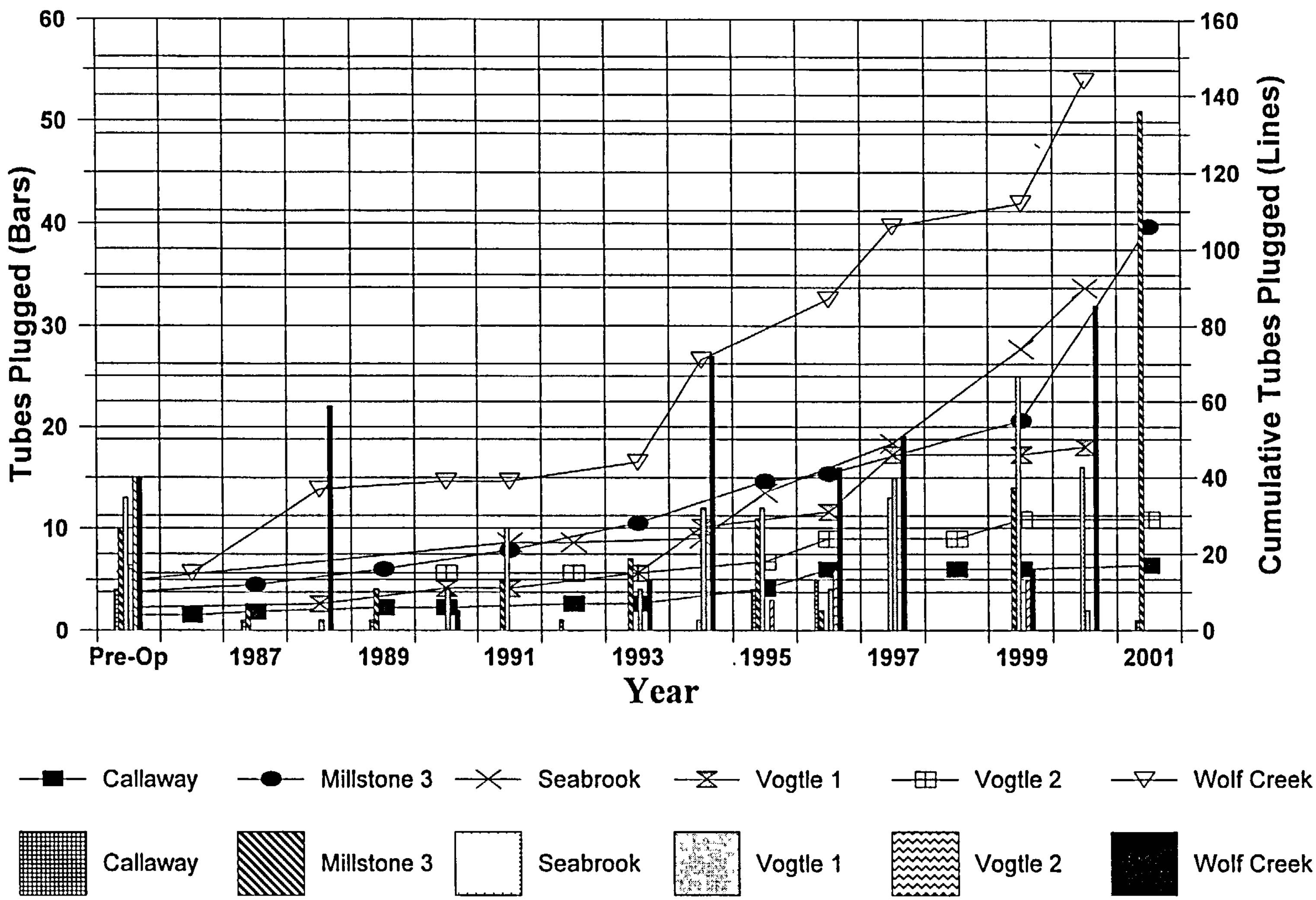


Figure 4-7: Model F: Cumulative Plugging Per Refueling Outage

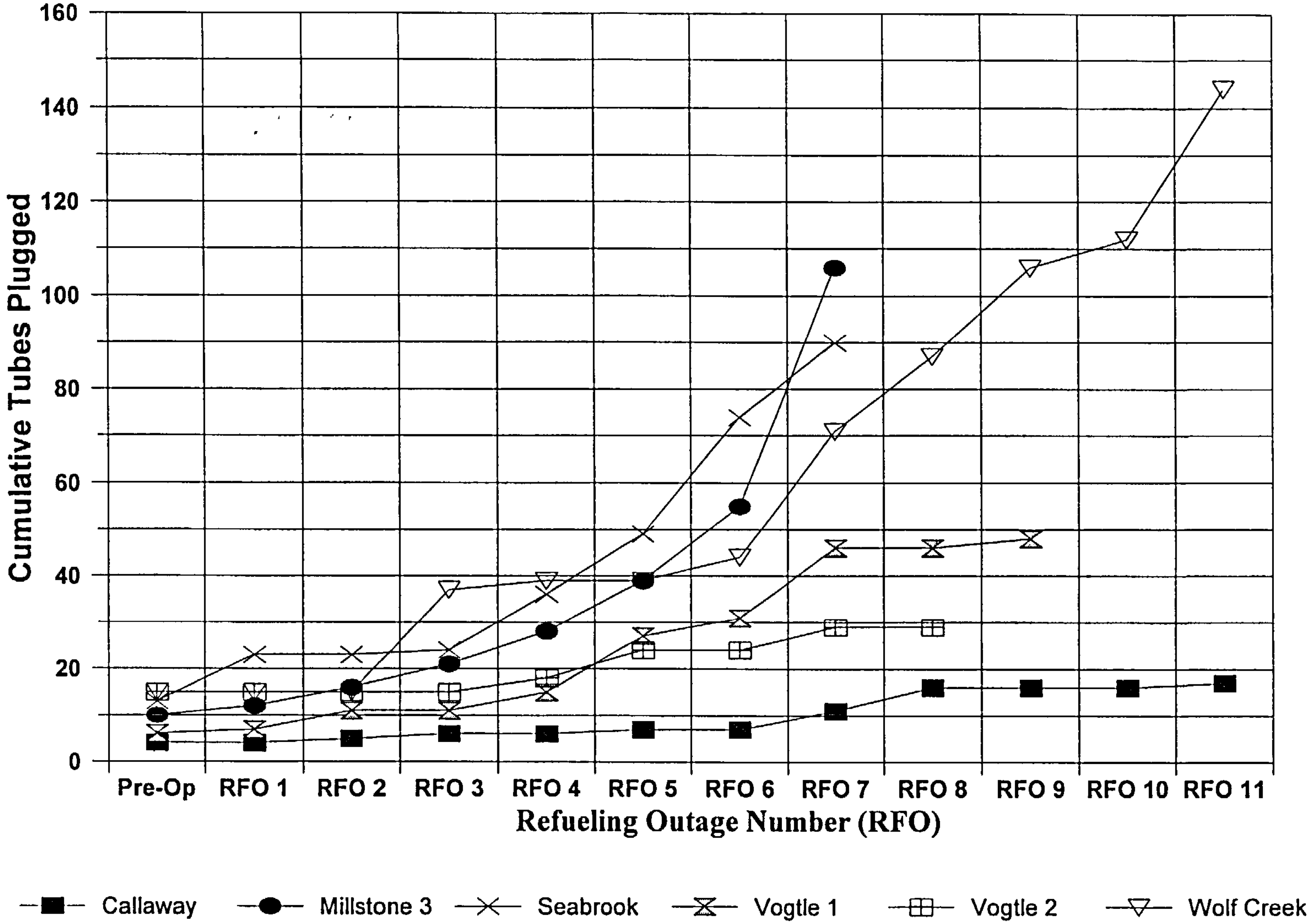


Figure 4-8: Model F: Causes of Tube Plugging Per Year

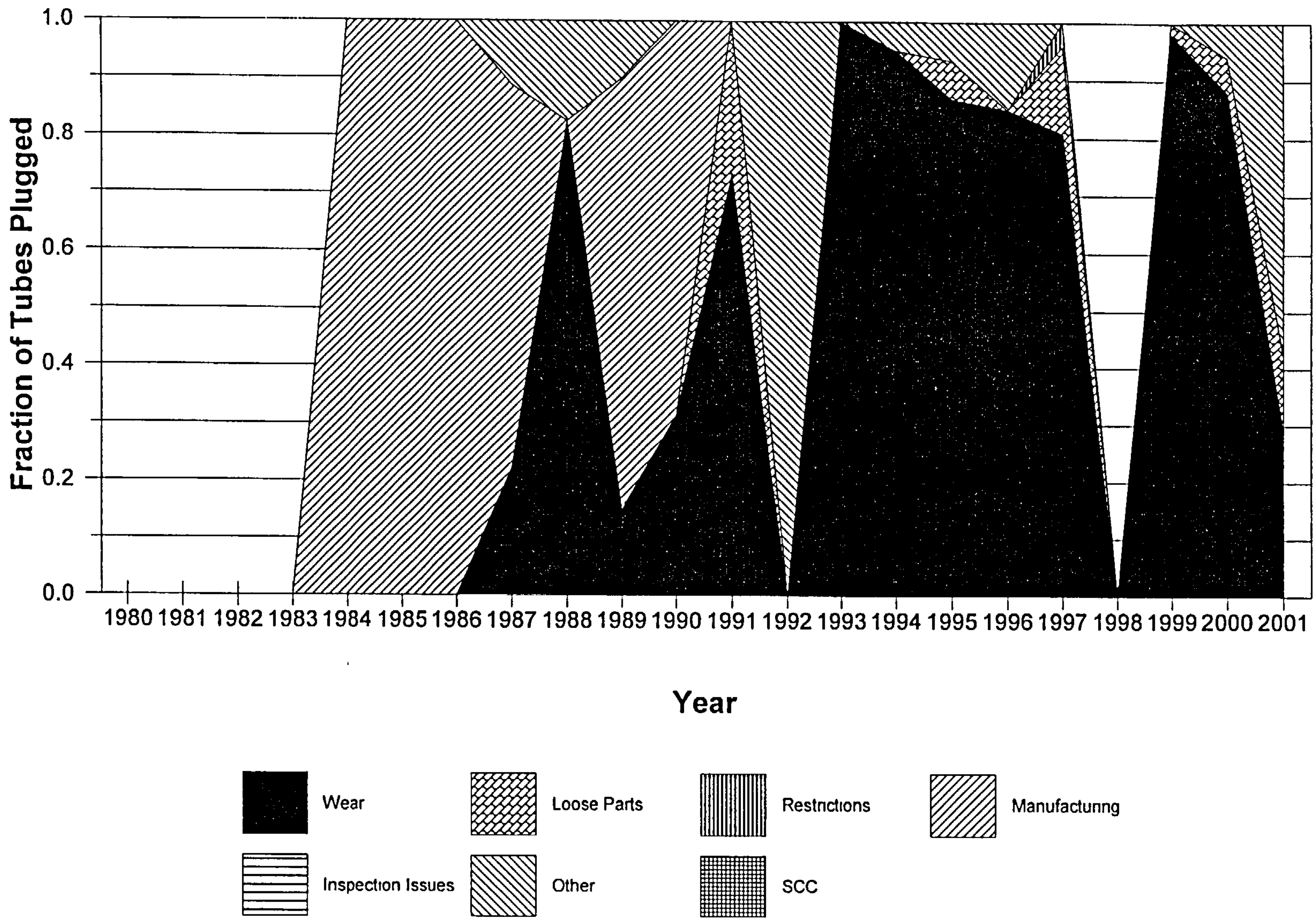


Figure 4-9: Replacement Models: Causes of Tube Plugging (12/01)

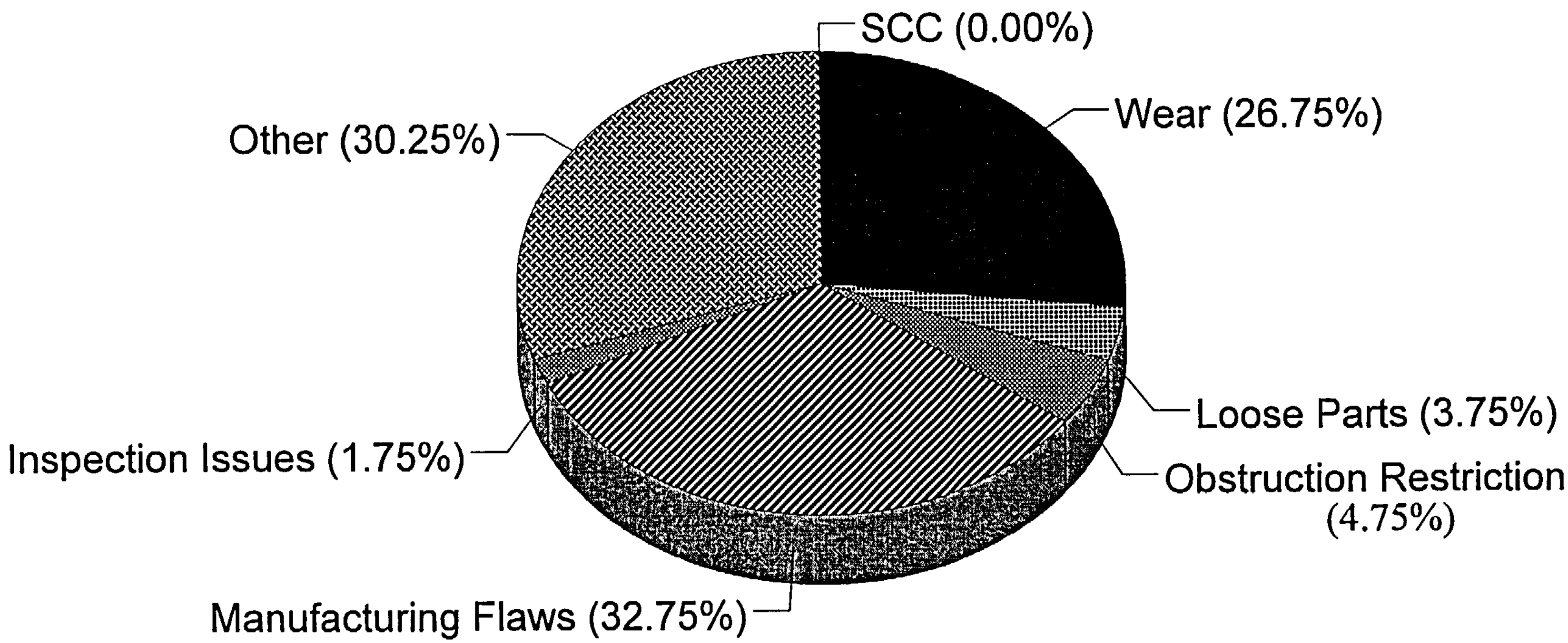


Figure 4-10: Replacement Models: Plugging Per Year

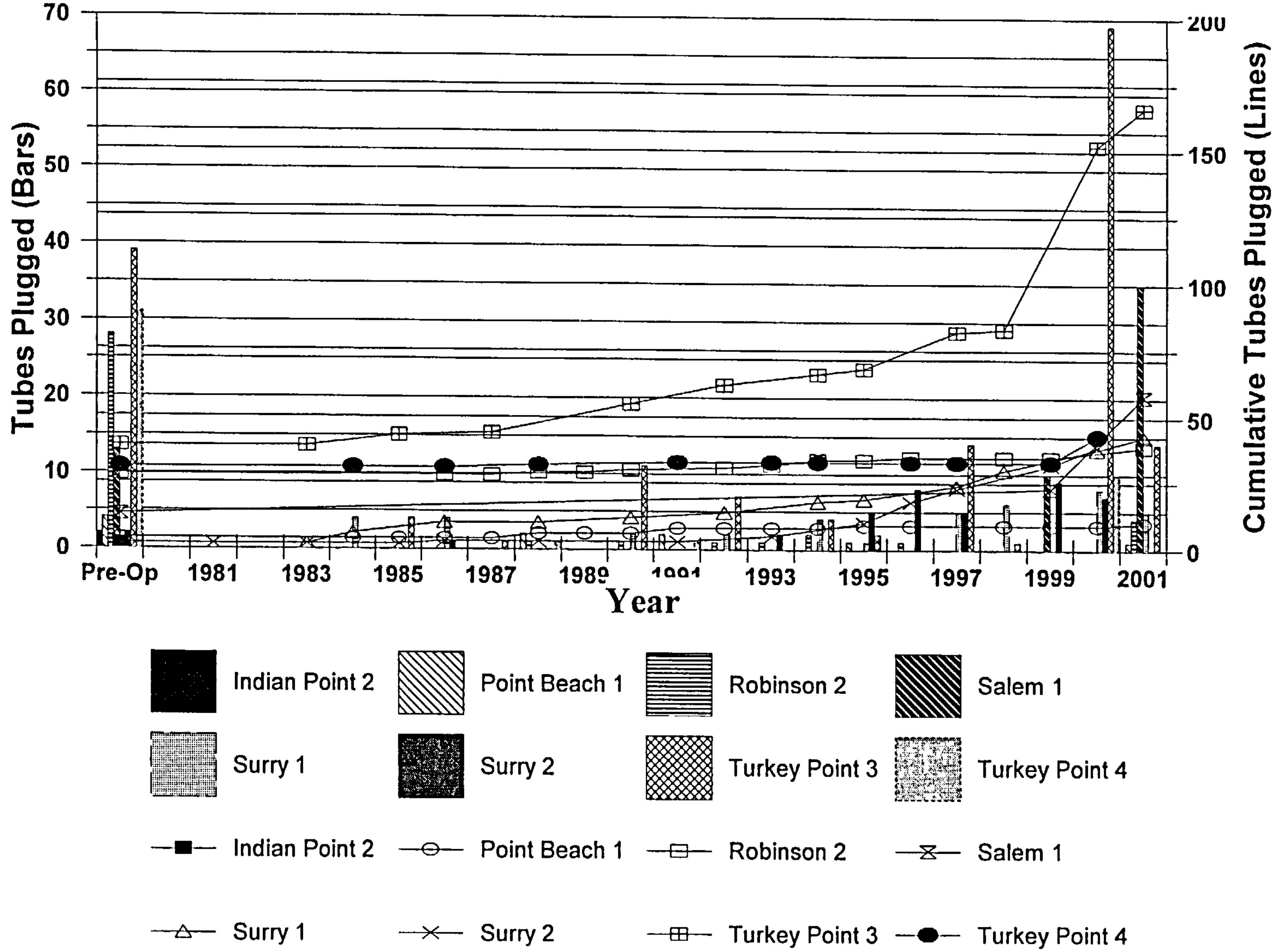


Figure 4-11: Replacement Models: Cumulative Plugging Per Refueling Outage

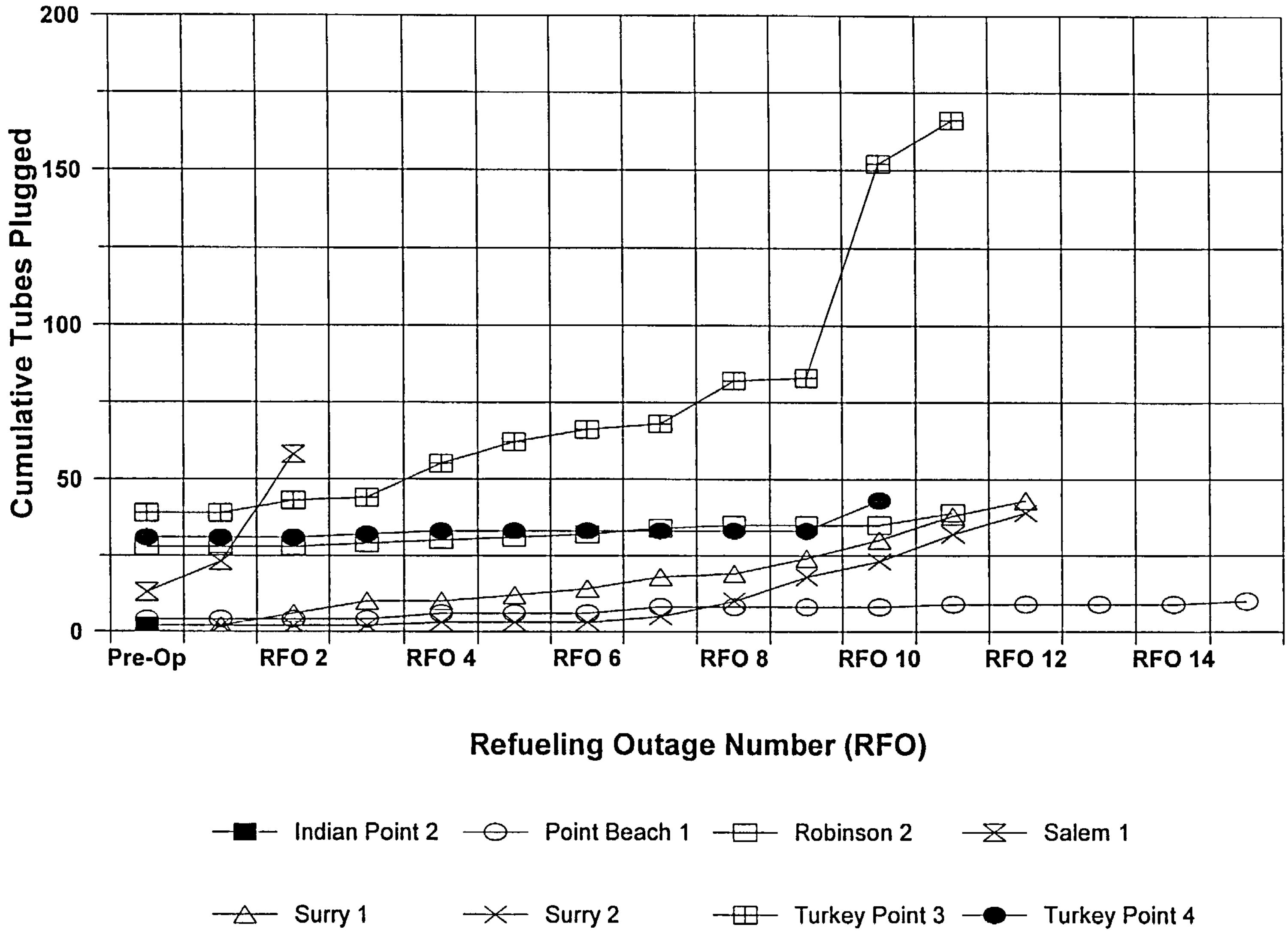


Figure 4-12: Replacement Models: Causes of Tube Plugging Per Year

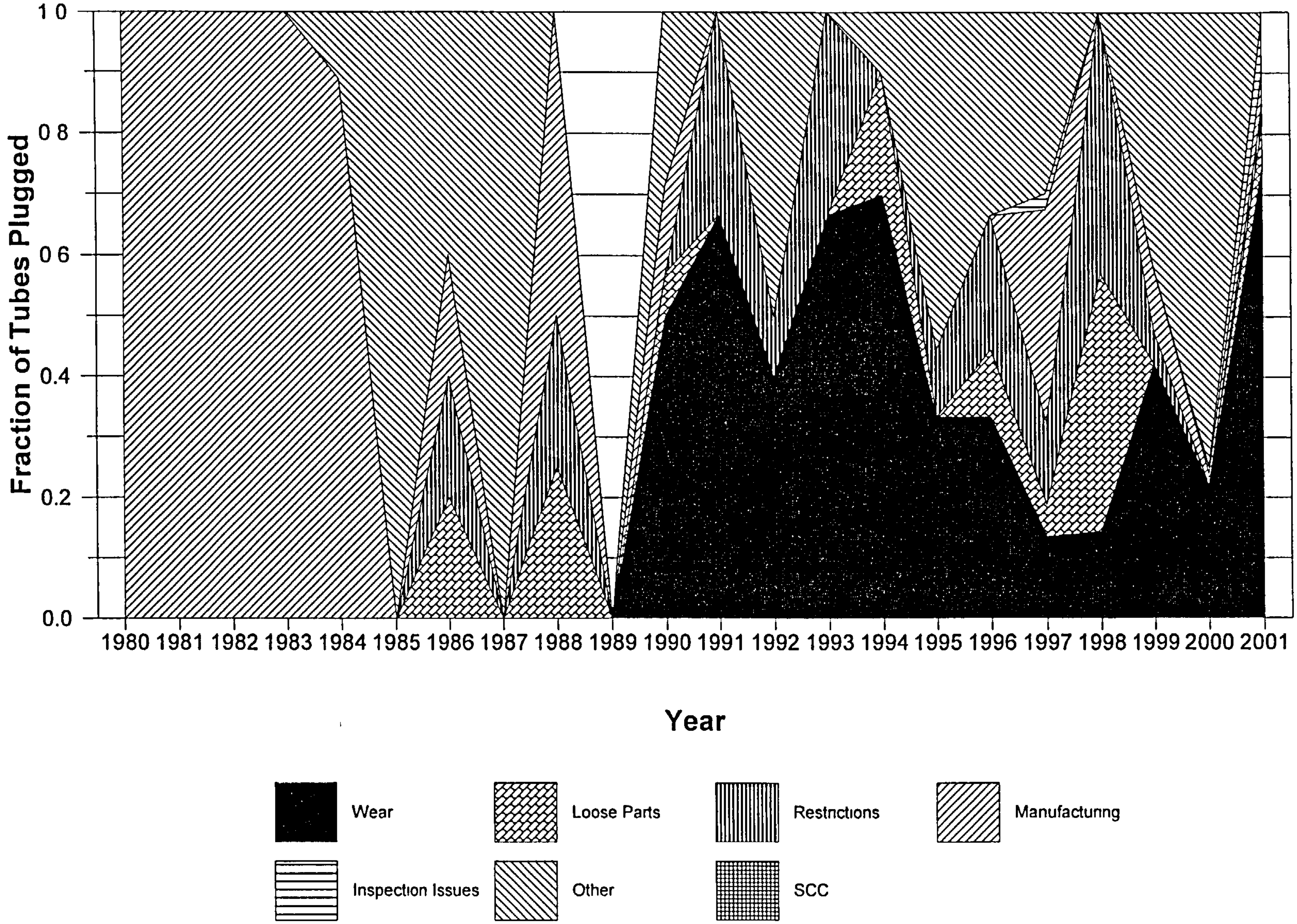


Figure 4-13: Number of Thermally Treated Alloy 600 Tubes in Service Per Year

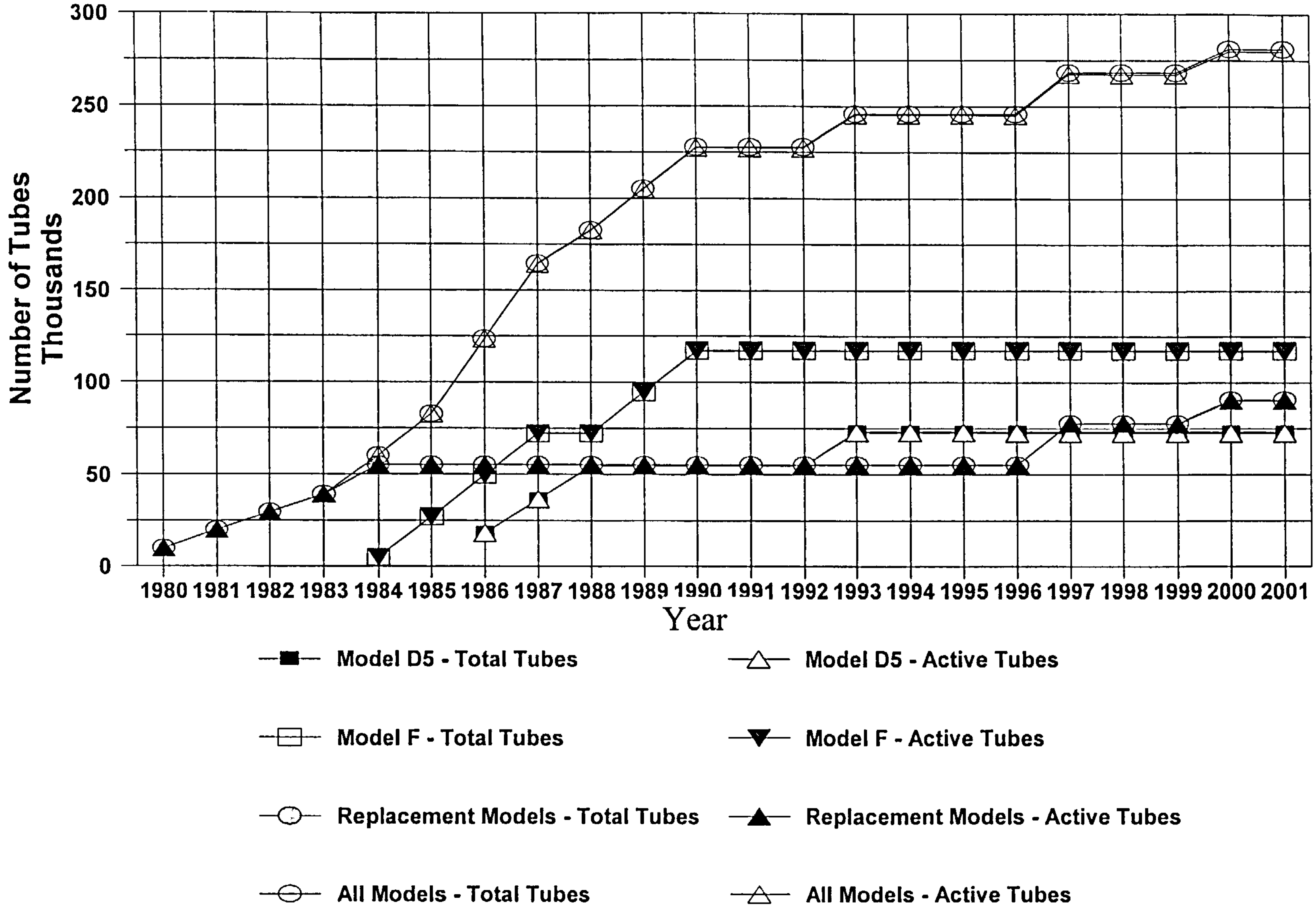
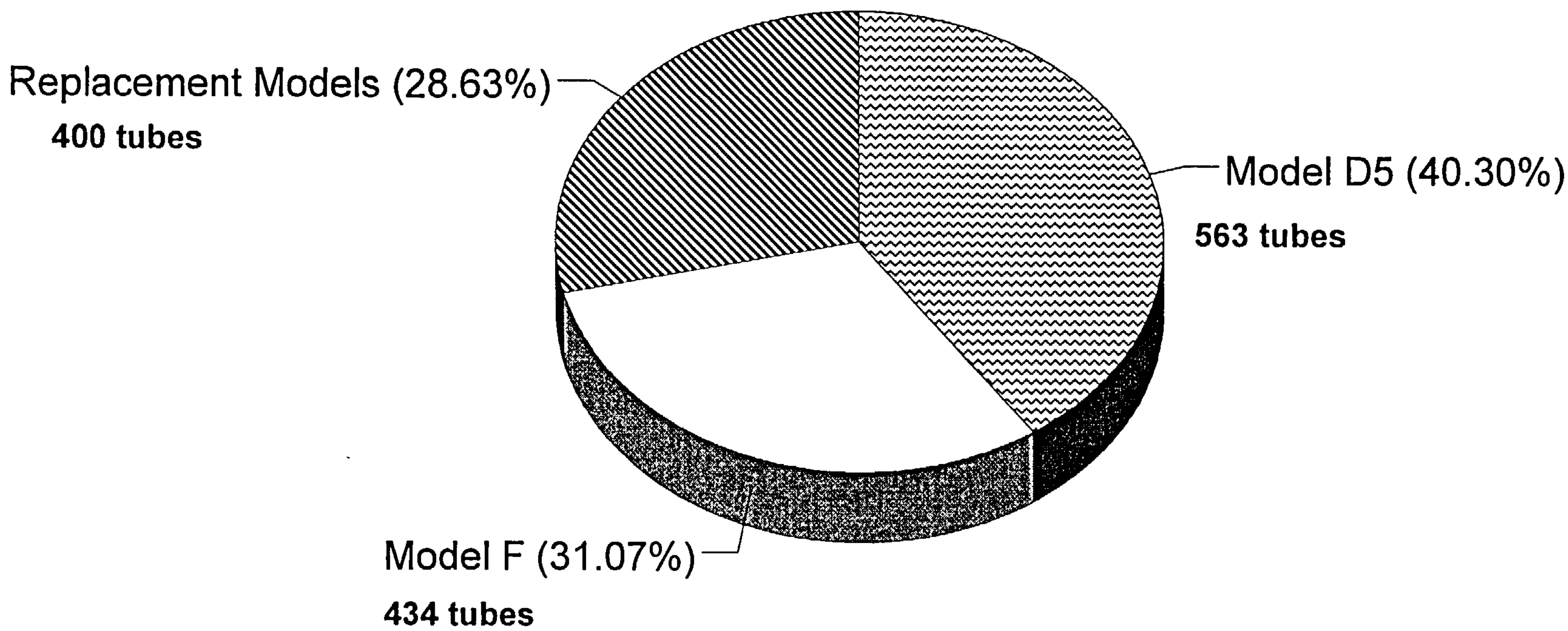
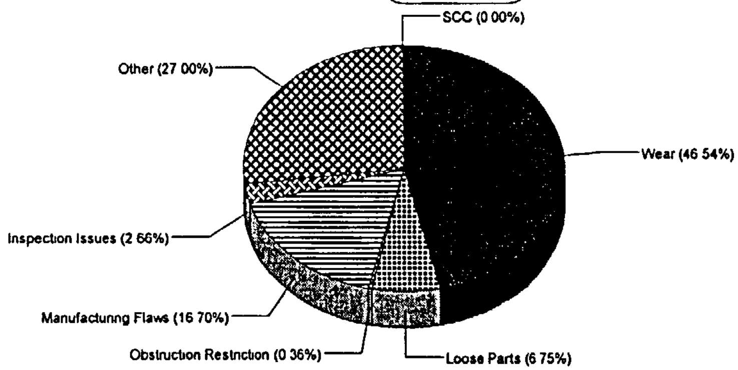


Figure 4-14: All Models: Tubes Plugged Per Grouping/Model (12/01)

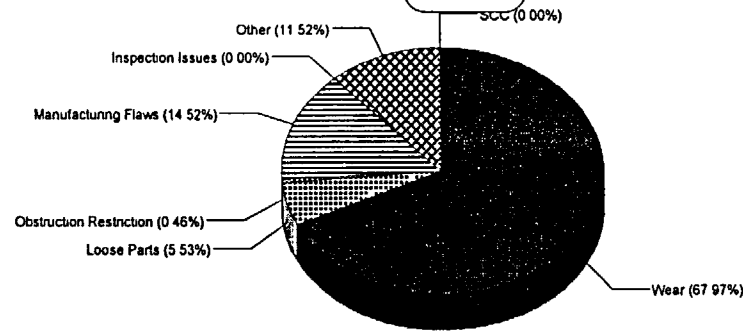


Model 4-15: All Models: Causes of Tube Plugging (12/01)

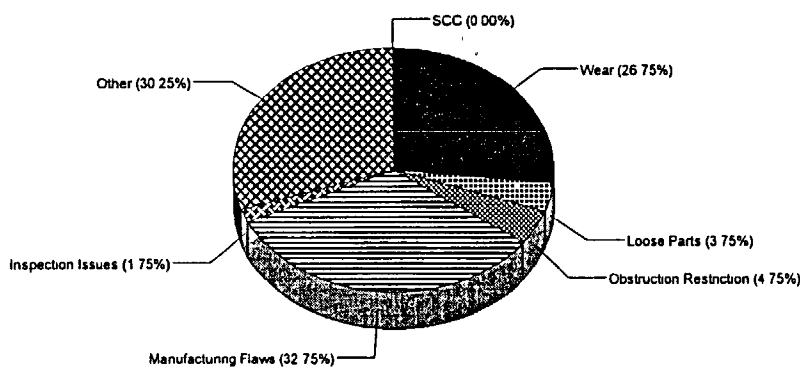
Model D5



Model F



Replacement Models



All Models

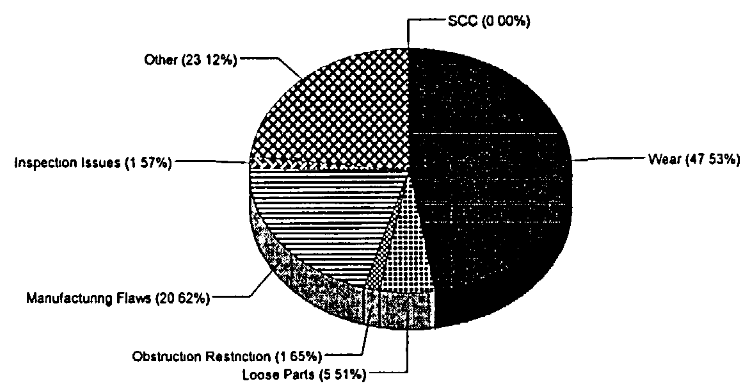


Figure 4-16: All Models: Number of Tubes Plugged Per Year

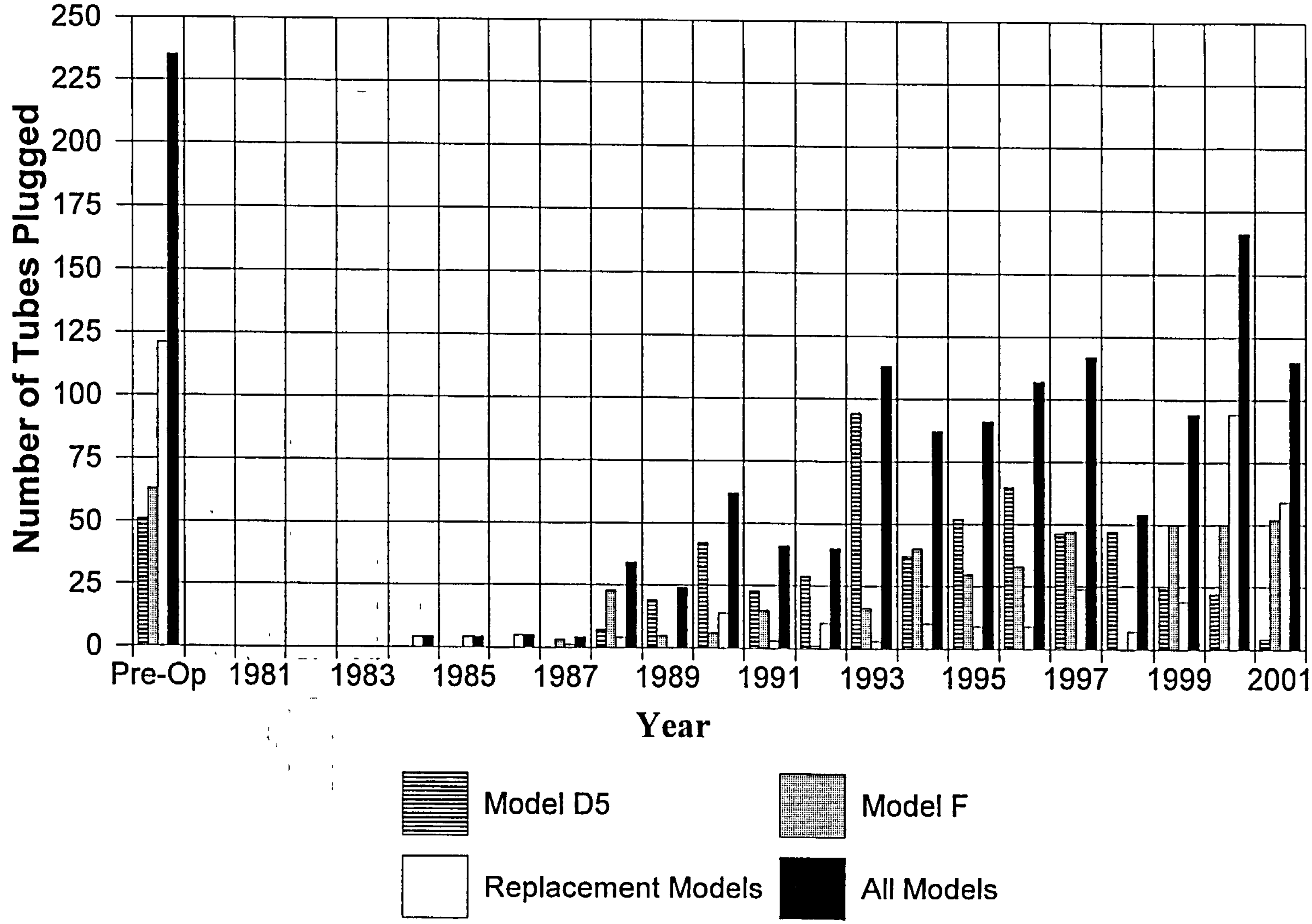


Figure 4-17: All Models: Percentage of Tubes Plugged Per Year

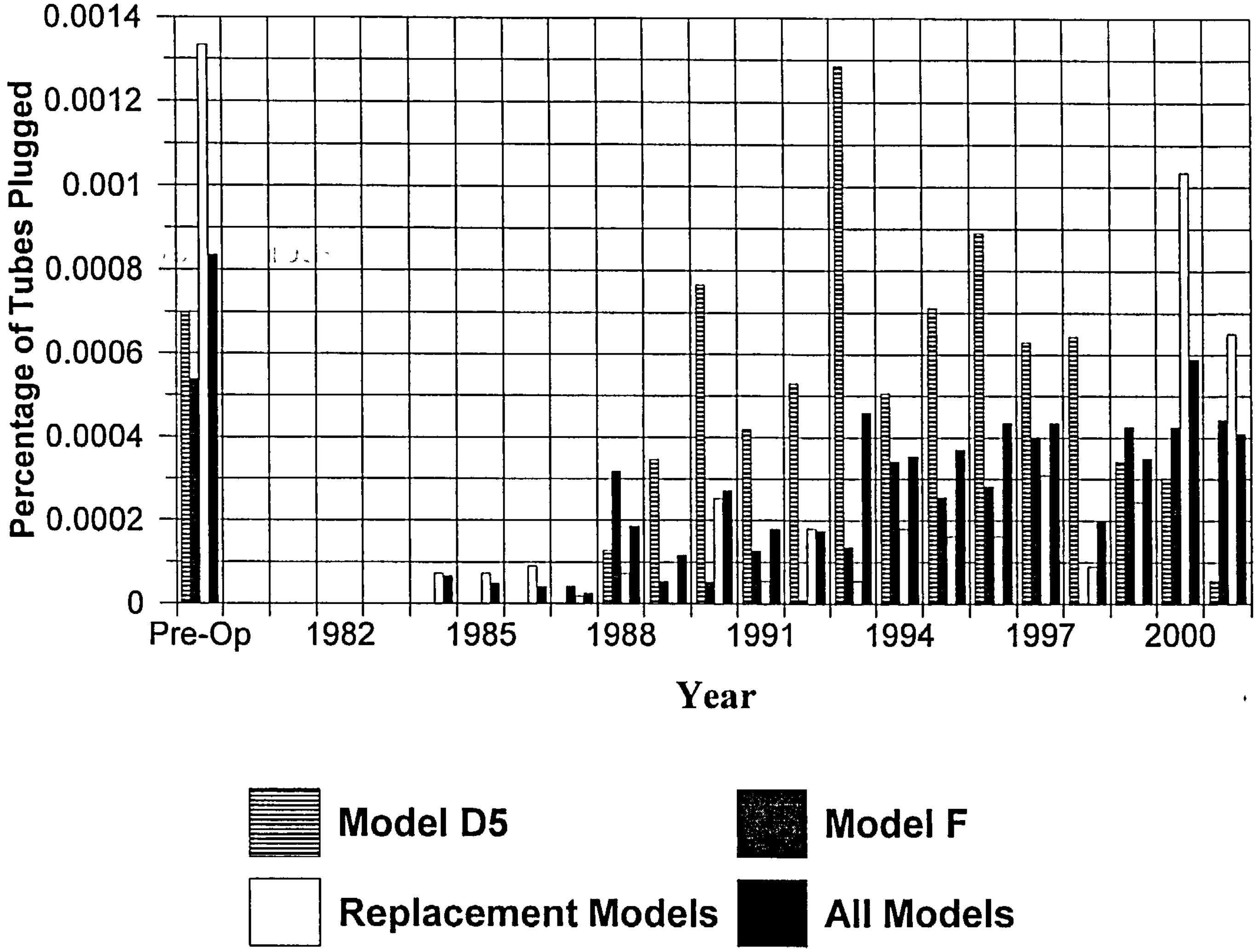
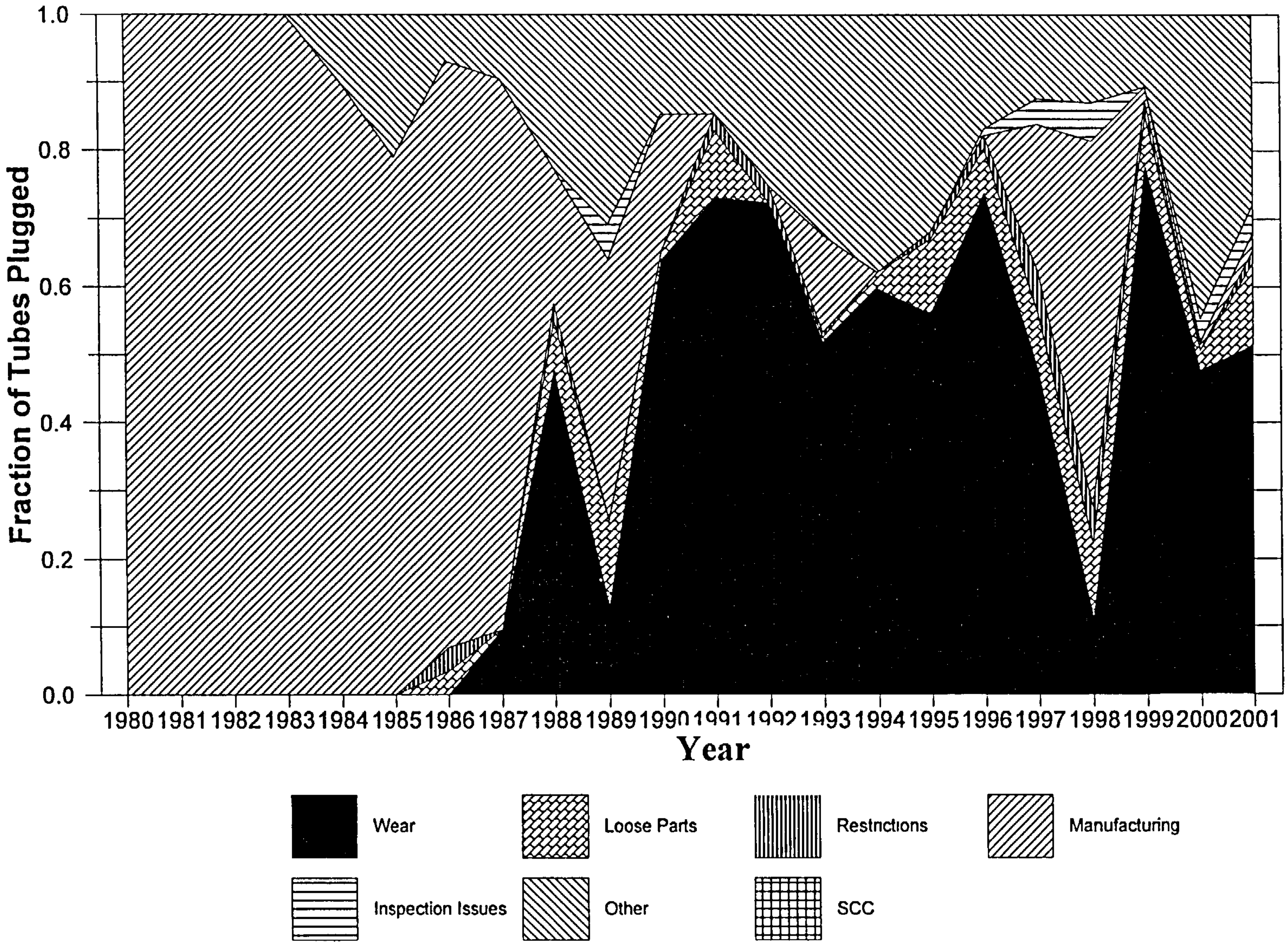


Figure 4-18: All Models: Causes of Tube Plugging Per Year



APPENDIX A: ACRONYMS

ADI	absolute drift indication
ADS	absolute drift signal
AVB	anti-vibration bar
AVT	all volatile treatment
BPH	hot-leg flow distribution baffle (baffle plate hot)
CLP	confirmed loose part
EFPM	Effective Full Power Month
EFPY	Effective Full Power Year
FBH	hot-leg flow distribution baffle (flow baffle hot)
FS	freespan
gpd	gallons per day
gpm	gallons per minute
ID	inside diameter
MAI	multiple axial indication
MBM	manufacturing burnishing mark
NDF	no degradation found
NQI	non-quantifiable indication
NRC	Nuclear Regulatory Commission
OD	outside diameter
ODI	outside diameter indication
ODSCC	outside diameter stress corrosion cracking
PLP	possible loose part
psi	pounds per square inch
PWR	pressurized-water reactor
PWSCC	primary water stress corrosion cracking
RFO	refueling outage
SAI	single axial indication
SG	steam generator
TSP	tube support plate
TT	thermally treated
UT	ultrasonic testing

APPENDIX B: BIBLIOGRAPHY

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<u>Braidwood 2</u>

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Callaway

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Catawba 2

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Letter from M.S. Tuckman, Duke Power Company, to the NRC dated August 21, 1991, "Catawba Nuclear Station, Docket No. 50-414, Unit 2 EOC-3 Refueling Outage, Steam Generator Inspection." NUDOCS Accession No. 9108260279

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Letter from G.R. Peterson, Duke Power Company, to the NRC dated October 8, 1998, "Catawba Nuclear Station, Unit 2, Docket No. 50-414, Special Report - Steam Generator Tube Plugging." NUDOCS Accession No. 9810190294

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Letter from G.R. Peterson, Duke Power, to the NRC dated September 11, 2000, "Duke Energy Corporation, Catawba Nuclear Station, Docket Nos. 50-413, 50-414, Steam Generator Tube Inspection Summary Reports." ADAMS Accession Nos. ML003751571, ML003751594, ML003751637, ML003751640, and ML003751742

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Comanche Peak 2

Letter from C.L. Terry, TU Electric, to the NRC dated November 7, 1994, "Comanche Peak Steam Electric Station (CPSES) - Unit 2, Docket No. 50-446, Special Report on the Unit 2, First Refueling Outage, Steam Generator Inservice Inspection Tube Plugging." NUDOCS Accession No.

Letter from C.L. Terry, TU Electric, to the NRC dated February 17, 1995, "Comanche Peak Steam Electric Station (CPSES) - Unit 2, Docket No. 50-446, Submittal of Unit 2 First Refueling Outage Inservice Inspection (ISI) Summary Report (Unit 2: 1986 Edition of ASME Code, Section XI, No Addenda, Interval Start Date - August 3, 1993, First Interval)." NUDOCS Accession No. 9502210330

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Letter from C.L. Terry, TU Electric, to the NRC dated July 10, 1997, "Comanche Peak Steam Electric Station (CPSES), Docket No. 50-445 and 50-446, NRC Inspection Report Nos. 50-445/97-09 and 50-446/97-09, Supplement to Response to Notice of Violation." NUDOCS Accession No. 9707180059

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Letter from C.L. Terry, TU Electric, to the NRC dated April 15, 1999, "Comanche Peak Steam Electric Station (CPSES) - Unit 2, Docket No. 50-446, Unit 2, Fourth Refueling Outage (2RFO4), Steam Generator Inservice Inspection Tube Plugging, Special Report No. 2-SR-99-001-00." NUDOCS Accession No. 9904210175

Letter from C.L. Terry, TU Electric, to the NRC dated July 16, 1999, "Comanche Peak Steam Electric Station (CPSES) - Unit 2, Docket No. 50-446, Submittal of Unit 2 Fourth Refueling Outage (2RFO4) Inservice Inspection (ISI) Summary Report, 1986 Edition of ASME Code, Section XI, No Addenda, and Containment Inservice Inspection (CISI) Summary Report, 1992 Edition of ASME Section XI 1992 Addenda." NUDOCS Accession No. 9907200177

Letter from C.L. Terry, TXU Electric, to the NRC dated January 28, 2000, "Comanche Peak Steam Electric Station (CPSES) Unit 2, Docket Nos. 50-446, Unit 2 Fourth Refueling Outage, Condition Monitoring Report Special Report 446/00-001-00." ADAMS Accession No. ML003679671

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<u>Indian Point 2</u>

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Surry 1 and 2

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Letter from J.H. McCarthy, Virginia Electric and Power Company, to the NRC dated May 17, 1999, "Virginia Electric and Power Company; Surry Power Station Unit 2; Steam Generator Tube Inspection Report." NUDOCS Accession No. 9905210220

Letter from D.A. Christian, Virginia Electric and Power Company, to the NRC dated February 28, 2000, "Virginia Electric and Power Company; Surry Power Station Units 1 and 2; Annual Steam Generator Inservice Inspection Summary Report." ADAMS Accession No. ML003692154

Letter from J.H. McCarthy, Virginia Electric and Power Company, to the NRC dated May 8, 2000, "Virginia Electric and Power Company; Surry Power Station Unit 1; Steam Generator Tube Inspection Report." ADAMS Accession No. ML003715079

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Letter from S.P. Sarver, Virginia Electric and Power Company, to the NRC dated February 28, 2001, "Virginia Electric and Power Company; Surry Power Station Units 1 and 2; Annual Steam Generator Inservice Inspection Summary Report." ADAMS Accession No. ML010650310

Letter from S.P. Sarver, Virginia Electric and Power Company, to the NRC dated November 5, 2001, "Virginia Electric and Power Company; Surry Power Station Unit 1; Steam Generator Tube Inspection Report." ADAMS Accession No. ML020090607

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<u>Turkey Point 3</u>

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Letter from J.W. Williams, Jr., Florida Power and Light Company, to the NRC dated September 3, 1985, "Turkey Point Units 3 and 4; Docket Nos. 50-250 and 50-251; 10 CFR 50.59 Report." NUDOCS Accession No.

Letter from C.O. Woody, Florida Power and Light Company, to the NRC dated June 23, 1987, "Turkey Point Unit 3; Docket No. 50-250; Technical Specification 4.2.5.5.a. Report." NUDOCS Accession No. 8706260344

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Letter from C.O. Woody, Florida Power and Light Company, to the NRC dated August 31, 1987, "Turkey Point Units 3 and 4; Docket Nos. 50-250 and 50-251; 10 CFR 50.59 Report." NUDOCS Accession No.

Letter from C.O. Woody, Florida Power and Light Company, to the NRC dated June 19, 1989, "Turkey Point Units 3 and 4; Docket Nos. 50-250 and 50-251; NRC Bulletin No. 89-01; Failure of Westinghouse Steam Generator Mechanical Plugs." NUDOCS Accession No. 8906230148

Letter from K.N. Harris, Florida Power and Light Company, to the NRC dated April 6, 1990, "Turkey Point Unit 3; Docket No. 50-250; Technical Specification 4.2.5.5.a." NUDOCS Accession No. 9004170137

Letter from K.N. Harris, Florida Power and Light Company, to the NRC dated September 7, 1990, "Turkey Point Unit 3; Docket No. 50-250; Inservice Inspection Report." NUDOCS Accession No. 9009170013

Letter from K.N. Harris, Florida Power and Light Company, to the NRC dated August 30, 1990, "Turkey Point Units 3 and 4; Docket No. 50-250 and 50-251; 10 CFR 50.59 Report." NUDOCS Accession No.

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated December 30, 1991, "Turkey Point Unit 3; Docket No. 50-250; Inservice Inspection Report." NUDOCS Accession No. 9201070255 and 9201080229

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated October 28, 1992, "Turkey Point Unit 3; Docket No. 50-250; Steam Generator Tube Plugging." NUDOCS Accession No.

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated March 10, 1993, "Turkey Point Unit 3; Docket No. 50-250; Inservice Inspection Report." NUDOCS Accession No. 9303160060

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated November 18, 1993, "Turkey Point Units 3 and 4; Docket No. 50-250 and 50-251; 10 CFR 50.59 Report." NUDOCS Accession No. 9312020007

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated May 2, 1994, "Turkey Point Unit 3; Docket No. 50-250; Steam Generator Tube Plugging." NUDOCS Accession No.

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated August 15, 1994, "Turkey Point Unit 3; Docket No. 50-250; Inservice Inspection Report." NUDOCS Accession No. 9408260153

Letter from W.H. Bohlke, Florida Power and Light Company, to the NRC dated June 22, 1995, "Turkey Point Units 3 and 4; Docket Nos. 50-250 and 50-251; Response to Generic Letter 95-03, Circumferential Cracking of Steam Generator Tubes." NUDOCS Accession No. 9506300133

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated October 11, 1995, "Turkey Point Units 3 and 4; Docket Nos. 50-250 and 50-251; Response to Request for Additional Information - Generic Letter 95-03, Circumferential Cracking of Steam Generator Tubes." NUDOCS Accession No. 9510190030

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated September 29, 1995, "Turkey Point Unit 3; Docket No. 50-250; Steam Generator Tube Plugging." NUDOCS Accession No. 9510060358

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated January 3, 1996, "Turkey Point Unit 3; Docket No. 50-250; Inservice Inspection Report." NUDOCS Accession No. 9601110198

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated January 17, 1996, "Turkey Point Unit 3; Docket No. 50-250; Steam Generator Tube Plugging Inservice Inspection Report." NUDOCS Accession No. 9601220367

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated March 27, 1997, "Turkey Point Unit 3; Docket No. 50-250; Steam Generator Tube Plugging - 15 Day Special Report." NUDOCS Accession No. 9704030004

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated July 10, 1997, "Turkey Point Unit 3; Docket No. 50-250; Inservice Inspection Report." NUDOCS Accession No. 9707160093

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Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated October 14, 1998, "Turkey Point Unit 3; Docket No. 50-250; Steam Generator Tube Plugging 15-Day Report." NUDOCS Accession No. 9810200272

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated January 20, 1999, "Turkey Point Unit 3; Docket No. 50-250; Inservice Inspection Report." NUDOCS Accession No. 9902120286

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated March 16, 1999, "Turkey Point Unit 3; Docket No. 50-250; Steam Generator Tube Plugging; Inservice Inspection - 12 Month Special Report." NUDOCS Accession No. 9903250292

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated March 27, 2000, "Turkey Point Unit 3; Docket No. 50-250; Steam Generator Tube Plugging 15-Day Report." ADAMS Accession No. ML003715540

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated April 6, 2000, "Turkey Point Unit 3; Docket No. 50-250; Reportable Event: 2000-001-00; Date of Event: March 11, 2000; Steam Generator Tube Plugging Places Steam Generator 3B in Category C-3." ADAMS Accession No. ML003705889

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Letter from J.P. McElwain, Florida Power and Light Company, to the NRC dated October 20, 2001, "Turkey Point Unit 3; Docket No. 50-250; Steam Generator Tube Plugging 15-Day Report." ADAMS Accession No.

Letter from J.P. McElwain, Florida Power and Light Company, to the NRC dated January 24, 2002, "Turkey Point Unit 3; Docket No. 50-250; Inservice Inspection Report." ADAMS Accession No. ML020330094

Letter from J.P. McElwain, Florida Power and Light Company, to the NRC dated February 28, 2002, "Turkey Point Unit 3; Docket No. 50-250; Steam Generator Tube Plugging Inservice Inspection 12-Month Special Report - Revision." ADAMS Accession No. ML020720442

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Turkey Point 4

Letter from R.E. Uhrig, Florida Power and Light Company, to the NRC dated August 12, 1983, "Turkey Point Unit 4; Docket No. 50-251; Inservice Inspection Report." NUDOCS Accession No. 8308180180

Letter from J.W. Williams Jr., Florida Power and Light Company, to the NRC dated September 4, 1984, "Turkey Point Unit 4; Docket No. 50-251; Inservice Inspection Report." NUDOCS Accession No. 8409100191

Letter from J.W. Williams Jr., Florida Power and Light Company, to the NRC dated June 18, 1985, "Turkey Point Units 3 and 4; Docket Nos. 50-250 and 50-251; Generic Letter 85-02." NUDOCS Accession No. 8506240503

Letter from C.O. Woody, Florida Power and Light Company, to the NRC dated December 1, 1986, "Turkey Point Unit 4; Docket No. 50-251; Inservice Inspection Report." NUDOCS Accession No. 8612090435

Letter from W.F. Conway, Florida Power and Light Company, to the NRC dated March 18, 1988, "Turkey Point Units 3 and 4; Docket Nos. 50-250 and 50-251; NRC Bulletin 88-02: Rapidly Propagating Fatigue Cracks in Steam Generator Tubes." NUDOCS Accession No. 8803250093

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Letter from W.H. Bohlke, Florida Power and Light Company, to the NRC dated July 30, 1991, "Turkey Point Units 3 and 4; Docket Nos. 50-250 and 50-251; NRC Bulletin 89-01, Supplement 2; Failure of Westinghouse Steam Generator Mechanical Plugs." NUDOCS Accession No. 9108050317

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated January 27, 1992, "Turkey Point Unit 4; Docket No. 50-251; Inservice Inspection Report." NUDOCS Accession No. 9202030140

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated May 4, 1993, "Turkey Point Unit 4; Docket No. 50-251; Steam Generator Tube Plugging." NUDOCS Accession No. 9305140226

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated August 20, 1993, "Turkey Point Unit 4; Docket No. 50-251; Inservice Inspection Report." NUDOCS Accession No. 9308260306

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated October 24, 1994, "Turkey Point Unit 4; Docket No. 50-251; Steam Generator Tube Plugging." NUDOCS Accession No. 9411010123

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated February 9, 1995, "Turkey Point Unit 4; Docket No. 50-251; Inservice Inspection Report." NUDOCS Accession No. 9502210127

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated October 6, 1995, "Turkey Point Unit 4; Docket No. 50-251; Steam Generator Tube Plugging Inservice Inspection Report." NUDOCS Accession No. 9510110118

Letter from T.F. Plunkett, Florida Power and Light Company, to the NRC dated January 31, 1995, "Turkey Point Units 3 and 4; Docket Nos. 50-250 and 50-251; Alloy 600 Steam Generator Mechanical Tube Plugs." NUDOCS Accession No. 9502070106

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated January 16, 1996, "Turkey Point Unit 4; Docket No. 50-251; Generic Letter 95-03 - Circumferential Cracking of Steam Generator Tubes." NUDOCS Accession No. 9601220369

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated February 27, 1996, "Turkey Point Unit 4; Docket No. 50-251; Generic Letter 95-03 - Circumferential Cracking of Steam Generator Tubes." NUDOCS Accession No. 9603040329

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated July 1, 1996, "Turkey Point Unit 4; Docket No. 50-251; Inservice Inspection Report." NUDOCS Accession No. 9607170072

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated October 1, 1997, "Turkey Point Unit 4; Docket No. 50-251; Steam Generator Tube Plugging." NUDOCS Accession No. 9710100290

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated January 7, 1998, "Turkey Point Unit 4; Docket No. 50-251; Inservice Inspection Report." NUDOCS Accession No. 9801130203

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated December 30, 1997, "Turkey Point Unit 4; Docket No. 50-251; Steam Generator Tube Plugging Inservice Inspection Report." NUDOCS Accession No. 9801060277

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated June 30, 1999, "Turkey Point Unit 4; Docket No. 50-251; Inservice Inspection Report." NUDOCS Accession No. 9907080066

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated October 16, 2000, "Turkey Point Unit 4; Docket No. 50-251; Steam Generator Tube Plugging 15-Day Report." ADAMS Accession No. ML003762437

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated January 19, 2001, "Turkey Point Unit 4; Docket No. 50-251; Inservice Inspection Report." ADAMS Accession No. ML010250129

Letter from R.J. Hovey, Florida Power and Light Company, to the NRC dated August 10, 2001, "Turkey Point Unit 4; Docket No. 50-251; Steam Generator Tube Plugging; Inservice Inspection 12-Month Special Report." ADAMS Accession No. ML021760007

Vogtle 1

Letter from J.A. Bailey, Georgia Power Company, to the NRC dated June 13, 1986, "NRC Docket Numbers 50-424 and 50-425, Construction Permit Numbers CPPR-108 and CPPR-109, Vogtle Electric Generating Plant - Units 1 and 2, SER Confirmatory Item 18: Examination of Steam Generator Tubes." NUDOCS Accession No. 8606180002

Letter from W.G. Hairston III, Georgia Power Company, to the NRC dated November 7, 1988, "Plant Vogtle - Unit 1, NRC Docket 50-424, Operating License NPF-68, Technical Specification, Special Report 88-007, Steam Generator Tube Plugged." NUDOCS Accession No. 8811150487

Letter from W.G. Hairston III, Georgia Power Company, to the NRC dated February 22, 1989, "Plant Vogtle - Unit 1, NRC Docket 50-424, Operating License NPF-68, Inservice Inspection Summary Report." NUDOCS Accession No. 8903010197

Letter from W.G. Hairston III, Georgia Power Company, to the NRC dated June 16, 1989, "Plant Vogtle - Units 1, 2, NRC Dockets 50-424, 50-425, Operating Licenses NPF-68, NPF-81, NRC Bulletin 89-01: Failure of Westinghouse Steam Generator Tube Mechanical Plugs." NUDOCS Accession No. 8906200329

Letter from W.G. Hairston III, Georgia Power Company, to the NRC dated March 22, 1990, "Vogtle Electric Generating Plant, Special Report, Number of Steam Generator Tubes Plugged During 1R2." NUDOCS Accession No. 9003280482

Letter from W.G. Hairston III, Georgia Power Company, to the NRC dated July 5, 1990, "Vogtle Electric Generating Plant, Inservice Inspection Summary Report." NUDOCS Accession No. 9007130318

Letter from W.G. Hairston III, Georgia Power Company, to the NRC dated July 31, 1991, "Vogtle Electric Generating Plant, Response to NRC Bulletin 89-01 Supplement 2, Failure of Westinghouse Steam Generator Tube Mechanical Plugs." NUDOCS Accession No. 9108060366

Letter from C.K. McCoy, Georgia Power Company, to the NRC dated February 13, 1992, "Vogtle Electric Generating Plant, Inservice Inspection Summary Report." NUDOCS Accession No. 9202260291

Letter from C.K. McCoy, Georgia Power Company, to the NRC dated November 5, 1992, "Vogtle Electric Generating Plant, Correction to Inservice Inspection Summary Report." NUDOCS Accession No. 9211160103

Letter from C.K. McCoy, Georgia Power Company, to the NRC dated April 22, 1993, "Vogtle Electric Generating Plant, Special Report 1-93-3, Number of Steam Generator Tubes Plugged During 1R4." NUDOCS Accession No. 9304270197

Letter from C.K. McCoy, Georgia Power Company, to the NRC dated May 6, 1993, "Vogtle Electric Generating Plant, Special Report 1-93-3, Number of Steam Generator Tubes Plugged During 1R4." NUDOCS Accession No. 9305130223

Letter from C.K. McCoy, Georgia Power Company, to the NRC dated July 21, 1993, "Vogtle Electric Generating Plant, Inservice Inspection Summary Report." NUDOCS Accession No. 9307270164

Letter from C.K. McCoy, Georgia Power Company, to the NRC dated October 6, 1994, "Vogtle Electric Generating Plant, Technical Specifications Special Report - Unit 1, Number of Steam Generator Tubes Plugged During 1R5." NUDOCS Accession No. 9410120113

Letter from C.K. McCoy, Georgia Power Company, to the NRC dated January 10, 1995, "Vogtle Electric Generating Plant, Inservice Inspection Summary Report." NUDOCS Accession No. 9501230321

Letter from C.K. McCoy, Georgia Power Company, to the NRC dated January 25, 1995, "Vogtle Electric Generating Plant, Steam Generator Mechanical Tube Plugs." NUDOCS Accession No. 9502010150

Letter from C.K. McCoy, Georgia Power Company, to the NRC dated April 1, 1996, "Vogtle Electric Generating Plant, Special Report 1-96-1, Number of Steam Generator Tubes Plugged During 1R6." NUDOCS Accession No. 9604050023

Letter from J.D. Woodard, Georgia Power Company, to the NRC dated July 17, 1996, "Vogtle Electric Generating Plant, Inservice Inspection Summary Report." NUDOCS Accession No. 9607230176

Letter from J.D. Woodard, Georgia Power Company, to the NRC dated June 10, 1996, "Vogtle Electric Generating Plant, Confirmed loose Part 14-Day Report." NUDOCS Accession No. 9606140081

Letter from C.K. McCoy, Southern Nuclear Operating Company, Inc., to the NRC dated October 13, 1997, "Vogtle Electric Generating Plant, Technical Specification Report 1-97-2, Number of Steam Generator Tubes Plugged During 1R7." NUDOCS Accession No. 9710200005

Letter from C.K. McCoy, Southern Nuclear Operating Company, Inc., to the NRC dated November 21, 1997, "Vogtle Electric Generating Plant, Confirmed Loose Part 14-Day Report - Revision 1." NUDOCS Accession No. 9712010215

Letter from C.K. McCoy, Southern Nuclear Operating Company, Inc., to the NRC dated January 16, 1998, "Vogtle Electric Generating Plant, Inservice Inspection Summary Report." NUDOCS Accession No. 9801260450

Letter from J.B. Beasley Jr., Southern Nuclear Operating Company, Inc., to the NRC dated March 29, 1999, "Vogtle Electric Generating Plant, Technical Specification Report 1-99-1, Number of Steam Generator Tubes Plugged During 1R8." NUDOCS Accession No. 9904070055

Letter from J.B. Beasley Jr., Southern Nuclear Operating Company, Inc., to the NRC dated June 21, 1999, "Vogtle Electric Generating Plant, Inservice Inspection Summary Report." NUDOCS Accession No. 9907010009

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Vogtle 2

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11 ABSTRACT *(200 words or less)*

Steam generators placed in service in the 1960s and 1970s had tubes primarily fabricated from mill-annealed Alloy 600. Over time, this material proved to be susceptible to stress corrosion cracking in the highly pure primary and secondary water chemistry environments of pressurized-water reactors. The corrosion ultimately led to the replacement of steam generators at numerous facilities, the first U.S. replacement occurring in 1980. Many of the steam generators placed into service in the 1980s used tubes fabricated from thermally treated Alloy 600. This tube material was thought to be less susceptible to corrosion. Because of the safety significance of steam generator tube integrity, this paper evaluates the operating experience of thermally treated Alloy 600 by looking at the extent to which it is used and results from steam generator tube examinations

12 KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report)*

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