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NUCLEAR REGULATORY COMMISSION
Docket No. 50-424/425-OLA-3 EXHIBIT NO. II · 198
In the matter of Georgia Power Co. et al., Vogtle Units 1 & 2
☐ Staff ☑ Applicant ☐ Intervenor ☐ Other
☐ Identified ☑ Received ☐ Rejected Reporter SD
Date 9/19/95 Witness HILL and WARD

Plant Vogtle

Diesel Generators
Airstart Cap Evaluation

Log No. 95-MT-039

Southern Company Services
Stress and Metallurgy

Originator: Date: 8/31/95
Reviewer: Date: 8/31/95
Manager: Date: 8/31/95

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OBJECTIVE:

REA 95 - VAA083 has requested an evaluation of the probability of creep-based deformation of the diesel generator airstart caps, thereby affecting the functioning of the Plant Vogtle diesel generators. The objective of this evaluation is to determine the feasibility of this mode of degradation and its' possible impact on the functioning of the air generators.

diesel

BACKGROUND:

During the start-up sequence of the diesel generators, air is injected into the cylinders of the diesel, through a typical internal combustion engine valving mechanism. In the case of these diesels compressed air is used as the initial operative fluid to open the combustion chamber valves. The pilot compressed air actuates a piston mechanism that in turn allows higher pressure compressed air to enter the combustion chamber and initiate the starting cycle. According to information obtained, the clearance between the stainless steel piston and the airstart cap cylinder walls may vary from 0.001 to 0.0[illegible]3 inches. There has been evidence of the stainless steel piston seizing within the surrounding cap.

EVALUATION:

In order to determine the susceptibility of the airstart cap to creep degradation a number of varying evaluations were performed. Among the metallurgical examinations were chemical analysis, hardness measurements and an evaluation of the microstructure of a representative sample.

By definition a gray cast iron is an iron compound that has a relatively large proportion of the graphitic carbon present in the form of flake graphite. Consequently, there is no specific formulation of gray cast irons and actual values of constituents may vary over a wide range. Chemical analysis, was performed to determine the composition of the sample.

Results of this analysis yield a chemistry of:

Carbon, %	3.19
Silicon, %	2.11
Manganese, %	1.15
Phosphorus, %	0.064
Sulphur, %	0.066
Lead, %	0.0018

In many irons the carbon contents normally vary from 2.75% to 3.3%. Silicon content also ranges from approximately 0.65% to 2.9%. Other elements such as manganese and chromium may be added to produce specifically desired physical properties. The above chemical analysis meets the requirements of American Society for Testing and Materials Specification A278 Standard Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650F. This specification indicates that chemical composition is secondary to mechanical properties. However, the specification does indicate that for gray iron castings operating above 450F the carbon equivalent shall be limited to 3.8% as calculated by the equation CE = Total carbon plus 0.3 (silicon + phosphorus). Using this equation the resulting carbon equivalent is 3.842. This value is in line with the requirement of the specification.

As noted previously, other alloying elements may be added to impart specifically desired traits. The manganese content of the sample, 1.15%, is slightly above what would be normally expected in a gray cast iron. Manganese in quantities above 1.25% in gray cast irons increase the strength, hardness and resistance to wear of the component. The slight increase of manganese in the sample would be in line with the anticipated service and not a cause of concern.

After the chemical analysis a sample was polished and etched to reveal the microstructure. A photomicrograph of the sample is located in Appendix A. The microstructure is indicative of a gray cast iron. The additional amount of manganese present in the sample could cause the amount and configuration of the flake graphite to differ slightly from that of a normal gray cast iron.

Hardness measurements were performed and the measured values were subsequently related to the tensile strength of the component. The hardness values equated with a tensile strength of approximately 50,000 psi. This value also compares favorably with the values stated in ASTM A 278.

A dimensional analysis and empirical determination of the stress resulting from the bolt torque values stated on the customers' component drawing was performed. This evaluation determined that there is a 2500 psi stress transmitted to the main portion of the cap. It was further empirically determined that this stress level would not cause significant distortion in a compact section such as that of the airstart cap. However, the contribution made by the configuration of the dome of the cap is not fully appreciated. Believing a worst case scenario, there may be some slight amount of distortion introduced by the applied load. However, it is believed that this distortion would occur in the elastic range of the material and would not cause a permanent deformation of the cap.

An American Society for Metals publication, "An Atlas of Creep and Stress-Rupture Curves", ASM International, edited by Howard E. Boyer, 1988, was researched in an effort to determine a creep rate for gray cast iron. The lowest temperature for which data is available is 700°F. At this temperatures the life of a specimen is in the range of thousands of hours. Extrapolation of the curves contained in the charts in this publication, indicates that creep declines significantly as temperature is reduced. A copy of the information used in this evaluation is attached in Appendix B. A more sophisticated analysis and evaluation, such as using a finite element model could be performed, but was considered to be beyond the scope of the initial evaluation.

Additional information was obtained from conversations with Helmut Thielsch of Thielsch Engineering, Cranston, Rhode Island; 401/467-6454 and Peter Ellis, Radian Corporation, Austin, Texas; 512/454-4797. Mr. Thielsch indicated that he has not encountered creep degradation occurring in cast irons in his over thirty year industry experience. Mr. Ellis indicated that Radian had performed numerous evaluations of paper mill gray cast iron dryer rolls that operate on saturated steam at approximately 250 - 300°F. Based on these evaluations it has been Radians experience that creep is not an active degradation mechanism in gray cast irons operating at those temperatures.

CONCLUSIONS:

Creep is the distortion of a material over time and is a function of applied load and temperature. The distortion is the result of the movement of atoms within the microstructure of the component. As loads are increased in a component the material attempts to deform in response to the applied load. If the load is applied rapidly the component may crack. If slowly and constantly applied, creep may occur. If the temperature acting on the specimen or component is increased, the atoms within the microstructure more easily respond or move in response to the applied load. If such a condition could occur in the airstart caps, this distortion could cause a binding of the stainless steel piston within the cast iron airstart cap.

Based on the chemical analysis of the sample, measured hardness values, empirical analysis of the loading of the installed cap, and review of the mechanism of creep, the probability of creep degradation is remote. Gray cast irons are relatively immune to creep due to the microstructure of the component. In order for creep to be a significant factor, the atoms of the materials structure must move within the individual crystals of the microstructure. The structure of gray cast iron with the numerous flakes effectively prevent the movement of the atoms within the structure. While there is no specific temperature for the initiation of creep, the operating temperature of the airstart cap, stated to be 165°F, is significantly less than what would be considered to be a contributor to the creep mechanism.

Therefore, based on the type of material, its' operating temperature and, an empirical evaluation of the loads applied, the probability of creep serving as a primary deformation mechanism and contributor to the seizing of the stainless steel piston is minimal if not non-existent.

APPENDIX A

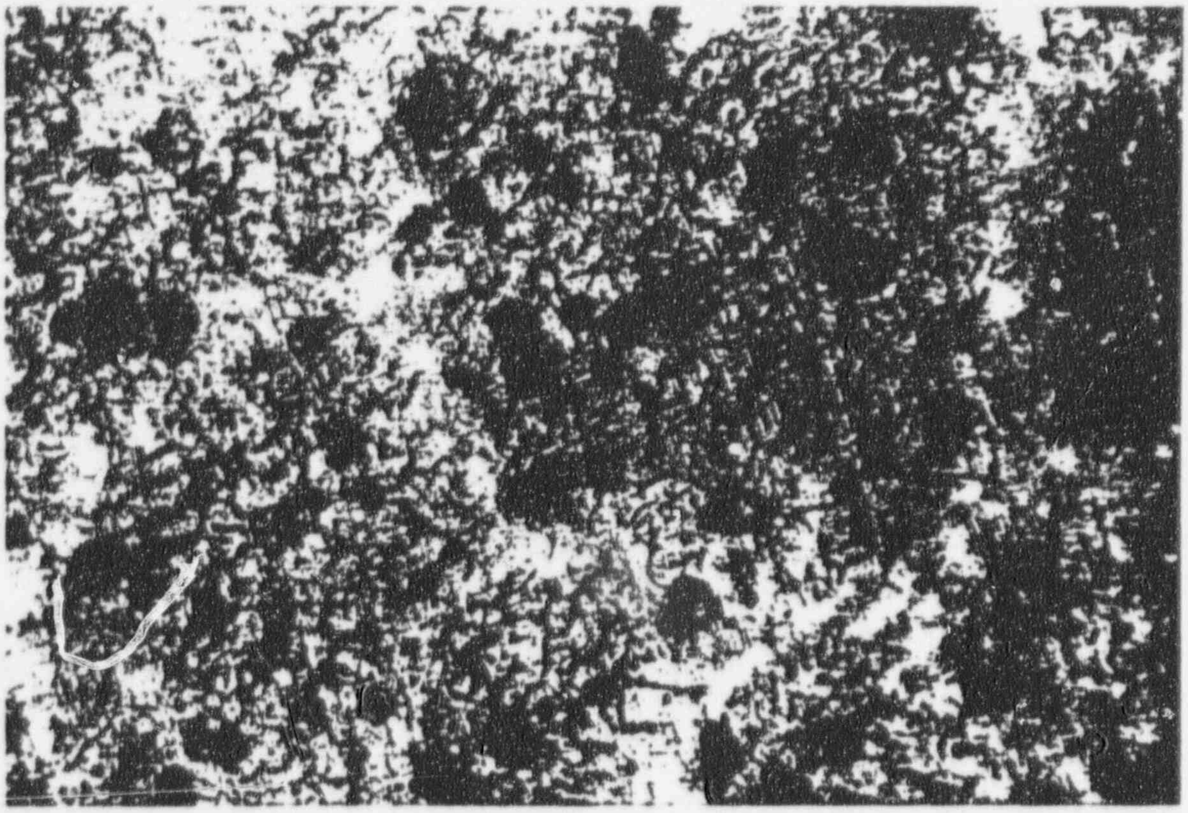


Figure 1. View of the microstructure of the airstart cap 100X

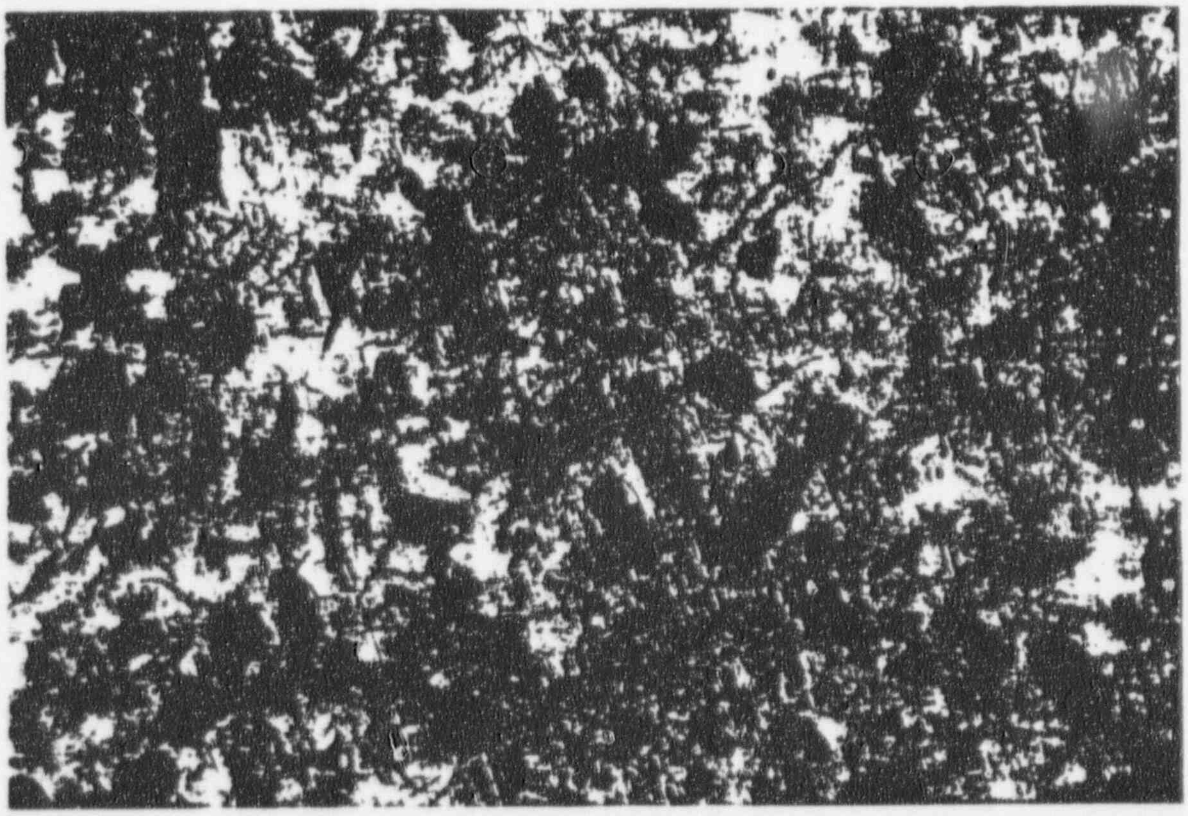
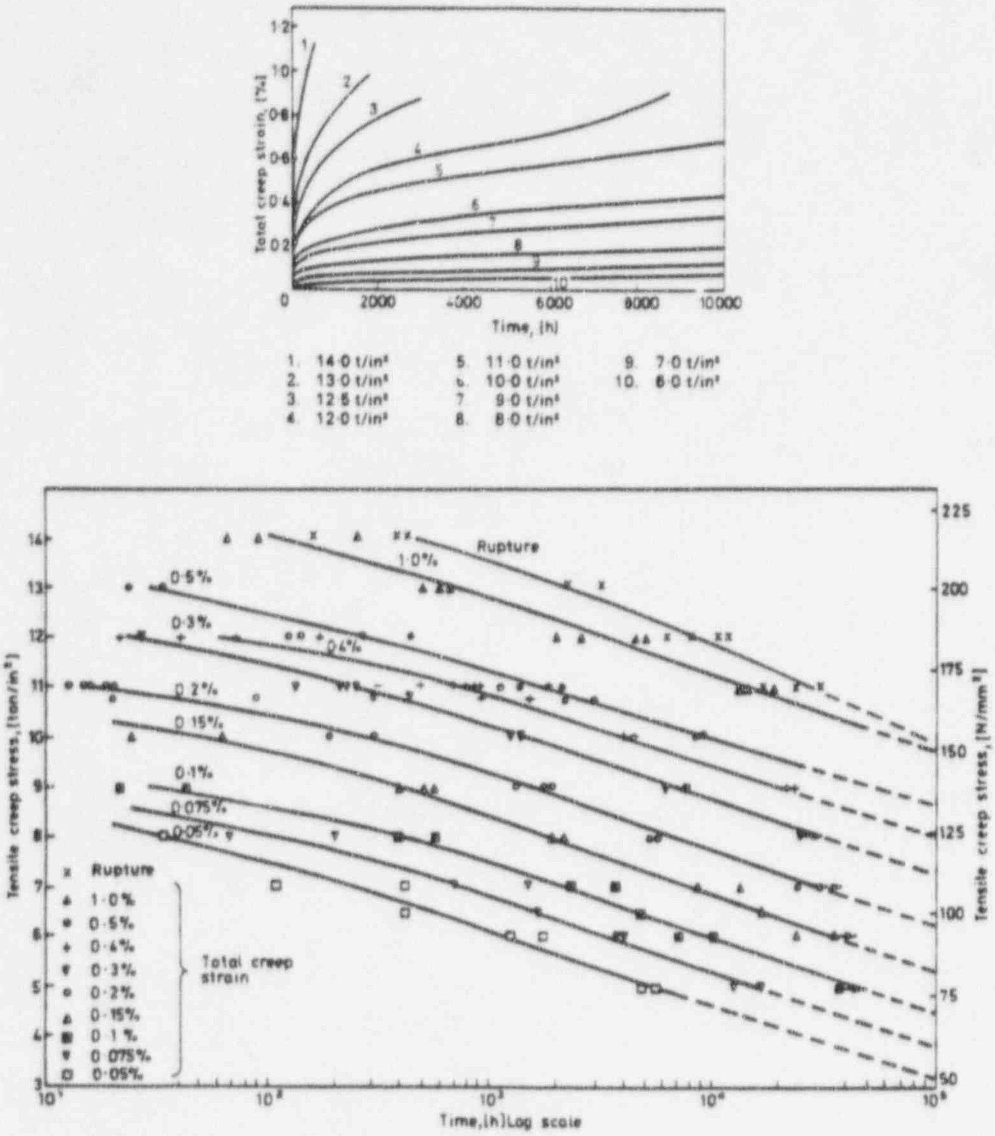


Figure 2. View of the microstructure of the airstart cap 400X

APPENDIX B

Grade 17 Gray Cast Iron: Effect of Cast Section Size



Creep curves of strain against time at 350 °C for 1.2-in. cast section size (top) and stress/log time curves for given strains and rupture of 3-in. cast section size at 350 °C.

Typical total creep strain curves for tests at stresses ranging from 6 tons/in.² (90 N/mm²) to 14 tons/in.² (215 N/mm²) for times up to 10,000 h are shown for a 1.2-in. (30-mm) section size in the top figure. A similar family of curves was obtained on a 3-in. (76-mm) section size, and from these curves, the stresses to produce various creep strains and rupture are shown plotted against the logarithm of time in the bottom figure. For a grade 17 gray iron, variations in cast section size from 1.2-in. (30-mm) to 3-in. (76-mm) diameter have little effect on stress-rupture properties at 350 °C. The rupture specimens had elongations after failure of 1.2-2.3%.

Source: K.B. Palmer, "High Temperature Properties of Cast Irons," Iron and Steel, Vol. 44, Feb. 1971, p 43

September 1, 1995

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of **GEORGIA POWER COMPANY, et al.** **(Vogtle Electric Generating Plant, Units 1 and 2)**	:	**Docket Nos. 50-424-OLA-3** **50-425-OLA-3** **Re: License Amendment (Transfer to Southern Nuclear)** **ASLBP NO. 93-671-OLA-3**

AFFIDAVIT OF LEWIS A. WARD

I, Lewis A. Ward, being duly sworn, state as follows:

1. During my testimony at the hearing on June 7, 1995, I testified about a problem with the Vogtle diesel air start valves discovered in July 1990 in which the air start valve pistons were sticking in the valve caps due to a lack of adequate clearance.

2. In response to a question from Intervenor's counsel, I stated that I could not explain why there were not any weak air rolls for five years prior to January 1990, "other than tying it together with the fact that we had changed surveillance methods around this same general time frame." Tr. 7776. I was referring to a change in the method of performing surveillance tests of the diesels such that, instead of always starting the diesels using both air receiver banks, one of the two air receiver banks would be isolated on a periodic basis. I recalled this change from a telephone conversation on this test method

sometime in that general time frame. Following my testimony, I have discussed this with several other people (Ken McCoy, Skip Kitchens and Jim Bailey) who also remembered this discussion.

3. Chairman Bloch later asked for the date that the surveillance procedure had been changed. Tr. 7780.

4. Following my testimony on June 7, 1995, I reviewed a sample of completed surveillance procedures (No. 14980) for the period August 1989 through April 1990 for the Unit 1 diesels and February 1989 through July 1990 for the Unit 2 diesels.

5. My review revealed that the provision to alternately isolate air banks when starting the diesels was in effect and no change had been made to that provision on either Unit 1 or 2 during those periods.

6. Therefore, my testimony on June 7, 1995, quoted above, was in error, although I believed it to be accurate at the time.

7. With respect to Unit 2, where the sticking valve problem first surfaced, it is my understanding that the first time the provision to alternately isolate air banks was used on the diesels was when the surveillance procedure was first implemented on that unit. Based on my review of surveillance procedures, I believe that date was February 1989.

8. My review also revealed that the alternating air bank provision was included in Revision 0 of the Unit 1 surveillance procedure which was approved on September 11, 1986.

9. A "weak air roll" apparently occurred only when one or more valves were "sticky" or were stuck in either the open or closed position. However, this condition by itself would not necessarily prevent the engine from starting. Factors that aggravated this condition were the initial starting position of the crankshaft in relationship to the valves that happened to be stuck at that particular time, and whether one or both air start systems were in service for the start. The initial position was important because if the first cylinder to receive compressed air for the start attempt was opposed by a cylinder that also was receiving air due to a stuck open piston, then enough force to roll the engine may not be developed. This situation would be further aggravated if the air system was aligned to only one air header (8 cylinders), rather than to two headers (all 16 cylinders). However, a stuck piston should not have any affect if it was on the side of the engine that had its air system isolated, since that cylinder would not receive starting air to pneumatically lock it. In summary, conditions required to produce a "weak air roll" include the air start system alignment, the number and location of stuck pistons, and the initial starting position of the crankshaft in relationship to the valves that happen to be stuck at that particular time.

10. When the cause of the DG2A start failure was determined during July 1990, all air start valves were pop tested, then removed, and clearances were checked for all four DG's. MWO's for this work (see GPC Exhibits II-150 A through E)

contain the following information, which I have summarized below. These MWO's indicate that the pistons either failed the pop test (e.g., did not audibly click open or closed), had inadequate clearances between the piston and cap, or were otherwise determined to need rework or replacement. This list does not indicate that the listed piston was necessarily "stuck," but only that it could have conditions that could cause it to possibly stick:

DG2A - 7 valves - (cylinders 1L, 4L, 5L, 1R, 6R, 7R, 8R)
DG2B - 6 valves - (cylinders 6R, 7R, 8R, 6L, 7L, 8L)
DG1A - 4 valves - (cylinders 3L, 8L, 4R, 6R)
DG1B - 10 valves - (cylinders 1L, 2L, 4L, 7L, 1R, 2R, 5R, 6R, 7R, 8R)

11. In addition, many of the caps were not flat on the bottom surface, which caused some distortion when the two mounting bolts were torqued to the engine. During untorquing of one of the improperly operating valve cap bolts on DG2A, the piston audibly snapped closed as the torque was decreased. This fact was recorded in Event Report No. 2-90-005 (GPC Exhibit II-136), at page 4, by the critique team, and clearly demonstrates that the valve was mechanically stuck in the open position and could freely close when the mechanical binding was relieved.

12. The recorded start failures occurred on the following dates:

1/24-25/90 DG2A - Right (#1) air system isolated
4/12/90 DG2A - Right (#1) air system isolated
7/11/90 DG2A - Right (#1) air system isolated
7/05/90 DG1B - Right (#1) air system isolated

Note that all of the recorded failures occurred with one of the air systems isolated, during which the attempt to start the DG was initiated by applying air to only 8 of the 16 cylinders.

13. Also note from the inspection data that all of the recorded start failures occurred on the two DGs (2A and 1B) which had the most valves with problems.

14. The 10 CFR 21 notification issued by Cooper Industries on July 19, 1990, (OwYoung/Johnston Exhibit F; GPC Exh. II-158), as a result of the VEGP problem, contains the following observations:

> It has been determined that the cause of the failure to start was the air start piston sticking in the air start valve cap. Sticking in the piston cap can cause the air valve to stick in either the closed or open position.
>
> A valve stuck in the closed position will result in a "dead" cylinder. This will have a slight negative impact on engine start time, but the increase in starting time will not be significant and in almost all cases not noticeable. Multiple closed valves on an engine can result in a very slow engine start or failure to start.
>
> A valve stuck in the open position would most likely result in a very slow engine start or failure to start. If this were to occur on an operating engine, the engine would lose the output of the affected cylinder until normal vibrations freed the piston sufficiently for the valve to close. This could impair the engine's ability to carry rated load if the valve did not reseat.

15. This explanation by Cooper Industries clarifies the potential non-static nature of the "sticking" issue. It explains that, with inadequate clearances, a valve can stick open, stick closed, or engine operation can cause a stuck valve to change position. Thus, the propensity of a valve to stick may have always existed, but it may not have always stuck in the same

condition each time a start attempt was made on the engine. Therefore, its effect on subsequent start attempts when the crankshaft was also in a different initial position could easily vary with time.

16. Additionally, I requested a review by Southern Company Services, Inc. ("SCS") to determine whether creep deformation might have contributed to the binding of air start valve parts. SCS performed a detailed metallurgical examination of a valve cap, obtained from the Plant Vogtle warehouse in August 1995, and contacted other industry metallurgists. As discussed in the report attached hereto as Exhibit ~~D~~ H, SCS found that, under the worst case stress levels, there might be some slight amount of distortion of the valve cap introduced by the applied load; however, it is believed that this distortion would occur in the elastic range of the material and would not cause a permanent deformation of the cap. Based on this analysis, I do not believe that creep deformation was a contributing factor to the air start valve binding which occurred in 1990.

17. I believe that the above discussion reasonably explains why the manufacturing problems with the starting air valve caps were not observed until some 1-3 years after the DGs had been placed in service.

I hereby certify that the foregoing statements are true and correct to the best of my personal knowledge and belief.

Lewis A. Ward

Lewis A. Ward

Sworn to and subscribed
before me this 1st day of
September, 1995.

Mary N. Bentley

Notary Public

My commission expires:

Sept 9, 1999