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I-MOSBA-225

Cooper Energy Services

CORRESPONDENCE RELATING TO JULY 1990 STARTING AIR VALVE PROBLEM

COPY

NUCLEAR REGULATORY COMMISSION
Docket No. 50-424/425-OLA-3 EXHIBIT NO. II-225
In the matter of Georgia Power Co. et al., Vogtle Units 1 & 2
☐ Staff ☐ Applicant ☑ Intervenor ☐ Other
☐ Identified ☑ Received ☐ Rejected Reporter SD
Date 10/6/95 Witness

ENERGY SERVICES GROUP
ENTERPRISE ENGINE SERVICES
14490 Catalina Street
P.O. Box 1837
San Leandro, CA 94577
(415) 614-7400

MEMO

Date: July 14, 1990
To: Ken Stokes
From: Robert Johnston
Subject: Georgia Power, Vogtle Electric Generating Plant
Reference: Enterprise Diesel Generators S/N 76021/24

To help identify the root cause of sticking air start valves we would like to have Georgia Power obtain some dimensional data before reworking the valve caps. As a minimum I'd like to see the cap's bore diameter measured at 30 degree intervals around the circumference and two points along the axis, say 1/3 and 2/3 of the bore depth. Diameters should be measured with a two point micrometer rather than a bore gauge so as to best determine the degree of ovality. The other important measurement is to somehow determine the flatness of the valve cap flange face. This data will be of great assistance for us to develop a plan of corrective action.

Please call Lanny McHugh monday morning at 415-614-7400 to get information on the maximum allowable material removal from the cap flange face during rework. He has the detailed drawings at his desk and should be able to develop the necessary numbers.

Regards, [signature]

Distribution:

File: Engine S/N: 76021
Project Admin:
Sales:
Other:

INTEROFFICE MEMORANDUM

TO: DPQ GROUP

FROM: ROBERT JOHNSTON

DATE: JULY 27, 1990

SUBJECT: 10CFR21 REPORT NO. 154

REFERENCE: STARTING AIR VALVES

The subject report was discussed between Allen Gillette, Lanny McHugh, Maurice Lowrey and myself on July 26 so as to develop recommendations for examination, corrective action and further testing. This summary is being provided to DPQ for consideration and, as appropriate, inclusion in the follow up to report *No. 154.*

Recommended Customer Response To 10CFR21:

1. Examine site operating history for occurance of unexplained failures to start of diesel generators.

Yes No Failures _ Defer further action until next scheduled outage.

_

2. Test function of air start valves by applying a 100 PSI pneumatic signal to the subcover tubing connection and listen for audible actuation, both opening and closing, of the air start valve at keepwarm or operating temperature.

No Actuation Yes, Valve Works _ Defer further action until next scheduled outage.

_

3. Confirm failure of air start valve actuation by boroscope examination thru injector bore while repeating test outlined by *Item 2*. Note: Customer may elect to proceed directly to *Item 4*; that depends on site specific documentation and procedure requirements.

No Visual Actuation Yes, Valve Works _ Defer further action until next scheduled outage.

_

4. Remove air start valve cap and piston only. Do not disturb valve body or intake rocker assembly. This way it will not be necessary to reset valve lash or perform hot retorque of air start capscrews. Measure cap bore and piston diameter with components at room temperature and at least at 30° intervals around the circumference of the parts. Nominal clearance required is .002" to .003".

   Measured Clearance Clearance Is Correct _Fault lies within the valve assembly; replace air
   Is Insufficient start valve assy.
   _

5. Mount piston in a suitable lathe and <u>sand</u> down the outside diameter to obtain a nominal clearance of .002" to .003" at room temperature. Use emery paper only. Do not attempt to turn down O.D. with lathe tooling. Retest valve at keepwarm temperature after rework.

   Test Fails Test OK _ Work Concluded.
   _

6. Replace valve.

Recommended Enterprise Response To 10CFR21:

1. R&D test to determine if cap distortion results from manufacturing operations.
2. R&D test to determine if flange face distortion can cause valve failure when torqued to valve body.
3. R&D test to determine allowable range of nominal diametrical clearance which provides satisfactory actuation.

Based On Test Results:

1. Revise manufacturing drawings to specify control of flange face flatness.
2. Revise bore and/or piston diameter to obtain proper nominal diametrical clearance.
3. Revise piston material specification to minimize, or eliminate, differential in thermal expansion coefficients.
4. Revise manufacturing process to eliminate set up induced distortion.

5. Revise published table of clearances to reflect allowable piston to cap clearances.

RJ:djl

Cooper Energy Servic.
14490 Catalina Street
San Leandro, CA 94577

COOPER

Inter-Office Correspondence

Date: November 15, 1991

To: Greg Desin

From: John Gildea

Subject: Air Start Valve Investigation Progress

To date, all planned testing of the subject Georgia Power Air Start Valve caps has been completed *(reference attached outline)*. I anticipate all data reduction and report writing to be completed by November 22. However, at this time I can comment on some of my findings.

1. A review of the manufacturing history shows we have had a problem maintaining the close tolerance of the cap bore diameter in the past. Up until about 8 years ago the C and C lathe was employed to bore the parts. This technique often produced out of round bores because the v-chucks that held the caps at the bolt hole flanges were hydraulically operated and tended to exert too much force to the structure. That machining method was subsequently changed to utilize an end mill and 4 point chucks to bore caps. The chucks gripped the parts about the smaller axis *(opposite the flanges)* and were manually adjusted to better control clamping force and out of roundness attributed to it.

   Currently, our Grove City Manufacturing site uses 3 or 4 point chucks to hold the cap cylinder (away from the flanges) during milling. The bores are then honed with virtually no clamping forces to ensure bore integrity. As such, parts are now being manufactured without out of round characteristics.

2. The subject cap bores were measured at subscribed depths and intervals (see attached outline) and plotted for analysis. The measurements were compared to those of new air start cap *(I.D. Number 1J2735)*. In general, the Georgia Power caps were found to have out of round bores elongated in the axis coincident with the bolt hole flanges. The new cap bore was found to better maintain its roundness.

   The caps were then chucked in a lathe to simulate the hydraulically controlled v-chuck of the C and C lathe and the bores were again measured. Although it was not possible to rechuck the caps as to produce perfectly round bores, the resulting diameters showed the material did deform and cause the direction of the bore elongation to change to the axis perpendicular to the bolt hole flanges. This suggests the current bore out of roundness measured in the caps is most likely the result of machining technique.

3. Flatness of the cap seating surface was measured for both the Georgia Power caps and new cap taken from Enterprise stock. All the caps exhibited a dished shape about the flange axis with a center high point of 1-2 mils. The absence of any flatness disparities tends to discount the possibility of creep pneumonia or plastic deformation of the cast iron caps.

4. Each cap was assembled with an air start valve and torqued to a cylinder head at 150 ft lbs. Bore diameters were again measured. All caps deformed in the same manner, pinching the bore about the flange axis. In that direction it was found that the diameter was reduced by as much 1-3 mils.

Conclusions

Preliminary analysis to the test results yields the following conclusions:

1. Manufacturing techniques employed in certain vintage caps induced out of roundness of the bores. The subject Georgia Power caps have bore dimensions representative of those manufactured caps .

2. Material creep or yielding does not appear to have occurred in the bolt hole flanges of the caps. Any permanent material deformation would most likely be apparent as an improper flatness. All the caps were found to be flat within 2 mil as was the new cap.

3. Torquing the caps to 150 ft-lbs causes the bores to pinch along the bolt hole flange axis and reduce clearance by as much as 1.3 mils. Existing air start valves with 1-3 mils clearance are subject to piston to cap interference.

JRG:sr:dg

Attachment

91CHRON\NOV\ME15276

DETAILED OUTLINE

OF

PROPOSED AIR START VALVE TEST PROCEDURE

A. *OBTAIN TEST COMPONENTS*

1. Request subject air start caps from Georgia Power Engine 2B (S/N 76021). Samples should include but not be limited to caps taken from the malfunctioning valves.

2. Select one random air start valve cap from Enterprise stock.

3. Select one random air start valve piston from Enterprise stock.

B. *ESTABLISH DIMENSIONAL BASELINE FOR SUBJECT COMPONENTS*

1. Define a reference point and mark air start valve cap bores at 30° intervals about circumference.

2. Using 2-pt instruments readable and accurate to .0001", take diametrical measurements at marked intervals at bore lip and at planes approximately 1/3 and 2/3 of the distance along the axis of the bore depth.

3. Mark air start valve cap flanges at 10 equally spaced points about circumference.

4. Using *"feeler"* type gap gages accurate to .0005", place caps on flat surface and determine flatness at marked points. Record gap sizes.

5. Define a start point and mark piston at 30° intervals about circumference.

6. Using 2-pt instruments readable and accurate to .0001", record diametrical measurements at reference points about planes approximately 1/3 and 2/3 the distance along the axis of piston height.

C. *FABRICATE TESTING FIXTURE*

1. Machine a steel plate 1-3/4" to 2" thick, approximately 6" x 4".

2. Bore a 1-15/16" hole through center of plate and (2) 13/16" holes 2-1/4" from center of 1-15/16" hole along major axis of plate.

3. Indicate the test fixture for flatness and grind as necessary to obtain flatness within .001" and surface finish to 125 MU in RMS or better.

D. ASSEMBLY AIR START CAPS AND TEST FIXTURE

1. Bolt caps to test fixture with (2) 3/4" capscrews coated with 50/50 lube oil and powder graphite compound.

2. Torque capscrews to 150 ft-lbs + 25 ft-lbs/-0 ft-lbs.

E. MEASURE CAP BORE DIMENSIONS WHILE BOLTED TO TEST FIXTURE. REPEAT PROCEDURE DESCRIBED IN STEP B.2 PASSING GAGE THROUGH THE TEST FIXTURE INTO THE CAP BORE.

F. PERFORM STEPS D AND E FOR EACH AIR START VALVE CAP OBTAINED.

G. ANALYZE RESULTS

1. Construct diagrams of each cap and the piston to illustrate bore distortions and flatness deviations.

2. Compare *"torqued"* cap profile to *"as machined"* cap profile for each subject cap.

3. Test results should indicate the degree with which, if any, machining, torquing, and creep deformation affect cap bore distortions.

H. PLAN ADDITIONAL TESTING BASED ON ABOVE RESULTS

1. Review current and past machining processes.

2. Calculate clearance reduction due to thermal growth of assembly to establish design limits.

3. Calculate maximum allowable cap to piston clearance that would satisfy the five-start requirement.

4. Establish a course for corrective action based on test results. Considerations:

4.1 Revise manufacturing processes to eliminate machining induced distortions.

4.2 Revise piston material to minimize or eliminate differential in thermal expansion coefficients.

4.3 Revise cap bore and/or piston diameter to obtain proper running clearance.

4.4 Alter cap material to prevent bore distortion due to creep deformation.

91REPORT\MISC\RP07001

ENGINEERING REPORT NO. HE-05-1991

STARTING AIR VALVE INVESTIGATION

NOVEMBER 25, 1991

*PREPARED BY:*______________________ *DATE:*______________________

*REVIEWED BY:*______________________ *DATE:*______________________

*APPROVED BY:*______________________ *DATE:*______________________

DISTRIBUTION:

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J. MANNO
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S OWYOUNG

I. OBJECTIVE

Failure to start of a diesel generator in nuclear standby service was attributed to a starting air valve piston seizing in its valve cap. This report documents the subsequent investigative actions performed on the suspect failure components.

II. FAILURE BACKGROUND

In July of 1990, Engineer Bob Johnston investigated a failure to start of the unit 2B diesel generator at Georgia Power's Plant Vogtle *(S/N 76021)*. At that time the engine had accrued four separate failures to start; three of which while the engine was attempting to start on the left bank air system and the fourth with both systems active. In troubleshooting the system Bob *"pop"* tested each starting air valve, pressurizing its pilot air inlet and confirming valve actuation. He determined piston seizure restricted valve actuation in several of the assemblies. Subsequently, six of the eight left bank starting air caps were returned to Enterprise for further analysis.

III. DESIGN HISTORY

The starting air system employs a poppet valve assembly housed in each cylinder head. Upon valve actuation, starting air from a manifold at roughly 250 psi is admitted to the cylinder, translates the power piston, and rotates the crank. The valve is normally closed by a compressive spring. Actuation is controlled by a timed pilot air signal that is admitted in the air start cap. The pressure of that pilot air overcomes the spring force and depresses the piston in the air cap to actuate the valve. Upon termination of the pilot signal the air above the piston is vented and the spring force retracts the valve and piston.

The Georgia Power air start valve assembly *(P/L 02-359-03-04)* was released 2/18/78 and is a revision of the original air start valve assembly for nuclear application *(P/L 02-359-03-01)* released 12/03/74 *(see Figure 1: Air Start Valve Assembly)*. The valve housing *(P/N 02-359-03-AK)* and cap *(P/N 02-350-03-AL)* are cast iron, ASTM A48 Class 40, and are bolted together in the cylinder head. The starting air piston *(P/N 02-359-03-AH)* is stainless steel and is contained in the air start cap. Unlike previous air start piston designs, this assembly does not include piston compression seals. Instead, the piston to cap clearance is closely maintained and the piston wall is grooved to provide a labyrinth seal.

On 11/18/75 the piston material was changed from 310 to 316 stainless steel. Cost reduction was cited as the change reason. On 2/15/77 the piston O.D. was revised from 2.249"/2.248" to 2.2485"/2.2475" which in turn changed the piston to cap diametral clearance from 1-4 mils to 1.5/4.5 mils. The clearance was again revised on 6/19/78 when the cap bore diameter was changed from 2.252"/2.250" to 2.2505"/2.2495". That revision was prompted by the desire to limit pilot air blow-by between the cap and piston which was believed to affect starting air time. The diametral clearance since that revision has been 1-3 mils. However, as a result of the reported failure to start at Georgia Power,

new pistons and caps are matched as a 1A-7818 assembly to limit clearance to 2-3 mils.

Seizure of the piston could result in two sequences of events leading to a failure to start. A piston stuck in the closed position could result in a *"dead"* cylinder. This type of seizure would most likely have only a slight impact on starting time since engine momentum would roll the engine past the *"dead"* cylinder. If, however, the engine is at rest or does not have sufficient momentum when a pilot signal is given to a valve stuck closed it is possible that a failure to start would result. The second mode of failure to start would occur when a piston seized in the open valve position. If the valve remained stuck open during the compression stroke of the cycle the entrapped starting air would oppose engine rotation and result in a very slow start or failure to start.

IV. TEST PROCEDURE

Six of the eight left bank starting air caps were returned to Enterprise by Georgia Power for analysis. The following outline details the investigative work performed:

A. Design Review

1. Review air start cap manufacturing techniques.

2. Calculate clearance reduction as a function of thermal growth in the assembly.

3. Calculate maximum allowable piston to cap diametral clearance as to ensure proper valve actuation.

B. Obtain Test Components

1. Request subject air start caps from Georgia Power. Samples should include but not be limited to caps taken from malfunctioning valves.

2. Select one air start cap from Enterprise stock *(S/N 1J2735)*.

3. Select one air start piston from Enterprise stock *(S/N 1K1513)*.

C. Establish Dimensional Baseline For Subject Components

1. Define a reference point and mark air start cap bores at 30° intervals about circumference.

2. Using Bore gage accurate to .0001", measure bore diameters at marked intervals at four equally spaced planes along the axis of the bore depth.

3. Map measured results.

D. <u>Measure Machining Dimensions Of Cap Bores</u>

1. Chuck each cap at bolt hole flanges.
2. Remeasure bores at defined intervals and depths.
3. Map measured results.

E. <u>Measure Assembled Dimensions Of Cap Bores</u>

1. Assemble bore gage in valve housing in cylinder head.
2. Calibrate gage.
3. Torque each cap to head to 150 ft lbs.
4. Remeasure bores at defined intervals and depths.
5. Map measured results.

F. <u>Measure Cap Flatness</u>

1. Mark cap flanges at eight equally spaced points about their circumference.
2. Place caps on flat surface and determine cap sizes using feeler gages at marked points.
3. Record gap sizes.
4. Place inverted caps on 3-inch joe blocks.
5. Sweep cap flange surfaces with dial indicator.
6. Record greatest height variations.

G. <u>Determine Maximum Allowable Diametral Clearance</u>

1. Measure cap I.D.
2. Measure piston O.D.
3. Assemble one air start valve *(P/L 02-359-03-04)*.
4. Pop test valve at 100 psi.
5. Reduce pilot pressure by 10 psi.
6. Repeat steps 4 and 5 until valve fails to fully open.

7. Record final pressure.

8. Using lathe and fine grade sand paper turn down piston O.D. approximately .001".

9. Repeat steps 4 thru 8 until final pressure ≤ 60 psi.

V. DISCUSSION

The following items are pertinent results to the above detailed investigation.

1. Manufacturing History

   A review of the cap manufacturing history shows that Enterprise has had difficulties maintaining the close bore diameter tolerance in the past. Until 1983 a lathe was used to bore the caps. That technique often produced out of round bores because the v-chucks that gripped the caps at the bolt hole flanges were hydraulically operated and tended to exert too much force in that direction of the structure. The machining method was subsequently changed to utilize an end mill and four point chucks. The caps were gripped on the flange along the minor axis *(perpendicular to the bolt hole)* and clamping force was manually adjusted to better control bore out of roundness.

   Currently our Grove City manufacturers use three or four point chucks to hold cap body *(away from the flanges)* during milling. The bores are then honed with virtually no clamping force to best control bore integrity.

2. Differential Thermal Growth

   The gray iron air start cap *(ASTM A48 Class 40A)* and stainless steel piston *(316 SS)* are known to have different coefficients of thermal expansion. Thermal growth of the dissimilar metals was calculated to determine its effect on the cap to piston clearance.

   Using a coefficient of thermal expansion, α, for ASTM A48 of 6×10^{-6} in/in °F, an $\alpha = 8.9 \times 10^{-6}$ in/in °F for 316 stainless steel, and assuming a maximum temperature gradient of 100°F , the equation

   $$\delta = \alpha \Delta T L$$

   shows the differential growth to reduce the clearance by .00065 inches. This reduction of clearance alone should not jeopardize the function of the valve at standby temperature since the expected clearance is 1-3 mils. However, the calculated differential growth is substantial if other clearance reducing factors are present.

3. Bore Measurements

The bores of the six subject air start caps *(L1, L3, L5, L6, L7, L8 designating engine bank and cylinder)*, and the new cap *(S/N IJ2735)*, were measured per the above test procedure and those results are shown in *Attachment I*. Note the alpha variables represent the 30° intervals from bolt flange to bolt flange, the numeric variables show the depth of the measurements from the bottom of the bore to the lip. The measurements are in 1/10 mils.

Several comments can be made regarding the results. Firstly, all of the cap bores conformed to the design specification of 2.2495"/2.2505" with the exception of cap L5. Measurements of that bore were found to be as much as 1.9 mils over nominal diameter along the bottom depth. Diametral deviation was no greater than the other caps at that location and the remaining depths were measured within specification. No reasons for that nonconformance were visibly apparent but it should be noted that those measurements were taken as close as possible to the 3/32" re-entrant fillet at the bottom of the bore. A slightly oversized fillet, chamfer, or taper could have attributed to the unexpected bore measurements. Additionally, the oversized bore at that location would not induce piston seizure.

Graphical representation of the bore measurements is shown in *Attachment II*. The linear graphs trace the deviation from the mean diameter at each 30° interval from bolt hole flange to bolt hole flange. The four measurement depths are shown equally spaced from the bottom of the bore to the bore lip. Measurements are in 1/10 mils. In general the bores appear to be slightly elongated along the axis coincident to the bolt hole flanges. Some exceptions to that are the measurements taken at the lip of cap bores L1, L3 and L8. Those measurements show the bores at that location to be slightly longer in the direction perpendicular to the bolt hole flanges.

The cap bores were remeasured while chucked in a lathe at the bolt hole flanges to simulate the forces imparted by the hydraulically operated v-chucks that were at one time used during cap manufacturing. These measurements and the corresponding graphs are shown in *Attachments III* and *IV*. Although I was not able to chuck the caps to produce round bores, the plots show that material did deform and cause the bores to elongate in the direction perpendicular to the bolt hole flanges. A comparison of the chucked and unchucked measurements shows the Georgia Power caps to be out of round in the direction one would expect if excessive clamping force was applied to the bolt hole flanges during machining.

4. Cap Flatness

Each of the caps were examined to determine flatness integrity. Both the six Georgia Power caps and the new Enterprise cap were found to be

slightly dished along the bolt hole flange axis with a high point between 1-2 mils. The absence of any flatness disparities tends to discount the possibility of creep or plastic deformation of the cast iron caps.

5. Torquing contributions

To determine if the clamping force of the bolts on the air start cap flanges affects bore roundness, the caps were remeasured after being torqued in a valve housing in a cylinder head per the above outline. A special bore gage with a neck length of 20 inches was obtained for this purpose and was dismantled, reassembled, and calibrated in the cylinder head. Each cap was then torqued to the head with (2) 3/4"-10 UNF-3A capscrews *(P/N GB-032-113)* lubricated with 50/50 oil and graphite. The required 150 ft lbs of torque was consistently reached in three steps. Both new and old caps deformed in the same manner, pinching at the bore lip in the direction of the bolt hole flanges. Analysis of the test results suggest the cap flanges behave as cantilever beams, bending under the transverse loading of the capscrews. The cap walls bow in the unconstrained region between the flange and cap top along that axis. The cap bores were found to pinch an average .71 mils with cap L7 displaying the most reduction of clearance at 1.1 mils. *(See Attachment V.)* Note, the valve housing flange was measured with respect to flatness and determined to be within .001 inch.

Additional testing with the new air start cap was performed. Firstly, the cap mating surface was coated with a moly grease prior to assembly to reduce relative friction between the cap and housing and accent any bore distortions caused by torquing. No dimensional changes were apparent. Measurements of the bore were also made after torquing the cap to 150 ft lbs in one step. Again, no significant change in bore distortion was observed. Finally, the cap was torqued to 175 ft lbs in four steps to predict bore deformation at the high limit *(150 + 25/-0 ft lb)*. That test showed the bore to pinch in the bolt hole flange direction by 1.3 mils or an additional 44% for 16.7% added torque.

6. Upper Limit of Clearance

Per design, the cap to piston diametral clearance can be between 1-3 mils. Prompted by the Georgia Power failure to start and controlled by the 1A-7818 matched cap & piston assembly, the clearance is currently maintained at 2-3 mils. An upper limit of 9 mils has traditionally been accepted to allow wear of the mating parts but no physical tests of record confirm that such a large diametral clearance would allow proper valve actuation. As such, the *"blow by"* test described in the outline was performed to determined at what maximum clearance pilot air pressure will be sufficient to overcome the valve spring force and actuate the valve.

Because proper starting air admission into a cylinder is dependent upon valve actuation duration and valve travel distance, and those parameters are governed by pilot air pressure and engine speed, certain assumptions were made for the test. Firstly, although air start tank pressure is maintained at 250 psi, head loss due to friction in the tubing and venting at

the air distributor significantly reduce that pressure to some unknown value at the air start valve pilot inlet. A value of 60 psi was assumed to be the lowest pilot air pressure to the air start cap in this test. Secondly, in performing the test, pilot air signal duration was assumed to be infinite and proper starting air flow was determined to be a function of valve travel distance. Minimal pilot air pressure for a particular cap to piston diametral clearance was considered to be the lowest pressure at which the valve could fully open.

At 5.5 mils diametral clearance the subject starting air valve could be fully actuated with a pilot air signal at 60 psi. At 6.2 mils diametral clearance the valve could not fully open with the subscribed pilot air pressure. At the minimal clearance tested, 1.5 mils, the valve performed similarly at 35 psi. Note, the nominal pressure required to overcome the spring force is calculated to be 33 psi.

VI. CONCLUSIONS

1. The stainless steel air start piston and cast iron cap have dissimilar coefficients of thermal expansion. Calculations show that initial or ambient temperature diametral clearance can be reduced by as much as .00065 inch at operating temperature.

2. Manufacturing techniques employed prior to 1983 are known to have induced out of round cap bores elongated along the bolt hole flange axis. That out of round condition was attributed to the high clamping force imparted on the caps by the hydraulic v-chucks that were used during machining. The physical tests performed and measurements recorded show the subject Georgia Power caps to be slightly out of round in a manner representative of that manufacturing vintage.

3. Material creep or yielding does not appear to have occurred in the bolt hole flanges of the air caps. Any permanent material deformation would most likely be apparent as an improper flatness. All of the subject caps were found to be flat within 1-2 mils as was a new cap.

4. Torquing both old and new caps to 150 ft lbs caused the cap bores to pinch along the bolt hole flanges and reduce diametral clearance between .5 and 1.1 mils. The unsupported cap flanges behave as transversely loaded cantilevers deflecting under the bolt loads. At 175 ft lbs of torque, the new cap was found to pinch 1.3 mils along the bolt hole flanges.

5. Pilot air flow between the air start piston and cap limits pilot air pressure and valve actuation. A maximum diametral clearance of 5.5 mils was determined to allow the test valve to fully actuate with a pilot pressure of 60 psi.

VII. RECOMMENDATIONS

1. Change piston material from 316 to 416 stainless steel. The 416 type has a coefficient of thermal expansion very similar to the gray iron air start cap (5.5×10^{-6} in/in °F vs. 6.0×10^{-6} in/in °F). That material is resistant to corrosion caused by water in the starting air system. Its annealed hardness at 155 Brinnel is very similar to 316 type at 149 Brinnel and should be sufficient to guard against galling. However, the material can be heat treated to obtain a hardness up to 390 Brinnel.

2. Revise piston dimensions to limit cap to piston diametral clearance to 2-4 mils. The tests performed determined the caps could deform under 175 ft lbs of torque by as much as .0013 inch. A revision to the piston O.D. would eliminate the need to supply matched piston and cap sets as 1A-7818 assemblies.

3. Change the current published acceptable wear limits for the assembly from .009 inch to .005 inch. Although only an actual engine air start test can accurately determine an upper limit to cap to piston diametral clearance, the test performed and parameters assumed indicate the existing wear limit to be too large.

JRG:dg

ATTACHMENT I

ATTACHMENT II

ATTACHMENT III

ATTACHMENT IV

ATTACHMENT V

ATTACHMENT VI

· Cooper Energy Servic .
14490 Catalina Street
San Leandro, CA 94577

COOPER

Inter-Office
Correspondence

Date: December 3, 1991

To: Bruce Guntrum

From: John Gildea

Subject: Starting Air Valve Cap Design Actions

At this time I am sure you are cognizant of all the conclusions and recommendations reached in the starting air valve cap investigation *(Ref. R&D Report HE-05-1991).* Engineering is presently undertaking the design revisions therein addressed:

1. The starting air piston *(P/N 02-359-03-AH)* material is being changed to Type 416 stainless steel. The corresponding E-315 form is also being revised to incorporate this change. As this material is ferromagnetic you will have a practical means with which to inspect future stock.

2. The new piston O.D. will be 2.2475"/2.2465" and allow an assembly design clearance of 2-4 mils. This revision will preclude the need to match caps and pistons as 1A-7818 assemblies.

Note, the accompanying change notice will be marked to show a *"major optional"* type change and the engineering disposition will be to use all existing 316 type stainless steel caps in 1A-7818 assemblies.

JGildea

JRG:dg

Copy: R. Johnston
DPQ Group

91CHRON\DEC\ME03302

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14490 Catalina Street
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415 614-7400
Fax 415 614-7409

COOPER

Inter-Office Correspondence

Date: December 16, 1991

To: Greg Desin

From: John Gildea

Subject: Starting Air Cap Design Actions

With regard to your questions regarding the disposition of the air start cap assembly design:

1. The piston design changes are incorporated as a revision to the existing piston *(P/N 02-359-03-AU)*.

2. The air start cap design *(P/N 02-359-03-AL)* is not altered.

3. Ideally, we can eliminate the need to match pistons and caps as 1A-7818 assemblies since the designed clearance stack up will ensure proper fit and function. However, some sort of safe guard should be implemented to ensure that an old piston from a 1A-7818 assembly is not later used with a replacement air start cap. That combination could result in insufficient diametral clearance in the assembly.

JGildea

JRG:dg

Copy: R. Johnston

91CHRON\DECWE16315

INTEROFFICE MEMORANDUM

TO: ALLEN GILLETTE

FROM: JOHN GILDEA

DATE: JANUARY 9, 1991

SUBJECT: PROPOSED AIR START VALVE TEST PROCEDURE

Attached is a proposed step by step procedure to perform a root analysis of air start valve cap bore distortions.

Note this outline is primarily concerned with recording and analyzing bore distortions due to machining and torquing of the subject caps. Additional testing as required will be detailed later.

To date, I have spoken with Paul Hudson at Georgia Power with regard to sending us a sample of the air start caps removed from the site engine 2B which failed to start July 16, 1990. He has agreed to send the six or seven caps available. I have also spoken with Larry Bernstein with regard to fabricating a test fixture in our machine shop.

Barring any disagreement with the test plan, I will proceed to work with Larry in machining the fixture while we wait for the test components being sent from the Georgia Power site.

John Gildea

JG:djg

91CHRON\JAN\ME09009

ENERGY SERVICES GROUP

DETAILED OUTLINE

OF

PROPOSED AIR START VALVE TEST PROCEDURE

A. *OBTAIN TEST COMPONENTS*

1. Request subject air start caps from Georgia Power Engine 2B (S/N 76021). Samples should include but not be limited to caps taken from the malfunctioning valves.
2. Select one random air start valve cap from Enterprise stock.
3. Select one random air start valve piston from Enterprise stock.

B. *ESTABLISH DIMENSIONAL BASELINE FOR SUBJECT COMPONENTS*

1. Define a reference point and mark air start valve cap bores at 30° intervals about circumference.
2. Using 2-pt instruments readable and accurate to .0001", take diametrical measurements at marked intervals at bore lip and at planes approximately 1/3 and 2/3 of the distance along the axis of the bore depth.
3. Mark air start valve cap flanges at 10 equally spaced points about circumference.
4. Using *"feeler"* type gap gages accurate to .0005", place caps on flat surface and determine flatness at marked points. Record gap sizes.
5. Define a start point and mark piston at 30° intervals about circumference.
6. Using 2-pt instruments readable and accurate to .0001", record diametrical measurements at reference points about planes approximately 1/3 and 2/3 the distance along the axis of piston height.

C. *FABRICATE TESTING FIXTURE*

1. Machine a steel plate 1-3/4" to 2" thick, approximately 6" x 4".

2. Bore a 1-15/16" hole through center of plate and (2) 13/16" holes 2-1/4" from center of 1-15/16" hole along major axis of plate.

3. Indicate the test fixture for flatness and grind as necessary to obtain flatness within .001" and surface finish to 125 MU in RMS or better.

D. *ASSEMBLY AIR START CAPS AND TEST FIXTURE*

1. Bolt caps to test fixture with (2) 3/4" capscrews coated with 50/50 lube oil and powder graphite compound.

2. Torque capscrews to 150 ft-lbs + 25 ft-lbs/-0 ft-lbs.

E. *MEASURE CAP BORE DIMENSIONS WHILE BOLTED TO TEST FIXTURE. REPEAT PROCEDURE DESCRIBED IN STEP B.2 PASSING GAGE THROUGH THE TEST FIXTURE INTO THE CAP BORE.*

F. *PERFORM STEPS D AND E FOR EACH AIR START VALVE CAP OBTAINED.*

G. *ANALYZE RESULTS*

1. Construct diagrams of each cap and the piston to illustrate bore distortions and flatness deviations.

2. Compare "*torqued*" cap profile to "*as machined*" cap profile for each subject cap.

3. Test results should indicate the degree with which, if any, machining, torquing, and creep deformation affect cap bore distortions.

H. *PLAN ADDITIONAL TESTING BASED ON ABOVE RESULTS*

1. Review current and past machining processes.

2. Calculate clearance reduction due to thermal growth of assembly to establish design limits.

3. Calculate maximum allowable cap to piston clearance that would satisfy the five-start requirement.

4. Establish a course for corrective action based on test results. Considerations:

4.1 Revise manufacturing prccesses to eliminate machining induced distortions.

4.2 Revise piston material to minimize or eliminate differential in thermal expansion coefficients.

4.3 Revise cap bore and/or piston diameter to obtain proper running clearance.

4.4 Alter cap material to prevent bore distortion due to creep deformation.