PACIFIC AIR PRODUCTS CO.
3133 West Harvard Street · Santa Ana, California 92704 · P.O. Box 5277 · Telephone 714/557-1710 · Telex No. 67-8319

March 28, 1984

United States Nuclear Regulatory Commission
1717 H Street, N.W.
Washington, D.C. 20555

Attention: Director, Office of Inspection & Enforcement

Regarding: Final Report and Conclusions -
Pacific Air Products Co. Linear Converters
Investigation

Gentlemen:

Pacific Air Products Co. has been investigating the causes of abnormal wear on linear converter units that we have manufactured and furnished to power generating facilities, both nuclear and conventional.

We began this investigation in January of this year, after becoming aware of the abnormal wear of units at the Edgewater Generating Plant (coal). Shortly thereafter, some units at the Byron Nuclear Station also exhibited similar wear patterns and were returned to our facility for examination.

Considering that we have furnished almost eight hundred of the linear converter units to power plants throughout the Country, it was the decision of our top management to handle the situation as a potentially reportable item under the 10CFR Part 21 regulations. We filed notification with the Nuclear Regulatory Commission and conducted the investigation to determine if a generic defect did exist in the linear converter unit.

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The investigation and test program have been completed with the following conclusions:

1. Linear converter shaft guides and bearings require lubrication for the standard brass components.

2. Linear converter units that show abnormal wear have been cycled many more times than original design had considered to be the life span of the unit.

3. Related components of the HVAC system may be being cycled so much during start-up testing that they are, in effect, worn out and should be replaced.

Based on the results obtained during testing, Pacific Air Products Co. has taken the following steps:

1. Notified all customers of test results and conclusions.

2. Provided all customers with field lubrication procedure to be employed on linear converters.

3. Provided all customers with maintenance interval information and alternate lubrication options available.

4. Notified all customers of actuator/system "hunting" condition that could affect their plant.

We have concluded that a generic defect does not exist in the linear converter unit. As built and installed at present, with brass shaft guides and bearings, the units will perform the designed function for the normal life span of the unit. Lubrication will extend the interval between maintenance. The field lubrication procedure that was developed is included as part of the attached correspondence.

All test data, records, photographs and materials are available for review at our Santa Ana, California facility.

If you have any questions, please contact me at (714) 557-1710.

Sincerely,

PACIFIC AIR PRODUCTS CO.

James Dodson

James P. Dodson
Director of Quality Assurance

Attachments: 7043-38, Report 7043-03 (Part III), 7043-P1

cc: Clifford Hale, NRC. Region V. Arlington. Texas

PACIFIC AIR PRODUCTS CO.
3133 West Harvard Street · Santa Ana, California 92704 · P.O. Box 5277 · Telephone 714/557-1710 · Telex No. 67-8319

March 26, 1984

Log No. 7043-38

..
.. (To Utilities, Engineers, etc.
.. on attached list.)

Attention: Quality Assurance Director

Regarding: (Project)
Investigation Findings
Linear Converter (Abnormal Wear)

Gentlemen:

On February 1, 1984, we issued a concern under 10CFR21 regarding the linear converter we manufacture, to the effect that we had some cases of abnormal wear reported. On March 7, 1984, we issued a report of the second portion of our investigation into the problem. Since the issuance of the first and second reports, we have been involved in an extensive testing program as well as field investigation. Attached to this letter is our Investigative Report No. 7043-03 (Part III) which outlines the causes of the abnormal wear pattern and the measures that are needed to prevent the re-occurance of the problem.

To over simplify the investigation and its results, the explanation is:

"The cause of the abnormal wear is and was actuator 'hunting' (for whatever reason) and the solution is lubrication."

Even though this statement is "brief", it is based upon thousands of test hours on various lubricants, guides, bearings and materials, all of which culminated in the final round-the-clock tests conducted after selection of lubricant.

1. A linear converter with a 40 foot pound torque load, lubricated in accordance with our field maintenance procedure, ran more than 1,000,000 3½" cycles or 2,000,000 3½" strokes. This is 50 times the requirements set forth in IEEE 382-80 for modulating actuators and 500 times the IEEE 382-80 requirement for two position actuators.

   During the course of the test, the linear converter was relubricated at approximately 330,000 cycles and at 660,000 cycles.

2. A test running simultaneously with the above test was a linear converter equipped with lubricant impregnated shaft guides and bearings, as described in our Investigative Report No. 7043-03 (Part III) under the title "Maintenance/Rebuilding Program No. 3", which also ran 1,000,000 3½" cycles WITHOUT LUBRICATION OR MAINTENANCE.

If the linear converters are put on a regularly scheduled maintenance program and are lubricated before and during service in accordance with the Linear Converter Lubrication Procedure (attached), the linear converters can absorb the system abnormalities without abnormal wear to the linear converters.

Should you desire to convert your linear converters to the "no maintenance" version or if you desire our services at any time, please feel free to call. If you have difficulty in obtaining the recommended lubricants, we have a ready supply in stock.

Unless we discover any unusual conditions, abnormalities or field conditions that would affect your linear converters, this letter and the attachments conclude our investigation and our concerns and we feel that our responsibility under 10CFR21 has been fulfilled.

A copy of the complete test data, logs, photos, field reports, etc., is on file in our office in Santa Ana, California. We will be glad to arrange an appointment for you to review this test report in detail at our office should you desire to do so.

Thank you for your patience and understanding. If I can be of service, please call.

Very truly yours,

PACIFIC AIR PRODUCTS CO.

Louis R. Hess
President

LRH:dg

Attachments: Investigative Report No. 7043-03 (Part III)
Field Lubrication Procedure No. 7043-P1

cc:

Subject: Linear Converters
PAPCo's final report (7043-03-Part III) dated 3/22/84 and PAPCo Field Lubrication Procedure 7043-P1 was sent to the following with PAPCo transmittal letter dated 3/26/84.

ILLINOIS POWER COMPANY
Clinton Power Station
P.O. Box 678
Clinton, Illinois

cc: Sargent & Lundy (Q.A.)
Steve Ornberg (S&L)
Rick Servey (Illinois Pow

BINGHAM MECHANICAL
P.O. Box 1856
1300 Pancheri Drive
Idaho, Falls, ID 83401

cc: Sabol & Rice

WISCONSIN POWER & LIGHT CO.
Columbia Generating Station
Milwaukee, Wisconsin 53081

cc: Willkomm Co., Inc.
Sargent & Lundy (Q.A.)
Steve Ornberg (S&L)

WISCONSIN POWER & LIGHT CO.
Edgewater Generating Station
Sheboygan, Wisconsin 53081

cc: Willkomm Co., Inc.
Sargent & Lundy (Q.A.)
S. Ornberg (S&L)
Joe Dalheimer (Aldag)

CONSUMERS POWER COMPANY
Midland Nuclear Power Station
Midland, Michigan 48640

cc: Bechtel Ann Arbor (Q.A.)

The CLEVELAND ELECTRIC ILLUM. CO.
c/o Perry Nuclear Power Plant
P.O. Box 97
Perry, Ohio 44081

cc: MCC Powers-Skokie (Q.A.)

DUKE POWER COMPANY
Catawba Nuclear Station
Newport, S.C. 29730

cc: Bahnson Service Co. (Q.A.

VIRGINIA ELECTRIC & POWER CO.
P.O. Box 26666
Richmond, Virginia 23261

cc: Stone & Webster (Boston)

NIAGARA MOHAWK POWER CORP.
300 Erie Blvd. - West
Syracuse, N.Y. 13202

cc: Stone & Webster (J. Plant

PUBLIC SERVICE CO. INDIANA
Marble Hill Generating Station
P.O. Box 190
New Washington, Indiana 47162

cc: Sargent & Lundy (Q.A.)
S. Ornberg (S&L)

COMMONWEALTH EIDSON COMPANY
c/o Braidwood Station
P.O. Box 81
Bracevill, Illinois 60407

COMMONWEALTH EDISON CO.
c/o Byron Station
P.O. Box B
Byron, Illinois 61010

United States NRC
1717 H. Street NW
Washington, D.C. 20555

Cliff Hale
U.S. NRC
Dallas, Texas

cc: Sargent & Lundy (Q.A.)
S. Ornberg (S&L)

cc: S. Ornberg (S&L
Sargent & Lundy (Q.A.)
Shankar Planjery (S&L)
Jim Westermeyer (Comm Ed.

INVESTIGATIVE REPORT NO. 7043-03 (Part III)

DATE: March 22, 1984

SUBJECT: Investigation Findings
Pacific Air Products Co. Linear Converter

INVESTIGATION CONDUCTED BY:

L.R. Hess, President
James P. Dodson, Director of Quality Assurance
William Nagurski, Engineering Project Manager

CAUSE:

Recent on-site inspections have confirmed our suspicion that the abnormal wear on the linear converters was caused by abnormal actuator oscillation, normally called "hunting". We have confirmed that the following conditions exist when abnormal wear conditions have been reported:

1. The ITT actuator does hunt when it is at the end of the power stroke (when the spring is compressed). The hunting varies in frequency depending on the condition of the high pressure hydraulic seals. From the ones we observed, the frequency of oscillation ranges from one every three minutes to four every minute. This condition is unique to the electro-hydraulic actuator. The actuator stem moves a distance of from 3/16 inches to 3/8 inches. Since the linear converter is linked directly to the actuator stem, this oscillation causes the linear converter input shaft to move the same distance.

   At an oscillation frequency rate of one every three minutes, the number of short strokes of wear on the linear converter would be:

Per Hour	20
Per Day	480
Per Month	14,400
Per Year	172,800

2. An additional cause of actuator oscillation (hunting) is caused by the location and type of sensing elements that control the actuator such as:

A. The location of volume sensing devices that are directly influenced by velocity stratification thus giving false velocity readings which are overcorrected by the sensing units and the open/close cycle is started. (This process was explained in our Bulletin dated March 7, 1984.)

We estimate that the frequency of this type of oscillation ranges in a cycle time of two to four per minute. At an oscillation frequency of two per minute, the number of cycles on the linear converter would be:

Per Hour	120
Per Day	2,880
Per Month	86,400
Per Year . . .	1,036,800

This type of hunting is particularly bad because the length of the stroke can be as much as 3½" versus the 3/8" stroke as mentioned under Paragraph #1.

B. The location and type of thermo sensing devices cause much the same oscillation pattern. A particularly acute problem in thermo sensing devices is the setting of the differential control.

There seems to be a tendency to set the differential at the minimum which causes the sensing device to overreact. If this problem is present, it rarely shows up in the occupied space and is, therefore, rarely detected unless it is observed at the damper actuator. When sensor differentials are set too fine (close) the actuator never arrives at a normal position; it is always seeking a position to satisfy the sensor.

We estimate the oscillation rate due to this condition to be as high as 10 short cycles per minute. At this rate, the number of short strokes would be:

Per Hour	600
Per Day	14,400
Per Month	432,000
Per Year . . .	5,184,000

3. The third, and probably the least recognized cause of actuator oscillation is system unbalance. This is particularly prevalent during the start-up phase of the construction program. Whole systems are subjected to this unbalanced stage during start-up and remain so until the system is completely balanced. There is no way to estimate the cycle frequency under these conditions, but it is substantial.

It would appear that regardless of the cause, short and long stroke actuator oscillation does exist and should be recognized as having far reaching effects such as:

1. Abnormal wear on linear converters.
2. A much shortened life expectancy for the electro-hydraulic actuators.
3. A shortened life expectancy for the damper itself.
4. Increased frequency of maintenance on all components.
5. Possible actuator, linear converter, damper or entire system failure if the system conditions go undetected.

CORRECTIVE ACTION

It is apparent that on-site/system abnormalties do exist and probably will continue to exist and therefore measures will have to be taken to absorb these conditions into the linear converter design and maintenance program to minimize the effect of the abnormalties. It is obvious that in some circumstances, the linear converters as furnished will fail unless certain prevention and maintenance procedures are followed.

At the first report of abnormal wear on a linear converter (January 15, 1984), we immediately issued a "concern" under 10CFR21. At the same time, we established an extensive investigation and test program to diagnose the cause and cure.

In conjunction with the testing program, we undertook a program of conferences with concerned engineers and on-site personnel. This combined with extensive on-site inspections, has given us the background to recommend certain corrective action procedures to prevent abnormal linear converter wear due to system abnormal conditions. Our recommended items are as follows:

A. Correct the abnormalities causing the actuator "hunting".

B. To protect against the effects of actuator "hunting", establish an effective maintenance program such as the one recommended in our attached Maintenance Bulletin. To prepare this Maintenance Bulletin, we have been testing for all related phases such as:

1. Various lubricants and their ability to function under load for extended periods.

2. Various lubricant impregnated sintered materials.

CONCLUSION

With the completion of the testing program, the field inspection program and the issuance of the corrective action to be taken, we have fulfilled our obligation as a manufacturer of the linear converter. All of the direct causes of the abnormal wear characteristics noted were beyond our control and were far beyond the only published data for actuator qualification as published in IEEE382-80.

We do, however, willingly accept the responsibility to work hand in hand with the utilities and the engineers to expedite the corrective action measures as fast as can be efficiently done. We recommend that the user select any one of the three following programs that best suits their needs:

MAINTENANCE PROGRAM NO. 1

The first maintenance procedure involves lubrication as recommended in Maintenance Bulletin 7043-P1. This procedure provides for the lubrication on input shaft guides, racks and gears and output shaft bearings without the necessity of removing the linear converter or the actuator. The actual lubrication process will take less than ten minutes. We feel confident that if this procedure is repeated every six months, the linear converter will operate at least 2,000 full cycles and 100,000 20% strokes.

MAINTENANCE PROGRAM NO. 2

The second maintenance procedure involves returning the linear converter to the factory for a more comprehensive application of special lubricants as recommended in Maintenance Bulletin No. 7043-P1. This procedure requires that the linear converter be removed from the damper, totally disassembled, lubricated, reassembled and reinstalled. Our tests indicate that if this maintenance procedure is repeated every 2¼ years, the linear converter will operate 2,000 full cycles or 100,000 20% cycles.

MAINTENANCE/REBUILDING PROGRAM NO. 3

Our tests on linear converters equipped with lubricant impregnated bronze shaft guides and bearings and utilizing polished input and output shafts coupled with surface impregnation of molybdenum disulfide will produce a linear converter capable of operating for six years (or 250,000 full cycles) without maintenance.

Note: Our recommendations all reference cycles as the time factor for repeated maintenance. This, of course, is due to the fact that the number of cycles and the length of the stroke determine the wear and the time/effectiveness of the lubricant. To convert the cycle factor to a time factor, a time/cycle study must be done - possibly for each damper. Then the damper maintenance program should be monitored to prove the effectiveness of the program.

SERVICES:

PAPCo personnel are ready to provide assistance in the maintenance program you may select. We have in stock the recommended lubricants, spare parts, replacement loaner linear converters, etc.

We also have available mobile service units and technicians to provide services on site should they be desired. Please contact us for prices on parts and service.

Louis R. Hess, President

James P. Dodson, Director of Quality Assurance

William Nagurski, Project Manager

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Field Lubrication Procedure No. 7043-P1
LINEAR CONVERTER MODEL SL100LC

This procedure is intended to provide instruction for field personnel in the acceptable method of adding lubricants to the SL100LC linear converter manufactured by Pacific Air Products Co.

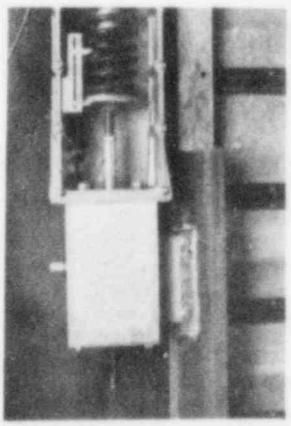
Field lubrication of the linear converter unit should be performed:

1. When the damper is installed, prior to start up of the system for testing.
2. During normal shut down period of the equipment or system.
3. After excessive cycling of the equipment or usage beyond actuator manufacturer's recommended period of maintenance.

The field lubrication procedure requires the following tools or materials:

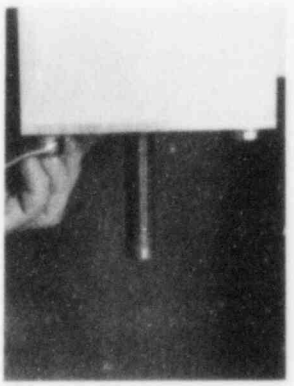
1. One 9/16" box end wrench.
2. One large screwdriver.
3. One trigger type oil can with flexible spout.
4. One stiff bristle brush (acid brush or tooth brush).
5. SAE 80-90 WT heavy duty gear oil.
6. Dow Corning Molykote G-n Paste or Exxon Unirex N-2 Grease.

PLEASE NOTE: LOCK OUT ELECTRIC UNTIL REQUIRED



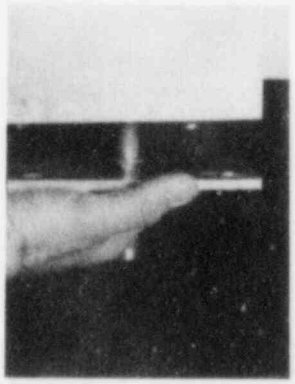
1.

Rotate damper to fail position. Linear converter input shaft should be fully extended.



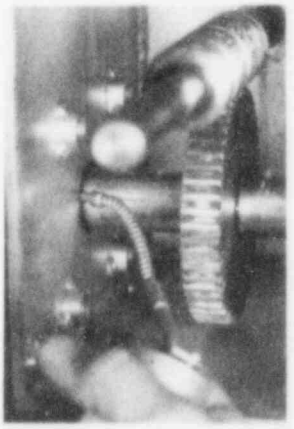
2.

Remove and retain four bolts and lock washers from linear converter end plate.



3.

Slide linear converter end plate off input shaft.

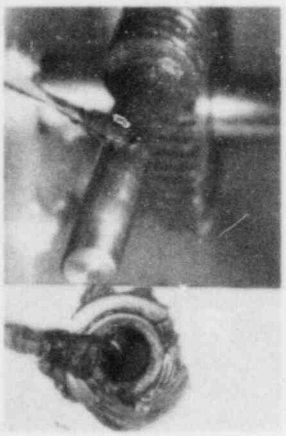


4.

Apply a generous amount of oil between the output shaft and bearing. An applicator with a flexible spout is best suited for this purpose.

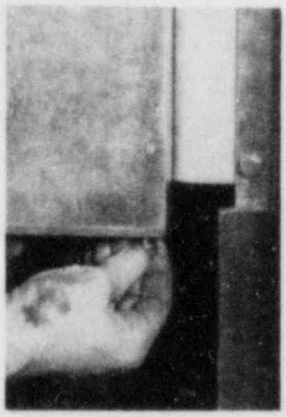
5.

Apply a generous amount of grease between the gear and rack to all exposed areas of the gear and rack with a short bristled brush.



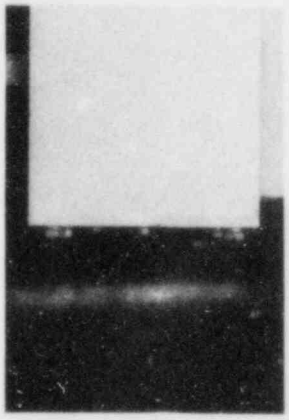
6.

Apply a generous amount of grease to the lower input shaft and both end plate shaft guides.



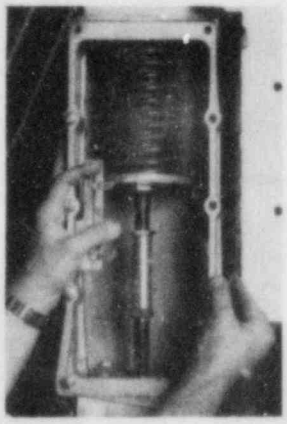
7.

Slide end plate onto input shaft and replace four bolts and lockwashers. (Finger tight only.)



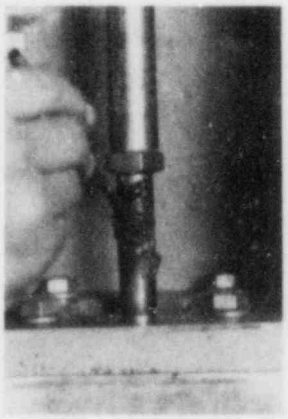
8.

Rotate damper 90° to actuator's full up position.



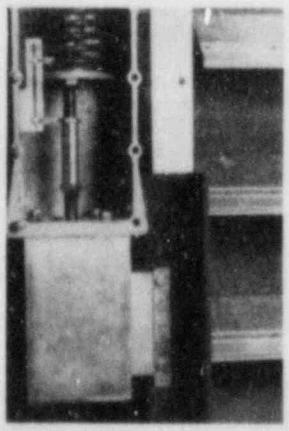
9.

Remove plastic cover plate from actuator.



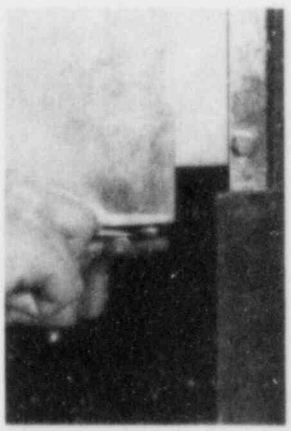
10.

Apply a generous amount of grease to the upper input shaft.



11.

Cycle unit from full open to full close several times to evenly distribute lubricants.



12.

Replace ITT cover plate. Tighten four bolts on linear converter end plate.

PACIFIC AIR PRODUCTS CO.
P.O. Box 5277, Santa Ana, CA 92704 Telex 678319 Phone 714/557-1710