

November 8, 1989

P137

Samuel Fry, Engineer in Charge  
Engine Starting Systems  
Ingersoll Rand Corporation  
7500 Shadwell Drive  
Roanoke, VA 24019

Dear Mr. Fry:

The Nuclear Regulatory Commission is in the process of preparing an information notice entitled "Failure of Ingersoll Rand Air Start Motors As a Result of Pinion Gear Assembly Fitting Problems."

A copy of the latest draft of this information notice is enclosed for your review and comment. Comments, particularly those dealing with the facts presented in the information notice, received by November 16, 1989, will be considered in the final version.

Sincerely,

Original Signed By  
Carl H. Berlinger  
Carl H. Berlinger, Chief  
Generic Communications Branch  
Division of Operational Events Assessment  
Office of Nuclear Reactor Regulation

Enclosure:  
Draft Information Notice

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UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
OFFICE OF NUCLEAR REACTOR REGULATION  
WASHINGTON, D.C. 20555

November xx, 1989

NRC INFORMATION NOTICE NO. 89-XX: FAILURE OF INGERSOLL RAND AIR START MOTORS  
AS A RESULT OF PINION GEAR ASSEMBLY  
FITTING PROBLEMS

Addressees:

All holders of operating licenses or construction permits for nuclear power plants.

Purpose:

This information notice is intended to alert addressees to the potential malfunctioning of Ingersoll Rand air start motors caused by the inadequate fitting of the pinion gear, the pinion gear retainer and the rotor shaft. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

On February 1, 1989, during the performance of a surveillance test at Diablo Canyon Unit 1, the number one emergency diesel generator failed to start. Each diesel generator at this plant is started by four Ingersoll-Rand air start motors, two of which are controlled by the primary dc power source and the other two by the backup dc power source. In accordance with the normal test procedure, the backup dc power source was disabled during the test. After repeated tests showed that the diesel generator could not be started with the primary dc power source but could be started with the backup dc power source, the two primary start motors were disassembled for inspection. Both motors were found to have broken pinion gear retainers that allowed the start motor rotor shaft to turn without driving the pinion gear (see Figure 1). In addition, both motors had broken and bent retainer bolts and cracks in the rotor shafts.

During normal operation, the diesel generators are started using both dc power sources, and in an emergency the number one diesel generator would have been started by the still functional backup start motors. However, many related problems were found on other air start motors as a consequence of this event. The Diablo Canyon site has a total of 20 air start motors, four on each of its five emergency diesel generators. All of the motors were disassembled and

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inspected, and a total of 10 were found to have cracks in their rotor shafts. Many motors had pinion gears or pinion gear retainers and retainer bolting that were loose. All of the motors with cracked shafts had well-developed wear patterns on the retainers and on the tangs at the ends of the rotor shafts that engage slots in the retainers, indicating that the pinion gears had been loose for a long time. In two cases, the retainer bolts had backed out until the retainer was on the point of becoming disengaged from the rotor shaft tang.

## Discussion:

When a diesel generator receives a start signal, solenoid valves open to admit air pressure (normally 150 psi) to the air motor rotor, which turns the shaft and pinion gear in question. This pinion gear meshes with and turns a larger drive gear that provides torque through a clutch to a Bendix drive. The rotation through the Bendix drive forces a second pinion gear to engage the ring gear on the diesel engine flywheel, causing the diesel engine to turn. The pinion gear retainers, which were broken during this event, consist of a disk bolted to the end of the rotor shaft (Figure 1). The retainer has a transverse slot that engages both a flat-sided tang on the end of the shaft and lugs on the pinion gear. Thus, the shaft cannot turn relative to the pinion gear without breaking the retainer. However, this retainer is not designed to transmit the main torque from the drive shaft to the pinion gear. The torque is intended to be transmitted directly from the shaft to the pinion by means of a press fit between the tapered shaft and the matching tapered pinion bore. The retainer is only designed to maintain the press fit by keeping a clamping force on the outside end of the pinion.

The basic cause of the air start motor problems at Diablo Canyon was loss of the pinion gear to shaft press fit as a result of an inadequate fitting of the shaft, pinion gear, retainer, and bolting. This loss allowed the pinion gear to slip on the shaft, forcing the retainer to transmit the full torque of the motor. This situation caused abnormal wear of the retainer and of the tang on the end of the shaft, cracking and deformation of the tang, and the loosening and backing out of the retainer bolts. Eventually two retainers for the start motors on diesel generator 1-1 failed completely, preventing the diesel generator from starting.

The loss of contact was attributed to a number of subsidiary problems, including poor fit between the pinion gear and the shaft surfaces, dirt on the surfaces, lack of "setting" pressure on the pinion gear during assembly onto the shaft, and incorrect torquing of the retainer bolts. However, the main problem appears to have been improper fit between the retainer and the pinion gear. As shown in the detail on the lower half of Figure 1, there is a sharp angle at the transition between the retainer inner surface and its slot wall. On the mating surface of the pinion gear, however, there is a radius between the side of the lug and the outer flat surface of the gear. As a consequence, the sharp edge of the retainer slot presses on the curvature of the radius at the base of the pinion gear lug. This small contact area eventually degenerates as a result of shock loading, relieving the pinion retainer clamping force. This problem was identified on 13 of the air start motors at Diablo Canyon.

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A possible contributory cause to the failure of one of the two air start motors that failed on February 1 was the fact that the air supply to this motor was higher than normal on that day. Records indicate that the pressure supplied to this motor was 190 psi compared to a normal value of 150 psi. The vendor indicated that a pressure in excess of 160 psi would begin to be of concern. It has been suggested that the unusually high pressure caused the first motor to fail, which left the second motor to carry the full load, causing it to fail also. However, vendor tests show that only one air start motor is required to start a diesel generator within the required time limit. Furthermore, the clutch in the start motor drive train should have limited the torque in the train to the design limits.

The corrective actions for this problem included the replacement of all of the damaged parts, using revised reassembly procedures. The reassembly procedures included lapping and blueing checks to ensure the correct fit. The procedures also specified the correct retainer bolt torque and the use of lock washers and lock wiring to maintain the correct retainer force on the pinion gears. In addition, measures were taken to ensure that the start motor air header pressures would be maintained below 160 psi.

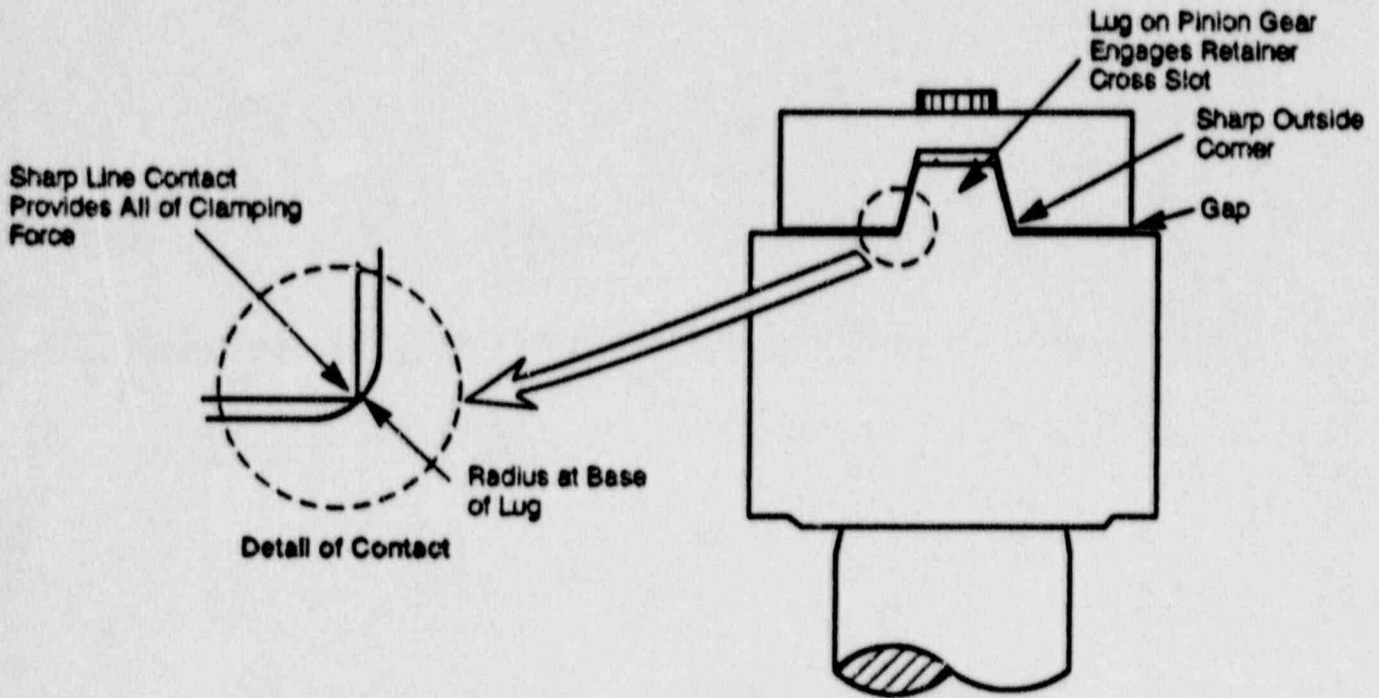
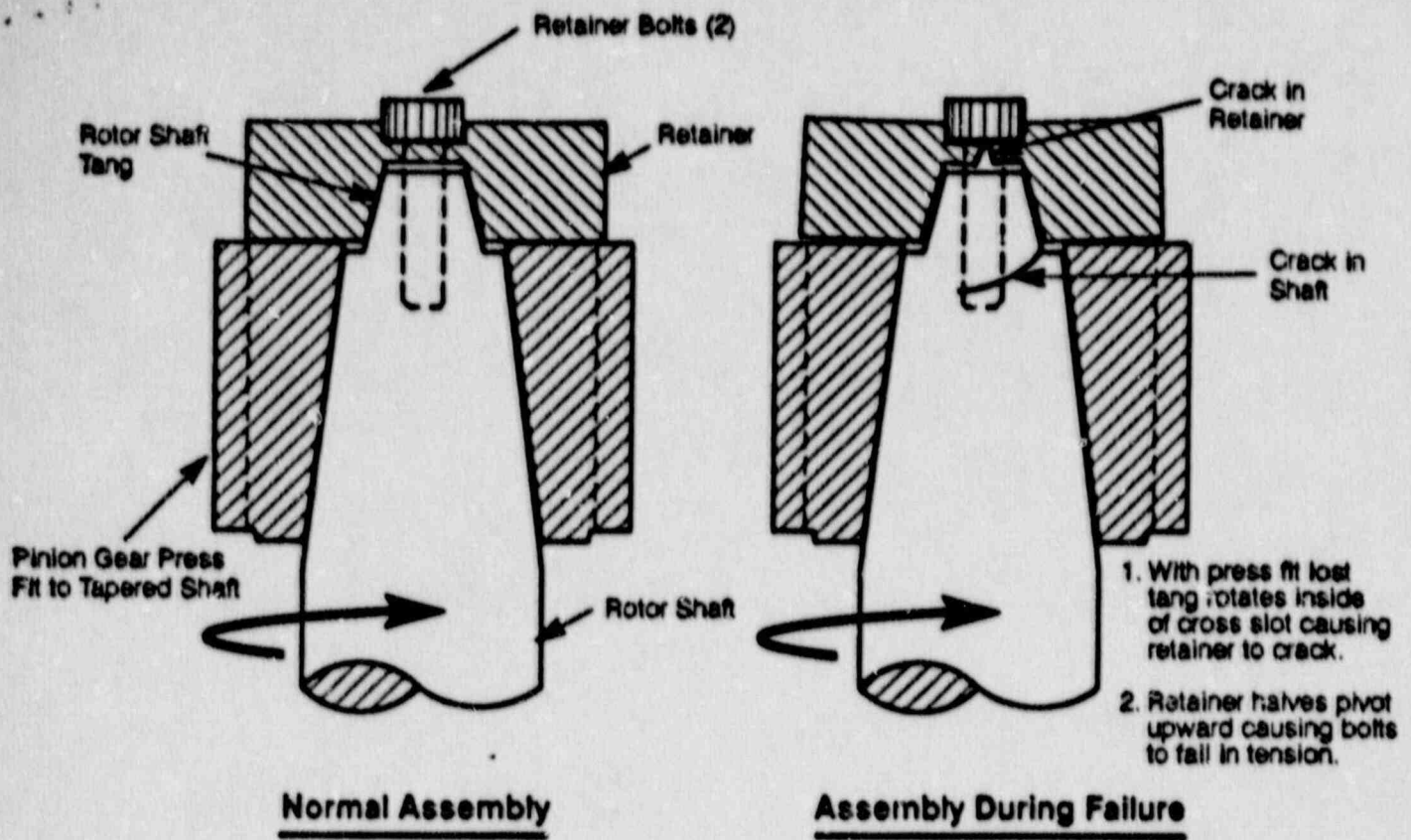
This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate NRR project manager.

Charles E. Rossi, Director  
Division of Operational Events Assessment  
Office of Nuclear Reactor Regulation

Technical Contact: D. C. Kirkpatrick, NRR  
(301) 492-1152

Attachments:

1. Figure 1
2. List of Recently Issued NRC Information Notices



**Assembly Showing Poor Fit Between Retainer and Gear**

**Figure 1 Rotor Shaft and Pinion Gear Assembly**