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July 29, 1983

United States Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Mr. Harold R. Denton
Office of Nuclear Reactor Regulations

SUBJECT: Beaver Valley Power Station - Unit No. 2
Docket No. 50-412
Turbine Missile Analysis

Gentlemen:

Attached for your review and consideration is a copy of the worst case deterministic inspection interval report for the Beaver Valley Power Station Unit 2 turbine.

It was our intention originally to submit this report to satisfy the turbine missile analysis requirements. We feel that the worst case deterministic analysis is both an acceptable and a conservative approach to turbine missile analysis. However, as a result of Mr. G. W. Knighton's letter dated April 28, 1983, concerning the acceptability of utilizing this type of analysis, and subsequent conversations with the NRC staff, this report is being submitted for information purposes only. Accordingly, although the text is written in the FSAR format, it is not our intention to amend the FSAR to include this information.

For the development of a final Beaver Valley Power Station, Unit 2, turbine maintenance and inspection program, it is DLC's intention to implement the results of the NRC's review of the Westinghouse generic reports and any subsequent Westinghouse evaluation.

DUQUESNE LIGHT COMPANY

By E. J. Woolever
E. J. Woolever
Vice President

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JJS/wjs
Attachment

SUBSCRIBED AND SWORN TO BEFORE ME ON THIS 29th DAY OF July, 1983.

Elva G. Lesondak
Notary Public

ELVA G. LESONDAK, NOTARY PUBLIC
ROBINSON TOWNSHIP, ALLEGHENY COUNTY
MY COMMISSION EXPIRES OCTOBER 20, 1986

COMMONWEALTH OF PENNSYLVANIA)
) SS:
COUNTY OF ALLEGHENY)

On this 29th day of July, 1983, before me, a Notary Public in and for said Commonwealth and County, personally appeared E. J. Woolever, who being duly sworn, deposed and said that (1) he is Vice President of Duquesne Light, (2) he is duly authorized to execute and file the foregoing Submittal on behalf of said Company, and (3) the statements set forth in the Submittal are true and correct to the best of his knowledge.

Elva G. Lesondak
Notary Public

ELVA G. LESONDAK, NOTARY PUBLIC
ROBINSON TOWNSHIP, ALLEGHENY COUNTY
MY COMMISSION EXPIRES OCTOBER 20, 1986

3.5.1.3 Turbine Missiles

Advancements in turbine technology, reliability of protection systems, and a conservative in-service inspection program are utilized to prevent the potential hazard of turbine missiles. The partial integral rotors manufactured by Westinghouse Electric Corporation (Westinghouse) have significantly reduced the traditional concern of stress-corrosion cracking, as discussed in Section 3.5.1.3.4. The redundant overspeed protection system and turbine valve testing program are explained in Sections 3.5.1.3.2 and 3.5.1.3.3, respectively. The deterministic analysis method, establishing turbine in-service inspection intervals meeting Nuclear Regulatory Commission (NRC) criterion, is presented in Section 3.5.1.3.1. To provide still additional assurance of public safety, inspection intervals determined in Section 3.5.1.3.1 are further reduced by a factor of five.

3.5.1.3.1 Deterministic Inspection Interval

The stress-corrosion crack growth rate and the critical crack size for the partial integral rotor has been calculated by Westinghouse. The analysis is based on the worst case material properties as defined by the manufacturing specification (Westinghouse 1982) and listed in Section 3.5.1.3.4. By using worst case material properties, the inspection interval developed is more conservative than an interval based on actual material properties. Using this data and the NRC criterion limiting crack growth to half the critical length, inspection intervals were determined for each of the non integral discs as follows:

Step 1: Determine the inherent material toughness, K_{IC} (ksi $\sqrt{\text{inches}}$)

$$K_{IC} = [5\,\sigma_{YS}\ (.85\ CVN - \frac{\sigma_{YS}}{20})]^{1/2} \qquad (3.5\text{-}1)$$

where:

σ_{YS} = Minimum yield strength at upper shelf temperature, ksi
CVN = Charpy V-notch energy at upper shelf temperature, ft-lb

Step 2: Determine the Critical Crack Size, A_{CR} (inches)

$$A_{CR} = \frac{Q}{1.21\,\pi} \left(\frac{1.2K_{IC}}{\sigma_{Bore}}\right)^2 \qquad (3.5\text{-}2)$$

where:

Q = Flaw shape (2.30 for bore, 1.35 for keyway)

σ_{Bore} = Bore stress at overspeed, ksi

K_{IC} = Toughness (Step 1)

Step 3: Determine the Crack Growth Rate, R (in/hr)

$$\ell n\ R = \frac{-7302}{T + 460} + 0.0278\ \sigma_{YS} + \text{Constant} \qquad (3.5\text{-}3)$$

where:

T = Metal temperature, °F

Constant = -4.205 for keyway

= -3.531 for bore

σ_{YS} = Maximum yield strength at upper shelf temperature, ksi

Step 4: Establish Reinspection interval for $A_{CB}/2$

$$\text{Reinspection interval} \quad T = \frac{\frac{1}{2}\ [A_{CR} - \rho]}{8760R} \ \text{(years)} \qquad (3.5\text{-}4)$$

where:

A_{CR} = Critical Crack Size (Step 2)

ρ = Keyway radius for keyway

= Zero for Bore

R = Average crack growth rate (Step 3)

The results of the above analysis using the assumptions listed below are reported in Table 3.5-5.

1. No inspection of the central integral portion (first three discs) is required since it does not have keyways and the bore will not be exposed to steam (no stress-corrosion cracking is expected to occur).

2. The inspection interval is controlled by disc 4 or 5.

3. The inspection interval is calculated using the alternate method discussed in Westinghouse memorandum report No. MSTG-1-P (Westinghouse 1982) approved by the NRC.

4. Crack growth rate is determined for the expected bore/keyway temperatures in the BVPS-2 discs.

5. Yield strength is assumed to be the maximum permitted by the Westinghouse materials specifications (Westinghouse 1982) for the BVPS-2 discs (this gives the higher crack growth rate).

6. Charpy impact values are assumed to be the minimum acceptable by the Westinghouse materials specifications for the BVPS-2 discs.

7. The K_{IC} is computed using the minimum impact energy determined in Item 6 above and minimum yield strength (this gives the minimum toughness).

8. The critical crack size is calculated using the bore stress at 120 percent of running speed for discs 4 and 5 of the BVPS-2 rotors.

Note: The yield strength is assumed to be the highest permissible by the specification for calculating the crack growth rate, while the lowest required by the specification for computing the K_{IC}.

Despite the conservative approach used in determining the above intervals, the importance of public safety is acknowledged by still further reductions. The LP rotors will be ultrasonically inspected during the refueling outage which most nearly coincides with 5 years of operation since the last inspection. In no case will the inspection interval exceed 6 years of operation.

3.5.1.3.2 Turbine Overspeed Protection

The turbine speed control system has adequate redundancy to ensure that the turbine does not attain destructive overspeed. The standard Westinghouse analog electro-hydraulic control (EHC) system and electromechanical trip system includes three separate speed sensors mounted on the turbine stub shaft located in the turbine front pedestal. These sensors are:

1. Mechanical overspeed trip weight (spring-loaded bolt),

2. Electromagnetic pickup for main speed governing channel, and

3. Electromagnetic pickup for the overspeed protection control channel. This pickup uses the same toothed wheel as item 2.

An overspeed protection controller is provided and is activated in the event turbine speed exceeds 103 percent of rated speed (1,800 rpm), or the measured electrical output of the generator as compared to the low pressure turbine inlet pressure indicates a power mismatch (load impulse pressure feedback). The low pressure turbine inlet pressure represents the energy input to the turbine generator. If a mismatch occurs, one of the following actions is initiated:

1. During a partial load drop, the interceptor valves are closed and then reopened after a set time delay, or

2. During a full load drop, both the governor and the interceptor valves close. The governor valves remain closed until the speed is decreased to rated speed (1,800 rpm). The interceptor valves are modulated and reopen when speed decreases to below 103 percent of rated speed to remove

entrapped steam in the reheat system. If speed again increases above 103 percent, they reclose and continue to modulate until speed remains below 103 percent of 1,800 rpm.

The overspeed protection controller is the first line of overspeed protection and is designed to prevent the turbine from reaching the overspeed trip point.

Should the turbine exceed approximately 110 percent of rated speed, the throttle (stop), governor, reheat stop, and intercept valves will all be tripped closed by both the mechanical overspeed bolt and the backup electrical trip. Thus, the turbine is tripped by redundant trip systems from independent speed sensors to assure utmost safety.

The electromechanical trip system also trips the turbine generator on excessive thrust bearing wear, low bearing oil pressure, low condenser vacuum, and low control system fluid pressure.

The turbine is tripped by the dumping of control system hydraulic fluid from all valve pistons, causing the heavy springs to close the throttle (stop), governor, reheat stop, and intercept valves in 0.15 second. Two valves in series in each steam entrance to the turbine are closed simultaneously upon a unit trip to provide redundant steam isolation to the turbine. The turbine operation, trip, and overspeed protection are discussed in more detail in Sections 10.2.2.1.1, 10.2.2.1.2, and 10.2.2.1.3.

The redundancy, component reliability, and test procedures of the turbine control system are detailed in Section 10.2.2.1.

3.5.1.3.3 Turbine Valve Testing

Throttle, governor, interceptor, and reheat stop valves of the turbine generator are tested periodically in the single valve mode while the EHC system is in operator automatic and load impulse pressure feedback is in service.

Throttle and governor valves are tested individually. Upon completion of each test, the valve is returned to its original position before the next valve is tested. Interceptor and reheat stop valves are interlocked so that a pair of these valves in one crossover pipe are tested together. Each pair of valves is returned to the open position before the next pair is tested.

Reducing load when testing valves is not necessary since valves may be tested at any load. The maximum load reduction during any valve test occurs when the unit is at full load. Under these circumstances, a test of a governor valve results in a short-time load reduction of about 4 percent of full load. The test of a throttle valve or an interceptor-reheat stop valve pair at full load results in a load decrease of 1 to 3 percent of full load. When

valve tests are made below full load, the control system acts to maintain load.

When governor valves are tested at full load, the pressure drops are those normally experienced at the 75 percent admission operating point (that is, 3 out of 4 governor valves open). When governor valves are tested at less than full load, the pressure drops are no different than those experienced in normal operation at reduced load.

3.5.1.3.4 Turbine Characteristics

The partial integral rotor employed for BVPS-2 is illustrated in Figure 3.5-1. The basic concept of the design of these rotors is to fabricate the shaft and first three discs on each side of the rotor's center as a single integral part. This eliminates the keyway which has been the source of stress corrosion cracking problems in previous rotor designs. The bore of the integral part is not exposed, while the exposed areas have lower stresses, which in turn allows the use of material less susceptible to cracking. For the above reasons, there is no need to calculate the inspection interval for the integral part of the rotor.

The disc and keyway configuration of discs 4 and 5 is shown in Figure 3.5-2. Because these discs are beyond the transition region from dry to wet steam where most cracks have occurred, the use of the equations of Section 3.5.1.3.1 is very conservative as these are developed from historical crack data. The following material properties (Westinghouse 1982), bore stresses, and temperatures are used in calculating the values presented in Table 3.5-5.

Charpy V-notch energy at upper shelf temperature = 88 ft-lbs

Yield strength at upper shelf temperature:

Minimum = 100 ksi
Maximum = 110 ksi

	Disc 4	Disc 5
Bore stress at overspeed	78.2 ksi	73.5 ksi
Metal temperature inlet	192°F	186°F
Metal temperature outlet	182°F	192°F
Keyway radius	0.375 in	0.375 in

3.5.1.3.5 References

Westinghouse Electric Corporation, MSTG-1-P, Criteria for LP Nuclear Turbine Disc Inspections, June 1981.

Westinghouse Electric Corporation, Material Purchasing Department Specification 10325TC, June 1982.

TABLE 3.5-5

INSPECTION REQUIREMENTS - DETERMINISTIC APPROACH*

Disc No.	Potential Crack Location	Critical Crack Size (inches)	Crack Growth Rate (inches/ year)	Reinspection Interval (years)
4	Bore (Inlet)	4.972	0.07468	33.28
4	Bore (Outlet)	4.972	0.06273	39.630
4	Keyway	2.917	0.03197	39.756
5	Bore (Inlet)	5.628	0.0673	41.812
5	Bore (Outlet)	5.628	0.07468	37.676
5	Keyway	3.3025	0.03806	38.459

NOTE:

*The required reinspection intervals for critical turbine locations based on a deterministic analysis (Section 3.5.1.3.1) are tabulated here. This table demonstrates the conservatism inherent in the imposed inspection interval limit of 6 years.

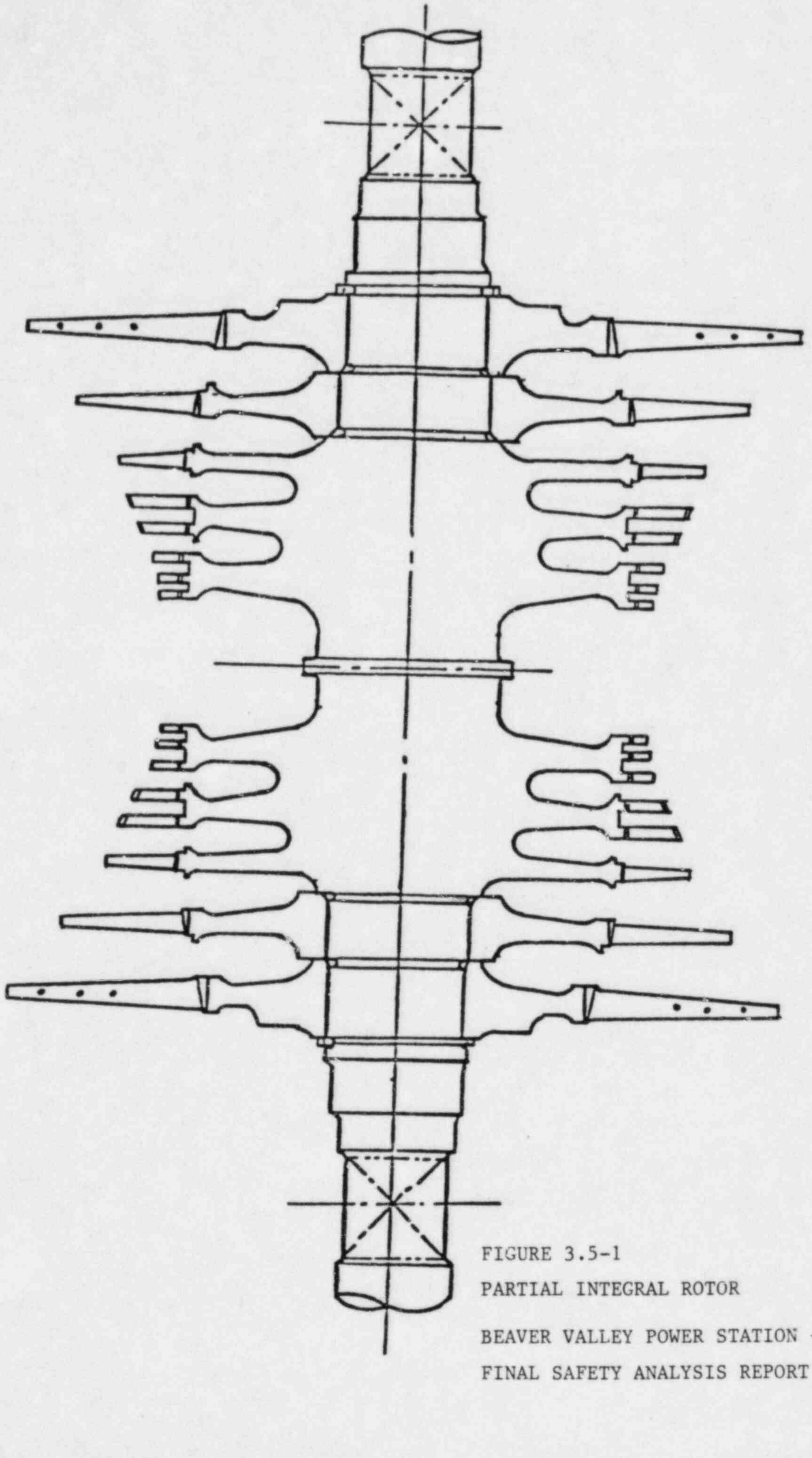

FIGURE 3.5-1

PARTIAL INTEGRAL ROTOR

BEAVER VALLEY POWER STATION - UNIT 2

FINAL SAFETY ANALYSIS REPORT

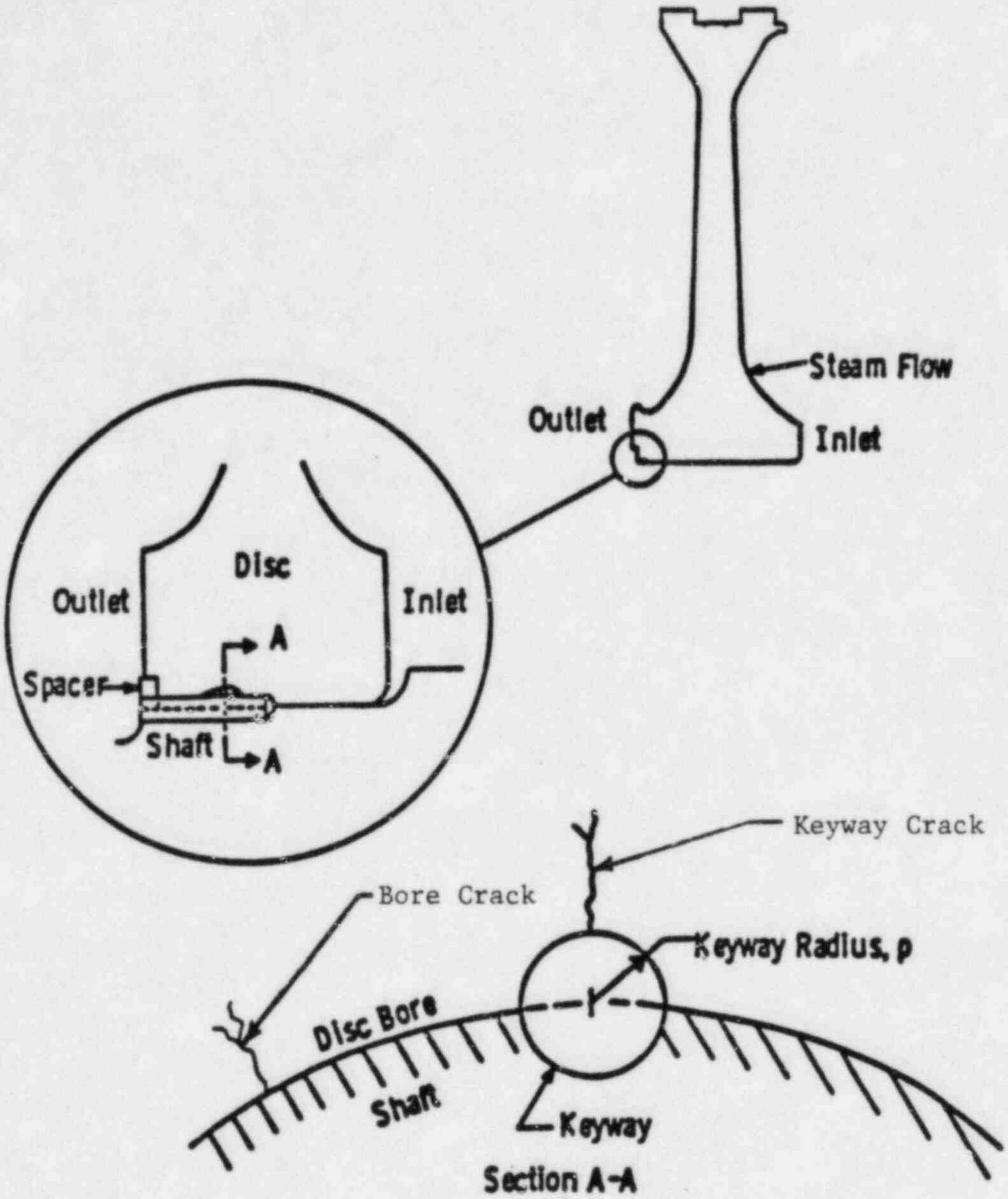

FIGURE 3.5-2

DISC KEYWAY CONFIGURATION

BEAVER VALLEY POWER STATION - UNIT 2

FINAL SAFETY ANALYSIS REPORT