Docket File

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

April 8, 1994

Docket No. 52-003

APPLICANT: Westinghouse Electric Corporation

FACILITY: AP600

SUBJECT: SUMMARY OF MEETING TO DISCUSS THE REACTOR COOLANT PUMP (RCP) FLYWHEEL MATERIALS

On March 29, 1994, representatives of the Nuclear Regulator Commission (NRC) and its contractor, and Westinghouse Electric Corporation (Westinghouse) met in the Westinghouse office in Monroeville, Pennsylvania, to discuss the materials used in the design of the RCP flywheel for the AP600. Enclosure 1 is a list of attendees.

During the meeting, Westinghouse presented its rationale for selecting a canned motor pump and for selecting depleted uranium as the material for the RCP flywheel. In addition, Westinghouse presented the safety basis for the RCP design. Enclosure 2 contains the information presented by Westinghouse.

Subsequent to their formal presentation, Westinghouse provided and discussed their written responses to the staff's proposed discussion topics for the meeting. The staff's proposed discussion topics are in Enclosure 3. Westinghouse's written responses are in Enclosure 4.

The following actions will be taken as a result of the meeting:

1. Westinghouse will reevaluate the flex foot design and associated welds for the Inconel 600 enclosure surrounding the depleted uranium flywheel, and will provide the staff with its final design.

2. Westinghouse will reevaluate the extent of material characterization testing that will be performed on the depleted uranium flywheel and provide the staff with its final testing plan.

3. Westinghouse will reevaluate the need for purge flow to the RCP, as currently described in the SSAR, and provide an amendment to the SSAR if necessary.

DF03 1/1

During the meeting, proprietary information pertaining to the specific alloy used in the construction of the flywheel was discussed.

(Original signed by)

Kristine M. Shembarger, Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal, NRR

Enclosures:
As stated

cc w/enclosures:
See next page

DISTRIBUTION w/enclosures:

Docket File	PDST R/F	DCrutchfield	KShembarger
PDR	PShea	RBorchardt	RArchitzel
FHasselberg	TKenyon	EJordan, 3701	JMoore, 15B18
WDean, EDO	ACRS (11)(w/o enc)	GBagchi, 7H15	DTerao, 7H15
DSmith, 7H15			

OFF:	LA:PDST:ADAR	PM:PDST:ADAR	PM:PDST:ADAR	SC:PDST:ADAR
NAME:	PShea	KShembarger	TKenyon	RArchitzel
DATE:	04/6/94	04/8/94	04/6/94	04/8/94

OFFICIAL RECORD COPY: W0329RCP.KMS

cc: Mr. Nicholas J. Liparulo
Nuclear Safety and Regulatory Analysis
Nuclear and Advanced Technology Division
Westinghouse Electric Corporation
P.O. Box 355
Pittsburgh, Pennsylvania 15230

Mr. B. A. McIntyre
Advanced Plant Safety & Licensing
Westinghouse Electric Corporation
Energy Systems Business Unit
Box 355
Pittsburgh, Pennsylvania 15230

Mr. John C. Butler
Advanced Plant Safety & Licensing
Westinghouse Electric Corporation
Energy Systems Business Unit
Box 355
Pittsburgh, Pennsylvania 15230

Mr. M. D. Beaumont
Nuclear and Advanced Technology Division
Westinghouse Electric Corporation
One Montrose Metro
11921 Rockville Pike
Suite 350
Rockville, Maryland 20852

Mr. Sterling Franks
U.S. Department of Energy
NE-42
Washington, D.C. 20585

Mr. S. M. Modro
EG&G Idaho Inc.
Post Office Box 1625
Idaho Falls, Idaho 83415

Mr. Steve Goldberg
Budget Examiner
725 17th Street, N.W.
Room 8002
Washington, D.C. 20503

Mr. Frank A. Ross
U.S. Department of Energy, NE-42
Office of LWR Safety and Technology
19901 Germantown Road
Germantown, Maryland 20874

Mr. Victor G. Snell, Director
Safety and Licensing
AECL Technologies
9210 Corporate Boulevard
Suite 410
Rockville, Maryland 20850

Mr. Raymond N. Ng, Manager
Technical Division
Nuclear Management and
Resources Council
1776 Eye Street, N.W.
Suite 300
Washington, D.C. 20006-3706

WESTINGHOUSE AP600
REACTOR COOLANT PUMP FLYWHEEL MATERIALS MEETING
MEETING ATTENDEES
MARCH 29, 1994

Name	Organization
D. Lingren	Westinghouse
J. Livingston	Westinghouse
G. More	Westinghouse
R. Schreiber	Westinghouse
I. Wilson	Westinghouse
K. Shembarger	NRC/NRR
D. Terao	NRC/NRR
D. Smith	NRC/NRR
C. Czajkowski	BNL (NRC Consultant)

Enclosure 1

RATIONALE FOR A CANNED MOTOR PUMP

AP600

- CANNED REACTOR COOLANT PUMP
  - No Shaft Seals Required
  - Self Lubricating
  - Pump Shell - System Pressure Boundary

- SHAFT SEAL REACTOR COOLANT PUMP
  - Shaft Seals Required
  - Auxiliary Systems Prevent Leakage Past Shaft Seals
  - Auxiliary Systems Provide Lubrication

NO SHAFT SEALS REQUIRED

AP600

- REDUCE REQUIRED MAINTENANCE
  - Reduce Exposure and ALARA Concerns
  - Remove Replacement Cost of Seals
    - Material
    - Manpower
    - Downtime
- Remove Seal LOCA Probability
- Remove Auxiliary Support Systems - CVS
  - Reduce Operating Procedures
  - Reduce Operator Actions
  - Reduce Piping and Material

SELF LUBRICATING

- Remove Auxiliary Support Systems - Oil Lubrication
  - Reduce Operating Procedures
  - Reduce Operator Actions
  - Reduce Piping, Pumps, and Material
- Reduce Probability of Damaging Bearings
- Reduce Maintenance Cost
  - Never Change Lubricating Medium

PUMP SHELL - SYSTEM PRESSURE BOUNDARY

AP600

- REDUCE LOCA PROBABILITY

- REMOVE MISSILE GENERATION PROBABILITY

  - Reactor Coolant Pump Pressure Boundary Will Contain Any Missile Fragments

RATIONALE FOR URANIUM FLYWHEEL

- MATERIALS CONSIDERATION
  - SEE TABLE

- APPLICATION FOR D. U.
  - Counterweights (aircraft)
  - Projectiles (armor piercing)
  - Sinker bar

    (oil wells) (steel coated D.U.)
  - Gyroscope rotors, high performance
  - Flywheels for energy storage
  - Vibration damping
  - Radiation shielding

* Source - ASM Handbook

FLYWHEEL MATERIALS EVALUATION

Material	Density Lb/In^3	CTE °F^{-1}	E 10^6 psi	Sy 10^3 psi	Elong.	Machine-ability	Avail-ability	Cost
Steel	.29	6.7	30	48	30%	Easy	Cast/ Forge	Low
Tungsten	.69	.034	59	220	Not Available	Conventional Carbide Tools	Powder Met	Med.
Tantalum	.60	3.6	27	48	Not Available	Similar to SST	Powder Met	Med.
Depleted Uranium	.69	7.6	22.5	60	20%	Conventional Carbide Tools	Casting	Med.
*Platinum								High
*Gold								High
*Rhenium								High
Inconel 600		7.0						

OH-94-005-3

DEPLETED URANIUM: PROPERTIES OF INTEREST

D. U ALLOYS

- High Density
- Availability

ALLOYS

- U-2 Mo
  - strength
  - hardness
  - toughness
  - availability
  - existing data
  - heat treatment
  - corrosion
  - other alloy considered was U - 1/2 Ti

HEAT TREATMENT

Homogenize and slow cool to prevent shrinkage cracks
1000°C/24 hours/cool at 100°C per hour

TOXICITY

As with many heavy metals, it is toxic. Radiological concerns are for airborne contamination. Procedures to deal with this are well established due to extensive usage

FRACTURE CAPTURE

FLYWHEEL CONTAINMENT

- Located within pressure boundary
- Surrounded by stator shell and flange
- Surrounding structure contains the energy of flywheel fragments without boundary rupture

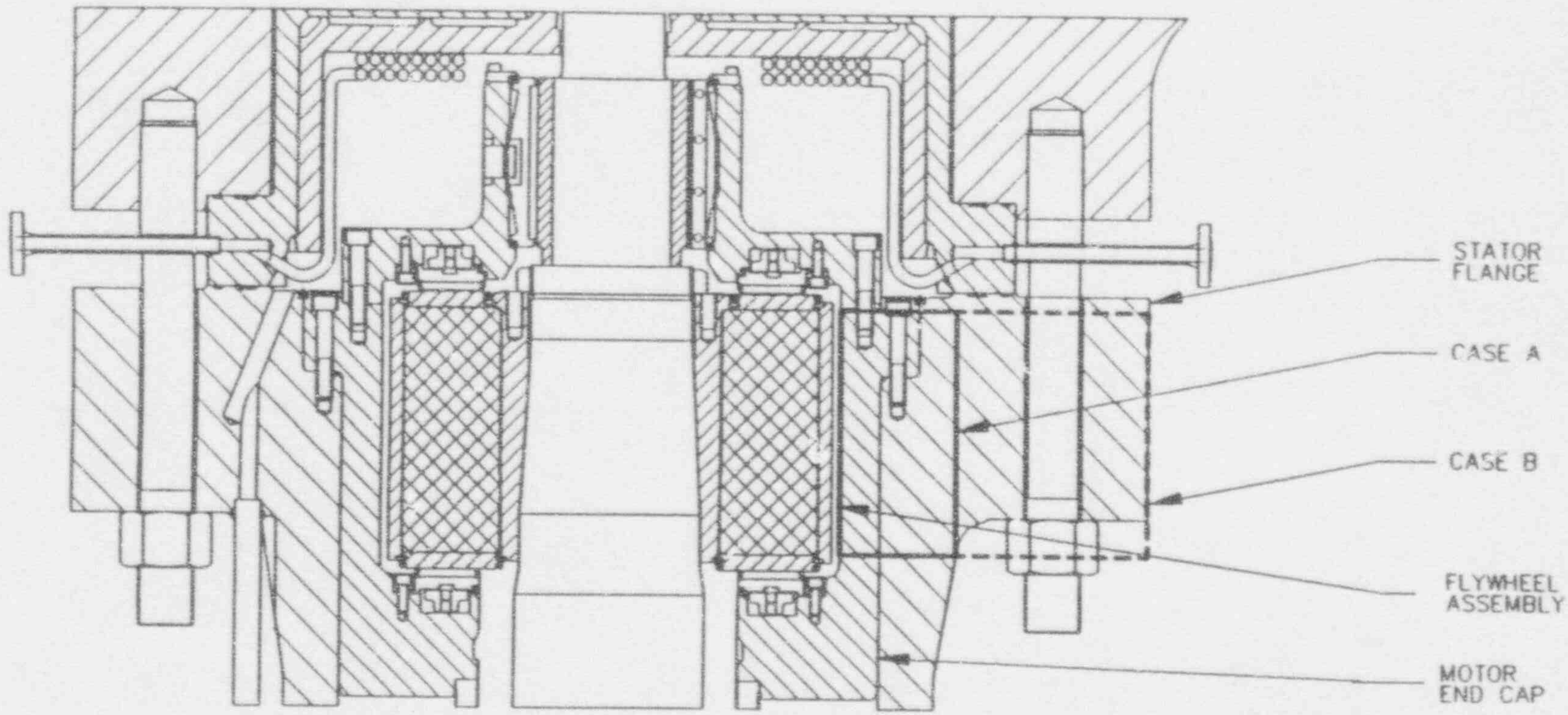
FRACTURE TOUGHNESS ANALYSIS

- $K_{IC} = 50$ ksi $\sqrt{in}$
- Ignores the enclosure and welds
- 125% of design speed is considered
- Worse case 134° fragment sector

RESULTS

- Only a small percent of the containment capacity is utilized in the event of any improbable flywheel fracture

	Fragment Energy (ft.lb.)	Required for Penetration (ft.lb.)	% of Capacity
Case A - Stage 1	2.91×10^5	8.93×10^6	3.2
- Stage 2	3.20×10^5	3.76×10^6	8.5
- Total	6.11×10^5	1.27×10^7	4.8
Case B - Stage 1	4.66×10^5	5.45×10^7	0.9
- Stage 2	1.45×10^5	1.33×10^7	1.1
- Total	6.11×10^5	6.78×10^7	0.9



Case B includes area marked Case A

Flywheel Containment Model Thickness Assumptions

FLYWHEEL ANALYSIS

FLYWHEEL ANALYSIS

- Limits for ASME Code, Section III, Subsection NG
- Evaluated for 125% of Operating Speed

ANALYSIS RESULTS

- All stresses are within allowable limits
- No failure will occur at design speed of 125% of operating speed
- Uranium flywheel stresses are well below faulted stress criteria per Section III, App. F, and ductile failure will not occur
- Critical flaw size of 3.28 in. axial flow, and 1.25 inch for a full length axial flow is calculated
- Flaw size for fatigue crack grwoth is (> detectable) approx. 0.4 inch)

FATIGUE USAGE

- 3000 start-up/shutdown cycles
- 200 loss of cooling water cycles
- highest usage of .24 is at the outer flex foot weld, with a limit of 1.0

Safety Basis

The AP600 reactor coolant pump complies with the requirements of General Design Criteria 4.

> "Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These structures, systems, and components shall be appropriately *protected against dynamic effects, including the effects of missiles,* pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit."

The AP600 canned motor pump satisfies this requirement without inservice inspection of the flywheel.

Regulatory Guide 1.14

This regulatory guide is specific to shaft seal pumps with steel flywheels.

- Provides for flywheel integrity by inspection and material requirements
- Has no requirements on the housing around flywheel
- Not all of the recommendations are applicable to uranium flywheels
- AP600 has adopted many of the regulatory guide recommendations as good engineering practice

AP600 Approach to GDC 4 Compliance

- The reactor coolant pump pressure boundary captures the fragments of a postulated flywheel fracture.
- The analysis of the flywheel capture is based on energy calculations.
- For the worst case flywheel fracture, there is an order of magnitude between the retention capacity required and the capacity available.
- In the AP600 canned motor pump, flywheel integrity is of interest for operational reliability.
- Inservice inspection and other guidelines of Regulatory Guide 1.14 are not required for safe operation of the plant.

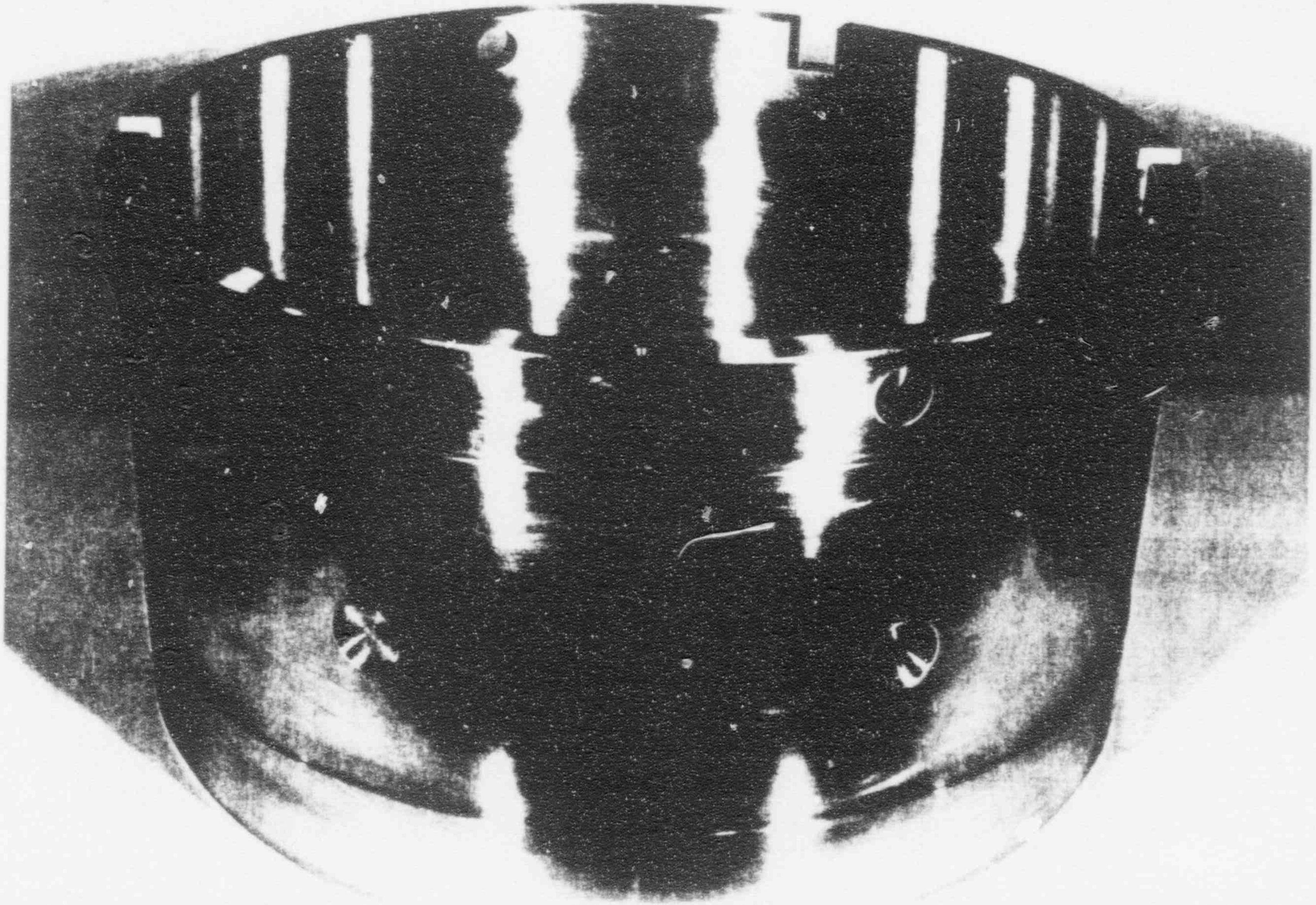


Figure 3 — Cylindrical shroud for half-inch radial gap.

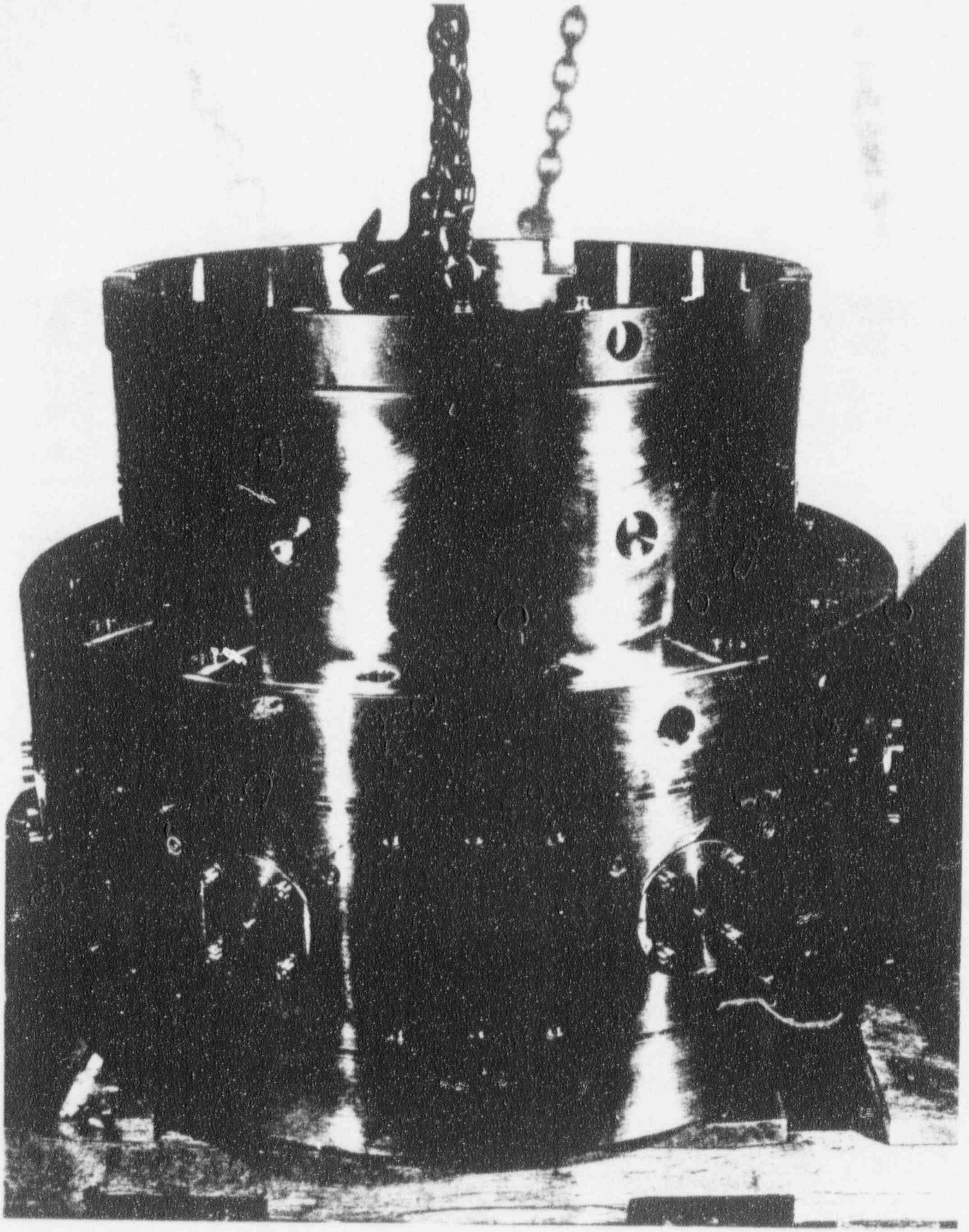


Figure 4 — Installing the cylindrical shroud in the test housing.

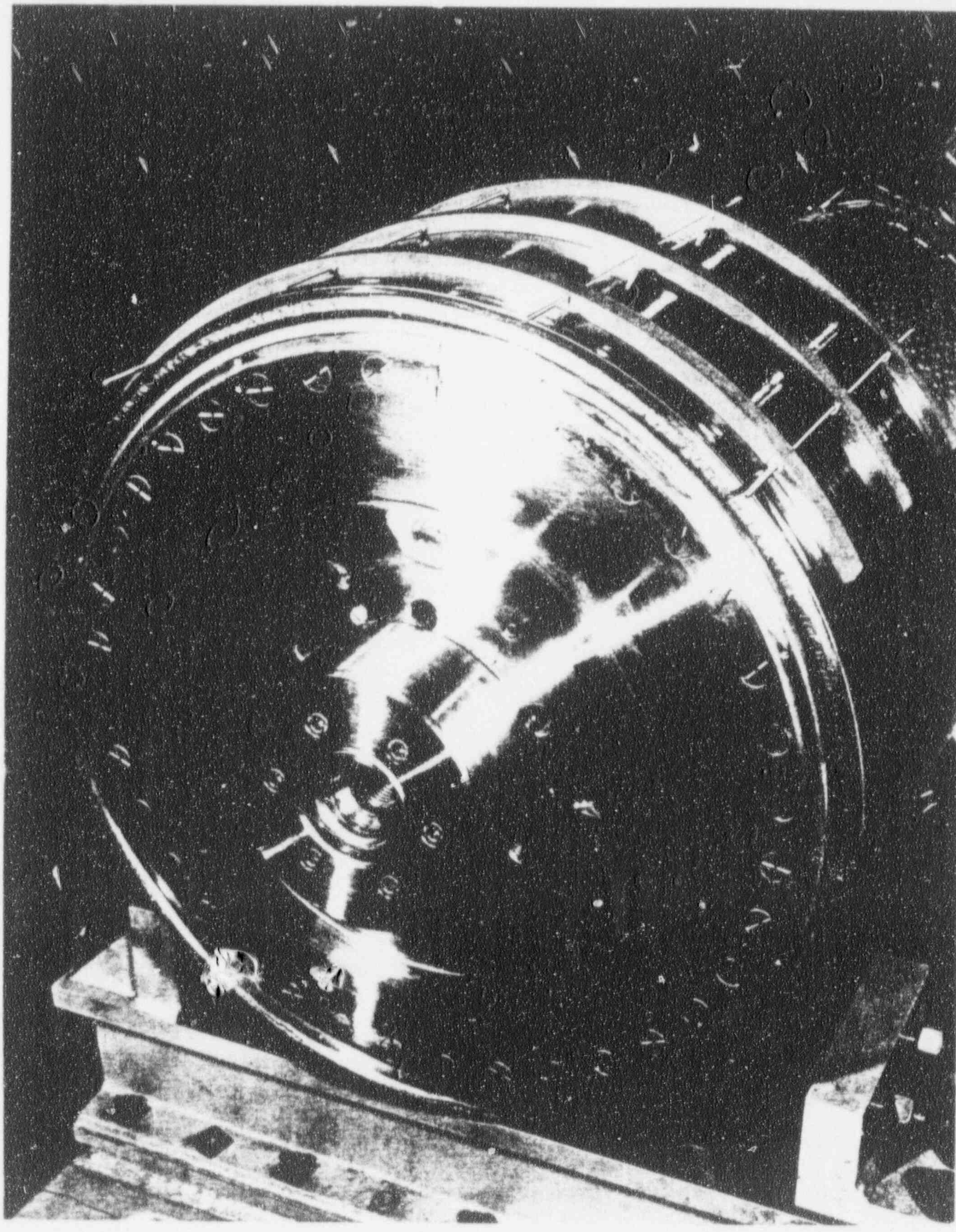


Figure 5 — Test rotor with Micarta spacer for transporting the rotor/housing assembly to the test facility.

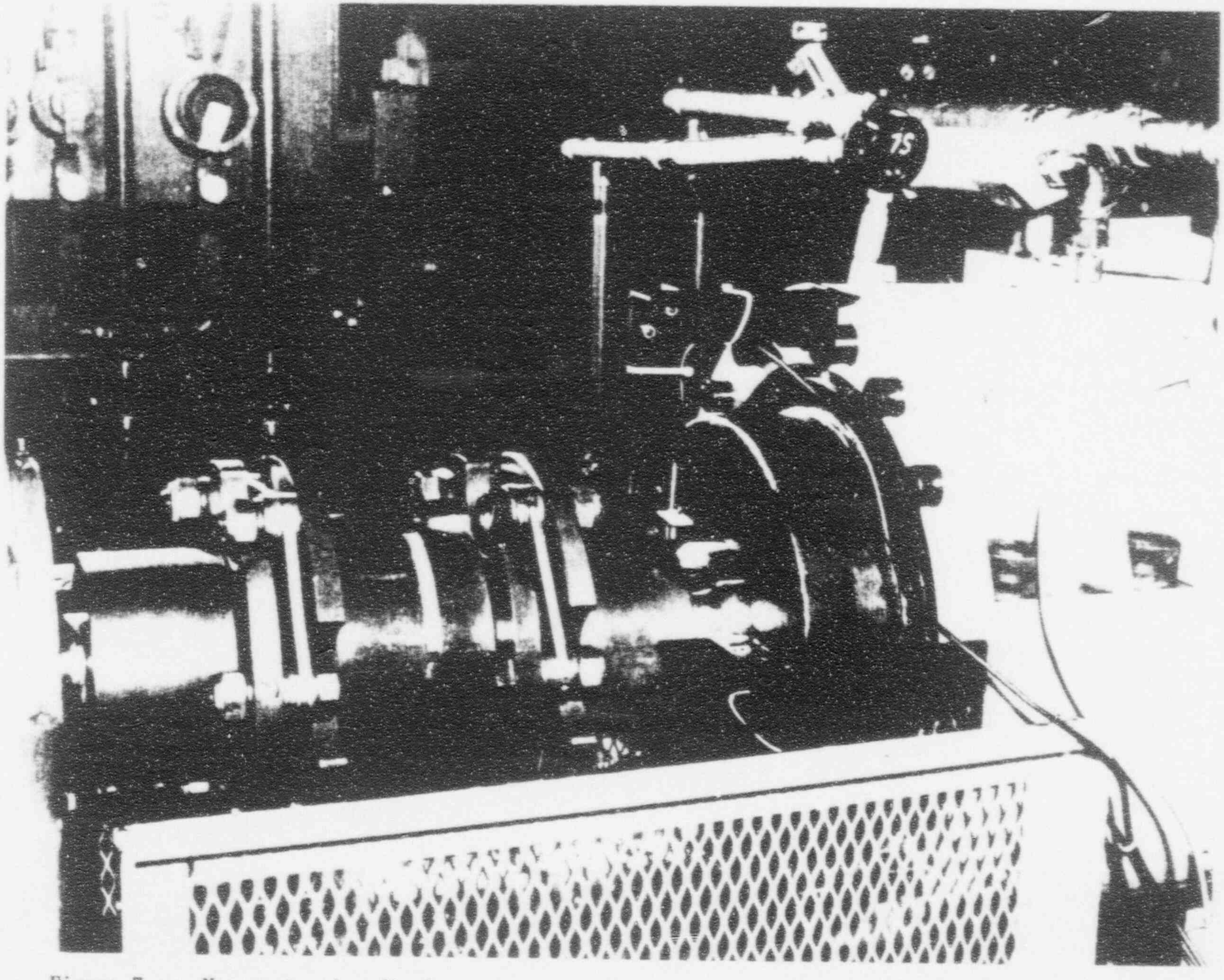


Figure 7 — Non-contacting displacement transducers mounted between the coupling and the thrust-loading cylinder.

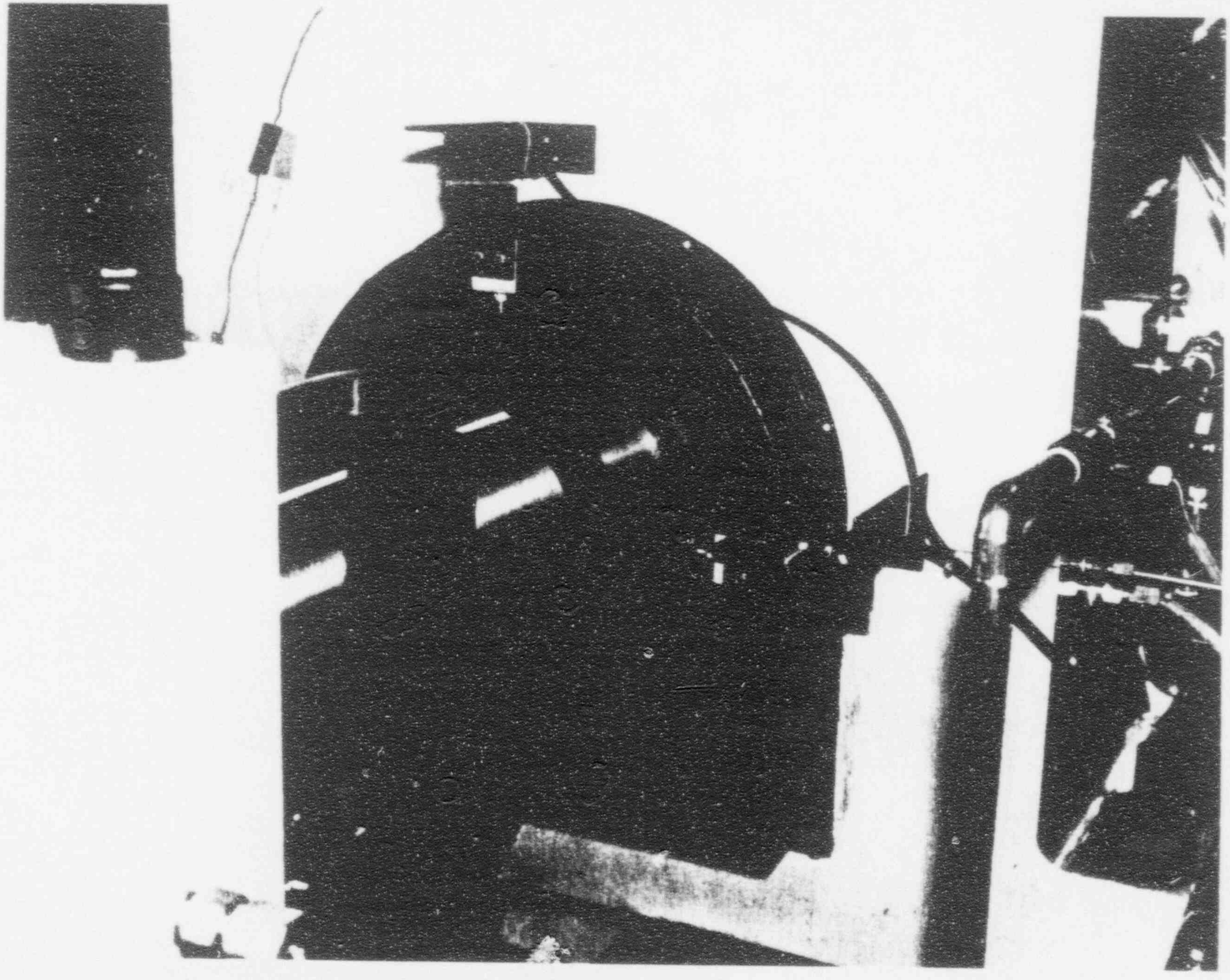


Figure 8 — Non-contacting displacement transducers mounted near the large support bearing housing.

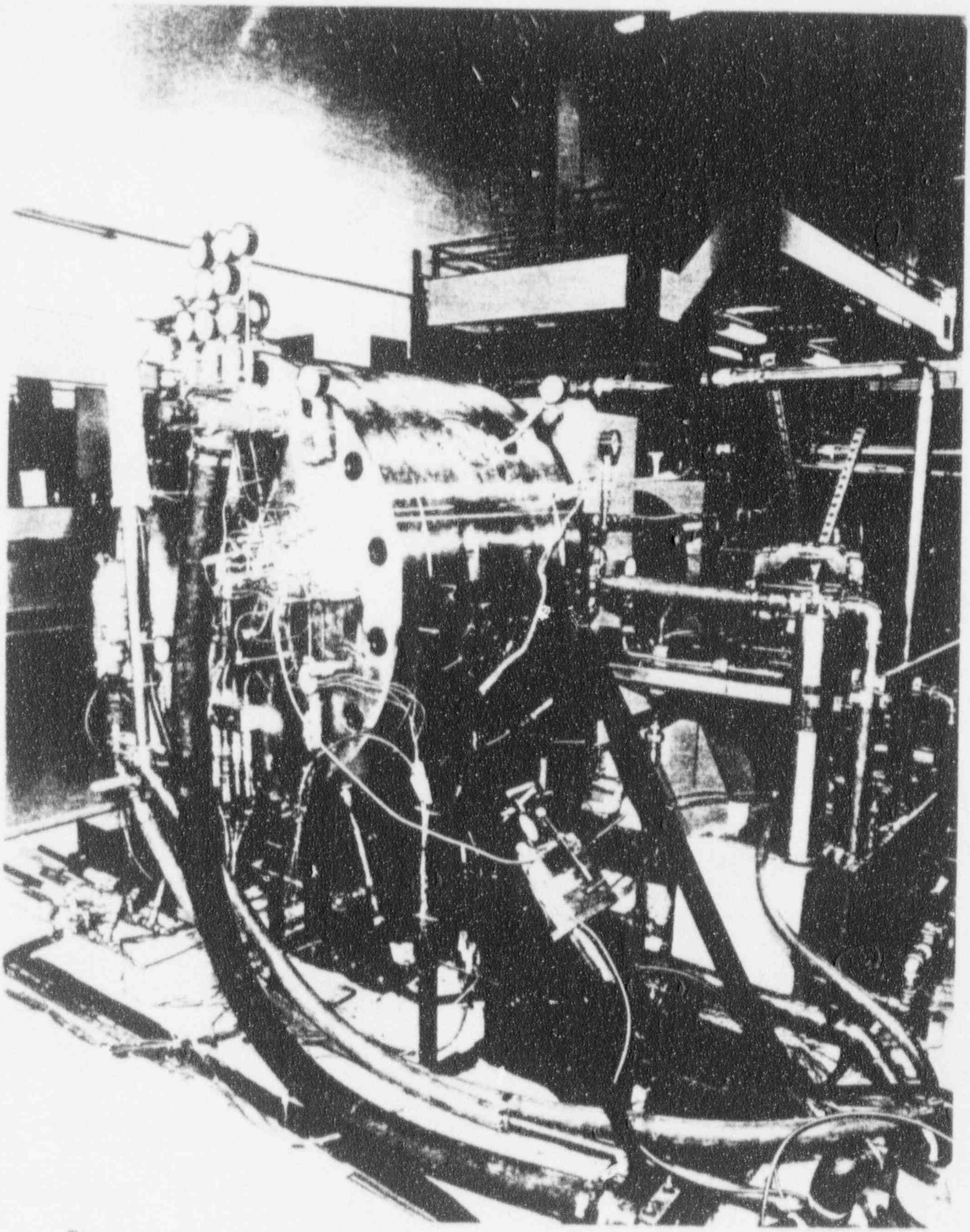


Figure 9 — Test housing with support framework holding the non-contacting displacement transducers.

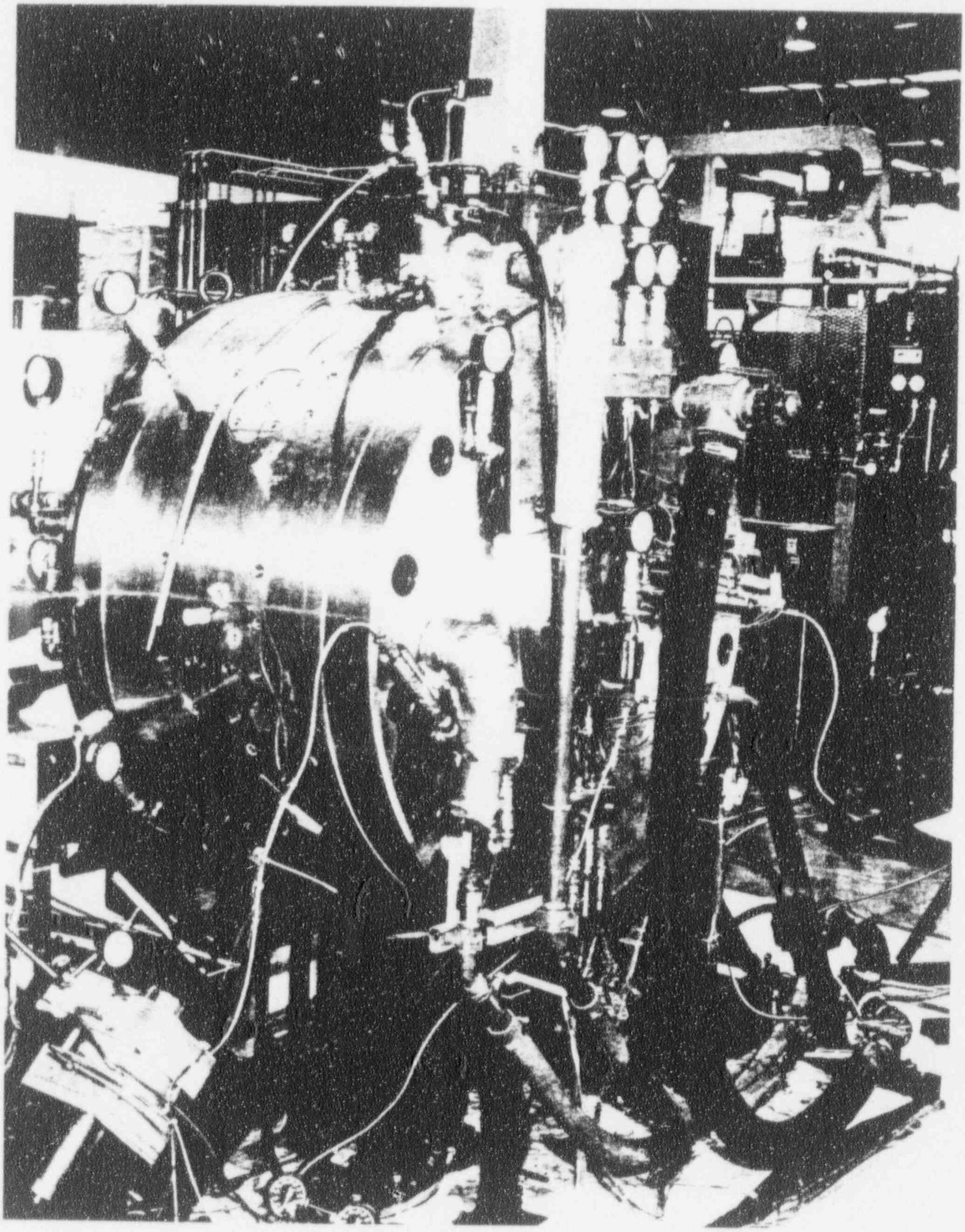


Figure 10 — Test housing with instrumentation.

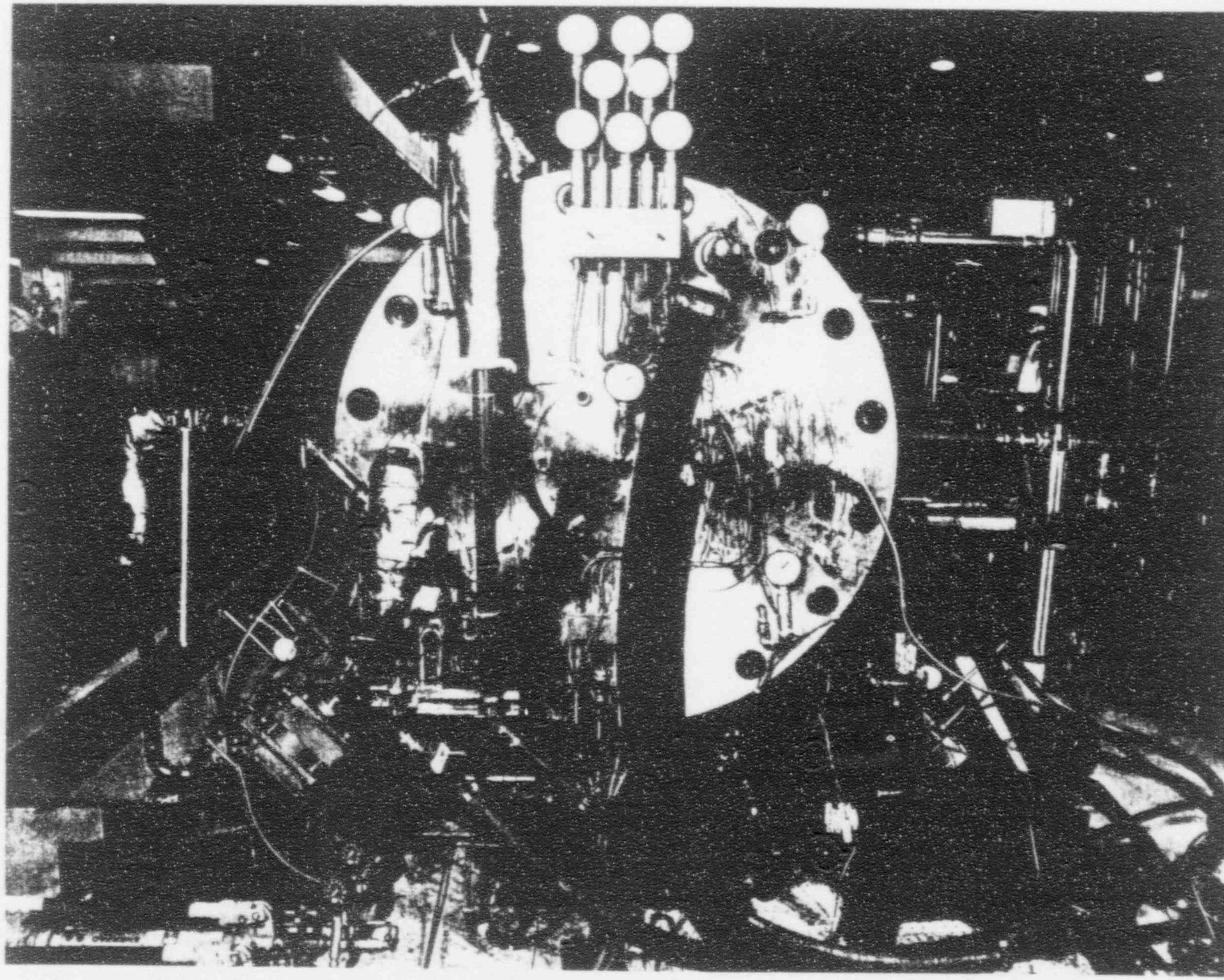


Figure 11 — End view of test housing.

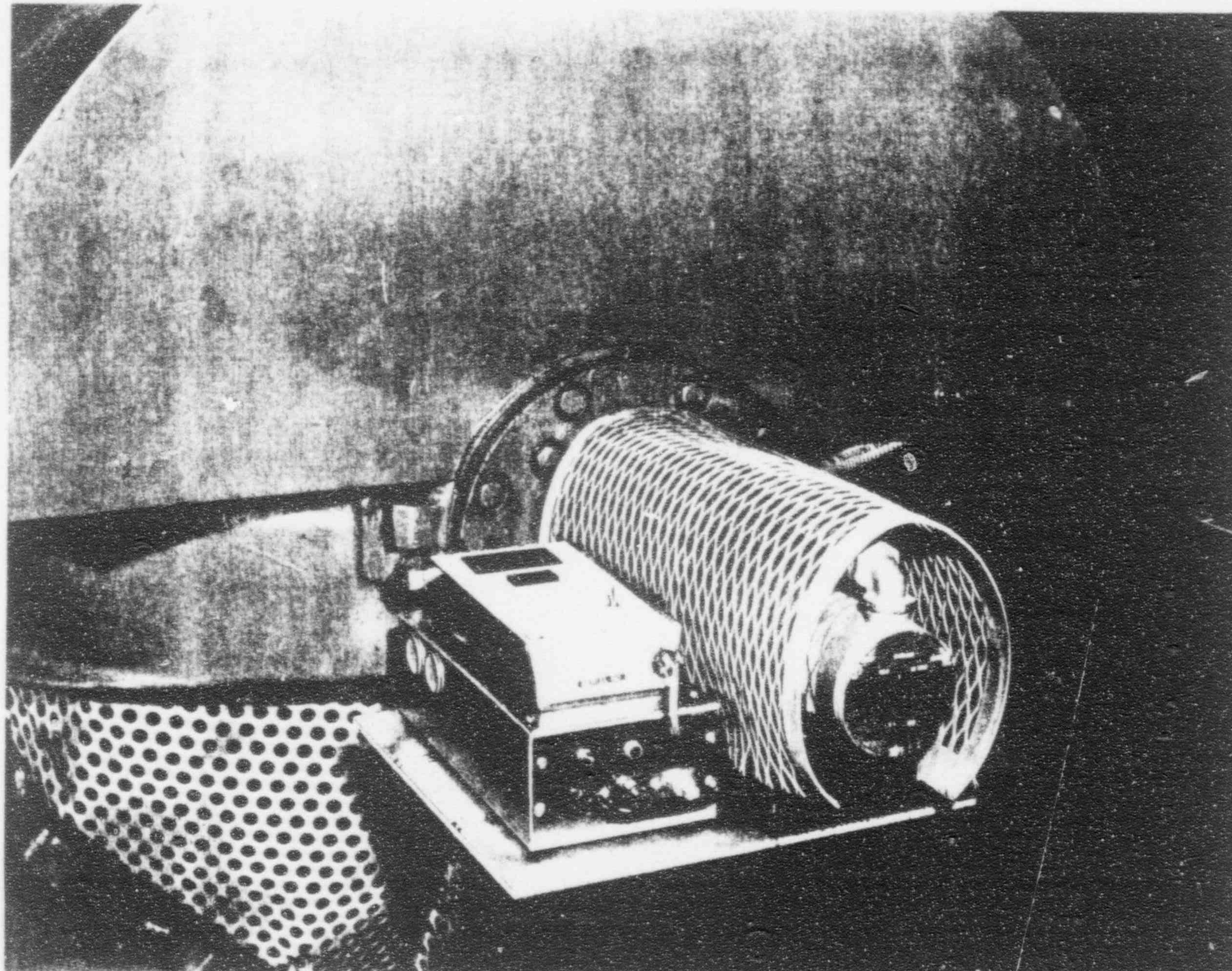


Figure 12 — Optical tachometer.

DISCUSSION TOPICS FOR MARCH 29, 1994 MEETING
REGARDING WESTINGHOUSE RCP FLYWHEEL

MATERIALS SELECTION AND EXPERIENCE

1. EPRI URD, Volume III, Chapter 1, (URD) Paragraph 5.2.1.2, "Use of Unproven Material" requires that the use of unproven materials be justified. Depleted uranium would be an unproven material as it has not had proven service in LWR plants.

   a. Justify the use of uranium for the flywheel and the concept of enclosure (vs. no enclosure) as specified in the AP600 SSAR and describe the basis for the acceptability of this design over the alternative materials considered.

   b. Justify the concept of enclosure for the flywheel, rotorbars, etc. Include similar uses and their histories (positive and negative).

   c. Compare the proposed uranium flywheel design with the alternative materials studied. Include the advantages of using depleted uranium, considering there is no previous experience with this material for flywheel applications.

   d. Provide the reasoning which led to the selection of uranium and the enclosure design for this application. Provide an explanation of why a dense, tough, corrosion resistant material which does not need an enclosure, such as tantalum, was not used for this application

2. The EPRI URD, Volume III, Chapter 1, Paragraph 5.2.4.3, states that preference shall be given in the ALWR to designs which do not push material limits and which make use of conventional materials applied well within the limits where successful experience has been obtained. Accordingly, what conventional materials were considered in the design of the flywheel? Why were the alternative materials eliminated?

3. The EPRI URD, Volume III, Chapter 1, Paragraph 5.2.2, "Identification of Material in Critical Components," requires that all materials and any special requirement be identified. Volume III, Chapter 3, Paragraph 3.4.2.10.1 identifies the reactor coolant pump flywheel to be such a component. Provide a discussion of any other special requirements developed that need to be imposed because of the use of uranium as the reactor coolant pump flywheel aside from requiring a protective enclosure.

4. Provide a discussion of any previous experience or prototypes of rotating machinery with uranium rotating structural components.

5. Provide a discussion of any previous experience or prototypes of rotating machinery with a flywheel susceptible to corrosion in a welded enclosure exposed to a corrosive medium.

6. Have other means of providing corrosion resistance to the uranium flywheel, such as weld overlay (Zr, Ta, Ti) or plasma spray coatings been considered?

7. ALARA is a concern, especially for the 60-year life plant.

   a. Compare ALARA exposure between the AP600 design and the present 40-year life design for the expected maintenance and inspection of the RCP flywheel.

   b. Estimate the radiation exposure likely at the end of the 60-year life.

8. a. How do you ensure adequate fracture toughness of the depleted uranium castings/forgings (allow and residual) for the 60-year life of the plant?

   b. What elements will adversely effect the fracture toughness of uranium?

   c. Will the alloying elements, including residual elements, cause a degradation of properties, particularly fracture toughness, at the temperatures at which this material will be used over the life of the component?

   d. Will thermal cycling over the life of the plant cause a significant change in properties of the uranium?

9. Provide:

   a. the specifications for the uranium in both part forms (casting and forging), and

   b. the specified alloy control, residual element control, grain morphology, and NDE requirements.

10. Demonstrate that the Charpy V-notch specification criteria is a valid indication of fracture toughness.

11. Explain why the standard measures of fracture toughness, such as K_{Ic} and J_{Ic}, are not used for the uranium flywheel.

ENGINEERING ASPECTS

1. Provide the analysis that was used to evaluate the adequacy of the surrounding pump structure to contain the fragments of a postulated flywheel failure.

2. Provide the analysis that was used to evaluate the adequacy of the surrounding pump structure to contain the fragments of the remaining rotating machinery components.

3. Provide the critical flaw size analysis/calculations of the uranium flywheel for review.

4. Provide the fatigue stress analyses that were performed to determine the adequacy of the uranium pump flywheel design.

5. Provide the structural stress analyses that were performed to evaluate the flywheel's design.

6. Demonstrate the adequacy of the flywheel enclosure's use of stresses higher than those recommended by the Standard Review Plan guidelines for normal and design speeds.

7. The ASME Code is used for pressure vessels and piping, and at most a low-cycle fatigue environment. Explain why the ASME Code would be appropriate for rotating machinery, and a high-cycle fatigue application.

8. Provide the structural analysis of the shaft and bearing supports taking into account normal operation, anticipated transients, the design basis of loss-of-coolant accident and safe shutdown earthquake.

9. a. Provide for this design the standard reliability/maintainability information, i.e., mean time between failures, etc.

   b. Make comparisons with the present reactor coolant pump design.

10. In response to Q251.14, it was stated that the welds connecting the pieces of the enclosure are seal welds. The ASME Code does not credit seal welds and zero joint efficiency should be used for such joints. The uranium flywheel and its Inconel 600 enclosure are parts in rotating machinery. The factor which controls rotating machinery design is usually high cycle fatigue, and in a water environment, corrosion fatigue. Demonstrate that the inspection criteria for the uranium flywheel and its welded Inconel 600 enclosure, based upon the ASME Code, are appropriate for the 60-year design life.

11. Only "seal" welds are used to connect the component parts of the Inconel 600 flywheel enclosure. Demonstrate that the Inconel 600 enclosure weldments (of the enclosure's joint designs) have corrosion fatigue lives in reactor coolant at operating temperature for the 60-year design life.

12. a. Describe the connections between the shaft, the uranium flywheel, and the Inconel 600 enclosure.

    b. Provide drawings with dimensions and weld joint details.

13. Provide the data that has been developed to demonstrate the retention of adequate fracture toughness of the uranium flywheel for the 60-year life under operating conditions, i.e., constant temperature, temperature cycling, and stress and temperature cycling together.

14. Uranium is an anisotropic material, i.e., it has different mechanical properties in different crystalline directions. What data has been developed to demonstrate the retention of dimensions of the uranium flywheel as a casting and as a forging for the 60-year life under operating conditions, i.e., stresses at constant temperature, temperature cycling, and stress and temperature cycling together.

15. Provide the inspection criteria for the finished Inconel 600 enclosure.

16. Specify the means of monitoring the leak tightness of the Inconel 600 enclosure during the 60-year life and revise the SSAR accordingly.

    a. Explain how the soundness (freedom from significant casting defects) of the parts produced from cast depleted uranium is ensured.

    b. Describe the inspection requirements for the finished machined uranium flywheel.

    c. Provide procedures, special techniques, and acceptance standards used.

17. Provide any special procedures required to protect personnel from toxicity of the uranium while performing routine maintenance and inspection in an operating plant.

18. a. Explain whether or not the ultrasonic testing procedures of the uranium flywheel be subject to the requirements of Appendix VIII of Section XI, 1989 Addenda.

    b. Demonstrate that the ultrasonic testing procedure(s) for the uranium flywheel are adequate and appropriate.

19. Evaluate whether or not the location of the reactor coolant pump housings and associated components interfere with eddy-current examination of <u>all</u> of the steam generator tubes.

20. Describe the means of ensuring the leak tightness of the Inconel 600 enclosure for the 60-year design life.

21. Identify the largest pipe (system, size, and maximum pressure) that is not qualified for leak-before-break that is used to determine maximum overspeed of the reactor coolant pump.

CONSEQUENCES AND REPAIRS

1. In EPRI URD, Volume III, Volume 1, Paragraph 5.2.5, Hazardous Materials, it is stated that the use of materials which present a hazard to personnel or equipment (e.g., toxicity, etc.) shall be limited to those applications where no satisfactory alternatives exist.

   In the case of a loss in leak tightness of the flywheel Inconel 600 flywheel enclosure, identify if there are any procedures in place that will specify the shipping, storing, handling and overhaul to be required for the repairs of the reactor coolant pump and its associated heat exchanger contaminated with uranium corrosion products. If procedures exist, where are the procedures referenced in the SSAR?

2. In the event of a leak developing in the Inconel 600 enclosure:

   a. What controls or operational procedures exist to prevent spreading the uranium corrosion products once failure of the flywheel's enclosure has been detected?

   b. What would be the consequences of the spread of uranium corrosion product to all components in contact with reactor coolant?

   c. What would be the exposure hazard to workers in the worst case scenario?

   d. What are the specified corrective measures in the event of a loss of leak tightness of the Inconel 600 flywheel enclosure?

   e. What are the requirements/procedures for repair in the event of loss of leak tightness of the Inconel 600 enclosure?

3. Specify the effectiveness of the heat exchanger water system and its motor purge water to restrict the introduction of uranium corrosion products into the reactor coolant.

4. In the event of flywheel fracture with the boundary remaining intact:

   a. What is the threat of these broken parts getting into the reactor vessel and causing other damage or preventing other components from performing their functions?

   b. Are there any radiation hazard conditions in such a scenario?

5. Are weld repairs to a cast or forged uranium flywheel allowed?

WESTINGHOUSE RESPONSES TO NRC GENERATED DISCUSSION TOPICS FOR MARCH 29, 1994 MEETING REGARDING WESTINGHOUSE RCP FLYWHEEL

Materials Selection and Experience

1. a. Several materials were considered for the RCP flywheel, this discussion does not include all the considered materials, but rather gives an explanation for the rejection of the most obvious materials. Steel, which is known as the conventional RCP flywheel material, was removed from consideration due to the relative low density of steel. In order to obtain the required rotating inertia from a flywheel made of steel, the flywheel size could not be incorporated within a canned motor design. Other potential materials such as tungsten, tantalum, gold, and platinum were dismissed from consideration due to characteristics that could not compete with uranium. These characteristics included material costs and material availability, difficulties in working with the material, and inferior material properties. Uranium offers excellent density and material characteristics for a flywheel application, due to these characteristics it is possible to design a flywheel which is compact enough to fit within the canned motor pump confines and structurally sound enough to ensure flywheel integrity for the 60 year design life. Finally, the chemical behavior of uranium in reactor coolant is well known, in the unlikely event that the jacket should fail and allow trace amounts of flywheel material to escape.

   b. The concept of an inconel enclosure to protect the flywheel from the corrosive reactor coolant was chosen due to the fact that it offers the most complete and effective means of protecting the flywheel and WEMD has extensive experience using inconel enclosures in RCPs to protect components susceptible to the corrosive properties of the reactor coolant system. Please refer to response 6 of this section for a discussion on alternative means to provide corrosion resistance to the flywheel.

   c. Please refer to the above response(# 1.a.) for a discussion on the selection of the flywheel material.

   d. Please refer to the above response(# 1.a.) for a discussion on the selection of the flywheel material.

2. Please refer to the above response(# 1.a.) for a discussion on the selection of the flywheel material.

3. The use of an uranium flywheel will not require any special requirements during normal operation, inspection, and maintenance of the reactor coolant pump.

4. The flywheel design has been prototype manufactured and tested at WSTC. Present testing has been performed up to speeds of 1785 RPM and has included:

   a) Friction Dynometer testing(Drag Loss)

   b) Flywheel as a thrust and radial bearing

   c) Modifications to improve drag loss

   Future testing of the flywheel will include overspeed testing and a destructive examination of the flywheel inconel casing and uranium insert.

5. WEMD manufactures canned motor pumps for naval main coolant pump applications, where the RCP design also requires the rotor to have a minimum specified inertia, and the rotor then acts as a "flywheel". The design includes a rotor lamination of electrical steel which is corrosion susceptible. The rotor can serves as a welded enclosure to separate the corrosion susceptible materials from the corrosive environment. The welds used in the flywheel construction are similar to the service proven welds used in rotor construction.

6. Other means for providosion resistance to the uranium flywheel have been considered. From these evaluations it was determined that an inconel enclosure would be the most effective and desirable option. There are concerns in how a plasma spray coating or a corrosive resistant plating would hold up in the reactor coolant pump application. On the other hand, there is broad experience with seal welded inconel and it has proven to hold up well when used as a reactor coolant pump can.

7. a. There is no expected inspection and maintenance of the reactor coolant pump flywheel. Estimated occupational radiation exposure associated with the reactor coolant pump is due only to the inspection of pressure boundary welds and threaded fasteners.

   b. The uranium in the flywheel assembly will not significantly contribute to radiation exposure from the reactor coolant pump. The radiation exposure from the pump is primarily due to radioactive corrosion products.

8. a. The 10 ft. lb. Charpy test data for this material is the basis for the fracture toughness value of 50 ksi in. The test data came from Battelle BMI-2032, The Mechanical Properties of Depleted Uranium, prepared for U.S. DOE, 7/16/79, by Deel and Burian. Also, testing was performed by Martin Marieta, showing that this level can be consistently achieved.

b. The controlled elements are listed in the SSAR Table 5.4-2 and will be specified in the material ordering document. They are as follows:

Carbon	150	ppm Max.
Iron	75	ppm Max.
Silicon	75	ppm Max.
Copper	20	ppm Max.
Aluminum	20	ppm Max.

c. The flywheel operates in the motor bearing region, below the thermal barrier, and does not see the pumped fluid temperature. The bearing water temperature will be around 150 degrees F for normal operating conditions. Due to this low temperature, no degradation of material properties is expected.

d. As described above, the service temperature of the flywheel is sufficiently low that thermal aging of the flywheel is not expected to occur. According to the Metals Handbook, Desk Edition, written by the American Society for Metals in 1985, a temperature of 350 °C (662 °F) is needed for thermal aging.

9. a. Please refer to response # 8. b. in this section for a discussion on the uranium material specifications.

b. The alloy control, grain, and NDE is controlled by using an approved melting and casting practice and by providing adequate specifications in the material procurement document.

10. Test data from Battelle BMI-2032, The Mechanical Properties of Depleted Uranium, prepared for U.S. DOE, 7/16/79, by Deel and Burian contains data supporting the Charpy V-notch testing as an indication of fracture toughness. The validity of the Charpy V-notch test will also be verified during the destructive examination of the prototype flywheel. Since the prototype flywheel was prepared and tested using the procedures as presently outlined, the results from prototype testing will indicated the validity of the procedures presently employed.

11. JIC is being evaluated as a requirement and may be added to the materials ordering documents (MOD). It could give a more reliable and direct indication of the material toughness than a Charpy test. Acceptance of the test requirement by suppliers may mean that the test will be in the MOD for information, with judgement and responsibility on acceptability of the material being exercised by Westinghouse.

Engineering Aspects

1. This information is provided in WCAP-13734.

2. A qualitative evaluation was performed to evaluate the credibility of an event in which rotating parts, other than the flywheel, could become missiles with sufficient energy to breach the pressure boundary. Due to the size and mass of the stator core and surrounding RCP shell it is not considered that this is a credible enough event to warrant quantitative analysis. It is important to note that, minus the flywheel, WEMD has extensive experience with operation of canned RCPs with this configuration.

3. This information is provided in WCAP-13734.

4. This information is provided in WCAP-13734.

5. This information is provided in WCAP-13734.

6. This information is provided in WCAP-13734.

7. This information is provided in WCAP-13734.

8. The structural analysis of the rotating components and bearings will be provided as part of the final analysis design package. This will account for steady state operation, emergency, and seismic conditions.

9. The estimated downtime for the AP600 due to unavailability of the canned motor reactor coolant pump is conservatively estimated at 10.5 hours per year. The historic number for Westinghouse designed two loop plants is 26.3 hours per year.

10. The flywheel enclosure welds are not pressure boundary welds and therefore are not subjected to the ASME Code Section XI pressure boundary weld inspection criteria. The welds are designed and examined to Section III requirements because the Code provides good guidance for creating such a weld. It is important to note that the enclosure welds are not credited in the flywheel missile analysis. Since the welds and materials that are being used on the flywheel enclosure are similar to the welds and materials that are used to seal the stator and rotor cans, WEMD has a great deal of operational experience in creating an enclosure that is sufficiently robust to withstand the cycle fatigue and corrosion fatigue experienced by a RCP.

11. Please refer to the above response(# 10.) for a discussion on the adequacy of the enclosure welds.

12. a. This information is provided in WCAP-13734.

    b. This information is provided in WCAP-13734.

13. The heat treatment on the flywheel material is 1000 °C for 24 hours followed by a slow cool at less than 100 °C per hour in a vacuum of 10-4 torr. The slow cooling will provide a stable metallurgical structure which is relatively stress free. The operating temperature of the flywheel is approximately 150 °F. Even in less stable, quenched condition, aging will only occur with temperatures in the region of 300 °C (518 °F). (See Metals Handbook, Desk Edition ASM 1985.) The stresses on the flywheel are low and will not produce any strain induced changes in the flywheel properties. The low thermal and stress transients of the design are not expected to produce any degradation of properties. At the end of the testing of the prototype, the material will be cycled prior to disassembly for material property testing. This testing will include fracture toughness and tensile properties.

14. The uranium casting material does not exhibit anisotropy. Metalograpy shows an equiaxed grain structure to exist.

15. The NDE will be visual 5X, PT no bleeds, and the welds are RT accessible.

16. As stated in SSAR paragraph 5.4.2.3.6.3, a leak in the flywheel enclosure will be detected by an out of balance vibration in the RCP, which is monitored by the RCP vibration monitors. The pump vibration monitors are designed and will be calibrated to detect extremely small variations in the flywheel mass.

    a. Soundness and (freedom from significant defects) is ensured by a two step process. The first step is to employ strict casting procedures which include that all melting and casting processes are performed in a vacuum. The second step involves strict inspection techniques. The soundness of the casting will be verified by UT and PT and then the final machined surfaces of the flywheel will be PT tested for flaws.

    b. The finished machined uranium flywheel will be liquid penetrant tested (PT) for any flaws.

c. The liquid penetrant examination of the prototype flywheel was performed to ASME Section V. The planned dye penetrant method to be used is the solvent removable red dye on 100% of the finished machined surfaces. Acceptance will be as specified in the applicable code or standard. It is noted that the inspection report for the prototype flywheel shows that there were "no signs of an indication". Specific procedures and acceptance criteria will be developed as part of the final design efforts. The UT testing will be performed in both tne axial and radial directions. Based on the results of the prototype flywheel UT testing, a 1/8 inch diameter FBH was used and good resolution was obtained. Based on this experience, it is believed that the acoustic properties of the casting are relatively good and this material can be inspected to the requirements of SA-609. There is currently no available history of performing shear wave testing on this material, however the configuration may permit shear wave examination. Specific procedures and acceptance criteria will be developed as part of the final design efforts.

17. There are no expected routine inspection and maintenance activities that would require opening of the reactor coolant pump flywheel assembly. No special procedures are required during routine inspection and maintenance of an operating AP600 to provide protection from uranium toxicity.

18. a. UT - Ultrasonic examination will be performed in accordance with ASME Code Section III, Subsection NB-2574.

    b. Since it is not feasible to perform radiographic examinations on the flywheel due to the thickness and density of the uranium, ultrasonic testing is the only other possible choice for volumetric inspection that satisfies the ASME Code requirements. Based on results from UT testing that has been performed on the prototype flywheel by Martin Marieta, the acoustic properties of uranium cast material are relatively good. This material is capable of being inspected to the requirements of the ASME Code Section III, Subsection NB-2574, specifically SA-609.

19. The reactor coolant pump does not interfere with eddy current inspection or other inspection or maintenance activities of any steam generator tube.

20. The leak tightness of the flywheel enclosure is ensured by the manufacturing and inspection procedures as outlined in response # 15 of this section. Response #16 of this section describes how a leak in the flywheel enclosure would be detected.

21. The largest diameter pipe that will not be qualified for leak-before-break is 3 inches. Previous piping and RCP analyses have demonstrated that a 3 inch pipe break will not release sufficient RCS volume to create a RCP 125% overspeed condition. Therefore, the maximum overspeed is conservatively taken as 125 percent of nominal speed.

Consequences and Repairs

1. The procedures required to store, handle, ship, or overhaul the canned motor pump with postulated depleted uranium contamination are not significantly different than those for any radioactive contamination. Precautions for addressing postulated depleted uranium contamination will be included in the reactor coolant pump inspection manual.

2. a. To prevent spreading of depleted uranium contamination from a postulated leak of the flywheel enclosure the plant would be shut down and the affected pump stopped.

   b. The consequences of the spread of postulated depleted uranium flywheel corrosion product to components in contact with the reactor coolant would be comparable to corrosion product transport or fuel failures.

   c. There would be minimal exposure hazard due to the worst case postulated leak of a flywheel enclosure to properly protected workers.

   d. Recommended corrective measures for addressing a leak in the flywheel enclosure will be included in the reactor coolant pump instruction manual. These could include shutdown and replacement or refurbishment of the pump.

   e. The requirements for the repair and refurbishment of a pump found with a leaking flywheel enclosure will be determined during an inspection of the RCP. The spare pump will be used, in the RCS, while repair and refurbishment operations are being performed on the pump requiring maintenance.

3. The flywheel is encased in a welded inconel enclosure. It is not expected that there will be any communication of depleted uranium corrosion products across the inconel or the enclosure welds.

4. a. In the event of a flywheel failure, the parts will remain contained within the flywheel region of the RCP. This is aided by the fact that the pump has been designed to limit the communication between the fluid in RCS and the fluid internal to the pump. This is accomplished by the circulatory flow of the RCP cooling system and the labyrinth seal between the RCP motor region and hydraulic region.

   b. There is no special radiation hazard in the event of a fracture of the depleted uranium flywheel.

5. There are no weld repairs allowed or qualified for repair of the uranium flywheel.