APPENDIX

BJNPQ - 203

G.E. REACTOR SIZE 251

APPENDIX TO TOPICAL REPORT

BJNQP - 101

TO QUALIFY THE PERFORMANCE AND
SAFETY FEATURES OF THE

BYRON JACKSON

PRIMARY REACTOR RECIRCULATION PUMP

FOR USE ON

GENERAL ELECTRIC NUCLEAR
STEAM SYSTEM SIZE 251

FIRST DRAFT - FEBRUARY 1979

2251 029

BYRON JACKSON PUMP DIVISION
BORG WARNER CORPORATION
LOS ANGELES, CALIFORNIA

7906200227

DISCLAIMER OF RESPONSIBILITY

This document was prepared by or for the Byron Jackson Pump Division, Borg-Warner Corporation. Neither the Byron Jackson Pump Division, Borg-Warner Corporation nor any of the contributors to this document:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information disclosed in this document may not infringe privately owned rights; or

B. Assumes any responsibility for liability or damage of any kind which may result from the use of any information disclosed in this document.

2251 034

Appendix tc Topical Report BJNPQ-101 to qualify the Byron Jackson Primary Recirculation Pump for use on General Electric Nuclear Steam Supply System Size 251.

1.0 INTRODUCTION

Byron Jackson Nuclear Pump Qualification BJNPQ-101, outlining the performance and safety features of the Byron Jackson Primary Reactor Pump for light water reactors, is written in a general form, therefore is applicable for use with different NSSS systems.

Specific appendices make the report applicable to individual systems.

1.1 This Appendix, titled BJNPQ-202, is specific for application within a General Electric Nuclear Steam Supply System Size 251.

1.2 All specific operating, design and characteristic data listed in this appendix is referenced with the paragraph numbers of the Topical Report BJNPQ-101, where applicable. Therefore, starting with Par. 2.0 of this appendix, all paragraphs of the two documents complement each other.

2251 035

1.3 In some instances, where no specific data is required or applicable to the content of the Topical Report BJNPQ-101, the paragraph number is listed with the notation N/A (not applicable).

1.4 The specific operating and design conditions and other requirements listed, are as required for Reactor Recirculation Pumps for use in a General Electric Company standard boiling water nuclear power plant of the Size 251.

2251 036

2.0 DESIGN BASIS/CRITERIA - ENVELOPE - OPERATING REQUIREMENTS

2.1 Normal Operating Conditions

2.1.1 Hydraulic Performance - System Requirements

2.1.1.1 Capacity

The minimum rated flow is:

47,100 GPM at head per 2.1.1.2

2.1.1.2 Head - Design and Maximum Shut-Off

The rated (design) head of the pump is:

835 ft at flow per 2.1.1.1.

The maximum shut-off head is dictated by the requirement for constantly rising pump characteristic, to allow parallel operation. The pump performance test shall demonstrate that the pump total dynamic head continually rises from a point not less than 85% of specified rated head at 115% of specified rated flow to a point not more than 132.5% of specified rated head at 20% flow.

2.1.1.3 $NPSH_A$

The net positive suction head available at rated flow is:

115 ft.

2251 037

2.1.1.4 Size, Speed, Type, $NPSH_R$, BHP, Efficiency for above requirements:

Size: 24 x 24 x 35

Speed: 1780 RPM operating

1800 RPM synchronous

Type: DVSS

(Double Volute Single Suction)

$NPSH_R$: Sufficient to insure cavitation - free operation

BHP: Rated - 9180 HP

Hot Operation (Normal) - 7,198 HP

Cold Operation (Start-Up)

See Par. 3.6.5 for low speed start-up procedure.

EFF: 87% at design point

2.1.1.5 Flywheel Requirement - WK^2

The kinetic energy WK^2 is:

Pump only: 900 $lb\text{-}ft^2$

Pump and Motor combined: 21,500 $lb\text{-}ft^2$

2.1.2 Mechanical Requirements

2.1.2.1 Design Pressure

1,650 psi

2.1.2.2 Design Temperature

575°F.

2.1.2.3 Suction Pressure

1,032 psia

2.1.2.4 System Temperature

533°F.

2251 038

2.1.2.5 Liquid Characteristics

Demineralized water of the following quality level:

1. Total Solids - 0.1 to 1.0 ppm
2. pH - 5.6 to 8.6 at 25°C
3. Additives - none
4. Chloride - 0.5 ppm max.
   0.2 ppm normal

2.1.3 Normal Operating Loads

2.1.3.1 Pipe/Nozzle Loads

The pipe/nozzle loads imposed on the pump during different operating modes, including OBE, SSE and LOCA, are superimposed on pump mechanical and thermal stress loads for stress analysis as discussed in Paragraph 4.1 and 4.3

Requirements and limits for allowable stresses are in accordance with Section III of the ASME Code.

The loads are calculated and specified by the NSSS after the system and support locations are established for the specific pump/reactor piping system.

2251 039

2.1.3.2 Temperature Transients

The pump must start and operate at any temperature of the reactor coolant between:

$70^{\circ}F$ and $550^{\circ}F$.

See Paragraph 3.6.5 for operation under cold (start-up) condition.

2.1.3.3 Seismic Loads

See Paragraph 2.1.3.1 for note on piping loads for OBE and SSE.

All other components affecting pump operation are designed and analyzed to insure operability of pump during OBE and pressure integrity during SSE, at intensities as specified in the seismic spectra of the design specifications.

2251 040

2.1.4 Applicable Codes

2.1.4.1 ASME Nuclear Component Code

1. Section III - Nuclear Power Plant Components

2. Section VIII - Pressure Vessels

3. Section IX - Welding Qualifications

4. Section XI - Inservice Inspection

2.1.4.2 Hydraulic Institute Standards

Centrifugal Pump Section

2.1.4.3 Other Standards

1. B31.1 - Code for Pressure Piping, Power Piping

2. B1.1 - Unified Screw Threads

3. B18.2.1 - Square and Hex Bolts and Screws

4. B18.2.2 - Square and Hex Nuts

5. B18.3 - Socket Cap, Shoulder and Set Screws

6. ASTM Book of Standards

7. AWS Group A5, Filler Metal Specifications

8. ISA Recommended Practice P.P.1.1

9. American Institute of Steel Construction

2.1.4.4 Customer Design Specifications applicable to individual installations.

2251 041

2.2 Upset Operating Conditions

The following values are maximum fluctuations, representing the most severe transients anticipated during plant operations including upset conditions with a maximum anticipated number of cycles of 40 for turbine/generator trip and 10 for loss of feed water.

Normal operational fluctuations of lesser amplitude or rate of change have been omitted.

2.2.1 Flow Changes

47,100 GPM Normal

54,165 GPM max (115% of Normal)

Normal rate of flow change is 10% per second.

2.2.2 Pressure Changes

Turbine/Generator Trip	:	1320 psi to 1490 psi in 10 sec.
	:	At 1490 psi for 5 sec.
	:	1490 psi to 1295 psi in 15 sec.
	:	1295 psi to 553 psi in 1.5 hrs.
Loss of Feed Water	:	1355 psi to 1615 psi in 3 sec.
	:	1615 psi to 1405 psi in 19 sec.
	:	1405 psi to 175 psi in 50 min.

2.2.3 Temperature Gradients

Turbine/Generator Trip	:	533°F to 350°F at Rate of 100°F/Hr
Loss of Feed Water	:	528°F to 573°F in 6 min.
	:	573°F to 490°F in 7 min.
	:	490°F to 573°F in 8 min.
	:	573°F to 425°F in 7 min.
	:	425°F to 350°F in 45 min.
	:	350°F to 552°F in 2 hrs.

2.3 Emergency or Abnormal Operating Conditions

2.3.1 Loss of Cooling Water

Pump to operate continuous with seal injection on.

2.3.2 Loss of Injection Water

Pump to operate continuous with cooling water on.

2.3.3 Simultaneous Loss of Cooling Water and Injection Water

This is not considered to be a probable event, as the two systems are independent of each other.

2.3.4 Loss of Off-Site Power

Pump to be capable of hot stand-by with cooling water and/or injection water on.

2.3.5 Hot Stand-By with/without Cooling Water and/or Injection Water

See Paragraph 2.3.4 and 2.3.3.

2.3.6 Forward/Reverse Flow through Deenergized Pump

Forward Flow - 15% of rated or 7,065 GPM

Reverse Flow - 50% of rated or 23,550 GPM

2.4 Faulted Conditions

2.4.1 Loss of Coolant Accident

Pressure Boundary and Mounting Loads and Stresses Calculated in Stress Analysis

See Paragraph 4.0

2251 043

3.0 DESIGN - CONSTRUCTION DESCRIPTION

3.1 Hydraulic Considerations

3.1.1 Hydraulic Performance

See Paragraph 2.1.1

3.1.2 Stable Operation

See Paragraph 2.1.1.2

3.1.3 Pressure Pulsation - Vibration

Maximum vibration measured at motor mounting flange 0.003 inches peak to peak at normal operating speed.

Note: The above is for pump operating at design condition.

3.1.4 Cavitation and Minimum Flow

1. NPSH required shall not exceed NPSH available of 115 ft. at normal operating capacity and $NPSH_A$ of 53 ft at minimum flow.
2. Minimum flow is 20% of rated.

3.1.5 Hydraulic Thrust Balance

N/A - Pump design consideration

2251 044

3.2 Hydrostatic Bearing

The pump bearing shall have sufficient dynamic load capability to withstand the design basis earthquake at rated operating conditions and for the first 10 seconds of coastdown or to 40% of rated shaft speed.

3.3 Internal Heat Exchanger

3.3.1 Injection Provision

3 to 5 GPM @ 60°F to 110°F at 1066 psi to 1462 psi

3.3.2 Hot Stand-By Protection

Sufficient to cool seal assembly during hot stand-by. Cooling water available is 60°F to 105°F at 75 psi pressure. Allowable pressure drop is 10 psi.

3.4 Seal Cartridge

3.4.1 Series Arrangement

Shaft seal assembly composed of multiple seals.

3.4.2 Controlled By-Pass

3.4.2.1 Pressure Breakdown

Equally divided across all seals, with each seal capable of full pressure operation.

3.4.2.2 Flow to Control Temperature Rise

The normal seal injection flow is 3 to 5 GPM min., at 60°F to 110°F. The normal flow through the controlled by-pass system plus seal leakage is 1.5 GPM.

2251 045

Flow will be measured in the seal leakage plus controlled by-pass outlet line.

Maximum bleed-off temperature shall not exceed 180°F, with normal cooling water flow without injection.

3.4.2.3 Pressure/Temperature Monitoring

1. Outlets shall be provided to measure pressure at the inlet to first seal, between each pair of seals and in the seal leakage plus controlled by-pass outlet.

2. Thermowells with ISA Type T thermocouples shall be provided to monitor the temperature in each seal cavity.

3.4.3 Replacement Feature

Seal assembly is a self contained, preassembled cartridge.

3.4.4 Preassembly and Test

Each seal assembly shall receive a pretest inspection to verify that it has been properly assembled and shall verify seal axial clearances and dimensions.

2251 046

3.5 Curvic Coupling

Selection of the coupling is left to the pump manufacturer, subject to acceptance by customer.

Byron Jackson Pumps use a curvic coupling as outlined in Topical Report BJNPQ-101.

3.5.1 Reduction of bearing span

N/A See Par. 3.5

3.5.2 Positive Alignment

N/A See Par. 3.5

3.6 Interface with Motor

Motor is supplied by others. The interface requirements dictated by the pump, as listed in Topical Report BFNPQ-101, must be satisfied.

3.6.1 Fits and Tolerances for Runout

Per Paragraph 3.6.1 of BJNPQ-101

3.6.2 Thrust Bearing Loads

The thrust bearing must be capable of operation at the following loads:

21,500 lbs up normal hot operation

30,800 lbs down cold startup

65,200 lbs up stationary at hydrotest

2251 047

3.6.3 Flywheel

N/A See Par. 2.1.1.5

3.6.4 Anti-Reverse Rotation Device

No anti-reverse rotation device is used on the G.E. Size 238 system.

3.6.5 Special Starting Conditions

Motor energized with rated voltage for less than 20 sec., allowed to coast down to between 600 and 500 RPM, then energized with low frequency power supply for 25% of rated speed operation. Operation at that speed until system temperature and pressure reaches design condition. Motor will then be switched from low frequency source to rated voltage and frequency in less than 10 seconds.

3.6.6 Fluid Systems

Motor cooling and lubricating piping requirements are incorporated in motor specifications.

3.6.7 Instrumentation

Motor instrumentation requirements are in motor specifications.

2251 048

3.7 Interface with System

3.7.1 Pump Case Nozzles

The nozzles shall be terminated with a material suitable for field welding to reactor coolant piping.

3.7.2 Auxiliary Piping Termination

The minimum size of all connections into the reactor coolant pressure boundary shall be 3/4 inch nominal.

3.7.3 Instrumentation Termination

Instrumentation leads shall be wired to terminal strips within NEMA enclosures. Leads from similar type instrumentation shall be terminated within the same enclosure to the maximum extent possible.

3.7.4 Mounting Provisions

Pump is suspended from constant support hangers by hanger rods which are attached to brackets mounted on the pump motor support bracket. Hydraulic snubbers are provided to control horizontal seismic forces.

2251 049

4.0 ANALYSIS

The requirements for a stress analysis report (Reference Paragraph NA-3352 of ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components) shall be satisfied by performing an analysis in accordance with Section NB-3400 or NF-3200 of ASME Section III. The pump assembly shall be designed for nozzle loads and support reactions resulting from design, normal, upset, emergency, Faulted I and Faulted II conditions. The most severe combinations of the load associated with each category applied simultaneously in all directions specified shall be evaluated.

Faulted I condition loads are the combination of deadweight, SSE and pipe rupture conditions with pump on unruptured line.

Faulted II condition loads are the combination of deadweight, SSE and pipe rupture condition with pump on ruptured line.

Although the analysis of Faulted II conditions is not required to comply with ASME Section III, it should be performed to the limits of Faulted I conditions as defined in Paragraph NB-3225 and Appendix F of ASME Section III.

The method used by Byron Jackson is described in Paragraphs 4.1, 4.2 and 4.3 of Topical Report BJNPQ-101.

4.1 Pressure Boundary Analysis - See Paragraph 4.0

4.2 Heat Exchanger Analysis - See Paragraph 4.0

4.3 Support Structure Analysis - See Paragraph 4.0

4.4 Dynamic Analysis

Complete pump rotating assembly should be analyzed using the Faulted I criteria of Appendix F of ASME Boiler and Pressure Vessel Code, Section III.

If the Faulted I criteria cannot be met, the supplier shall propose alternate analysis methods, criteria and limits, for purchaser's approval.

The method used by Byron Jackson is described in Paragraph 4.4 and 4.5 of Topical Report BJNPQ-101.

4.5 Hydrostatic Bearing Analysis - See 4.4

2251 051

5.0 QUALITY CONTROL

Byron Jackson Quality Assurance Program and Quality Assurance Manual has been certified by ASME and Certificate No. N-1130 for Class 1, 2 and 3 pumps and Certificate No. N-1131 for Class 1, 2, and 3 pump parts and component support pumps issued.

Quality Control procedures described in Section 5.0, Paragraph 5.1 through 5.7 of Topical Report BJNPQ-101 comply with requirements for Class 1 pumps.

6.0 QUALIFICATION TESTING

All testing to be in compliance with Hydraulic Institute Standards, Centrifugal Pump Section. Byron Jackson procedures as described in Section 5.0, Paragraph 6.1 through 6.3 of Topical Report BJNPQ-101 comply with this requirement.

7.0 EFFECTS OF POSTULATED EVENTS

The events of postulated events described in Section 7.0, Paragraph 7.1 through 7.9 of Topical Report BJNPQ-101 satisfy or exceed the requirements of the General Electric Specifications for Recirculation Pumps.

2251 052

8.0 OPERATING ENVELOPE

8.1 Max/Min Pressure

1615 psi Max.

50 psi Min.

8.2 Max/Min Temperature

573°F Max.

60°F Min.

8.3 Max/Min Flow

48,300 GPM Max. (115% of normal)

8,400 GPM Min (20% of normal)

8.4 Maximum Nozzle Loads

Maximum nozzle loads are encountered during Faulted II condition. Their value is determined in the Analysis, see Paragraph 4.0.

8.5 Maximum g - Loads

Horizontal - 4.5 g

Vertical - 3.0 g

8.6 Maximum Overspeed

N/A

2251 053

8.7 Minimum NPSH

Minimum NPSH of 53 ft is available during start-up at 20% flow. The pump NPSH required does not exceed this value.

8.8 Maximum Vibration

Pump assembly vibrations measured at the motor mounting flange shall not exceed 0.003 inches peak to peak at normal operating speed and rated conditions.

8.9 Two Phase Flow

N/A

9.0 IN-SERVICE INSPECTION - ASME SECTION XI

Pump construction to provide for in-service inspection per ASME Boiler and Pressure Vessel Code, Section XI, in-service inspection of Nuclear Power Plant components. Affected components per Paragraph 9.1 through 9.4 of Topical Report BJNPQ-101.

10.0 SERVICEABILITY

One set of special tools, per plant, to be supplied. The set shall consist of:

One (1) Seal Removal Tool

One (1) Hydraulic Stud Tensioner

One (1) Set of special tools not normally available in a power plant

2251 054

11.0 RELIABILITY

The pump shall be designed to meet the following requirements:

1. Withstand all normal, upset and emergency operating conditions and maintain pressure boundary integrity for Faulted I and Faulted II conditions.

2. Design life of the pump assembly shall be forty (40 years.

3. It shall be a design objective to limit maintenance to five (5) year intervals.

4. The first critical speed shall not be less than 130% of operating speed.

2251 055