ATTACHMENT 2

STUB TUBE
360° CRACK EVALUATION
NINE MILE POINT 1

PREPARED FOR

NIAGARA MOHAWK POWER CORPORATION

BY

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SCOPE

Multiple cracks have been found in the area of stub tube to control rod drive (CRD) housing welds in the Nine Mile Point 1 reactor pressure vessel (RPV). This report evaluates the effects of cracks postulated to grow 360° around the circumference of the stub tube. Control blade alignment, flow induced vibration (FIV), scram forces, and seismic loading are considered.

SUMMARY

1. Failure of the stub tube will not cause failure of the control rod drive housing. If a housing failure were postulated, the restraining action provided by the control rod drive housing support structure would prevent ejection of a control rod drive housing.

2. Should a CRD housing be rolled into the bottom head to stop leakage, the potential movement at the bottom of the CRD housing resulting from the rolling operation will be limited, to the extent possible, by procedural control. During testing at GE control rods were inserted with offsets at the bottom of the CRD in excess of one (1) inch. Movement will be measured and recorded during the rolling operation. The maximum horizontal offset for an unrolled housing having a 360° through wall cracked stub tube is limited by the geometry of the hardware and is calculated to be 0.35 inches, which is still much less than one (1) inch.

3. The possibility of upward motion of a housing at the end of the scram has been investigated. Vessel pressure above 372 psi results in a downward force on the housing that is sufficient to resist motion caused by the end of scram force (including a factor of 2 for a suddenly applied force). If scram occurs below 372 psi the insertion function of the drive will already have been accomplished.

4. Calculations show that the pressure between the housing and the bottom head resulting from the rolling operation results in a friction force which will independently resist the end of scram forces.

5. During normal operation there is a compressive load due to hydrostatic pressure acting on the CRD housing which resists the moment caused by loads resulting from lower plenum flow acting on the housing. The resisting moment is calculated to be an order of magnitude greater than the applied moment. The calculation is supported by test data from the GE High Flow Facility during testing of the BWR-6 in which measured strains and measured flows again show an order of magnitude margin. The geometry of the lower plenum flow path for Nine Mile Point 1 is similar to the geometry for BWR-6. The flow rate for the BWR-6 is significantly higher than the flow rate for Nine Mile Point 1 resulting in additional conservatism.

6. While a simultaneous failure of more than one stub tube during normal operation is extremely unlikely, the potential of simultaneous failure is more plausible during a severe transient. Both vertical and horizontal components of acceleration due to an earthquake have been considered in detail and will not cause failure of the drives to function.

7. Based upon the above considerations, the functional requirements of the CRD to insert the control blades will not be adversely affected provided the plant is operated within the specified design operating conditions used in the current technical specifications.

DISCUSSION

1. Movement Due to Removed Restraint

The concern is that the top of the CRD housing could move if the stub tube breaks near the J-weld. Excessive movement of the housing could cause misalignment of the control blade with the core and result in problems inserting the blade. The maximum movement of any housing is limited to 0.35 inch. The calculation is shown in Appendix I. From the construction drawings the maximum diametral clearance between the housing and the stub tube is 0.030 inch. Since the minimum length of lower head plus stub tube is approximately 13.0 inches the maximum slope of the housing is .0023 in/in.(.030/13.0). This is equivalent to a horizontal translation of the lower housing flange of approximately .0023 x 154 = .35 inch. Tests at GE have shown that there is no significant increase in scram time for a horizontal translation of greater than one (1) inch.

2. Seismic Loading

A simultaneous failure of more than one stub tube during steady state operation is extremely unlikely. The potential of a simultaneous failure is more plausible during a severe transient, which imposes a significant stress rise so as to initiate a coincident failure of more than one drive housing assembly. This is especially true if the transient load is "primary" (stress not limited by deformation such as induced by pressure and weight). Two such transients are the earthquake and maximum credible accident. Both these transients are discussed in detail.

a. Earthquake (vertical acceleration component)

The primary effect of the vertical acceleration component would be to apply vertical load most of which would be attributed to the weight of four fuel assemblies. No tensile load would be applied because the upward acceleration would not be enough to overcome the fuel weight. Since the applied load would be compressive, there are no serious consequences of the vertical component of the earthquake.

b. Earthquake (horizontal acceleration component)

If a failure were postulated due to a horizontal acceleration, the mode of failure would be such as to leave a radial protrusion on the housing such that the housing could not be ejected through the minimum bore of the vessel and stub tube. The possibility of the weld failing in such a manner as to leave the outer diameter of the housing smooth enabling an unrestricted passage through the vessel and stub tube bore is extremely remote. The stress distribution resulting from the

horizontal "g" load is such as to result in linear stress distribution with diametrically opposite sides being in tension and compression. Failure will initiate partially around the circumference of the stub tube which is exposed to the tensile stress. As a failure starts to progress, the housing tends to rotate or pivot until it comes in contact with the bore in the stub tube and vessel below the field weld. There is only a 0.015 inch maximum radial clearance in an axial length of about thirteen inches between the outer diameter of the drive housing and the vessel stub tube bore. This limits the rotation of the drive housing to 0.1 degree after which the stub tube is no longer required to sustain the applied moment.

It may be concluded that simultaneous failure of stub tubes at several control rod drive penetrations under a horizontal earthquake is a remote possibility under the conservative assumptions utilized in the failure analysis. Nevertheless, simultaneous failure will not cause housing ejection nor hinder the drives performance from scramming within safe limits.

From a statistical viewpoint housing ejection of one failed drive housing may be remotely possible. If such a failure were further postulated, then the ejection would be limited by the drive housing support. The maximum leak that could be postulated for such a remote event is 685 gpm. Such a leak is easily detectable and is well within ECCS capability.

3. Design Basis Accidents

As a criteria for load application during a Design Basis Accident, a differential pressure is applied to the control rod drive housing. This differential pressure results in a hoop tension and compression respectively being applied to the housing above the field weld. Resulting stresses are considered trivial and will not lead to an individual or multiple failure.

The most deleterious effect of the design basis accident loadings would be a steam line break where the differential pressure applied to the bottom of the guide tube is significant enough to overcome the weight of the fuel assemblies, guide tube, and fuel supports and apply an axial tension to the control rod drive housing above the field weld. If this force occurred coincident with a failure in the stub tube the result would be a tendency for the housing to be pulled into the vessel. However, this is not possible because of the axial component of pressure force at the bottom of the housing still applies a downward force on the housing. Therefore, it may be concluded that the design basis steam line break would not lead to an individual control rod drive penetration failure much less a multiple simultaneous failure.

For a recirculation line failure all the resultant forces caused by the differential pressure result in additional compressive forces being applied to the housing above the field weld and in the stub tube. Unless the field weld were sheared off in such a manner that no protrusion is present to

prevent a rod rejection, no deleterious consequences to housing assemblies may be postulated for this accident. Such a shear under such low loads is deemed extremely remote for an individual failure much less than a simultaneous failure. The control rod drive housing support is capable of handling an individual ejection. Consequently, the recirculation line break would not prevent a safe shutdown of the reactor.

4. Upward Motion of Housing at End of Scram

The concern is that the end of scram up-force on the housing will lift the housing relative to the head. The upforce is produced by the inertia of the drive and control blade as their upward velocity is stopped at the end of the insertion (or scram) stroke. The end of scram force for BWR 2 drives will be not greater than 7000 lb. In addition, a suddenly applied load factor of 2.0 will be used so the equivalent static force is 14,000 lbs. The scram force is resisted by deadweight and vessel fluid pressure. The net upward force, when the downward deadweight force of 3.5 kips is subtracted, is 10,500 lbs. The vessel fluid pressure necessary to resist 10,500 lbs. is obtained by equating the pressure load on the 5.995 diameter hole in the bottom head to 10,500 lbs. and solving for the pressure:

$$p = \frac{3.14(5.995)^2}{4} = 10{,}500 \text{ lbs.}$$

$$p = 372 \text{ lb/in}$$

Therefore, when the vessel is pressurized to 372 psi or higher, the pressure will resist the end of scram upforce.

The contact pressure between the housing and head at the roll joint is calculated to be a minimum of 3100 psi during normal operation. Assuming a friction factor of 0.2 , the friction force is calculated to be:

$$A = 3.14 \text{ dl} = 3.14 (5.995) (3) = 56.5 \text{ in}^2$$

$$\text{Radial force} = pA = (3100) (56.5) = 175{,}154$$

$$\text{Vertical Friction Force} = .2 (175{,}154) = 35030 \text{ lb.}$$

The vertical friction force is three times the value needed to resist the vertical end of scram upforce.

For penetrations which have not been rolled, the reactor pressure above 372 psi will resist the end of scram force. For a postulated case where there is low pressure in the reactor when a scram occurs, the scram upward force occurs only at the end of the control rod blade movement. In this case, the blade would almost be totally inserted before any upward force is possible and the insertion function of the drive will have already been accomplished.

It is concluded that friction of the roll joint as well as internal vessel pressure, when the pressure is above 372 psi, can resist the end of scram vertical loads so the housing will not lift.

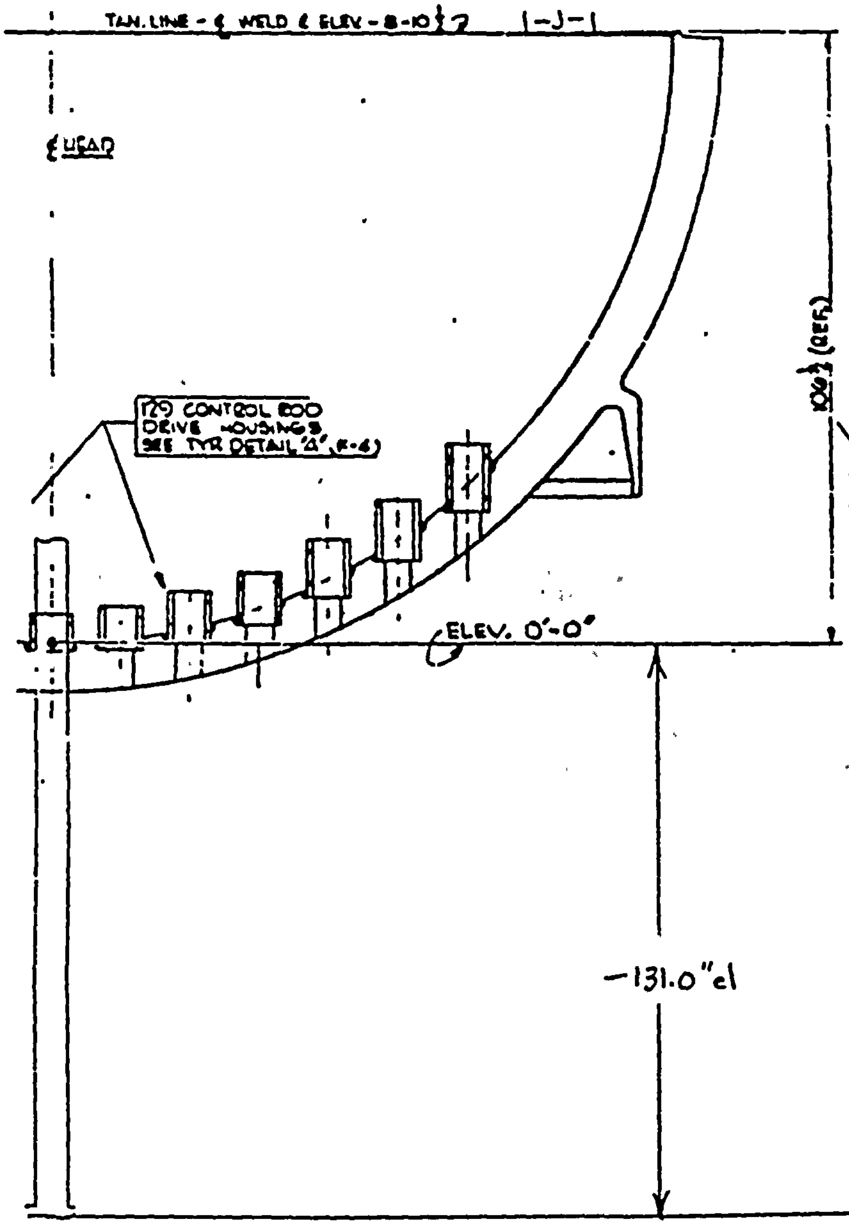
APPENDIX I

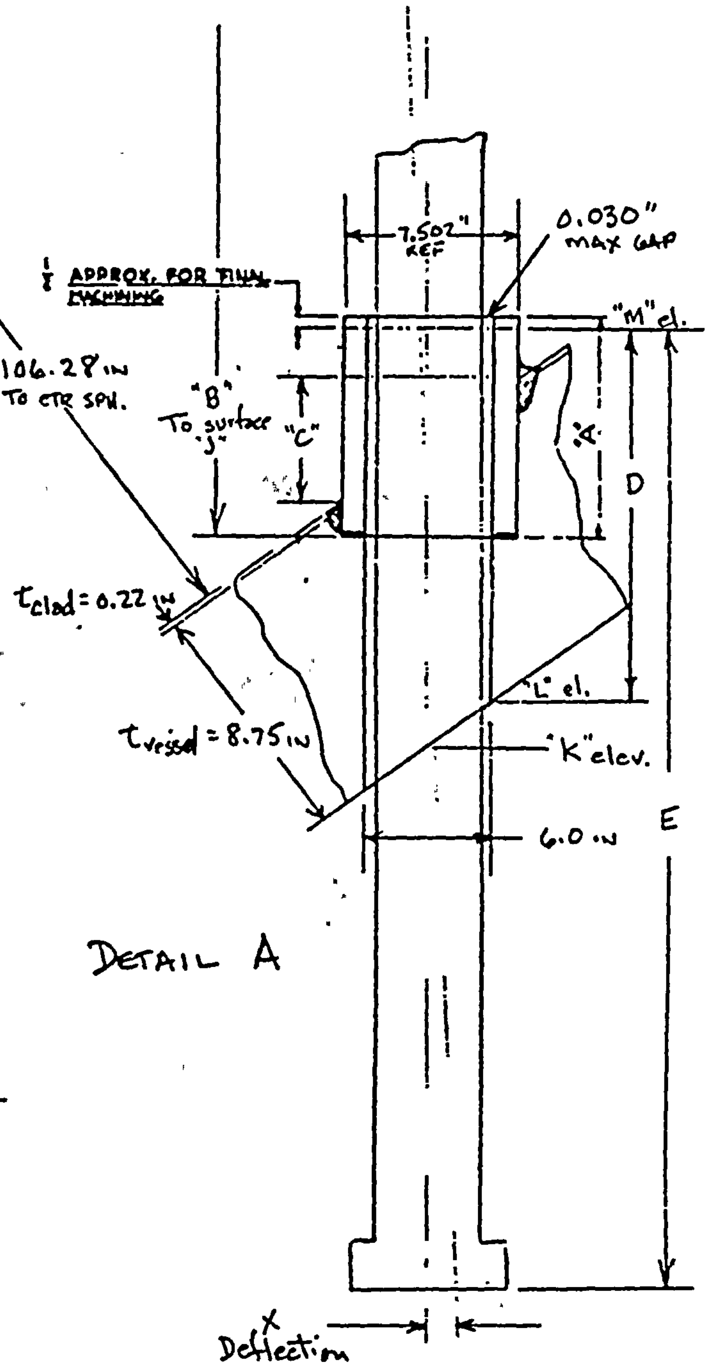
CONFIGURATION

REF. DWGS: 104R859 GE

E 231-568 CE

E 231-570 CE





DETAIL A

CALCULATION of x deflection

ALL DIMENSIONS IN INCHES.

POSITION				el.	el		el			
x'	z'	"B"	"A"	"M"	"K"	"C"	"L"	D	E	x
0 ,	0	107.84	9.56	7.72	−8.75	0.00	−8.75	16.47	138.72	0.25
60 ,	0	91.84	9.06	23.22	8.10	5.16	10.16	13.06	154.22	0.35
72 ,	24	79.72	11.91	38.19	19.76	7.59	22.80	15.39	169.19	0.33

FORMULAS:

$$\text{"M"} = 106.5 - \text{"B"} + (\text{"A"} - 0.5)$$

$$\text{"K"} = 106.5 - \sqrt{(106.28 + 0.22 + 8.75)^2 - (x'^2 + z'^2)}$$

$$\text{"L"} = \text{"K"} + \frac{y'}{2} \qquad \frac{\text{"C"}}{7.502} = \frac{y'}{6.0}$$

$$D = \text{"M"} - \text{"L"}$$

$$E = \text{"M"} - (-131.0)$$

$$x = \frac{E(0.030)}{D} \qquad \frac{x}{.030} = \frac{E}{D}$$

CALCULATION of "FREE LENGTH" AT POSITION $x' = 60, z' = 0$
(BOTTOM OF "C" DIMENSION TO BOTTOM END OF GUIDE TUBE)

"N" = 44.0 IN (ELEVATION OF END OF GUIDE TUBE)

"P" = 16.20 (EL. BOTTOM OF "C")

FREE LENGTH = "N" − "P" = 27.80 IN

CALCULATION OF "P"

$$\text{"P"} = 106.5 - \left(\sqrt{106.28^2 - 60^2} + \frac{\text{"C"}}{2}\right) \qquad \text{"C"} = 5.16$$

$$= 16.20 \text{ IN.}$$

CALCULATION OF RADIUS (VESSEL ℄ TO BOTTOM OF "C" AT POSITION $x' = 60, z' = 0$)

$$R = \sqrt{(106.28)^2 - (106.5 - 16.20)^2}$$

$$= 56.05 \text{ IN}$$