Public Service
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Public Service
Company of Colorado

July 5, 1985
Fort St. Vrain
Unit No. 1
P-85226

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JUL - 8 1985

Regional Administrator
Region IV
U. S. Nuclear Regulatory Commission
611 Ryan Plaza Drive, Suite 1000
Arlington, TX 76011

Attn: Mr. E. H. Johnson

Docket No. 50-267

SUBJECT: Licensee Event Report 84-005, Final Report

REFERENCE: Facility Operating License No. DPR-34

Dear Mr. Johnson:

Enclosed please find a copy of Licensee Event Report No. 50-267/84-005, Final, submitted in the interest of operational information.

Sincerely,

J. W. Gahm
J. W. Gahm
Manager, Nuclear Production

Enclosure

cc: Director, MIPC

JWG/djm

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NRC Form 366
(9-83)

U.S. NUCLEAR REGULATORY COMMISSION
APPROVED OMB NO. 3150-0104
EXPIRES: 8/31/85

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
Fort St. Vrain, Unit No. 1	0 5 0 0 0 2 6 7	1 OF 1 1

TITLE (4): Corrosion of PCRV Tendon Wires (Voluntary LER)

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAMES	DOCKET NUMBER(S)
0 3	2 7	8 4	8 4	— 0 0 5 —	0 3	0 7	0 5	8 5	N/A	0 5 0 0 0
										0 5 0 0 0

OPERATING MODE (9): N

POWER LEVEL (10): 0 0 0

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more of the following) (11)

[ ] 20.402(b)	[ ] 20.405(c)	[ ] 50.73(a)(2)(iv)	[ ] 73.71(b)
[ ] 20.405(a)(1)(i)	[ ] 50.36(c)(1)	[ ] 50.73(a)(2)(v)	[ ] 73.71(c)
[ ] 20.405(a)(1)(ii)	[ ] 50.36(c)(2)	[ ] 50.73(a)(2)(vii)	[XX] OTHER (Specify in Abstract below and in Text, NRC Form 366A)
[ ] 20.405(a)(1)(iii)	[ ] 50.73(a)(2)(i)	[ ] 50.73(a)(2)(viii)(A)	
[ ] 20.405(a)(1)(iv)	[ ] 50.73(a)(2)(ii)	[ ] 50.73(a)(2)(viii)(B)	
[ ] 20.405(a)(1)(v)	[ ] 50.73(a)(2)(iii)	[ ] 50.73(a)(2)(x)	

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER
Jim Eggebroten, Technical Services Engineering Supervisor	AREA CODE 3 0 3 — 7 8 5 - 2 2 2 3

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS
X	A B	R P V	W 0 9 4	N					

SUPPLEMENTAL REPORT EXPECTED (14)

[ ] YES (If yes, complete EXPECTED SUBMISSION DATE) [X] NO

EXPECTED SUBMISSION DATE (15): MONTH | DAY | YEAR

ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

This report supplements the initial LER in which an inservice inspection of the anchor end assemblies of the Prestressed Concrete Reactor Vessel (PCRV) prestressing tendons revealed some individual wire failures in some tendons due to corrosion attack.

Since then, detailed evaluations and inspections have been performed to assess | the severity of tendon wire corrosion. Results from corrosion analyses have | indicated that microbiological corrosion has occurred, and present efforts are concentrating on corrosion prevention, protection, and monitoring methods.

| Since the extent of corrosion has been determined not to compromise plant safety, this report is being submitted in the interests of operational information.

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TEXT (If more space is required, use additional NRC Form 366A's) (17)

EVENT DESCRIPTION:

The Prestressed Concrete Reactor Vessel (PCRV) utilizes a system consisting of 448 prestressing tendons in two basic configurations consisting of 152 or 169 1/4 inch diameter wires. Each wire terminates at a buttonhead supported by an anchor (buttonhead) washer which seats through a split shim onto a bearing plate on the PCRV surface (see Figure 1). The tendons may be delineated into four different types according to the following table (also see Figure 2).

448 Tendons Total	27 Load Cells Total
310 Circumferential	17 Load Cells
90 Longitudinal	6 Load Cells
24 Top Cross Head	2 Load Cells
24 Bottom Cross Head	2 Load Cells

Load cells, designed to detect any significant loss of prestress in the PCRV tendons, are installed on select tendons as noted above.

The tendons maintain the concrete of the PCRV in a continuous state of compression under nominal design loads. Prestress is applied by the individual wires of the various tendons by established strain values determined by the split shim thickness.

While the plant was shutdown for refueling, performance of In-Service Inspection by Maintenance Quality Control personnel indicated that some Prestressed Concrete Reactor Vessel tendons had experienced individual wire failure as evidenced by raised buttonheads on the anchor washer. Removal of these wire ends indicated failure due to corrosion within approximately 36 inches of the end, just below the anchor washer. No significant corrosion attack beyond this point has been observed on the complete wire samples removed from the tendons to date.

Liftoff testing has verified tendon operability on tendons with raised buttonheads, as well as tendons with no apparent failures. Lift-off testing measures the load applied by individual tendons and verifies that it is above a minimum value based upon the original design end-of-life applied tendon load.

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TEXT (If more space is required, use additional NRC Form 366A's) (17)

ANALYSIS OF EVENT:

| Corrosion of some wires near the anchor washer ends within the prestressing tendons occurred as a result of moisture, oxygen, and microbiological activity products. In addition, corrosion inhibiting agent was apparently either never applied adequately to some wires or removed at some stage during the fabrication, installation, or operation phase so that conditions favorable to local corrosion attack were present at this location. Few corrosion failures were observed at tendon anchor assemblies (bottom of longitudinal tendons and top crosshead tendons) where any gravity flow of the corrosion inhibiting grease would tend to protect the wire ends. Most failures were observed near the top anchor assembly of longitudinal tendons and near the anchor assembly on bottom crosshead tendons.

Failures of individual wires within tendons would result in a fractional loss of the overall prestress applied by that tendon. Failure of individual wires would not, however, result in increased loads on adjacent wires (hence increased probability of failure of such wires) due to the constant strain method of anchoring (i.e., the relaxation of the concrete from complete removal of applied stress is orders of magnitude lower than the strain change of the wires so that concrete dimensional changes are essentially nil).

| Longitudinal tendon load levels established by shims at prestressing allowed for losses over the PCRV life due to effects such as concrete shrinkage and wire relaxation. Nominal load for a 169 wire longitudinal tendon at prestressing was 1395 KIPS; minimum design value is 1087 KIPS. Liftoff testing established that all tested tendon loads were well above the minimum design end-of-life load levels, hence fully capable of meeting all design loads determined for the PCRV. Further, the load cells will detect any significant degradation in a representative sample of the prestressing system. Consequently, this event does not represent an unanalyzed condition that compromises plant safety.

CAUSE DESCRIPTION:

| The results of metallurgical, chemical, corrosion, and microbiological tests indicate that the corrosion of the tendon wires was caused by microbial action on the anti-corrosion grease creating acetic and formic acids which, in turn, produced general corrosion and stress corrosion cracking on unprotected wires.

| The results also indicate that moisture is necessary for corrosion attack. Original construction practice (vertical tendons) may have allowed condensation to occur prior to establishing uniform elevated vessel temperature, since the vessel was constructed prior to reactor building completion. In addition, split shim assemblies frequently had air gaps allowing communication with the cover air space. Finally, corrosion-resistant grease coverage apparently was inadequate or removed, where moisture was occasionally observed on the interior of the tendon wire bundle in the vicinity of the buttonhead washer.

CORRECTIVE ACTION:

| The examinations through February 26, 1985 include the following:

Visual Inspection of Anchor Assemblies

				Tendons With 1 or More Wire Failures
|	Longitudinals	89 of 90	Tophead	12
|		1 of 90	Bottomhead	
|	Bottom Crossheads	43 of 48		9
|	Top Crossheads	2 of 48		2
|	Circumferentials	34 of 620		6

| NOTE: Some additional wire failures occurred during liftoff testing.

| Liftoff Testing To Verify Design Conditions

| NOTE: For longitudinal tendons, a liftoff of one end is adequate for the entire tendon due to low friction. All others must have each end considered individually.

|	Longitudinals	75 of 90
|	B-Crossheads	32 of 48
|	T-Crossheads	29 of 48
|	Circumferentials	79 of 620

Detensioning For Wire Removal and Further Inspection

| VM-17, Longitudinal

BILU4, Bottom Crosshead

BILU3, Bottom Crosshead

CO2.5, Circumferential

| TORL2, Top Crosshead

Atmosphere Sampling

The atmospheres of a representative number of each type of accessible tendon have been tested and found to contain sufficient moisture to allow corrosion. Based on this conclusion, continued atmosphere sampling is not anticipated as existing moisture levels have been established. Several tendon atmospheres were analyzed for H_2S and a content of less than 1 ppm was reported. Sulfate reducing bacteria therefore are not considered to be involved in the corrosion mechanism.

Metallurgical Analyses

Sample wire sections have been taken from wires removed from the detensioned tendons. These samples have been mechanically tested per Reg. Guide 1.35.

The fifty failed wire samples which were sent to GA Technologies have been analyzed and a final report has been prepared ("Evaluation of the Causes of Corrosion in the Fort St. Vrain Tensioning Tendon Wires", November 27, 1984). This is an attachment to Letter P-84543, dated December 31, 1984.

Other failed samples have been analyzed by Public Service Company and a final report was prepared ("Examination of Failed Tendon Wires from Fort St. Vrain Unit No. 1", Lab Report No. 52, Public Service Company of Colorado, Metallurgy Laboratory Report). This is an attachment to Letter P-84543, dated December 31, 1984.

Final results from metallurgical analyses indicate that microbiological corrosion is the primary contributor to the corrosion problem. Additional evaluations related to bacterial control, and short term, as well as long term protection have been initiated.

Tendon Surveillance Program:

The scope of the tendon surveillance program has been established to monitor the adequacy of the new corrosion protection methods to be provided for the PCRV prestressing components, and to assure that the required prestressing forces are sustained throughout the operational life of the plant.

The most recently proposed surveillance program was submitted to the Nuclear Regulatory Commission in Letter P-85084 of March 18, 1985. The provisions of the proposed interim surveillance program supercede the provisions of all other proposed surveillance programs and are described below. The interim program was implemented on April 22, 1985, and will be in effect for three years or until such time as effective corrosion control has been established.

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An ongoing PCRV Tendon Surveillance Program will be established after the interim program, subject to Nuclear Regulatory Commission review and approval of proposed Technical Specification revisions. Additional surveillance requirements which may be included in this proposed future tendon surveillance program are also outlined below and will be described more fully in a later official Technical Specification submittal. The most recent engineering report on tendon surveillance results was submitted as Letter P-85084, dated March 18, 1985.

Examination of Sample Wires

The informally proposed Technical Specification revisions described in Letter P-84523 of December 14, 1984, called for additional sample wires to be inserted into selected tendons with areas of known corrosion. As indicated in Letter P-85039 of January 31, 1985, no action will be initiated during the interim period. Surveillance of additional sample wires may be proposed as part of a future ongoing PCRV Tendon Surveillance Program, however.

Tendon Atmosphere Sampling

The informally proposed Technical Specification revisions called for sampling of the atmosphere for corrosion products contained in at least one each of the longitudinal, circumferential, bottom crosshead, and top crosshead tendon tubes and analysis for corrosion byproducts. As indicated in Letter P-85039 of January 31, 1985, no action will be initiated during the interim period.

Tendon caps have been removed on most tendons for examination; air, therefore, was introduced into the tubes. The corrosion prevention system has not been finalized as of this date and sampling of the tube atmosphere would provide no useful information. Tendon atmosphere sampling may be proposed as part of a future ongoing PCRV Tendon Surveillance Program, however.

During the original corrosion determination investigation, the atmospheres in ninty-seven tubes were sampled and tested.

Examination of Anchor Assemblies

Visual examination will consist of the removal of the tendon end cap and an in-place visual examination of the anchor assembly including tendon wires, button heads, anchor/bushing assemblies, shims, and bearing plate. A visual examination shall be performed on a sampling of each group at least once per six months.

Of the total number of tendon anchors in each group, a specified number of accessible tendon anchors will be randomly selected for inspection. These are referred to as new tendons. A second set of tendon anchors will comprise a control group which will be reinspected each six months.

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Standardized terminology will be used to describe any observed corrosion on the anchor assemblies. Discoloration shall signify the presence of any coloration of the anchor assemblies which may possibly be caused by incipient corrosion. Scaling shall indicate the presence of rust-like deposits which tightly adhere to surfaces. Oxidation shall indicate the presence of rust-like deposits which are thick enough to indicate that the corrosion could flake off.

Liftoff Testing

A liftoff test is a physical liftoff of a tendon to determine the load being carried by that tendon using a calibrated jack. Liftoff tests for tendons that have not previously been lifted off would include removal of the shim plates to permit visual examination and, as necessary, reapplication of grease to the accessible areas of the tendon. Repetitive liftoff tests on the same tendon not in a control group may not include removal of shim plates for visual examination. Liftoff tests for tendons in designated control groups will include removal of shim plates and visual examination.

A liftoff test shall be performed on a sampling of accessible tendons at least once in eighteen months. These tendons are referred to as new tendons and will be randomly selected.

Liftoff tests will be performed on a control group of tendons every six months. These tendons will be selected based upon their accessibility and history of corrosion.

Standard terminology will be used to describe any observed corrosion on anchor assemblies or tendon wires exposed during liftoff. Reduction of area shall indicate that the cross sectional area of a tendon wire has been reduced. Other standard terminology as described above under Examination of Anchor Assemblies will also be used.

Load Cell Surveillance

Technical Specification SR 5.2.3 establishes load cell surveillance requirements. Monthly monitoring of the load cells will continue in accordance with the commitment made in Letter P-84110, dated April 12, 1984.

The inspection findings to date do not reveal any specific tendency for tendon corrosion on a cluster basis. The corrosion is random in nature and there is no immediate concern for cluster failure of several tendons that would result in localized PCRV concrete tension.

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| <u>Long Term Resolution:</u>

| <u>Replacement of Corrosion Preventive Grease</u>

| The tendons in the PCRV have been coated with No-Ox-Id CM casing filler, a grease manufactured by Dearborne Chemical Division of W. R. Grace & Co. This grease is a petrosulfonate which has a fatty material additive, lanolin, which is a naturally occurring fat obtained from sheep. This organic mixture of alcohols and fatty acids is neutral to slightly acidic and will hydrolyze with moisture. Experiments have shown that an alkaline based grease would not be conducive to microbiological life. However, radiation effects have been found to decompose the alkaline based grease, and for this reason, a radiation resistent synthetic oil is being tested in the laboratory. The feasibility and effectiveness of replacing the corrosion preventive grease is presently under study.

| <u>Use of Nitrogen Blanket</u>

| The feasibility of using a nitrogen blanket to displace and prevent future ingress of air and moisture in the tendon tubes is under study. The use of this method to arrest further corrosion depends on the ability to limit the leakage rate from the tendon tubes by sealing existing leaks (Letter P-85115, dated May 23, 1985). Based on laboratory tests, a nitrogen blanket is effective in preventing corrosion resulting from the action of acetic and formic acids on tendon wires.

| <u>Conclusion:</u>

| The PCRV Tendon Surveillance Program, subject to Nuclear Regulatory Commission review and acceptance, will adequately monitor the PCRV prestressing system to permit assessment of the PCRV integrity on a continuous basis and identify any need for corrective actions.

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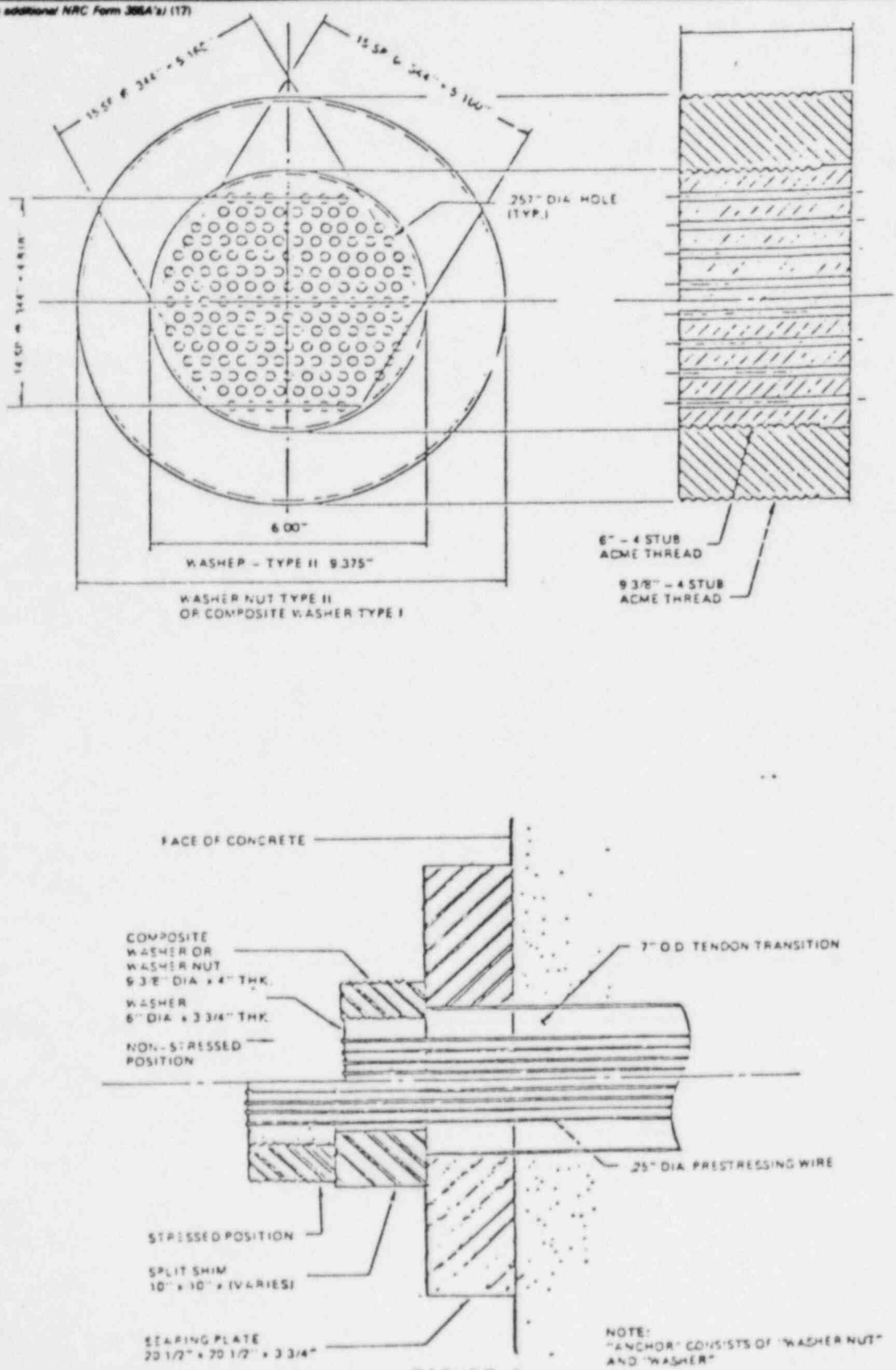

FIGURE 1

NRC Form 366A
(9-83)

U.S. NUCLEAR REGULATORY COMMISSION

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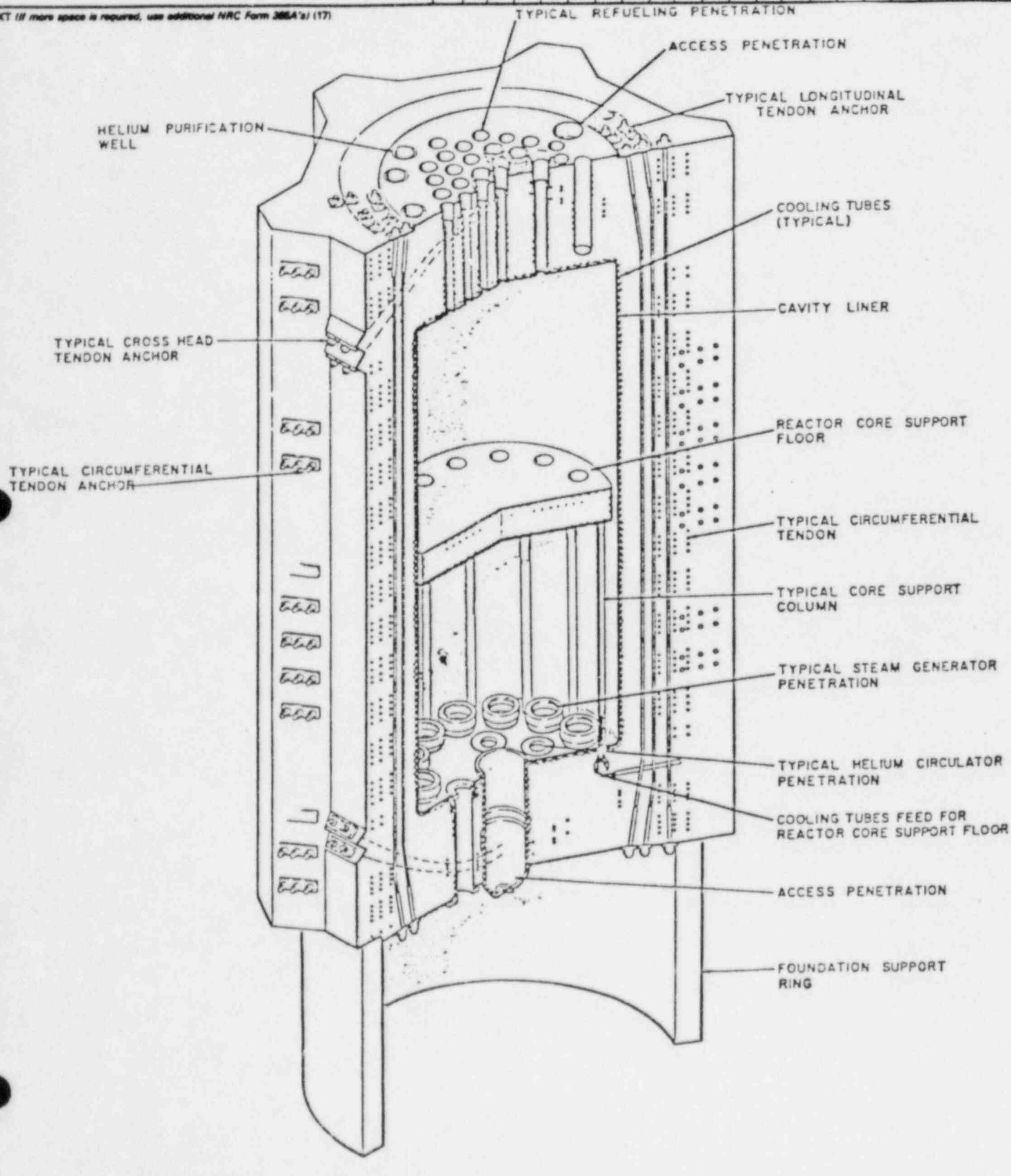

FIGURE 2

NRC FORM 366A
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NRC Form 366A
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