VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

February 4, 1977

Mr. Benard C. Rusche
Director of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attn: Mr. Robert W. Reid, Chief
Operating Reactors Branch 4

Serial No. 031A/011977
PO&M/ALH:dgt

Docket No. 50-280
50-281
License Nos. DPR-32
DPR-37

Dear Mr. Rusche:

This is in response to your letter of January 19, 1977 wherein you requested information regarding the Surry Unit No. 1 steam generators. The response to your specific requests are provided in the attachment to this letter.

It is noteworthy that the analysis presented in our response to Question 1 shows that the steam generators can be safely operated for 4 effective full power months (EFPM) after the installation of the flow slot blocking devices. As you are well aware, the energy situation in the Vepco service area is very bad. We believe that it is imprudent to shut down Surry Unit No. 1 during the winter peak period. We therefore request authorization to operate Surry Unit No. 1 for a period of 4 EFPM from January 19, 1977.

We realize that this is a departure from our initial course of action but the energy situation and the results of our analyses indicate that additional operating time is necessary and warranted. We would appreciate your prompt attention on this matter.

Very truly yours,

C. M. Stallings

C. M. Stallings
Vice President-Power Supply
and Production Operations

Attachment

cc: Mr. Norman C. Moseley
Office of Inspection and Enforcement
U. S. Nuclear Regulatory Commission
Region II - Suite 818
230 Peachtree Street, Northwest
Atlanta, Georgia 30303

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NRC REQUEST FOR ADDITIONAL INFORMATION

Question 1

I. We have correlated support plate expansion with actual months of operation by means of a finite element model which utilized a pseudo-thermal expansion technique. In order to do this, relationships between field data, EFPM's and results of the finite element analysis were established. Since the denting phenomenon extends over the entire plate, there is good correlation between measured denting and expansion of a dented plate. Although our finite element model is not detailed enough to yield denting rates, it does quantify the extent of flow slot closure for a prescribed expansion. Since the amount of closure over an extended period of EFPM's is available from field data, a relationship between model closure and EFPM's can be established. The rate of expansion is independent of boundary effects, the insertion of blocking devices, and time. The procedure for calculating the rate of expansion per EFPM is as follows:

For a plate expansion of .014 in/in (hot leg) and .010 in/in (cold leg) applied to the updated plate model (Figure 1), the average flow slot closure which results is .675 inches

For the actual plate the most conservative rate of closure (derived from field data) for a top support plate flow slot is .15 inches/month

Thus .675 inches of closure represents 4.5 EFPM's

And the pseudo-thermal expansion equivalent of a single EFPM is

$\frac{.014}{4.5} = .0031$ in/in-EFPM (hot leg side) and

$\frac{.010}{4.5} = .0022$ in/in-EFPM (cold leg side)

As indicated earlier the rate of plate expansion occurs on a very local level and is not affected by insertion of the blocking device.

Thus, for 2 months additional operation an additional plate expansion of

.0062/.0044 in/in is required. We have made a run with an additional plate expansion of .0124/.0088 in/in beyond closure, which represents 4 EFPM's.

Figure 2 shows the strain intensity plots for the plate just prior to insertion of the flow slot blocking device. Figure 3 shows the plate at .0124/.0088 in/in additional expansion beyond that associated with insertion of the flow slot blocking device. Note that both strain intensity plots confirm that the areas of excessive hard spots do not change after insertion of the blocking device and 4 EFPM of continued operation.

II. We have been unable to quantify the effects of plate expansion on the strain in the tubes; however a conservative preventive plugging plan has been derived from the strain intensity profiles provided by the analytical model. Our letter serial no. 260C/092276 dated January 3, 1977 shows the details of this plan, which has been implemented on Surry Unit No. 1.

Model Characteristics

1. Hot/Cold Side Expansion Bias
2. Improved Perforated Area Material Behavior (Anisotropic)
3. Elastic Behavior of Channels at Support Locations
4. Wrapper Stiffness Incorporated at Periphery

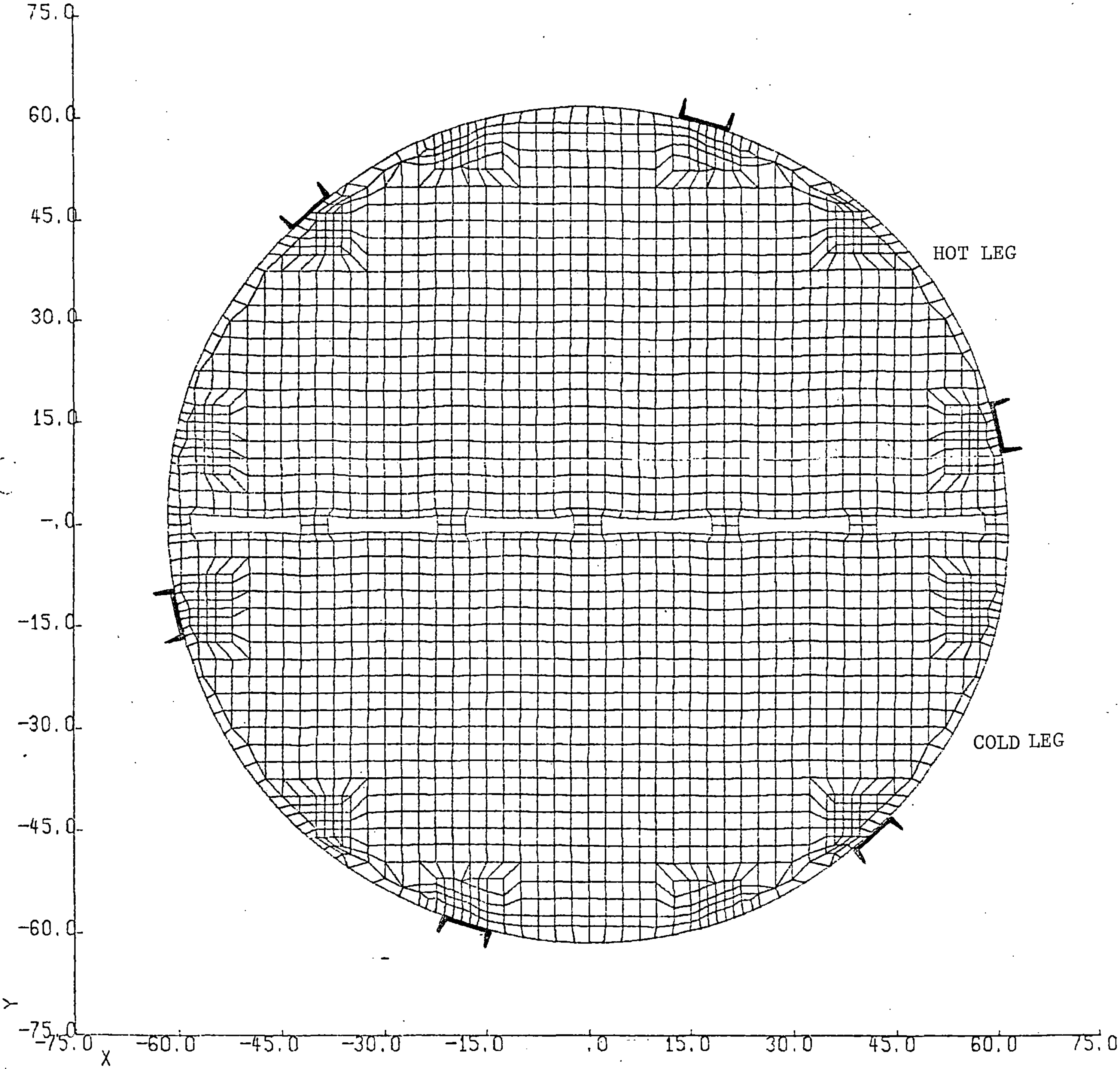


Figure 1. Finite Element Model.

CONTOURS REPRESENT % OF MAXIMUM STRAIN INTENSITY:

1 - 10%

2 - 50%

3 - 60%

4 - 70%

5 - 80%

.050/.036 in/in Expansion Load

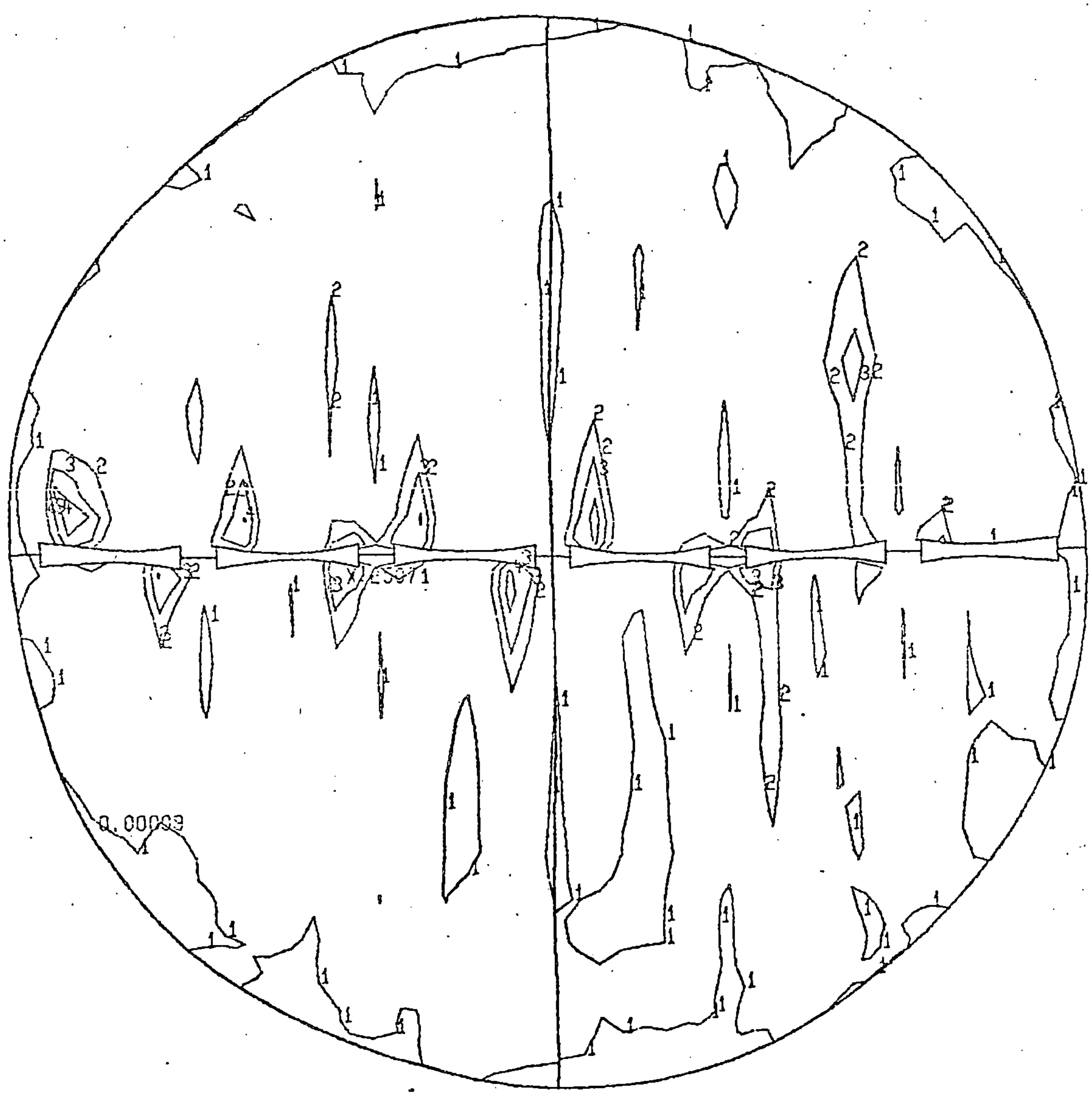


Figure 2. In-Plane Strain Intensities 0.8 EFPM Prior to Insertion of Flow Slot Blocking Devices

CONTOURS REPRESENT % OF MAIXMUM STRAIN INTENSITY:

1 - 10%

2 - 50%

3 - 60%

4 - 70%

5 - 80%

.067/.048 in/in Expansion Load

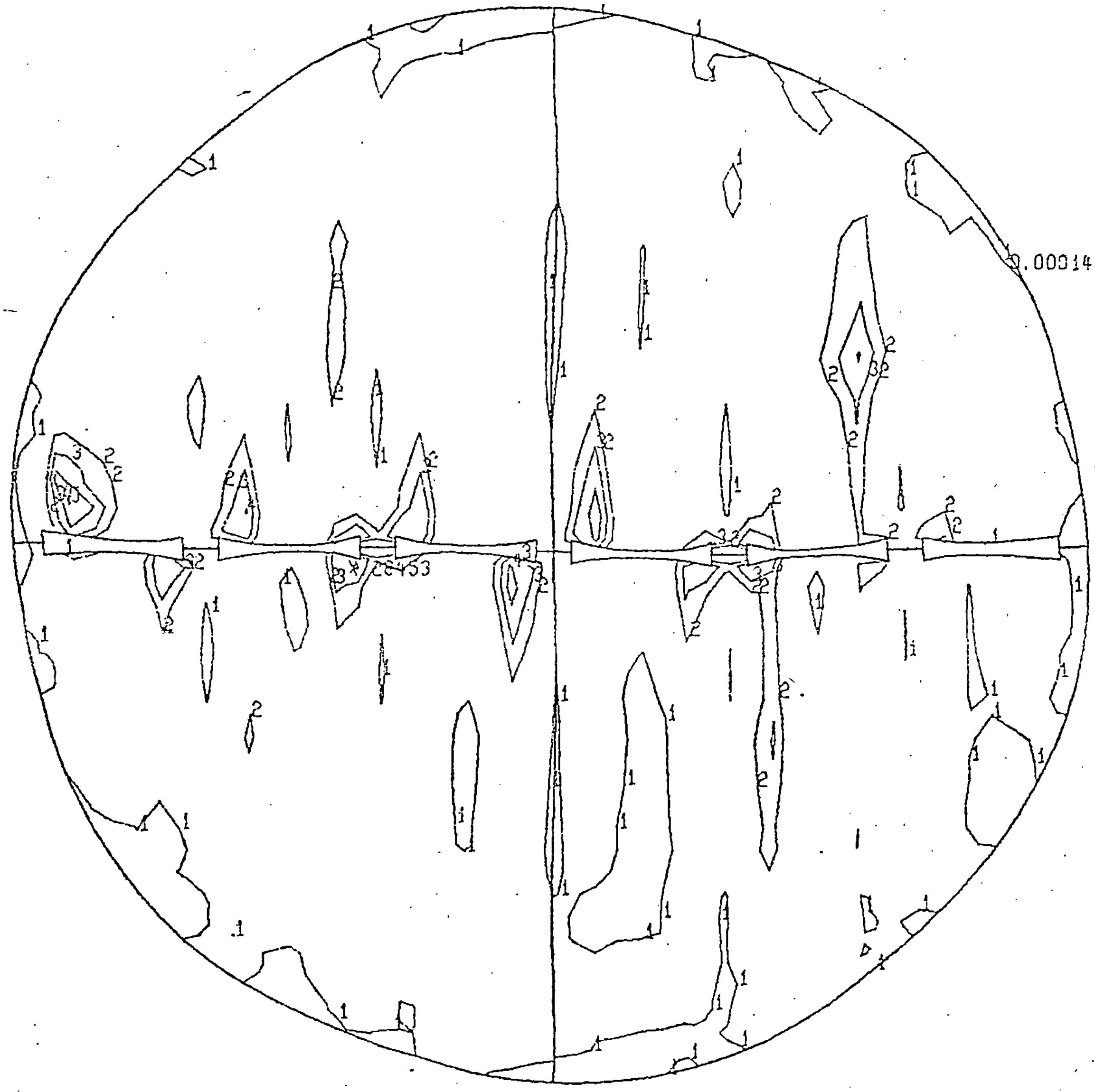


Figure 3. In-Plane Strain Intensities 4 EFPM After Insertion of Blocks.

NRC REQUEST FOR ADDITIONAL INFORMATION

Question 2

I. Program to Investigate Leakage at Dented Regions

A. A continuing effort is underway to investigate the particulars of the cause of leakage at certain dented regions of the steam generator tubes. This effort is given in the diagram of scope shown in Figure 1 and consists of three principal tasks: Analysis, In-Plant Data, and Material Properties. The estimated completion dates associated with the major activities are also shown on the diagram.

1. Analysis: The objective of this study is to correlate the location of leakage events at dented regions with the results of finite element analysis. The finite element analysis shows the distribution of strains across the tube support plate as dilation of the plate occurs with time. This correlation, along with mechanical crush tests provides a basis for establishing a preventive plugging program.

2. In-Plant Data: The results of examination of the one leaking-dent tube sample, Surry 1, steam generator C, R2C42, indicated that additional in-plant data should be obtained by both NDE methods and additional tube sample removals. Shown in Figure 1 are the planned efforts to address these issues.

   Eddy current techniques for detection of flaws in dented regions have been pursued for some time without much success. The effort is continuing, however, with the development of new probe configurations which are designed to null out tube deformations at dented regions and allow the presence of a flaw to be disernable. Once the newly developed probes are manufactured for field use, trials at Surry 1 or 2 will be scheduled. Because of the uncertainty of this development work, a target date of the end of February, 1977 is shown in Figure 1.

   Additional tube sample removals are shown in Figure 1. One sample of a leaking dent will be pulled when a suitable candidate is identified and available. This tube will serve the purpose of confirming the mode of failure determined for the C-2-42 tube. Another tube, which has not leaked, will be identified to confirm the boundary for those tubes subject to leakage.

3. Material Properties: The materials test program is composed of two concurrent phases: fundamental tests to determine the role of strain and strain rate on the propensity to cracking and empirical or engineering tests. The former include

the dynamic strain tests presently underway or planned as part of the U-bend test program; it is judged that the phenomena are essentially the same. The engineering tests are primarily directed toward determining the critical crack length, with and without denting, and the leak rate as restrained by the tube support plate. These latter tests are scheduled to be completed in February, 1977.

II. Program to Investigate U-Bend Defects

A. The investigation program which pertains to the cause of failure of the Surry Unit 2 U-bend (September 15, 1976) is a continuing study which comprises the principal elements given in Figure 2. A combination of analytical studies, in-plant inspections and samples and laboratory tests of tubing material properties will provide the basis for corrective actions.

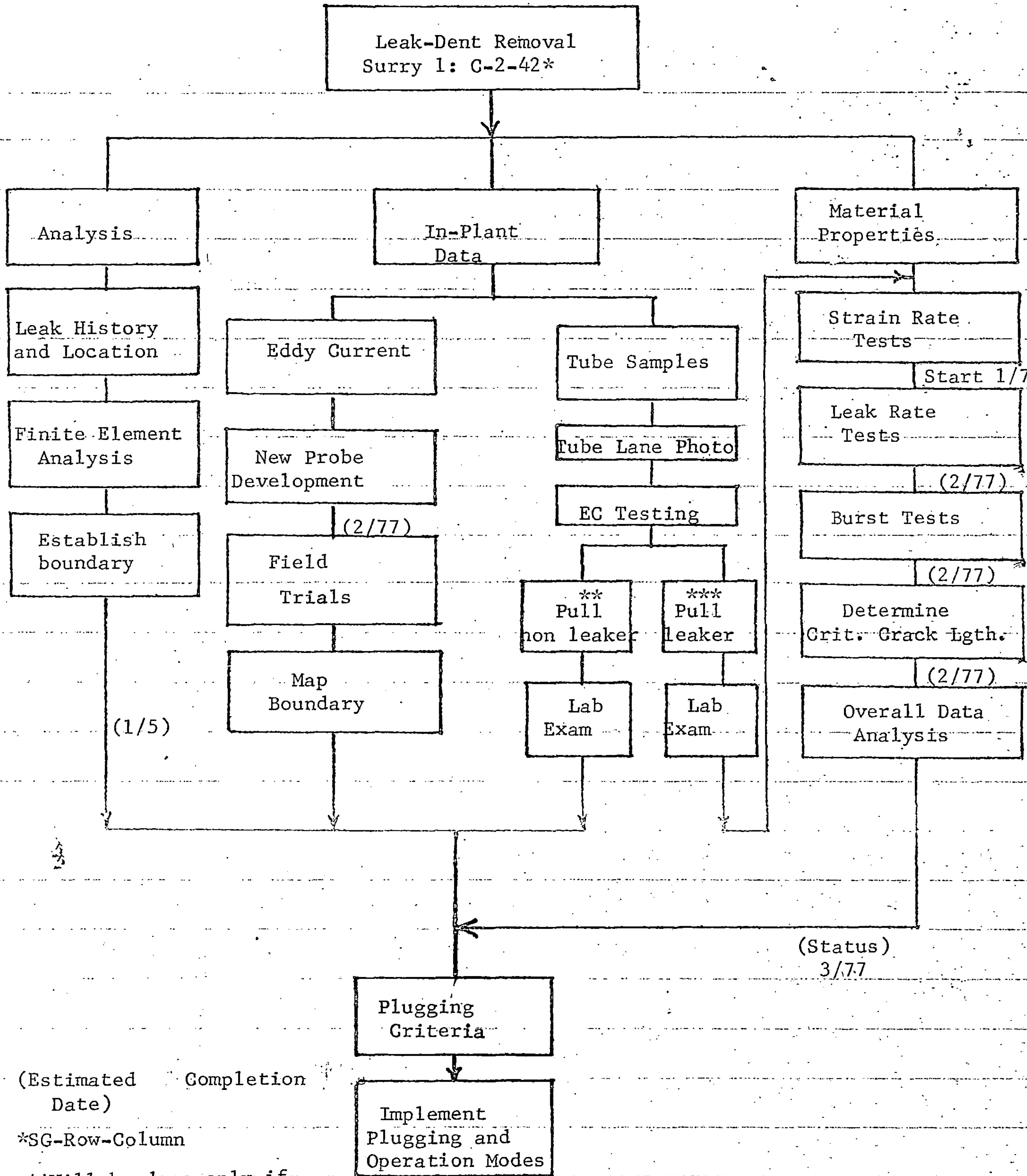
1. Analysis: The results of a considerable number of analyses have been described to the NRC in Vepco submittals of October 19, 1976, November 15, 1976, January 3, 1977 and January 14, 1977 which included comments and responses to NRC questions. The conclusions drawn thus far is that only the narrowest radius U-bends (Row 1) are subject to the cracking phenomena. This is based primarily on the results of tube sample examinations from Surry 1, Surry 2, and Turkey Point 4. Equivalent strain calculations, which have been submitted, also provide a measure of the greater susceptability of Row 1 tubes as compared to tubes in Row 2 and beyond. As stated previously, it is judged that continuous dynamic straining, as a result of continuous hourglassing, is also an important factor.

2. In-Plant Inspections: The results of in-plant inspection programs, as available, have been submitted to the NRC by Vepco, FP&L, Consolidated Edison, and Southern California Edison in various submittals or presentations. The inspections have consisted of upper tube support plate flow slot measurements, eddy current testing of all available tubes in Row 1 through 5, and removal of a large number of U-bend samples from Rows 1, 2 and 3 of Surry 1, Surry 2, and Turkey Point 4. The in-plant inspection program has been essentially completed at this time and has served to provide the basis for corrective actions as warranted for Surry 1 and the other potentially affected units.

3. Material Properties: The materials test program is composed of two concurrent phases: fundamental tests to determine the role of strain and strain rate on propensity to cracking and empirical or engineering tests intended to simulate the actual operating conditions insofar as feasible, to duplicate the failures and to identify corrective actions. The fundamental tests provide input to the empirical ones and will hopefully reduce the number of variables requiring evaluation. The work

to date has been directed at (1) defining the state of stress, i.e. the magnitude and direction of the stresses and strains in as-fabricated U-bends and their change as a function of leg displacement and ovalization, and (2) dynamic testing of the response of Inconnel 600 to constant strain rates in primary water. Initial results from the latter tests have not indicated any tendency toward accelerated attack at relatively rapid strain rates of 4 x 10^{-5} to 5 x 10^{-7} in/in/sec., but additional tests are pending at slower rates. The most definitive tests are those which will be conducted on actual U-bends, exposed to the primary water environment, and strained at varying rates; these began February 1, 1977.

PROGRAM TO INVESTIGATE LEAKAGE AT DENTED INTERSECTIONS



(Estimated Completion Date)

*SG-Row-Column

**Will be done only if results of analyses on C-2-42 so indicate

***Completed

Figure 1

III. Examination of a Steam Generator Tube with Defect at a Dented Region Surry Unit 1, S/G "C", December, 1976

A. The examination of the section of tube R2-C42, which leaked at a dented region is continuing. Visual examination revealed two major through wall longitudinal cracks, each about 3/4" long, centered within the tube support plate intersection, and separated raidally by about 110°. The two cracks were identified as 160° and 270° respectively, based on an arbitrarily chosen origin. The examination proceeded as follows:

1. Double-wall Radiography: The two major cracks showed branching at their centers and at their ends; some additional minor indications were present but were not interpretable.

2. Diametral Measurements: A six-inch long section of the tube containing the cracked region was chucked up in a lathe and rotated under a dial indicator. Readings were taken at 45° intervals at a number of axial locations centered on the cracked region; these measurements were then plotted to define the tube OD geometry at these various locations. There is considerable uncertainty in these results because of the deformed condition of the tubes (believed tobe caused during extraction) and the inherent difficulty of establishing a true center line. Despite this, the measurement indicate some ovality at the tube support plate location and a limited reduction in diameter from the original 0.875".

3. Metallographic Evaluation: A two-inch long section containing the cracks was removed and split longitudinally into two halves, each containing one of the major cracks. Metallography was initially performed on the 270° crack by sectioning through five transverse locations and examining before and after etching.

   a. Crack Morphology

   The crack was intergranular in nature and initiated from the ID surface.

   b. Structure

   The material was very fine grained, ASTM 9-10 grain size, with a large amount of intragranular precipitates, both at the cracked region and at an unattacked location 16" away. The structure is not judged to be abnormal (although not typical of current tube fabrication) or directly related to the cause of failure.

   c. Hardness

   The hardness at the cracked region was RB 95 to RC 23 as opposed to RB 88 to 94 at the unattacked location. The higher hardness may be associated with cold work i.e. plastic strain at the crack location, and is being further investigated.

   d. Wall Thickness

   Measurements taken at several locations around the periphery in the region of the crack indicated thickness within the normal tolerance band.

e. Scanning Electron Microscopy (SEM)

This examination also revealed the intergranular nature of the crack and the numerous intragranular precipitates previously observed in the optical microscopy.

4. Chemical Analysis: A bulk analysis of the tube material indicated a normal composition:

C:	0.046%
Fe:	7.1%
Cr:	15.2%
Ni:	74.8%

A preliminary EDAX analysis from the fractured surface of the 270° crack was not definitive. Somewhat higher than background readings were observed for certain fission product residues.

Fractography has been started on the 160° crack. The initial results confirm that this crack is also intergranular in nature and originating from the ID. SEM examination of the fracture face indicates a relatively clean surface with no definitive aspects. EDAX analysis of several adherent particles indicated typical Fe, Ni and Cr. The examination of this crack is continuing, including a planned Spark Source Mass Spectroscopic analysis of the fractured face.

The results to date suggest a fracture mechanism of a stress related intergranular attack, but a quantitative description, including the role of strain and strain rate, awaits further tests and analysis.

IV. <u>Eddy Current Testing of Small Radius U-Bends</u>

A. During the refueling outage of Surry Unit 1, testing of the small radius U-bends, Rows 1 through 5, was performed by eddy current technique. The procedure which was followed was based on laboratory development work showing the need to use a reduced frequency with an undersized probe diameter to give maximum sensitivity for flaw detection.

Since most of the intersections of tubes and tube support plates have experienced diametral denting, a reduced diameter probe was required to pass these locations in order to enter the U-bend region. The standard practice for U-bend inspections employs a probe with a 700 mil diameter for a 775 mil ID tube, which displays adequate sensitivity for flaw detection at 400 KHz. However, a probe diameter of 540 mil was used for the Surry 1 inspection to insure the probe would reach the U-bend region. For this diameter probe in a 775 mil ID tube, it was found that flaw detection at 400 KHz was somewhat reduced, whereas a lower frequency of 70 - 100 KHz was found to amplify a flaw signal. The lower frequency is also more questionable in precise signal interpretation as pertains to signal origin and flaw depth, if judged to be a flaw. The lower frequency may be overly sensitive in that signals may arise from scratches or normal variations in wall thickness, especially as expected in the U-bends.

Additionally, at whatever frequency used, the smaller, standard "flex" probe (used for U-bend examinations) necessarily gave a higher noise level than desired, which led to a modification of probe design. To improve the centering and flexibility of the probes as it traverses the U-bend, a series of beaded spacers were placed before and after the differential coil. These beads have proved to be very effective in reducing the noise which previously was due to lack of coil centering in the bend region.

Eddy current examination of all available tubes in Rows 1 through 5 was performed at Surry 1 in each steam generator utilizing a 540 mil diameter, beaded-flex probe, at 100 KHz and on selected tubes at 400 KHz. The probing was performed by Vepco personnel with on-site evaluation by Zetec. At 100 KHz, B steam generator, approximately 24 signals were recorded of tubes mostly in Row 4 and 5. These signals were randomly scattered, forming no pattern of occurrence with respect to the tube lane flow slots. Close examination of the signals proved that all but five were obviously due to probe wobble as the probe negotiated the U-bend tangent point. The remaining five, plus a sample of the other tubes with indications were reprobed at both 100 and 400 KHz using the beaded-flex probe. The repeat data at 100 KHz showed the possibility of a flaw in three of these tubes; the remaining ones were diagnosed to be clear of flaw signals. At 400 KHz, the signals in two of the three tubes completely disappeared within the background, indicating that if a flaw were present, the penetration would be less than 40 percent. The remaining tube showed a very small signal persisting at 400 KHz, which could not be diagnosed as a flaw. However, for this one tube, if judged to be a flaw, the penetration would also be less than 40 percent based upon calibration data developed at the Westinghouse R & D Laboratories.

The data collected from steam generators A and C was reported to be clear of flaw signals by the Zetec data analyst, thus no reprobing was performed.

A review of the signal to noise (S/N) ratios for the eddy current probes utilized during this testing was performed to verify the logic employed to classify the signals recorded. It was noted that 100 KHz testing with the smaller probe (0.540") produces higher S/N values than does 400 KHz, thereby increasing the detectability of shallow depth flaws; however the greater responsiveness of the probe at 100 KHz to non-relevant tube conditions detracts from the simplicity of interpretation. The lower S/N ratios characteristic of 400 KHz testing cause greater difficulty in detecting shallow flaws, but the relative insensitivity to non-relevant tube conditions permits discrimination among the potentially ambiguous signals obtained at 100 KHz. Thus although a 20% penetration flaw might not be detectable at 400 KHz because of the low S/N value, flaws above--say 40% penetration can be confirmed at 400 KHz. On the other hand, though 100 KHz testing will detect a 20% penetration in the absence of non-relevant tube conditions, 100 KHz testing might respond to a non-relevant tube condition, e.g. magnetic material on the tube O. D., by producing signals which can be confused with high penetration indications.

By utilizing 100 KHz testing, detection of all departures from uniform wall condition is assured. When the 100 KHz data is susceptible to characterization as a flaw signal, retest at 400 KHz provides the necessary intelligence to eliminate those signals produced at 100 KHz by non-relevant effects. The result is assurance of the detection of flaws with about 40% or greater penetration.