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March 12, 1986

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Byron Station Units 1 and 2
Braidwood Station Units 1 and 2
Inspection of Cast Stainless Steel
Component Welds
NRC Docket Nos. 50-454/455 and 50-456/457

Dear Mr. Denton:

Enclosed is a report titled "Ultrasonic Examination of Cast Stainless Steel Welds at Byron and Braidwood Stations". This report describes the cast stainless steel components in the reactor coolant system at Byron and Braidwood and outlines a plan for developing an improved technique for examining the welds associated with these components. Previous ultrasonic examination of this cast stainless material during preservice inspections has not produced meaningful results because the statically cast component material significantly attenuates ultrasonic sound.

This report also describes the Electric Power Research Institute (EPRI) involvement with examining the Byron Unit 2 cast components and Commonwealth Edison's review of the examination of cast components at the Vogtle Nuclear Generating Station. Based on these activities, the Commonwealth Edison System Materials Analysis Department (SMAD) is attempting to develop an improved ultrasonic examination technique for the cast components at Byron and Braidwood. The program for development of this technique is described in Section VIII of the enclosed report. This program is scheduled to be completed by May 15, 1986. The results of the program will be evaluated and reported to the NRC.

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Rec'd w/check $150.00

Enclosed is a fee remittance in the amount of $150.00 in accordance with 10 CFR 170 for the review of the Byron Unit 1 ISI program, transmitted February 6, 1986, and this related report.

One signed original and fifteen copies of this letter and enclosure are provided for NRC review.

Please direct any questions you may have regarding this matter to this office.

Very truly yours,

K. A. Ainger

K. A. Ainger
Nuclear Licensing Administrator

lm

Enclosure

cc: Byron Resident Inspector
Braidwood Resident Inspector

1403K

ULTRASONIC EXAMINATION OF CAST STAINLESS STEEL WELDS
AT BYRON AND BRAIDWOOD STATIONS

References (a): Letter from A.D. Miosi to H.R. Denton dated July 17, 1985.

(b): EPRI Report dated December 18, 1985 by Xaver Edelman and Mark Davis, "Ultrasonic Examination of Cast Stainless Steel Components in the Main Coolant Piping System at the Byron Nuclear Power Plant".

I. INTRODUCTION

Difficulties associated with performing ASME code required ultrasonic examination of cast stainless steel components have been recognized by the nuclear industry for many years. Coarse grain size and elastic anisotropy due to the dendritic structure of the as-cast stainless make it difficult to perform meaningful testing of the cast stainless component welds. Special efforts are required to develop techniques and procedures that will permit some limited examination of these castings.

Recognizing that even limited examination would be better than no examination at all, Commonwealth Edison has undertaken a major program to develop ultrasonic techniques for the preservice inspection of the cast component welds at both Byron Unit 2 and Braidwood Unit 1. The results of the program also affect the inservice inspection commitments for Byron Unit 1. The purpose of this report is to explain the work completed so far and define the scope of the program yet to be completed.

II. BYRON AND BRAIDWOOD DESIGN

Byron and Braidwood Units 1 and 2 are Westinghouse four loop pressurized water reactors of essentially identical designs. The reactor coolant system design is shown in Figure 1. Each plant utilizes statically cast stainless steel elbows, pump casings and valve bodies in the reactor coolant system. The material specifications for these stainless steel components are as follows:

Elbows	-	SA351 CF8A (Grade 304)
Pump Cases	-	SA351 CF8M (Grade 316)
Valve Bodies	-	SA351 CF8M (Grade 316)

The Byron and Braidwood reactor coolant piping was forged from SA376 (Grade 304N) stainless steel. Reactor vessel and steam generator primary nozzles were fabricated from carbon steel and then clad with stainless steel on the inner diameter (I.D.) surfaces. Forged stainless steel safe-ends (SA182, Grade F316) are welded to the reactor vessel nozzles. The reactor cold leg nozzle safe-ends are welded to cast stainless steel elbows. The hot leg nozzle safe-ends are welded to pipe. The clad steam generator nozzles are welded directly to cast stainless steel elbows.

The cast stainless steel welds in the reactor coolant system can be categorized as follows:

1. Forged safe-end - to - cast elbow welds

2. Steam generator nozzle - to - cast elbow welds

3. Forged pipe - to - cast elbow, pump or valve welds

4. Cast elbow - to - cast pump or valve welds

III. BYRON UNIT 1 PRESERVICE INSPECTION

The Byron Unit 1 Preservice Inspection was performed to the requirements of ASME Section XI 1977 Edition with addenda through Summer 1978 Addenda which state that ASME Class 1 welds must be volumetrically examined. An attempt was made by Commonwealth Edison to develop an ultrasonic procedure to examine cast component welds to the maximum possible extent per Code requirements.

Cast stainless steel material was obtained from the manufacturer of the cast stainless steel elbows at Byron and Braidwood Stations. This material was welded to other steel blocks to represent a calibration standard for the reactor nozzle - safe-end - cast elbow configuration. Two calibration holes were drilled into the cast stainless steel material. One hole was at the weld fusion line, 1/4 of the wall thickness (T) from the inner diameter (I.D.) of the cast stainless material. The other hole was in the corner of the required inspection volume, 1/3 T from the inner diameter and approximately 1/2 inch from the fusion line into the cast material. The mockup is shown in Figure 2.

An examination procedure was developed with state of the art ultrasonic techniques. Forty-five (45) degree (2.25 megahertz) refracted longitudinal wave transducers were utilized to maximize penetration of the cast material. However, the procedure yielded very limited results. During calibration on the mockup, the hole at the weld fusion line, 1/4 T from the I.D., could not be seen from the cast side. Refracted longitudinal wave ultrasonics were ineffective in examining the mockup material.

The acoustic properties of cast stainless steel at Byron and Braidwood vary from component to component. For this reason, a comparison of the attenuation characteristics of the mockup and the Byron and Braidwood elbows was made. Using a 1 MHz longitudinal wave transducer on the cast side of the mockup, gain settings of 24 to 26 decibels (dB) were needed to obtain an 80 percent back wall reflection. With a

2.25 MHz transducer, 32 to 34 dB gain was needed to see the back reflection. Performing the same test on a Byron cast elbow, 28 to 32 dB gain was needed for 1 MHz and 40 dB gain was required for 2.25 MHz. Similar results were obtained from measurements made on Braidwood elbows. It was concluded from these tests that the cast elbows installed at Byron and Braidwood are more attenuative than the cast material in the mockup.

The attempt to develop the examination procedure demonstrated that, with techniques available at the time, the statically cast components at Byron could not be ultrasonically examined to Section XI requirements. The refracted longitudinal wave technique did not penetrate the lower 1/4 T of the cast material in the mockup. The attenuation tests proved that the cast components in the plant would be examined to a lesser extent with these techniques. Commonwealth Edison realized that more long-term developments would be necessary to perform significantly improved ultrasonic examinations of the Byron welds. Since it was unlikely that these developments would occur prior to the scheduled fuel load for Byron Unit 1, relief from the Code examination requirements for the cast side of the welds was requested from the Nuclear Regulatory Commission (NRC). The relief requests were submitted to the NRC in August, 1983. These requests were approved in October, 1984.

Partial ultrasonic examinations were performed on some Byron Unit 1 cast stainless steel welds. Ultrasonic axial scanning for parallel reflectors was performed on the non-cast side of the welds. Forty-five (45) degree shear wave transducers were used to examine pipe-to-cast component welds. Forty-five (45) degree refracted longitudinal wave was utilized on all safe-end - to - cast component welds. Both techniques adequately examined the weld metal and the non-cast component heat-affected zones of these welds. Additionally, circumferential scans for transverse reflectors were made in both directions along the crown of these welds.

The inability to examine the Byron (and Braidwood) cast components can be attributed to the microstructure of statically cast stainless steel. Because of the course dendritic structure (columnar grains) of this material, the components are much more difficult to examine than the centrifugally cast components (equiaxed grains) used at other plants. The ultrasonic opacity of the Byron/Braidwood components was verified by Argonne National Laboratories. Mr. D.S. Kupperman, from Argonne, performed tests on Byron/Braidwood components as part of a program sponsored by the NRC. The results of these tests were presented at the Twelfth Water Reactor Safety Research Information Meeting held in Gaithersburg, Maryland in October, 1984.

IV. PRESERVICE INSPECTIONS AT BRAIDWOOD UNIT 1 AND BYRON UNIT 2

The preservice inspections (PSI) at Braidwood Unit 1 and Byron Unit 2 began in June, 1983 and August, 1984, respectively. The inspections at both plants are currently near completion. These inspections were performed to the requirements of Section XI 1977 Edition with addenda through Summer 1978 Addenda. As part of PSI efforts, Commonwealth Edison obtained best-effort ultrasonic baseline data for ASME Class 1 welds, including cast stainless steel welds, at both plants.

The Braidwood Unit 1 and Byron Unit 2 reactor coolant system welds were inspected prior to NRC approval of the Code relief requests for the Byron Unit 1 PSI. At the time of these inspections, there had been no known advancements in state of the art ultrasonic techniques since the inspection of the Byron Unit 1 cast stainless steel welds (January, 1983). Consequently, the ultrasonic examinations performed on the Braidwood Unit 1 and Byron Unit 2 cast stainless steel welds were identical to the examinations performed on Byron Unit 1 welds. These examinations are identified in Section III of this report. The necessary Code relief requests for Braidwood were submitted to the NRC with reference (a). The Byron Unit 2 relief requests are currently being prepared.

In late October and early November, 1985, a safety inspection was conducted at the Byron site by Messrs. H. Kerch, R. Harris and Ms. A. Lodewyk of the NRC Mobile Non-Destructive Examination Laboratory of the Region I office. During this inspection, ultrasonic data reports for cast stainless steel elbow welds were reviewed by the NRC personnel. The review revealed that Unit 2 cast stainless steel elbow welds did not receive complete ultrasonic examinations. In a meeting with Commonwealth Edison on November 5, 1985 at Byron, the NRC stated the limited ultrasonic examinations performed on the Byron Unit 2 cast stainless steel elbow welds were unacceptable and recommended that Commonwealth Edison perform the required ASME code examinations for each of these welds. Furthermore, they requested that if ASME code ultrasonic examinations are not performed, then a commitment to inservice radiography be made.

The basis for the NRC position regarding the examination of the cast elbow welds at Byron was the completion of successful preservice inspections of similar welds at other plants. In a conference call on November 13, 1985, with NRC Materials Engineering Branch, reference was made to preservice inspection examinations performed at the Vogtle Nuclear Generating Station near Augusta, Georgia. In July, 1985, Georgia Power Company completed ultrasonic examinations of cast stainless steel welds on Vogtle Unit 1. Carefully designed 1.0 MHz dual element transducers were utilized to examine both statically and centrifugally cast stainless steel in Vogtle reactor coolant loops. These transducers had focal depths and curved contact surfaces adapted to the thickness and curvature of the pipes and components to be inspected. Examinations with these transducers were demonstrated to detect flaws 25 percent through-wall and greater. Because of this success at Vogtle, the ultrasonic techniques used there were being considered the latest state of the art technology.

VI. EPRI INSPECTION OF BYRON CAST COMPONENTS

To become more familiar with the ultrasonic techniques used at Vogtle, Commonwealth Edison contacted the Electric Power Research Institute (EPRI) personnel who participated in the Vogtle Unit 1 preservice inspection. On November 18, 1985, Dr. Xaver Edelman and J. Mark Davis of EPRI visited the Byron site to examine the Byron Unit 2 cast stainless steel material with the ultrasonic techniques used at Vogtle. Examinations were performed on the Byron weld mockup and on several cast stainless steel welds in the plant. The results of these examinations are documented in reference (b). The following is a summary of the EPRI findings:

1. Reliable angle beam measurements could not be made on the Byron mockup with the EPRI transducer (those used at Vogtle) due to the flat, rectangular shape of the mockup. The EPRI tranducers were relatively large, with curved shoes which prevented proper coupling to the flat mockup. A change in thickness in the scanning surface of the mockup also prevented good examination results. However, the ultrasonic transparency was measured on the cast portion of the mockup with 2.25 MHz and 1 MHz straight beam transducers and was determined to be very poor.

2. The ultrasonic techniques used at Byron are no longer the state of the art. Examinations should be performed on the Byron cast stainless steel welds with transducers similar to those used at Vogtle. To use these transducers, curved calibration standards are needed.

3. The Byron Unit 2 cast components have a sound transparency much more attenuative than in Vogtle Unit 1. The cast components in the Byron plant are even more opaque to sound than the Byron cast mockup. For pipe-to-cast component weld joints, a good ultrasonic technique might be able to reach the heat-affected regions at the inner diameter surface through the weld metal from the pipe side. Additional work by Commonwealth Edison will be needed to determine the inspectability of the cast components at Byron.

EPRI and Commonwealth Edison personnel discussed the efforts required to improve the inspection techniques at Byron (and Braidwood) and noted that they would take at least several months to complete. When informed of the Byron and Braidwood construction schedules and of the possible delays which could result from the reexamination of the cast component welds, EPRI recommended that arrangements be made with Georgia Power Company to borrow the Vogtle transducers and statically cast stainless steel calibration block for use at Byron and Braidwood. However, EPRI noted that before the Vogtle equipment could be utilized, the attenuation differences between the Vogtle calibration block and Byron/Braidwood cast components must be studied in more detail. Large attenuation differences in the materials would render examination data meaningless.

VII. ATTENTUATION DIFFERENCES BETWEEN BYRON/BRAIDWOOD AND VOGTLE CAST STAINLESS STEEL MATERIALS

Commonwealth Edison personnel visited Vogtle Nuclear Generating Station on November 26, 1985 to make attenuation measurements on the Vogtle preservice inspection calibration blocks. Upon arrival they learned that Georgia Power had prepared two calibration blocks: #329A representing statically cast stainless steel and #331A representing centrifugally cast stainless steel. Each block had side drilled holes at 1/4T, 1/2T and 3/4T locations and I.D. notches of 0.25 and 0.625 inches. Commonwealth Edison inspectors were able to detect all calibration holes and notches using 1 MHz, 45 degree refracted longitudinal wave tranducers. On this basis, it was concluded that 25 percent through-wall flaws could be detected in the Vogtle cast components provided their attenuation properties were similar to those of the calibration blocks.

A 1.0 MHz straight beam transducer was used to make attenuation measurements on the Vogtle calibration blocks. With this transducer, the first back reflection was easily seen in all surface areas on the block and a second back reflection was visible in most areas. Gain settings required to see the first back reflection varied from 39 to 55 dB for the statically cast block and from 39 to 51 dB for the centrifugally cast block. When using the same transducer on a Byron cast elbow, the first back reflection was seen in some areas and a second back reflection was never seen. In most locations on the elbow, 56 to 64 dB were needed for the back reflection. In a few areas the required gain dropped to 48 dB. Similar attenuation results were obtained using a 1.0 MHz, 45 degree through-transmission technique.

Comparison of the attenuation measurements made at Vogtle and Byron demonstrated that few areas of the Byron components did not have acoustical properties similar to those of the Vogtle block. In most areas, the Byron elbow was 2 to 4 times (8 to 12 dB) more attenuative than the Vogtle block. Consequently, it was concluded that the Vogtle calibration blocks and transducers could not be utilized for Byron and Braidwood examinations. A calibration block more representative of the Byron components and transducers designed for that block must be procured to improve examination techniques.

VIII. DEVELOPMENT OF IMPROVED EXAMINATION TECHNIQUES FOR BYRON AND BRAIDWOOD

It has always been Commonwealth Edison's practice to keep abreast of the latest developments in nondestructive testing. Commonwealth Edison is willing to make every reasonable attempt to meet the requirements of ASME Section XI. For this reason, a program has been initiated to develop an improved ultrasonic examination technique for the statically cast components at Byron and Braidwood. The following is a summary of the program:

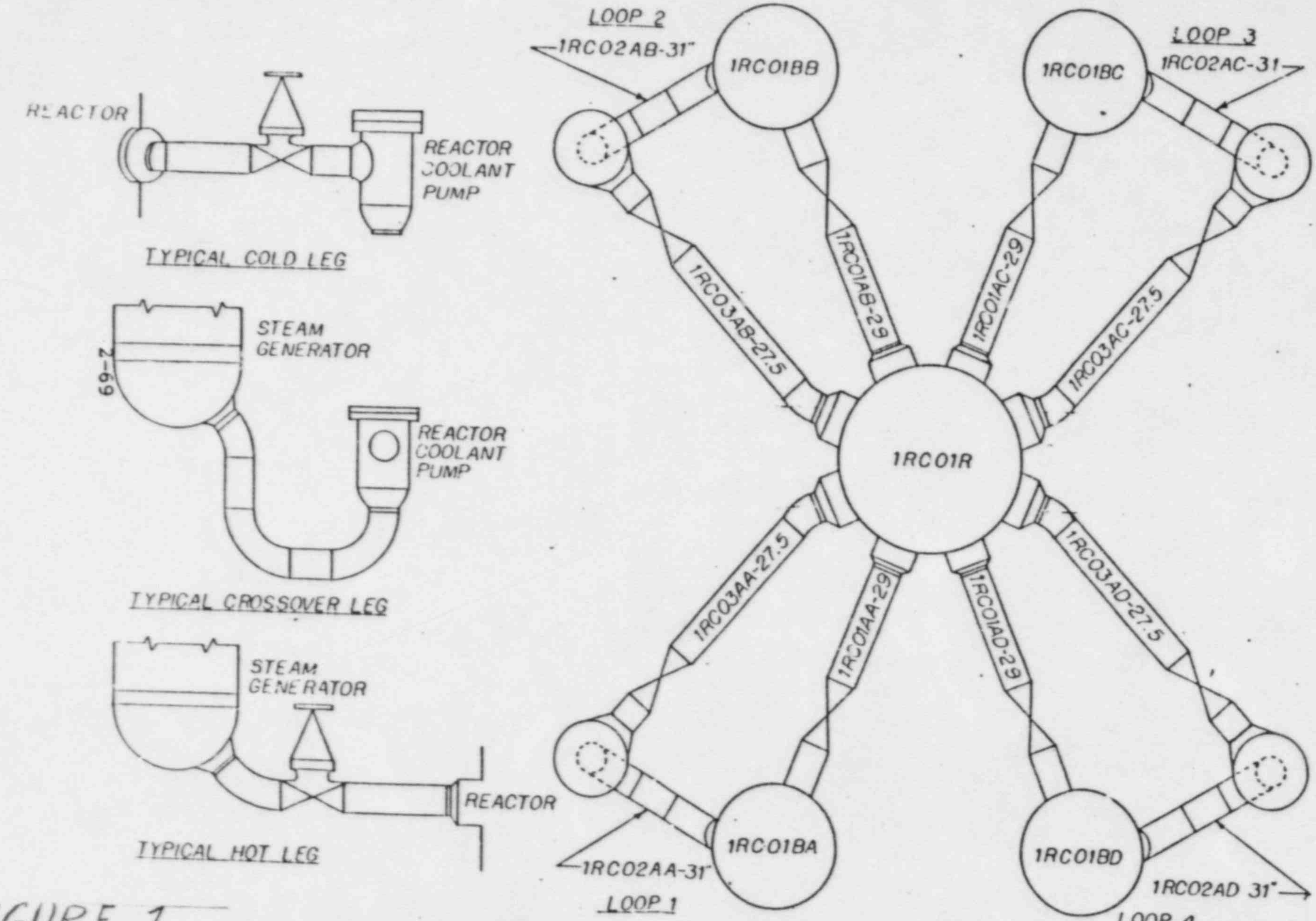
1. Procure statically cast elbow material and fabricate curved calibration blocks representative of Byron and Braidwood cast components.

2. Procure specially designed transducers which are optimized to detect the calibration holes and notches in the curved calibration block.

3. Develop an ultrasonic examination procedure for the Byron and Braidwood cast component welds using the curved calibration block and the special transducers. The procedure will provide an ASME Code examination to the extent possible. As a minimum, the procedure shall detect flaws 25 percent through-wall and greater.

This program is currently in progress. A cast elbow with attenuation properties similar to those of the Byron/Braidwood elbows has been procured from the Marble Hill site. A portion of the elbow is now being machined as a calibration block. The block will most likely be sent to a transducer manufacturer for the construction of optimized transducers.

Completion of this program is projected for May 15, 1986. At that time the results of the program will be evaluated. If a usable examination procedure is developed, then it will be used to the extent possible to meet Section XI preservice examination requirements for the cast component welds at Byron Unit 2 and Braidwood. If an acceptable procedure does not result, then the additional examinations will not be performed on these welds. Any necessary revisions to the existing Braidwood preservice inspection relief requests will be made. The outcome of this program will be incorporated into the Byron Unit 2 preservice inspection relief requests and will help finalize the pending inservice inspection commitments for Byron Unit 1.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LOOP 2
1RCO2AB-31"
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1RCO1BC
LOOP 3
1RCO2AC-31
1RCO3AB-27.5
1RCO1AB-29
1RCO1AC-29
1RCO3AC-27.5
1RCO1R
1RCO3AA-27.5
1RCO1AA-29
1RCO1AD-29
1RCO3AD-27.5
1RCO1BA
1RCO1BD
1RCO2AA-31"
LOOP 1
1RCO2AD 31"
LOOP 4

FIGURE 1

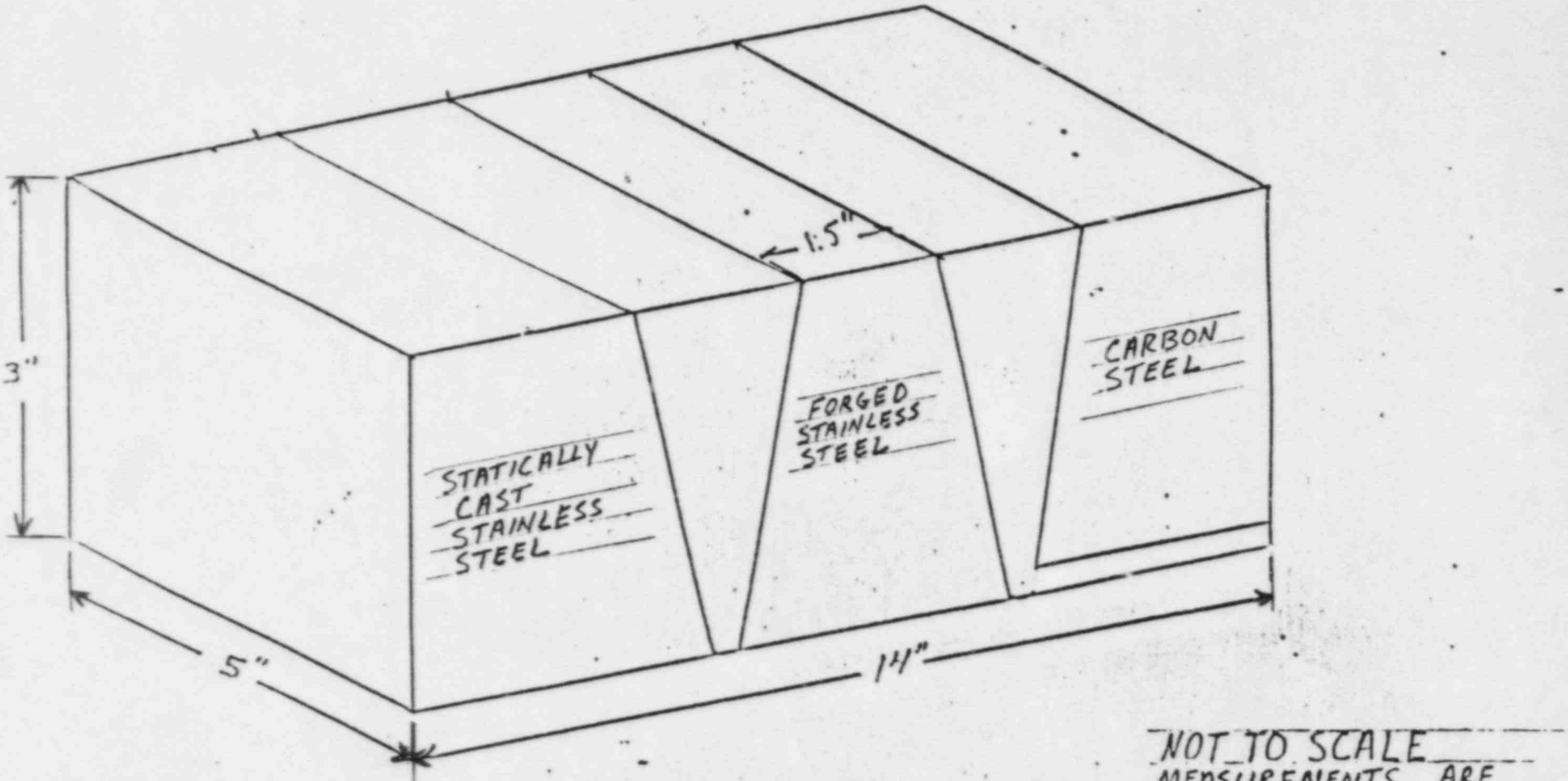

Figure 2: Sketch of Byron Safe End to Elbow Calibration Block BY50