INVESTIGATION OF FIELD CONDITION OF
THE VENTILATION STACK BASE RING GIRDER

Commonwealth Edison Company
LaSalle County Station - Units 1&2
Project No. 4266-00

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1071 013

TABLE OF CONTENTS

1071 014

I. INTRODUCTION

In September 1978, Sargent & Lundy was informed by Commonwealth Edison personnel at the LaSalle Station that a crack had been found in the base ring girder during erection of the ventilation steel stack. Follow-up ultrasonic testing and a visual examination were performed to assess the situation.

The purpose of this report is to present S&L's analytical and field investigation of the stack ring girder. The possible causes of the improper field conditions are identified. The structural safety of the stack and ring girder in their present conditons are evaluated. Finally recommended repairs are proposed.

II. BACKGROUND INFORMATION

The ventilation stack located above the auxiliary building roof of LaSalle County Units 1&2 serves as a single elevated point of gas release for the reactor building, turbine building, solid radwaste building, off-gas standby gas treatment, and gland seal exhaust system. The stack is classified under "other seismic category I structures." The stack design included the effects of dead load, wind load, operating basis earthquake, safe-shutdown earthquake, tornado wind, and tornado-induced missile.

As shown in Figure 1, the stack is 237'3-1/2" in height and has inside diameters of 18'6" at the top and 24'0" at the base, with a 30-ft long tapered section starting at 79'7-1/2"

from the stack base. The design shell thickness varies from 5/16" at the top to 1-1/4" at the base. The stack is supported at its base by a ring girder, which is anchored to the top of the auxiliary building roof steel at eight locations, 45° apart. The base ring girder consists of two flanges, each 3 ft wide and 2 in. thick, and a center web 3 ft deep and 1-1/4" thick. Figure 2 shows a typical cross section of the ring girder. At each of the eight supports, the ring girder is reinforced with six pairs of bearing stiffeners, 8 in. apart.

The stack was released to John Mohr & Sons for fabrication on January 26, 1977 under S&L's project specification J-2982. All shell plates and stiffeners were specified to meet the requirements of ASTM A-588 50 ksi yield steel with supplementary Charpy impact tests. The welding electrodes specified were AWS E-7018.

III. FIELD EXAMINATION OF THE STACK BASE RING GIRDER

The stack was fabricated by John Mohr & Sons beginning in September 1977. After the stack was erected, a crack open to the surface was observed in the base ring girder at the outer face of the juncture of the top girder flange to the stack shell plate. Subsequent to this finding, S&L engineers made a number of site examinations of the condition of the stack, particularly the base ring girder.

A brief summary of the observed field condition of the ring girder is given below.

A. Extent of Cracks

In the southeast quadrant of the ring girder (see Figure 3), a crack of approximately 17 ft was detected by nondestructive ultrasonic testing (UT). The crack runs along the circumference where the outer top flange is welded to the center stack shell plate (web). The crack is no deeper than 5/16" from the shell plate surface. It runs in and out of the base metal and weldments, and is visible and partially open to the surface. At the present time, welds in this area have been gouged out and have not yet been repaired. Aside from this long crack, testing has confirmed two other visible but much shorter cracks in the northwest quadrant of the ring girder (Figure 3).

B. Extent of Crack-Like Discontinuities Near Joints

Linear indications were detected using the shear wave mode of UT testing in approximately 75 percent or 270° of the shell circumference that is adjacent to the top flange-web joint, a double-welded full-penetration groove joint. The locations of linear indications are presented in Figure 3. Indications are continuous and pronounced in some areas, but intermittent and weak in other areas. These linear indications represent the existence of discontinuities in the plates. The discontinuities could be

lamellar tears, minute cavities in the lamination, or nonmetallic inclusions. UT testing alone cannot differentiate between the types of discontinuities. The area of most concern is in the northwest quadrant, where the entire inside top flange-to-web joint is considered ineffective and only about 50 percent of the outside top flange-to-web joint can be considered effective. The conditions at the northeast and southwest quadrants are considerably better; at least 50 percent of both the inside and the outside web-to-flange joints are in good condition. The top flange-to-web joint in the southeast quadrant cannot be ultrasonically tested because part of the outside flange has been gouged out.

Each of the eight girder supports has twelve stiffeners (six on each side of the web) connected to the girder web (shell plate) by full-penetration welds, and to the top and bottom flanges by 3/8" double fillet welds. So far, ultrasonic testing of these stiffeners and stiffener welds has been limited to the outside stiffeners in the southeast quadrant. Linear indications of discontinuities were found in parts of these stiffener-to-web joints. Four of the ten stiffeners examined are free of any indications; 50 percent of the stiffener-to-web welds at the support near the south side are effective; and 72 percent of the stiffener-to-web welds at the support near the east side are free of any discontinuities.

1071 018

C. Extent of Laminations in Ring Girder

The longitudinal mode of ultrasonic testing was performed to examine the extent of laminations in girder plate materials. The top flange of the ring girder was found to be sufficiently clean and smooth and free of any gross laminations. Ultrasonic testing was performed in the southeast quadrant of the ring girder; except for one 3'x6' area near the end of the plate, no gross laminations were found. The distribution of laminations in the girder web is shown in Figure 4.

IV. ASSESSMENT OF POSSIBLE CAUSES OF RING GIRDER DEFECTS

The indications revealed by ultrasonic testing of the stack ring girder are twofold: one is associated with plate lamination, the other may possibly be related to lamellar tearing.

The laminations referred to herein are discontinuities in rolled steel products resulting from the flattening and elongation of inclusions or cavities during the rolling process. They are commonly found in almost every type of rolled structural steel. The steel specified for the stack is ASTM A588, which is a high-strength, low-alloy structural steel having a minimum yield strength of 50 ksi. The A588 steel is a "fully killed" (completely deoxidized) fine grain steel of better quality than other structural steels such as A283 and A36. Laminations have very little influence on the mechanical strength of the material in the rolled direction. Tests conducted for Commonwealth Edison by Kawin Laboratory on two steel specimens cut from the girder web verified

that the A588 plate at the site meets the requirements of the ASTM A588 specification. The results obtained from the Kawin Laboratory report dated May 15, 1979 are shown in Table 1. There was no requirement for checking steel laminations in the ASTM A588 Standard Specification prior to 1978.

Laminations found in the stack shell plate are not considered detrimental to the safety of the structure. No known cases of structural failure of steel stacks have ever resulted from laminations, although they have probably been present in almost every stack, including those made of lower grades of steel. Laminations can reduce the strength and ductility of steel in the through-thickness direction, but the stack at the site has very small stresses in the plate through-thickness direction under design loads. Therefore, it is concluded that the safety of the stack is not affected by the presence of laminations.

The cracks and tear-like discontinuities detected by UT in the stack ring girder most likely result from lamellar tearing, a phenomenon commonly defined as "the separation in the base or parent metal caused by through-thickness strains induced by weld metal shrinkage." This type of tearing is characterized by terrace fracture surfaces parallel to the rolling plane and located either in the vicinity of the toe or root of the weld or outside the heat-affected zone, but always within 1 cm (approximately 0.4 in) of the weld metal. It may or may not come to the plate surface. The tearing occurs principally in tee- and corner-type joints involved with thick plates

and/or heavy structure shapes. Some of the linear indications seem to follow the pattern of lamellar tears and thus suggest the probable existence of tearing.

In summary, the causes of lamellar tearing could be a combination of the following factors:

A. Use of Field Fabrication and Field Welding

The stack ring girder was originally detailed to be shop-fabricated in four pieces before being shipped for field erection. However, this work was carried out in the field instead.

B. Existence of Laminations and Nonmetallic Inclusions in Steel

Like any rolled structural steel, A588 steel contains certain lamination-type impurities and nonmetallic inclusions. Although laminations do not have a detrimental effect on the strength of the member in the rolled direction, reduction in the through-thickness direction is anticipated. Laminations can open up as a result of weld shrinkage induced in the through-thickness direction. The long crack detected in the southeast quadrant seems to be such a tear.

Nonmetallic inclusions are microscopic particles of compounds in the steel matrix. These inclusions can reduce through-thickness ductility. Under a condition of high restraint, the weld shrinkage strains imposed on the base metal in the through-thickness direction can exceed the ductility limitation and cause tiny tears.

C. High Internal Joint Restraint

Since the stack was designed to resist tornado wind and safe shutdown earthquake, use of thick plates and heavier connections was necessary. Thick plates provide large joint restraint because of their larger out-of-plane bending stiffness.

It should be noted that lamellar tears are not unique to A588 steel. Lamellar tearing can occur and has been observed in structures made of A36 and other structural steels. Recent test results from Lehigh University, presented at the 1979 AISC Annual Engineering Conference, indicated that the susceptibility of steel to lamellar tearing decreased with increased yield strength. When the stack was designed in 1973 and 1974, A588 was the best structural steel available that possessed both high yield strength and high impact toughness. Specially treated steels with improved through-thickness ductility, such as TRIMAX from US Steel and Fineline from Lukens steel, were not commercially available at that time.

V. EVALUATION OF EXISTING STACK AND RECOMMENDED REPAIRS

Based on the UT test results described in Section III, the following conservative assumptions were made to evaluate the safety of the stack ring girder:

- consider one-half of the web thickness as effective for checking tension and compression in stack shell.
- consider one-half of the top flange totally ineffective in all quadrants.

1071 022

- consider the outside top flange-to-web joint as being 50% effective in all quadrants.

- consider a minimum of two sets (i.e., 33%) of the stiffeners at each support as having good welds with the shell plate and two bolts per support as being able to effectively resist uplift.

The stack and its ring girder are presently capable of withstanding the 90 mph design basis wind using the conditions listed above, but they will not be able to resist the 360 mph tornado wind. Since the plant is still under construction, the structural integrity of the stack under tornado wind is not a nuclear safety-related matter. Thus, no immediate remedial action is required. However, a permanent correction of the stack base ring girder will be needed before plant operation begins. A number of alternative schemes have been studied, and the final scheme recommended for the fix is shown in the attached Sargent & Lundy drawing (No. S-1123).

The basic concept of the recommended repair is to replace the existing stack base ring girder, segment by segment, with a new girder. The material for all flanges, web and stiffeners of the new girder will be ASTM A588 Lukens Fineline steel, which offers better control of laminations and is more resistant to lamellar tearing during welding.

Removal and replacement of the existing ring girder will be carried out in eight segments, one segment at a time. Work can be started at any segment and then continued in one direction

around the circumference. Each new girder segment, spanning approximately 45 degrees, will be fabricated in the shop. Prior to shop fabrication, all new plates will be 100% ultrasonically tested in accordance with the ASTM A578 straight beam method for lamination check. Plates containing laminations or discontinuities greater than 1 in. in diameter should not be used. Each new girder segment will be stress-relieved in the shop before it is shipped to the field.

Prior to any repair work, a WT 8x28.5 ring stiffener will be installed around the stack at a vertical distance of 1'-11" above the existing base ring girder. This ring stiffener, plus two vertical stiffeners at each segment, are designed to serve as temporary stack reinforcing during the field work to ensure the safety of the stack. Field measurements of the existing stack ring girder will be made by the contractor before the fabrication of the new girder segments for proper fit-up. The contractor will determine if any shimming is required in the field for maintaining the proper alignment of the stack. Anchor bolts will be reinstalled on the new girder segments in the field in accordance with the original installation procedure. All field and shop welding shall follow the requirements of AWS-D.1.1.

VI. <u>SUMMARY</u>

A. The field problems at the LaSalle ventilation stack ring girder have been identified as material laminations and

possible lamellar tears in plates. The existence of some laminations in A588 steel is not unusual and does not have an appreciable effect on the mechanical strength of the rolled steel. Cracks due to lamellar tears are of concern in the load resistance of the ring girder.

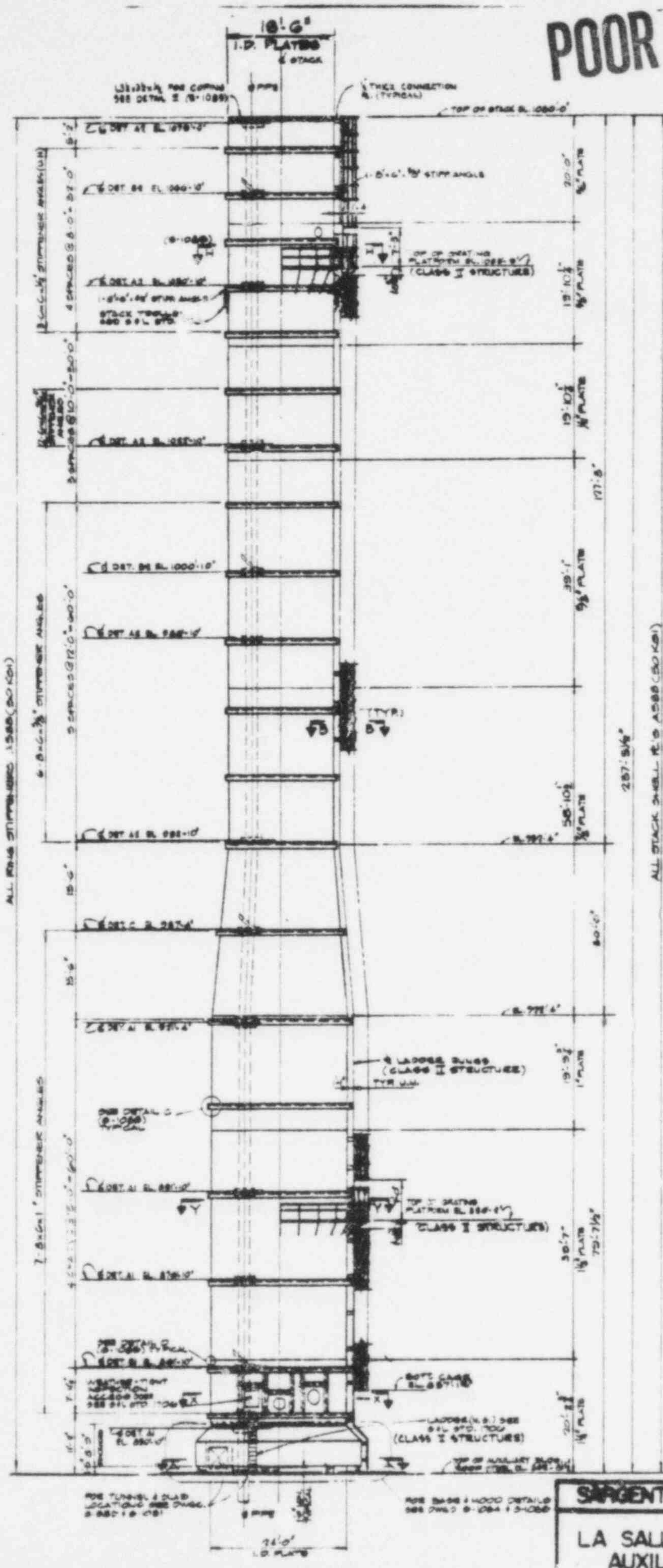
B. Existence of nonmetallic inclusions and laminations in the steel in conjunction with the use of field welding are the possible causes of the cracks and crack-like discontinuities detected in the ring girder.

C. Use of heavy plates and joints was required because of the required tornado wind resistance. Existence of impurities is common to all rolled structural steels. Compared to other structural steels, the A588 steel used to construct the stack was the best steel available on the market before 1974, in view of its high yield strength, better impact toughness, and fine-grain microstructure. Desulfurized steels, which have improved resistance to lamellar tears, were not used because they were not commercially available to the construction industry at that time.

D. The stack ring girder in its present condition will be able to withstand the 90 mph design basis wind, but not the tornado wind. No immediate repairs are required. A permanent repair scheme is proposed to restore the full design load-carrying capacity of the stack prior to the start of plant operation.

Table 1 Test Results of Mechanical Strength of Stack Plate Material

	Sample 1	Sample 2	A588 Specified Values
A. In Rolling Direction			
Ultimate Tensile Strength, ksi	74.8	75.6	70 ksi/min
Yield Strength, ksi	50.9	50.9	50 ksi/min
Elongation, in 2", Percent	33.0	34.0	21
Reduction in Area, Percent	71.3	72.0	—
B. Transverse to Rolling Direction			
Ultimate Tensile Strength, ksi	74.1	73.6	70 ksi/min
Yield Strength, ksi	50.9	52.2	50 ksi/min
Elongation, in 2", Percent	32.5	32.5	21
Reduction in Area, Percent	57.3	59.1	—



1071 027

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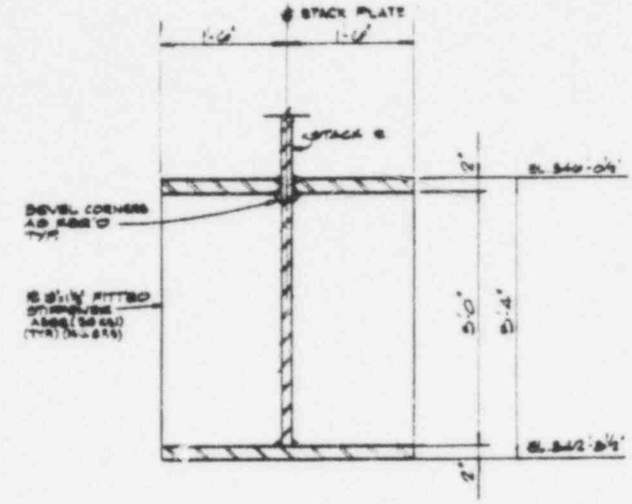
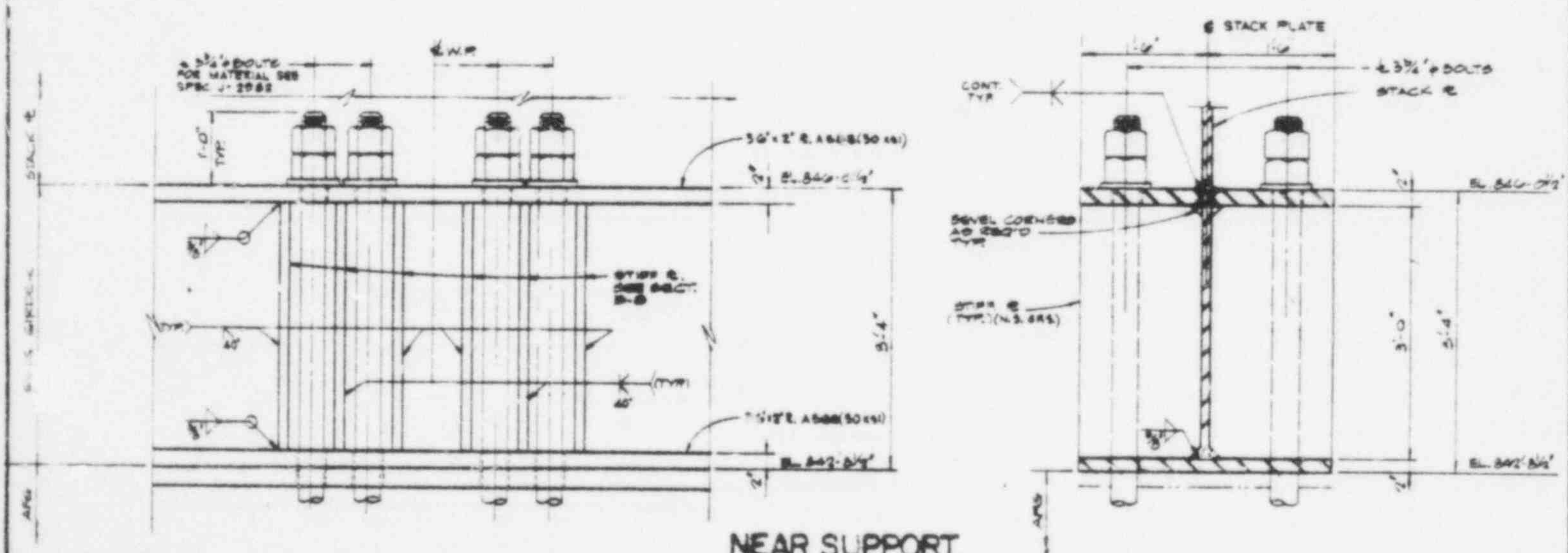
LA SALLE COUNTY STATION
AUXILIARY BUILDING
ROOF VENT STACK

FIG. 1.— ELEVATION OF STACK (LOOKING SOUTH)

POOR ORIGINAL



AWAY FROM SUPPORTS



NEAR SUPPORT

FIG.2 - CROSS SECTION OF RING GIRDER

1071 028

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LA SALLE COUNTY STATION AUXILIARY BUILDING ROOF VENT STACK

H. B. ROBINSON'S OPERATOR REQUALIFICATION PROGRAM

H. B. Robinson's Requalification Program is designed to ensure that all licensed reactor operators and senior reactor operators will maintain proficiency in their assigned plant operating tasks. Further, it is expected that participation in this program will allow all licensed personnel to meet or exceed the requirements set forth by USNRC operator licensing group.

The following is a detailed summary of the H. B. Robinson's Operator Requalification Program which will be conducted to fulfill the requirements of 10 CFR 55. The full program will be implemented in such a manner as to minimize scheduling difficulties that will be incurred by plant management. It is the intention of CP&L to have a continuing training program between the time each annual examination is given. This consists of 2-4 months of formal lectures given weekly, if plant operation allows, a simulator training program, continuing with on-shift training through the remainder of the year. This will exclude the 1-3 months that the plant is down for maintenance and refueling.

The entire Requalification Program will be conducted in two (2) phases:

1. Retraining on-site, and
2. Operator evaluation

The Training Coordinator will be responsible for the scheduling and supervision of all training.

PHASE I - RETRAINING ON-SITE

The on-site portion of the Requalification Program will consist of approximately 120 hours of instruction. This instruction will be given in two (2) parts:

1. Formal classroom lectures, and
2. On-shift training

The scheduling on-site will be such that every licensed operator will have the opportunity to attend all lectures. The following is an outline of what subjects may be covered in each of these parts, but not necessarily in the order stated.

1. Formal Classroom Lectures
    a. Theory and Principles of Operations
        1) Atomic and nuclear physics
        2) Subcritical multiplication
        3) Xenon and samarium effects
        4) Rod worth
        5) Boron worth
        6) Coefficients and defects
            a) Moderator temperature
            b) Fuel temperature
            c) Voids

            d) Pressure
            e) Redistribution
            f) Power
        7) Shutdown margin
        8) Rod insertion limits

b. General and Specific Plant Operating Characteristics

1) Normal plant transients
    a) Rod worth curves
    b) Xenon transients
    c) Step load changes
2) Safety analysis
    a) Review of minor accidents
    b) Review of major accidents

c. Plant Instrumentation and Control Systems

1) Excore nuclear instrumentation
2) Incore nuclear instrumentation
3) Full length rod control
4) Part length rod control
5) Rod position indication
6) Pressurizer pressure control
7) Pressurizer level control
8) Make-up water control
9) Steam dump control
10) Steam generator level control
11) Reactor protection system
12) Electrohydraulic control
13) All logics

d. Normal and Abnormal Procedures and Emergency Instructions

1) Engineered safety systems
2) Site emergency plan
3) Overall plant operating procedures

e. Radiation Control and Safety

1) Nuclear radiation
2) Biological effects of radiation
3) 10 CFR 20
4) Radiation protection manual
5) Radiation monitoring system
6) Radiation procedures

f. Technical Specifications

1) Safety limits, reactor core
2) Heatup and cooldown limits
3) Core power distribution
4) Discharge limits

g. Chemistry

1) Chemistry control
2) Radiation chemistry
3) Specifications and criteria

h. Quality Assurance Responsibilities

Annually a comprehensive examination will be given to each licensed operator. From the results of this exam an annual schedule will be formulated using the above topics as a guide. If any operator shows that he is clearly deficient in his performance (his examination results are less than 70% overall) he will be removed from work requiring an operator's license and placed in an accelerated requalification program until the management is satisfied that he is again proficient. This will be determined by a written and/or an oral examination.

Any operator who clearly shows he would have passed an NRC exam on a particular section (with an 80 percent or greater on that section) will be exempt from the lecture series on that section. If he scores less than 80% on a particular section, he will be required to attend a lecture series on that particular section. Upon completion of the classroom lectures a topical examination on that section will be given. A grade of 80% will be considered passing.

Certain licensed personnel, in the performance of their normal duties, may be very much involved with one or more of the areas covered in classroom lectures. These individuals would not be required to attend the applicable classroom lectures. In some cases, these individuals may be called upon to conduct lectures in their areas of expertise, i.e., Environmental and Radiation Control Supervisor for Radiation Control and Safety lectures.

2. <u>On-Shift Training</u>

On-shift training will be conducted in accordance with Volume 1, Administrative Procedures, Section 4.1.6, Shift Operations Readiness as described below:

"It is essential to individual and crew readiness that emphasis periodically be given to vital information on alarm settings, safety limits, abnormal condition symptoms for operation, operating sequences, and emergency immediate-action steps.

Individual reviews, instructional sessions, and where applicable, a walk-through of controls and instrumentation will be conducted with such duration and frequency that the information contained in the following volumes is covered once each quarter, with the exception of the 1-3 months during each operating cycle when the unit is being refueled:

a. Volume I - Administrative Procedures - Section 4
b. Volume V - Abnormal Procedures
c. Volume VI - Emergency Instructions
d. Volume VII - Precautions, Limitations, and Setpoints
e. Volume VIII - Radiation Control and Protection Manual
f. Volume XIII - Emergency Plan and Procedures

When covering the above six (6) volumes, the Technical Specifications, along with flow diagrams, logics, and functional diagrams will also be reviewed where applicable.

Before the end of every quarter (with the exception of the quarter in which the unit is being refueled), the Shift Foreman will submit to the Training Coordinator a report of the instructional sessions conducted during that quarter. The report will detail the information covered for each member of the shift operation crew, and will contain the Shift Foreman's judgment of each operator's familiarity with the information contained in the above volumes, as well as each operator's ability to take the required action.

The Training Coordinator will maintain a file of the reports filled out by the Shift Foremen. They will be used in compiling qualification information for NRC Reactor Operator license applications."

To insure that each licensed operator is cognizant of facility design changes, procedure changes, and facility license changes, significant safety related modifications or changes to procedures and license will be reviewed. This may be accomplished by group or individual review and documented in the training files. The staff personnel holding an NRC operator license will stand an average of four (4) hours watch in the control room per month. If he is regularly participating in a simulator training program, 75% of this time can be satisfied on the simulator. During this four (4) hours he will carry out those duties normally conducted by either the Shift Foreman or control room operator.

During all plant operations a record will be kept of any major reactivity changes a licensed operator will perform. The following is a list of some reactivity changes CP&L considers as major:

1. Startup to point of adding heat
2. Orderly shutdown
3. Manual control of S/G's during startup
4. Operation of EHC in manual during startup
5. Boration
6. Dilution
7. Operation of manipulator crane during refueling
8. Any power changes greater than ten (10) percent in manual rod control.

CP&L does not mean that the above list is complete. If credit is taken for any other major reactivity change other than those listed above, they will be documented fully.

A combination of 10 reactivity manipulations will be performed during the two-year period. Each licensed operator will either manipulate the controls or direct the activities of individuals during plant control manipulations. If the required number of reactivity manipulations cannot be performed on H. B. Robinson - Unit 2, a simulator with similar arrangement of the instrumentation and controls that reproduces the general operating characteristics of the Robinson Unit will be used.

PHASE II OPERATOR EVALUATION

At the completion of Phase I each licensed operator will take a USNRC type comprehensive written examination. Periodically a CP&L instructor will conduct oral examinations on 1 or 2 licensed operators.

Annually, each licensed operator will attend a simulator training program if scheduling permits. Any licensed operator not attending the simulator training program will be given an oral examination which includes a walk-through of controls and indications. The simulator used will have a similar arrangement of instrumentation and controls and will reproduce the general operating characteristics of the Robinson Unit. The program will be concluded with evaluation of the licensed operator performance during abnormal/emergency conditions.

The following is a list of records to be kept in a personal file on each licensed operator:

1. Startup, Shutdown, and Reactivity Changes
2. Formal Lecture Attendance
3. On-Shift Training
4. Grade Sheet for Periodic Examinations
5. Evaluation Sheets for Written Comprehensive Examinations
6. Evaluation Sheets for Oral Examination
7. Evaluation from Simulator Staff
8. Additional Training

In a master file will be copies of all periodic examinations and a copy of all comprehensive examinations given.

Any licensed operator absent from the site for a period of four (4) months or longer will be given a written examination and/or an oral walk-through of the plant to determine if an accelerated training program is necessary prior to returning him to his normal duties.

NOTE: The term "licensed operator" means any person holding an NRC license to operate a nuclear power plant, whether it be senior reactor operator or reactor operator.