Final Construction Deficiency Report

Damage Resulting From Derrick Failure During Hurricane David

Name of Station:	St. Lucie Plant - Unit #2
Owner:	Florida Power & Light Company
Architect/Engineer:	Ebasco Services, Incorporated
Date of Deficiency:	September 3, 1979
Interim Report Filed:	October 4, 1979
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Final Report Filed:	February 1, 1980

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I. SUMMARY

On Monday morning, September 3, 1979, at approximately 10:45 a.m., the Chicago Bridge & Iron guyed derrick buckled, twisted, and collapsed during Hurricane David. The lower portion of the derrick (below Elevation +192 feet) did not collapse and was leaning at a slight angle from the vertical, remaining braced to the containment shield wall by virtue of the horizontal strut braces. The upper portion of the derrick became dismembered and four major sections came to rest in or on the Reactor Auxiliary Building. A portion of the boom remained suspended by guy wires from the top of the containment shield wall. The guy wires performed their intended function and did not fail.

Per the requirements of 10CFR50.55(e), the event was deemed reportable because the derrick failure caused significant damage to safety-related structures, which, were it to have remained uncorrected, could adversely affect the safety of operations of the plant, and did require extensive evaluation and repair. Notification of the incident was telephoned in to the NRC Inspection and Enforcement Office on September 4, 1979 (approximately 11:45 a.m.) by Mr N Weems, Florida Power & Light Company's Assistant Manager, QA Construction.

Via numerous onsite inspections by the Architect/Engineer and engineering review of onsite confirmatory destructive and nondestructive testing, all damaged areas were identified and corrective actions were issued.

II. DESCRIPTION

The concrete Shield Building and the Reactor Auxiliary Building were at the following stages of construction when the hurricane passed the jobsite: The concrete Shield Building cylinder had been completed to Elevation +191.42 feet and the Reactor Auxiliary Building, being constructed in a staggered manner, had walls and columns completed to the underside of floor slabs at Elevations +43 feet, +62 feet and +82 feet.

Actions taken to Identify Damage

A storm damage team was assembled to determine and document the extent of damage resulting from the derrick failure. The team consisted of the Ebasco Civil Site Support Engineer and two civil construction office engineers. In

conjunction, the Architect/Engineer visited the jobsite, both before and after derrick removal and cleanup, to observe the damage and to confirm and task force findings. Nonconformance reports were prepared for observed damage to concrete and reinforcing, and corrective actions for removal and initial repair were issued with Architect/Engineer review and approval. Architect/Engineer directed construction to proceed with two testing programs to confirm the extent of damage within the Reactor Auxiliary Building and Shield Building. The first program required testing of reinforcing steel samples removed from the damaged floor beams and slabs of the Reactor Auxiliary Building at Elevation +62 feet. Test results would indicate if the reinforcing which extends into the surrounding sound concrete had been overstressed during missile impact. The second program required nondestructive testing of:

a) Reactor Auxiliary Building concrete members

   1) adjacent to damaged floor slab areas at Elevations +43 feet and +62 feet, including all the beams at Elevation +43 feet which were observed to have surface cracks, and

   2) an exterior wall along the north side of the building which had only five day concrete strength when a section of the derrick hit the top of the wall.

b) Shield Building cylinder wall

   1) at three locations on top of wall where dowels were bent and sheared off, and

   2) at a gouged area on outside face of wall at Elevation +112 feet.

The pulse echo method was selected and was performed by Muenow and Associates of Charlotte, North Carolina. The attached Figures 1 and 2 show the concrete members which were investigated.

Areas completely unaffected by the derrick failure were released for continued planned construction.

III. ASSESSED DAMAGE

The initially observed damage to the containment shield wall was limited to bent and sheared dowels projecting from the top of the cylinder wall and a small surface gouge on the exterior wall face.

The initially observed damage within the Reactor Auxiliary Building was extensive and consisted of penetration of floor slabs, shattered floor beam, spalled concrete, and bent and sheared dowels for columns and walls. The location of derrick and boom section resting positions, and details of observed damage to the Reactor Auxiliary Building are presented on Sketches, SK-2998-FG 75.01 to 75.06 (Attachment). In addition to the noted damage on the sketches, cracks were observed on the surface of a few elevation +43 feet floor beams. These cracks were chipped back to determine depth and were observed to be only surface shrinkage cracks.

In addition to the above structural damage in the Reactor Auxiliary Building, the following is a listing of damaged equipment and supports:

1) Conduit on Elevation +43 feet
2) Cable tray restraint on Elevations +43 feet and +62 feet
3) 4.16 kV Switchgear 2A3-1, 2, 3, 4, 5, 6, 7, 8
4) Station Service Transformer 2A2
5) 480V Switchgear
6) Pressurizer heater buses 2A3 and 2B3

The destructive testing of reinforcing steel and nondestructive testing of concrete members proceeded in the following sequence with results as noted:

Reactor Auxiliary Building Elevation +62 feet (floor slab, beams, girders, and supporting column and exterior wall).

- All shattered and badly cracked concrete of beam 3B3 between Column lines 2RA1 and 2RA2 and adjacent slabs were removed.

III. ASSESSED DAMAGE (Cont'd)

- Samples of exposed beam and slab reinforcing were removed and tested by Construction Quality Control to determine if ASTM minimum requirements were met or if the reinforcing had become overstressed upon impact. Test results indicated that the slab reinforcing (No. 6 and 8 rebars) met all ASTM requirement and beam reinforcing (No. 9 rebars) met all ASTM requirement except percent elongation which indicated values as low as 3 percent vs a minimum allowable of 7 percent.

- To check the field test results, samples of the field tested rebars and additional samples of the beam reinforcing were sent to the Architect/Engineer for investigation and tensile testing. Microscopic inspection of the field tested rebars did not reveal the elongated grain which typify material exposed to plastic strain. Tensile testing of two rebar samples indicated that all ASTM requirements were met except for elongation in one sample. It was noted that both samples failed at surface indentations which were caused by nicks and gouges during concrete removal. The testing program concluded:

1) There is no evidence of rebar straining due to the crane collapse.

2) The New York Office tested rebars failed at the gouges (stress risers) (Copy of the report is contained within J Brodsky (Ebasco Materials Engineer) memo to L M Petrick (Chief Materials and Welding Engineer) dated 12-18-79.

For additional information on the effects of loading of reinforcing steel past-yield, the Architect/Engineer requested field tensile testing of reinforcing of same size (No. 9 rebars) and heat number as installed in Beam 3B3. Testing proceeded as follows:

1) Measure diameter,
2) Load to yield point and hold for 5-10 sec,
3) Slowly release load,

III. ASSESSED DAMAGE (Cont'd)

4) Measure elongation and diameter,

5) Load to ultimate and

6) Determine elongation.

For all rebars tested all ASTM requirements were met.

- Nondestructive testing of visually sound concrete members adjacent to the impact area indicated the following:

1) Microcracking and loss of concrete bond to reinforcement in the top four inches of concrete within beams 3B2 and 3B4 adjacent to impacted Beam 3B3, and in Beam 3B3 south of Column Line 2RA2.

2) Microcracking in adjacent slabs through out the one foot depth and for a distance of 3.5 feet past beams 3B2 and 3B4.

3) Microcracking on exterior wall at support point of Beam 3B2 for a depth of less than three inches.

- To document validity of test results, nondestructive testing of concrete members away from the damaged area was also performed and results indicated sound concrete.

Reactor Auxiliary Building Elevation +43 feet (beams, girders and supporting columns)

- Shattered and badly cracked concrete of slab east of column line RAG and between column lines 2RA2 and 2RA3 was removed.

- Samples of exposed slab reinforcing were removed and tested, and were found to meet ASTM minimum requirements.

- Nondestructive testing was performed on all beams on which a portion of the derrick had come to rest and girders and support columns adjacent to the damaged concrete slab (beams 2B4 - 2B13 between columns lines 2RA2 and 2RA3). No microcracks were detected and any visually observed surface cracks were found not to extend beyond two to three inches in depth.

III. ASSESSED DAMAGE (Cont'd)

Reactor Auxiliary Building Walls between Elevation +19.5 feet to +43.0 feet

- Nondestructive testing of north exterior wall between column lines RAB and RAE indicated microcracking in the top two to three feet for a portion of the wall.

- Nondestructive testing of interior wall on column line RAE between column lines 2RA2 and 2RA3, around an area which had been damaged and unsound concrete removed, indicated no microcracking.

Reactor Building Shield Wall

- Nondestructive testing, performed at Azimuths 70,130 and 160 degrees between Elevations +191.42 and +186 feet, indicated microcracking up to six inches below top of wall for the complete thickness.

- Nondestructive testing around a gouge located at Azimuth 160 degrees at Elevation +112 feet indicated surface microcracking for a four square foot area on the outside face of the shield wall.

For complete description of nondestructive testing program, including technique and test results for all areas investigated, see Muenow and Associates "Final Report On the NDE Evaluation of Concrete Damage at St Lucie Unit No. 2" which is filed at the site.

IV. CORRECTIVE ACTIONS

Actions Taken

Florida Power & Light Company retained Cadcom, a division on ManTech of New Jersey Corporation, to investigate the cause of the derrick failure and to make recommendations concerning the erection of a replacement derrick.

The Cadcom Report concludes that the guyed derrick should have withstood the hurricane force winds had different securing precautions been taken. In

IV. CORRECTIVE ACTIONS (Cont'd)

addition, the report recommends minor modifications that could be made to further enhance the hurricane withstand capability of the crane.

The Cadcom Report was subsequently reviewed by Chicago Bridge and Iron (CBI), who designed, manufactured and supplied the crane. CBI concurred that the Cadcom Report provides a reasonable account of the derrick collapse, and that the recommendations for securing the derrick when hurricane winds are expected are technically sound.

Following their own design review, and consideration of the Cadcom Report CBI has concluded that the following actions should be taken to secure the replacement derrick when hurricane winds are expected:

1) Raise the boom as high as possible and allow the boom and mast to "weathervane."

2) Remove the spreader beam from the boom.

3) Fix the mast-tower swivel joint to the tower with bolts or welded lugs.

A duplicate replacement derrick will be erected at the site, with installation commencing January 7, 1980..

Florida Power & Light Company's Quality Control Department had the responsibility to prepare nonconformance reports (NCRs) where damage occurred to completed construction activities (i.e., after concrete placement) or equipment. Table I contains dispositioned NCR's summarizing categories of structural members, types of damage and corrective action to be taken.

Table 2 contains dispositioned NCR's summarizing the equipment damage and corrective action be taken.

IV. CORRECTIVE ACTIONS

Table 3 contains design change notifications (DCN's) which were issued by the Architect/Engineer to repair damaged concrete and reinforcing as determined from visual observations and from the results of the destructive and nondestructive testing programs.

QC Involvement

The procedures utilized to identify damage, evaluate and disposition corrective action are the following:

1) Site Quality Procedure SQP-21 "Corrective Actions"
   - for the handling of NCR's.

The Florida Power & Light Company's Quality Control Department has independently reviewed the damaged areas and issued NCR's to identify damaged areas and equipment. They follow-up the corrective action dispositioned by Engineering and apply the normal testing and inspection requirements for final approval.

In addition to the above normal QC inspection and approval process and documentation, the storm damage team has photographed and mapped the damaged areas to permit additional documentation on the extent of damage.

V. SAFETY IMPLICATIONS

The Chicago Bridge & Iron derrick failure caused significant damage to the Reactor Auxiliary Building structure which required extensive evaluation and repair to establish the adequacy of the structure to perform its intended safety function and meet the criteria and bases stated in the Preliminary Safety Analysis Report. If it were to have remained uncorrected, the structural damage could have possibly affected the safety of operations of the plant.

VI. CONCLUSION

The Chicago Bridge & Iron derrick failure was determined to be a potentially reportable accident on September 4, 1979 and such notification was made to the

VI. CONCLUSION (Cont'd)

NRC Inspection and Enforcement Office the same day. Prior to any repair work or new construction in the affected areas, each area was specifically evaluated for structural soundness and repair measures approved. Adequate documentation on the structural evaluation and repair work is maintained at the site.

As a result of the dispositioned corrective action described above, the damaged portions of the Reactor Auxiliary Building and Reactor Building shield wall have been restored to original structural soundness.

Table 1

Dispositioned Concrete NCRs

Issued NCRs	Categories Covered by NCR	Type of Damage	Corrective Action
830C	Interior wall and projecting reinforcing	Bent rebars	Rebend rebars to original positions
831C, 841C, 845C, 846C, 848C, 850C	Columns, walls and projecting reinforcing	Spalled concrete and bent rebars in walls and columns	Chip concrete back 1'-6, cut off damaged rebars and mechanically splice rebars
835C	Wall and projecting reinforcing	Cracked concrete and bent rebars	Chip back 1 ft into sound concrete and mechanically splice rebars
832C	Columns and projecting reinforcing	Bent rebars	Chip concrete back to specified elevation for full rebar lap splice and install new rebars.
833C	Columns and projecting reinforcing	Cracked near floor level	Chip concrete column and replace damaged reinforcing
836C	Reactor Shield Building and projecting reinforcing	Microcracking at top of wall, and bent rebars	Chip back 1 ft into sound concrete and mechanically splice rebars.
834C	Slab, beams and girder at Elevation +62 feet (RAB)	Concrete microcracking and damaged rebars	See DCN 550.203 and 513.609
851C, 860C	Beams at Elevation +43 feet (RAB)	Superficial surface cracks.	None
870C	Exterior Wall (RAB)	Superficial surface cracks.	None
842C	Slab and girders at Elevation +43 feet (RAB)	Cracked concrete and bent rebars	Chip concrete and lap splice slab rebars and mechanically splice girder rebars.

Table 2

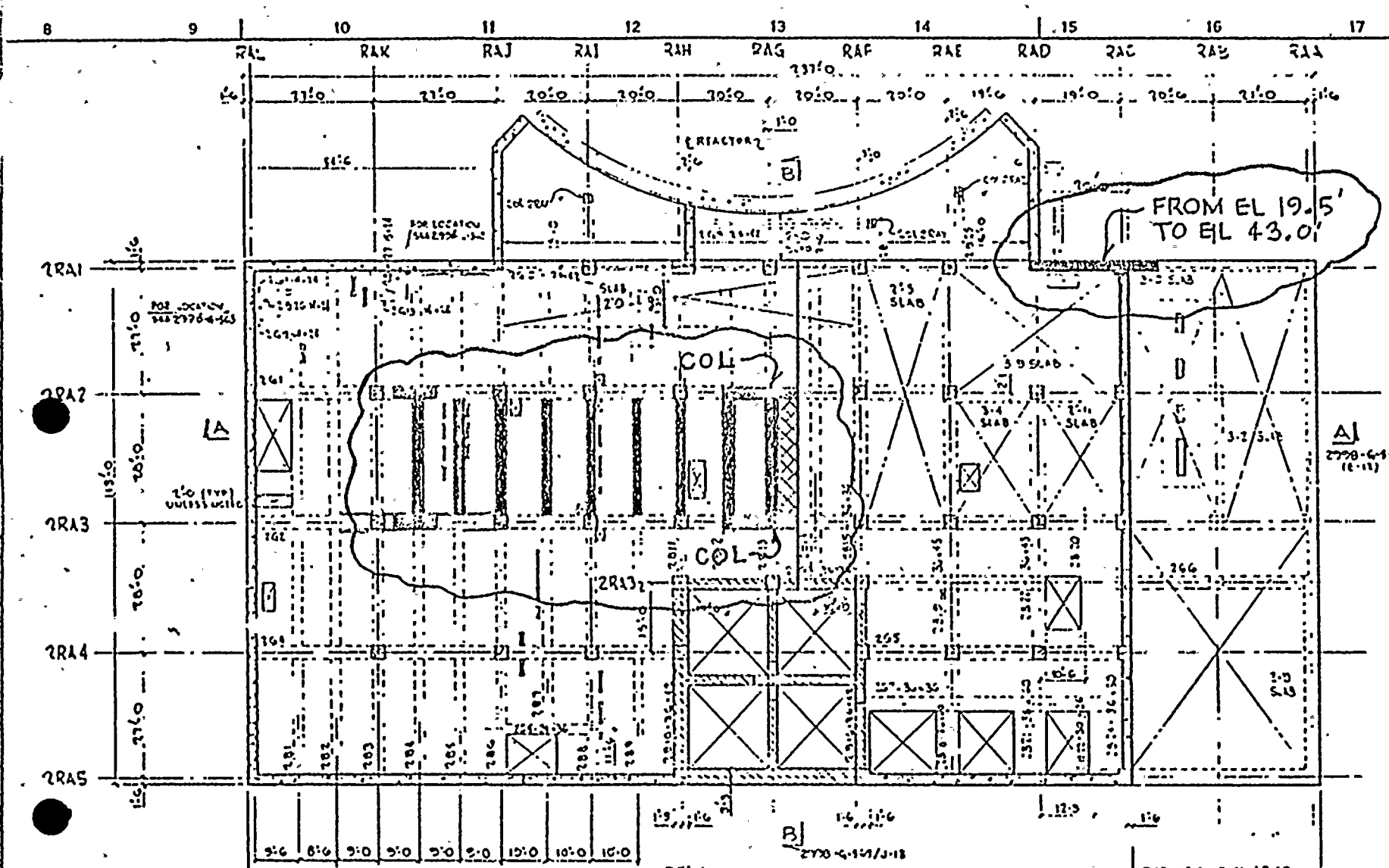
Dispositioned Electrical NCRs

Issued NCRs	Equipment Covered by NCR	Disposition
839E 840E	Conduits on Elevation +62 feet	Remove damaged conduit and replace with new
838E	Electrical Equipment	Scrap and replace
837E	Cable tray restraints on Elevations +43 feet and +62 feet	Two restraints are to be repaired by Construction to within AISC tolerances. Balance to be scrapped.

Table 3

Concrete DCNs

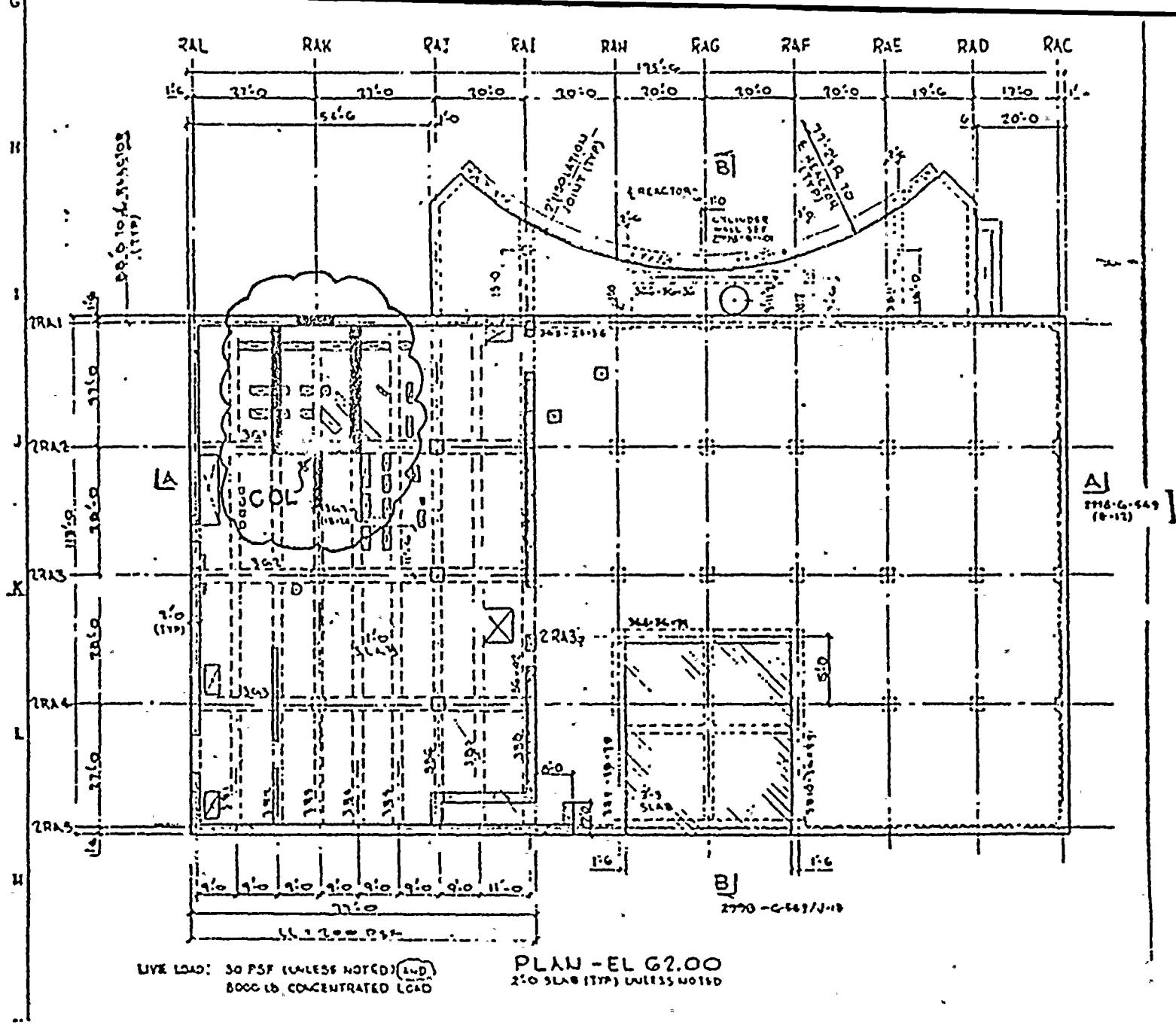
Issued DCNs	Categories Covered by DCN	Type of Damage	Corrective Action
550.203 513.609	Slab, beams and girder at Elevation +62 feet (RAB)	Concrete microcracking and damaged rebars	Remove concrete and rebars, and lap splice and mechanically splice as specified.
550-208	Wall (RAB)	Concrete microcracking	Chip back into sound concrete as specified
550-207	Slab Elevation +43 feet (RAB)	Cracked concrete and damaged rebars	Remove concrete and rebars, and splice as specified.



LIVE LOAD: 200 PSF AND 8000 LD CONCENTRATED LOAD

PLAN - EL 43.00 UNLESS NOTED

EBASCO SERVICES INCORPORATED		
DIV. ____ DR. ____ DATE ____ CH. ____ SCALE ____	APPROVED	FIG. 1 REACTOR AUXILIARY BUILDING LOCATION OF PULSE ECHO TESTING



PLAN - EL 62.00
2'-0 SLAB (TYP) UNLESS NOTED

EBASCO SERVICES INCORPORATED		
DIV. ____ DR. ____ DATE ____ CH. ____ SCALE ____	APPROVED	FIG. 2 REACTOR AUXILIARY BUILDING LOCATION OF PULSE ECHO TESTING