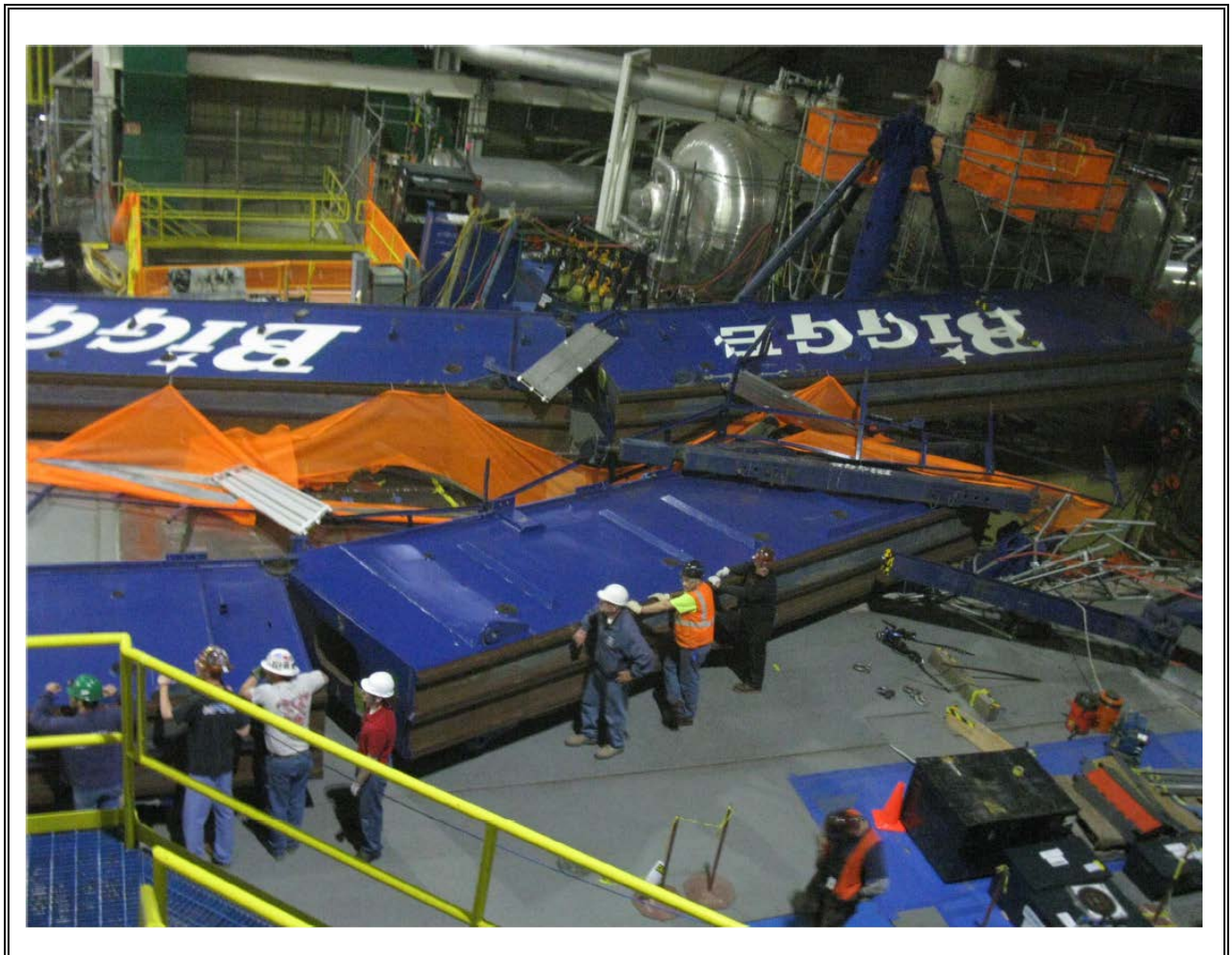


# INVESTIGATION OF THE MARCH 31, 2013 TEMPORARY OVERHEAD CRANE COLLAPSE AT ARKANSAS NUCLEAR ONE POWER PLANT IN LONDON/RUSSELLVILLE, AR

---

U.S. Department of Labor  
Occupational Safety and Health Administration  
Directorate of Construction

August 2013



**INVESTIGATION OF THE MARCH  
31, 2013 TEMPORARY OVERHEAD  
CRANE COLLAPSE AT ARKANSAS  
NUCLEAR ONE POWER PLANT IN  
LONDON/RUSSELLVILLE, AR**

August 2013

This report was prepared by  
Mohammad Ayub, P.E., S.E.  
Directorate of Construction

Contributions to this report made by  
Scott Jin, Ph.D., P.E.  
Directorate of Construction

Carlos M. Reynolds, Area Director  
Roosevelt Shavers, Assistant Area Director  
Little Rock Area Office, AR

**TABLE OF CONTENTS**

	Page
Background	5
The Project	6
The Incident	11
Structural Analysis	14
Load Test	19
Fall Zone	20
Field observation of the retrieved structural members	22
Conclusions	28

## LIST OF FIGURES

Figure 1	Isometric view of crane supporting structure
Figure 2	Runway girders being erected
Figure 3	Lifting in progress
Figure 4	Detail drawing of lateral brace
Figure 5	Lateral brace installed
Figure 6	Section drawing of the north frame
Figure 7	North frame being erected
Figure 8	Runaway girders after the collapse
Figure 9	Stator looking west
Figure 10	Stator looking east
Figure 11	Southeast pedestal remains standing
Figure 12	Stator looking west
Figure 13	NE column and west girder
Figure 14	3D Model
Figure 15	Displacements
Figure 16	Omnidirectional pin at base of column
Figure 17	Looking south
Figure 18	Looking east
Figure 19	ANO Stator replacement lift plan letter
Figure 20	ANO Stator replacement lift plan (attachment)
Figure 21	General view of the recovered structural members in the storage yard
Figure 22	Bottom pin of lower NW column
Figure 23	Lower NW column
Figure 24	Lower NW column
Figure 25	Top connection of the lower NW column
Figure 26	Close-up of lower NW column
Figure 27	Close-up of lower NW column
Figure 28	Lower connection of the NW column
Figure 29	Close-up of the lower upper
Figure 30	Top pin connection of the upper NW column
Figure 31	Upper connection of the lower NE column
Figure 32	Lower connection of the upper NE column
Figure 33	Close-up view
Figure 34	Close-up view
Figure 35	Foot beam
Figure 36	East end of the top header beam
Figure 37	West end of the top header beam

**Background:**

An incident occurred on March 31, 2013 inside the turbine building of Unit 1 at the Arkansas Nuclear One power plant in London/Russellville, AR. The Arkansas Nuclear One plant has two units, e.g., Unit 1 and Unit 2. Unit 1 generates 836 megawatts, and Unit 2 generates 987 megawatts of electricity. These units run continuously at maximum capacity, and provide a significant portion of Arkansas's electricity needs. However, these units are occasionally shut down for re-fueling, called refueling outage. These outages are well planned in advance, and such outages provide opportunities for some maintenance work.

During the refueling outage of Unit 1 scheduled for March 2013, it was pre-planned to replace the turbine stator located in the turbine building with a replacement one. As the stator weighed over a million pounds, it required considerable planning. A temporary overhead crane had to be erected to move the stator from its location to the train bay for hauling it away, and then to bring in the new stator. While the old generator stator was being removed and transported to the trailer deck, the temporary overhead crane supporting the old stator suddenly failed and collapsed, killing an employee. Eight other employees were injured.

The Occupational Safety and Health Administration's (OSHA) Regional Administrator, Region VI asked the Directorate of Construction (DOC), OSHA National Office in Washington, DC for technical assistance in the investigation of the incident, and to determine if OSHA and other industry standards had been violated, and to determine the cause of the collapse. A structural engineer visited the incident site on April 7-11, 2013 to observe the failure and obtain necessary documents to conduct a forensic examination. Later, another structural engineer from DOC visited the storage yard on June 4-6, 2013 where the retrieved structural members were laid out for closer examination and to take measurements and photographs.

Construction documents, specifications and contractual papers were obtained from key contractors. OSHA's Little Rock Area Office was highly instrumental in obtaining the documents and arranging the interviews. This report would not have been possible without assistance and co-operation of the Area Office.

The following is our report.

**The Project:**

The following were the key players:

1. Entergy Arkansas, Inc.: Owner of the Arkansas Nuclear One plant in London/Russellville, AR
2. Entergy Operations, Inc.: Agent for Entergy Arkansas, Inc., and Operator of the nuclear power plant.
3. Siemens Energy, Inc.: Sub-contractor of Entergy Arkansas, Inc.
4. Bigge Crane and Rigging Co.: Sub-contractor of Siemens Energy, Inc.
5. DP Engineering, Ltd.: Independent contractor retained by Entergy Arkansas, Inc.

The following documents were obtained:

1. Drawings prepared by Bigge pertaining to the temporary overhead crane.
2. Structural computations of the temporary overhead crane performed by Bigge.
3. Contractual papers from Siemens.
4. Contractual papers from Entergy.
5. Photographs and video from Entergy.
6. Photographs from Siemens

On March 31, 2013 at approximately 7:45 a.m., a temporary overhead crane collapsed in the turbine building of the Unit 1 of the Arkansas Nuclear One (ANO) plant in Russellville, AR. At the time of the incident, the unit was in a refueling mode (aka outage), and was, therefore, not in operation. As a result of the incident, there were no radiological releases as the unit was already shut down. The adjoining Unit 2, however, was in full operation at the time of the incident. The incident which occurred in Unit 1 created an offsite power outage in Unit 2 which automatically went into shutdown mode. Emergency diesel generators immediately restored power to the necessary switchgears in Unit 1 and Unit 2. As a result of the incident, one worker was killed, and eight others were injured.

The refueling outage of Unit 1 was planned ahead of time in 2011. It was decided to remove the aging primary generator stator of Unit 1, and replace it with a replacement one during this planned outage. The old stator, approximately 16 ft. in diameter and 39 ft. long, weighed some

525 tons, and had to be hoisted and moved approximately 80 to 100 feet, and then slowly lowered 29 ft. to the trailer deck for transportation outside the plant. To hoist such heavy equipment, a temporary overhead crane had to be erected inside the turbine building, see figure 1. In the early hours of March 31, 2013, the old stator was successfully rigged and was near its final destination, when the crane with its massive runway girders and supporting structural frame suddenly collapsed, and fell towards the west.

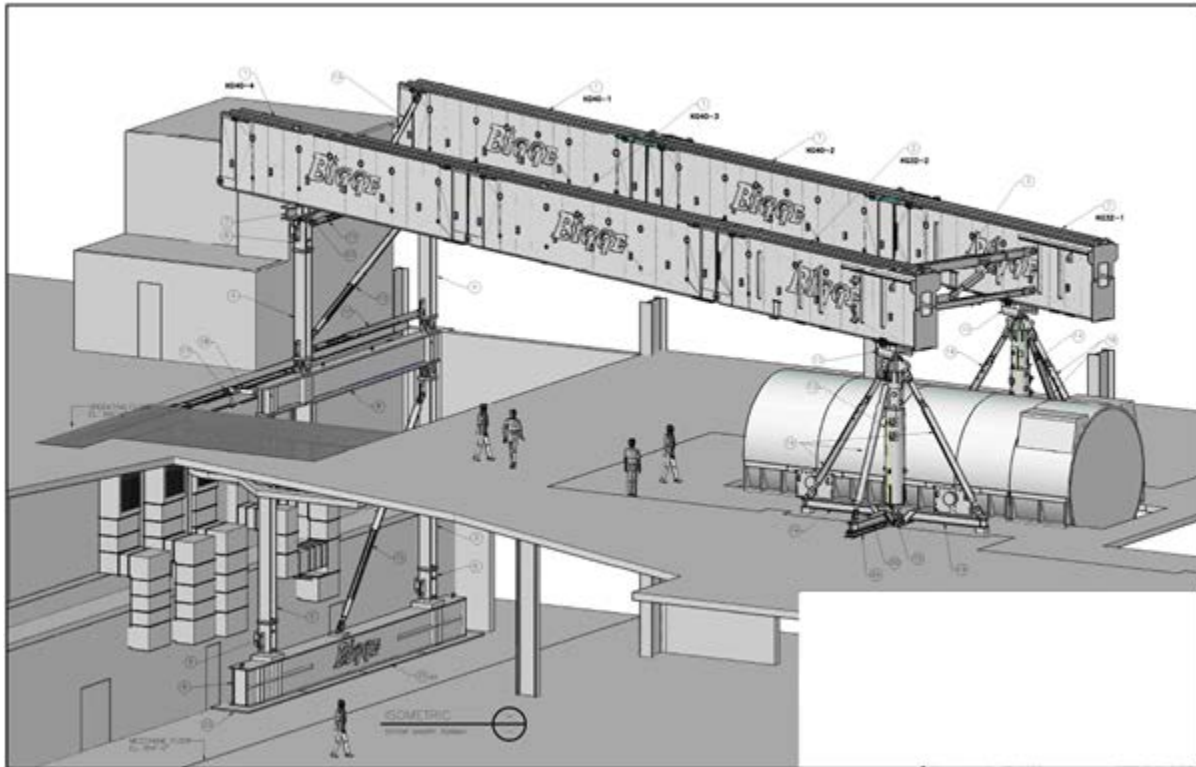


Figure 1 – Isometric view of crane supporting structure (from Bigge)

Entergy Corporation of New Orleans, LA owns and operates power plants across the United States, and delivers retail power to industrial and residential customers. Entergy Arkansas, Inc. (Entergy) owns Arkansas Nuclear One in Russellville, AR which has a license from the Nuclear Regulatory Commission to operate it since 1974. Entergy Operations, Inc. is an agent of Entergy Arkansas, Inc. Entergy decided to replace the primary generator stator of Unit 1 and retained Siemens Energy, Inc., (Siemens) to perform the work, and signed an “alliance agreement” in June, 2012. The scope of work for Siemens included a host of other associated items necessary to accomplish the removal and replacement of the stator. Entergy specifically stated in the

agreement that “Entergy will be responsible for the engineering evaluation and approval of the proposed haul path including train bay floor”. It further stated that Entergy will review and accept the Siemens contractor’s engineering deliverables for the turbine building floor loading areas supporting the stator swap, including the generator’s pedestal, and staging area of the overhead crane, etc. Entergy, however, did not clearly state that it would review Siemens contractor’s engineering drawings for the overhead cranes and its supporting structures. However, in another section, the agreement states that “Siemens will allow Entergy to view drawings, calculations, internal specifications, installation work packages, etc., at a mutually agreed upon time and location”.

Regardless of the above stipulations, Entergy retained DP Engineering, Ltd., of Fort Worth, TX who have acknowledged to OSHA they reviewed the design and calculations performed by Bigge on behalf of Entergy. Additional reviews were conducted by Entergy’s own engineer. Siemens forwarded the following documents to Entergy “*for Entergy’s review and approval*” on September 12, 2012:

- Heavy Lift Gantry Calculations
- Stator Gantry Lift Drawings
- Strand Jack and Trolley Drawings
- Stator Gantry Runway Drawings
- Stator Lift Rigging Drawings
- Gantry Assembly Drawings

Siemens issued a purchase order to Bigge Crane and Rigging, Inc. (Bigge) of San Leandro, CA in July 2012 for engineering, supervision, labor and equipment to handle the old and replacement stators during the refueling outage of Unit 1 scheduled for spring, 2013. Bigge is well-known for heavy lifts and had worked as a subcontractor in other nuclear power plants for similar lifts and stator exchange projects. Bigge had submitted a proposal to Siemens outlining how they proposed to handle the stator, and the method and means to transport the stator out of the building. They assured Siemens that air handling ducts on the north side did not have to be relocated as they intended to off-set the column to clear the ducts. Bigge started the project in earnest providing all necessary documents to Siemens, and from Siemens to Entergy for their



review and approval. Bigge produced structural calculations of the overhead crane, sketches and drawings for the same, erection/dismantle sequence with step-by-step instructions for the manner in which the stator exchange program was to be undertaken.

Entergy had retained DP Engineering Ltd., (DP) as an independent contractor in 2000. DP's role in the current stator exchange project was to review, examine, and advise Entergy of engineering issues in the work performed by other contractors.

The project essentially consisted of rigging the stator weighing over a million pounds, moving it slowly to the train bay 90 feet away, and rotating it approximately 45 degrees before carefully lowering it 29 ft. to the trailer deck to be hauled away, see figures 2 to 7. To install the new stator, the same steps will be taken in the reverse order.



Figure 2 - Runway girders being erected

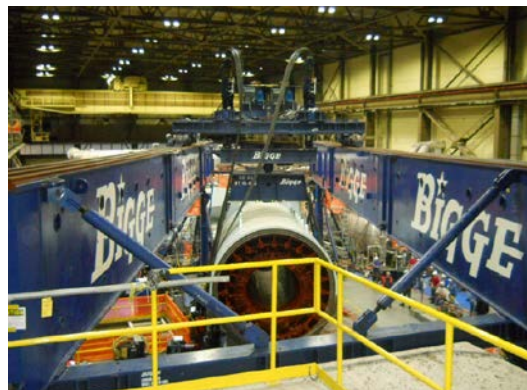


Figure 3 - Lifting in progress

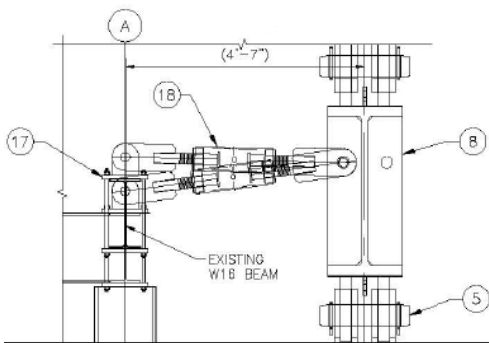


Figure 4 - Detail drawing of lateral brace (from Bigge)



Figure 5 - Lateral brace installed

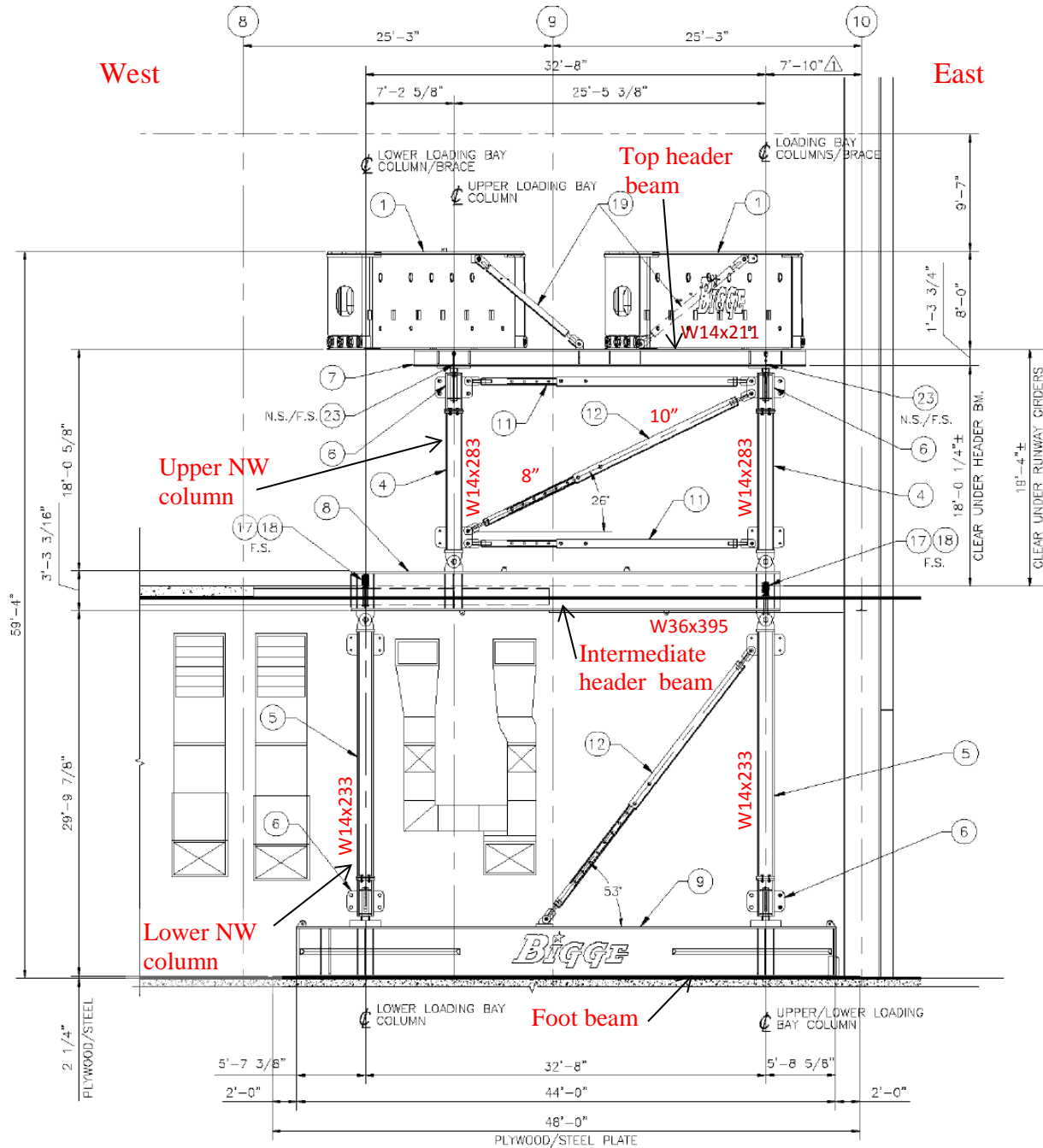


Figure 6 – Section drawing of the north frame (from Bigge)



Figure 7 – North frame being erected

**The Incident:**

The structural engineer of Bigge who designed the overhead crane arrived at the plant approximately a week before the actual lift. A majority of the structural components used in the overhead crane have been around for many years as they have been used in similar lifts at other locations. Those components were shipped to Russellville, AR for assembly. Only two structural members were fabricated specially for this project. The final erection of the temporary overhead crane began on the evening of March 30, 2013 and was completed in the early hours of March 31, 2013.

The first attempt to rig the stator began sometime between 3:00 to 4:00 a.m. on March 31, 2013. It took at least two or three attempts before the stator was finally balanced over the points of support, and was off the ground. Before the rigging began, the two lateral supports of the intermediate header beam, as per Bigge's erection instructions, were removed. Entergy had retained Precision Surveillance Corporation (PSC) to remove the guard railings, among other things, which were in the path of the stator's scheduled movement. First, all railings were supposed to be removed before the hoisting of the stator, then Bigge decided to let some of the railings remain in place, as they thought they would be able to work around them. When the stator was hoisted, and was being moved, it was realized that the railing at the train bay had to be removed. PSC employees were called in to remove the railings while the crane was moving the stator. As the PSC employees were stepping away from the railings after the railings were

removed, the crane failed and fell onto the deck, killing one of those PSC employees who just removed the railing, see figure 8.



Figure 8 – Runaway girders after the collapse

The actual movement of the stator began approximately 6:40 a.m. The stator was moved for approximately an hour when it reached within a few feet of the final destination when the stator was to be rotated. At approximately 7:50 a.m., the crane collapsed towards the west, crashing the two 8 foot deep girders on the turbine deck, with all the north supporting frames twisted and intertwined with the stator which partially dropped into the train bay, see figures 9, 10 and 13.



Figure 9 – Stator looking west



Figure 10 – Stator looking east

One fatality occurred, but the incident had a potential of much greater catastrophe. Eight workers were injured.



An employee of PCS reported that that he heard a loud “pop like a gunshot” immediately before the collapse. Another person, a technician working for another company also reported to have heard similar pop sounds twice, once when the stator was lifted, and another just before the incident. Possible explanations of such sounds will be discussed later.

The two blue gantry girders fell towards the west. The girders consisted of three segments which remained connected to each other at the bottom flanges with the pins, while the top compression flanges separated as they were not positively connected to each other. The girders sustained little damage. The southeast pedestal remained standing while the southwest pedestal fell into the pit, see figure 11. Most of the damage occurred on the north frame supporting the gantry girders. The stator fell into the train bay.

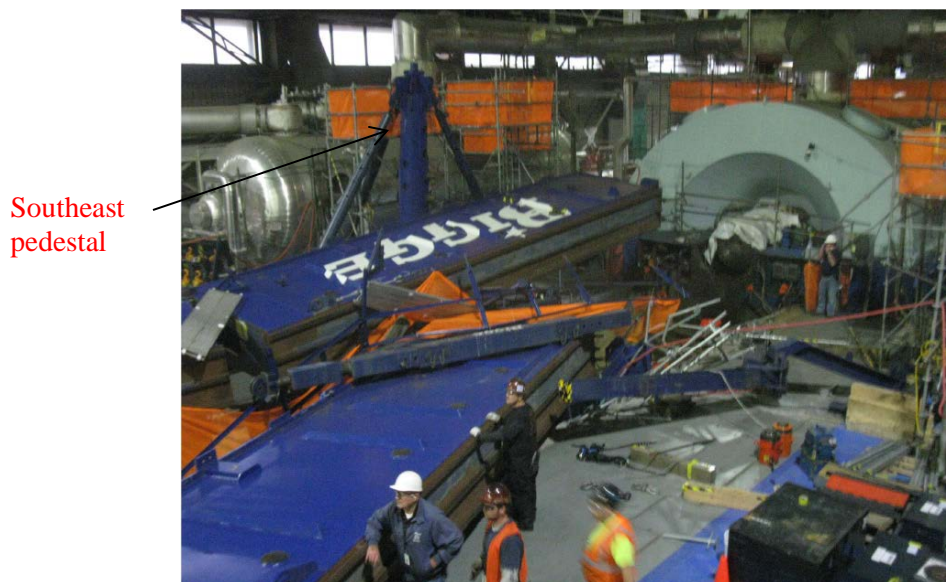


Figure 11 – Southeast pedestal remained standing

The upper connection of the lower northwest column to the intermediate header beam bottom flange failed at the welds. The lower pinned connection of the lower northwest column to the foot beam was intact except it jumped out of its socket, and was lying flat. The stator fell over the lower northwest column creating a sharp bend, see figure 12.

The upper northwest column remained intact except that the welded connection to the upper flange of the intermediate beam failed similarly to the failed welded connection of the lower northwest column. The northeast columns remained intact except that at the junction of the

intermediate header beam, the columns rotated through the pin but remained straight, and were not damaged. The upper header beam also remained undamaged. See, figures 12 and 13, below with all fallen members identified.

A review of the video capturing the collapse clearly showed that the failure initiated at the northwest corner of the north frame. The west girder dipped at the northwest corner initiating the collapse.

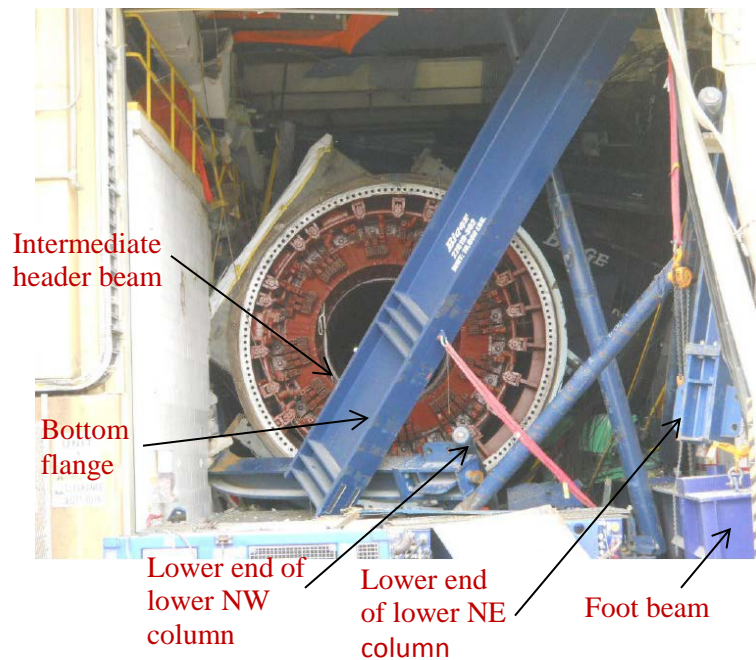


Figure 12 – Stator looking west

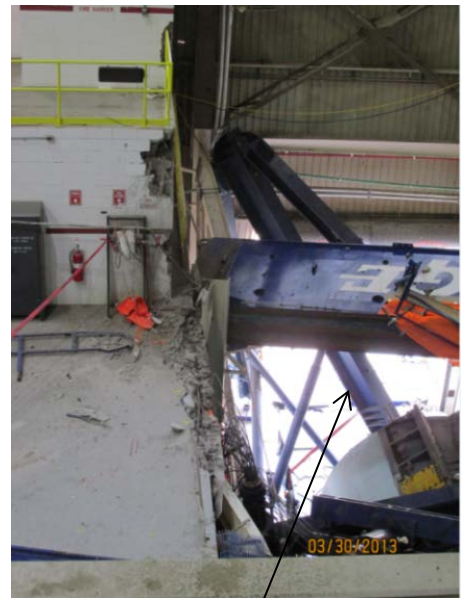


Figure 13 – NE column and west girder

### **Structural Analysis:**

We ran a three-dimensional structural analysis using the commercially available program STAAD.Pro V8i. Our analysis indicated that the failure initiated at the lower NW column essentially due to instability as the top of the column underwent increasing lateral displacements in the N-S direction.

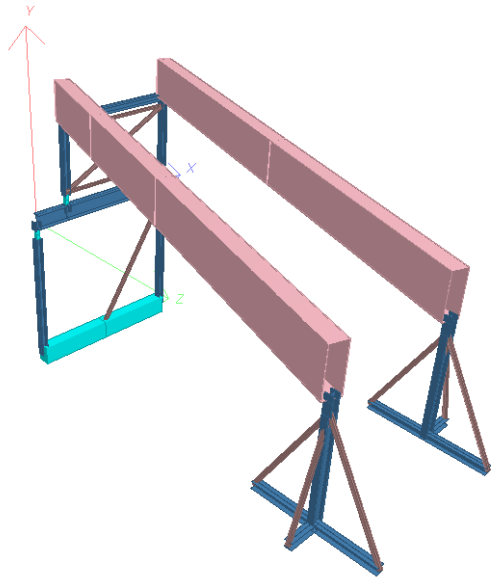


Figure 14 – 3D Model

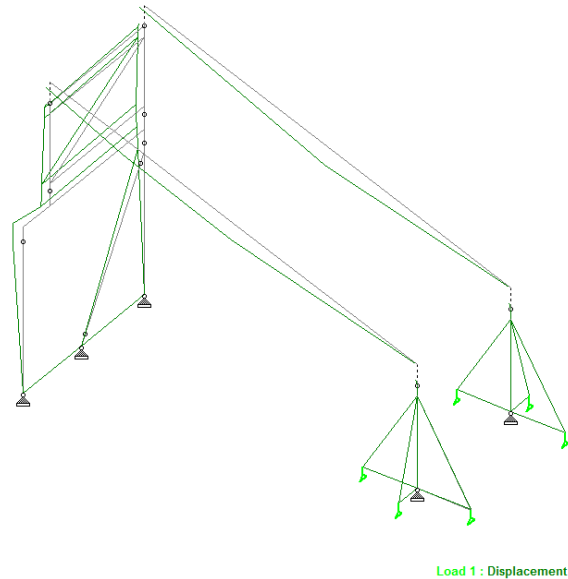


Figure 15 – Displacements

The lower NW column and the other two columns, i.e., upper NW column and the NE column were not braced in the N-S direction either by any diagonal braces or any horizontal struts at the intermediate header beam level. At the specific instruction of Bigge, the horizontal struts were removed before the hoisting began, rendering the NW column unstable. See, erection/dismantle procedure, below. The NE column and the upper NW columns were, however, braced in the N-S direction at the level of the top header beam due to the presence of braces at the pedestal columns at the far south end of the overhead crane. All the columns were adequately braced in the E-W direction, see figure 6. The lack of bracings of the north columns in the N-S direction at the level of the intermediate header beam proved to be highly consequential and eventually became the cause of the collapse. We will examine the north columns and the intermediate header beam in detail. This was a serious structural design flaw responsible for the collapse of the overhead crane.

Lower NW column:

The column was W14x233, approximately 24'-7" high between pins. The bottom of the column was a true pin which was omni-directionally placed over the foot beam which is rarely seen in industrial buildings. The top of the column was connected to the intermediate header beam by a joint that acted as a pin in the E-W direction, and the diagonal bracings provided full

translational restraint to the joint in the E-W direction. In the N-S direction, however, the joint had freedom of translation because of the lack of any bracings or any horizontal strut, and also had limited rotational freedom. Due to the displacement of the joint at the top of the NW column in the N-S direction, the column was subjected to flexural moment which needed to be balanced by an equal and opposite moment in the intermediate beam producing torsion on the beam. The intermediate header beam was sized as W36x395 which had more than adequate strength to resist torsion although it was not a closed section. This torsional moment on the beam will, however, induce stresses to the welds of the 2" plates connected to the bottom flange of the intermediate beam. The larger the displacement of the joint, the greater will be the flexural moment, and the torsion, and thus the stresses will be greater on the welds until they fail. The larger displacements were created by the instability of the NW column joint at the top. Our P-delta analysis showed that the convergence was not easily achieved until large displacements had occurred, essentially indicative of instability. The welds were vulnerable to failure under increasing torsional moment due to increasing displacement of the top of the column. Physical examination of the retrieved structural members indicated that the welds had indeed failed due to higher stresses. Figures 15 and 25 shows a simplified version of how the intermediate beam is subject to torsion. At least two employees reported to have heard "pop like gunshot sounds" just before the incident, possibly during the failure of the welds.

Considerable thought was also given to determine the buckling load of the column, and its effective unbraced length. A minimum K factor of 2.0 was recommended by the American Institute of Steel Construction (AISC) on the premise that the bottom of the column was pinned and the top was fixed but free to translate as was the case in this instance. In fact, the AISC cautions that the real K value could even be higher than 2.0 if the bottom was a true pin as was the case in this instance. AISC in its ninth edition commentary states that "*If the column base in Case f of Table C-C2.1 were truly pinned, K would actually exceed 2.0 for a frame such that pictured in Fig. C-C2.1, because the flexibility of the horizontal member would prevent realization of full fixity at the top of the column*". In this instance, the top of the column was not fully fixed anyway due to the manner in which the joint was detailed.



As the stator was near its final position, it is estimated that the actual loads on the column were of the order of 526 kips without considering any load factors. If a K factor of 2.4 is considered, buckling could occur.

Upper NW Column:

This column, 16'-4" long between the pins, was W14x283, and was connected with a pin (effectual in the E-W direction) to the top flange of the intermediate beam and connected to the top header beam with a true pin which was omni-directional. See figures 16 to 18.



Figure 16 – Omnidirectional pin at base of column

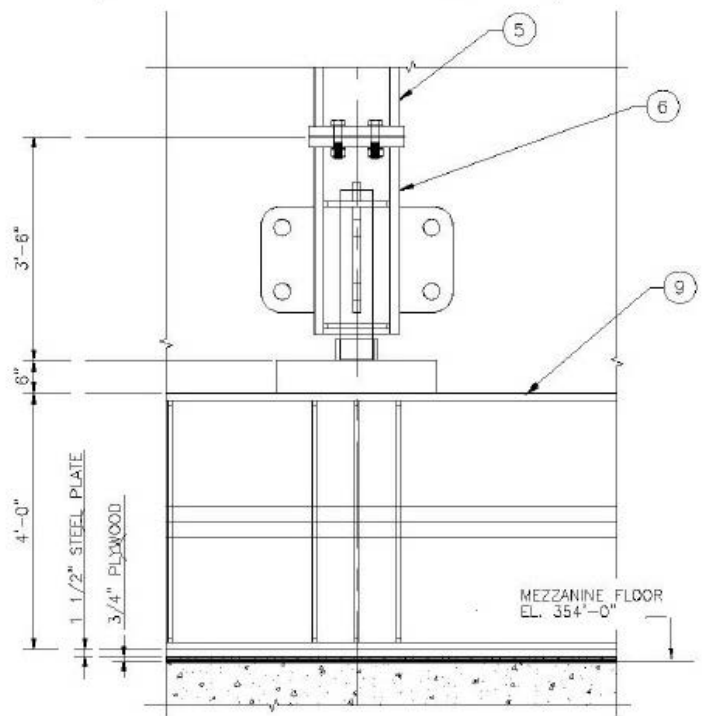


Figure 17 – Looking south (from Bigge)

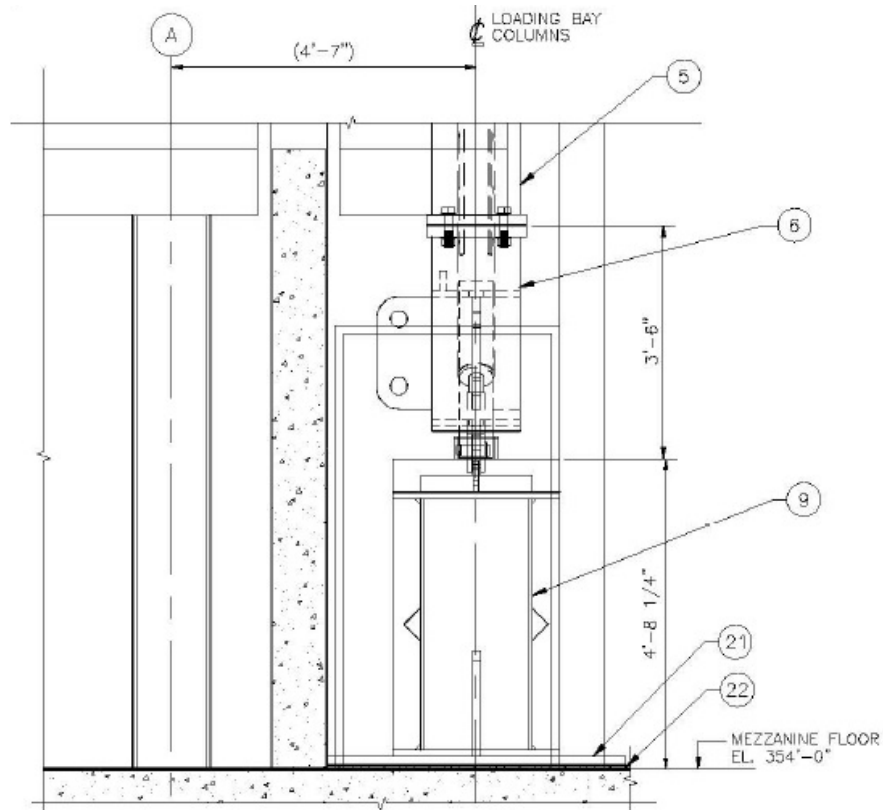


Figure 18 – Looking east (from Bigge)

The bottom connection of the upper NW column was identical to the connection of the top of the lower NW column. The bracings provided translational restraint in the E-W direction, but there were no bracings provided to the column in the N-S direction. Our finite element analysis indicated that the lateral translation at the bottom of the column in the N-S direction was comparable to the top of the lower NW column. The increasing translation created flexural moment in the column which would, in turn, produce torsion in the intermediate header beam, except that the torsion would be in opposite direction to the torsion produced by the lower NW column, but would not be equal in magnitude because of the greater load carried by the upper NW column. Similar to the situation in the lower NW column, the torsion in the column would produce stresses in the welds which would increase with the increasing displacements until they failed. If the lower NW column failed first, as it is believed, then the welds at the upper NW column would be subject to greater stresses until failure. The intermediate header beam would be adequate to resist torsion.

### NE Column:

The NE column was 45'-8" between pins at the foot beam and the top header beam. The column was divided in two parts. The lower column was identical to the lower NW column, connected to the foot beam with a true pin which was omni-directional, and connected to the top intermediate header beam with a pin effectual in the E-W direction. The upper NE column was also identical to the upper NE column with a pin at the bottom effectual in the E-W direction, and with a true pin at the top. Our analysis indicated that the middle joint of the column was subject to lateral translations in the N-S direction because of the lack of any restraint against movement provided by either any strut or bracings. The displacements would produce moments in the upper and lower columns which would be equal and opposite in nature. This will not produce any torsion in the intermediate beam. As the moments in the upper and lower columns were equal and opposite in magnitude, welds connecting the plates to the beam flanges would be spared of any torsional stresses, and thus the connections survived the collapse.

### Load Test:

OSHA's standard 1926.1438 entitled "Overhead & Gantry Cranes" refers the temporary overhead cranes to OSHA's standard 1910(k) which requires (i) operational tests, and (ii) rated load tests. It states that "***Test loads shall not be more than 125% of the rated load unless otherwise recommended by the manufacturer. The load test reports shall be placed on file where readily available to appointed personnel***". The load test was never performed in violation of the above OSHA's standard.

Entergy Nuclear Management Manual EN-MA-119 addresses the temporary hoisting assemblies. It states that "***the assembly shall be designed for at least 125 percent of the projected load and should be load tested and held for at least five minutes at 125 percent of the actual load rating before initial use. The assembly shall be load tested in all configurations for which it will be used.***" This was not done.

Bigge addressed the question of load test in its letter of February 8, 2013 signed by Mr. Frederiksen, PE, who was an employee of Bigge at the time. Mr. Frederiksen argued in his letter that: "***This hoist assembly has been used at other electric power stations to lift components that exceed the anticipated weight of the unit 1 stator. That loading history is documented in the***

*attachment and may be used in lieu of a load test (per EN-MA-119 rev 15 Section 5.2(7))*". The letter and its attachment are reproduced below. The letter does not address OSHA's requirements of a load test. Although the letter was addressed to Siemens, it is our understanding that DP engineering and Entergy also received the letter at a later date. The attachment lists nine items out of which the upper columns (item 4) and the intermediate Header (item 8) are listed as "New": the rest of the items had been employed in previous successful lifts at other locations. We do not have in our possession any formal response by either Siemens, Entergy or DP Engineering on the question of the load test. It is obvious that Siemens, DP Engineering and Entergy tacitly concurred with Bigge's rationale of not conducting the load test, as representatives of the companies were present on the day of the incident when the load was being rigged without any load test.

Bigge's argument that "loading history" could be substituted for an actual load test has little merit because the configuration of the supporting frame of the temporary overhead crane was not identical to the previous lifts, and, therefore, the previous loading lifts could not be relied upon. Besides, there were at least three new members which had not been tested in an actual load test. The configuration of the temporary overhead crane at ANO was unique, particularly on the north side, because the lower north-west column was not braced in the north-south direction. This absence of the brace became even more critical as Bigge removed the lateral braces of the intermediate header beam before the rigging of the stator. The lateral braces of the intermediate header beam, although not a substitute for the diagonal brace of the column, would provide a degree of stability to the column.

### **Fall Zone**

After reviewing video and photographs, it is clear that employees, some of whom were bystanders observing the lift, were not kept away from the travel path and fall zone during the Stator movement. Therefore the incident could have been catastrophic involving many lives. If the load had fallen on the concrete slab, it would have disastrous consequences, in particular because no load test was performed. This could have been mitigated if a clear fall zone was ear marked, and all employees, not directly involved in the lift, were asked to stay clear of the crane and the load. OSHA standard 1926.1425 was violated.



February 8. 2013

Siemens Energy  
4400 North Alafaya Trail  
Orlando, FL 32826

Attention: Pat Safran  
patrick.safran@siemens.com

Subject: ANO Stator Replacement Lift Plan

Bigge will use a temporary hoisting assembly to lift and move the existing stator out of the turbine building and the replacement stator to the turbine/generator pedestal. This temporary hoisting assembly has been analyzed by Bigge's calculation # 27619-C1 dated 9/12/2012 for the loads from the ANO Unit 1 Stator. The design drawings, including material specifications, is shown on Bigge drawings DWG # 001 Sheets 1-5, DWG # 010 Sheets 1-3, DWG # 020 Sheets 1-4, DWG # 030 Sheets 1-5, DWG # 050 Sheet 1, DWG # 070 Sheets 1-2, DWG # 090 Sheets 1-5, DWG # 091 Sheets 1-4, DWG # 092 Sheets 1-2.

This hoist assembly has been used at other electric power stations to lift components that exceed the anticipated weight of the unit 1 stator. That loading history is documented in the attachment and may be used in lieu of a load test (per EN-MA-119 rev15 Section 5.2[7] NOTE). These proof loads on the individual assembly components range from 103% to 162% of the anticipated ANO unit 1 stator loads.

Safe lifting Capacity of Assembly 577 TONS

Regards,



Claus Frederiksen, PE  
Bigge Crane & Rigging Co.

Figure 19 – ANO Stator replacement lift plan letter (from Bigge)

**ANO STATOR REPLACEMENT PROJECT**

**Structural Component Load History**

<u>Item</u>	<u>Description</u>	LOAD	MAXIMUM	<u>JOB</u>
		<u>AT ANO</u>	<u>PREVIOUS LOAD</u>	
1	Jacking Beams (Item 6, Drawing 10)	525 Kips	662 Kips	McGuire
2	Trolley Beams (Item 1, Drawing 10)	1049 Kips	1324 Kips	McGuire
3	Girders (Item 1 & 2, Drawing 30) -	1049Kips@95' span	1150 Kips@105' span	Surry Unit 2
4	Pedestal Columns (Item 13, drawing 30)	677.3Kips	700 Kips	Ravenswood
5	Upper columns (Item 4, Drawing 30)	636.3 Kips	New	
6	Upper columns (Item 6, Drawing 30)	636.3 Kips	1031.7 Kips	McGuire
7	Intermediate Header (Item 8, Drawing 30)	636.3 Kips	New	
8	Lower Column (Item 5, Drawing 30)	721.3 Kips	1031.7 Kips	McGuire
9	Lower Column (Item 6, Drawing 30)	721.3 Kips	1031.7 Kips	McGuire

Figure 20 – ANO Stator replacement lift plan (attachment, from Bigge)

**Field observation of the retrieved structural members:**

On June 4, 2013, a structural engineer from the Directorate of Construction, OSHA National Office visited the secured yard, under 24-hour guard, where the structural members recovered from the incident site were stored. The purpose of the visit was to visually observe and examine the failed members of the overhead crane, and make notes which could later aid in causal determination. The following members were examined which were laid out in the yard in a logical and sequential manner, see figure 21.

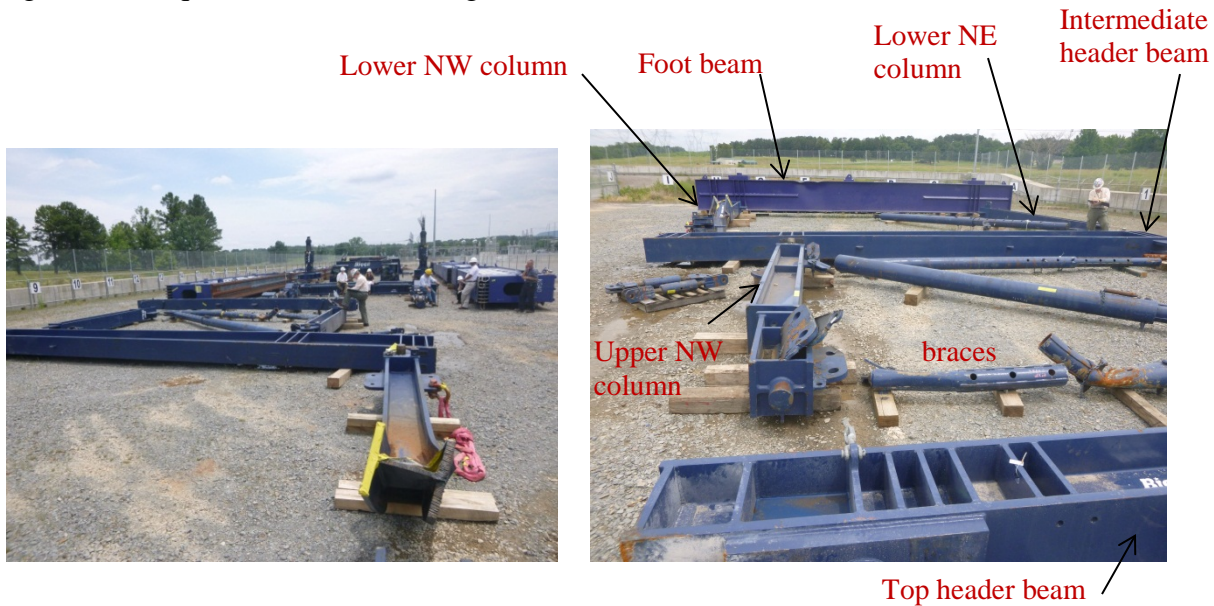


Figure 21 – General view of the recovered structural members in the storage yard

The engineer took some measurements to verify the as-built conditions compared to the designed conditions.

- Lower and upper NW columns
- NE columns
- Foot Beam
- Intermediate and top header beams
- 8' deep girders
- Trolley beams
- Diagonals
- Pedestal columns

Field measurements indicated that the primary erected structural members were mostly different from the design. The table below indicates the designed sections and the actual sections used:

Member	Designed	Actual
Lower NW Column	W14x211	W14x233
Upper NW column	W14x211	W14x283
Lower NE Column	W14x211	W14x233
Upper NE column	W14x211	W14x283
Intermediate Header Beam	W36x441	W36x395
Top Header Beam	W14x257	W14x211

All columns sizes were changed to higher sizes, perhaps due to their availability and, therefore, did not impact the design. However, the intermediate header beam was downsized which reduced the capacity by approximately 4% but did not contribute to the incident.

Lower NW column:

This was the most damaged structural member, the damage coming from the direct hit by the falling stator. The member had to be cut during the retrieval process. The sharp bend sustained by the upper piece of the column is illustrated in the figure, below. In addition to the bend, the flanges had local deformations as a result of the collapse. The lower true pin was intact, see figure 22 but the upper unidirectional pin welded connection to the bottom flange of the intermediate header beam was sheared off, see figures 23 to 25. The 16" long fillet welds on either side of the two 2 ½" thick plates failed, see figure 26 and 27. The welds connecting the four lower 1½" plates to the top of the column remained intact. The pin was practically undamaged.





Figure 22 – Bottom pin of lower NW column



Figure 23 – Lower NW column



Figure 24 – Lower NW column



Figure 25 – Top connection of the lower NW column



Figure 26 – Close-up of lower NW column



Figure 27 – Close-up of lower NW column



Upper NW column:

The upper column remained intact except that the lower unidirectional pinned connection failed in a manner similar to the lower NW column. The welds connecting the 2 ½” plates to the top flange of the intermediate header beam fractured, see figures 28 and 29. The top true pin remained intact, see figure 30. No remarkable observations were made on the column except those mentioned above.



Figure 28 – Lower connection of the NW column.



Figure 29 – Close-up of the lower upper connection.



Figure 30 – Top pin connection of the upper NW column

Lower and upper NE columns:

The columns were unremarkable. Unlike the NW lower and upper columns, the NE column uni-directional pin connections to the bottom and top flanges of the intermediate header beam did not fail. The connection was undone during retrieval process, see figures 31 and 32.



Figure 31 – Upper connection of the lower NE column



Figure 32 – Lower connection of the upper NE column.

Intermediate header beam:

The beam remained intact and practically without any bow or deformation. The failure of the welds at the lower and the upper flanges could be seen as the welds remained attached to the flanges with a clear separation with the 2 ½” plates, see figures 25 to 27, 33 and 34. Both pins remained intact. No torsional twist or damage was visibly noticeable. The stiffeners were undamaged and the beam survived remarkably well.



Figure 33 – Close-up view



Figure 34 – Close-up view



Foot beam:

The top flange of the 4-ft. deep foot beam sustained local deformations believed to be the result of the collapse but otherwise remained unremarkable, see figure 35. The plates containing the open ended receptacles for the pins sustained no visible damage. Most of the stiffeners were intact.



Figure 35 – Foot beam

Top header beam:

See figures 36 and 37 for the top header beam which was practically undamaged. The plates containing the receptacles for the true pins were intact. Little damage is seen elsewhere.



Figure 36 – East end of the top header beam



Figure 37 – West end of the top header beam

**Conclusions:**

1. The primary cause of the collapse of the temporary overhead crane was the flaw in the structural design of the temporary overhead crane. The structural columns on the north end were not provided with any diagonal braces or lateral ties in the north-south direction at the intermediate header beam level, and thus created instability of the columns. If diagonal braces or lateral ties were provided in the design, this incident would not have occurred.
2. In violation of the OSHA standard, this overhead crane was not load-tested prior to its use in the turbine building. OSHA 1926.1438(b) was violated. Entergy's "Material Handling Program" also called for a load test.
3. Bigge's contention that the load test was not necessary because most of the structural members were used in prior lifts has little merit. The configuration of the structural members was significantly different from other lifts, and, therefore, a load test was required. Besides, a number of components of the supporting frame were new.
4. Bigge designed the overhead crane for 100% of the hook load instead of 125 percent as called for in the Entergy's "Material Handling Program".
5. Entergy's "Material Handling Program" called for nondestructive tests of welds prior to and after the load test. Welds were not tested.
6. Siemens, Entergy and DP Engineering had multiple opportunities to review and question the structural design performed by Bigge, but did not do so.
7. Siemens, Entergy and DP engineering knowingly permitted Bigge to conduct the lift without making sure that Bigge had conducted a load test. Thus, OSHA's standard 1926.1438(b) was violated.
8. DP Engineering Ltd., performed poorly in reviewing Bigge's computations, and failed to question Bigge's structural design. DP also did not question Bigge's incorrect arguments that load test was not required. Thus, OSHA's general duty clause 5(a) (1) was violated.
9. Employees not directly involved in the lift were permitted to stay in close proximity of the load and the crane. Thus OSHA standard 1926.1425 was violated.