Engineering Report No. IP-RPT-09-00011 Rev 0

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Engineering Report Cover Sheet

Engineering Report Title:
Corrosion/Cathodic Protection Field Survey and Assessment of Underground Structures at Indian Point Energy Center Unit Nos. 2 and 3 during October 2008

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Approved by:	Vincent Andreozzi / [signature] Supervisor (Print Name/Sign)	Date:	2/26/09

*: For ASME Section XI Code Program plans per ENN-DC-120, if require

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Engineering Report
Technical Review Comments and Resolutions Form

Engineering Report Number	IP-RPT-09-00011	Rev. 0	Title: Corrosion/Cathodic Protection Field Survey and Assessment of Underground Structures at Indian Point Energy Center Unit Nos. 2 and 3 during October 2008
Quality Related: ☐ Yes ☒ No		**Special Notes or Instructions: None**	

Comment Number	Section/ Page No.	Review Comment	Response/Resolution	Preparer's Accept Initials
No Comments			N/A	

Verified/Reviewed By:	Christopher A. Ingrassia		Date	2/26/09	Resolved By: N/A
Site/Department:	IPEC / System Engineering	Ph. 914-271-7047			Date:

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Prepared for:

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Corrosion / Cathodic Protection Field Survey and Assessment of Underground Structures at Indian Point Energy Center Unit Nos. 2 and 3 during October 2008

Prepared by:

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PCA Job No. 28457
November 10, 2008
Revised December 2, 2008

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I. INTRODUCTION

During the month of October 2008, PCA Engineering, Inc. personnel performed a corrosion/cathodic protection field survey and assessment of the underground structures associated with the Entergy Nuclear Operations Indian Point Unit Nos. 2 and 3 Facility located in Buchanan, New York.

This included a review of site drawings and a site survey. The field survey procedures essentially consisted of structure-to-soil potential measurements, electrical isolation testing, temporary impressed current testing and soil resistivity measurements.

II. SITE DESCRIPTION

The operating systems at the Indian Point Facility consist of Unit Nos. 2 and 3, estimated to be in operation since approximately 1968. The underground piping and structures under consideration as part of this investigation include the following:

- Intake Structure, including sheet piling
- Circulating Water Piping
- Service Water Piping

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II. **SITE DESCRIPTION** (Cont'd)

- Condensate Piping
- City Water Piping
- Underground Diesel Generator Tanks

The majority of the underground piping is reported to be welded carbon steel. The construction specifications called for external coal tar coating or tape wrapped pipe. It is unknown if the piping was inspected for quality and coating holidays at the time of installation. The service water and city water service piping are also reported to be cement lined.

The intake structure consists of a sheet piling wall located on the north and south sides of Unit No. 2 and Unit No. 3. An additional segment of sheet pile wall also extends south of Unit No. 3.

The circulating water piping consists of six (6) 84-inch underground pipes for each of the two units. The service water piping primarily consists of two (2) 24-inch underground pipes with some smaller runs of piping for each of the two units.

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II. **SITE DESCRIPTION** (Cont'd)

An impressed current cathodic protection system was installed during power plant construction for the intake structures and the circulating/service water piping. The majority of these systems have been removed or are out of service, with the exception of that for the intake structure sheet piling associated with Unit No. 2. An impressed current cathodic protection system is also in place for the Unit No. 1 main dock, but is not a part of this investigation. The original cathodic protection design was not based upon providing electrical isolation of the protected underground piping from the unprotected copper grounding grid or other metallic structures (i.e. building steel, aboveground piping, reinforcing steel).

The underground portion of the Unit No. 2 condensate piping is located between the on-grade Condensate Storage Tank and Auxiliary Feed Pump Building and consists of a 12, 10 and 8-inch carbon steel coated pipe. The corresponding lines at Unit No. 3 are aboveground (heat traced, insulated and jacketed).

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II. **SITE DESCRIPTION** (Cont'd)

The applicable portion of the City Water Piping consists of a 16-inch steel cement lined pipe located between the on-grade water storage tank at Broadway and the Air Monitor House. The pipe is then installed within a utility tunnel. The city water piping crosses the Algonquin Gas Pipeline.

The tanks at the Unit No. 2 Diesel Generator Building consist of three (3) 7,700-gallon capacity underground storage tanks. These tanks are mounded and reported to be backfilled with sand. Two (2) underground diesel tanks associated with Unit No. 3 were also investigated. This consisted of a TSC diesel tank and an APR diesel tank. The TSC tank was found to be of sti-P_3 (Steel Tank Institute - corrosion protected) construction and the APR tank was observed to be located in a concrete vault.

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III. TEST PROCEDURES

Pipe-to-soil potential measurements were obtained using a Fluke Model 77 Digital Voltmeter and a portable copper/copper sulfate reference electrode. Temporary impressed current testing was performed using a portable 80-volt, 8-amp rectifier. Two (2) existing rectifiers at Unit No. 2 were also employed for the testing.

Soil resistivity readings were obtained using the Wenner 4-Pin Method in conjunction with a Nilsson Model 400 Soil Resistance Meter. Resistivity measurements were obtained at representative depths of 5 feet, 10 feet and 15 feet.

IV. CORROSION/CATHODIC PROTECTION - GENERAL

1. Corrosion of Buried Structures

Corrosion is an electrochemical process by which steel and other metals attempt to return to their natural ore condition. In this process, the metal is corroded by discharges of electrical metallic ions to earth.

There are many different causes of corrosion, among which the most common are:

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IV. CORROSION/CATHODIC PROTECTION - GENERAL (Cont'd)

a) Dissimilar metals that are electrically tied together

b) Dissimilar soils

c) Differential aeration

d) Anaerobic bacteria

e) Outside sources of D.C. current

Power plants generally consist of a congested underground environment consisting of multiple service piping in the presence of an extensive grounding network. The existence of underground piping of various materials of construction (i.e. steel, ductile iron) in the presence of a bare copper grounding network is conducive to galvanic corrosion from dissimilar metals. The corrosion is detrimental to the ferrous piping materials as it is anodic in the presence of copper. Any breaks or holidays in the pipe coating are conducive to a high ratio of anode to cathode. This can lead to accelerated rates of corrosion in steel and ferrous materials, particularly if soil resistivity is low.

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IV. **CORROSION/CATHODIC PROTECTION - GENERAL** (Cont'd)

Soil resistivity measurements indicate the relative ability of the earth to carry electrical currents. Corrosiveness of soil is generally an inverse function of the resistivity. Lower resistivity soils are generally considered to be more corrosive than soils of higher resistivity.

The general classifications of soil resistivity relating to the degree of corrosivity are as follows:

a) 0 to 2,000 ohm/cm - extremely corrosive

b) 2,000 to 10,000 ohm/cm - moderately corrosive

c) 10,000 to 30,000 ohm/cm - mildly corrosive

d) 30,000 ohm/cm and over - progressively less corrosive

These classifications are general. Under certain conditions, severe corrosion can occur in the higher resistivity soil. Large variations in resistivity indicate the existence of variations in soil composition, and such variations can be conducive to the creation of galvanic corrosion activity on an underground structure.

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IV. **CORROSION/CATHODIC PROTECTION - GENERAL** (Cont'd)

2. Cathodic Protection

In order to stop corrosion, the natural flow of current from a metallic structure to earth has to be stopped. This can be accomplished by the use of sacrificial anodes that supply current to earth, which is picked up by the structure, thus reversing the flow of current and stopping the corrosion process; this is called cathodic protection.

Sacrificial anodes, such as magnesium, make use of the voltage difference between the structure metal and the anode material. The anode is always more negative than the structure; therefore, the flow of current through the wire connection is from structure to anode and the flow of current through the electrolyte (earth) is from anode to structure.

The impressed current type of cathodic protection makes use of a DC output rectifier. The current output from the rectifier is discharged to earth through anodes. The current, in turn, is picked up by the structure in contact with the earth (providing cathodic protection in the process) and returns through cable connections to the negative terminal of the rectifier.

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V. CRITERIA FOR CATHODIC PROTECTION

The criteria for determining the adequacy of protection on a buried structure is defined in the NACE Recommended Practice SP0169-2008 entitled "Control of External Corrosion on Underground or Submerged Metallic Piping Systems". In essence, the requirements for steel structures are as follows:

A. A negative voltage of at least 850 mv as measured between the structure and a saturated copper/copper sulfate reference cell contacting the earth directly over the structure.

B. A negative polarized potential* of at least 850 mV relative to a saturated copper/copper sulfate reference cell.

*Polarized Potential: The potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.

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V. CRITERIA FOR CATHODIC PROTECTION (Cont'd)

C. A minimum polarization voltage shift of 100 mV as measured between the structure and a saturated copper/copper sulfate reference cell contacting the earth directly over the structure. This polarization voltage shift shall be determined by interrupting the protective current and measuring the polarization decay. When the protective current is interrupted, an immediate voltage shift will occur. The voltage reading, after the immediate shift, shall be used as the base reading from which to measure polarization decay.

VI. TEST RESULTS AND RECOMMENDATIONS

The prior surveys of the Unit No. 2 sheet piling performed in 2006 and 2008 generally indicate satisfactory levels of cathodic protection were being provided to the structures (with some limitations of available test locations). The results of these surveys were furnished in a separate report.

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VI. TEST RESULTS AND RECOMMENDATIONS (Cont'd)

The structure to soil/water potential measurements obtained at various locations during this site investigation are as shown on the enclosed Corrosion Field Survey Data Table Nos. I, II and III. The data includes "as found" potential measurements of the various piping/structures and results of the change in potential due to the temporary addition of impressed current, where possible. As expected, the test data indicates all "as found" potential measurements for the piping are below the 850 millivolt criteria as an indication of satisfactory cathodic protection as described in Section V of this report. This was to be expected as there is no dedicated cathodic protection on these structures.

With an additional 100 amperes of impressed current applied during the survey, the Unit No. 2 circulating water piping showed potential shifts of less than 10 millivolts as compared to the as found potential. This demonstrates a very limited distribution of protective current and the

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significant load that the copper grounding system places on a cathodic protection system. The circulating water piping at Unit Nos. 2 and 3 were found to be electrically continuous to the plant copper grounding system, as expected.

A review of the original cathodic protection plan drawings indicates the installation of distributed high silicon iron anodes for the intake structures and the sheet piling. These components were installed during plant construction. There is little historical operational data to indicate the level of effectiveness of the system. With the exception of the Unit No. 2 intake structure sheet piling and a sewage pipeline operating cathodic protection system, all other original cathodic protection systems have been removed and/or abandoned.

The city water piping potentials are as shown on the enclosed Data Table III. The most significant finding of the field testing indicates a positive shift in the potentials of the city water piping where it crosses the Algonquin gas pipeline. This static stray current is

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caused by the impressed current system presently in service for the Algonquin pipeline. Stray current can result in serious corrosion at the point of current discharge from the "foreign" pipe. Impressed current demand testing utilized two steel bollards as temporary anodes near the Broadway storage tank and provided 2 amperes of current. This provided only some localized protection to the piping near the storage tank and reduced the magnitude of the effect of the stray current.

The Diesel Generator Tank Nos. 21, 22 and 23 were found to be unprotected as there is no cathodic protection system associated with these structures. The TSC diesel tank was found to be of sti-P_3 construction and partially protected. Tanks of sti-P_3 construction include a high quality external coating, factory installed galvanic anodes and electrical isolation as a defense against corrosion. The APR tank could not be accessed as it was located within a vault identified as a confined space entry.

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VI. TEST RESULTS AND RECOMMENDATIONS (Cont'd)

Soil resistivity measurements were obtained at two (2) locations in proximity to the Unit No. 2 condensate piping and at two (2) locations in close proximity to the city water piping. The resistivity values are as shown on the attached Data Table No. III and range from 8,043 ohm/cm to 63,195 ohm/cm with an average value of 28,589 ohm/cm.

VII. DISCUSSION AND RECOMMENDATIONS

Installation of a cathodic protection system during power plant construction can be cost effective and is generally easily installed prior to backfilling/grading. The installation of a cathodic protection system after plant construction can become difficult and generally expensive. This problem is exaggerated in the presence of subsurface rock as reported for this site. Impressed current system options include distributed anodes, linear anodes and anode deepwell systems.

Connection of the copper grounding system to an impressed current system increases cathodic protection requirements by several order of magnitude. Bare copper structures are difficult to polarize as compared to steel

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structures that can be well coated. Prior studies have indicated the current density required to polarize copper to an adequate potential necessary to protect a ferrous structure may be 10 to 20 times as high - on a per unit area basis - as the level required to polarize ferrous structures.[1]

Overall, current requirements for this facility without electrical isolation can be estimated to be one thousand or more amperes.

In addition to total current demand, the distribution of protective current is an important factor. Congested areas result in limited anode "throw". Piping under reinforced concrete slabs (i.e. turbine generator building) can be shielded from protective current-by-current pickup to the reinforcing rods. The reinforcing rods can also be electrically continuous to the buried piping. For this reason, distributed or linear anodes are generally a preferred choice for power plants if the cathodic protection system can be installed during plant

[1] "Electrical Grounding and cathodic protection Issues in Large Generating Stations", Materials Performance 40,11 (November 2001): p. 17

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construction. The installation of distributed type anodes after large plant construction can be cost prohibitive.

Deepwell cathodic protection systems are an alternate consideration after plant construction inasmuch as excavation can be minimized. However, as indicated, distribution of current must be carefully evaluated and all underground piping should be electrically continuous. Electrical continuity is generally lacking in applications where mechanical joint ductile or cast iron piping is utilized unless the joints are fitted with a bonding strap at time of installation.

Based on the results of the testing and the complex configuration of power plants, a multi-phase plan will provide the most effective return. The following recommendations are suggested:

- As a priority, install a mitigation bond to eliminate/minimize stray current to the city water piping at the location that crosses the Algonquin gas pipeline. This will require joint communication and cooperation. The purpose of the bond is to provide a low resistance path between the foreign

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VII. DISCUSSION AND RECOMMENDATIONS (Cont'd)

structure and the protected structure. An alternate method to a mitigation bond is the installation of sacrificial anodes at the crossing. The sacrificial anode provides a path where the collected current can leave the foreign structure with corrosion occurring at the anode rather than the foreign structure.

- Provide a progressive evaluation of cathodic protection needs for high priority piping services on a zone basis.

  Although a distributed or linear anode system would be the best performance choice, its installation to an existing facility is likely not feasible. Therefore, a deepwell anode system would offer the most feasible approach. Once installed, an assessment and evaluation of the system effectiveness can be compared to the application for additional piping zones.

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VII. DISCUSSION AND RECOMMENDATIONS (Cont'd)

- The implementation of an inspection program based on API 570 can identify high priority zones. These zones could be determined by excavation and inspection of existing pipe. Upon excavation, an ultrasonic thickness measurement of the pipe wall and coating evaluation could be made.

WILLIAM J. SIMPSON
NACE CATHODIC PROTECTION
SPECIALIST NO. 3634
PCA ENGINEERING, INC.

WJS:lms

IPEC00220870

PCA ENGINEERING, INC. 430 Montclair Avenue, P.O. Box 196 Pompton Lakes, NJ 07442	**CORROSION FIELD SURVEY DATA AND TABLES**	
OWNER: ENTERGY	**STRUCTURE TO SOIL**	**PCA JOB NO: 28457**
STRUCTURE : INDIAN POINT UNIT #2	**POTENTIAL MEASUREMENT**	**TABLE I**
DATE OBTAINED: OCTOBER 2, 2008	**NEGATIVE MILLIVOLTS**	**SHEET 1 OF 1**
SURVEYED BY: W. SIMPSON / D. RAWA	**UNLESS OTHERWISE SHOWN**	

LOCATION	FOUND	OFF	INCR.		REMOTE	COMMENTS
CIRCULATING WATER PIPE						AS FOUND -RECT A. WATERSIDE 15.8 V- 84 A.
PIPE RISER # 21	504	491	512		443	AS FOUND – RECT B. LANDSIDE 12.9 V-39.4 A
PIPE RISER # 22	532	525	535		443	
PIPE RISER # 23	580	576	569		443	TEMP. INCREASE RECT A TO 24.4 V – 148 A.
PIPE RISER # 24	594	589	573		445	TEMP. INCREASE RECT B TO 23.3 V – 74 A.
PIPE RISER # 25	559	549	543		445	
PIPE RISER # 26	613	575	607		445	NORTH
SERVICE WATER PUMPS	463	466			445	
GROUND CABLE					431	
RECTIFIER A WATERSIDE NEGATIVE LUG					445	
RECTIFIER B LANDSIDE NEGATIVE LUG					430	
CONDENSATE PIPING AT TANK	296	248				
GROUND CABLE AT TANK	328					
DIESEL GENERATOR BUILDING TANK 21 FOST	140					NORTH
TANK 22 FOST	130					MIDDLE
TANK 23 FOST	130					SOUTH

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CORROSION FIELD SURVEY DATA AND TABLES

OWNER: ENTERGY	**STRUCTURE TO SOIL**	**PCA JOB NO: 28457**
STRUCTURE : INDIAN POINT UNIT #3	**POTENTIAL MEASUREMENT**	**TABLE II**
DATE OBTAINED: OCTOBER 2, 2008	**NEGATIVE MILLIVOLTS**	**SHEET 1 OF 1**
SURVEYED BY: W. SIMPSON / D. RAWA	**UNLESS OTHERWISE SHOWN**	

LOCATION	**FOUND**				**REMOTE**	**COMMENTS**
CIRCULATING WATER PIPE						
PIPE RISER # 31	**347**				**159**	SOUTH
PIPE RISER # 32	**279**				**159**	
PIPE RISER # 33	**249**				**159**	
PIPE RISER # 34	**305**				**160**	
PIPE RISER # 35	**268**				**159**	
PIPE RISER # 36	**343**				**160**	NORTH
SERVICE WATER VENT #34,35,36	**232**				**159**	
SERVICE WATER VENT #31,32,33	**236**				**159**	
GROUND CABLE AT BUILDING	--				**158**	
SHEET PILE DISCHARGE	**263**					
	N	**S**	**E**	**W**	**C**	
TSC DIESEL UNDERGROUND TANK	**888**	**792**	--	**885**	**853**	CONCRETE
	755	**718**	**865**	**662**	--	SOIL

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CORROSION FIELD SURVEY DATA AND TABLES

OWNER: ENTERGY	**STRUCTURE TO SOIL**	**PCA JOB NO: 28457**
STRUCTURE : CITY WATER PIPING	**POTENTIAL MEASUREMENT**	**TABLE IV**
DATE OBTAINED: OCTOBER 15, 2008	**NEGATIVE MILLIVOLTS**	**SHEET 1 OF 1**
SURVEYED BY: W. SIMPSON / D. RAWA	**UNLESS OTHERWISE SHOWN**	

LOCATION	AS FOUND	ON	OFF		
BROADWAY PUMPHOUSE	369	460	411		NO ISOLATION CITY & PLANT PIPING
SOUTH MANWAY OF TANK	363	1586	710		TEMPORARY RECTIFIER 65 VOLTS, 2.12 AMP
AT GATE	433	9590	1562		
115' WEST OF GATE	398	1349	719		
FIRE HYDRANT	234	580	439		
EAST PIPELINE MARKER	+200/400	+20/180	+20/180		
WEST PIPELINE MARKER	0 /+400	+200/300	+200/300		
CONCRETE BARRIER	120/150	100	100		
OVERLOOK ROAD	333	270	270		
FIRE HUDRANT UPPER PARKING LOT	383	367	367		
NEXT TO POLE IN PARKING LOT	317	304	304		
NEAR STAIRWAY TOP OF HILL	272	292	292		

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CORROSION FIELD SURVEY DATA AND TABLES

OWNER: ENTERGY	**SOIL RESISTIVITY MEASUREMENT**	**PCA JOB NO: 28457**
STRUCTURE : PIPING	**OHM-CM^3**	**TABLE IV**
DATE OBTAINED: OCTOBER 7, 2008	**UNLESS OTHERWISE SHOWN**	**SHEET 1 OF 1**
SURVEYED BY: W. SIMPSON / D. RAWA		

LOCATION	**5 FT**	**10 FT.**	**15 FT.**			
CONDENSATE PIPING – UNIT #2						
LOCATION #1	**30,640**	**31,598**	**8,043**			PH= 6
LOCATION #2	**63,195**	**28,725**	**11,490**			PH = 5.9
CITY WATER PIPING						
UPPER PARKING LOT NEAR STAIRWAY	**30,161**	**36,385**	**40,215**			12' SE OF LIGHT POLE MOVING EAST
OVERLOOK ROAD	**24,895**	**21,065**	**16,660**			3' SOUTH OF FIRE LANE SIGN MOVING SOUTH

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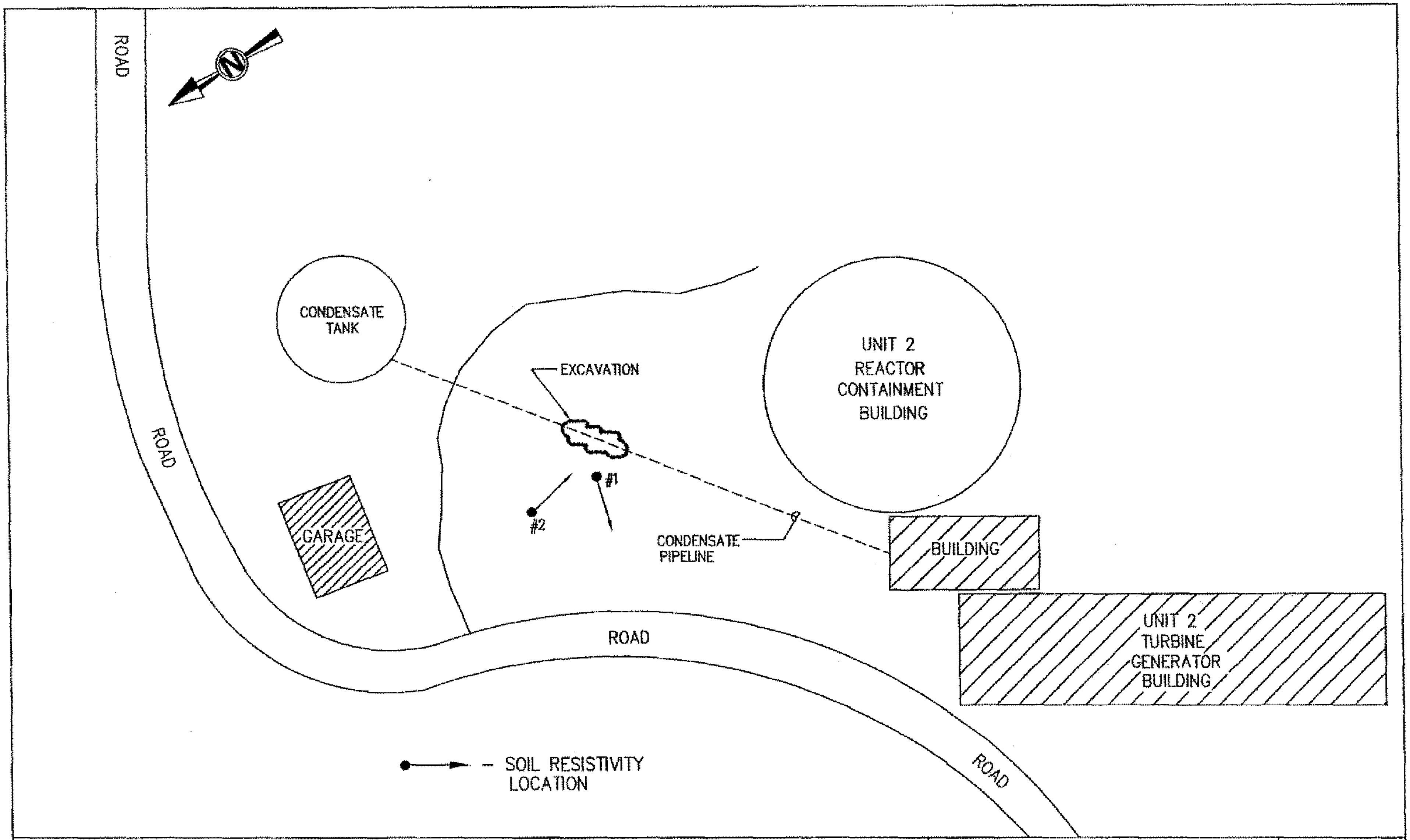

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ENTERGY NUCLEAR OPERATIONS, INC.
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SOIL RESISTIVITY TEST LOCATION

Drawing Number: AW-28457-02

Approved: W.J.S.
Scale: N.T.S.
Drawn By: A.U.Z.
Date: 12-30-08

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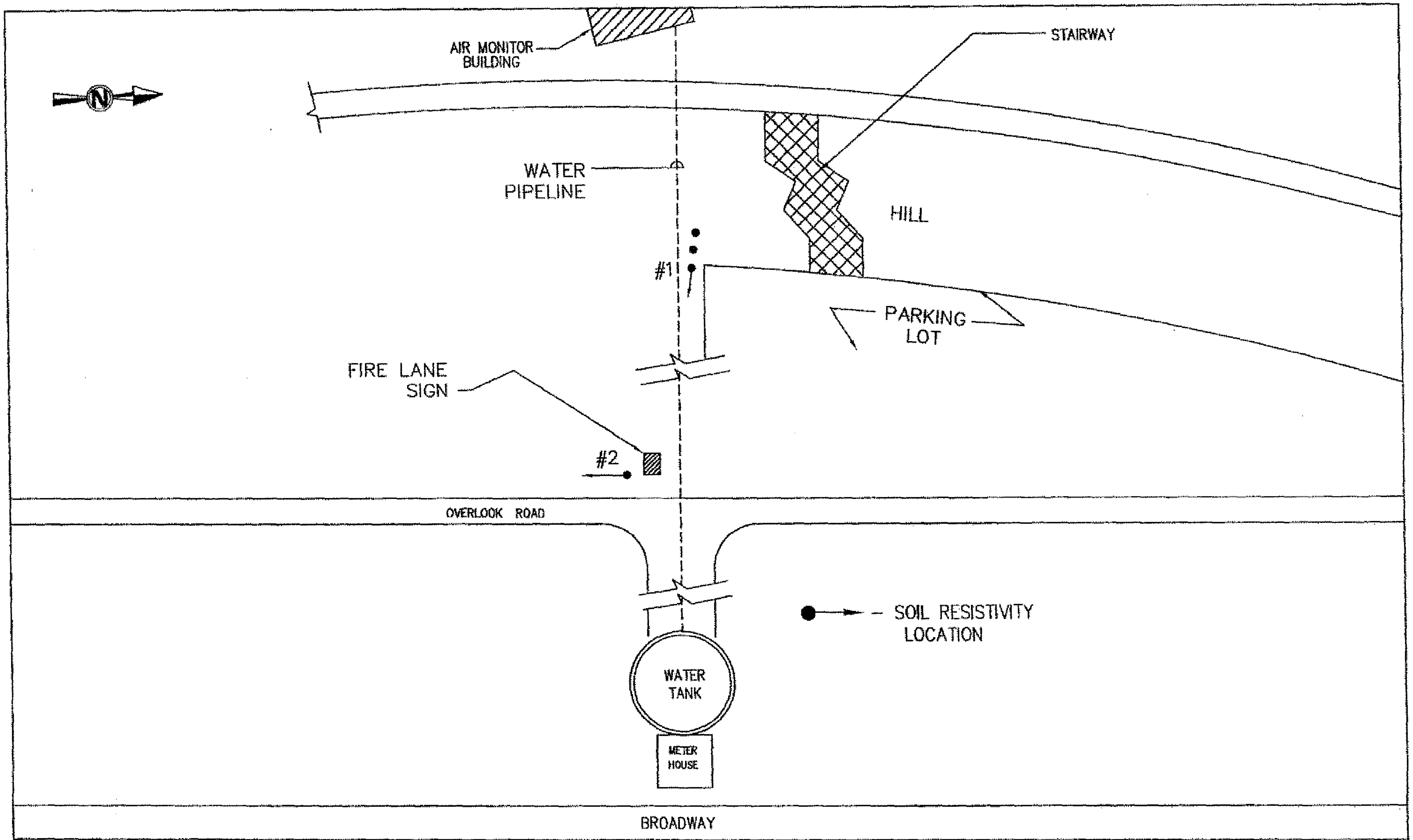

PCA ENGINEERING, INC. 430 Montclair Ave. Pompton Lakes, NJ. TEL. (973) 616-4501	ENTERGY NUCLEAR OPERATIONS, INC. INDIAN POINT ENERGY CENTER 450 BROADWAY BUCHANAN, NY 10511	SOIL RESISTIVITY TEST LOCATION	Approved: W.J.S. Scale: N.T.S.
	ENTERGY NUCLEAR OPERATIONS, INC. INDIAN POINT ENERGY CENTER 450 BROADWAY BUCHANAN, NY 10511	Drawing Number: AW-28457-03	Drawn By: A.U.Z. Date: 12-30-08

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