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UNITED STATES
NUCLEAR REGULATORY COMMISSION
BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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In re: Docket Nos. 50-247-LR; 50-286-LR
License Renewal Application Submitted by ASLBP No. 07-858-03-LR-BD01
Entergy Nuclear Indian Point 2, LLC, DPR-26, DPR-64
Entergy Nuclear Indian Point 3, LLC, and
Entergy Nuclear Operations, Inc. December 9, 2011
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PRE-FILED WRITTEN TESTIMONY OF
DR. ROBERT C. DEGENEFF
REGARDING CONTENTION NYS-8

On behalf of the State of New York ("NYS" or "the State"),
the Office of the Attorney General hereby submits the following
testimony by Dr. Robert C. Degeneff regarding Contention NYS-8.

Q. Please state your name and describe your professional
qualifications to give this testimony.

A. My name is Robert C. Degeneff. Since 1991, I have
been the owner of Utility Systems Technologies (UST), Inc., a
leading developer of electronic voltage regulators and sag
mitigation equipment used for power quality improvement in
utility and industrial power systems, P.O. Box 110 Latham, New

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1 York 12110. Among other things, UST designs and builds
2 equipment to improve power quality. Transformers are a major
3 component of such equipment. My education and experience are
4 described in my curriculum vitae, provided as Exhibit NYS000004.

5 I hold a doctorate of engineering (D. Eng.), a Master of
6 Science degree in electrical power engineering, and a bachelor's
7 degree in mechanical engineering. For four decades, I have
8 worked, taught, and researched in the power engineering field,
9 with an emphasis on the electrical behavior and design of power
10 transformers. I have published more than 80 papers on topics
11 relating to transformer design and performance and power system
12 design and hold eight patents relating to transformer winding
13 design and electronic tap changer design. A full list of these
14 articles and patents is contained in my curriculum vitae.

15 Q. I show you what has been marked as Exhibit NYS000005.
16 Do you recognize that document?

17 A. Yes. It is a copy of the report that I prepared for
18 the State of New York in this proceeding. The report reflects
19 my analysis and opinions.

20 Q. What is the purpose of your testimony?

21 A. The purpose of my testimony is to provide support for,
22 and my views on, New York's Contention 8 ("NYS-8"), which was
23 admitted by the Atomic Safety Licensing Board ("ASLB") on July

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1 31, 2008.¹ NYS-8 asserts that transformers are static devices
2 that belong within the category of components for which an aging
3 management program ("AMP") is required under 10 C.F.R. §
4 54.21(a)(1)(i). NYS-8 also asserts that transformers are more
5 similar to components which for which an AMP is required than
6 those components for which an AMP is not required. See July 31,
7 2008 Board Order, at 45.

8 Q. Have you reviewed materials in preparation for your
9 testimony?

10 A. Yes.

11 Q. What is the source of those materials?

12 A. Many are documents prepared by government agencies,
13 peer reviewed articles, or documents prepared by Entergy or the
14 utility industry.

15 Q. Dr. Degeneff, I show you what has been marked as
16 Exhibit NYS000001. Do you recognize this document?

17 A. Yes. It is a list of the State's exhibits, and
18 includes those documents which I referred to, used, or relied

¹ See *Entergy Nuclear Operations, Inc.* (Indian Point Nuclear Generating Units 2 and 3) LBP-08-13, 44-45 (July 31, 2008). The Board later denied Entergy's motion for summary disposition of Contention 8. *Entergy Nuclear Operations, Inc.* (Indian Point Nuclear Generating Units 2 and 3) ASLBP No. 07-858-03-LR-BD01, 6-8 (ruling dated Nov. 3, 2009).

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1 upon in preparing my report and this testimony, NYS000006
2 through NYS000038.

3 Q. I show you Exhibits NYS000006 through NYS000038. Do
4 you recognize these documents?

5 A. Yes. These are true and accurate copies of each of
6 the documents that I referred to, used and/or relied upon in
7 preparing my report and this testimony. In some cases where the
8 document was extremely long and only a small portion is relevant
9 to my testimony, an excerpt of the document is provided. If it
10 is only an excerpt, that is noted on the cover of the Exhibit.

11 Q. How do these documents relate to the work that you do
12 as an expert in forming opinions such as those contained in this
13 testimony?

14 A. These documents represent the type of information that
15 persons within my field of expertise reasonably rely upon in
16 forming opinions of the type offered in this testimony.

17 Q. What materials have you reviewed in preparation for
18 your testimony?

19 A. I have reviewed all of the filings involving NYS-8,
20 including: New York State Notice of Intention to Participate and
21 Petition to Intervene, Contention 8, at pp. 103-105 (November
22 30, 2007); New York State Notice of Intention to Participate and
23 Petition to Intervene, Declaration of Paul Blanch (November 30,

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1 2007); Answer of Entergy Nuclear Operations, Inc. Opposing New
2 York State Notice of Intention to Participate and Petition to
3 Intervene, section on NYS-8, at pp. 69-72 (January 22, 2008);
4 NRC Staff's Response to Petitions for Leave to Intervene,
5 section on NYS-8, at pp. 44-46 (January 22, 2008); State of New
6 York's Reply in Support of Petition to Intervene, Contention 8,
7 at pp. 58-61 (February 22, 2008); the portion of the transcript
8 of the March 2008 hearing before the Board concerning
9 transformers; the July 31, 2008 Board Order (see supra, note 1);
10 Applicant's Motion for Summary Disposition of New York State
11 Contention 8 (Electrical Transformers) (August 14, 2009)
12 (including the August 12, 2009 declarations of Dr. Dobbs, Mr.
13 Craig and Mr. Rucker); NRC Staff's Answer to Applicant's Motion
14 for Summary Disposition of New York Contention 8 (September 14,
15 2009); Response of the State of New York to Entergy's Summary
16 Disposition Motion and NRC Staff's Supporting Answer (September
17 23, 2009); Response of the State of New York to Entergy's
18 Summary Disposition Motion and NRC Staff's Supporting Answer,
19 Declaration of Paul Blanch (September 23, 2009); and the
20 November 3, 2009 Board Order (see supra, note 1).

21 I am also familiar with the Updated Final Safety Analysis
22 Reports ("USFAR") for Indian Point Units 2 and 3 filed by
23 Entergy in this licensing proceeding and documents generated by

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1 Sandia National Laboratories and EPRI relating to aging
2 management and transformers. I have also reviewed the body of
3 scholarly work that discusses the scientific and engineering
4 basis for the operation of power transformers. A complete list
5 of the documents I reviewed is also attached to my report.

6 Q. What conclusions have you reached about the
7 applicability of 10 C.F.R. § 54.21 to transformers?

8 A. In my professional judgment, and as I describe in more
9 detail below, and in my report, transformers are static devices
10 and, as such, they belong within the category of components for
11 which an AMP is required under 10 C.F.R. § 54.21(a)(1)(i).
12 Transformers do not contain any moving parts, and during their
13 operation, transformers experience no change in properties, no
14 change in configuration, or any other sort of change. The
15 transformer is: a static electrical device, involving no
16 continuously moving parts, used in electrical power systems to
17 transfer power between circuits through use of electromagnetic
18 induction. See, e.g. Harlow, Electric Power Transformer
19 Engineering, page 2-1, CRC Press (2004) ISBN 0-8493-1704-5
20 (referencing ANSI / IEEE (NYS000008)). Because of these
21 characteristics, transformers are more similar to pipes,
22 electrical cables and other components for which an AMP is

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1 required than they are to components like transistors and
2 batteries for which an AMP is not required.

3 Q. Please explain the general function that transformers
4 perform.

5 A. The electrical transformer takes advantage of the unique
6 properties of electromagnetic fields to transform electrical
7 power of one voltage to electrical power of another voltage.
8 The mathematical relationship between the voltage and the
9 current is described by the following: voltage in x current in =
10 power in = power out = voltage out x current out. Assuming zero
11 resistance, the electrical power flowing through a transformer
12 remains constant; consequently if the voltage of electrical
13 power flowing through a transformer decreases and the power
14 remains constant, current will increase proportionally, and vice
15 versa. Another way the voltage and current relationship is
16 often expressed: $V_{in}/V_{out} = I_{out}/I_{in}$ or $V_{in}/V_{out} = \text{Current}_{out}/\text{Current}_{in}$.

17 Transformers typically contain two insulated wires that are
18 wrapped or coiled around a form called a "core" that is
19 frequently made of iron or metal alloys. Transformers contain a
20 primary winding (a winding supplying the energy to the circuit)
21 and one or more secondary windings (the windings through which
22 the power flows out of the transformer). The ratio of the coils
23 each winding possesses is called the turns ratio and that ratio

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1 may be taken as the voltage transformation ratio between the
2 input and output winding and the inverse of the current
3 transformation ratio. When an electric current passes through
4 the primary winding, a magnetic field is developed around that
5 winding. When that generated magnetic field touches (or links)
6 the secondary winding, a voltage is generated across it. If the
7 second winding is connected so that current can flow, electric
8 power is transformed from the first winding to the second
9 winding.

10 Q. Are transformers replaced on a specified interval
11 based upon a qualified life?

12 A. No, transformers are long-lived instruments, and if
13 properly maintained can remain in service for decades, certainly
14 for periods exceeding the license term of nuclear power plants.
15 Due to their expense, transformers are generally replaced only
16 when they fail or when age related degradation has progressed
17 such that it indicates a high likelihood of near-term failure.

18 Q. Are transformers passive or active devices?

19 A. Transformers are passive, or static, devices, the
20 properties of which do not change during operation. Every
21 authority that I have reviewed also characterizes transformers
22 as static devices. For example, the IEEE Standard Dictionary of
23 Electrical and Electronic Terms, IEEE Std 100-1996 (6th

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1 Edition), page 1131, ISBN 1-55937-833-6 (1996) (NYS000010)
2 defines transformers as: "A static electrical device consisting
3 of a winding, or two or more coupled windings, with or without a
4 magnetic core, for introducing mutual coupling between
5 electrical circuits," and Flanagan, Handbook of Transformer
6 Design & Application (2nd Edition), page 1.1, McGraw-Hill, 1993,
7 ISBN 0-07-021291-0 (NYS000007), states that "Transformers are
8 passive devices for transforming voltage and current."

9 Q. What are the properties of a transformer?

10 A. The key property of any transformer is its turns
11 ratio. The turns ratio determines that no matter what level of
12 electrical power is fed into a transformer, the voltage and
13 current will be transformed in a uniform ratio. This property
14 does not change during the operating life of the transformer.
15 Other properties of the transformer include its windings,
16 conductor size, insulation type and thickness, and cooling
17 capability, which depend on the intended function of the
18 transformer. These properties are the same whether the
19 transformer is carrying power or not.

20 Q. Entergy and its experts say that voltage, current, and
21 electromagnetic field are properties of a transformer. How
22 would you respond to this assertion?

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1 A. Entergy and its experts incorrectly conflate the
2 properties of the transformer and the properties of the power
3 being transformed (voltage and current) by the transformer.
4 Voltage and current are properties of the electrical power being
5 fed into the transformer and supplied to the load to which the
6 transformer is connected: whichever level of power flows through
7 a transformer, it will be transformed at a uniform ratio,
8 determined by the transformer's turns ratio. Thus, if the
9 "transformation ratio" is 2 to 1, then the ratio of input to
10 output voltage will always be 2 to 1, and the ratio of input to
11 output current will be 1 to 2 with the input power equaling the
12 output power. Both the input voltage and the load served are
13 completely independent of the design and characteristics of the
14 transformer, which is a static device.

15 Similarly, the flux of the magnetic field produced in
16 transformer is a product the power supplied to the transformer.
17 Transformers are designed to take advantage of the magnetic flux
18 created by the flow of alternating current. The flow of direct
19 current will not produce a magnetic flux with the desired
20 properties, and the coils and the core do not produce a magnetic
21 field on their own when there is no incoming electrical current
22 at all. Everything is dependent on the properties of the power,

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1 e.g. its magnitude and frequency, supplied by an external
2 source.

3 Q. Do any of the transformer's properties change during
4 the course of its operation?

5 A. No, the transformer's properties do not change during
6 the course of its operation. The transformer is a passive
7 component, with no moving parts. This understanding is widely
8 accepted among the technical community. The Handbook of
9 Transformer Design & Application states that "Transformers are
10 passive devices for transforming voltage and current."

11 Flanagan, The Handbook of Transformer Design & Application (2nd
12 Edition), page 1.1, McGraw-Hill, 1993, ISBN 0-07-021291-0
13 (NYS000007). Another text book states that a transformer is "a
14 static electrical device, involving no continuously moving
15 parts, used in electrical power systems to transfer power
16 between circuits through use of electromagnetic induction."

17 Harlow, Electric Power Transformer Engineering, page 2-1, CRC
18 Press (2004) ISBN 0-8493-1704-5 (referencing ANSI /

19 IEEE) (NYS000008); see also Harlow, Electric Power Transformer

20 Engineering, page 2-1 (2d Edition) CRC Press (2007) ISBN 0-8493-

21 9186-5 (NYS000009). The sixth edition of the IEEE Standard

22 Dictionary of Electrical and Electronic Terms includes the

23 following definition of transformer: "A static electrical device

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1 consisting of a winding, or two or more coupled windings, with
2 or without a magnetic core, for introducing mutual coupling
3 between electrical circuits." IEEE Standard Dictionary of
4 Electrical and Electronic Terms, IEEE Std 100-1996 (6th
5 Edition), page 1131, ISBN 1-55937-833-6 (1996) (NYS000010). This
6 same definition is repeated in ANSI/IEEE C57.12.80, An American
7 National Standard, IEEE Standard Terminology for Power and
8 Distribution Transformers, Section 2.1.1.. NRC has also
9 acknowledged that "transformers perform their primary function
10 without the use of moving parts." NUREG/CR-5753, at 50
11 (NYS000012).

12 Q. Entergy and its experts assert that the voltage and
13 magnetic flux vary through time and consequently, a transformer
14 must be an active device. How would you respond to this
15 assertion?

16 A. The fact that voltage, current and magnetic flux vary
17 over time does not imply any change in a transformer's
18 properties. The changes in the properties of the power flowing
19 through a transformer are a consequence of the power being
20 supplied and the load being served, which are completely
21 independent from the transformer structure. But the
22 determination of whether current is alternating or direct does
23 not come from the properties of the transformer through which it

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1 flows, but from the source of the power. It is true that
2 transformers are designed to take advantage of the properties of
3 alternating current, but it is not true that the properties of a
4 transformer change when a certain kind of current is passed
5 through it. A transformer may not operate correctly if it is
6 connected to direct current, but to suggest that a transformer
7 is only a transformer so long as alternating current flows
8 through the transformer is like saying that a hot water pipe's
9 properties have changed because it is hooked up to a cold water
10 source.

11 Q. Does a transformer change its state when it steps up
12 or steps down voltage during its operation. How would you
13 respond to this assertion?

14 A. No. Entergy and its experts are incorrect in this
15 assertion, which is contrary to the consensus of the technical
16 community. Entergy's position that transformers change state
17 during their normal operation apparently refers to the Statement
18 of Consideration ("SOC") that the Commission included in
19 adopting the Final Rule on Nuclear Power Plant License Renewal,
20 which is available at, 60 Fed. Reg. 22,461, 22,477 (May 8,
21 1995) (NYS000016). In adopting the rule, NRC, "concluded that 'a
22 change in configuration or properties,' should be interpreted to
23 include 'a change in state,' which is a term sometimes found in

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1 the literature relating to 'passive.'" The Commission then went
2 on to use the battery as an example of something that changes
3 state because its electrolytic properties change as it is
4 discharged. However, characterizing stepping up voltage, or
5 stepping down voltage, or providing electrical isolation with a
6 transformer as a change in state is scientifically incorrect.
7 The transformer does not change state while it is performing its
8 assigned activity any more than a pipe carrying a fluid changes
9 state as the fluid flows through it. Only the electricity
10 flowing through the transformer changes in a constant ratio
11 determined by the unchanging properties of the transformer.

12 Q. What specific NRC regulatory provisions lead you to
13 conclude that transformers require an AMP?

14 A. In preparing this declaration, I reviewed 10 C.F.R. §
15 54.21. Specifically, § 54.21(a)(1) provides:

16 Structures and components subject to an aging management
17 review shall encompass those structures and components . . .
18 that perform an intended function, as described in § 54.4,
19 without moving parts or without a change in configuration or
20 properties. These structures and components include, but are
21 not limited to, the reactor vessel, the reactor coolant system
22 pressure boundary, steam generators, the pressurizer, piping,
23 pump casings, valve bodies, the core shroud, component supports,

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1 pressure retaining boundaries, heat exchangers, ventilation
2 ducts, the containment, the containment liner, electrical and
3 mechanical penetrations, equipment hatches, seismic Category I
4 structures, electrical cables and connections, cable trays, and
5 electrical cabinets, excluding, but not limited to, pumps
6 (except casing), valves (except body), motors, diesel
7 generators, air compressors, snubbers, the control rod drive,
8 ventilation dampers, pressure transmitters, pressure indicators,
9 water level indicators, switchgears, cooling fans, transistors,
10 batteries, breakers, relays, switches, power inverters, circuit
11 boards, battery chargers, and power supplies; and (ii) that are
12 not subject to replacement based on a qualified life or
13 specified time period. 10 C.F.R. § 54.21(a)(1)(i), (ii).

14 I cannot offer a legal opinion on this regulatory language,
15 however, reading the regulation as a technical statement, and
16 using my expertise, I can interpret what the regulation means
17 for transformers. First, and as I already explained,
18 transformers contain no moving parts, and do not change
19 configuration or properties. These characteristics make
20 transformers subject to an AMP under 10 C.F.R. § 54.21(a)(1)(i).
21 Second, transformers are long-lived components, and can have
22 operational periods of sixty years or more if properly
23 maintained, meaning that a transformer may operate for longer

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1 than the original license and relicense periods, another
2 characteristic which satisfies 10 C.F.R. § 54.21(a)(1)(ii). I
3 have also reviewed the Statement of Consideration, Nuclear Power
4 Plant License Renewal; Revisions, 60 Fed. Reg. 22,461 (May 8,
5 1995) (NYS000016) and, in addition to the fact that transformers
6 do not change state, the aging effects in transformers are not
7 "readily monitorable" for purposes and many types of degradation
8 because aging effects may not cause observable effects in a
9 transformer's operating characteristics. The SOC specifically
10 listed the inability to detect failure as a factor in
11 determining whether an AMP is necessary. An objective
12 assessment shows that transformers are more similar to
13 components for which an AMP is required than to components for
14 which an AMP is not required.

15 Q. In the Atomic Safety and Licensing Board's July 31,
16 2008 decision admitting Contention 8, the Board stated: "In
17 addressing this contention, the Board will require, inter alia,
18 representations from the parties to help us determine whether
19 transformers are more similar to the included, or to the
20 excluded, component examples." How are transformers similar to
21 the 'included' components listed in 10 C.F.R. § 54.21(a)(1)(i)?

22 A. 10 C.F.R. § 54.21(a)(1) contains a non-exhaustive list
23 of those structures and components which are to be included in

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1 an aging management review. The regulation also provides
2 another non-exhaustive list of structures and components that
3 are not within the scope of the rule. In general, transformers
4 are similar to many of the "included" structures and components,
5 because a transformer may increase or decrease the voltage of
6 the electrical power that passes through that transformer
7 without the properties of the transformer changing. Thus, the
8 included components change the "properties" of the fluids,
9 electric power, or fuel that travel through or are contained
10 within those structures and components, the "properties" of the
11 included structures and components, themselves, do not during
12 their intended use.

13 Additionally, transformers may have service lives exceeding
14 60 years, like many of the 'included' components. If properly
15 maintained, a transformer is not subject to replacement based on
16 a qualified life or a specified time period.

17 Q. In which specific ways are transformers similar to
18 cables which are 'included' components listed in 10 C.F.R. §
19 54.21(a)(1)(i)?

20 A. In its most basic form, a transformer is simply two
21 current carrying conductors or cables adjacent to each other.
22 The purpose of the electric cable is to transmit electric power
23 from one point to another. When AC current passes through a

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1 cable, a varying magnetic field is generated around the cable.
2 The magnitude and phase of the currents through the cable and
3 voltages across the electric cable may change, but the physical
4 properties of the cable (e.g., conductor shape, material
5 composition of the cable, cable insulation and the resultant
6 resistance, capacitance per unit length) are not designed to
7 change. Notably, cables are included as within the scope of
8 §54.21(a)(1). The physical laws that describe how the magnetic
9 field is developed around a cable are exactly the same physical
10 laws that describe how a magnetic field is developed in a
11 transformer. In fact, in many applications two cables are laid
12 parallel to each other in a raceway. The equations that
13 describe the electrical performance of these cables are exactly
14 the same equations that describe the performance of a two
15 winding transformer with no iron core.

16 Q. In which specific ways are transformers similar to
17 pipes which are 'included' components listed in 10 C.F.R. §
18 54.21(a)(1)(i)?

19 A. Like the voltage of the power flowing through a
20 transformer, the properties of fluids contained within a pipe
21 can change. The properties of such fluids include temperature,
22 pressure, velocity, specific volume, specific weight, viscosity,
23 density, etc. The phase of the fluid in a pipe may even change.

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1 Yet, a pipe itself is a component which is included within the
2 scope of § 54.21(a)(1). A pipe's diameter may narrow at a
3 particular location or the pipe may contain a restriction (e.g.,
4 "elbow," or "tee") that may change the velocity and/or pressure
5 of the fluid contained in the pipe; however, the properties of
6 the pipe itself have not changed. Stated differently, the
7 properties of the contents of the pipe (a fluid) may change, but
8 not the conduit (pipe). The pipe itself is not designed to
9 change its own properties. In fact, if the pipe's properties
10 changed it would present significant engineering and design
11 problems. For example, when a fluid passes through a pipe with
12 a constriction, the amount of fluid that passes through the pipe
13 is constant. The pressure of the fluid will change at the
14 constriction, but the pipe remains invariant, its properties and
15 characteristics unchanged. This is exactly the same situation
16 with transformers, in that power merely passes through a
17 transformer. It is the unchanging physical properties of the
18 transformer that cause that power to change voltage at a ratio
19 determined by the transformer's unchanging design properties.
20 Different amounts of power may be applied to a transformer, but
21 the voltage will always change at the same ratio, because the
22 unchanging properties of the transformer dictate only one turns
23 ratio.

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1 Q. In which specific ways are transformers similar to
2 steam generators which are 'included' components listed in 10
3 C.F.R. § 54.21(a)(1)(i)?

4 A. Both the properties of a steam generator and the state
5 of the fluids in it may change. The fluid's temperature may
6 increase and the fluid's state may change from liquid to steam.
7 However, the steam generator itself (another component which is
8 included within the scope of § 54.21(a)(1)) is not designed to
9 change its own properties during its normal use, as is also the
10 case with the transformer.

11 Q. In which specific ways are transformers similar to the
12 reactor pressure vessel & containment which are 'included'
13 components listed in 10 C.F.R. § 54.21(a)(1)(i)?

14 A. Various nuclear processes do occur within the reactor
15 vessel, the containment liner, or the containment, but those
16 components are included in § 54.21(a)(1). Those processes cause
17 some wear on those components, and that wear is the subject of
18 aging management. Likewise, the magnitude of the currents and
19 voltages in and out of a transformer may change, but the
20 properties and configuration of the transformer and its
21 capabilities (ability to transform electric power from one
22 voltage to another) are not designed to change during normal
23 operation.

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1 Q. Entergy and its experts assert that transformers are
2 most similar to transistors, which are 'excluded' components
3 listed in 10 C.F.R. § 54.21(a)(1)(i). How would you respond to
4 this assertion?

5 A. The assertion that a transformer is similar to a
6 transistor is incorrect for several reasons. First and
7 foremost, the characteristics and properties of the transformer
8 do not change during its operation, e.g., the size, weight,
9 turns ratio, etc. do not change if it is operated within its
10 design limits; they are invariant. In contrast, the properties
11 of a transistor, itself, do change during its normal intended
12 use. Transistors are made from semiconductor materials, the
13 resistivity of which can be changed by applying an electric
14 current to the material; a semiconductor's electrical resistance
15 can be made to vary between that of a conductor (full flow or
16 very low resistance) and that of an insulator (very low flow or
17 very high resistance). In fact, a transistor is designed to
18 change its resistivity, which change is clearly a change in its
19 properties and, in some cases, a change in state as from
20 conductor to insulator. The transistor cannot change the
21 properties of the power flowing through it unless it also
22 changes its own resistivity. The change in resistivity that
23 occurs in the semiconductor device can be thought of as a valve

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1 whose position may be changed through an external electric
2 stimulus. A small change in the voltage input to a basic
3 transistor gate drive changes the properties (resistance and/or
4 conductance) of the semiconductor's main conducting path.
5 Nothing of this nature is present in a transformer, which
6 performs its intended function without the need for an external
7 control.

8 Q. How does the transistor change its resistivity?

9 A. The transistor, unlike the transformer, cannot perform
10 its intended function without the application of a control
11 voltage. As a result of applied control voltage, the transistor
12 changes its properties and, depending upon the control input,
13 will act as an insulator, or a conductor, or variable resistor
14 controlling large currents in its main conducting path. These
15 variable device characteristics are the direct result of a
16 change in properties of the semiconductor of which the
17 transistor is made.

18 Q. How is the transformer distinguishable from this
19 description of the transistor's function?

20 A. A transformer's physical characteristics are
21 completely independent of the applied power. The turns ratio,
22 which determines how the power is transformed, is not dependent
23 on what kind of power is fed to the transformer. The turns

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1 ratio is designed and built into the transformer and becomes one
2 of its properties. If a transformer were like a transistor, the
3 ratio between the voltages of input and output power would
4 depend on the amount of power and the size of the load. This
5 does not occur, however, because unlike a transistor, the
6 transformer does not change its properties in operation. An
7 examination of how the current flowing through a transformer
8 changes provides another illustration of the distinction between
9 the properties of the transformer and the properties of the
10 electricity flowing through it.

11 For example, when 100 volts are applied to the primary
12 winding of a two winding isolation transformer where the
13 transformer has a one to one turns ratio and the secondary
14 winding of the transformer is connected to a 50 ohm load, the
15 current flowing through the transformer is 2 amperes. If the
16 voltage is increased to 150 volts the current increases to 3
17 amperes, while if the voltage is reduced to 50 volts the current
18 reduces to 1 ampere. The connecting conductors, transformer and
19 load have not changed. Only the current flowing in the system
20 as a function of the applied voltage has changed, according to a
21 fixed ratio that is an unchanging property of the transformer.

22 Q. What do you mean when you say that a transistor
23 requires an external force to perform its intended function?

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1 A. An analogy may be helpful to understand the active
2 nature of a transistor. A simple garden hose has properties
3 such as internal and external diameters, length, stiffness, and
4 materials of construction. A garden hose also have design
5 capacities such as maximum flow rate and temperature
6 limitations. Accordingly, I would suggest that a hose is a
7 passive device similar to a pipe or electrical cable. When
8 water flows through a hose, the properties of the hose do not
9 change. Increasing or decreasing the flow does not change the
10 properties of the hose. However, if some external force is
11 applied to the hose, such as squeezing or crimping the hose with
12 one's hand or foot in a controlled manner, the properties of the
13 hose are changed as a result of changing the effective internal
14 diameter of the hose. Turning back to electrical components, a
15 resistor is an electrical component that restricts the flow of
16 electrical current, but it does so at a fixed rate, much like a
17 section of hose or pipe. In much the same way that a person
18 might squeeze a hose, the invention of the transistor made it
19 possible for a small control voltage from an external source to
20 change the electrical properties of a fixed resistance
21 previously provided by a resistor - thus, the name "transistor."
22 The semiconductor in the transistor changes state in much the
23 same way that the diameter of the hose is decreased when someone

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1 squeezes the hose. The resistivity properties of a transistor
2 can be changed as power goes it with on an ongoing manner
3 through the application of an external electrical stimulus.

4 Q. Would your "garden hose" analogy apply to the
5 transformer?

6 A. Transformer does not require an external signal to
7 perform its intended function, in contrast to a transistor that
8 responds to changes in external forces like a hose that is
9 squeezed. The properties of a transformer do not change at all
10 in normal operation, just as the properties of a pipe, e.g., its
11 diameter, will not change unless the pipe is squeezed to its
12 failing point.

13 Q. Would you describe the figures that appear on pages
14 11-12 of your report?

15 A. Yes, those are figures that I prepared to assist the
16 judges and the parties and to demonstrate the differences
17 between the transformers and transistors.

18 Q. How do the figures demonstrate the difference between
19 transformers and transistors?

20 A. The figures illustrate visually the scientific fact
21 that transformers perform their intended function without
22 application of an external force, in contrast to transistors

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1 that cannot perform their intended function unless an external
2 electrical force is applied.

3 Q. In which specific ways are transformers different from
4 batteries which are 'excluded' components listed in 10 C.F.R. §
5 54.21(a)(1)(i)?

6 A. A battery produces electrical energy through a
7 chemical reaction. The electrolytic properties of the chemicals
8 of which the battery is composed change as the battery
9 discharges. In contrast, only the properties of the power
10 flowing through a transformer change. The key properties of a
11 battery that has been discharged will be different from a full
12 battery, but the key properties of a transformer that has had
13 power flow through it will not be different from the properties
14 of a transformer which has not been used.

15 Q. In which specific ways are transformers different from
16 power inverters which are 'excluded' components listed in 10
17 C.F.R. § 54.21(a)(1)(i)?

18 A. Like a transistor, the inverter requires an external
19 control in order to perform its intended function. An inverter
20 takes direct current power and converts it into alternating
21 current power. Inverters accomplish this power conversion by
22 controlling the magnitude, frequency and wave shape of the
23 output power. The external control allows the power inverter to

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1 vary the relationship between the input and output power, e.g.,
2 to decrease or increase the magnitude, frequency, and wave shape
3 of the power, which is wholly unlike the transformer, in which
4 the relationship between the input and output power is fixed and
5 determined by the characteristics of the power fed into it and
6 the load supplied by it. The transformer will not change the
7 magnitude, frequency or wave shape of the power flowing through
8 it.

9 Q. In which specific ways are transformers different from
10 power supplies which are 'excluded' components listed in 10
11 C.F.R. § 54.21(a)(1)(i)?

12 A. A power supply takes alternating current power and
13 converts it into direct current power. Like the transistor and
14 the inverter, the power supply requires an external control to
15 perform its intended function. Power supplies require voltage
16 regulation, which regulation is controlled by an electric
17 control circuit, apart from the main circuit, which converts the
18 bulk power. The external control will adjust the properties of
19 the power supply to deliver the desired voltage and current to
20 the load that is being supplied. The voltage and current
21 supplied by the transformer, on the other hand, depend on the
22 properties of the load, itself, and not on the properties of the
23 transformer, which only controls the turns ratio. The power

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1 supply, decides, so to speak, what kind of power to supply to
2 the load, whereas the transformer can only supply the power that
3 the load requires.

4 Q. In what general ways are transformers different from
5 other components 'excluded' in 10 C.F.R. § 54.21(a)(1)(i)?

6 A. The operation of a transformer is not at all similar
7 to that of 'excluded' components such as a power supply, circuit
8 breaker, inverter, or battery charger. Each of these "excluded"
9 devices has a mechanism to dynamically control the relationship
10 between the input and output and, as such, each is a truly
11 active devices. The transformer, on the other hand, is a static
12 device, having no moving parts, no control mechanism, and the
13 relationship between the input and output is fixed by the turns
14 ratio of the windings. A transformer is a passive device.
15 Further, active devices, including transistors and other solid
16 state devices, typically require two sources of power: the first
17 is a bulk source of power which supplies the large amount of
18 power used by the device to perform its intended function; the
19 second source of power, normally much smaller, controls the
20 operation of the device. The second source of power controls
21 the operation or state of the device, determining its
22 configuration or its properties.

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1 Q. Entergy and its experts have asserted that as with
2 "excluded" components, age-related degradation in transformers
3 is observable through deterioration of the transformer's
4 performance. How would you respond to this assertion?

5 A. Age related degradation in transformers will not be
6 observable through changes in the operating characteristics of a
7 transformer during its normal operation. Many kinds of age
8 related degradation are undetectable without complex testing.
9 If one were able to detect that a transformer were failing
10 through monitorable changes in its performance, transformers
11 would not fail because any prudent operator would replace them
12 before they did. Instead, in many instances transformers
13 operate within normal parameters until catastrophic failure
14 occurs.

15 Q. Can you describe some of kinds of age related
16 degradation which would not be monitorable through a degradation
17 of the transformer's performance?

18 A. The vast majority of age related degradation in a
19 transformer cannot be observed based on changes in electrical
20 performance. For example, the insulation integrity of a
21 transformer's winding structure cannot be determined by
22 monitoring a change in the electrical performance, because the
23 dielectric strength of the insulation may not be affected until

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1 the transformer fails. Degradation of insulation may cause the
2 build up of certain gasses in a transformer, but this will not
3 affect the transformer's performance, nor will routine
4 monitoring, such as dissolved gas analysis, will not provide
5 sufficient data. Although a dissolved gas analysis may reveal
6 the presence of gasses associated with one of several types of
7 degradation, those gasses can originate from numerous places in
8 a transformer. One must look at the insulation capability of
9 the oil and paper structure, which requires physical inspection
10 of the windings at various points in the transformer to identify
11 precisely the actual magnitude of degradation in the
12 transformer.

13 Q. Is the integrity of the insulation important to proper
14 transformer operation?

15 A. Yes, the transformer cannot operate without
16 insulation, and without proper insulation the windings would
17 automatically short circuit. When insulation experiences the
18 effects of age related degradation, its ability to protect the
19 transformer during power surges is diminished.

20 Q. Can you provide another example of age related
21 degradation that is not readily monitorable?

22 A. Another example would be the ability of the
23 transformer to withstand a short circuit, which cannot be

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1 determined with routine monitoring because this degradation is
2 mechanical and doesn't affect the transformer's performance.
3 Instead, detection requires internal inspection or an "impedance
4 versus frequency" scan of the winding structure. The impedance
5 versus frequency scan is a complicated procedure that requires
6 precise calibration and which must be repeated frequently in
7 order to develop the trending data which is necessary to
8 effectively reveal degradation. If the testing is too
9 infrequent, the probability of failure between testing intervals
10 increases.

11 As I explained in my report (NYS00005), other failure modes
12 that do not lead to degradation in performance include:

13 Polymerization, which results from normal transformer
14 operation, and is the disintegration of longer polymer chains
15 into smaller polymer chains, diminishing the insulation
16 integrity of the transformer windings. Polymerization has a
17 dramatic effect on the electrical strength of the transformer,
18 but until an electrical failure occurs, polymerization does not
19 affect the operating characteristics of the transformer. If a
20 short circuit occurs in a transformer in which a high degree of
21 polymerization has occurred, that short circuit is much more
22 likely to lead to the failure of the transformer, even if the
23 transformer had been designed to withstand such a short circuit.

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1 Some tests may reveal broad information about the degree of
2 polymerization in a transformer, but insulation degradation is
3 not uniform and a visual inspection is necessary to determine
4 whether the polymerization is occurring to a small degree,
5 without significant risk, throughout the insulation or whether
6 it is occurring more uniformly in scope or more intensely and
7 with significant risk at a small amount of locations.

8 Similarly, diminished mechanical and structural integrity
9 of the core and coil assembly may have no effect on the
10 operating characteristics of the transformer, that is until a
11 loose core and coil assembly results in a devastating short
12 circuit failure of the transformer. Over time, as insulation
13 compacts, the coil assembly will become less tightly packed, and
14 a less tightly packed coil assembly is less able to withstand a
15 short circuit. This form of age related degradation is
16 detectable only through visual inspection, because it does not
17 produce any of the electrical or chemical tracers picked up by
18 other tests.

19 In addition to degradation in the entire coil assembly,
20 individual windings may also deform and affect adjacent
21 windings, leading to internal arcing in the insulation
22 structure. Such deformation can occur due to the movement of
23 windings with age, use or abuse. This internal arcing due to

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1 deformed windings would have no effect on the operating
2 characteristics until it causes failure. As discussed
3 previously, while a dissolved gas analysis could produce some
4 evidence of insulation failure or hotspots, a relatively
5 frequent inspection interval is required to identify whether the
6 problem is worsening and, even then, such testing cannot
7 identify the specific places within the winding where the
8 degradation is occurring, since the coil assembly may contain
9 2,000 or more turns. Eventually, this deformation degradation
10 can cause the transformer to fail.

11 Movement of the winding structure due to a short circuit
12 fault in the system could cause a catastrophic insulation
13 failure but, until the failure occurs, it will not effect the
14 operating characteristics of the transformer.

15 A "corona" or radio interference voltage ("RIV") generated
16 by the transformer will have no effect on the operating
17 characteristics of the transformer but is a sure indication of a
18 problem with the transformer. When some structural flaw exists
19 in a transformer, it can disrupt the normal flow of the magnetic
20 field, which can manifest audibly as RIV. Although an
21 acoustical test could identify the existence of a corona, a
22 visual inspection is required to identify the actual flaw in the
23 transformer that is causing the corona or RIV.

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1 Q. Is it, then, a valid assertion that performance
2 monitoring will adequately detect age related degradation in
3 transformers?

4 A. No. Measuring changes in a transformer's electrical
5 performance is not sufficient, and does not capture evidence of
6 failure modes that are not detectable from performance
7 degradation.

8 Q. Considering the kinds of degradation you already
9 described, have you reached conclusions have you reached about
10 protecting transformers from age related degradation?

11 A. Some kinds of age related degradation can be reversed
12 contaminated oil can be replaced; other types of degradation
13 cannot, e.g., polymerization of the insulation. Where
14 polymerization has occurred, the best that can be done is to
15 identify the age related degradation before it causes
16 catastrophic failure of the transformer. Regardless of whether
17 age related degradation is reversible or not, in either case a
18 robust surveillance program relying on various monitoring
19 techniques is necessary. In the end, many types of age-related
20 degradation are only identifiable through visual inspections
21 made when the transformer is offline, even where a monitoring
22 technique may identify a general concern.

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1 Q. Entergy and its experts assert that large power
2 transformers are equipped with instrumentation to detect
3 degradation conditions. How would you respond to that
4 assertion?

5 A. As I have already described, external and advanced
6 monitoring methods such as infrared thermography, electrical
7 circuit characterization and diagnosis techniques cannot account
8 for several kinds of age related degradation, and if one kind of
9 test were able to detect a certain kind of degradation, it will
10 be unable to detect another. Even Entergy's own staff has
11 concluded "that dissolved gas analysis and other PM maintenance
12 tasks are not sufficient to identify all non-random degradation
13 mechanisms internal to the transformer since no indication of
14 this degradation mechanism was observable with existing
15 maintenance." Email String June 26, 2007 (NYS000038).

16 Q. Can you describe the kind of comprehensive program
17 which would prevent transformer failure due to age related
18 degradation?

19 A. As discussed in the 1994 Sandia Report, the 2003 EPRI
20 report, the 2006 EPRI report, and the 2006 IEEE report,
21 discussed in my Report (NYS000005), monitoring procedures such
22 as component performance monitoring, personnel training, and
23 quality assurance audits are not adequate. Such monitoring

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1 procedures do not provide the level of aging management
2 sufficient to demonstrate that the various transformers will
3 perform their intended functions during the period of extended
4 operation including a potential design basis accident or
5 incident. Specific and additional aging management programs
6 need to be implemented to detect aging degradation of
7 transformers and their component parts in advance of failure.
8 *See, e.g., EPRI 2003 Report, at 7-2 & sec. 7.1.2 (NYS000034).*
9 The 2003 EPRI report indicates that aging management programs
10 for age related degradation of transformers may include physical
11 inspections, power factor testing, analysis of insulation
12 resistance, oil leakage, gas- in-oil, comparison with original
13 factory test reports, vibration (humming), and impedance versus
14 frequency analysis. For example, the 2003 EPRI Report, on pages
15 6-1 to 6-16 identifies additional testing, surveillance, and
16 inspection techniques that could support a meaningful aging
17 management program.

18 The 2009 Information Notice, EPRI' s 2003 report entitled
19 Large Transformer End-of-Expected-Life Considerations and the
20 Need for Planning [1013566] (NYS000034), and IEEE' s 2007 report
21 entitled IEEE Guide for the Evaluation and Reconditioning of
22 Liquid Immersed Power Transformers [C57.140TM-2006] (NYS000017),
23 all discussed in my Report, indicate that current performance

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1 monitoring procedures for detecting transformer problems, such
2 as those in use at Indian Point, are not adequate to detect, in
3 advance of failure, all of the aging defects and degradation
4 phenomena in transformers. The idea that surveillance and line
5 maintenance or "trending" can effectively and sufficiently
6 prevent transformer failure is contradicted by the actual
7 failure rate of these transformers. Ultimately, a complex
8 mixture of testing at different intervals is required to manage
9 the effects of aging in transformers. As I discussed previously
10 degradation detection of different kinds of age-related
11 degradation requires varied tests performed at regular
12 intervals, both when the transformer is online and offline.

13 Q. Which transformers require this kind of program to
14 manage age related degradation?

15 A. Not only should transformers in active operating
16 electrical systems be subject to aging management programs,
17 transformers that are part of electrical systems that are used
18 less frequently, such as the IP3 transformers for Appendix R
19 (6.9KV/480V), 15 KVA GRD transformers for the gas turbines,
20 Station Service Transformers and transformers for Station Black
21 Out (SBO) should also be regularly tested for age degradation.
22 Some of these transformers may not normally be energized and/or
23 operating under full load conditions, so unidentified flaws may

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1 only be made apparent when they are energized in an emergency
2 condition.

3 Q. Have transformers failed due to age related
4 degradation at nuclear power plants?

5 A. As I explain in my Report, pp. 18-21, performance
6 monitoring certainly has not eliminated transformer failure. I
7 have reviewed the transformer failures discussed in NRC
8 Information Notice 2009-10 and have reviewed licensee event
9 reports concerning transformer failures at nuclear power plants.
10 Since 2007, transformers have failed catastrophically at 18
11 nuclear power facilities, including Indian Point: Indian Point,
12 Unit 3, Indian Point Unit 2, Limerick Generating Station, Unit
13 2, Diablo Canyon, Unit 2, North Anna, Unit 2, Oyster Creek
14 (three times), LaSalle County Station, Units 1&2 (twice),
15 Comanche Peak, Unit 1, Fermi, Unit 2, Salem, Unit 1, Sequoya
16 Nuclear Plant, Watts Bar, Turkey Point, Unit 1, Perry Nuclear
17 Power Plant, and Monticello Nuclear Generating Station.
18 Performance monitoring failed to prevent these failures.

19 Q. Can you provide some examples of how age related
20 degradation led to some of these failures and examples of
21 methods for detecting that degradation?

22 A. For example, in 2010 a transformer failed at Comanche
23 Peak Nuclear Power Plant with the reactor operating at 100%

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1 power. The unidentified failure occurred within the
2 transformer. The identification of that failure might have been
3 made through dissolved gas analysis, acoustic technique,
4 infrared inspection or frequency analysis while the transformer
5 was not energized; it was not the Comanche Peak transformer's
6 failure illustrates the need to rigorously pursue a maintenance
7 program consisting of several techniques, some of which can only
8 be implemented effectively when the transformer is not in
9 operation. The fact that the cause of the failure was not
10 identified, is itself an indication of the difficulty in
11 detecting age related degradation.

12 In 2010, a transformer failed at Fermi Unit 2, despite the
13 transformer operating normally. Consequently performance
14 monitoring would not have revealed the underlying problem, which
15 was discovered, after the fact, to be shorted CT conductors. It
16 is not clear how quickly the conductors were degrading, but if
17 the degradation was slow, visual or other kinds of detection
18 might have detected it. If the degradation occurred quickly, it
19 is unlikely that such testing would have been effective. The
20 underlying cause of the short was abrasion where the wire
21 entered the bushing, which should have been identified through a
22 simple visual inspection before failure. See Degeneff Report
23 at 20 (NYS000005).

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1 Also in 2010, a transformer failed at Turkey Point, Unit 3.
2 In this case, a flash over occurred on a bushing while it was
3 raining. A healthy bushing should function normally in the
4 rain, but a bushing covered in contamination can be susceptible
5 to this kind of failure. A simple visual inspection could have
6 revealed that this transformer would likely fail. *Id.* at 21.
7 Similar bushing failures occurred at Oyster Creek in 2009,
8 Diablo Canyon, Unit 2, in 2008, Limerick Generating Station,
9 Unit 2 in 2008, and at Indian Point, Unit 2 in 2010. *Id.* at 18-
10 19.

11 Q. Could any of these failures have been prevented with
12 present remote measurement technologies such as those discussed
13 by Entergy in pleadings and other documents?

14 A. Present remote measurement technology would likely not
15 have identified these kinds of deterioration, which eventually
16 led to the transformers' catastrophic failure. Physical
17 inspection of the type done with other in-scope components could
18 have prevented some of these failures, e.g., those due to build
19 up of contamination on a bushing, but performance monitoring
20 could not have detected these failures. The kind of testing
21 that would have been very effective in identifying evidence of
22 degradation - oil and gas analysis tests, for example - must
23 generally be conducted while transformers are offline. The

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1 instances of unanticipated transformer failures at nuclear power
2 plants demonstrate that the health of a transformer cannot be
3 accurately determined from external measurements. Remote
4 testing may not identify small flaws, which may cause large
5 problems. Power transformers can have thousands of turns, and
6 the ability to measure within the accuracy of one turn would be
7 required to assess the health of the transformer. This is
8 physically impractical with the transformer energized.

9 Q. What functions do transformers have Indian Point Units
10 2 and 3?

11 A. A review of Entergy's license application indicates
12 that Indian Point possesses Station Auxiliary Transformers,
13 Station Service Transformers, Station Black Out (SBO)
14 transformer, 15 KVA GRD Transformer for the gas turbines,
15 instrumentation transformers, and lighting transformers among
16 others. Some smaller transformers in use at power reactors
17 would include those used in control circuits.

18 A review of various publicly available electrical one-line
19 diagrams for IP2 and IP3 reflects that there are numerous
20 electrical transformers ranging from 345 KV to 120 volts located
21 throughout the Indian Point facilities that perform a function
22 described in §§ 54.4(a)(1)/(2) and (3). The role of some of the
23 transformers in providing for safety functions is described in

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1 Chapter 8 (Electrical Systems) of the UFSAR for each Unit on pp.
2 1167-68, 1333-43 of the UFSAR for IP3 and on pp. 1039-50 of the
3 UFSAR for IP2. The UFSAR for IP2 includes a one-line diagram
4 for the electrical plan for IP2; that diagram identifies some of
5 the transformers at IP2 and the central role that they play in
6 the electrical system of the plant. IP2 UFSAR, figure 8.2-1,
7 8.2-2 (NYS000014); Indian Point No.3 Nuclear Power Plant,
8 Electrical Distribution & Transmission System, DWG NO 9321-F-
9 33853, REV 17 (NYS000015).

10 Q. Can you summarize your Opinion of Entergy's Argument
11 that Transformers are Active Devices?

12 A. Entergy's argument is technically inaccurate. The
13 transformer is a static device as defined by the IEEE and its
14 Transformers Committee. A transformer does not change its
15 configuration nor its properties when it is performing its
16 intended operation. Neither the physical and electrical
17 configuration nor physical and electrical properties of a
18 transformer change while it is operating. The transformer
19 certainly does not change "state" when it is operating. Each of
20 a transformer's key properties demonstrates that it is a
21 passive device, which is long-lived if properly maintained and
22 monitored by an aging management program that goes beyond the
23 sort of remote monitoring up until now contemplated by Entergy.

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1 **UNITED STATES**

2 **NUCLEAR REGULATORY COMMISSION**

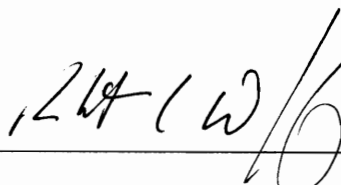
3 **BEFORE THE ATOMIC SAFETY AND LICENSING BOARD**

4 -----x
5 In re: Docket Nos. 50-247-LR; 50-286-LR
6 License Renewal Application Submitted by ASLBP No. 07-858-03-LR-BD01
7 Entergy Nuclear Indian Point 2, LLC, DPR-26, DPR-64
8 Entergy Nuclear Indian Point 3, LLC, and
9 Entergy Nuclear Operations, Inc. December 9, 2011

10 -----x
11 **DECLARATION OF DR. ROBERT C. DEGENEFF**

12 I, Robert C. Degeneff, do hereby declare under penalty of
13 perjury that my statements in the foregoing testimony and my
14 statement of professional qualifications are true and correct to
15 the best of my knowledge and belief.

16 Executed in Accord with 10 C.F.R. § 2.304(d)

17
18 
19

20 Robert C. Degeneff, D. Eng.
21 70 Cohoes Road
22 Watervliet, New York 12189
23 December 9, 2011

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