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

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

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

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

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

Q. What is the purpose of your testimony?

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

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

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

A. Yes.

Q. What is the source of those materials?

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

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

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

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[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).

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

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

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

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

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

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

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

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

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

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

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

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

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

Q. Please explain the general function that transformers perform.

A. The electrical transformer takes advantage of the unique properties of electromagnetic fields to transform electrical power of one voltage to electrical power of another voltage. The mathematical relationship between the voltage and the current is described by the following: voltage in x current in = power in = power out = voltage out x current out. Assuming zero resistance, the electrical power flowing through a transformer remains constant; consequently if the voltage of electrical power flowing through a transformer decreases and the power remains constant, current will increase proportionally, and vice versa. Another way the voltage and current relationship is often expressed: $V_{in} / V_{out} = I_{out} / I_{in}$ or $V_{in} / V_{out} = Current_{out} / Current_{in}$.

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

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

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

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

Q. Are transformers passive or active devices?

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

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

Q. What are the properties of a transformer?

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

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

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

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

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

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

A. No, the transformer's properties do not change during the course of its operation. The transformer is a passive component, with no moving parts. This understanding is widely accepted among the technical community. The Handbook of Transformer Design & Application states that "Transformers are passive devices for transforming voltage and current." Flanagan, The Handbook of Transformer Design & Application (2nd Edition), page 1.1, McGraw-Hill, 1993, ISBN 0-07-021291-0 (NYS000007). Another text book states that a transformer is "a static electrical device, involving no continuously moving parts, used in electrical power systems to transfer power between circuits through use of electromagnetic induction." Harlow, Electric Power Transformer Engineering, page 2-1, CRC Press (2004) ISBN 0-8493-1704-5 (referencing ANSI / IEEE)(NYS000008); *see also* Harlow, Electric Power Transformer Engineering, page 2-1 (2d Edition) CRC Press (2007) ISBN 0-8493-9186-5 (NYS000009). The sixth edition of the IEEE Standard Dictionary of Electrical and Electronic Terms includes the following definition of transformer: "A static electrical device

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Q. How does the transistor change its resistivity?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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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DECLARATION OF DR. ROBERT C. DEGENEFF

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

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

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December 9, 2011