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.	June 28, 2012

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REBUTTAL TESTIMONY OF DR. ROBERT C. DEGENEFF, D. ENG. 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, D. Eng., regarding Contention NYS-8.

Q. Please state your full name.

A. Dr. Robert C. Degeneff, D. Eng.

Q. Dr. Degeneff, could you briefly summarize the testimony you provided on December 9, 2011?

A. I was retained by the State of New York to provide expert testimony in connection with the State's Contention 8,

which asserts that Entergy's license renewal application ("LRA") should be denied because it improperly excludes transformers from aging management review ("AMR") in violation of 10 C.F.R. § 54.21 and does not include an aging management plan ("AMP") for transformers in violation of 10 C.F.R. § 54.29. In my testimony, as well as my expert report, I explained that transformers are passive devices, which are more similar to components for which AMR is required than those components for which AMR is not required. I also explained that age-related functional degradation in transformers is not readily monitored and so an AMP is needed to assure continued transformer functionality.

Q. What is the purpose of this rebuttal testimony you are now providing?

A. The State of New York has asked me to respond to Entergy's March 30, 2012 and NRC Staff's March 29, 2012 testimony on Contention 8.

Q. Have you reviewed any additional documents since your December 9, 2011 testimony in preparation for this rebuttal testimony?

A. Yes. I have reviewed the following documents filed by Entergy on March 30, 2012: Applicant's Statement of Position Regarding Contention NYS-8 (Electrical Transformers) (ENT000090)

("Entergy SOP"); Testimony of Applicant Witnesses Roger Rucker, Steven Dobbs, John Craig, and Thomas McCaffrey Regarding Contention NYS-8 (Electrical Transformers) (ENTR00091) ("Entergy Test."); and the supporting exhibits (ENT000092-ENT00130B).

Additionally, I have reviewed the following documents filed by NRC Staff on March 29, 2012: NRC Staff's Initial Statement of Position on Contention NYS-8 (Transformers) (NRC000030) ("Staff SOP"); NRC Staff's Testimony of Roy Mathew and Shelia Ray Concerning Contention NYS-8 (Transformers) (NRC000031) ("Staff Test."); and the supporting exhibits (NRC000032-NRC000038).

Q. Do any of these documents change your opinion that transformers are passive components that require AMR?

A. No. I maintain that transformers qualify as components for which AMR is required under 10 C.F.R. § 54.21. *See* Pre-Filed Written Testimony of Dr. Robert C. Degeneff Regarding Contention NYS-8 (NYSR00003) ("Degeneff Pre-Filed Test.") at 6. Furthermore, in order to maintain transformer functionality, under 10 C.F.R. § 54.29, an aging management program ("AMP") is required to provide a reasonable assurance that the effects of transformer aging will be managed during the relicensing period. The failure to properly manage transformer aging may compromise: the integrity of the reactor coolant pressure boundary; the capability to shut down the reactor and

maintain it in safe shutdown condition; or the capability to prevent or mitigate the consequences of accidents which could result in offsite exposures. *See* Report of Dr. Robert C. Degeneff In Support of Contention NYS-8(NYSR00005) (Dec. 12, 2011) ("Degeneff Report") at 17-22.

Q. Are there any significant points of agreement between your testimony and that of Entergy's and NRC's experts?

A. Yes. In order to qualify for AMR under 10 C.F.R. § 54.21 a component must: (1) have an intended function as set out in 10 C.F.R. § 54.4; (2) perform that intended function without moving parts; (3) perform that intended function without a change in configuration or properties; and (4) not be subject to replacement based on a qualified life or specified time period. In their testimony, Entergy's and NRC's experts admit that transformers: (1) perform an intended function as set out in 10 C.F.R. § 54.4 (Entergy Test. at 98, A109; Staff Test. at 11, A17); (2) perform that intended function without moving parts (Entergy Test. at 40-41, A58; Staff Test. at 12, A20); and (3) are not subject to replacement based on qualified life or specified time period (Entergy Test. at 14, A24; Staff Test. at 8, A.13). Neither set of experts asserts that transformers experience a change in configuration when functioning. Therefore, the only criteria on which their experts and I

disagree is whether transformers function without a change in properties (or state).

Q. Dr. Degeneff, Entergy asserts that you have no experience specific to the nuclear power industry or nuclear regulation (Entergy SOP at 9). Do you have any experience with transformers that are used at nuclear plants similar to Indian Point?

A. Yes. I own a small manufacturing company that assembles systems of equipment containing transformers, which have been applied in several nuclear facilities. These transformers function no differently than transformers that my company supplies for other industries. This is because a transformer's characteristics are exactly the same whether they are applied in a nuclear facility, utility, industrial site, factory, or residential setting. As I explained in my December 9, 2011 testimony, my education and professional experience provide me with in-depth knowledge of how transformers work and what is required to maintain their functionality. *See* Degeneff Pre-Filed Test. at 1-2.

Additionally, I have been a member of the Institute of Electrical and Electronics Engineers ("IEEE") Transformers Committee for approximately forty years. I currently serve as a fellow on the committee—a position that requires nomination and

election, and is held by only 2% of members. As a committee member, I have served on subcommittees and working groups that have written numerous standards providing guidance on the necessary specifications for transformers applied in nuclear plants. For example, I was involved in the creation of IEEE C57.12.00, which provides the general requirements for liquid immersed, distribution power and regulating transformers. I have also worked on guides for the installation of transformers (IEEE C57.12.11) and the testing of transformers' insulation capabilities (IEEE C57.12.14), among others. These IEEE guides are used by nuclear plants across the country.

Unlike Entergy's experts, this is the first time I have consulted for anyone in the nuclear industry— as such I have no longer term agenda other than to report the characteristics of a transformer properly.

Q. Entergy's expert Dr. Dobbs takes issue with your use of the terms "static" and "passive" in your December 9, 2011 report and testimony (Entergy Test. at 49-54). Can you please explain your use of these terms?

A. In my report and testimony, I have used the terms "static" and "passive" interchangeably to describe a component that has no moving parts and that performs its function without a change in configuration or properties. 10 C.F.R. § 54.21 does

not use the terms “static” or “passive” to refer to AMR-included components. In fact, the term “passive” is only used for convenience in the 1995 License Renewal Statement of Consideration (“SOC”), (NYS000016) at 22477, to refer to components that perform an intended function without moving parts or without a change in configuration or properties. Thus, Dr. Dobbs’s argument that I incorrectly conflate the terms “static” and “passive,” is irrelevant to 10 C.F.R. § 54.21, which uses neither term. As the Commission used the term “passive” for convenience in the SOC, so too have I used the terms “passive” and “static” interchangeably in my testimony to succinctly refer to a device that has no moving parts *and* that functions without a change in configuration or properties.

Q. Do the electrical engineering materials cited in your expert report also use the terms “static” and “passive” interchangeably?

A. No, the electrical engineering materials refer to components that do not have moving parts or are fixed in one place as “static” and components that do not experience a change in configuration or properties as “passive.” The electrical engineering materials frequently describe passive devices as those that cannot be controlled externally. This is because an external control is used to change a device’s properties, state,

or configuration. A device that the electrical engineering community considers to be both *static and passive* would require AMR under 10 C.F.R. § 54.21.

The electrical engineering community considers a transformer to be both static and passive (*see* NYS000006 and NYS000007). A transistor, on the other hand, is considered static and *active* because it does not have moving parts but it undergoes a change in properties and state during its normal intended use. The second edition of the IEEE dictionary defines a transistor as “An *active* semiconductor device with three or more terminals.” NYS000415 (emphasis added). And so, a component can be both static and active under the electrical engineering community’s definitions, but such a component would not be subject to AMR under 10 C.F.R. § 54.21.

Q.   Dr. Dobbs argues that the electrical engineering materials cited in your expert report are not relevant to determining if AMR is required under 10 C.F.R. § 54.21 (Entergy Test. at 49-52). Do you agree?

A.   No. The materials from the electrical engineering community that I cite are applicable to the Commission’s Part 54 concept of a passive component because they describe how a transformer functions. Since transformers function the same way in every context, the materials from the engineering community

are relevant to understanding how transformers function at Indian Point. Only with an understanding of transformer functionality can one determine if a transformer is the type of component that requires AMR under 10 C.F.R. § 54.21. The materials I cite reflect the consensus in the engineering community that transformers function without moving parts and without a change in configuration or properties.

Additionally, in their testimony, Entergy's experts acknowledge that Entergy relies on materials from the electrical engineering community in its transformer management plan. Entergy Test. at 104 ("The 'Indian Point Energy Center Large Power Transformer Life Cycle Management Plan' (ENT000125) is based on guidance provided by EPRI and the IEEE."). Therefore, such materials are certainly relevant to this proceeding.

Properties of a Transformer

Q. Now let's turn to Dr. Dobbs's discussion of transformer properties (Entergy Test. at 30-37). Does 10 C.F.R. Part 54 or the 1995 Statement of Consideration define the term "property" as it is used in 10 C.F.R. § 54.21(a)(1)(i)?

A. No. Although the term "property" is not defined in 10 C.F.R. § 54.21(a)(1)(i), the Statement of Consideration does mention that "a battery changes its electrolyte *properties* when discharging." SOC at 22477. This example illustrates what is

considered a property for the purposes of the regulation. A battery is composed of chemicals that undergo physical changes (chemical reactions) in order to produce the desired electrical energy. As the battery discharges electrical energy, the electrolytic properties (such as the conductivity, viscosity, acidity, and density) of the chemicals change. Thus, the traits of the constituent parts of a battery change during its operation. This example shows that in 10 C.F.R. § 54.21(a)(1)(i) the term "property" refers to the qualities or traits of an object.

Q. Is Dr. Dobbs's definition of "property" consistent with the definition of property as it is used in 10 C.F.R. § 54.21(a)(1)(i)?

A. No. Dr. Dobbs expands the definition of property to include not only the traits of an object, but also the traits of other materials with which an object interacts during its operation. Dr. Dobbs's definition is incorrect. An object does not inherit the properties of another object or material simply by interacting with it. If this were a valid concept of property, then the pressure and flow rate (in gallons per second) of the fluid in a pipe would be considered properties of the pipe containing the fluid. The pipe then would be considered an active component because the pressure and flow

rate of the fluid in the pipe may change. However, a pipe is specifically listed in 10 C.F.R. § 54.21 as an object requiring AMR because pressure and flow are *not* properties of the pipe; they are properties of the fluid itself. This shows that Dr. Dobbs's concept of property does not match that of 10 C.F.R. Part 54.

Q. What effect does Dr. Dobbs's definition of property have on his testimony regarding transformers?

A. According to Dr. Dobbs's logic, since one must refer to electricity, current, voltage, and magnetic field in describing the operation of a transformer, these are the properties of a transformer. Dr. Dobbs's entire argument that transformers are active components hinges on his conflation of the properties of the electricity running through the transformer and the properties of the transformer itself. He argues that a transformer is an active component because the current, voltage, and magnetic field travelling through the transformer undergo a change during transformer operation.

Q. Do you agree with Dr. Dobbs that voltage and current are properties of a transformer (Entergy Test. at 33-34, A53)?

A. No. Dr. Dobbs argues that voltage and current cannot be properties of electricity because they are created by an external force. However, this is fundamentally incorrect. The

laws of physics dictate that voltage and current are properties of the electrical power flowing through the transformer, not properties of the transformer itself. Current is the flow rate of electric charge. Voltage is the electromagnetic force that causes charge to flow through a conductor. The voltage that pushes charge through a conductor is akin to the pressure that pushes water through a pipe. It is commonly accepted that voltage and current are properties of electricity. Dr. Dobbs himself recognizes this fact. He states, "In simple terms, electrical power is defined by the equation: Power = (Voltage) x (Current)." Entergy Test. at 62, A74. It is immaterial how current and voltage are created because the electricity is the same regardless of whether it is created by a generator or a battery. Electricity cannot exist without voltage and current—these are its properties.

Dr. Dobbs also makes the erroneous argument that since current and voltage are not "peculiar to" electricity they cannot be properties of it. Contrary to his assertion, there is no requirement that an object's properties be unique to that object. Moreover, a property does not cease to be a property of one object simply because another object also possesses that property. For example, one property of a transformer is its conductor dimensions. This same conductor size could be used

for a cable or in a breaker. Since this conductor size is not "peculiar" to the transformer, application of Dr. Dobbs's argument would mean that the conductor size is not a property of the transformer (or cable or breaker). This is obviously not the case.

Q. Do you agree with Dr. Dobbs that magnetic field is a property of a transformer (Entergy Test. at 33-34, A53)?

A. No. Magnetic field is a property of electricity caused by the movement of electric current. Dr. Dobbs acknowledges this: "[B]oth positive and negative electric charges are surrounded by an electric field, and movement of those charges produces a magnetic field." Entergy Test. at 33, A51. When there is no electric current flowing into the transformer, there is no magnetic field because the transformer's coils and core are incapable of producing one. A magnetic field is also created when electric current passes through a cable, but this component is still considered to be passive under 10 C.F.R. § 54.21. This is because the magnetic field created by the electric current does not change the properties of the component through which the current is traveling, be it a cable or a transformer.

Dr. Dobbs's statements regarding magnetic field illustrate the fundamental inconsistency in his argument. First, he argues

that something cannot be a property of an object if it is created by an external force. According to this reasoning, since voltage and current are created by external forces, they cannot be properties of electricity. Entergy Test. at 13 and 33. For the same reason, he concludes that pressure and flow are not properties of water. Entergy Test. at 69, A78. However, he then argues that a magnetic field is a property of a transformer, despite acknowledging that it is created by an external force. Dr. Dobbs states, "The change in magnetism that occurs in a transformer's core occurs automatically through *external electric stimuli* supplied by changes in the source and load." Entergy Test. at 35, A54 (emphasis added). He also states, "[T]ransformers respond to *external* voltages, currents, and changes in load." *Id.* at 78, A87 (emphasis added). Under Dr. Dobbs's own reasoning, magnetic field cannot be a property of a transformer because it is created by an external force.

Q. What are a transformer's properties?

A. As I stated in my December 9, 2011 testimony, transformer properties include turns ratios, winding conductor dimensions, insulation type and thickness, core dimensions, and cooling capability. *See* Degeneff Pre-Filed Test. at 9. These are the constituent parts of the transformer whose traits define the transformer's function. They remain the same before,

during, and after a transformer's operation.

Q. Is the transformation ratio of the input and output voltage a property of the transformer? If so, does this make voltage a property of the transformer as Dr. Dobbs asserts (Entergy Test. at 59-60, A71)?

A. The transformation ratio is a property of the transformer. It is equivalent to the transformer's turns ratio. Both are determined by the number of turns on a transformer's primary winding divided by the number of turns on its secondary winding. This ratio never changes because the number of turns on a transformer's primary and secondary windings never changes. The ratio is described by the equation Vp/Vs = Np/Ns=N, where v = voltage, N = turns, s = secondary, and p = primary. As described by this ratio, the voltage of electricity moving through the transformer will be stepped up or down in proportion to the number of turns in the transformer's windings. For example, if there are twenty turns on the primary and two turns on the secondary, the turns ratio is 10. The voltage transformation ratio is also 10. So if the input voltage is 1000 volts, the output voltage will be 100 volts. This does not make voltage a property of the transformer; it simply describes the change voltage will undergo as it moves through the transformer. Voltage is a property of electricity, not a

property of the transformer itself.

Q. Do you agree with Dr. Dobbs that transformers are electrical sources and loads (Entergy Test. at 60, A73)?

A. No, Dr. Dobbs is incorrect. A transformer cannot generate power. It is not a source of power any more than a transmission cable is a source of power. The power must be supplied from some other source— a generator or battery, for example. The transformer passively transmits power in exactly the same way a cable transmits power.

Q. When the State's former consultant, Mr. Blanch, stated, "Transformers have design properties such as turns ratios, current, voltage, and power," (*See* 2009 Blanch Declaration, ENT000096, at 6) did he mean that current and voltage are properties of a transformer, as Dr. Dobbs argues (Entergy Test. at 56, A69)?

A. No. Mr. Blanch was referring to the fact that each transformer is built to withstand the flow of a certain amount of current at a specified voltage magnitude. A transformer's properties, such as its insulation, must be designed to withstand the anticipated maximum voltage of the system in which it is installed. In like manner, the winding conductors are sized to carry the anticipated transformer current. Each transformer is built to withstand a certain range of voltage and

current. This does not make voltage and current properties of the transformer.

Q. When you stated that both the input voltage and the load served are completely independent of the design and characteristics of the transformer, did you mean, as Dr. Dobbs asserts, that any transformer will work in any application (Entergy Test. at 64, A76)?

A. No. My statement was that a transformer with certain design characteristics can be inserted into multiple systems and perform satisfactorily. For example, let's assume we have a 60 hertz ("Hz") 10 megavolt ampere ("MVA") transformer designed to accept 230 kilovolts ("kV") input voltage and output 69kV voltage. One would expect to apply this transformer with the input power delivered at 230kV and the load receiving the power at 69kV. However, this transformer could be applied equally well serving a 5MVA load receiving power at 115kV and deliver that power at 34.5kV. This may not be an economical arrangement, but it is perfectly acceptable technically. In short, a transformer's fixed design properties can work with multiple input and output voltages. In other words, a transformer's terminal voltages and currents are subject to change based on how the transformer is being applied or used. Under Dr. Dobbs's own reasoning, terminal voltages and currents

cannot be properties of a transformer because they are not inherent to the transformer.

Q. Does your description of transformer operation resemble that contained in EPRI's License Renewal Electrical Handbook, as Dr. Dobbs argues (Entergy Test. at 56, A69)?

A. No. The description of transformer operation contained in the EPRI handbook was written by representatives from Duke Power (now Duke Energy) as part of a prior, unrelated license renewal application. The change in the "physical properties of the transformer" that these representatives refer to is a change in the voltage and current traveling through the transformer. As I have stated, current and voltage are properties of electricity, not properties of a transformer. Thus, the description of transformer operation contained in the EPRI handbook conflates the properties of electricity and the properties of a transformer.

Q. Is your paper, "A Method for Constructing Reduced Order Transformer Models for System Studies from Detailed Lumped Parameter Models," at odds with your testimony, as Dr. Dobbs asserts (Entergy Test. at 56-57, A69)?

A. No. Dr. Dobbs has fundamentally misunderstood the paper, which discusses a method for creating a computer model that utility engineers can use to perform system studies

involving transformers. The paper states that a transformer's terminal impedance (the transformer's impedance to the flow of electricity at its input at a specific frequency) is influenced by the frequency of the electric current (the number of times the current alternates per second) flowing through it. During normal operations the frequency is unchanging (*e.g.*, it remains at 60 Hz); however, an external event (such as lightening striking the transformer or a breaker opening the circuit) can change the frequency and subject the transformer to transient voltages. The structure of a transformer's insulation must be engineered to withstand differing transient voltages. In order to design the insulation, transformer manufacturers maintain complex computer programs that compute the internal transient voltage distribution when the transformer is subjected to transient voltages. My paper suggests a method for creating a simpler model that can be used by utility engineers to perform system studies. This paper in no way conflicts with my testimony. In fact, it supports my argument that under normal operations, a transformer's properties do not change. The frequency characteristic of the transformer, like the turns ratio, is a property of the transformer, and unless there is a problem with the transformer (an internal failure or fault), it will be invariant. This is one measure to determine if there is

a problem with a transformer.

Q. Dr. Dobbs asserts that a transformer experiences a change of state when it is put into service (Entergy Test. at 11, A24). NRC's experts argue that a "transformer changes its state by transforming electrical energy into magnetic energy, then back into electrical energy again." Staff Test. at 6, A8. Do you agree with either of these assertions?

A. No. "State" refers to the condition of matter with respect to structure, form, constitution, phase, or the like. For example, water can change state from a liquid to a gas. During its operation, a transformer does not experience a change in state— its constituent parts are exactly the same before the transformer is placed in service and during the period it is in service. For example, unlike a transistor which changes state from a conductor to an insulator during operation, a transformer remains a conductor throughout its operation. NRC's experts incorrectly conflate the properties of electricity and the properties of the transformer. Although the current and voltage in the transformer change, the transformer itself does not.

Q. Does a transformer change configuration during its operation?

A. No. Configuration refers to the arrangement of an object's physical parts. A change in configuration is a

physical change in the object's arrangement that affects how that object functions. For example, a valve, which is on the AMR-excluded list, changes configuration by physically opening and closing. None of the transformer's physical parts change arrangement during operation, and therefore, a transformer does not change configuration. Neither Entergy nor NRC Staff contends that a transformer experiences a change in configuration during operation.

Comparisons of Transformers to AMR-Included and AMR-Excluded Components

Q. Dr. Degeneff, now let's discuss Entergy's and Staff's experts' arguments concerning the differences and similarities between transformers and the components listed in 10 C.F.R. § 54.21(a)(1)(i). Does Dr. Dobbs present an accurate analysis of your comparison between cables (AMR-included) and transformers (Entergy Test. at 65-68)?

A. No. Dr. Dobbs's statements regarding cables are technically misleading and misrepresent the physical reality of the situation. Dr. Dobbs presents three cable arrangements when only the third is relevant to my comments. This third arrangement can be represented with the same basic electrical equation that represents a simple two winding transformer. My point was that since a transformer's function can be represented

by the same equation as a cable's function, a transformer should also be considered a passive component.

A transformer in its simplest arrangement consists of two conductors, one supplied with power and the other delivering power to a load. As such, the equations and characteristics of the simple two cable arrangement and a more complex transformer are exactly the same. This is basic to the understanding of cable and transformer operation. It is discussed in Chapters 3 and 4 of N. Hancock's book "Matrix Analysis of Electrical Machinery," 2nd Edition, excerpted in NYS000416. Moreover, NRC Staff's experts agree that two cables can function as a simple transformer. Staff Test. at 23, A30 ("Dr. Degeneff is correct, in a theoretical sense, that two cables in close proximity to each other can function as a simple transformer. . .").

Q. NRC Staff's experts argue that the similarities between cables and transformers are not relevant to the question of whether a transformer is an active or passive component. Staff Test. at 23, A30. Do you agree?

A. No, the similarities are very relevant for this inquiry. Because cables and transformers are both passive devices involved in the transportation of electricity, the same elements that make it difficult to detect functional degradation in cables also make it difficult to detect functional

degradation in transformers. Responding to a commenter who argued that the aging effects of cables would be "immediately detected during normal operation or functional testing," the 1995 Statement of Consideration states:

> The Commission disagrees with the commenter's assertion that the aging effects of cable make it easy to monitor functional degradation. Although there have been significant advances in this area, there is no single method or combination of methods that can provide the necessary information about the condition of electrical cable currently in service regarding the extent of aging degradation or remaining qualified life. Degradation due to aging of electrical cables caused by elevated temperature and radiation can cause embrittlement in the form of cracking of insulation and jacket materials. The cracks degrade the electrical properties of the insulation materials. The major concern is that failures of deteriorated cable systems (cables, connections, and penetrations) might be induced during accident conditions. Because these components are relied on to remain functional during and following design-basis events (including conditions of normal operations) and there are currently no known effective methods for continuous monitoring of cable systems, these examples of passive electrical components subject to an aging management review will remain in 10 C.F.R. § 54.21(a)(1)(i) and Section III(f)(i)(a) of the SOC.

SOC at 22477-78.

Just as aging degradation can cause embrittlement in cables that is difficult to detect, it can also cause embrittlement (reducing the degree of polymerization) in transformer insulation structures that cannot be detected simply by monitoring the voltage and current moving through the

transformer. The concern with both is exactly the same—as the insulation embrittles and degrades, the component's ability to withstand electrical stress decreases. This decrease cannot be observed in the electrical performance of the transformer or the cable, and left undetected will lead to catastrophic insulation failures.

Q. Do you agree with Dr. Dobbs's analysis of the differences between pipes and transformers (Entergy Test. at 69-72)?

A. No. First, as I mentioned above, Dr. Dobbs presents an inconsistent argument on what constitutes a property of an object. He argues that pressure and flow are not properties of fluid because they result from outside forces acting on the fluid. Entergy Test. at 69, A78. However, on page 35, A54, he argues that magnetic field is a property of the transformer, despite admitting that the magnetic field is caused by an external force acting on the transformer. As discussed previously, this characterization of property is incorrect. Pressure and flow are properties of fluid, not properties of a pipe. Furthermore, if these were properties of the pipe, the pipe would be considered an active component, which it is not.

Second, Dr. Dobbs misrepresents the analogy between a pipe and a transformer, and fails to properly relate Bernoulli's

equation. The analogy between a transformer and a pipe with a changing diameter is as follows:

- The power delivered into the transformer ("S-in", *e.g.*, MVA or electrical power) is the same as the power flowing out ("S-out") of the transformer (the transformer may induce a change in voltage, yet the power remains unchanged). In other words S-in = S-out. The analogy with the pipe is that the volume of fluid per unit time in ("Q-in" *e.g.*, cubic feet/sec) is equal to the volume of fluid per unit time flowing out ("Q-out") or Q-in = Q-out.
- The voltage into the transformer ("V-in") is analogous to the area of the pipe at its start ("A-in"). The voltage out of the transformer ("V-out") is analogous to the area of the pipe at its termination ("A-out").
- The current flowing into the primary winding of the transformer is analogous to the velocity of the flow into the pipe. The current flowing out of the transformer's secondary winding is analogous to the velocity of the fluid flowing out of the pipe.
- The turns ratio of the transformer (which is invariant) dictates the relationship between the voltage in and the voltage out of the transformer, *e.g.*, N = V-in/V-out. In

like manner, the relationship between the area of the pipe in to that of the area of the pipe out (which is also invariant) is N = A-in/A-out.

- The current into the transformer divided by the current out of the transformer is inversely proportional to N, the turns ratio or (V-in/V-out). In an analogous manner, the velocity of the fluid flowing into the pipe divided by the velocity of fluid flowing out of the pipe is inversely proportional to N, the area of the pipe in divided by the area of the pipe out (A-in/A-out).

The pipe with a change in diameter is considered a passive device. Since the transformer is performing an analogous transformation it must also be considered a passive device. In both cases, the transformer and the pipe with a changing diameter, the fact that electric power or a fluid flows through each device does not change the properties of either device. Just as the unchanging properties of a pipe cause the change in the fluid, the unchanging properties of the transformer cause the change in the electricity moving through it.

Q. NRC Staff's experts argue that transformers are not like pipes because pipes can transport fluid without changing its properties, but transformers cannot transport power without changing current or voltage (Staff Test. at 22, A29). Do you

agree?

A. No. The electricity flowing through the transformer need not undergo a change during transformer operation. Normally, the transformer is used to adjust the voltage of the power flowing through the transformer, but if the turns ratio is 1 to 1 then the power transmitted through the transformer will remain at the same voltage. This type of transformation is often used in power quality applications. By providing isolation, a transformer with a turns ration of 1 to 1 reduces electrical noise. In such a situation, the current and voltage of the electricity flowing through the transformer would not undergo any change. I have supplied this type of transformer to the nuclear industry.

Q. Dr. Dobbs argues that the only aspect relevant to classifying a pipe, heat exchanger, steam generator, and reactor vessel as passive is that they all serve as pressure retaining boundaries (Entergy Test. at 72-73). Do you agree?

A. No. As stated in 10 C.F.R. § 54.21, the relevant inquiry is whether a component undergoes changes in configuration, properties, or state during operation. These objects are considered passive because they do not experience a change in configuration, properties, or state. The comparison I made between the pipe, heat exchanger, steam generator, reactor

vessel, and the transformer is that during operation, all of these components contain external materials (fluid or nuclear fuel) that undergo a change in properties or state; however, the components themselves does not change properties, configuration or state. For example, as a steam generator converts liquid to steam, the liquid undergoes a change in state and properties, but the steam generator is still considered passive. Similarly, the nuclear fuel within the reactor vessel changes properties or state, but the component itself does not change. My point is that a component is not considered active merely because the external materials moving through that component change configuration, properties, or state. This is also true of the transformer, where the electricity traveling through the transformer may change magnitude, but the component itself does not change.

Q. Do you agree with Dr. Dobbs that the change in resistivity in a transistor is directly analogous to the change in magnetic field inside a transformer (Entergy Test. at 74, A82)?

A. No, these changes are not analogous. Resistance is a property of a transistor. During operation, a transistor’s resistance is changed, causing a change in the transistor’s properties. Furthermore, the change in resistance can cause a

change in the transistor’s state from a conductor to an insulator. The Statement of Consideration specifically cites this change in state as the reason for excluding transistors from AMR:

> Further, the Commission has concluded that “a change in configuration or properties” should be interpreted to include “a change in state” . . . For example, a transistor can “change its state” and therefore would not be screened in under this description.

SOC at 22477.

As I discussed earlier, magnetic field is not a property of a transformer. It is created by the electric current flowing through the transformer. The magnetic field does not cause a change in the transformer’s properties or state. Unlike the transistor, the transformer always remains a conductor. In comparison, a magnetic field is also created by the electric current traveling through a cable, but this does not make a cable an active component under the regulations.

The similarities between transformers and transistors discussed by Dr. Dobbs in his testimony and in ENT000111 are not relevant for the purpose of determining whether a transformer is an active or passive device under 10 C.F.R. § 54.21. The relevant criterion here is whether the device undergoes a change in configuration or properties (including state). The

transistor undergoes a change in properties and state; the transformer does not. Dr. Dobbs attempts to complicate the matter in order to obscure this basic fact.

Q. Do you agree with Dr. Dobbs that the differences between batteries and transformers are the same as the differences between batteries and transistors?

A. No. Again, Dr. Dobbs attempts to confuse the matter to distract from the relevant distinction between the components. During operation, batteries and transistors undergo a change in properties. The chemical properties of the battery change, and the resistance of the transistor changes. A transistor may also experience a change in state from a conductor to an insulator. A transformer experiences neither a change in properties nor a change in state. This is the relevant difference for purposes of determining whether AMR is required under 10 C.F.R. § 54.21.

Q. As with transistors, Entergy's expert argues that the fact that power inverters and power supplies require external control in order to perform their intended functions is irrelevant because this is not a valid basis for including them in AMR (Entergy Test. at 81-82). Staff's expert makes a similar argument and notes that transformers can have external control mechanisms that dynamically control the relationship between

input and output voltages (Staff Test. at 24). What is your response?

A. First, the transformers to which NRC's expert refers contain on-load tap changers, which have the ability to automatically change the transformer ratio. Such devices are not necessary for transformer functionality and do not change the basic function of the transformer. A tap changer can be compared to a valve on a pipe.

Second, like the transistor, the external controls on power inverters and power supplies cause those devices to change state. If the device has an external control then, depending upon the signal from the outside source, the device will perform some activity and change state or configuration, making it an active device. A transformer never changes state, even if it has a tap changer.

Q. Is Dr. Dobbs correct in asserting that you apply a "theory of inherited exclusion" when classifying power inverters, circuit boards, battery chargers, and power supplies as active components (Entergy Test. at 83, A95)?

A. No. Dr. Dobbs provides a flawed analysis of the classifications in the chart entitled "Comparison of Various Structures and Components" on pages 36-38 of my report (NYS000005). He mischaracterizes my argument saying that I

present the idea that power inverters, power supplies, and circuit boards are all excluded from AMR merely because they have solid state devices. My actual statement was that since these components have solid state devices they can change state from a conductor to an insulator (or vice versa), and as such would be considered active devices. Contrary to Dr. Dobbs's statement, this is not true for transformers, which cannot change state.

Q. Staff's experts distinguish active and passive components arguing that "failure of active equipment is usually readily apparent" while "[f]ailure of a passive structure or component may not be readily apparent." Staff Test. at 8, A11 and A12. Do you agree with this characterization?

A. No. First, the 10 C.F.R. § 54.21 characterizes AMR-included, or passive, components as those that do not have moving parts, do not function with a change in configuration or properties, and are not subject to replacement based on a qualified life or specified time period. The license renewal rule does not say that AMR-included components are those for which failure is not readily apparent.

Moreover, the detectability of failure is not a valid criteria for distinguishing active and passive devices. Contrary to Staff's experts' assertion, the failure of passive

components may be immediately obvious. For example, the failure of a cable would be readily detected by protective relaying on the system. If a pipe failed it would also be obvious because there would be a drastic change in pressure on the system, an increase in temperature on the system, or liquid would be visually spilling from the pipe. Furthermore, the failure of an active device may not be readily apparent. For example, if a circuit breaker or a transistor failed, it would not be obvious until a signal was sent to one of those devices and it did not respond.

Monitoring of Age-Related Degradation in Transformers

Q. Dr. Degeneff, now let's discuss the monitoring of aging degradation in transformers. Do you agree with Entergy's and Staff's experts that an AMP is not necessary for transformers because aging management is addressed through the requirements of 10 C.F.R. § 50.65 (the "maintenance rule") (Entergy Test. at 87, A96, Staff Test. at 20, A26)?

A. No, I do not agree. The regulations do not state that those components that would otherwise qualify for AMR under 10 C.F.R. § 54.21, are excluded from AMR because they are covered by the maintenance rule. Therefore, the sufficiency of the maintenance rule is not relevant to determining whether a component qualifies for AMR.

Moreover, the high incidence of transformer failures at nuclear facilities in the last few years is indisputable evidence that the Part 50 regulatory framework is inadequate for monitoring aging degradation and preserving the functionality of transformers. NRC's 2009-2010 Information Notice found: "A relatively high incidence of transformer failures has occurred in the last few years, the majority of which could have been avoided had the licensee fully evaluated and effectively implemented corrective actions and recommendations identified in industry operating experience." NRC Information Notice 2009-10, Transformer Failures-Recent Operating Experience (July 7, 2009)(NYS000019) at OAG 10000526_ 000002. In other words, if the licensees had taken additional actions, the transformer failures could have been prevented. However, the corrective actions and recommendations indentified in industry operating experience, such as in the IEEE Guide for the Evaluation and Reconditioning of Liquid Immersed Power Transformers, have not been endorsed by NRC and are not NRC requirements. Therefore, the Information Notice states that the majority of transformer failures could have been prevented if licensees had taken voluntary steps. The problem is not that failures aren't preventable, but that such preventative measures are not requirements under the Part 50 regulations. Mandating an AMP

for transformers would force licensees to take such additional steps. As the numerous failures show, the Part 50 requirements alone are not effective at preventing transformer failure.

Q. Do you agree with Entergy's experts that NUREG/CR-5753 provides support for the argument that AMR is not needed for transformers (Entergy Test. at 93, A103)?

A. No. Although NUREG/CR-5753 found that "there is no *presently identified* transformer aging mechanism that would cause a safety concern," this study is outdated (NYS000012 at ix-x, emphasis added). It was published 16 years ago, prior to the eighteen instances since 2007 in which catastrophic failures have occurred in transformers at nuclear power reactors. *See* Degeneff Report at 18-22. The study itself noted that transformers were relatively young at the time of the study and recommended additional review every *five* years.

Entergy's experts cite an industry guidance document, EPRI 1002913, *Power Transformer Maintenance and Application Guide*, to support their argument that significant changes have been made in surveillance and maintenance practices and programs since NUREG/CR-5753 was written. Entergy Test. at 93, A103. This document itself is ten years old, and like NUREG/CR-5753, does not take into account the recent wave of large transformer failures.

Q. Entergy's experts also argue that AMR is not required for transformers because Generic Safety Issue ("GSI") 107 "found that the safety significance of identified transformer performance issues was not sufficient to justify new requirements, and that maintenance rule requirements provide a sufficient means by which to address transformer performance issues . . ." Entergy Test. at 94, A105. What is your response?

A. Again, I do not agree that the maintenance rule must be found insufficient for the license renewal rule to apply to transformers.

Like the other studies cited by Entergy's experts, GSI 107 was issued 12 years ago, in 2000, before the recent wave of transformer failures. Since GSI 107 compared the risk of transformer failure to the cost of regulatory development, the recent increase in transformer failure could change the outcome of the evaluation. Therefore, GSI 107 does not present an accurate assessment of the current situation.

Q. Are you arguing, as Entergy's experts assert, that Entergy is required "to detect, in advance of failure, all of the aging defects and degradation phenomena in components, including transformers" (Entergy Test. at 96, A107)?

A. No, I am not arguing that an AMP is required to detect all aging degradation in transformers. I am arguing that an AMP

is necessary to detect degradation that can cause the loss of transformer functionality. The SOC specifically states, “The Commission believes that regardless of the specific aging mechanism, only aging degradation that leads to degraded performance or condition (*i.e.* detrimental effects) during the period of extended operation is of principal concern for license renewal.” SOC at 22469. Clearly transformer degradation that causes transformer failure is the type of degradation this rule aims to prevent. On pages 14-17 of my December 2011 report, I listed types of aging degradation that can cause loss of transformer functionality. I also explained how these types of degradation can go undetected without an AMP. Entergy’s experts mischaracterize my argument when they assert that I am concerned with detecting “all” of the aging effects and degradation phenomena in transformers. I do not believe an AMP is needed to detect “all” aging effects, but to detect degradation that can lead to failure of the transformer and related systems. While there can never be a guarantee that no failures will occur, the purpose of the license renewal rule is to provide a reasonable assurance that transformers will not fail. The recent history of transformer failure shows that the maintenance rule is insufficient, on its own, to provide this reasonable assurance.

Q. Do you agree with Entergy's and NRC Staff's experts that a transformer's performance can be readily monitored as it performs its intended function (Entergy Test. at 42, A60; Staff Test. at 12, A20)?

A. No. Entergy's and NRC Staff's experts are incorrect when they contend that transformer degradation results in a change in the electrical performance of the transformer and the associated circuit. Due to the transformer's passive nature, electricity can continue to pass through a degraded transformer up until the moment of transformer failure. For example, degradation to a transformer's insulation will not result in any noticeable change to the current and voltage, but over time this can lead to transformer failure. This is explained in more detail on pages 38-40 of my report (NYS000005).

Q. Do you agree with Staff's and Entergy's experts that the relevant consideration for purposes of determining whether AMR is required, is whether gross failure of transformers is readily detectable (Staff Test. at 8, 15, 23-24; Entergy Test. at 107, A116)?

A. No, the purpose of the license renewal rule is to prevent gross failure, not to detect it. Entergy and NRC Staff argue that as long as electricity is flowing correctly through the transformer, its performance is not degraded, and when the

transformer fails it is obvious. But it is the failure that is readily apparent, not the degradation. Transformer failure is the effect of unnoticed degradation, which is what an AMP is meant to prevent. This is why the Statement of Consideration says that the Commission is concerned with "aging degradation that leads to degraded performance *or condition* (*i.e.* detrimental effects) . . ." A transformer that appears to be functioning properly can nonetheless be in a degraded condition that will lead to failure. The presence of certain age-related degradation that can cause failure and is undetectable by performance monitoring is the very reason why an AMP is necessary for transformers.

I have participated in numerous transformer failure post mortems, which have found that the transformer failure could have been prevented if the transformer owners had had an effective aging management program.

Q. Can the age-related degradation of transformers be monitored online (*i.e.*, while the transformer is operating)?

A. No. Many of the tests to determine transformer degradation must be conducted while the transformer is offline. For example, the aging of cellulose insulation cannot be monitored with the transformer operating. Nor can all the dissolved gas in the transformer's oil be determined with the

transformer operating. Additionally, the mechanical integrity of the core and coils can not be determined with the unit operating. This requires physical inspection of the transformer, where the transformer is taken offline and drained of oil. It is unrealistic to represent that the aging condition of a transformer can be ascertained while the transformer is in operation.

This is significant because Entergy states that for all electrical components without moving parts indentified in the AMR-excluded lists, the functional degradation resulting from the effects of aging can be monitored online (*i.e.*, while operating). Entergy Test. at 40, A57. In contrast, the AMR-included components have aging-related degradation of their passive intended functions that cannot be monitored online. This is true of the transformer.

Q. Are Entergy's experts correct that some of the procedures you suggest for monitoring age-related degradation in transformers may be detrimental to transformer operation because they can introduce moisture and contaminants into the transformer internals and oil?

A. No, Entergy's experts' representation of my comments about monitoring the condition of the transformer takes an extreme and unrealistic position. Monitoring the health of the

transformer does not place the transformer in danger. All of the monitoring activities I suggested have been applied safely in the utility industry. A program for inspecting a transformer must be tailored to each unique transformer and its performance history. This is alluded to in the EPRI Copper Book when it discusses the draining of oil from the unit. *See* ENT000129. A transformer monitoring program must meet the prudent guidance of the electrical industry.

On page 101 of Entergy's testimony a section of EPRI's Copper Book is reproduced. A careful reading shows that there are instances when internal inspection is warranted and this can be accomplished safely. Furthermore, Entergy's *Large Power Transformer Inspection Guidelines* (ENT000121) contains guidelines on conducting internal inspections of transformers. Entergy's experts state in their testimony: "If transformer degradation was detected through the current monitoring that Entergy performs on the transformers, then Entergy would, if warranted, perform an internal inspection of the transformer to determine and correct the cause. See generally, EN-EE-G-001 (ENT000121)." ENTR00091 at 104.

Q. In a chart on pages 103-104 of their testimony, Entergy's experts explain the means by which they claim to address your concerns regarding the monitoring of aging

degradation in transformers. Does this chart alleviate your concern that aging degradation will go unnoticed in transformers at Indian Point?

A. No. The rate of transformer failure at nuclear plants across the country shows that performance monitoring is insufficient to provide a reasonable assurance that transformer functionality will be maintained. This is because there are significant transformer failure modes that involve aging degradation of transformer components that do not affect transformer operating performance until the transformer fails. Therefore, the performance monitoring outlined in Table 4, which is in accordance with Part 50, is insufficient to maintain the functionality of aging transformers. For example, Entergy's experts assert that "[m]echanical changes in the transformer can be detected through capacitance testing as is performed at IPEC." Entergy Test. at 103. Capacitance testing, however, is inadequate for monitoring the mechanical and structural integrity of the coil assembly. Visual inspection of the coil assembly is the only way to properly assess its integrity. As this requires draining the oil from the transformer, such degradation is not observed through performance monitoring. Similarly, Entergy's experts assert that furanic compound analysis of the oil is Entergy's method of detecting

polymerization. *Id*. However, as I explain on page 14 of my December report, visual inspection is necessary to determine whether the polymerization is occurring to a small degree and without significant risk throughout the insulation, or whether it is occurring intensely and with significant risk at a small number of locations.

Importantly, this chart refutes Entergy's and Staff's claim that age-related degradation in transformers is readily monitored, since Entergy's experts admit that there are conditions that may require the transformer oil to be drained so that a physical inspection of the transformer's internal structure can be conducted. This shows that the transformer's ability to perform its intended function is not monitored solely by a change in the electrical performance of the transformer and associated circuits.

Q. Your December 9, 2011 report cited a number of recent transformer failures. NYS000005 at 18-22. Have you come across any additional transformer failures that were not prevented by performance monitoring but could have been prevented with an AMP?

A. Yes. I have found two additional licensee event reports involving transformer failures that were not prevented by current monitoring but could possibly have been prevented by

an AMP:

- On June 27, 2011, the off-site AC power sources to Unit 2 Prairie Island Nuclear Generating Plant were declared inoperable as a result of Transformer 2RY lockout and less than the required minimum voltage on the transmission system. The overcurrent ground detection relay actuated due to a bus phase to ground fault resulting from failed gasket material, causing the transformer lockout. It was determined that a less than adequate review of the Preventive Maintenance Deferral Process delayed bus inspection that would likely have identified and corrected the problem (a hole in the bus duct due to exposure to moisture and rain). *See* NYS000417. This problem could have been prevented with more frequent inspection of the bus duct. The bus duct's degradation did not result in a change to the transformer's electrical performance until the moment of lockout.
- On January 30, 2012, Byron Station Unit 2 experienced a loss of normal offsite power and a reactor trip. On February 28, 2012, Byron Station Unit 1 experienced a loss of normal offsite power. Both events were caused by the failure of system auxiliary transformer inverted

insulators (bushings). The insulator failures were caused by service propagation of a large manufacturing material defect. *See* NYS000418. It is possible that these bushing defects could have been found through visual inspection, but not performance monitoring. Several of the recent transformer failures have been caused by bushing failures. For example, the main transformer failures at Indian Point Units 3 and 2 in 2007 and 2010, respectively, were caused by bushing failures. Entergy Test. at 105-06, A115. The bushing is an integral part of the high voltage power transformer. A high voltage power transformer cannot function reliably without bushings. The bushing is the point of electrical connection between the electrical system and the transformer. The purpose of the electrical characteristics of the bushing are the same as those of the high voltage cable, *i.e.*, to provide a low impedance path over which the power can flow and concomitantly to provide insulation between the conductor and ground (or other phase conductors). The degradation of the ability of either to perform its intended task cannot be consistently determined by measuring the change in the transformer's electrical performance.

Q. Do you have any concluding remarks?

A. Transformers are a critical component in maintaining the safety and reliability of the Indian Point facility. Entergy claims that the program they have in place can maintain the safety and reliability of the system without an AMP for transformers. This is simply not the case, as demonstrated by the transformer failure rate in recent years. Without an AMP, there cannot be reasonable assurance that the effects of aging will be adequately managed so that transformer functionality will be maintained consistent with the CLB for the period of extended operation.

Q. Does this conclude your testimony?

A. Yes.

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.	June 28, 2012

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DECLARATION OF 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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June 28, 2012