Q. **Reference: At page 58 of the report, Liberty states that "triple redundancy for the supply of lubricating oil to the turbine generator comprises a minimum requirement".**

Please provide the basis and authorities that support this statement.

A. The basis for Liberty's statement on triple redundancy lies in the catastrophic consequences of lube oil failure in large steam turbine generators. Those consequences include a prolonged outage and high repair costs. In our experience, we have observed mostly triple redundant measures, or variants thereof, for lube oil systems associated with large steam turbines. While the basis for our conclusion is our experience, there is evidence in the literature to support that conclusion as well. Consider for example "Guidelines for Maintaining Steam Turbine Lubrication Systems"[1], which is an extensive document prepared by the Electric Power Research Institute (EPRI) and which benefited from the input of many utilities in the U.S. and Canada. It describes lube oil systems on Page 2-26 as follows:

> *In virtually all steam turbine generating systems, turbine bearings are lubricated with pressurized oil supplied by a main shaft oil pump (MSOP). When the machine is operating at or near synchronous' speed, the MSOP can supply the volume of oil necessary to maintain proper bearing lubrication; however, during startup or coastdown, when the rotor must turn at substantially less than synchronous speed, capacity of the MSOP decreases dramatically so that it can no longer supply an adequate volume of oil. During these operating periods, or in the relatively unlikely event that the MSOP fails while the system is operating at synchronous speed, an auxiliary source of lubricating oil must be provided. Most systems include a bearing oil pump that is driven by an ac motor. This pump is often referred to as the "auxiliary or backup" oil pump. Additionally, to accommodate emergency situations when ac power may not be available, most systems are also provided with a bearing oil pump driven by a dc motor; this pump is usually referred to as the "emergency" pump. Some systems may have yet another bearing oil pump for use when the turbine is being rotated by the turning gear.*

There are examples of systems in which an auxiliary AC pump (as opposed to a shaft-driven main oil pump or a main oil pump powered by the generator) is the primary source of lube oil, with an emergency DC pump as a backup. In such cases, however, a fully redundant AC pump is usually provided. Such a system would still be considered triply redundant if the probabilities of failure of the AC pumps were mutually independent; i.e., a single credible event would not disable both pumps.

The technical paper provided by Hydro in response to PR-PUB-NLH-178 also sheds light on the redundancy question:

[1] http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=CS-4555

> *GEC's [General Electric] common design practice in the late '70s was to provide triple redundancy of LO supply.*

The paper notes that the subject plant, San Onofre, chose to eliminate the shaft-driven main lube oil pump of the standard GE design, using instead two AC pumps (one operating and one in standby mode). San Onofre characterized this design as "double redundant". A key message of the paper is that the double redundant system was no longer considered acceptable.

At one time, there was an ASTM standard titled "Standard Practice for Design of Steam Turbine Generator Oil Systems (D 4248)". This described the three traditional pumps (main, auxiliary, and emergency) and noted that:

> *Many combinations of pumps can be satisfactory. As a minimum these should be two pumps driven from two independent and different power sources. Thus no single incident or equipment failure can cause loss of pumping.*

ASTM withdrew this standard in 2008 "due to lack of interest and support for its continued use"

Liberty continues to believe that large steam turbines demand a higher level of protection than what double redundant systems can provide. Double redundancy may prove satisfactory for smaller units that involve lower risks, costs, and damage potential, but large utility-scale turbines require more.