21st Annual RETS-REMP Workshop
June 28 – 30, 2011
Oakbrook, Illinois

Use of Collective Radiological Effluents as a Performance Indicator in the Commercial U.S. Nuclear Power Industry

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Abstract – In the U.S. nuclear power industry, long-term power plant effluent trends reveal improvements in industry-wide management of liquid and gaseous effluents and fuel condition. However, steady increases in tritium effluent activity have also been seen as the industry increases licensed thermal limits and availability factors. The trends highlight the potential for impact of individual events on industry-wide performance and individual site relative performance. Radiological effluents are used as an annual performance indicator by U.S. nuclear plant operators and their nuclear liability insurer.

I. INTRODUCTION

U.S. commercial nuclear power plants produce and monitor gaseous and liquid radiological effluents throughout the year. These facilities report the quantity of these effluents annually to the Nuclear Regulatory Commission in publicly available reports as described by Regulatory Guide 1.21. Commercial nuclear power facilities' operating staffs also calculate the dose imparted by these effluent activities on the public.

As part of the industry's ongoing drive to achieve and maintain operational excellence, a living system of performance indicators has been developed within the industry to be used in evaluating nuclear power plant performance.

The U.S. Nuclear Regulatory Commission (NRC) provides a comparison of U.S. nuclear power facilities effluents on a comparative basis and promulgates this comparison annually to the public (NRC 2008). American Nuclear Insurers and the Institute of Nuclear Power Operations both review and compare plant effluents as well.

From an operational perspective, trending and reporting of comparative effluent levels can provide useful insights to plant operators, helping to improve overall operational performance. The changes in noble gas and iodine effluent activities, for example, provide a way to measure the impact of industry efforts to keep the number of fuel defects as close to zero as possible.

Radiological effluent values are used by nuclear operators as part of the input to calculations of dose to the public. These calculations are a technical, scientific evaluation of the radiological risk to the public (NRC, 2009).

From a nuclear liability insurance perspective, effluent activity levels are a key means of comparing plant performance across the industry. Insurance experience indicates that litigation can be negatively affected by the amount of radioactivity released to the environment.

For 30 years, American Nuclear Insurers has compared effluent levels among the operating U.S. nuclear power reactors. Since 1981, these quantities have been compiled and used as a performance indicator for input to comparative nuclear liability insurance performance assessments (NRC, 1995).

The management of the effluent controls programs in the U.S., and therefore the reported data that supports this performance measure, is regulated by the requirements of U.S. Code of Federal Regulation (CFR) parts 20 and 50. Depending upon the specific license conditions of a given NRC licensee, part 40 (EPA) requirements of the CFR are usually in place as well. Several NRC Regulatory Guides ("Reg Guides") and NUREG documents provide the details of how these programs are implemented in the U.S. (Harris and Miller).

II. Method of comparison

Performance comparison across the U.S. nuclear industry is a basic tool of the industry's drive toward operational excellence.

In the U.S., the trending used as an input to nuclear liability insurance-related performance comparison is a rolling, three-year weighted average of the number of curies of principal radionuclides reported as effluents in accordance with NRC Reg Guide 1.21. The rolling three-year weighted averages are converted into subfactors that partially make up a rating factor (multiplier) for nuclear liability insurance premium for operating power reactors.

III. OBSERVATIONS

The trends shown here are those collectively discharged curies of radioactivity without normalization, e.g., per unit of electricity produced.

Figures 1 through 3 show the long-term decreases in the aggregate level of non-tritium effluents. Larger reductions in the 1980's and 1990's were followed by steadier levels in recent years.

These data trends can be explained by the ongoing efforts in the U.S. nuclear power industry at improving the condition of nuclear fuel and the development and use of more effective waste treatment systems.

Maintaining nuclear fuel integrity reduces the amount of noble gas, iodine and radioactive particulate in discharges by containing these components within the fuel cladding (Eisenbud).

Radioactive waste system improvements have brought increased effectiveness to those efforts at capturing radioactive material which is capable of being filtered, removed via ion exchange, reverse osmosis, chemical separation, etc.

The trends reveal the potential for individual annual power reactor effluent performance to affect the aggregate level of performance. Most of the relative peaks in Figures 1 – 3 can be attributed to an individual plant.

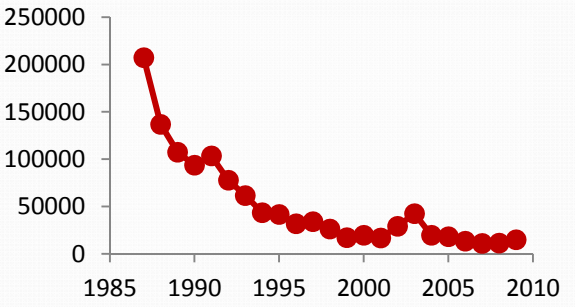

Figure 1 – Noble Gas Curies

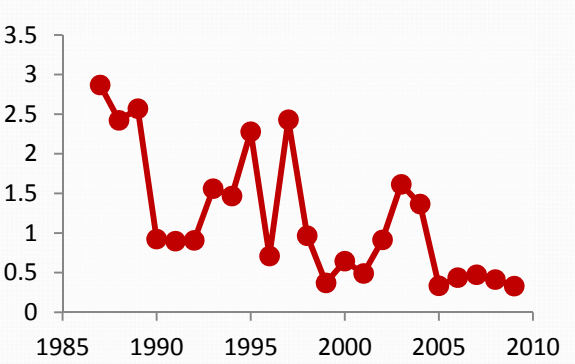

Figure 2 – Iodine and Particulate Curies

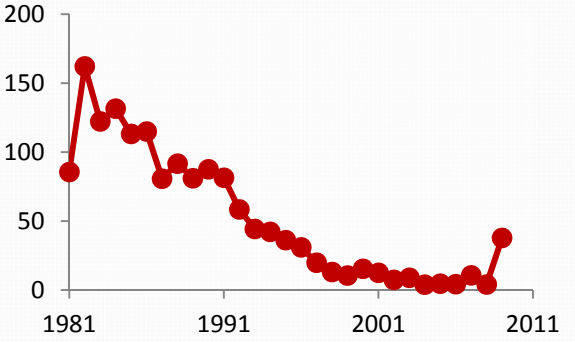

Figure 3 – Waterborne Non-Tritium Curies

Figures 4 and 5 display long-term annual tritium (H^3) discharge levels. Increases in industry-wide tritium discharges can be attributed to increases in industry-wide availability factors and licensed thermal power limit increases (power uprates) over the time frame shown.

Tritium production in power reactors is attributed to reaction with boron from PWR chemistry control, control blade leakage (as it occurs) in BWRs, and directly from fission (NRC). The tritium produced is present in the plant (BWR or PWR) coolant.

Since tritium and tritiated water behave chemically as hydrogen and water, respectively, there are no practical means available to reduce the tritium content of the typical licensed power reactor effluent discharge.

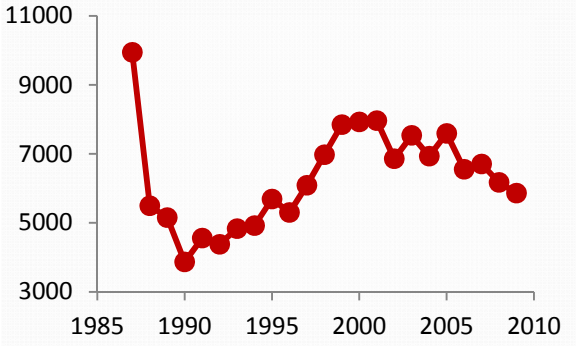

Figure 4 – Airborne Tritium Curies

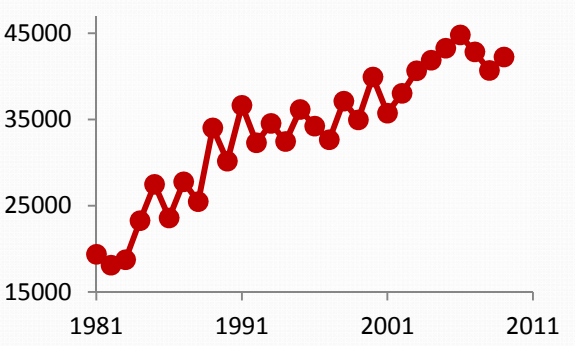

Figure 5 – Waterborne Tritium Curies

Perhaps the most dramatic results seen here are those from improvements in fuel condition. This improvement is beneficial from a nuclear insurance risk perspective.

In looking to reduce plant discharges however, tradeoffs are encountered. For example, the work required to modify and operate radioactive waste treatment systems or related to fuel defect management can increase worker dose. Cleanup of certain systems can and often will increase the amount of low-level radioactive waste produced.

Managing and minimizing the amount of radioactive effluents is importance to the avoidance of potentially costly nuclear liability insurance claims.

IV. Use of Effluent Trends as a Performance Indicator

The amount and type of overall effluent levels can be used as an indicator of plant performance in a number of ways.

In the U.S., the radiological impact of nuclear power plant effluents is determined through calculation of radiation dose to a hypothesized maximally exposed individual at the site boundary. Apart from the regulatory requirements involved, this quantification of potential dose to the public is desirable from a nuclear liability risk reduction standpoint as well. Quantifying the radiological impact of the plant in a formal, documented process is important to forming an understanding of the related radiological risk.

However, if the process in place can be used to support the perception that discharged radionuclides with lower dose impacts do not command a similar level of management attention as those leading to higher radiological risk, nuclear liability insurance risk can be increased.

Since the nuclear power industry has reduced the overall level of discharge of many radionuclides, an unexpected discharge from a power plant site can produce a much greater departure from the norm in comparison to the rest of the industry.

V. Quality of Data

U.S. nuclear power plant operators monitor and report radiological (and other) effluents to the appropriate jurisdictional authorities annually in publicly available reports.

Data from these reports are used as input to performance monitoring within the industry and by external parties with an interest in the various forms of risk presented by plant effluents. For nuclear insurance purposes, only data that has been submitted for regulatory compliance requirements is used in the comparative analysis.

Therefore, it is crucial that instrumentation and test equipment used to determine effluent levels is maintained carefully and adequate surveillances are performed to ensure these systems' proper operation.

Human error involved in the reading, calculation and reporting of this data is discussed in the regulations. Reports of errata are occasionally made through the same reporting process as the original data itself.

VI. Conclusions

The management and reporting of licensed radiological discharges from U.S. nuclear power plants has an influence on nuclear liability insurance risk and the perception of radiological risk.

Historically, the U.S. commercial nuclear power industry appears to have demonstrated, on the whole, an ability to reduce the overall level of radioactive effluents. Individual plant performance can, therefore, have a larger relative impact on combined industry performance than it has in past years.

Despite the many advances made in the reduction of overall nuclear power plant effluent radioactivity levels, no practical means is available to reduce tritium effluent activity levels from these facilities, though the dose impact from tritium releases has been extremely low. Overall tritium effluent levels have remained relatively steady for the past several years.

References

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