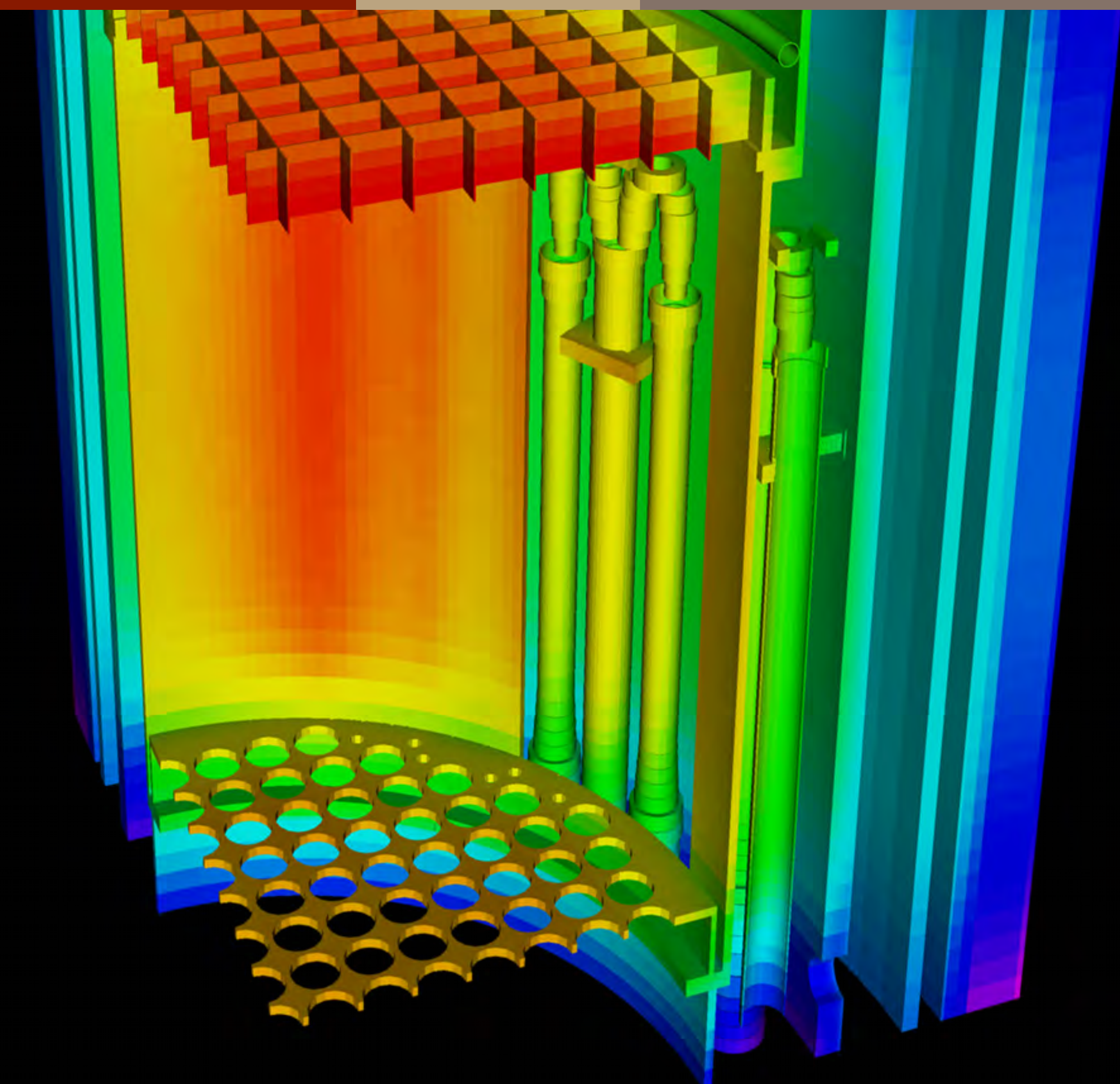
Fluence

The TransWare Advantage



Don't guess – know. Plant life extensions, P-T curve analyses, component flaws, and equipment qualifications all have something in common; they require an accurate assessment of fluence.

To some, fluence is just a number. At TransWare, fluence is our passion. We've spent more than 20 years developing and innovating this crucial area of plant support and operation. We are the principal developers of the RAMA Fluence Methodology, a three-dimensional, deterministic particle transport code, approved for use in RPV and internal component fluence calculations by the U. S. Nuclear Regulatory Commission.

Whether you're performing a plant life extension, P-T curve analysis, component flaw evaluation, or equipment qualification, fluence will be a critical part of your project, and we have the tools and expertise to help you.

What is fluence?

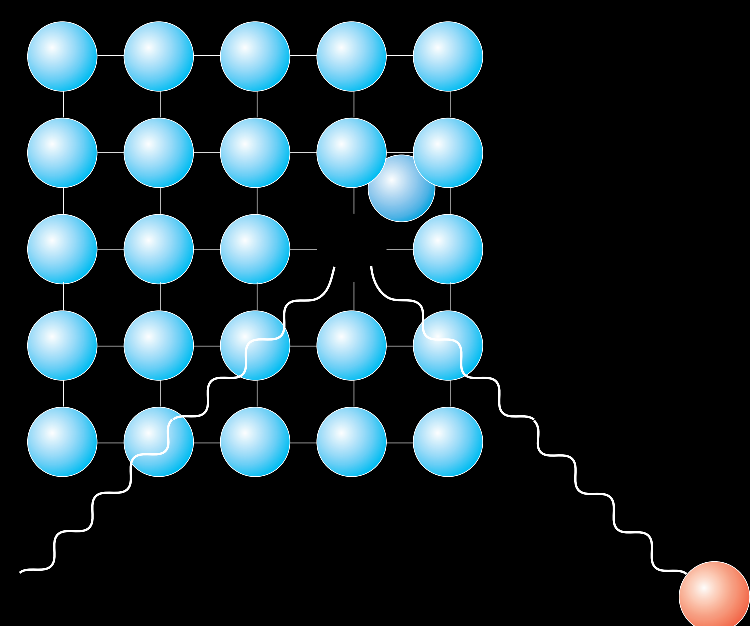
Fluence is the time-accumulated neutron or gamma flux through a given surface for a given period of time. In simpler terms, it's the amount of radiation a component has received over time. Many factors go into determining the rate of fluence accumulations, also known as flux, including reactor power, fuel bundle designs, and operating strategies. Fluence is further broken into two categories, fast fluence (neutrons with energy > 1.0 MeV), and thermal fluence (neutrons with energy of about 0.025 eV). The distinction between the two categories is important because the two types of fluence have vastly different effects on materials and require different approaches in their calculation.

Fast neutrons displace atoms in a material's structure, weakening the lattice and causing it to become more brittle. Embrittled material is more susceptible to cracking, and existing cracks will grow faster. Core shrouds and former plates are the most susceptible to cracking due to their proximity to the core. Fast fluence also causes structural lattices to expand, lengthening materials over time, which is a contributing factor to such industry issues as channel bow. More recently, concerns regarding the effect of fluence on the elongation of the core support plate rim bolts in BWR's have been raised.

Thermal neutrons tend to be absorbed by impurities in the material lattice, such as boron. The resulting heavy elements

Fluence Effects

Fluence has many effects on material structures. The type of effect is dependent on the energy range of the neutrons. In the simplified figure to the right, a fast, or high-energy, neutron displaces an element in the material lattice structure, leaving a weakening void. Other examples include the absorption of a thermal, or low-energy neutron, leading to unstable isotopes and, eventually, helium generation.



are often unstable, emitting alpha particles as they decay. These alpha particles, or helium atoms, get trapped in the material, which can affect its weldability for performing repairs, thus necessitating the replacement of failed components.

All material changes must be considered when it's time to repair a weld, develop your in-service inspection plans to monitor shroud weld crack growth, or update P-T curves.

When do you know if a component is approaching or has exceeded its durable lifetime? Inspections and calculations. With the aging of the current nuclear fleet, radiation effects on all material structures inside and outside the vessel, including reinforced concrete structures housing the pressure vessel, are being reviewed with all possible means. The most cost-effective means are calculations.

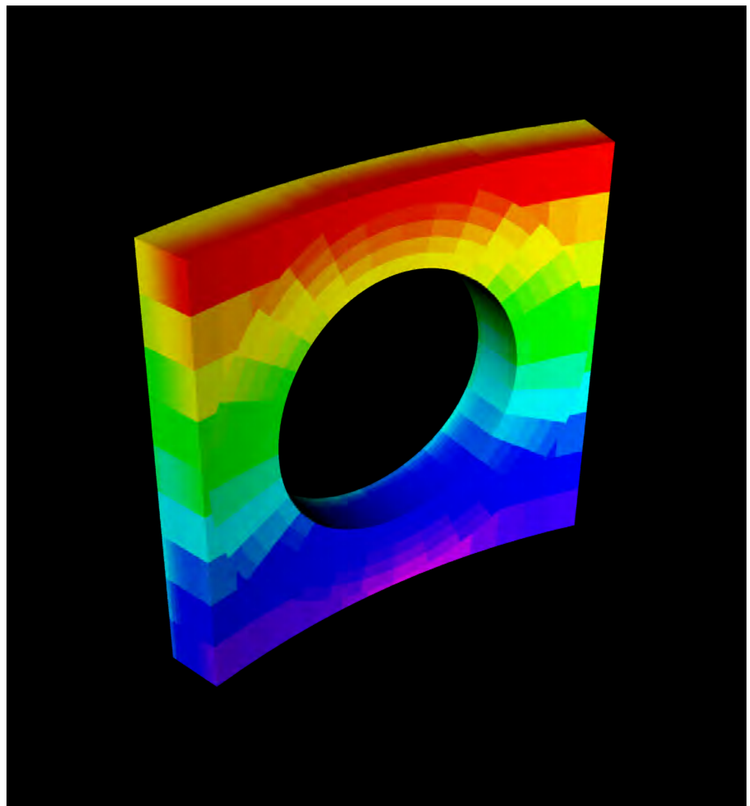
How is fluence calculated?

There are many tools for calculating fluence, the first of which were developed more than 50 years ago. Today, there are several categories of fluence codes, the broadest of which include Monte Carlo methods and deterministic methods. Monte Carlo codes function by brute force simulation of neutron particles and statistical analysis. With enough particle simulations, or histories, the method approaches an asymptotic solution along with a corresponding uncertainty. The process is time consuming, but it can produce very good results. Besides computational time, these methods are further limited by requiring the user to specify the specific tally regions in which to obtain a solution. As the number of tally regions increase, so does the solution time and statistical error.

To address these inherent limitations, another class of codes was developed that solve the Boltzmann transport equation analytically by making certain approximations. These methods are collectively referred to as deterministic methods. Since the equations are solved analytically for the entire problem geometry, a deterministic code allows the user to get detailed results for the entire reactor in a relatively short period of time.

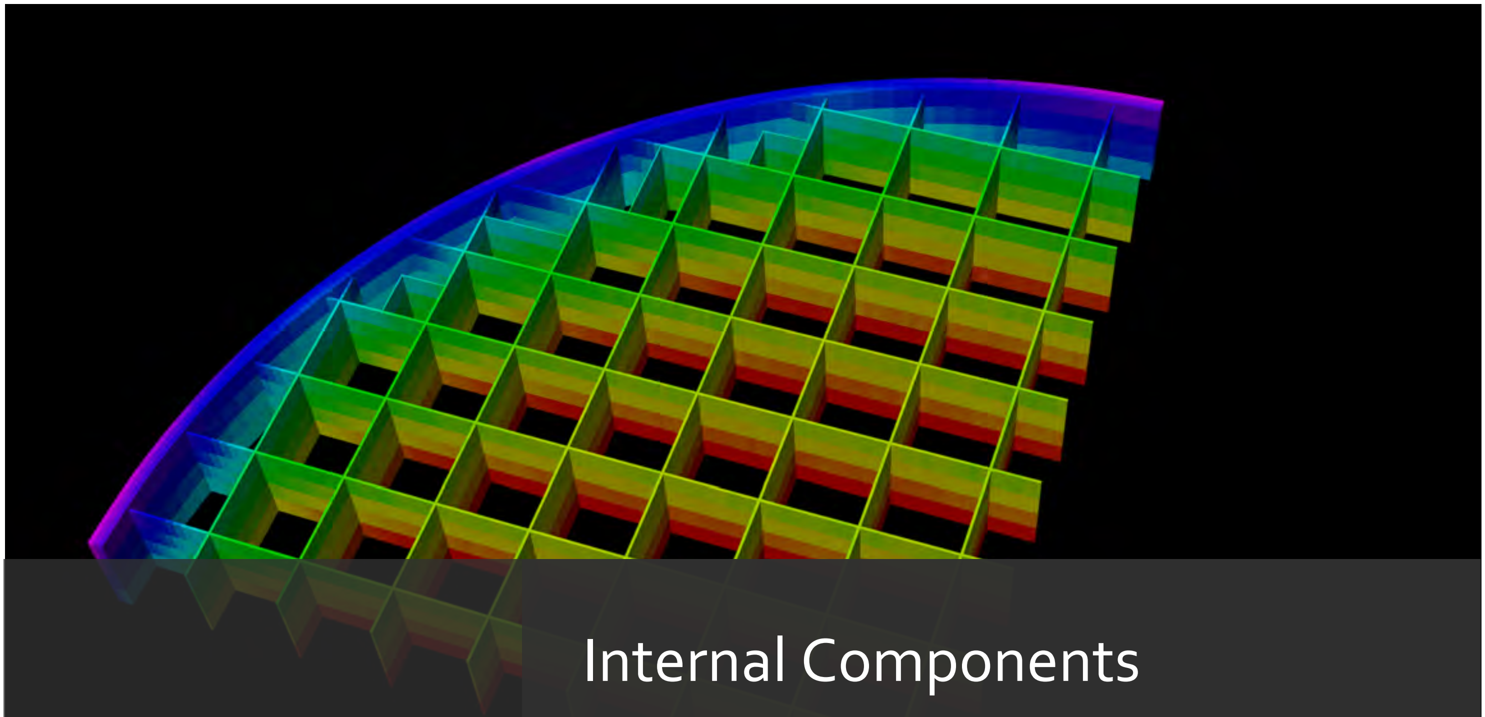
Regardless of the type of code used, the overall accuracy is limited by the quality of the input data. Since fluence is cumulative, data spanning the entire history of the plant must be obtained. This data includes plant mechanical drawings, core configurations, and operating parameters. In the absence of recorded data, approximations may be made, with a corresponding impact on the overall uncertainty of the evaluation.

TransWare Enterprises Inc. utilizes the RAMA Fluence Methodology, a deterministic fluence code developed by TransWare under a research program funded by EPRI. RAMA has been approved for use by the NRC for determining neutron fluence in accordance with U. S. Regulatory Guide 1.190 with a zero bias. RAMA utilizes a 3-D arbitrary geometry model builder, method-of-characteristics particle solver, and a series of pre- and post-processing tools to generate detailed and highly accurate fluence profiles for any component or region inside and outside of the pressure vessel.



Three Dimensions

Why model a plant in two dimensions when neutrons travel in three? A true 3-D model can accurately represent reactor components such as the pressure vessel nozzles and provide fluence anywhere in, around, and through the nozzle.



Internal Components

Since the RAMA Fluence Methodology employs a solver based on combinatorial geometry, RPV internals can be represented in their true form with curved walls and straight plates, such as this BWR top guide.

We've spent more than 20 years developing and innovating fluence methods. We've helped more than 18 plants around the world with their fluence needs.

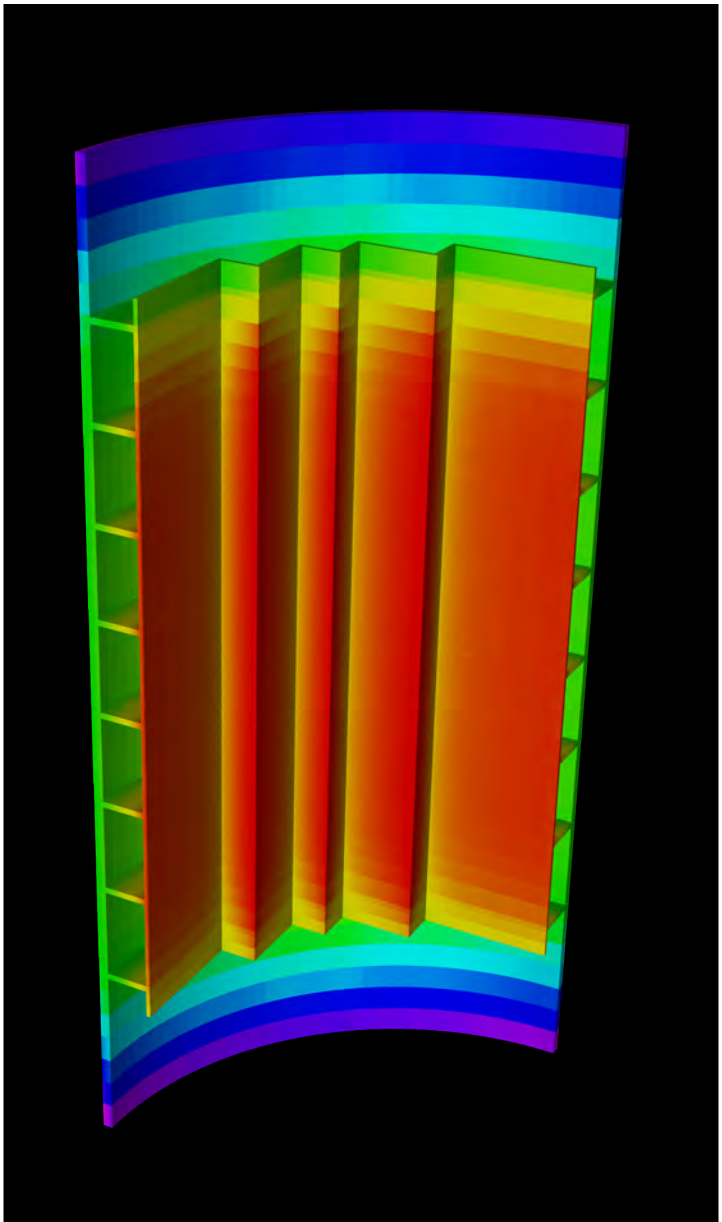
How accurate is it?

The RAMA fluence code has been tested against a series of industry benchmarks and real-world comparisons against BWR and PWR dosimetry samples. While pressure vessel calculations are required by U. S. Regulatory Guide 1.190 to have an uncertainty of less than 20%, RAMA performs much better. After performing comparisons to more than 1,000 data points, TransWare has achieved an overall unadjusted calculated-to-measured comparison ratio of 1.02 with a standard deviation of less than 10%.

Why use TransWare?

Fluence is highly dependent on an accurate geometric representation of your plant. In fact, a quarter inch difference in the positioning of a component can have a 10% or higher impact on its fluence. Our true three-dimensional, plant-unique approach means that all major components are modeled in their correct location according to each plant's respective design and as-built drawings are used when available. PWR models include representations of the baffle and former plates, core barrel, core plates, thermal shields and neutron pads, nozzles, pressure vessel, biological shield, and supporting structures. BWR models include the shroud, core support plate, top guide, spray spargers, jet pumps, pressure vessel, vessel insulation, and biological shield. Additionally, finer levels of detail are available for specific evaluations including jet pump hold down and repair hardware, core plate rim bolts, and in-vessel piping.

Since RAMA utilizes a solver based on combinatorial geometry, components are represented in their true form, with a mixture of curved and flat surfaces. The detail that goes into our fluence models renders a highly accurate model capable of providing fluence for any component, at any location and any reporting time.



BWRs and PWRs

Both BWRs and PWRs can be modeled, including all of their unique components such as the intersection of the baffle and former plates in this PWR.

TransWare has spent more than 20 years developing and innovating our transport, modeling, and fluence methods. We have modeled and analyzed more than 18 operating reactors around the world including both BWRs and PWRs, with more added every year. We were the first to bring true 3-D methods to the commercial fleet and we continually push boundaries to help solve industry issues before they become problems. Our latest developments include detailed nozzle models, studies on neutron streaming in the drywell region through nozzle penetrations, and most recently, thermal fluence.

Utilities are determining that thermal neutron fluence is crucial to their plant's operation, and vendors are just now beginning to respond, however, TransWare can solve thermal neutron problems now. We've developed an industry leading thermal cross-section library and invested heavily in developing the level of detail necessary in plant models to properly account for thermal effects.

In addition, TransWare offers a cost-effective fluence-monitoring program that includes updates to the fluence model as operating cycles are completed. This insures that your fluence model is always current with the latest model advancements and operating data. It also includes around the clock support during outages for all fluence needs.

TransWare performs all of its work under a NUPIC-approved quality assurance program that meets the requirements of 10CFR50, Appendix B and 10CFR21. By the end of a fluence project, many clients benefit from the comprehensive and QA-ready repository of historical data now available at their fingertips. Much of the data collected can also be used in areas like dry cask storage, which requires accurate fuel accounting back to the start of plant operations.

To learn more about TransWare and what we can do to help you, contact us by phone or email and we'll create a proposal geared toward *your* issue for *your* plant.

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