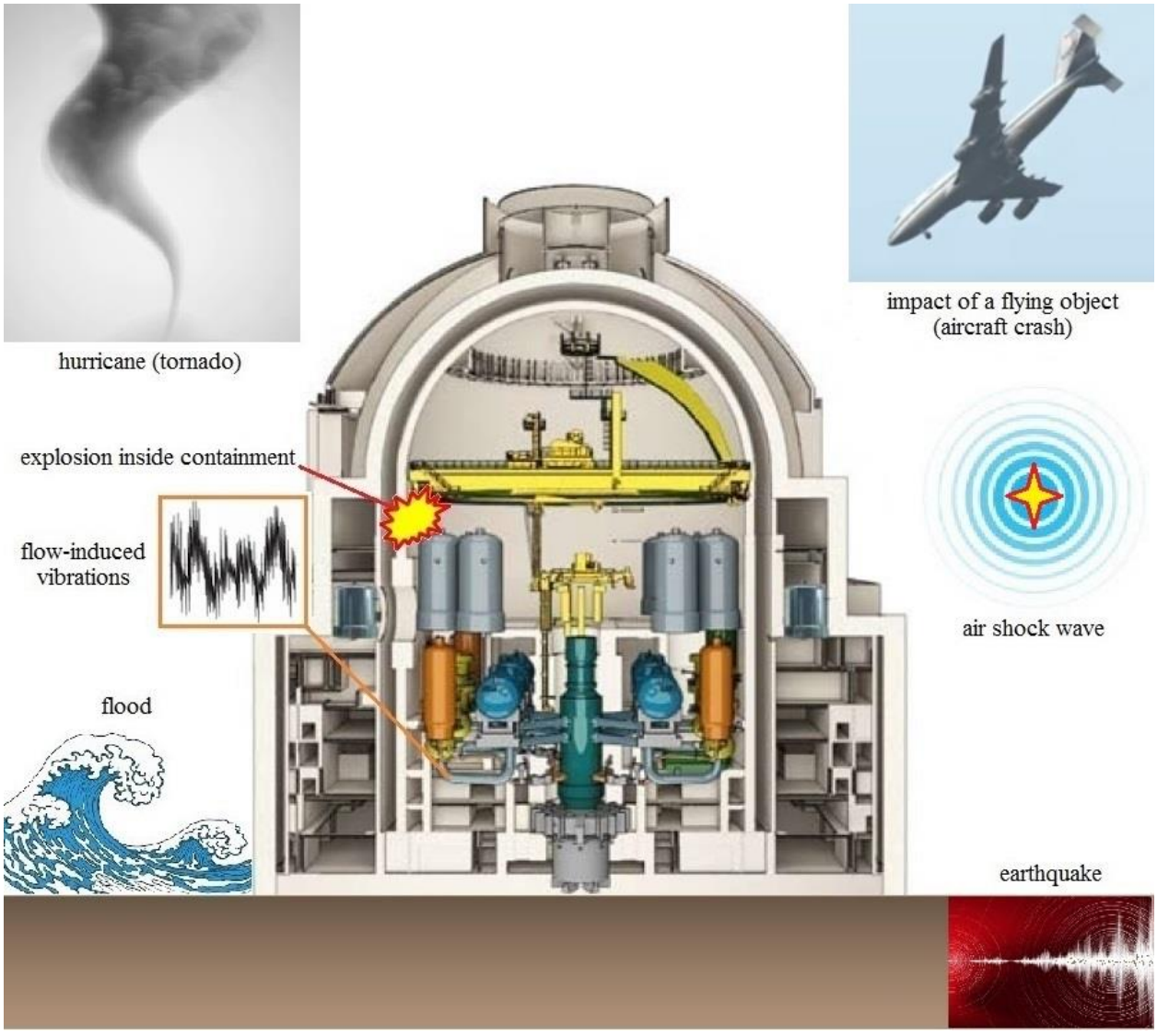
Dynamic analysis methods for NPP components

Regulatory documents of Russian nuclear power industry require designers to take into account loads on NPP components “at all considered initial events”, including events that cause dynamic loading. Such **dynamic loading events** are:

- earthquakes;
- vibrations from rotating units (e.g. pumps, turbines, generators);
- flow-induced vibrations (turbulence or vortex shedding in the coolant flow, fluid-elastic instability of structural parts);
- hydraulic shocks due to valve functioning (under normal operating conditions);
- external and internal incidents (impact of a flying object onto containment building, air shock wave, hurricane, flood or other similar natural phenomena rapidly developing over time, pipeline rupture, explosion inside containment, etc.).



Containment building and dynamic loading events

Response of components to the specified dynamic loads and the required strength of their structures, taking into account these events, are determined using dynamic analysis methods. In some cases, when dynamic loads depend on the response of the structure and are not directly

specified, an advanced dynamic analysis is needed to synchronously determine the load and response.

Some of the regulatory requirements, which relate, for example, to the substantiation of strength in the case of seismic loading or operational vibrations, were accompanied by recommended methods of dynamic analysis from the very moment of their establishment. But the range of methods provided for when creating the first Russian regulatory documents does not include modern ones, for example, the finite element method (FEM) or computational fluid dynamics (CFD) tools. Another part of the requirements concerning impulsive mechanical loads that act under normal operating conditions or in incidents is not supported at all by standardized dynamic analysis procedures.

This situation and the way out it, undertaken in Russian nuclear power industry in the 2010s, were described in the publication:

Spirochkin Y, Atroshenkov R (2011) Dynamic analysis methods for NPP components in Russian nuclear industry regulations under development. Transactions of the 21th International Conference on Structural Mechanics in Reactor Technology (SMiRT 21), 6-11 November, 2011, New Delhi, India. Div-V: Paper ID# 270.

The way is **updating the regulatory framework together with supporting standards** in order to

- give recommendation on modern effective methods for analyzing the dynamics of NPP components;
- meet existing requirements and challenges of new projects;
- provide for substantiation of optimized design and construction solutions;
- harmonize these solutions with advanced foreign approaches.

This great work was commissioned (by the State Corporation Rosatom) to NIKIET, and I took part in it until my retirement from the service in 2021. In the course of this work, several draft standards were developed, the content of which varied depending on the applicability to certain types of nuclear reactors and dynamic events specified in the design basis of new projects. The **general methodology of dynamic analysis** presented in these standards has the following content:

1 Application area
2 Terms, definitions and abbreviations
3 General provisions
    3.1 Categorization of dynamic loading events
    3.2 Dynamic loads and their impact on requirements for equipment and pipelines
    3.3 Basic principles of dynamic analysis
4 Requirements for dynamic analysis of equipment and pipelines
    4.1 Analysis methods and models
    4.2 Input data
    4.3 Strength criteria
    4.4 Additional requirements
5 Dynamic analysis rules
    5.1 Creating a calculation model
    5.2 Damping accounting
    5.3 Verification of the calculation model
    5.4 Choosing the calculation method
    5.5 Determination of dynamic response of a structure to non-stationary load by linear spectral method

Yuri Spirochkin November 08, 2022