
High-resolution time-resolved experiments on mixing and entrainment of buoyant jets in stratified environments

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ABSTRACT:

Fluid jets interacting with a stratified layer play an important role in the safety of several reactor designs. In the containment of nuclear power plants, fluid jets dominate the transport and mixing of gaseous species and consequent hydrogen distribution in case of a severe accident. The mixing phenomena in the containment are driven by buoyant high-momentum injections (jets) and/or low momentum injection plumes, depending on the transient scenario and break location. During a Pressurized Thermal Shock (PTS) scenario, the interaction between the cold ECCS injection plume and the stratified fluid present in the cold (or hot) leg is important in order to determine the temperature at the time-dependent temperature at the inlet of the reactor pressure vessel (RPV) and the potential to cause a thermal shock on the RPV wall. In sodium-cooled fast reactors (SFRs), the interaction of flow jets at the core channels outlet with the flow in the upper plenum might lead to oscillating thermal loads on the upper plenum structures (thermal striping). All the above phenomena are characterized by the interaction of buoyant jets with stratified flow.

In stratified layers baroclinic forces create significant redistribution of turbulent kinetic energy and scales, which leads to anisotropy. This important physical phenomenon is highly three dimensional and is challenging to capture even with high-fidelity CFD simulations, due in part to lack of sufficiently resolved validation data. Furthermore, the experimental data available in the open literature do not feature the level of fidelity needed for an extensive validation of turbulence models in lower order CFD. To shed new lights into the important phenomena object of the present research project, it is proposed to conduct coordinated experiments and simulations at two universities, in close consultation with a National Laboratory.

A unique feature of the proposed project is to measure the effect of stratification on turbulence redistribution and mixing at each university with different high-resolution diagnostics. By employing different diagnostics, the various sources of uncertainties in the diagnostics and facilities will be better understood providing uniquely characterized diagnostics, which in turn will shed new lights into this important phenomenon and provide tight validation datasets. Several flow regimes from stably stratified to breakdown of stratification will be studied for both a free round buoyant jet and a wall jet.

The project will result in a **high-resolution time-resolved experimental database**. The novel experimental data will then be used to validate computational fluid dynamic (CFD) codes, including both Large Eddy Simulations (LES) and unsteady Reynolds-averaged Navier-Stokes equations (URANS) methodologies. The data will complement the experimental program performed at the MAX facility, operated by Argonne National Laboratory within the NEAMS program, where stratified flows cannot be investigated.