

THE 'SAFRAN' TEST LOOP MODEL EXPERIMENTATION AND ANALYSIS OF FLOW INDUCED VIBRATION OF PWR REACTOR INTERNALS

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SUMMARY

Introduction to vibration phenomena. In a PWR the reactor coolant flow that goes through the reactor internals and the fuel assemblies is characterized by a high turbulence and this flow is able to induce some structural vibration.

A few years ago, some nuclear power plants were obliged to shut down during many months, due to the heavy damages caused by vibration. Presently, the design of reactors must be carefully checked taking into account the possible interaction between hydraulic excitations and reactor structure response.

The reactor assembly of a PWR consists of: (1) a reactor vessel which withstands to the internal pressure of the primary fluid and maintains the reactor core; (2) reactor internals which maintain fuel assemblies, guide the control rods and wear a thermal shield in order to reduce the fast neutron exposure of the reactor vessel wall; (3) fuel assemblies and control rods.

Description of the safran test loop. The SAFRAN Test loop consists of a reduced scale model of reactor vessel, reactor internals, dummies representing fuel assemblies and a system of three loops including pumps and damping tanks connected to the reactor vessel, the purpose of which is to simulate the flow distribution of 3 loops PWR. The scale of the model is 1/8.

The scaling laws for designing the model and the test loop are the following: same geometry and attach conditions; same flow velocity: $V_{\text{model}} = V_{\text{reactor}}$; same Cauchy number i.e: same ratio of inertia forces to stiffness forces; same Euler number i.e: same ratio of inertia forces to pressure forces.

Nevertheless, it is not possible to keep the same Reynolds number, the ratio between the Reynolds number of the reactor and the Reynolds number of the model, for a same fluid velocity, is equal to 70. This is mainly due to scale ratio and to the viscosity of the fluid in hot condition. But in most cases, we are above the critical values of Reynolds number where there is a variation of the Strouhal number $S = fD/V$. The measured frequencies on the model will be 8 times the frequencies occurring on the reactor.

In general the construction technology used for the model is the same as one used for the reactor. All the structures in contact with the fluid are made of stainless steel.

The instrumentation used on the SAFRAN test loop consists of: accelerometers, pressure sensors and relative displacement sensors.

Approaches used for studying vibration phenomena

1st approach. The vibration properties of the structure are measured by the mean of tests performed in air and in water in order to obtain in both cases: frequencies—modes—damping and stiffness values. The hydraulic excitation sources are measured by tests on the loop: frequencies, Δp values, direct and cross correlation lengths. During these tests, structures are stiffened in order to prevent their motion. By the mean of a computer program based on the POWELL method, the structural response can be calculated according to the density of Δp distributed around the structure.

2nd approach. This approach consists of measuring directly the structure response to hydraulic excitations.

Comparison of results. The comparison of results given by the above described approaches can show: (a) the system non-linearities, (b) the coupling between the fluid and the structure. By using two different approaches a better knowledge of complex phenomena can be reached.

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3. APPROACHES USED FOR STUDYING VIBRATION PHENOMENA

3.1. 1st Approach

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frequencies - modes - damping and stiffness values.
- The hydraulic excitation sources are measured by tests on the loop : frequencies, Δp values, direct and cross correlation lengths.
During these tests, structures are stiffened in order to prevent their motion.
- By the mean of a computer program based on the POWELL method, the structure response can be calculated according to the density of Δp distributed around the structure.

3.2. 2nd Approach

This approach consists of measuring directly the structure response to hydraulic excitations.



The comparison of results given by the above described approaches can show :

- the system non linearities
- the coupling between the fluid and the structure.

By using two different approaches a better knowledge of complex phenomena can be reached.

The instrumentation used on the SAFRAN test loop consists of :
accelerometers, pressure sensors and relative displacement sensors.

4. DATAS

The model experiments are presently underway. The characterization of acoustic excitation and turbulences generated by the pumps and the circuits has been performed.

The datas concerning the vibration properties of the model, the hydraulic measurements and a film showing the flow instabilities will be presented at the conference.

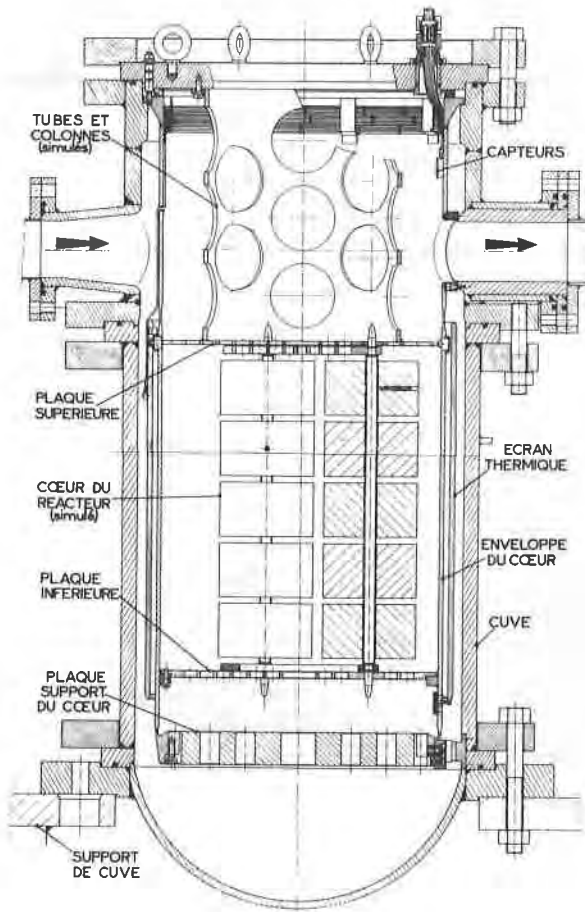


FIGURE N° 1

GENERAL ASSEMBLY OF THE MODEL

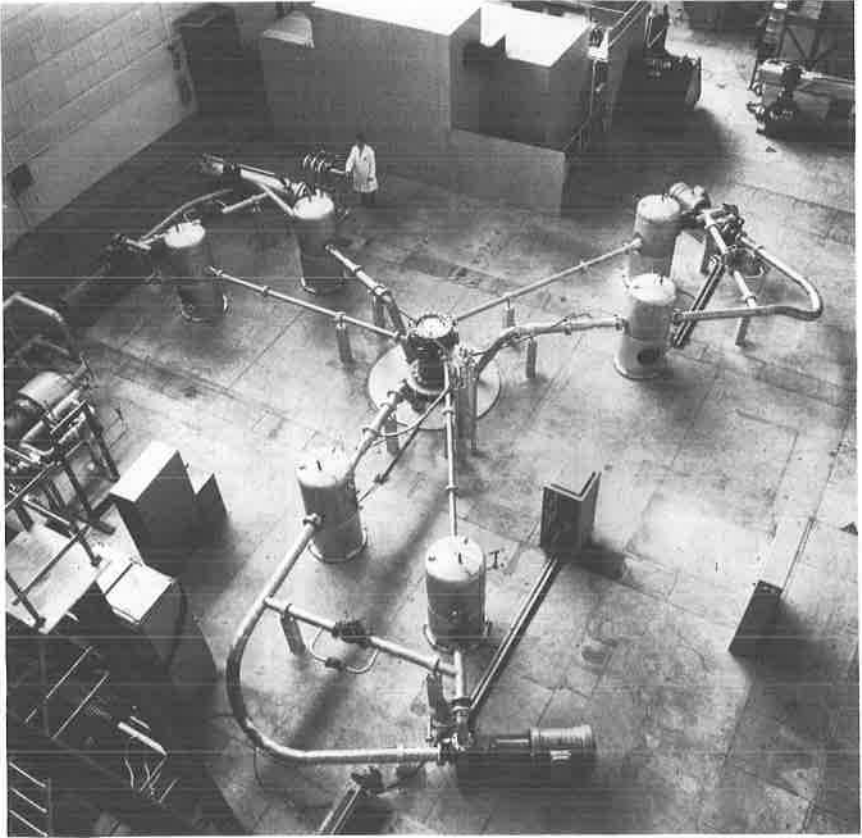


FIGURE N° 2

GENERAL VIEW OF THE SAFRAN TEST LOOP