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# Estimating the Required Flow Rate to Lift an Absorber in the Shutdown System of Nuclear Reactors

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## 1. Introduction

Many of the research reactors use electro-magnetic force or hydraulic force to lift and grab an absorber in the shutdown system [1-2]. When the shutdown system actuation signal occurs, the lifting force is stopped and the absorber drops in order to shutdown the reactor.

The present study deals with the shutdown system using hydraulic force to lift the absorber at a predetermined position. The required flow rate to lift the absorber is the key design parameter. The pressure drop while the operating fluid flows around the absorber and the buoyancy force determine the required flow rate. The detailed calculation procedure to obtain the required flow rate and the experimental result will be shown in the present paper.

## 2. Methods and Results

### *2.1 Estimation of the required flow rate*

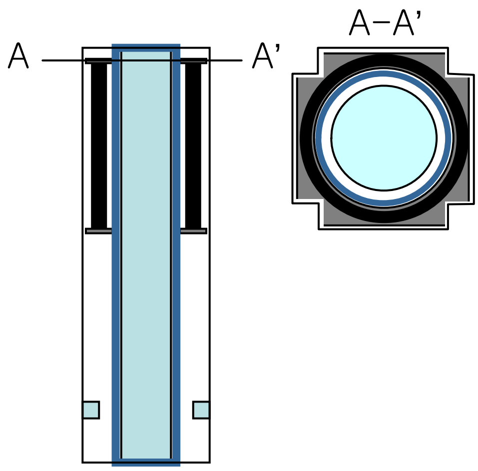


Fig. 1. Schematic diagram of the shutdown system using hydraulic force to lift the absorber

Fig. 1 shows the schematic diagram of the model shutdown system designed in the present study. It consists of piston(upper plate), absorber(middle cylinder), and damper(lower plate). The guide tube is located in the center. The operating fluid is water. The operating condition is 2bar and 50℃.

The purpose of the present study is to establish a method to determine the required flow rate and its experimental validation. Therefore SUS304 is chosen as the model absorber material. The model absorber mass is 4.42 kg and its height is 65cm.

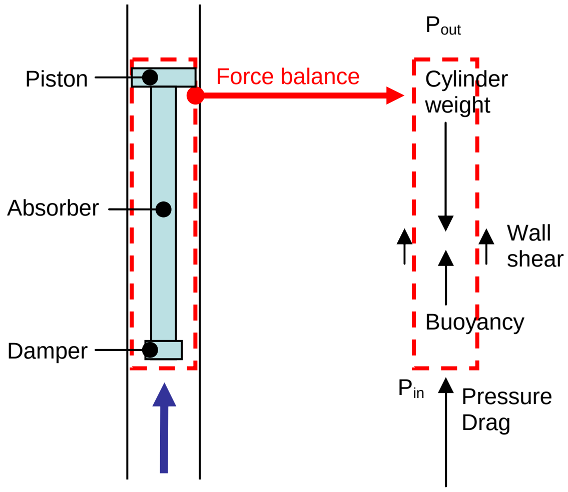


Fig. 2. Force balance diagram to lift the absorber

Fig. 2 shows the force balance diagram in the shutdown system. The required water velocity to lift the absorber can be obtained from the following relation.

*(absorber weight) = (pressure drag) + (wall shear drag) + (buoyancy)* (1)

The weight of the model absorber is 4.42kg × 9.81 m/s$^2$ = 43.4N. The volume of the absorber is 0.000517 m$^3$ and the buoyancy force is 5.07N.

Most of the pressure drop will occur in the narrow gap (width=0.5mm) between the piston/damper and guide tube/outer wall, which acts like an orifice. And the wall shear force is negligible compared to the pressure drag due to the large pressure drop through the narrow gap. Then the required pressure drag to lift the absorber is

*(required pressure drag) = (absorber weight) - (buoyancy) = 43.4N - 5.07N = 38.3 N* (2)

The pressure drag is

*(pressure drag) =* $(P_{in}-P_{out})$ *× (flow path area)* (3)

An iterative calculation is needed to obtain the required pressure drop, $(P_{in}-P_{out})$, and the water flow rate. The flow path through the absorber can be regarded as an orifice and the pressure drop can be obtained using the handbook[3].

The calculation result gives the required flow 1.1 kg/s, and the pressure drop through the absorber is 11100 Pa. The flow path area is 0.00352m$^2$. Therefore the pressure drag is

$$(pressure\ drag) = (11100\ Pa) \times (0.00352 m^2) = 39\ N \qquad (4)$$

which is slightly greater than the required pressure drag to lift the absorber. The shear force is 0.043N which is very small compared to the pressure drag and buoyancy, as expected.

*2.2 Experimental validation*

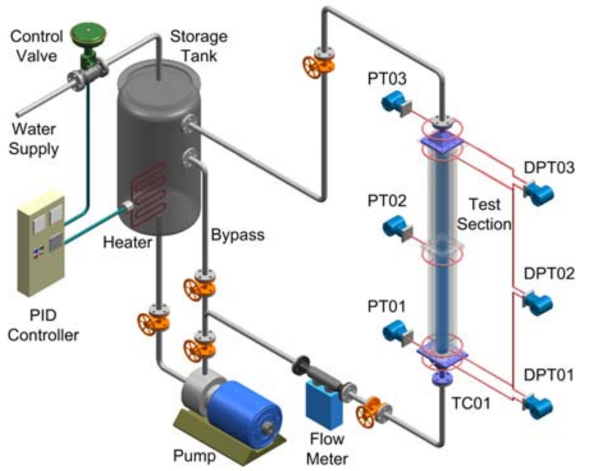


Fig. 3. Experimental apparatus

Fig.3 shows the experimental apparatus to validate the estimation method presented in the paper. The measured flow rate and pressure drop through the absorber when the absorber has just started to lift are shown in Table I with the estimated values.

Table I: Required water flow rate and pressure drop

| | Experiment | Estimation |
|---|---|---|
| Water flow rate (kg/s) | 1.5 | 1.1 |
| Pressure drop (kPa) | 13.5 | 11.1 |

The experimental study result shows that hydraulically lifting the absorber can be successfully realized. However the estimation error is relatively large. This could result from the simple assumption of the plates as an orifice.

## 3. Conclusions

A simple estimation procedure to obtain the required flow rate to lift an absorber is presented. The pressure drop through the narrow gap is the main source of the lifting force with buoyancy. The wall shear force was negligible compared to two main forces. The experimental validation study result is also given. Even though there is relatively large difference between the estimated values and measured values, the proposed method will be useful to design a shutdown system using hydraulic force to lift the absorber.

## REFERENCES

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