Assessment of TRACE VESSEL component for DVI direct bypass

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I. Introduction

- Reproducing the phenomena of Direct ECC bypass phenomenon is important for TH codes as the ECC bypass phenomenon is the one of the main safety issue for the Direct Vessel Injection system.
- Experimental investigations for the direct ECC bypass phenomenon [1,2,3,4]

UPTF 21D	Full scale	4HL-4CL PWR (Siemens-KWU)	Water / Steam	Complex test facility	TRACE Assessment matrix B.4
DIVA	1/5, 1/7 Scaled down (1/7.3, 1/4 to UPTF)	2HL-4CL PWR (APR1400)	Water / Air	Separate Effects Test	Hard to exclude the effects of various factor
MIIDAS	1/4.93 Scaled down	2HL-4CL PWR (APR1400)	Water / Steam	Separate Effects Test	Complementary assessment required.

II. Reference test and assessment methods

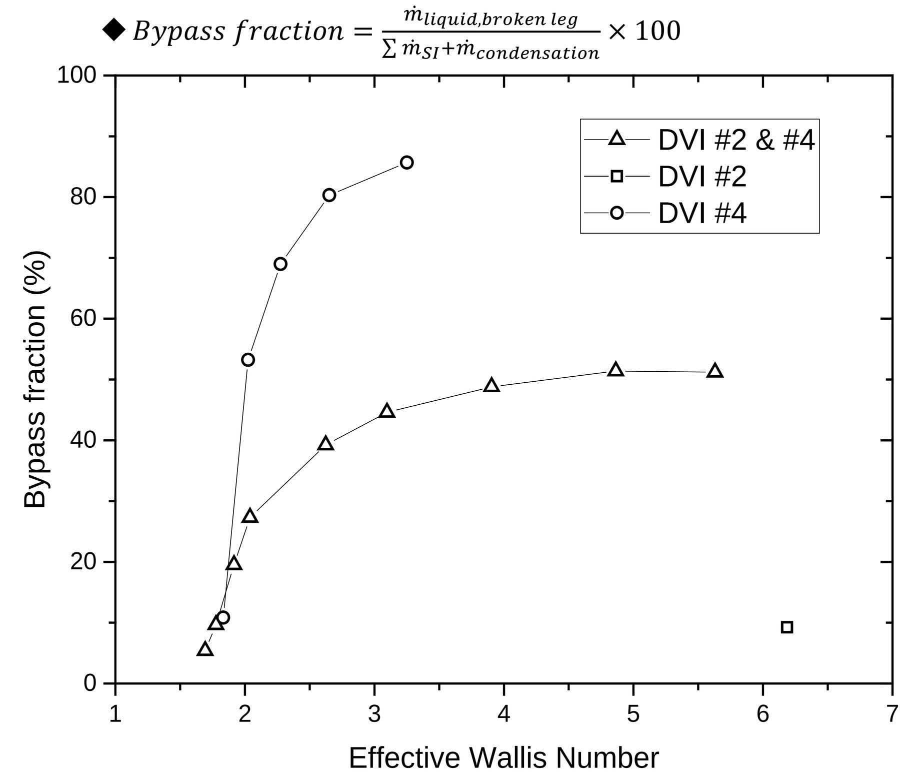
- **MIDAS test**

The MIDAS test facility is steam-water separate effect test facility could be simplified to five components; (1) boiler (steam supply system), (2) safety injection simulator (two activated SI lines; broken leg (#2) side & intact leg side (#4)), (3) test section (scaled down downcomer, cold-legs), (4) separator & containment simulator (sump for discharge flow from broken cold-leg of test section), (5) core barrel (sump for flow to lower part from outlet of test section). The maximum allowable operating conditions are 10 bars and 300 Celsius degrees

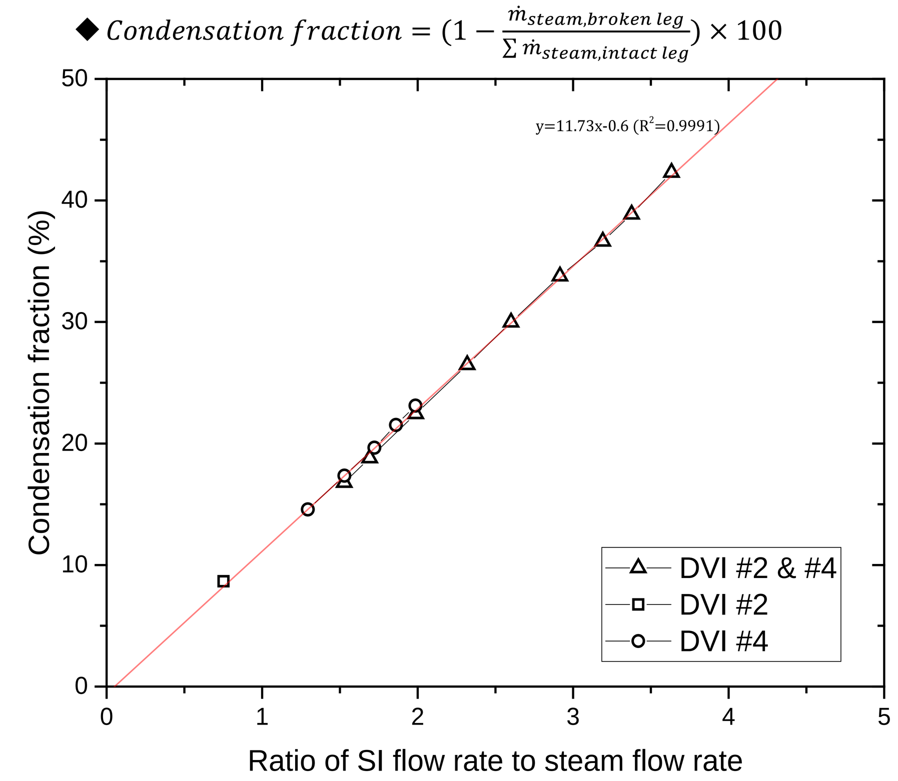
◆ Test modes
(1) Injection by DVI#2 and DVI #4 – 9 cases, (2) Injection by DVI#2 – 1 case, (3)) Injection by DVI#4 – 5 cases.

- **Abridgement of the MIDAS test results**

◆ $Bypass\ fraction = \frac{\dot{m}_{liquid,broken\ leg}}{\sum \dot{m}_{SI} + \dot{m}_{condensation}} \times 100$



◆ $Condensation\ fraction = \left(1 - \frac{\dot{m}_{steam,broken\ leg}}{\sum \dot{m}_{steam,intact\ leg}}\right) \times 100$



- **TRACE input modeling**

The MIDAS facility could be simplified with VESSEL, PIPE, FILL and BREAK components without heat structure as figure 3. The DVI lines and steam injection lines, intact cold-legs, are modeled with FILL and PIPE components. The broken cold-leg and the water sump are modeled with PIPE and BREAK components. The test section is modeled by VESSEL component with 15 axial cells and 2 radial cells. All faces of the first radial cells are blocked for representing downcomer shape. The mass flow rate and temperature of FILL components are assigned according to each test conditions.

The direct ECC bypass phenomenon is consequence of energy and momentum interaction of steam and water. The interfacial heat transfer and the interfacial friction should be assessed. However, there is no specific interfacial heat transfer model for VESSEL component except option for sensitivity analysis purpose. The effect of interfacial heat transfer would be assessed indirectly with other options. First of all, the effect of azimuthal VESSEL nodalization is considered. Modeling with 4-channel, 6-channel and 12-channel were investigated. Two optional interfacial friction model for VESSEL component are investigated also which are IBLAUS option and LBDRAG option. Finally, effect of adopting CCFL models, the Kutateladze model and Wallis model, is investigated. [6,7]

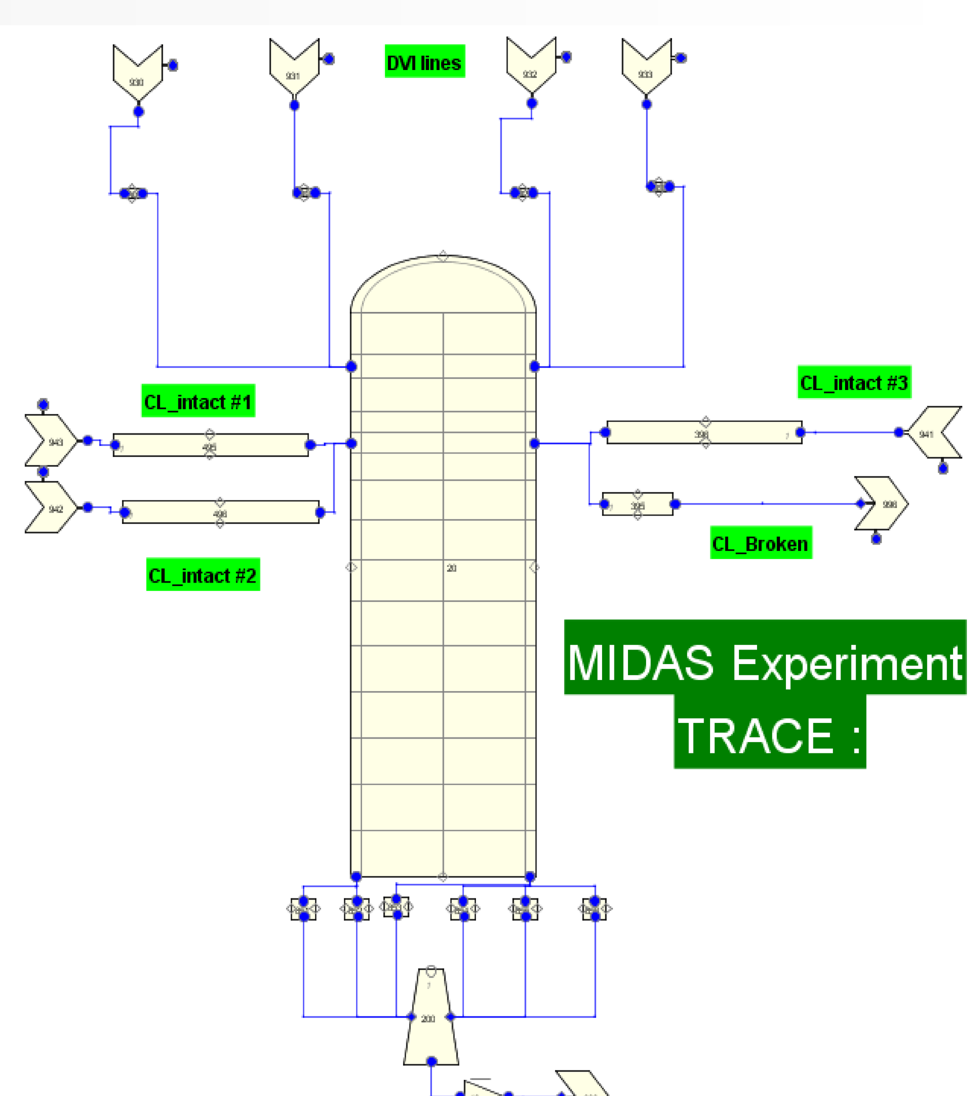
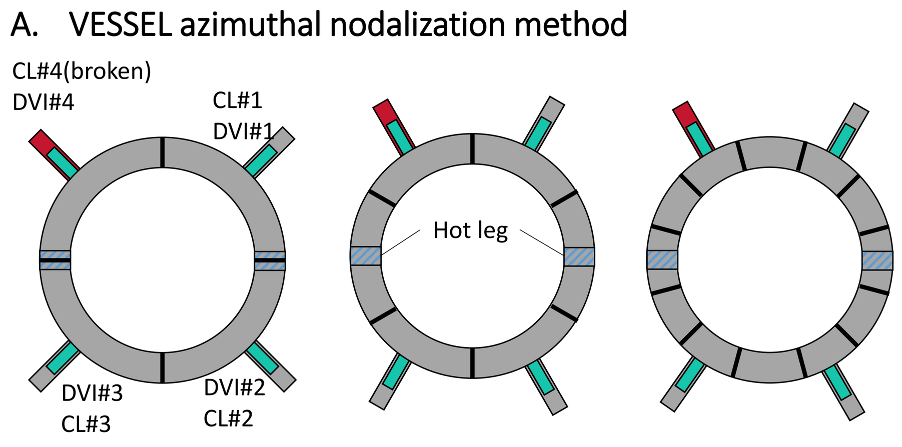


Figure 3. TRACE input model for MIDAS test facility

- **Sensitivity factor**

A. VESSEL azimuthal nodalization method



B. Interfacial friction model with 6-channel

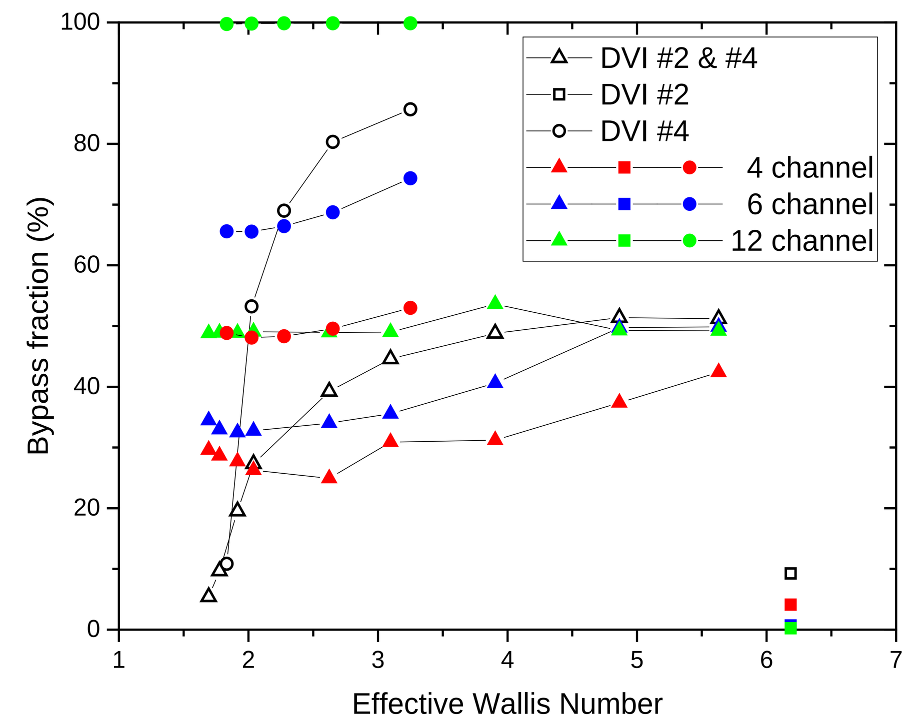
Basic model | LBDRAG | IBLAUS

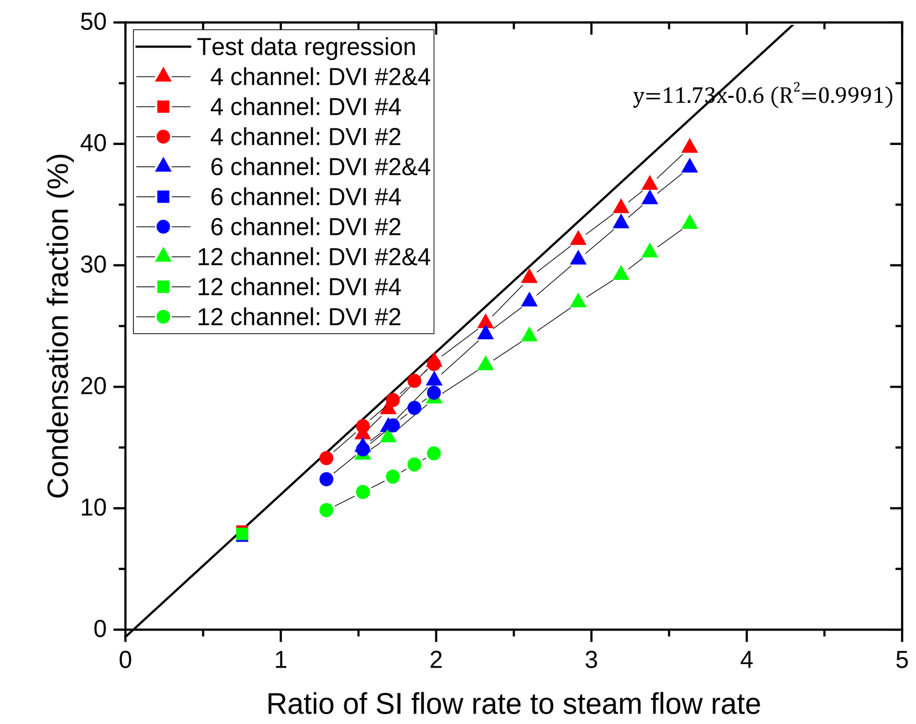
C. CCFL model with 6-channel

Basic model | Wallis (1.0/1.0) | Kutateladze (1.0/1.0)

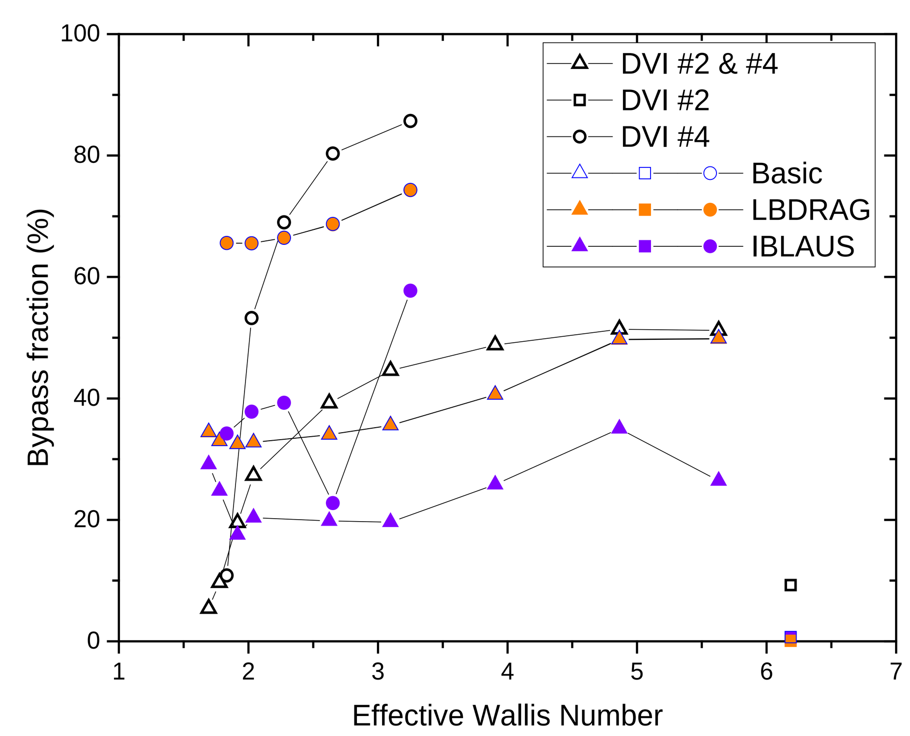
III. Assessment results

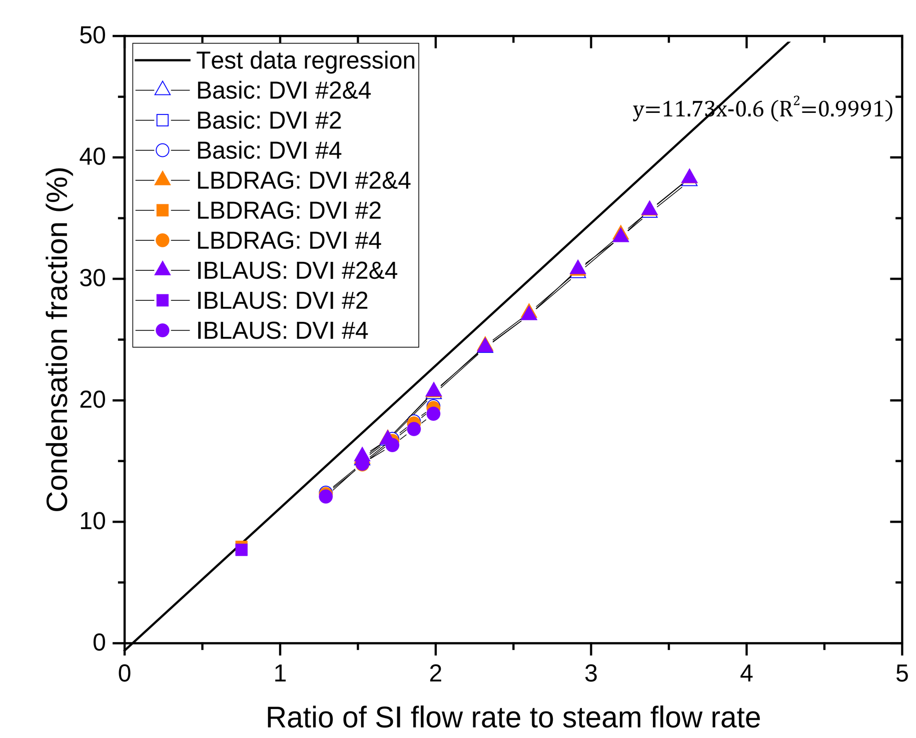
A. VESSEL nodalization



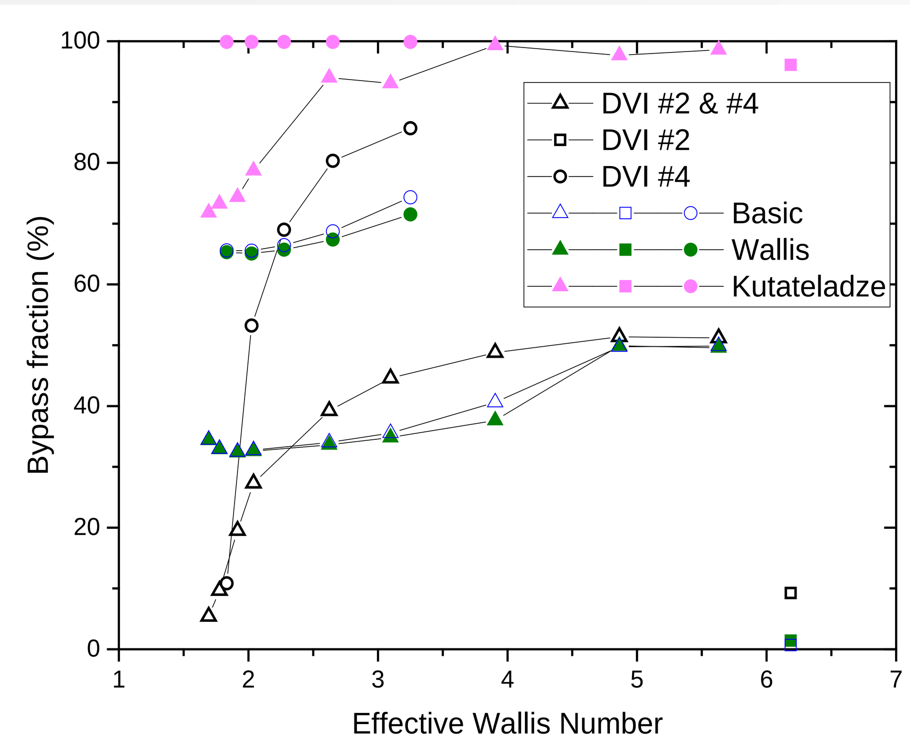


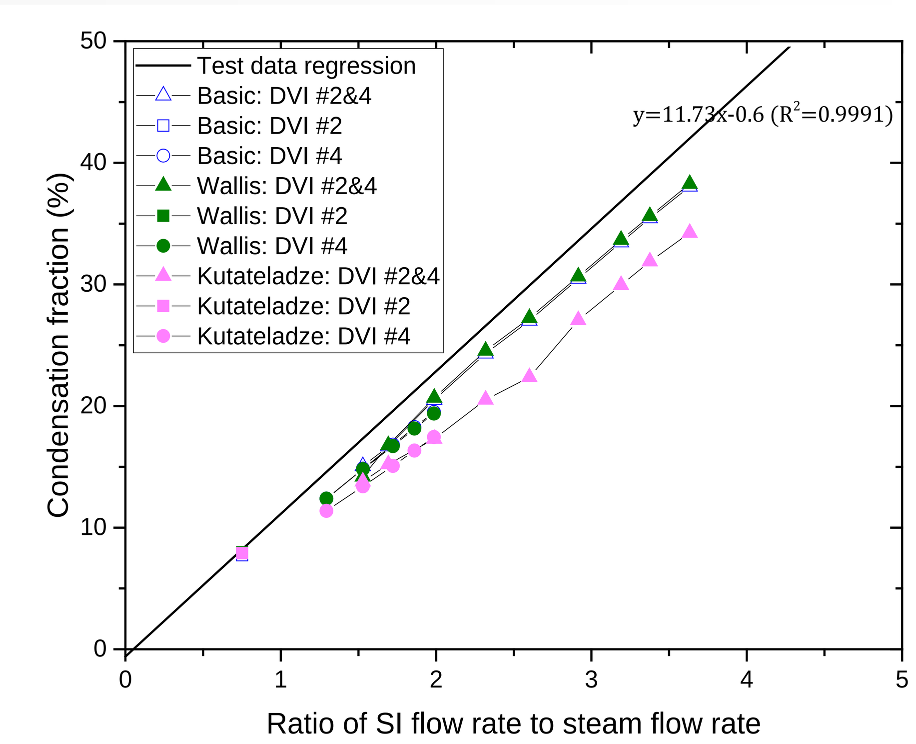
B. Optional interfacial friction model





C. CCFL model





- **Summary of calculation results**

Sensitivity factor	Base case	VESSEL node		Iterfacial friction		CCFL	
Model	6-ch (bypass/cond.)	4-ch (bypass/cond.)	12-ch (bypass/cond.)	LBDRAG (bypass/cond.)	IBLAUS (bypass/cond.)	Wallis (bypass/cond.)	Kutateladze (bypass/cond.)
Average of error(%)	46/22	35/24	63/19	46/22	28/22	92/20	45/22
Average of STDEV	9.46E-4 /5.42E-3	1.38E-6 /4.50E-6	3.29E-2 /7.45E-3	6.67E-4 /1.51E-3	5.32E-1 /2.84E-2	7.01E-2 /4.97E-3	2.28E-2 /2.72E-3

IV. Conclusions

The assessment for the VESSEL component in TRACE V5 Patch5 is conducted using MIDAS test data. Effects of nodalization method and interfacial friction models and CCFL models are investigated in this study. The calculation result with 4 azimuthal channel showed the most stable and moderate data. Some optional models for interfacial friction or CCFL showed better accuracy than basic model in an average manner, however those results showed rather unstable quality. The basic models are recommended to simulate RPV with DVI while using VESSEL component.

V. REFERENCES

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