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An Experience of Thermowell Design in RCP Test Facility

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1. Introduction

Thermowell is typically a circular cylinder installed like a cantilever pole into the process piping. It provides process condition protection and a process seal for temperature sensors. Thermowells were installed for the measurement of coolant temperatures at upstream and downstream points of the reactor coolant pump (RCP) in RCP test facility, which was constructed at the end of 2012 by KAERI, as shown in Fig. 1. For the first-kind-of-RCP developed by Doosan Heavy Industries & Construction with a support of Andritz in Austria, it was necessary to test the prototypic RCP in the view point of performance and endurance. Flowrates for the test should vary in the range of 90% to 130% of rated flowrate under prototypic operational conditions, as shown in Table 1. Generally for the flow control, a combination of a control valve and an orifice was used in previous RCP test facilities. From the commissioning startup of the RCP test facility, it was found the combination of valve and orifice induced quite a large vibration for the RCP. As a solution to minimize the vibration and to facilitate the flowrate control, one of KAERI's staff suggested a variable restriction orifice (VRO), which controls most of the required flowrates except highest flowrates, as shown in Fig. 2 [1,2]. For the highest flowrates, e.g., around run-out flowrate (130%), control valves in bypass lines were also used to achieve required flowrates. From a performance test, it was found the VRO is very effective measures to control flowrates in the RCP test facility.

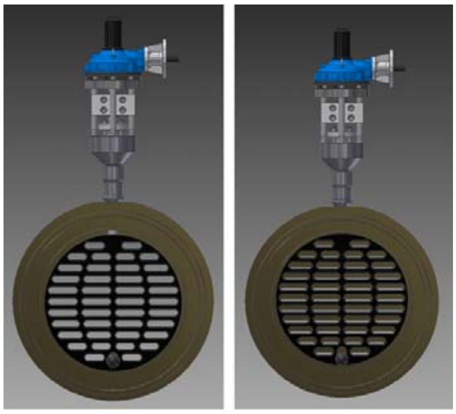
During the commissioning startup operation, one of thermowells located at the upstream of the RCP was cracked due to high speed coolant velocity, which was – fortunately - found under a leakage test before running the RCP test loop. The cracked thermowell, whose tapered-shank was detached from the weld collar after uninstalling, is shown in Fig. 3. As can be seen the figure, most of the cross-section at the root of the thermowell shank was cracked. As temporary measures, a modified robust design of thermowells was prepared with larger root and tip diameters, larger fillet radius at the root of the thermowell shank, and shorter unsupported length compared to the original design. All the original thermowells were replaced by the modified ones on early of Jan., 2013.

It is well known that ASME PTC 19.3 TW-2010 [3] was written to replace the thermowell requirement of ASME PTC 19.3-1974 [4] following some catastrophic failures, e.g., a thermowell failure in Monju fast breeder reactor in Japan in 1995, although these thermowells passed the criteria laid out in 1974. In this paper, an investigation of the integrity of thermowells in the RCP test facility was performed according to the current code and overall aspects on the thermowell designs were also discussed.

Fig. 1 Overall configuration of the RCP test facility in KAERI

Table 1. Summary of RCP test conditions

Test Conditions	*P* (MPa)	*T* (^{o}C)	*V* (m/s)	Remark
Cold Performance	15.0	93.0	11.3 – 15.5	90-130% of rated flowrate
Hot Performance	15.0	290.0	11.3 – 15.5	



(a) Full Open (b) Full Close

Fig. 2 Typical configuration of the VRO in the RCP test facility

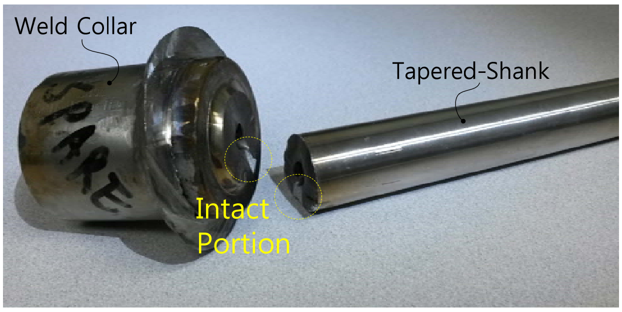


Fig. 3 Cracked thermowell (Weld collar and tapered-shank)

2. Development of New Thermowell

Both the original and modified designs of thermowells in the facility did not satisfy the code requirement, so it was determined to replace them with a new design. For a robust design of thermowells, design modifications were considered in the view point the shape of shank and unsupported length. A straight type rather than a tapered-shank was considered including shorter unsupported length of the thermowell. So in new design, the shape of shank and the unsupported length were main parameters. In addition, the material of thermowell was changed from A182 F316 to A182 F304 like as the nozzle's material. Major specification of new thermowells was compared to the modified design, as shown in Table 2. (The shielded length was to be changed corresponding to the unsupported length.) Variations of transverse frequency ratio (r) and in-line frequency ratio (r') for the whole ranges of flowrate of the new design were summarized in Table 3. With a new design, all the requirements of the current PTC code were satisfied for the whole ranges of flowrate.

Table 2. Major specification of thermowells (Modified and new designs)

Items	Modified Design	New Design[a]	Remark
A (m)	0.030	0.030	
B (m)	0.020	**0.030**	
d (m)	0.007	0.007	
t (m)	0.007	0.007	
b (m)	0.005	0.005	
L (m)	0.300	**0.215**	Unsupported length
L_0 (m)	0.270	**0.180**	Shielded length
Material	A182 F316	A182 **F304**	Same as nozzle's material

Note, a: A bold figure represents different from that of the modified design.

Table 3. Variations of r and r' for the whole ranges of flowrate (New design)

V(m/s)	10	11	12	13	14	15	16
$r\,(\equiv f_s/f_n^c)$	0.19	0.21	0.23	0.25	0.27	0.29	0.31
$r'\,(\equiv 2f_s/f_n^c)$	0.39	0.43	0.47	0.51	0.54	0.58	0.62

Installation configuration of new thermowells in the facility is shown in Fig. 4. As can be seen in the figure, the shape of shank is straight-type and thermowell attachment configuration is socket weld type including an additional note for thermowell fitting. As noted in a cloudy mark, the code requires that the clearance between a socket adaptor and the thermowell wall should be sufficiently large that the joint between the adaptor and thermowell wall cannot be treated as an interference fit.

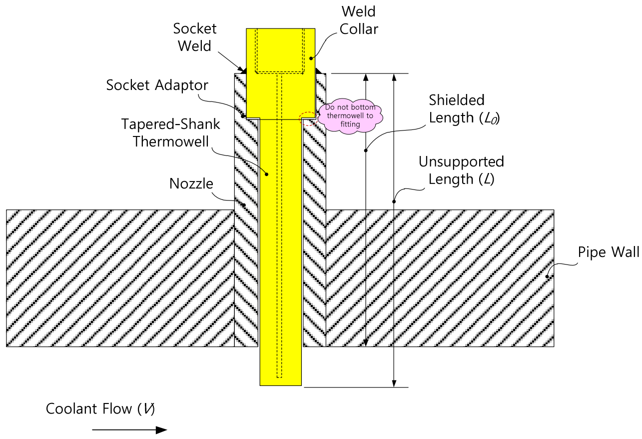


Fig. 4 Installation configuration of new thermowells in the facility

3. Summary and Conclusions

An RCP test facility has been constructed in KAERI. During the commissioning startup operation, one of thermowells was cracked due to high speed coolant velocity. To complete the startup operation, a modified design of thermowells was proposed and all the original thermowells were replaced by the modified ones. From evaluation of the original and modified designs of thermowells according to the recent PTC code, the original design did not satisfy the new requirement and even the old one, either, and the modified design just satisfied the old requirement. The fractured surface of original one seemed to be owing to the fatigue stresses in transverse oscillations. Two of three modified thermowells were found bent after about 4.1×10^8 fatigue cycles operation. Their tapered-shanks came in contact with the nozzle walls and each showed a rim of deformation on the root. The modified ones seemed to suffer the fatigue stresses in in-line oscillations. A new design of thermowells with straight shape and shorter unsupported length satisfied the current PTC code requirement was developed and installed in the RCP test facility

Acknowledgement

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