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Air Damper Sizing for the Decay Heat Removal System of the PGSFR

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1. Introduction

Decay heat removal system (DHRS) of the PGSFR begins to work when the air dampers installed at the air intakes and outlets of the sodium-to-air heat exchangers are open. Reliability of the DHRS strongly depends on the damper opening because the air flow passing through the shell side of a sodium-to-air heat exchanger removes the heat transferred from the reactor core and primary coolant to the final heat sink, the atmosphere. Therefore, damper sizing as well as its arrangement is significant for the DHRS operation. In this work, a systematic sizing approach is introduced and air damper sizing of the DHRS has been carried out following the addressed sizing procedure.

2. Methods and Results

2.1 Roles of the DHRS dampers

The DHRS of the PGSFR is composed of the Passive DHRS (PDHRS) and the Active DHRS (ADHRS). A helical-tube sodium-to-air heat exchanger (AHX) and a finned-tube sodium-to-air heat exchanger (FHX) are employed for the PDHRS and the ADHRS, respectively. The PDHRS loops are operated to cool down the reactor to a hot standby or a refueling temperature via a natural heads generated by density differences of working fluids. The ADHRS loops are also operated via forced heads by active components such as an electro-magnetic pump and a blower.

Dampers of the AHX have open/closed/slightly-open modes because the PDHRS loops will not have continuous active air flow control. On the other hand dampers of the FHX are controlled with the continuous opening rate capability because the ADHRS loops will control the heat removal rate elaborately especially for maintaining the refueling mode.

To decide the damper sizes and powers of the actuators design parameters have to be calculated. Required design parameters are provided from the sizing data of the DHRS components.

2.2 Sizing procedures of the dampers

First of all, damper types have to be determined for the inlet and outlet dampers. There are generally two types of dampers depending on the arrangement of damper blades, *i.e.*, parallel blade damper and opposed blade damper. Parallel blade dampers generate less pressure loss through itself while opposed blade dampers become better choice over parallel blade dampers to get a linear flow rate control. Therefore, opposed blade dampers are employed at the air inlets and parallel blade dampers are utilized at the air outlets because we will utilize the inlet dampers for the purpose of air flow rate control.

A term, characteristic ratio, is defined as the ratio of system resistance and damper resistance. This value has to be determined before damper sizing which decides linear characteristics of flow control. The system resistance is total pressure loss in the air flow path including the inlet duct, the shell side of the heat the exchanger, and the air stack and the damper resistance means pressure loss through the damper itself.

Systematic damper sizing procedure conventionally implemented by industries can be found in [1]. Damper area can be calculated following the steps given in Table 1.

Table 1. Damper sizing procedure [1]

Step	Procedure
1	Calculate the approach velocity [m/s]: Approach velocity [m/s] = Airflow [m^3/s] ÷ Duct area [m^2]
2	Using the approach velocity from Step 1, calculate a correction factor: Correction factor = 25.8 ÷ (Approach velocity [m/s])^2
3	Calculate the pressure drop [Pa] at 5.08 m/s: Pressure drop [Pa] at 5.08 m/s = Pressure drop [Pa] at approach velocity × Correction factor (Step 2)
4	Calculate free area ratio[a)] For pressure drops (Step 3) ≥ 57.1 [Pa]: Ratio = [1 + (0.0859 × Pressure drop)]$^{-0.3903}$ For pressure drops (Step 3) < 57.1 [Pa]: Ratio = [1 + (0.3214 × Pressure drop)]$^{-0.2340}$
5	Calculate damper area [m^2] For parallel blade dampers: Damper area [m^2] = (Duct area [m^2] × Ratio × 1.2897)$^{0.9085}$ For opposed blade dampers: Damper area [m^2] = (Duct area [m^2] × Ratio × 1.4062)$^{0.9217}$

a) The free area of a damper is the open portion of the damper through which air flows. The free area ratio is the open area in a damper divided by the total duct area.

After calculating the damper area, a required torque to actuate the damper can be determined as following equation [2].

$$Torque = Damper\ Area \times Rated\ Torque\ Multiplier \times Safety\ Factor$$

Rated torque multiplier is given in Table 2 according to specified conditions and the safety factor is set to 1.5 to meet the requirement of ASME AG-1.

Table 2. Rated torque multiplier [2]

Air velocity, [FPM][a)]	Rated torque multiplier, in-lbf/Ft²				
	Parallel Blades		Opposed Blades		Round Damper
	With Edge Seals	W/O Edge Seals	W/ Edge Seals	W/O Edge Seals	
< 1000 (=5.08 m/s)	7	4	5	3	10
1000 ~ 2500	10.5	6	7.5	4.5	14
2500 ~ 3500	14	8	10	6	20

[a)] Assumes pressure differential of less than or equal to 2 inch water column (=50.8 mmH_2O or 500Pa).

2.3 Damper sizing

Parameters required for the damper sizing are duct area, fluid temperature, system pressure loss, mass flow rate, fluid density, and characteristic ratio. Those parameters are summarized in Table 3.

Table 3. Parameters for damper sizing [3]

Parameters	PDHRS		ADHRS	
	AHX Inlet	AHX Outlet	FHX Inlet	FHX Outlet
Inlet/outlet duct area [m²]	1.3273	2.5447	7.7034	7.7034
Duct area at damper installation position [m²]	**1.3273**	**3.1416**	**1.3273**	**3.1416**
Fluid temperature [℃]	40.0	285.9	40.0	249.0
System pressure loss [Pa]	137	4	94	5
Mass flow rate [kg/s]	4.15	4.15	4.92	4.92
Density [kg/m³]	1.1271	0.6314	1.1271	0.6760
Volume flow rate [m³/s]	3.6820	6.5727	4.3652	7.2781
Velocity [FPM]	546	411	647	456
Characteristic ratio	**40**	-	**20**	-

Implementing the parameters of Table 3 to the steps listed in Table 1 and applying the torque equation and Table 2, damper sizing has been completed. Data after damper sizing is summarized in Table 4. Two damper units are installed at the air inlet and one damper unit with two sections is built up at the air outlet because damper installation space is not enough in the air outlet region. Actuators can be purchased which meet the calculated torques.

Table 4. Data from damper sizing [3]

	Dampers			
Position	AHX Inlet	AHX Outlet	FHX Inlet	FHX Outlet
Type	Opposed Blade Damper	Parallel Blade Damper	Opposed Blade Damper	Parallel Blade Damper
No. of damper units	**2**	**1**	**2**	**1**
Sections of a damper unit	**1**	**2**	**1**	**2**
No. of actuators on the unit	**1**	**2**	**1**	**2**
Pressure drop [Pa] at damper	3.425	0.8	4.7	1
Free area ratio	**0.6965**	**0.8058**	**0.6996**	**0.8037**
Damper area [m²]	**1.2736**	**2.9300**	**1.2788**	**2.9228**
Damper area [Ft²]	13.7087	31.5385	13.7644	31.4605
Rated torque multiplier	5.0	7.0	5.0	7.0
Torque [in-lbf]	**102.8153**	**165.5769**	**103.2331**	**165.1676**

3. Conclusions

A systematic damper sizing procedure has been addressed and the DHRS damper sizing has been carried out following the sizing procedure and an arrangement strategy has been decided to promote the DHRS operational reliability.

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