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Helium refrigeration system for the KSTAR☆

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Abstract

The KSTAR, a tokamak with fully superconducting (SC) magnets, is under construction in the National Fusion Research Center (NFRC). For the proper operation of the KSTAR, the superconducting magnets have to be maintained below the critical temperature of the SC components while charged at their corresponding operation current values. In this paper, a large scale helium refrigeration system (HRS) which has been designed and developed to fulfill such a mission is presented.

The cold components of the KSTAR are kept at their operating temperatures thanks to various kinds of cryogenic helium which are produced in the cold box (C/B) of the HRS in combination with the supercritical helium (SHe) cryogenic circulators and a liquid helium (LHe) thermal damper (TD) located in the primary helium distribution box (D/B #1). The relative distribution of the cryogenic helium among the cooling channels of each cold component of the KSTAR is performed by the secondary helium distribution system which consists of the secondary distribution box (D/B #2) and the cryogenic transfer lines (CTL's).

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Keywords: KSTAR; Tokamak; Superconducting magnet; Helium refrigerator

☆ KSTAR: Korea Superconducting Tokamak Advanced Research.

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1. Introduction

The cold components to be cooled down to cryogenic temperatures in the KSTAR tokamak [1] are: (i) the superconducting (SC) magnet system with its supporting structure, (ii) the current-feeder system [SC bus-line and current lead (CL) system] that transfers the current from the power supply to the magnets, and (iii) the thermal shield (TS) system that protects the SC components and the cryogenic part of the CL system from ambient radiation. (The cryopumps of the neutral beam injection system and their associated thermal shields are future consumers of the cryogenic helium.) The thermal load of each cold component during the various operation modes of the KSTAR is summarized in Table 1 [2].

The main components of the helium referigeration system (HRS) itself can be divided into the following major parts [3]:

- (i) The compressor station (C/S) and the oil removal system (ORS).
- (ii) The cold box (C/B) where the cryogenic helium is produced.
- (iii) The primary helium distribution system (D/B #1).
- (iv) The secondary helium distribution system (D/B #2 and cryogenic transfer lines (CTL's)).
- (v) The helium inventory system including the liquid nitrogen (LN_2) storage and vaporizer unit.

The HRS can be operated fully automatically when correct set-point values of the helium properties supplied to the KSTAR cold components are given. However, during the initial stage of the KSTAR operation, the control of the distribution system, except for safety related situations, has to be performed mainly manually in order to obtain the correct set-points.

Except for D/B #2 and the CTL's, the HRS is to be purchased by Samsung Engineering and Construction Cooperation from Air Liquide Advanced Technologies Division (ALDTA). Its final owner is the National Fusion Research Center (NFRC). A call for tender of the secondary distribution system will be announced in the near future.

Table 1
Summary of the thermal load on the KSTAR cold components during various operation modes

ITEM	duration	Toroidal field (TF) magnet	Poloidal field (PF) magnet	SC Bus-line	Thermal shield system	Current lead system	**SUM**
	hour	W@4.5 K	W@4.5 K	W@4.5 K	W@55 K	g/s@4.5 K	W@4.5 K
Idle (no current)	14	961.9	359.6	68.1	12168	10.3	3219
TF current ramp	1	1045.9	388.6	101.7	12168	15.9	3928
PF current Stand-by	7.65	1045.9	388.6	101.7	12168	15.9	3928
PF current Shot	0.35	6335.9	8329.6	415.2	12168	52.5	21143
TF current de-ramp	1	1045.9	388.6	101.7	12168	15.9	3928
Day average (av.)	24	1074.0	487.5	86.7	12168	13.2	**3765**
Shot/Stand-by av.	8	1277.3	736.0	115.4	12168	17.5	**4681**