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THERMODYNAMIC CHARACTERISTICS OF THE SUPERCONDUCTING QUADRUPOLE MAGNETS OF THE NICA BOOSTER SYNCHROTRON

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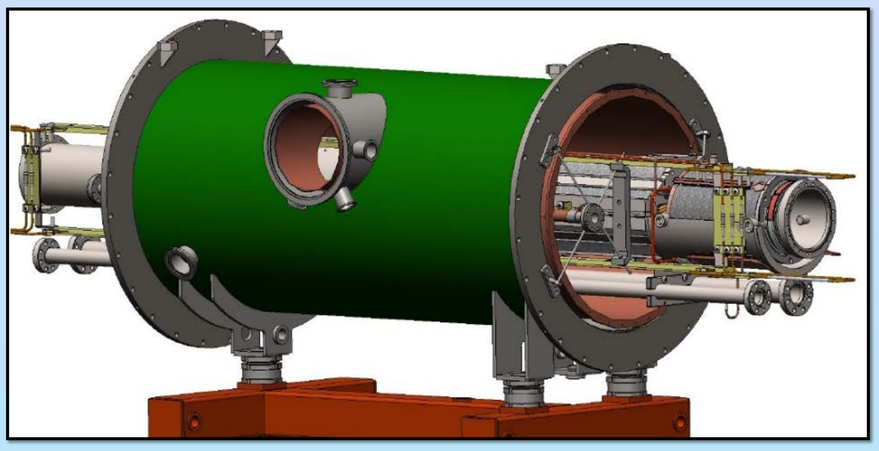
ABSTRACT

The Booster synchrotron of the NICA accelerator complex in Dubna is designed for acceleration of heavy ions before injection into the Nuclotron. The first run of the Booster synchrotron was carried out in the end of 2020. This work presents calculated and experimental data of the static heat leak and dynamic heat releases for quadrupole magnets of the Booster synchrotron with different configuration of the corrector magnets. Obtained results will be taken into account for development of new superconducting magnets and cryogenic installations.

INTRODUCTION

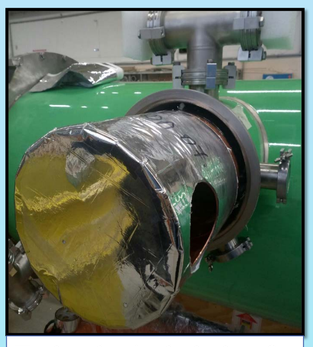
The magnetic system of the Booster synchrotron includes 40 dipole magnets, 16 doublets of quadrupole magnets with dipole corrector (DCM) and 8 doublets of quadrupole magnets with multipole corrector (MCM) and a reference dipole and a reference doublet of quadrupole magnets.
The magnets produced at JINR are subjected to cryogenic tests. One of the main stages of which is the measurement of the static heat leak and dynamic heat releases in the magnet.



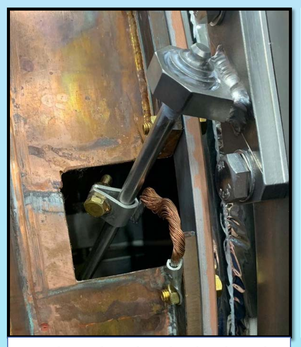
1. STATIC HEAT LEAK

The calculated total static heat input to the SC magnet is determined as the sum of :

- ❖Heat leak through residual gases;
- ❖Heat leak through thermal bridges;
- ❖Heat leak by thermal radiation.

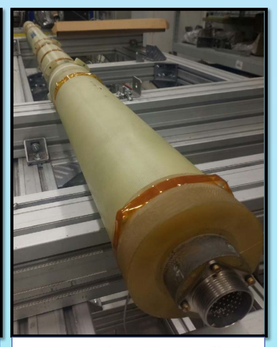


Technological hole for the vacuum system in the vacuum chamber.

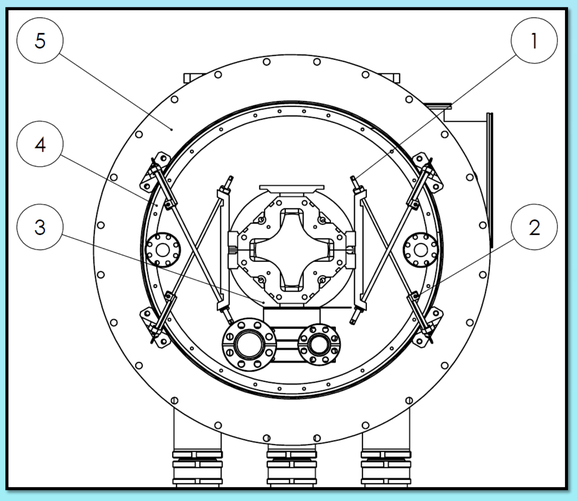


Technological hole in the thermal shield for the suspension system.

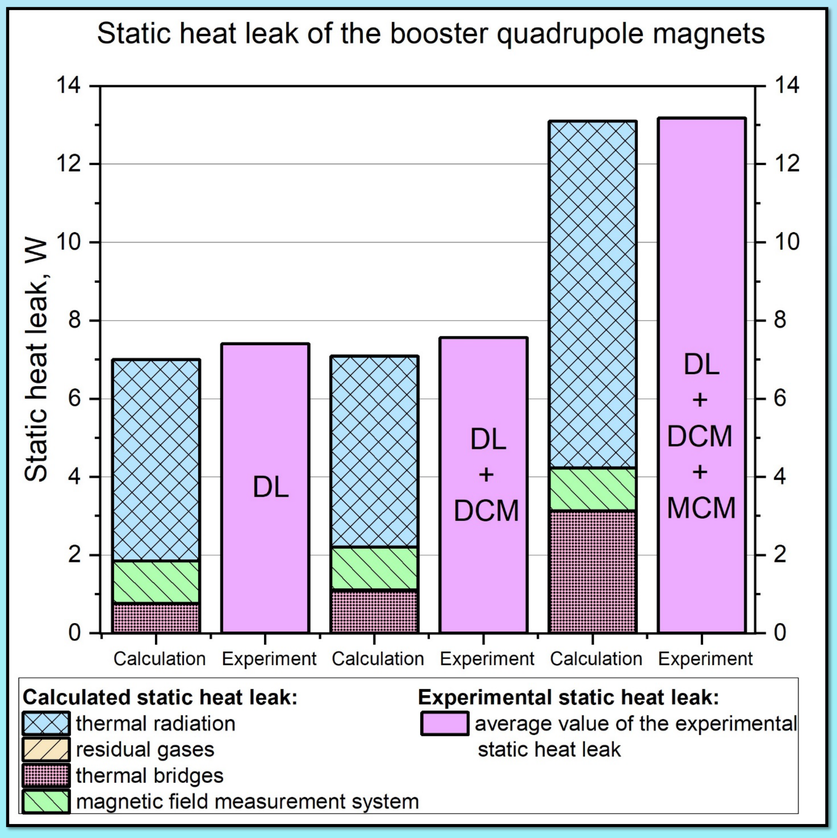
DCM with low - current leads.



Magnetic field measurement system.



Quadrupole magnet of the Booster synchrotron in the cryostat: 1 – suspension rod; 2 – thermal bridge to the thermal shield; 3 – yoke of the SC magnet, 4.5 K; 4 – thermal shield, 80 K; 5 – vacuum shell, 293 K.

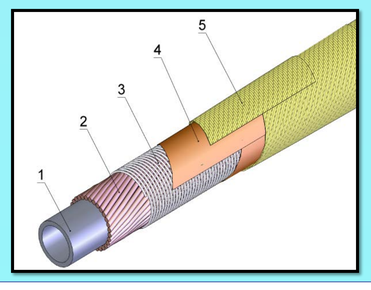


Calculated and experimental data of the static heat leak of the booster quadrupole magnets.

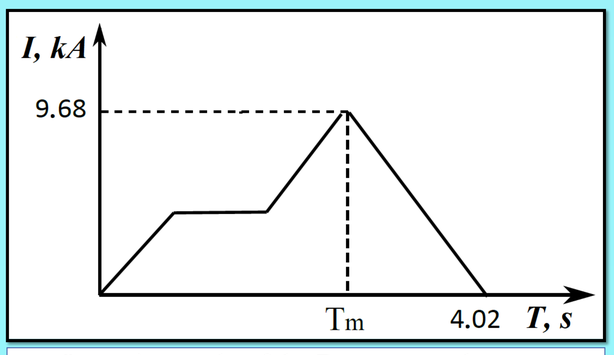
Type of the quadrupole magnet	Calculated static heat leak, W					Experimental value of static heat leak, W
	Thermal Radiation	Residual gases	Thermal bridges	Magnetic field sensor	Total	
Doublet of the quadrupole magnets	5.15	0.001	0.76	1.089	7.0	7.40
Doublet of the quadrupole magnets with DCM	4.89	0.021	1.09		7.09	7.56
Doublet of the quadrupole magnets with DCM and MCM	8.87	0.009	3.13		13.1	13.18

2. DYNAMIC HEAT RELEASES

Dynamic heat releases occurs in the SC coil and yoke of the magnet. The main dynamic heat releases in the SC coil with Nuclotron type cable: hysteresis losses and eddy current losses. Magnets with DCM and MCM have individual power supply through low-current leads (40 A for DCM, 80 A for MCM). The average experimental value of the dynamic heat releases for DCM is 0.42 W and for MCM is 1.61 W.



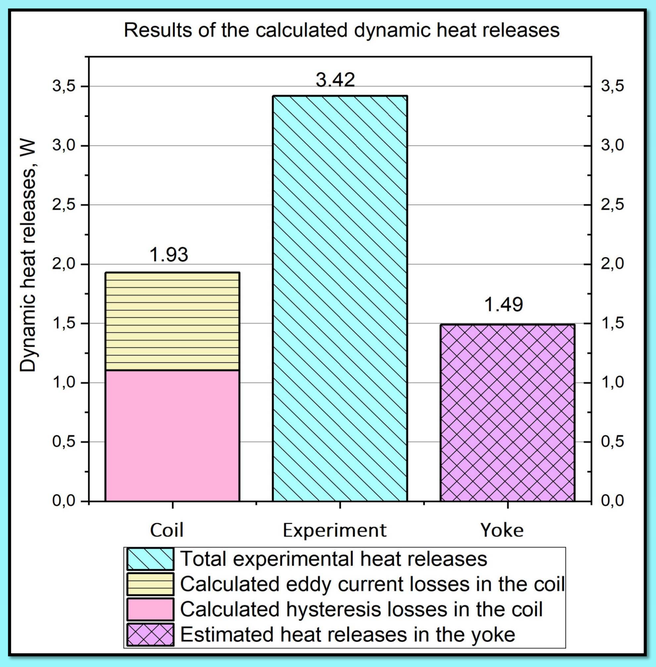
Nuclotron type SC cable: 1 – cooling tube; 2 – SC strands; 3 – fixation wire; 4 – polyimide tape; 5 – glass tape with epoxy compound.



Operating cycle of the Booster synchrotron.
I – current, kA; T – time, s; T_m – field rise time, s.

Calculated and experimental data of the dynamic heat releases of the booster quadrupole magnet.

Type of the quadrupole magnet	Calculated dynamic heat releases, W				Experimental value of static heat leak, W
	Coil			Yoke	
	Hysteresis losses	Eddy current losses	Total		
Doublet of the quadrupole magnets	1.10	0.83	1.93	1.49	3.42



3. EXPERIMENT

The experimental values of the static heat leak and dynamic heat releases in SC magnet during cryogenic test can be measured using calorimetric method.

CONCLUSION

The discrepancy between the calculated and experimental mean values for quadrupole magnets with DCM equals to 6.2 %, with DCM and with MCM M < 1 %. In addition, based on the analysis of the obtained data, it follows that about 44 % of the released heat falls on the yoke of the SC magnet.

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