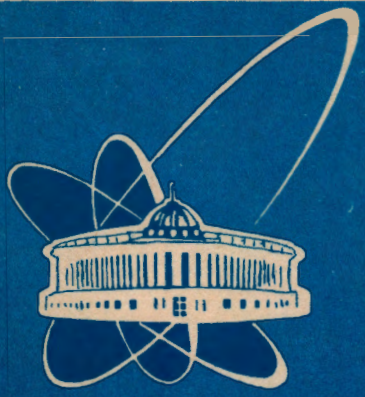

ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
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ИССЛЕДОВАНИЙ

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OPERATION OF CURRENT LEADS AT DIFFERENT KINDS OF COOLING

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Introduction

The magnets and the current leads are placed in the vacuum cryostat in the force-cooled mode. All heat leakages of the current leads have to be removed out only by a mass flow through the leads. In the vapor-cooled mode a part of the leads is immersed in liquid helium. In this case the greater part of the heat leakages is removed out by a mass flow through the leads, and another part can be removed out by surrounding liquid helium.

Construction Details

A couple of 6 kA current leads constructed and tested according to [1] was taken. A vacuum jacket for a length of 400 mm was taken out of the leads, and thermometers and voltage taps were installed, *Figure 1.* The current leads for the Nuclotron were of special design. Simpler current leads can be used for the vapor-cooled mode. A couple of 9 kA current leads constructed and tested according to [1] was taken. A vacuum jacket was taken out of the leads for a length of 400 mm, *Figure 2b,* and the heat exchange part of the leads was immersed in liquid helium.

Experimental Arrangement

Both types of current leads were tested practically in the same cryostat as for the Nuclotron leads. *Figures 1 and 2* show the set-up schematically. The force-cooled mode was done according to the cooling scheme of *Figure 1.* The leads are strapped together at their lower end by a copper tube - superconductor sandwich shortcircuit. The helium was separated and oscillations of a mass flow in the current leads were prevented by a 10 dm^3 intermediate vessel. The insulation vacuum in the cryostat was 10^{-8} MPa. The vapor-cooled mode was done according to the cooling scheme of *Figure 2.* The leads are strapped together at their lower end by a copper-superconductor sandwich shortcircuit operating in liquid helium. In 6 kA current leads the superconductor was soldered to the special copper ends of the leads, *Figure 2a.* In 9 kA current leads the

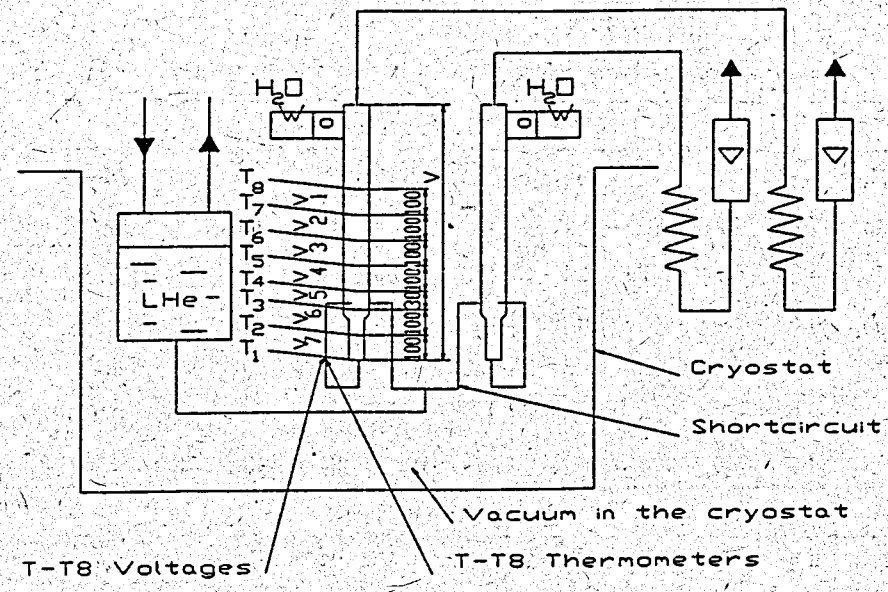

Figure 1. Schematic diagram of the experimental arrangement in the force-cooled mode.

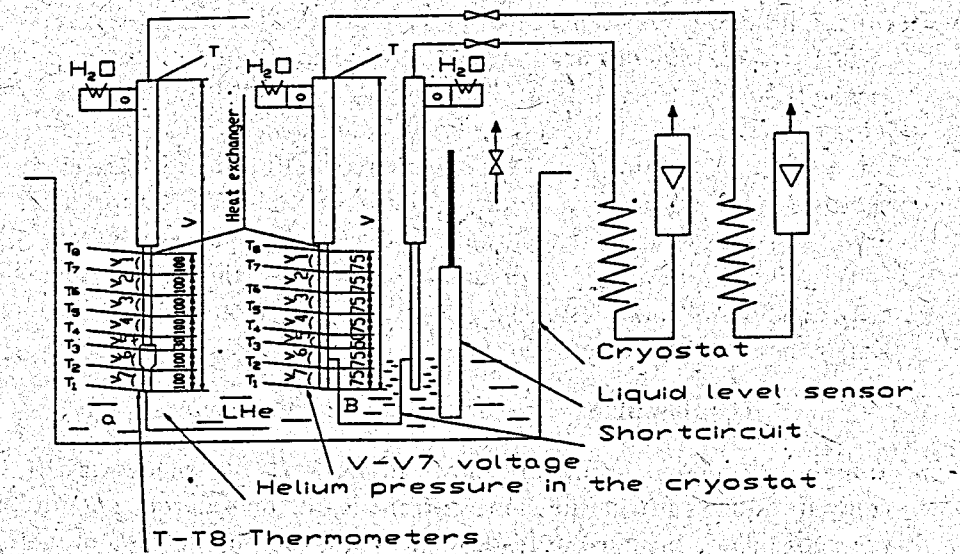

Figure 2. Schematic diagram of the experimental arrangement in the vapor-cooled mode.

TABLE I

PARAMETERS OF THE TESTS OF THE CURRENT LEADS

LHe	Temperatures (K)									M	J
(cm)	T1	T2	T3	T4	T5	T6	T7	T8	T	(g/S)	(kA)
6 kA current leads											
	5.03	5.14	5.29	4.46	7.1	11.83	14.8	16.8		0.35	5
16	5.83	5.68	6.69	10.0	14.6	21.6	30.2	45.6		0.335	5
26	4.47	4.62	5.09	8.3	13.53	19.1	24.6	39	343	0.3	5
	4.97	5.54	5.8	11.4	19.2	26.4	31.3	46	295	0.255	5
	4.6	5.0	5.08	7.26	12.7	19.8	24.4	43.5	300	0.23	6
9 kA current leads											
20	4.2	4.22	4.22	6.25	9.9	14.8	21.3	28	288	0.18	5
	4.7	6.1	6.8	12.3	19.7	27.1	31.3	46	298	0.16	6

superconductor was soldered directly to the current-carrying element (heat exchanger part), *Figure 2b.* More design details can be seen in [1]. The level of liquid helium was measured by levelmeter with precision of ± 1 mm. The error in measuring the mass flow was ~ 3 %. Thermometers T1-T8 were fixed along the current lead inside the cryostat and T in air. Thermometers T1-T8 and their fixing were made as in [1]. Thermometers T1-T3 showed the level of two-phase helium in the cryostat during operation with supercritical helium. The voltage drop was measured across the lead. Experimental data were taken at stable T and V.

Results of Measurements and Discussion

Some measurement results are shown in *Table 1.* It is necessary to compare the results of the same current leads for different cooling schemes. The 6 kA current leads operated in the force-cooled mode with a specific heat leak of 1.3 W/kA at 6 kA. They operated in the vapor-cooled mode with a lesser helium flow through the

TABLE II

PARAMETERS OF THE TESTS OF THE CURRENT LEADS (CONTINUE)

S	P	Voltage (mV)							
(W/kA)	(MPa)	V	V1	V2	V3	V4	V5	V6	V7
6 kA current leads									
1.4	10^{-8}	30.5	0.96	0.848	0.813	0.285	0.382	0.07	0.03
1.34	0.01	33.6	1.24	0.969	0.805	0.57	0.82	0.04	0.03
1.2	0.015	110		1.57	0.9	0.77	0.85	0.002	0.002
1.02	0.14	80		1.36	0.95	0.76	0.82	0.003	0.002
0.75	0.13	86		1.37	0.96	0.74	0.82	0.004	0.002
9 kA current leads									
0.7	0.04	70		0.92	0.81	0.74	0.82	0.002	0.002
0.53	0.136	76		1.38	0.97	0.76	0.81	0.002	0.002

LHe – level of liquid helium

M – mass flow through lead

J – current

P – pressure in the cryostat

S – spec. heat leak per lead

leads. In this case the specific heat leak was 0.75 W/kA at 6 kA at supercritical helium, and the lead head was at room temperature (300 K). The 9 kA current leads operated in the force-cooled mode with a specific heat leak of 1.17 W/kA at 6 kA. They operated in the vapor-cooled mode with a specific heat leak of 0.53 W/kA at 6 kA. It was possible to adjust the temperature of the lead head by correcting the helium flow through the lead. The 9 kA current leads operated with a specific heat leak being by 25% less than the current carrying element with a large cooling surface immersed in liquid helium, *Figure 2b.* In any case both couples of current leads operated with a specific heat leak of 20 – 25% less for supercritical

helium. The gaseous helium surrounding the current leads has no influence on the operation of the leads. It can be seen from the experimental data under different operating conditions, i.e. lines 1, 2, 4 of *Table 1*. It is possible to operate in the vapor-cooled mode with a helium flow through the leads being 50% less than in the force-cooled mode. In this case another half of the heat leak can be removed out by surrounding liquid helium. There were no design changes of the leads. But in the vapor-cooled mode it is possible to operate with a lesser helium flow through the leads and to keep the lead head at room temperature. It was hard to keep the level of liquid helium during operation at normal pressure with a small helium flow through the leads. During normal stable operation of the 9 kA current leads at 6 kA with a liquid helium being 15 cm, the helium gas outlet of one lead was closed, i.e. the condition "loss of cooling" was fulfilled. The liquid helium went from this lead very fast for less than one second, and the shortcircuit burnt through at the lead end at once. The current lead remained cold.

Conclusions

The real specific heat leak of the current lead can be obtained in the force-cooled mode. The vapor-cooling mode makes it possible to operate with a lesser helium flow through the lead.

Acknowledgment

The author thanks Yu.A.Shishov for discussion regarding the results of tests.

References

[1] **V.D.Bartenev and Yu.A.Shishov,** Force-cooled current leads for the force-cooled superconducting magnets of the Nuclotron, *Cryogenics* (1991) **31** 985.

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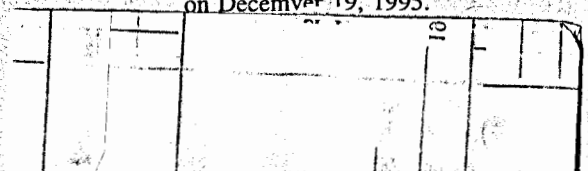
on Decemver 19, 1995.



Бартенев В.Д. E9-95-517

Работа токоввода при различных способах охлаждения

Экспериментально проведено сравнение работы токовводов при принудительном охлаждении и охлаждении парами гелия. Пара токовводов работала в режиме принудительного охлаждения с удельным теплопритоком 1,17 Вт/кА при 6 кА. Те же токовводы могли работать в режиме охлаждения парами гелия с удельным теплопритоком 0,53 Вт/кА при 6 кА. Конструктивных изменений токовводов не было, а появляется возможность работать с меньшим потоком гелия через токовводы и держать верхнюю часть токоввода при комнатной температуре.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 1995

Bartenev V.D. E9-95-517

Operation of Current Leads at Different Kinds of Cooling

An experimental comparison of the operation of current leads in the force-cooled and vapor-cooled modes was made. A couple of leads operated in the force-cooled mode with a specific heat leat of 1.17 W/kA at 6 kA. The same leads can operate in the vapor-cooled mode with a specific heat leak of 0.53 W/kA at 6 kA. There were no design changes of the leads and it became possible to operate with a lesser helium flow through the leads and to keep the lead head at room temperature.

The investigation has been performed at the Laboratory of High Energies, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 1995