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DISCLAIMER

PERFORMANCE OF THE MAGCOOL-SUBCOOLER CRYOGENIC SYSTEM AFTER SSC QUADRUPOLE QUENCHES*

K. C. Wu

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INTRODUCTION

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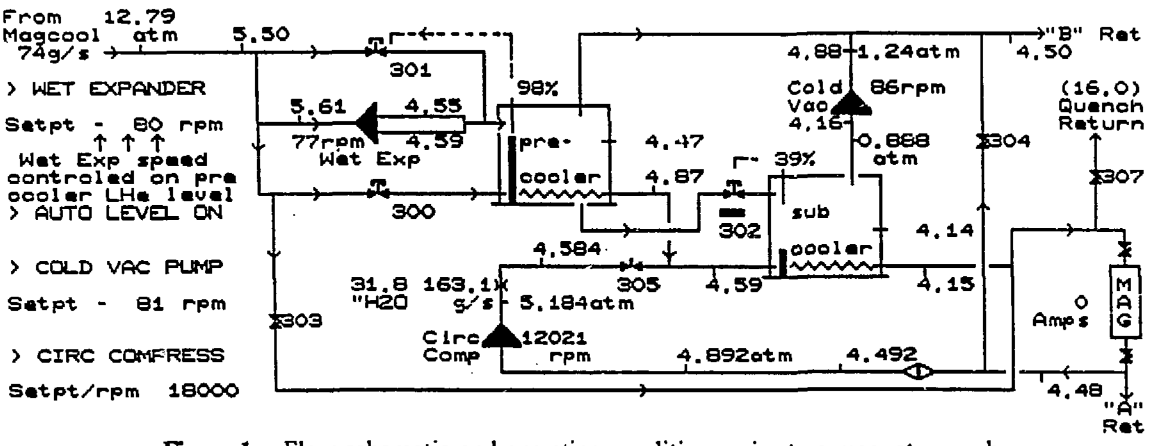

Figure 1. Flow schematic and operating conditions prior to a magnet quench

PRESSURE, TEMPERATURE AND FLOW RATE AFTER QUENCH

The following results were obtained from quenches of the SSC QCC404 quadrupole in MAGCOOL Test Stand B. The magnet was maintained at 4.3 K prior to a quench. A total of ten quenches with quench currents between 2000 and 7953 amperes were investigated. The 2000, 4000 and 5000 ampere quenches were initiated by a strip heater located on the magnet coil. The other quenches were natural quenches occurring between 7265 and 7953 amperes. The corresponding magnetic stored energies varied from 15 to 240 kilo-joules. The results for the 4000, 5000, 7396 and 7952 ampere quenches are presented graphically below.

The loop pressures as a function of time after a quench are given in Figure 2. As seen, the loop pressure first increases after a quench due to the heat released from the magnet to the cooling loop. As the system is cooled to the condition prior to the quench, the pressure decreases. The peak loop pressure increases linearly with the amount of energy released as shown in Figure 3. The time at which these peak pressures occur also increases with the energy released. In all cases, the loop pressure returned to the original pressure before the quench in less than 4 minutes.

Temperatures recorded at the return line in the subcooler assembly after quenches are given in Figure 4. The return temperature increases initially as heat is carried to the subcooler. The temperature reaches a peak value before returning to test condition. The return temperature is higher for higher current quenches whereas the supply temperatures is essentially the same for all cases.

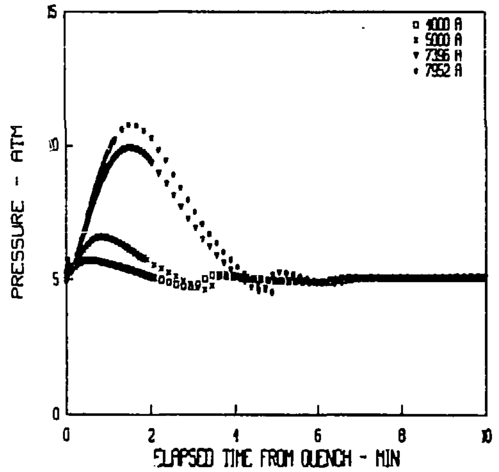

Figure 2. Loop pressures after quenches

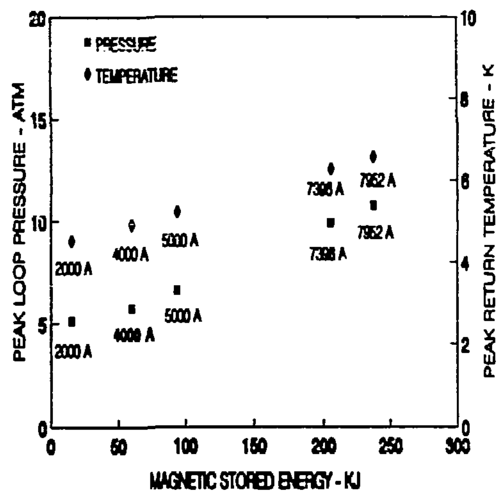

Figure 3. Peak loop pressure and temperature versus stored energy

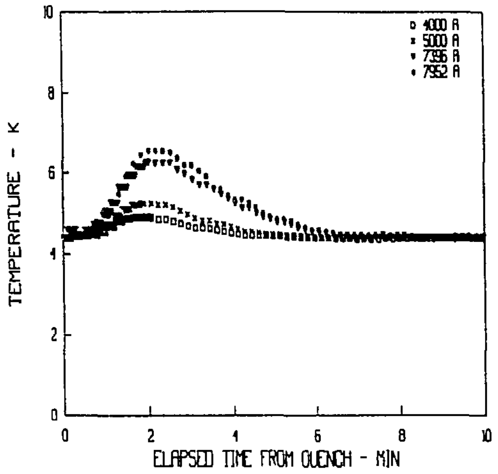

Figure 4. Return temperatures after quenches

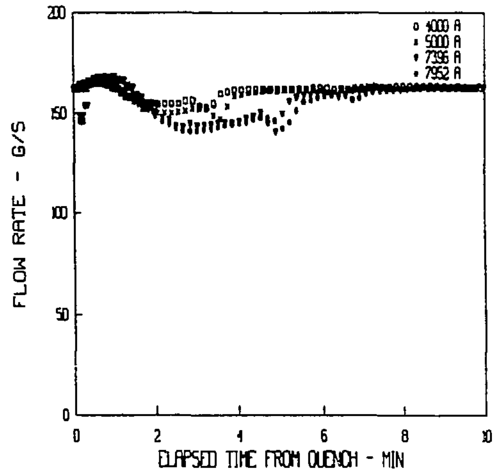

Figure 5. Mass flow rates after quenches

The peak temperatures recorded are proportional to the magnetic stored energy as shown in Figure 3. The time at which the peak temperatures were recorded depends primarily on the circulation of helium and was approximately 2 minutes after each quench. The recovery time for temperatures in the circulating loop is less than 10 minutes.

The helium flow through the magnet as a function of time is given in Figure 5. As can be seen, the mass flow rate only varies slightly because the energy released into the helium loop is not large. However a large energy release does cause a larger perturbation in flow rate.

COOLING RATE AND TOTAL COOLING

The apparent cooling rate applied to the magnet is defined as the difference in the enthalpy flux between the helium in the supply and the return lines. The net cooling rate for quench recovery equals the apparent cooling rate minus the background heat load. Because the system which started at a test condition is cooled to the original condition after a quench, the integration of the net cooling rate represents the total amount of cooling provided for quench recovery and should be equal to the stored energy released by the magnet. The apparent cooling rates during quench recovery are given in Figure 6. The total net cooling provided during quench recovery for each of the four quenches is given in Figure 7. The cooling provided increases with time and reaches a plateau when the loop is cooled to conditions existing prior to the quench.

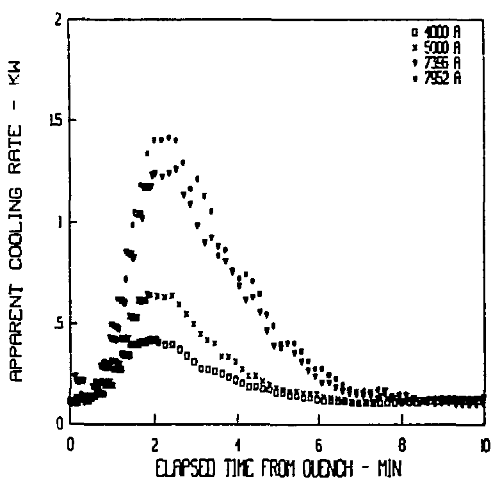

Figure 6. Apparent cooling rates

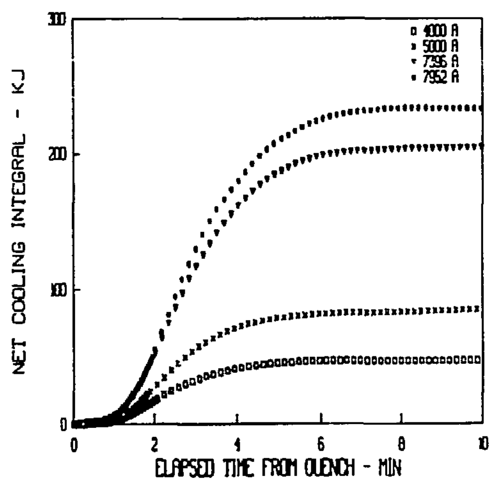

Figure 7. Total net cooling provided

SUMMARY

Key parameters and the corresponding stored energies for the ten quenches studied including the four quenches given above are summarized in Table 1. As can be seen, the total net cooling provided agrees with the magnetic stored energy very well for quench currents above 4000 amperes. For the 2000 ampere quenches, accuracy of the measurements is not good because the energy released is simply too small.

Table 1. Results from quench of QCC-404 quadrupole*

Quench Current	Peak Pres.	Time to Peak Pres.	Peak Return Temp.	Time to Peak Return Temp.	Max. Cooling Rate	Total Net Cooling Provided	Magnetic Stored Energy 1/2 L I^2	Ratio of Cooling to 1/2 L I^2
ampere	atm	sec	K	sec	kw	kj	kj	
2000	5.14	N.A.	4.52	N.A.	0.18	8.4	15.0	0.56
4000	5.74	N.A.	4.91	N.A.	0.42	52.4	60.0	0.87
5000	6.61	52	5.24	110	0.65	92.3	93.8	0.98
7265	9.64	92	6.16	132	1.18	201.3	197.9	1.02
7396	9.92	90	6.27	115	1.26	210.7	205.1	1.03
7715	10.07	90	6.51	131	1.38	222.2	223.2	1.00
7749	10.20	91	6.54	122	1.39	242.1	225.2	1.08
7773	10.18	93	6.53	133	1.39	244.1	226.6	1.08
7953	10.81	92	6.59	133	1.40	239.6	237.2	1.01
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*0.0075 Henries is used for the inductance of the quadrupole.

CONCLUSION

These results from testing a SSC quadrupole and those from earlier tests of SSC and RHIC dipoles provide useful information and a method for analyzing other superconducting magnet systems. The thermal characteristics of the MAGCOOL system after a magnet quench is primarily determined by the magnetic stored energy released into the helium cooling loop. As in all past tests, the peak loop pressure and peak return temperature are found to be linearly proportional to the magnetic stored energy. The agreement between the total net cooling provided and the magnetic stored energy has been confirmed. The energy releases for a quadrupole quench are less than 250 kilo-joules. The peak loop pressure observed is less than 12 atms and no helium was vented from the cooling loop. The system recovers in less than 15 minutes.

ACKNOWLEDGEMENT

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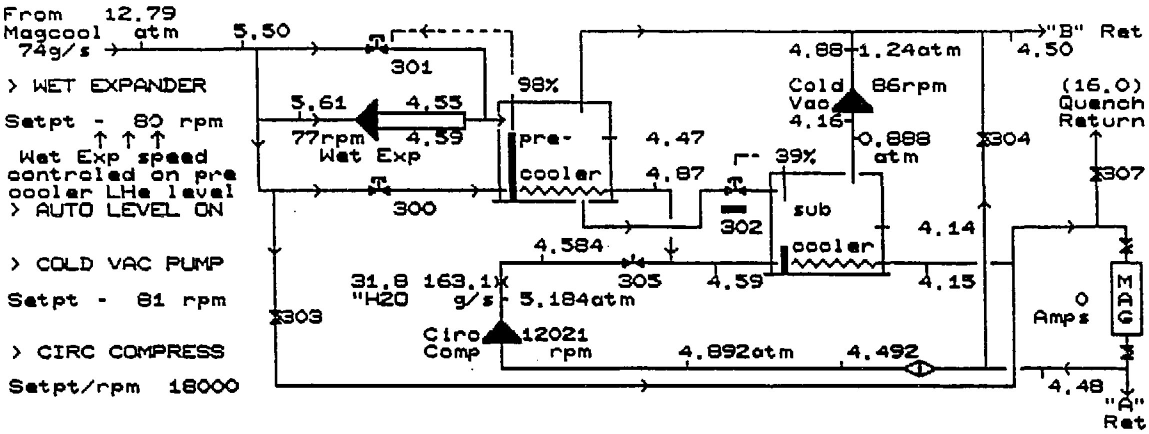

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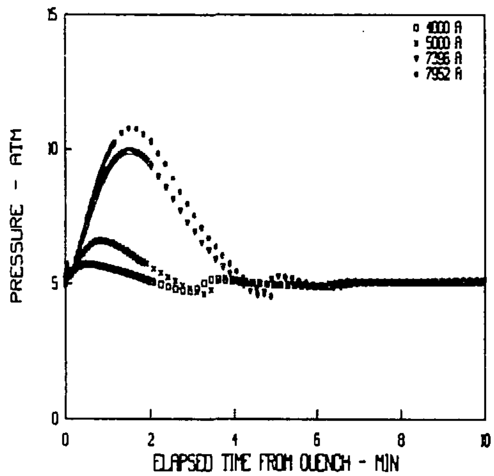

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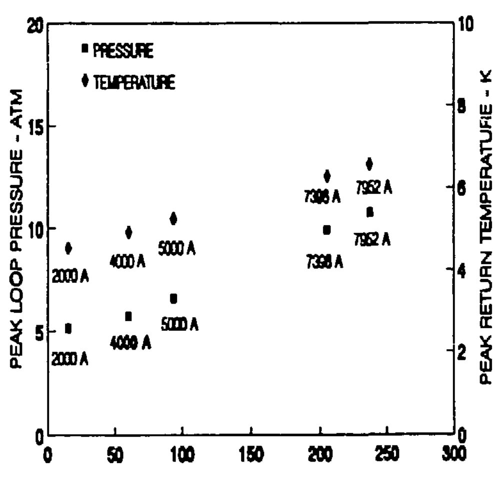

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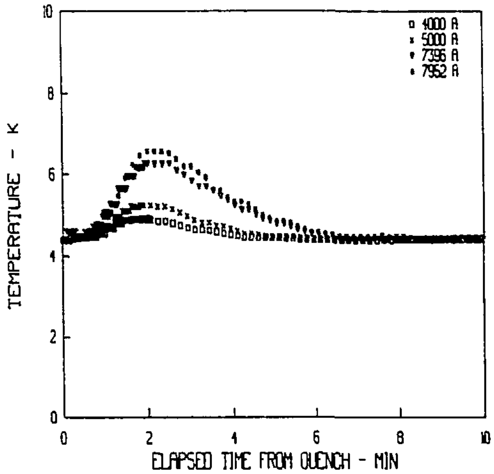

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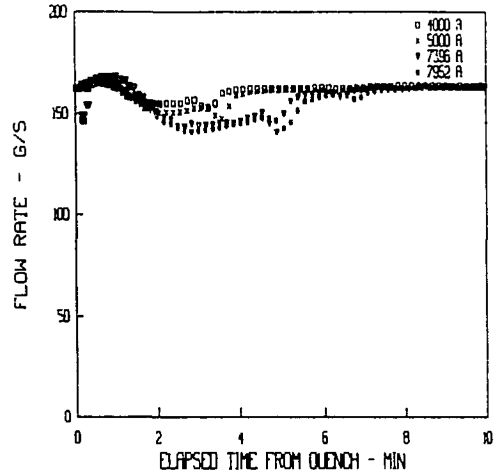

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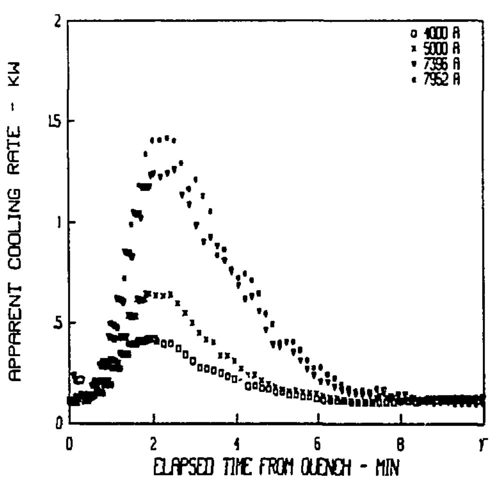

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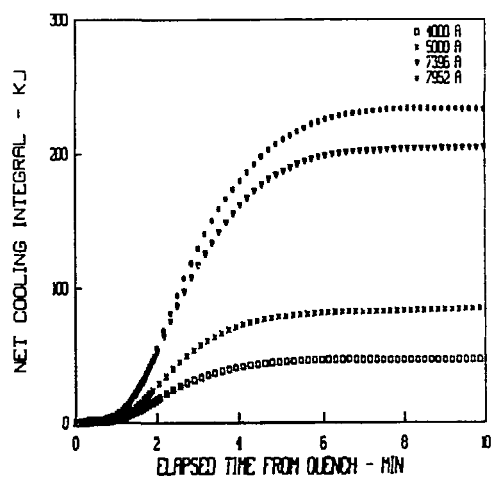

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