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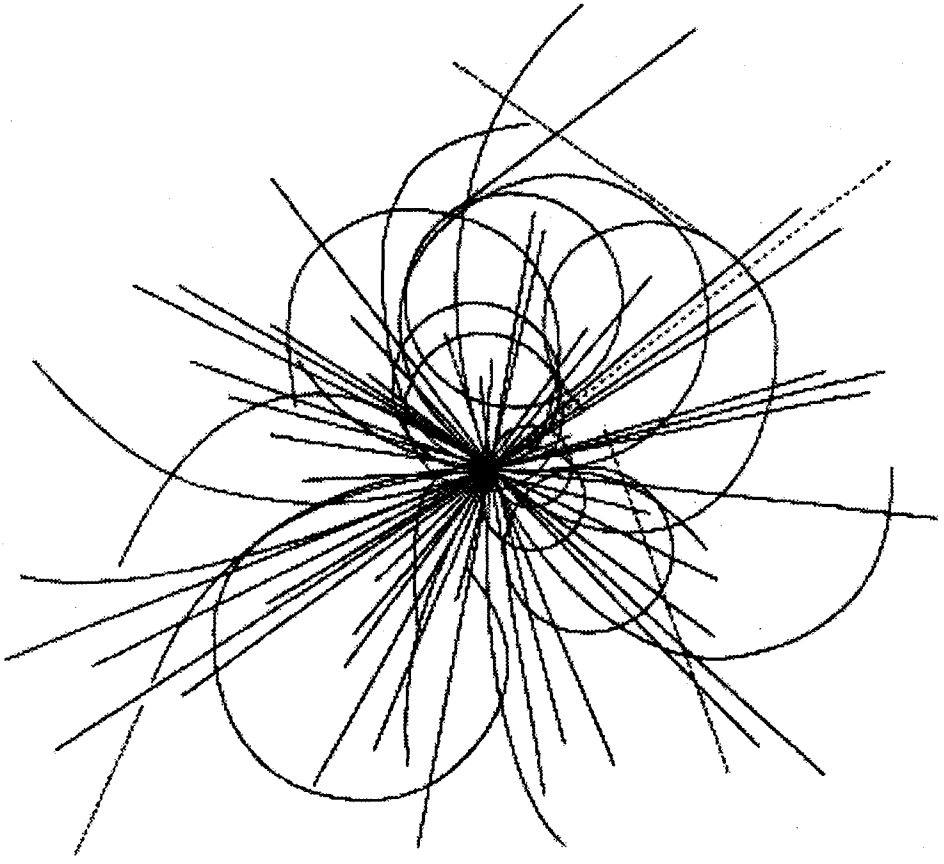

Superconducting Super Collider Laboratory

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SYSTEMS ANALYSIS DETERMINING CRITICAL ITEMS, CRITICAL ASSEMBLY PROCESSES, PRIMARY FAILURE MODES AND CORRECTIVE ACTIONS ON ASST MAGNETS

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INTRODUCTION

During the assembly process through the completion of the Accelerator Surface String Test (ASST) phase one test, Magnet Systems Division Reliability Engineering has tracked all the known discrepancies utilizing the Failure Reporting, Analysis and Corrective Action System (FRACAS) and data base.

This paper discusses the critical items, critical assembly processes, primary failure modes and corrective actions (lessons learned) based on actual data for the ASST magnets. The ASST magnets include seven Brookhaven Lab Dipoles (DCA-207 through 213), fourteen Fermi Lab Dipoles (DCA-310 through 323) and five Lawrence Berkeley Lab Quadrupoles (QCC-402 through 406).

Between all the ASST magnets built there were one hundred eighty six (186) class one discrepancies reported out of approximately eleven hundred total discrepancy reports. The class one or critical discrepancies are defined as form, fit, function, safety or reliability problem. Each and every ASST magnet is considered a success, as they all achieved the quench performance requirements and were capable of being incorporated into the string test.

This paper also discuss some specific magnet discrepancies, including failure cause(s), corrective action and possible open issues.

CRITICAL ITEMS AND ASSEMBLY PROCESSES

As shown in percentage of class one failures, Figure 1, Critical Items List, the top two items of concern are cryostat components. Problems encountered were cryogenic tubes not in the proper position and thermal shields not within the dimensional tolerances causing possible thermal shorts. These problems did not effect the string test, but do effect the heat load specified for the magnet and may increase the work load on the cryogenic system. The third item shown is strain gauge instrumentation, which is important for prototype test data, but has no effect on magnet quench performance and is not planned for production hardware.

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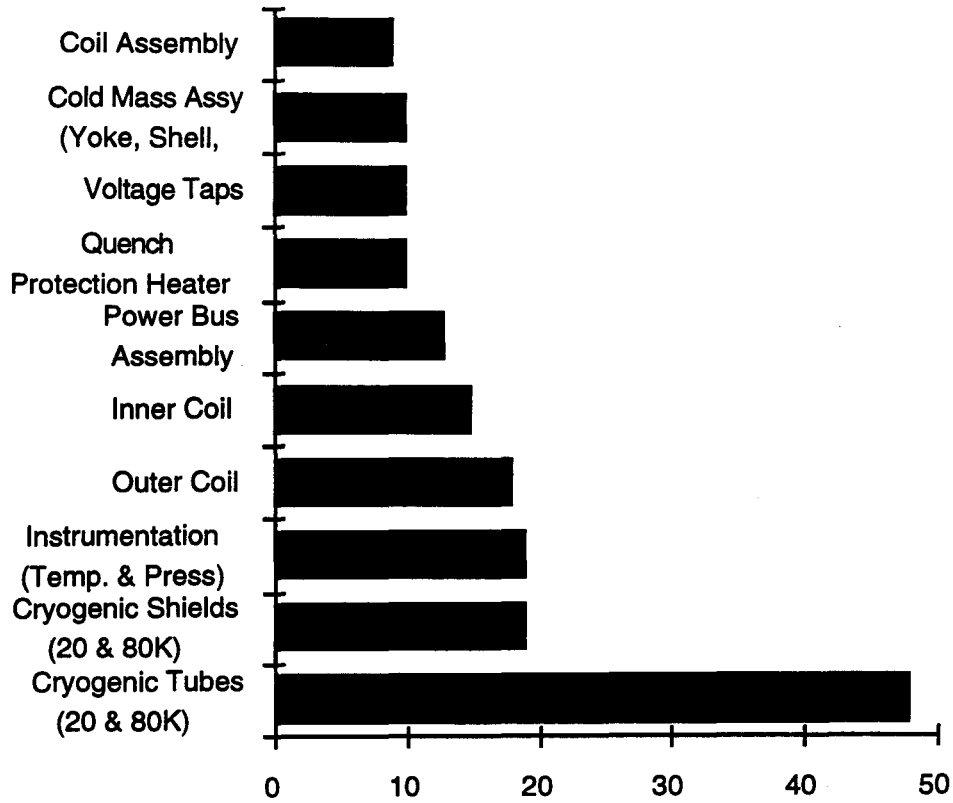

Figure 1. Critical Item List

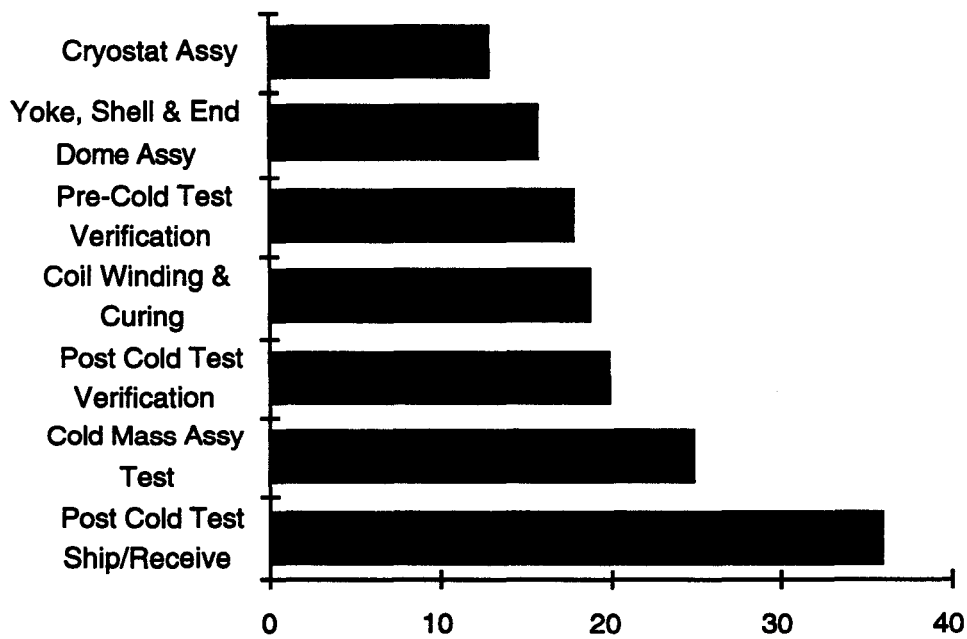

Figure 2. Critical Assembly Processes

Magnet cold mass items, which include the superconducting coils, power bus assembly, and the quench protection heaters are the next critical items on the list. Coil problems primarily include turn-to-turn shorts or coils damaged during the curing process. The primary bus problem was Hi-pot failures due to the bus absorbing moisture as a result using improper soldering-flux. Although this problem was observed early and fixed, subsequent bus problems were due to mechanical fit. The quench protection heaters had some dimples, pin holes in the kapton jacket and some discoloration along its length. Work developing manufacturing processes for the heaters continued with the vendor throughout the ASST magnet assembly phase. The low

volume, tight tolerance and the long length of the heaters resulted in some discrepancies. Not all heater problems were due to manufacturing, but assembly processes as well.

The data in Figure 2, Critical Assembly Process, is somewhat in error due to the inclusion of post cold test, shipping and receiving. Not that these checks are important or critical but they are not part of the magnet assembly. Post cold test failures were primarily due to open instrumentation voltage taps or cryogenic tubes out of location. Similarly, shipping and receiving problems included cryogenic tube position and damaged instrumentation.

Figure 2 shows that during primary electrical verification, which includes cold mass assembly test, yoke, shell and end dome assembly and post collar keying test, is where many of the failures were found. Figure 2 also shows that coil winding and curing, which is one of the primary assembly processes, is most critical among the magnet assemblies.

PRIMARY FAILURE MODES AND CAUSES

The top three primary failure modes shown in Figure 3: Primary Failure Modes, dimensional, workmanship, and configuration are basically due to initial assembly start-up and should be discovered in the prototype and preproduction stages. The coil shorts, power bus shorts, quench heater shorts, coil open and coil bonding items are considered more important, requiring assembly verification to detect potential failures.

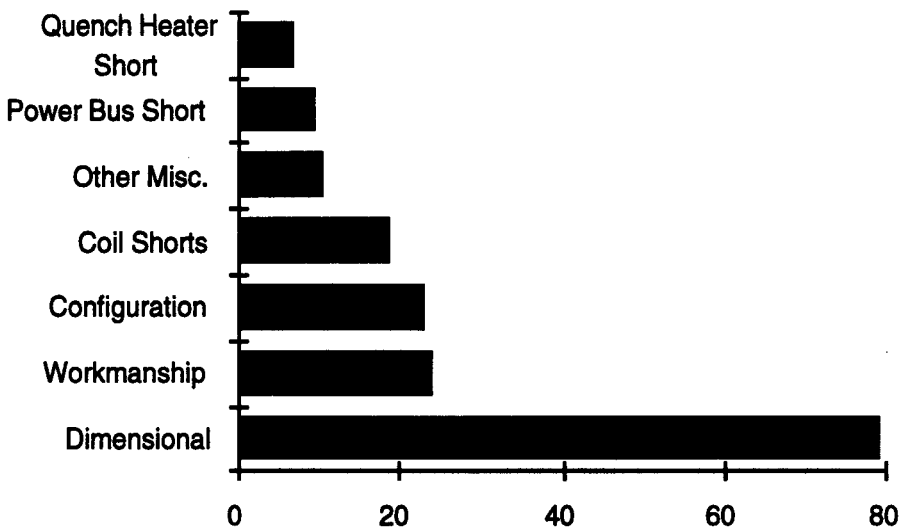

Figure 3. Primary Failure Modes

A fundamental part of the FRACAS procedures is to eliminate the cause of failures. Consequently, seven causes were identified and presented in Figure 4: Design was the primary cause for the failures identified; and points to the cryogenic tube problem as well as the short start-up time from design to magnet assembly. Similarly, processes were being developed along with initial assembly. These causes are basically due to start-up and could be controlled if not eliminated in a mature production environment.

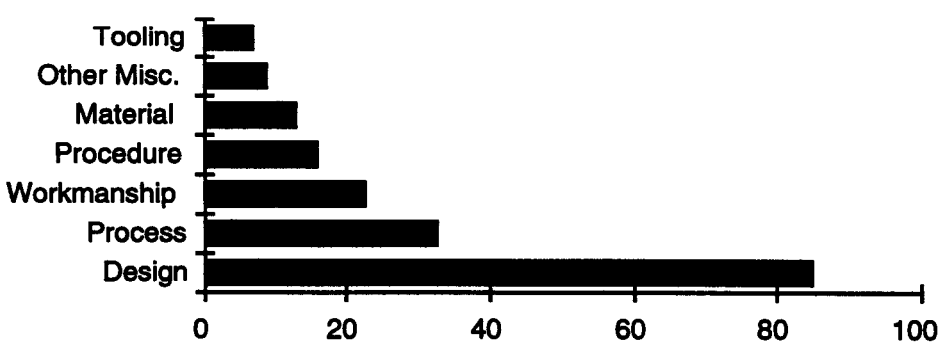

Figure 4. Primary Failure Causes

HARDWARE DISPOSITION AND CORRECTIVE ACTION

Hardware disposition identifies what actions are necessary in order for the magnet to be usable in the ASST. Therefore it is odd that Figure 5 shows "Use as Is" as the primary hardware disposition. This shows that even though some parts may not have been per print, but were more then just OK, and had no effect on the product integrity.

Briefly, the difference between repair and rework, is that repair includes disassembly of an assembly in order to perform the required repair. Similarly, replace is defined as remove and replace the in-doubt component.

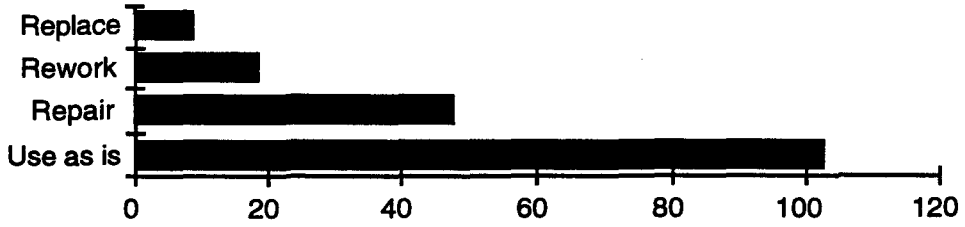

Figure 5. Hardware Disposition

In the long term, it is cost effective to prevent now known problems by incorporating corrective action. Figure 6 contains a list of actions taken or need to be taken for this purpose. "Vendor to Address" means that no effective corrective action was feasible during the brief and schedule driven ASST production and that the problem (primarily cryogenic tube position items) was left for the vendor to analyze and address during the next design generation magnets. "None" or no corrective action appears to be a poor closed loop preventive action. However, if the cause of the problem can not be specifically found, such as in coil turn-to-turn shorts, besides hardware repair, no logical corrective action can be or should be taken.

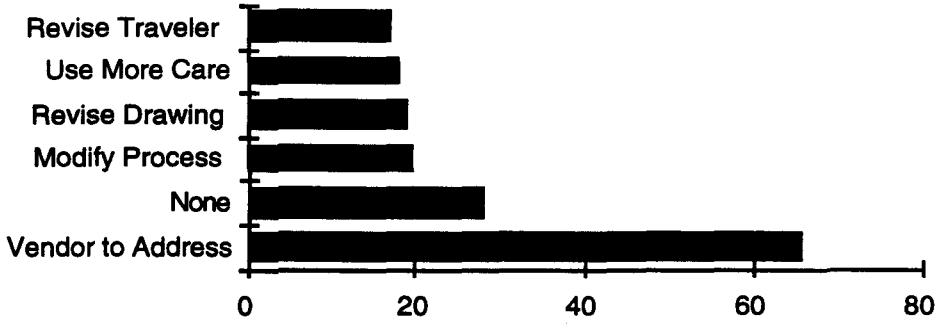

Figure 6. Corrective Actions Taken

SUMMARY

It is true many discrepancies were found, but it is also true that all the discrepancies which were found and corrected, was prior to magnet cold quench performance testing. This proves that with the proper verification and check points the SSCL superconducting magnets, which are critical items, are very achievable to produce and prove to be within or exceed the quench performance specification.

The primary open issue lies in the cryogenic tube position. Basically, the initial interface control attempted to make all items rigid and control tolerances, but this was not achieved. Magnet contractors have been made aware of this problem and have proposed various solutions that should prevent it from occurring on production magnets. These concepts allow final adjustment of pipe ends in late production stages or even in the tunnel, do not increase heat loads, and stay within allowable bellows misalignment requirements.

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