CHAPTER-2

STATEMENT OF THE PROBLEM
Statement of the Problem

A critical examination of the literature reviewed in Chapter 1 reveals that in most of the prototypes of HTSC based electrical apparatus, developed so far, LN$_2$ is used not only as a coolant but also as an insulating medium [34]. Before embarking upon commercial utilization of LN$_2$ as an insulator for HTSC, it is imperative that its electrical properties, particularly breakdown voltage under different electric fields, and its behavior as a component of a composite dielectric and other properties such as loss index are studied in detail.

Whenever a liquid dielectric is used as an insulant in electrical apparatus it is necessary to provide an insulating mechanical support to hold the conducting members at the required spacing. The space between the conductors is therefore bridged by a solid dielectric [5]. So the total behavior of the insulation system will be decided by the behavior of solid insulation in conjunction with liquid nitrogen.

Therefore, the breakdown mechanism of the solid insulators that are currently being used at room temperatures is also to be examined at temperatures of the order of 100 K in terms of their physical, electrical, mechanical and thermal properties so that their viability to be used as
spacers or for providing mechanical support and insulation for HTSC based systems can be determined.

In designing superconducting electrical apparatus, the knowledge of cryogenic gas and LN$_2$ insulation characteristics is almost essential. The 50 Hz breakdown voltage in air at room temperature and air at cryogenic temperature under uniform field conditions has been reported earlier [76,106-108]. However, when non-uniform field conditions exist, it should be possible to evaluate the breakdown voltage using the breakdown voltages under uniform field conditions and vice-versa.

Though studies have been carried out under uniform as well as non-uniform field conditions using different dielectrics at cryogenic temperature [76,106-108], it seems that little efforts are made to correlate these results.

It has been reported earlier that the breakdown strength in SF$_6$ gas or transformer oil decreases with increasing electrode surface area or volume subjected to high electric stress [35]. The area and the volume effects of SF$_6$ gas or transformer oil have been statistically taken into account in the practical design of electrical insulation. However limited literature is available as regards to such studies and designing of practical insulation for superconducting devices using LN$_2$. 
Keeping the above in focus a number of experimental studies were planned and carried out to derive useful inferences. The details of the experimental work done is as follows:

1. Breakdown voltage of LN\(_2\) and its dependence on various electrode configurations for small gap lengths.

2. Breakdown strength of different solid dielectrics under uniform field conditions in air at room temperature and when immersed in LN\(_2\).

3. Breakdown of cryogenic air under non-uniform fields at room temperature and at cryogenic temperature.

4. Loss index of different solid dielectrics in air at room temperature and when immersed in LN\(_2\).

5. Area and volume effects on breakdown strength in LN\(_2\).

The proposed work also includes the detailed analysis and formulation of results together; correlating relative permittivity \(\varepsilon_r\), dissipation factor \(\tan\delta\), volume resistivity \(\rho\) and thickness \(t\) with the breakdown voltage of solid insulating materials at low temperature and arrive at a relation

\[
\text{BDS} = f(\varepsilon_r, \tan\delta, \rho, t)
\]
It is expected that the study and data presented in this thesis will provide an understanding of the dielectric properties of insulants for HTSC, at cryogenic temperature in LN₂ medium.

It is envisaged that the work will lead to fixing the desired characteristics and finally will help in the selection of insulating materials to be used for insulating high temperature superconductors.

The studies listed above are presented in detail in the subsequent chapters 3-5. The experimental setup and the procedure followed have been discussed in Chapter 3. The results of these experiments have been analyzed discussed and presented in Chapters 4 & 5.

A summary of the results, conclusions and a brief discussion of possible future work have been given in the chapter 6.