I. INTRODUCTION AND HISTORICAL SUMMARY

The advent of man-made diamonds has greatly stimulated interest in high pressure as a research tool. James Hannay, Henri Moissan, and others had investigated high pressures in the hope of making diamonds.[1] However, not until Professor P. Bridgman began his studies in the early 1900's was high pressure systematically studied.[2] He investigated the effects of high pressure on chemical reactions,[3] densities,[4] synthesis of new materials,[5] and compressibilities.[6, 7] These classic studies, which culminated in the development of the "belt" apparatus[8] and the synthesis of diamonds,[9] have led to greatly expanded programs of high-pressure research both in this country and abroad.

It is not appropriate here to review all of these studies, but excellent reviews have been provided by K. L. DeVries, et al,[10] L. Berg,[11] and A. Zeitlen.[12] Continuing bibliographic coverage has been undertaken by H. T. Hall.[13]

It is worth noting that the studies have fallen into several broad categories. First, after the disclosure of the belt apparatus, the synthesis of new compounds and the formation of new, denser phases was extensively studied. Second, physical measurements at high pressure for clarifying the problems associated with solid-state physics and geology have been made. At present, this is the broadest field. Third, the application of high-pressure techniques to the fabrication of ceramics with improved properties resulting from the control of the microstructure has been actively studied at Avco.

The purpose of this work was the exploration of the realm of ultrahigh pressures and temperatures in synthesizing new solid-state materials, the study of pressure and temperature effects on possible phase transitions, the investigation of high pressure densification on such materials such as MgO, NiO, Cr_2O_3, Y_2O_3, lanthanide and actinide oxides, cubic BN, and possible combinations of these materials, and the study of the resulting structures and physical properties of newly obtained substances. In addition, measurements of the compressibility of metal halides, as well as sound velocities through various oxide materials, were made.

II. EXPERIMENTAL DEVELOPMENT OF APPARATUS

A. INTRODUCTION

To achieve the high pressures necessary for the effort, an apparatus had to be designed capable of providing pressures in the range of tens to hundreds of kilobars.

It is well known from elastic analysis that in a thick-walled cylinder subjected to hydrostatic pressure from the inside, the stresses are greater on the inner wall. However, it has been observed repeatedly that plastic flow on the inner wall results in a transference of the load to the outer wall which fails first. In order to overcome this tendency for the failure to originate at the outer wall, a series of concentric rings may be fitted together such that one ring is in compression and the other is in tension. The stress distribution throughout the rings can be arranged so that the proportional limit of the sustaining rings is not exceeded.

B. APPARATUS

1. Apparatus Design

In the design used, the die body proper was prepared from cobalt-bonded tungsten carbide, a composite which exhibits essentially no plastic flow. Similarly, the steel supporting rings used were unusually hard. With such materials it was possible to employ a classical elastic analysis[14] and treatment. In order to reduce the tensile stress at the interior wall of the die body, the die was put under initial compression by means of a series of surrounding steel rings. The interferences between these rings were so calculated that:

a. at the highest pressure of operation, the tensile stress on the inside wall of the die body did not exceed the proportional limit for such material,

b. in the unloaded condition, the compressive stress at the same place did not exceed the proportional limit,

c. conditions a. and b. were observed at each interface in the die proper after assembly, and

d. during assembly, the proportional limit was not exceeded in any subassembly.