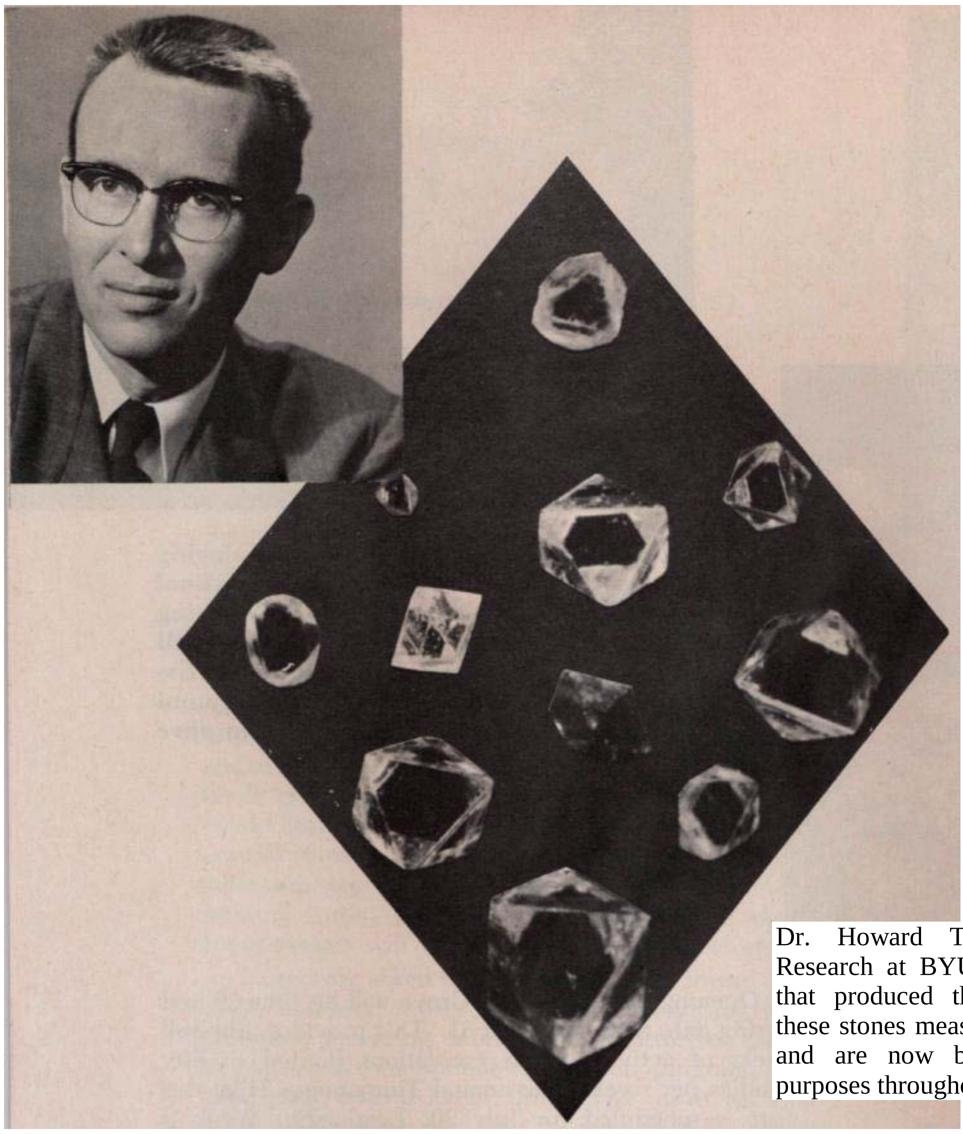
B YU'S King



Dr. Howard Tracy Hall, Director of Research at BYU, developed the machine that produced these diamonds. Some of these stones measure 1/10 of an inch across and are now being used for industrial purposes throughout the world.

by Barry G. Herein
Editorial Assistant

On December 16, 1954, a brilliant young scientist sat trembling with excitement in the General Electric research laboratory at Schenectady, New York.

In a tiny pressure chamber of his own invention he had just created the first true diamonds to be synthetically produced by man.

After only two and one-half years of research, 35-year-old, Ogden-born Howard Tracy Hall ended a 125-year-old search for the man-made diamond and became the apostle of high pressure.

He had come to General Electric in 1948 with a doctorate in physical chemistry following seven years of class and laboratory work at the University of Utah. He was the first student of Dr. Henry Eyring at the university to receive the Ph.D. degree and only the fourth in the school to receive it.

In 1951, Dr. Hall assumed an active interest in the synthetic production of diamonds along with three other scientists: Dr. F. P. Bundy and Dr. H. M. Strong. physicists, and Dr. R. H. Wentorf, a physical chemist. After spending a year with the chemical problems of diamond synthesis. Dr. Hall turned his attention to designing an apparatus which could produce the necessary high temperatures and pressures.

Within two months he had produced what came to be known as a "half belt" apparatus which, however, did not satisfy him nor General Electric. Consequently, support for a newly conceived "belt apparatus" did not come from the company and further experimentation was delayed for many months.

Dr. Hall became impatient to continue his work, and without official authorization took his project to friends in the machine shop at G. E., arranging for them to build his revised machine during slack times. This they did and by July 1953 the'first "belt" was completed with hardened steel components. At a comparatively nominal expenditure of about $1,000 the new apparatus was so successful in producing high pressures and temperatures that permission was obtained to have vital components constructed of a harder substance—cemented tungsten carbide.

And so it was that a year later after experimenting with hundreds of chemical combinations, Dr. Hall peered into the tiny, prismatic faces of the first real diamond produced by man.

On December 31, Dr. II. Hugh Woodbury, a G. E. physicist, produced similar diamonds under the direction of Dr. Hall, thereby fulfilling the important criterion that the work could be duplicated by another qualified researcher.

of Diamonds

In science, as in other fields, the creative breakthrough is sometimes only half the battle. Dr. Hall would probably verify this. The commercial uses of synthetic diamond were limitless, possible economic rewards were boundless, and the international importance of such man-made gems seemed staggering. For G. E., Hall's "belt apparatus" was an invention that called for strict secrecy if the company were to reap full benefit from it. To the United States Department of Commerce, the production of synthetic diamonds was an accomplishment to be kept, at all costs, from any foreign rival. As a result of such convictions, Hall's "belt apparatus" became a matter of rigid secrecy. G. E. was given full charge of the machine with explicit and welcome instruction that the secret of the synthetic diamond was to be kept that way.

Secrecy Hinders Research

To the scientist secrecy is anathema. It limits him. It halts his research work in many ways, and for Dr. Hall it rendered his own achievements of little value. He had research to do. Not only was the "belt" valuable for the production of diamonds, but he realized that in geology, chemistry, atomic science, physics and undreamed of other fields, his invention might encourage revolutionary advancements. With a secrecy order research was impossible.

To the scientist, or to any thinking man, time is precious. Tracy Hall lost two years of time—two years that could have been spent and that he would have spent for the advancement of man's sketchy knowledge in the realms of high pressure and temperature.

He left G. E. in 1955, accepting a faculty position at Brigham Young University as Director.of Research and Professor of Chemistry. Here he resumed his work and at the suggestion of friends set out to lick his problem with a plan as genius-like as the invention of his first diamond machine. He would produce a second pressure apparatus similar to the "belt" and yet different enough to acquire a new patent. This meant inventing two different machines with twin capabilities.

Additional Financial Help

Patient waiting and searching resulted in a financial grant of $10,000 from the Carnegie Institute of Washington and later a $25,000 grant from the National Science Foundation. With financial support, Hall began work in 1956 and by the summer of 1957 his prodigious efforts resulted in completion of the Tetra-hedral Anvil Press at Brigham Young University.

He did it. He successfully outwitted himself and the stifling secrecy order by producing a machine different enough mechanically to bypass the crippling patent on his first and yet able to produce the same diamond-making pressures and temperatures. The wheels of research began to roll now and in 1958 thousands of worldwide readers of the *Review of Scientific Instruments* received word of the diamond producing Tetrahedral Anvil Press. Scientists from around the world came (and are still coming) to examine Dr. Hall's extraordinary machine, and Hall became a popular lecturer on high-pressure research.

Then came another blow.

Late in 1959, more than two years after the new "press" had been completed and after it had been examined by countless scientific specialists and featured in scientific journals with thousands of readers, the Department of Commerce placed Hall's second apparatus under a secrecy order. Again research was halted and the young scientist, now five years older and becoming increasingly experienced in federal temperament, was asked to notify all parties who had examined or read about the "press" to the effect that it was now a matter of secrecy to the United States and should be treated accordingly. Needless to say, such a task was virtually impossible, and fortunately two months later in 1960 the secrecy order was lifted. After years of polite effort at breaking the secrecy rings surrounding Hall's discoveries, the United States Department of Defense sternly requested termination of the secrecy restrictions. Shortly the BYU press was freed along with Halls G. E. apparatus.

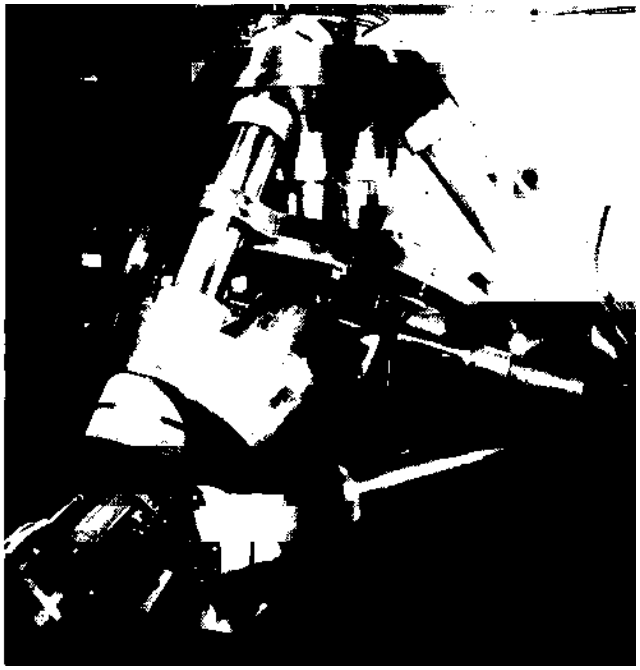
The saga was now complete and Dr. Hall began his research with new hope.

World Interest in Diamonds

What was it about Howard Tracy Hall's invention that had caused such excitement that two separate federal secrecy orders nearly resulted in stopping even its inventor from furthering his own work? And what is it that prompts over 100 scientists a year to file through BYU's Eyring Science Center examining Hall's machine?

The answer is obvious: synthetic diamonds. As soon as chemists learned that graphite, or ordinary black carbon, and diamond were composed of the same elemental substance, the search began to convert one into the other. Scientific achievement and a desire for quick wealth were the primary motives which led scientists to make what seems to have been the first false claims of success in synthesizing diamonds. That was in 1823. Now, over a century and hundreds of scientists, including several Nobel prize winners later, a third motive spurred the search for the success of diamond synthesis: the use of diamonds in industry.

Presently, $50,000,000 is spent annually in the United States alone for diamonds to be used in indus-



Dr. Hall's second and more elaborate Tetrahedral Anvil Press is located in the Eyring Science Center on the BYU Campus. Another press for creating high temperatures and great pressures is being constructed. Both may be viewed by the public during the day.

try. These diamonds are used primarily on diamond wheels designed to grind and cut tungsten-carbide— long-time mainstay of modern industry. Natural diamond fields are unable to produce enough material to satisfy industrial needs. Thus, a machine such as the "belt apparatus" or the Tetrahedral Anvil Press, which can produce relatively large and thoroughly genuine diamonds within two to three minutes, could very probably become extremely important to the industrial and military advancements of any nation possessing such.

According to Dr. Hall, synthetic diamonds produced after his own processes are now making "serious inroads" into the natural diamond business.

In 1957, BYU and the General Electric Research Laboratories were sole owners of Hall's diamond producing machines. Today, approximately 141 laboratories throughout the world are working in fields of high pressure as a result of his work. At least one corporation, Barogenics Incorporated of New York City, is now constructing the Tetrahedral Anvil Press commercially.

Temperatures and Pressures

It is more than diamonds, however, that attracts the scores of scientists each year to Dr. Hall's invention. It is the combination of Hall's undreamed of temperatures and pressures that excites the scientific mind. Both the G.E. "belt apparatus" and the tetrahedral press are capable of producing, in a space less than 1 100 of a cubic inch, temperatures of up to 7,000 degrees centigrade (hotter than the surface of the sun) and pressures of up to two-and-one-half million pounds per square inch. To understand the intensity of such pressures, Dr. Hall suggests that 4,000 Washington Monuments (each about 500 feet tall) be stacked top to bottom 400 miles into the air. At the base of such a column pressures would be reproduced similar to those obtained in his machines.

Unexplored Areas

These fantastic pressures have opened up fields of research heretofore totally unexplored. In geology, Hall's accomplishments are destined to prove invaluable as pressures similar to those found at 400 mile depths can now be examined for their various effects upon all manner of physical substance. In chemistry man is now able to synthesize completely new materials never before produced by nature or by himself. For instance, a combination of high pressures and temperatures has produced pure electricity from a blend of boron and sulfur. Similar discoveries may revolutionize the lives of future generations.

Dr. Hall's pressures in combination with high temperatures have changed the melting point and electrical conductivity of certain metals, and experimentation has shown that under pressure the melting point of ice can be raised from 32 to 1,000 degrees fahrenheit.

In order that scientists may observe the effects of high pressure and temperature upon atoms and the molecular construction of simple compounds, a twenty-eight-year-old BYU scientist, Dr. J. Dean Barnett, has made an important contribution to Hall's tetrahedral press. An X-ray tube has been incorporated into one of the four powerful, pressure producing hydraulic rams of the "press." As the four separate rams close in on and begin to squeeze material placed in their path, an X-ray beam passes from the hydraulic ram through the experimentation material. The beam is then diffracted from its original course and recorded on a highly sensitive electronic recording device. The angle and intensity of the X-ray is then examined and through mathematical computations any molecular change in a given substance may be discovered. Since Hall's machine is the first to ever actually force a change in the atomic arrangement of any material, knowledge of the extent of that change is vital.

Constructing Third Press

Following the construction of Hall's first tetrahedral press at BYU, a second and more elaborate one was constructed; and presently a third is being assembled for the purpose of extending the valuable research of Dr. Hall and Dr. Barnett.

After 21 years of marriage and seven children, five girls and two boys, Howard Tracy Hall is as purely a scientist as his home-made diamonds are real.

He honestly admits that though his life is "dominated by women" his every waking hour is spent contemplating or working with some scientific project. As Director of Research at BYU, he is kept constantly busy on some project of importance and in addition serves as a major scientific consultant for General Motors, Oakridge National Laboratories and the United States Steel Corporation.