Part II
Since the Beginning

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The first diamonds that I synthesized grew rapidly and, consequently, they were very imperfect with respect to a single crystal of natural diamond. At first, this was disappointing, but after making the first resin-bonded diamond grinding wheels with the new synthetic grit, it was discovered that the grinding ratio when grinding cemented tungsten carbide parts was very high. Shortly, it was realized that the friable, imperfect grit had a grinding ratio (the mass of tungsten carbide removed by the wheel divided by the amount of diamond lost from the wheel) as much as 100 times as good as wheels made of natural grit! This was a fortunate discovery and made it possible for manufactured diamond grit to quickly be commercialized.

At first, the natural diamond syndicate did not feel threatened by the entry of the new manufactured product. But by 1960, they realized that it would be necessary for them to get into the manufactured diamond business themselves if they were to remain competitive in the industrial diamond business. DeBeers formed a manufacturing group in South Africa and built a factory that utilized H. Tracy Hall's patented "BELT" high pressure/high temperature device (owned by General Electric). They also used Hall's and subsequent GE researcher's procedures for manufacturing the diamond grit.

General Electric sued, in South Africa, for infringement of Hall's and others General Electric patents. The lawsuit lasted for about six years and was carried to the supreme court of that land. I was present in this court of last resort in October of 1964. I was to be used as an expert witness on behalf of the General Electric Company. However, into the second week of the trial, an out of court settlement was reached wherein Anglo American, the parent company of DeBeers, paid General Electric several million dollars and obtained a license to use Hall's BELT and other GE patents.

The friable diamond grit being manufactured at this time was made at high temperatures and high pressures and short dwell time within the press. After several years of this being the only diamond product, GE, and later others, began to make grit at lower pressures and temperatures and a longer dwell time in the press. The grit had greater crystalline perfection and was less friable than the fast grown grit. It was generally called "Metal Bond" grit. In due time, both GE and DeBeers were making a still more perfect grit designated generally as "Saw Grade" grit. Reputedly, there is more profit to be made in the manufacture of Saw Grade grit than in any other diamond product manufactured at this time. However a very great investment in very large high pressure/temperature machines and very careful computer control of temperature and pressure cycling is required.

General Electric began producing a few gem quality diamonds in the early 1960's (the work of Herbert M. Strong and Robert H. Wentorf). About two weeks growing time was required for producing a one carat gem. This is not at all economical, but these manmade gems were more rare than natural diamonds. Consequently they have been cut and presented to very important personages as, for example, the Queen of England. Reputedly, GE still maintains constant manufacture of a few gems for promoting good will and favor to that company.

Robert Wentorf of GE succeeded in converting hexagonal boron nitride into a cubic form with the wurtzite structure back in 1956. It had a superior heat resistance for grinding and turning of group eight metal alloys of the periodic table. It is also the second hardest material known to man. On the Knoop microhardness scale, it has a hardness around 4000 whereas diamond is around 8000 and, for comparison, silicon carbide is around 2000.

The cubic BN finally became an article of commerce for use as grinding wheel grit and later as a polycrystalline tooling material. An officer of the General Electric Company told me that bringing cubic BN (Borazon) to market cost many fold more dollars than were required to bring diamond grit to market.

General Electric and DeBeers dominate the industrial diamond market. In recent years, both companies, for tax reasons, have shifted the major part of their manufacturing operations to Ireland. GE built a $50 million plant in Dublin and DeBeers a $175 million plant in Shannon. Within the United States, GE has captured 95% of the market.

As the years have gone by, a number of smaller diamond manufacturing companies have started operations. Most notable in the United States are Valdiamont, Megadiamond, U.S. Synthetic, and Precorp. Valdiamont is as associate company of Valeron, a manufacturer of carbide tools. Valdiamont and Valeron were both subsidies of GTE Sylvania. Former employees of General Electric's diamond manufacturing division brought Valdiamont into existence. The three companies Megadiamond, U.S. Synthetic, and Precorp, are all located in Provo, Utah. Former employees of Megadiamond formed U.S. Synthetic and a former employee of U.S. Synthetic later formed Precorp. About two years ago, Smith International Incorporated, a large manufacturer of oil well and mining drill bits, purchased Megadiamond. Consequently, Megadiamond is now knows as SII Megadiamond or Smith Megadiamond. In order of sales, Smith Megadiamond is first, U.S. Synthetic is second and Precorp third. Precorp specializes in the manufacture of miniature diamond drills of great precision.

Inasmuch as I was the principal person involved in the founding of Megadiamond, I will proceed with some of its history.

As indicated in Part I, a combination of GE and government secrecy delayed the publication of my scientific achievements for about seven years, thus robbing me of deserved professional recognition and remuneration. GE benefited enormously from the government secrecy because it resulted in an effective 22 years of patent protection instead of the usual 17. In addition, the secrecy hampered my efforts to maintain continuity in my research. GE did not point out, nor did the Federal Government, that I could have submitted a compensatory claim against the government over this matter. Unfortunately, I first learned of this provision 25 years later while studying to become a patent agent.

The only way that I could return to activity in HP/HT would be to invent new equipment that did not infringe on the Belt. As previously indicated, I did this and named the new apparatus "The Tetrahedral Anvil Press" (U.S. Patent No. 2,918,699, December 29, 1959). A rather crude Tet-Press was put into operation near the end of December 1957. I had now lost two years and would lose three more before inventing the Anvil Guide in 1962. The anvil guide provides precise and automatic anvil alignment, which dramatically reduced the time of making a run, and also significantly reduces the breakage of expensive tungsten carbide anvils used to generate the pressure.

The first really adequate Tet-Press, precisely constructed, fully engineered, and incorporating Anvil Guide (U.S. Patent No. 3,182,353 May 11, 1965) was designed and built in 1965 with personal funds.

In 1966, I designed and built, again with my own funds, the first Cubic Press (U.S. Patent No. 3,159,876) which also incorporated the anvil guide. Finally, after 11 years, I had HP/HT equipment that could compete with my Belt, which, of course, General Electric owned all the rights to. By coincidence, this was the year that Bill J. Pope and M. Duane Horton, both professors of Chemical Engineering at Brigham Young University (BYU) sought a business opportunity to go into the diamond synthesis market with me.

I was basically dedicated to fundamental research, and ultimately authored or co-authored about 100 publications for the professional scientific journals and inspired many others at BYU to also work in this field and publish.

However, I was not insensitive to the commercial possibilities and their monetary rewards for myself and BYU. At this writing I hold about 20 U.S. Patents and 60 corresponding foreign patents. BYU received royalties on some of these patents through an arrangement with Research Corporation.

I had also established three businesses relating to High Pressure/High Temperature (HP/HT) before Mega was founded. The first was "H. Tracy Hall, Consulting Scientist and Engineer" begun in 1957. The business originally consisted of lecturing about how I came to make diamond, and ideas and theories concerning chemistry at HP/HT that I had formulated. Later it expanded into design and construction of HP/HT equipment. In 1961, I organized a second business, together with my two sons, Tracy Jr. and David. It was named Provo Pressure Products Co. (3P Co.). In accordance with its name, this business would manufacture diamonds or some other HP/HT products according to many of the ideas in my scientific notebooks.

The consulting and lecturing business ended in 1965 at which time press design and construction, which was much more profitable, became the principle business of H. Tracy Hall, Consulting Scientist and Engineer. This continued as a proprietorship until 1972 when it was incorporated in the state of Utah under the name of H. Tracy Hall, Inc. The Hall family owns all of the stock in this company and to manufacture High Pressure/High Temperature equipment, and conducts research in diamond technology until this day.

As previously indicated, Bill J. Pope and M. Duane Horton sought a business opportunity in the field of industrial diamond manufacturing from me in 1966. The date of our first meeting concerning this occurred on February first. Interestingly, I had previously been approached by a number of individuals and companies, including DeBeers, and had always turned them down.

Further discussion led to the verbal agreement that I would give up 3PCo and would bring my technology, know-how, inventions, etc. to a new business that Tracy, Bill and Duane would form to exploit diamond-manufacturing opportunities. However, I would retain my business in HP/HT equipment. Furthermore, the newly formed company (Mega) would be excluded from manufacturing HP/HT equipment.

I did not want the burden of managing the new company but Bill and Duane wanted me to be president in order to use my name and international reputation to further the company's interests. Therefore, it was verbally agreed that I would have the title but Bill and Duane would manage the company's affairs. Duane and Bill were designated vice presidents. Within a short time, Bill became the executive vice president and Duane became the vice president and secretary-treasurer. The company was formally incorporated as "Mega Pressure Products and Research Corporation" (MPPR) on April 6, 1966. The company was started on a shoestring. We each put in $20,000 for a total of $60,000 to begin this venture. Previous parties who wanted to go into business with me had up to $1,000,000 to invest.

On March 1, 1966, we each started recording the time spent on the company's interests with the intent to pay ourselves a salary for this time when the company could afford it. However, the company never could afford it, so we all "wrote off" the approximately 2000 hours that each of us had accumulated over a period of more than four years.

On December 3, 1966, I invented a Nickel/Manganese catalyst for converting graphite into non-magnetic diamond grit. Diamond grit was the only kind of diamond product being produced by GE and DeBeers at this time and their diamond grit was magnetic. I thought that this difference might enable Mega to proceed with its manufacture and sale without running into infringement problems with GE. Additionally, the fact that GE was using the Belt while Mega would be using the 1200-ton Cubic Press that I was designing might help. I gave the Ni/Mn invention to Mega free of any royalty or other payment. Mega did not have the financial resources to file for patents, so the invention was kept as a trade secret.

Prior to Mega's acquiring a press of its own, I loaned my personal 200-ton Cubic Press to the company. After the 1200-ton press I designed was delivered late in 1967, manufacturing procedures required to make the nonmagnetic diamond grit in quantity were developed and it became Mega's first product. Sale of the Ni/Mn product proved to be profitable and is still manufactured to this day.

We constantly worried about GE claiming infringement. Mega was not in any position to face a legal battle, so in January of 1968 we decided to ask GE for a license to make grit. The request was refused so we worried even more. Mega desperately needed a new product that GE and DeBeers did not have that was distinctly different from diamond grit.

I undoubtedly invented the concept of sintered diamond (now called polycrystalline diamond or PCD) and proposed the use of the "catalyst metals" as well as silicon to sinter diamond powder, produce larger diamond crystals, or to make a carbonado-type product. However, lack of facilities, equipment, and money, as well as intimidation by GE and by the U.S. Government Secrecy Orders on my inventions, as previously reported, made it impossible for me to follow through on my ideas at that time.

I experimented, sporadically, with my sintered diamond concept through the intervening years and on May 7, 1968 began a concerted effort to develop a marketable product.

By April 1969, I felt that I had sintered diamond products suitable to sell. I had tested them in various ways and also had them tested for wear resistance by a diamond cutter in Los Angeles named Henri R. De Pue. He told me that they were the hardest, longest wearing substances he had ever encountered and that testing them was ruining his scaife.

I had developed these new products at my own expense and own resources, which included using my 200-ton Cubic Press. At this juncture, I offered a new business opportunity to Mega; namely the opportunity to be the first in the world to manufacture and sell a very promising new diamond product. Bill and Duane eagerly accepted.

It is important to note that the only product being manufactured and sold at this time by GE and DeBeers was diamond grit. No one was manufacturing or selling Polycrystalline Diamond (PCD). Mega was the first!

I sold this new business opportunity to Mega on April 11, 1969 in exchange for a 2% royalty to be paid on all the sintered diamond products that Mega would sell in the future. Mega now had a product to sell that GE did not have! By the end of the year, Mega had made and sold $1602 worth of sintered diamond, a small but prescient look into the company's future. Mega sold more than $10 million worth of PCD material in 1987.

Word of Mega's new product spread rapidly and created a great deal of interest. On September 24, 1970 Mega held a formal press conference at its office and plant, 275 West 2230 North, Provo, Utah. The news was published around the world. Dr. Harvey Fletcher, former Director of Research of the Bell Telephone Laboratory called the achievement "one of far reaching significance." Utah's governor, Calvin L. Rampton, issued the following statement: "The creation of a multi-carat diamond by man is, without question, a technological breakthrough of the highest order. We are justly proud that this event has been achieved in Utah…Utah salutes Dr. Tracy Hall and the Megadiamond Corporation." GE, no doubt, spurred on by Mega's success, worked overtime to get into this new business. GE finally entered the market in 1972, about three years after Mega.

It is worth noting, before passing on that General Electric never challenged the manufacture of the Ni/Mn catalyst diamond grit as infringing any of their patents. The three of us, in retrospect, should not have worried so much.

Smith International Incorporated (SII) acquired Mega on February 12, 1985 and changed its name to SII Megadiamond or Smith-Megadiamond as previously indicated.

With this bit of historical background behind us, let's turn to the subject of High Pressure/High Temperature equipment suitable for the production of diamond. My Belt (U.S. Patent No. 2, 941,248 June 21, 1960) is perfectly satisfactory for the mass production of industrial diamond products. However, my Cubic Press is better.

In the production of grit or PCD's, the pressure-temperature-time cycle is important. Perhaps the most critical factor is the falling off of pressure with time due primarily to the transformation of pyrophyllite to coesite and the transformation of graphite into diamond. Coesite and diamond both occupy more volume than their precursors. Consequently, the pressing members of the Belt and the Cubic Press must provide some type of follow-through to maintain the desired pressure. In the Belt, only two members are pressing forward to maintain the pressure. In the Cubic Press, there are six anvils pressing forward to maintain the pressure. Consequently, experience indicated what one might expect, the Cubic Press is four times as effective at maintaining or increasing pressure, as is the Belt. The great importance of this shows up in the dwell-time or soaking time required to make the desired product. In United States patent practice, the patent must indicate the preferred embodiment (the optimum conditions—pressure, temperature, time, etc.—to make the best product). GE's primary patent for making PCD's gives an optimum time of 60 minutes for the dwell time. This long time is required to let the pyrophyllite and other ingredients make the proper mechanical adjustments in the pyrophyllite, and other cell ingredients to maintain uniform pressure throughout the material being pressurized. In the cubic press, a dwell time of only three minutes is required for the dwell time in making PCD's. This is because of the fast pressure follow-through created by the six moving anvils that quickly reduces pressure gradients within the cell.

In connection with pressure follow-through and adjustment, the use of a salt (NaCl) liner inside of the pyrophyllite cell helps reduce pressure gradients within the cell. The use of NaCl is absolutely necessary for the Belt but it also improves the effectiveness of the Cubic Press.

Pyrophyllite cells give off various undesirable substances during the process of making diamond from graphite or in making PCD’s. Also, graphite itself is a harbinger of various gases absorbed from the air. In the case of converting very fine diamond powders into PCD’s, the diamond powders used have previously absorbed various gases from the air or have acquired impurities in the wet methods employed for their size classifications. All of these impurities degrade the quality of the products. Consequently, “getters” of very reactive metals such as thin sheets of zirconium and titanium are placed within the salt liners to react and remove deleterious products from the cell environment.

All of the PCD”s manufactured by GE and DeBeers have flat surfaces, i.e. the thin diamond surface is bonded to a flat surface of tungsten carbide. Only Smith Megadiamond makes PCD’s with curved surfaces. The attached brochure entitled “Megadiamond The Competitive Edge” shows some of the conical, spherical, and saddle-shaped tools that have been manufactured. On of my son’s, David, is indicated as the person to telephone for more information. None of the Hall’s, Tracy Sr., Tracy Jr., or David, are associated with SII Megadiamond at this time.

David R. Hall is now the president and chief executive officer of Novatek, 85 West Center Street, Suite 100, Provo, Utah 84601 (801) 374-6000. David was formerly Vice President of Mega and the prime mover in the invention and development of enhanced diamond products (multi-layered surfaces) and in the development of diamond bits that can withstand impact. Also attached to this report is an article reprinted from Design News of January 5, 1987 that shows the efficiency of diamond hammer bits in rock drilling. Note that the diamond drilling bits drilled six times the footage of carbide bits. Smith-Mega currently manufactures such bits up to 12 inches in diameter. David’s new company is engaged in the development of advanced, computer controlled drilling equipment that can effectively utilize the advanced diamond technology that is now available.

Tracy Jr. is a private inventor, currently working on the design of very large-scale high-pressure machines. His office is in Orem, Utah, a city that adjoins Provo on the north.

The phenomenal performance of enhanced PCD’s has opened many new avenues for their use. Diamond need no longer be considered a specialty material. It is relatively cheap in light of its dramatic properties. It is finding use in bearings of all types to operate in a very gritty, dirty environment. The use of down-hole motors for rock drilling that utilize diamond thrust bearings are a significant new development and have become a major money maker for Smith-Mega. Attention is now being given to the use of PCD in clutches and brakes, possibly for automotive use.

Possibly, the most significant use of diamond for the near future is the drilling of very deep holes to tap the thermal energy of the earth. When holes drilled into the earth become deep, a major expense of the drilling is pulling up the string of pipe to which the drill bit is attached in order to replace the worn out bit. Hammer bits drill faster and as shown in the attached Design News reprint, drill six times the footage of carbide. Hot, dry rock is everywhere below the surface at depths that could probably be economically drilled in the not to distant future to provide absolutely environmentally safe energy to everyone upon the face of this earth.