NATURAL DIAMONDS

FROM MINES TO MACHINES

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INTRODUCTION

Good afternoon. My name is Steve Roffman. It is an honor to have been invited here to give this presentation concerning the world of natural industrial diamonds. For more than twenty-five years, my profession has given me the opportunity to touch practically every phase of the diamond industry, thereby attaining a comprehensive understanding of the diamond world. My primary focus of responsibility is the procurement, management and marketing of natural industrial diamond to the world's diamond tool industry. Natural diamonds continue to play a critical role in the world superabrasive industry because they have special characteristics that give a competitive edge to those with the knowledge, skill and insight to use them properly. My mission this morning is to provide some understanding of the world of diamonds with particular emphasis on natural diamonds as used in industry.

In the early part of the 20th century during the height of the industrial revolution, mass production brought about the need for abrasive

products and tooling, which could outperform and out-last any conventional abrasives. Natural diamonds, the hardest material on earth, quickly became the best abrasive product available. Moreover, as this was before synthetic diamonds were invented, there were no other options. Diamonds were used to create better, more competitive, high precision products. Some diamond dealers began to specialize as suppliers of industrial diamonds. Governments were building stockpiles of diamonds for their national defense.

The world recognized diamonds as key in achieving production levels that surpassed conventional abrasives or tooling. From coarse grinding to final finish, natural diamond mesh and microns produced new levels of productivity and precision. From wire drawing, to dressing grinding wheels to drilling for natural resources, diamonds were required to get the job done quickly and efficiently. It is said that by the 1950's, no product was manufactured or mined without in some way being touched by natural industrial diamonds. Today, natural industrial diamonds are a powerful tool used as the material of choice for a variety of manufacturing and finishing applications.

In order to understand the world diamond situation and how it relates to the superabrasive industry, we should look at the bigger picture of the diamond business. We begin with the basics of mining and production of rough diamonds, review methods of categorization, evaluation and distribution, and finally, discuss the natural industrial diamond business and the affect of the diamond market upon the supply of diamonds needed for today's superabrasive industry.

We will examine the diamond tool market as well as market trends for the future.

WHY
DIAMONDS

Diamonds have always been associated with strength and prosperity. We can find mention of diamonds in various historical writings of the East and the West, with reference both to their value as gemstones and to their use in simple tools, as diamonds were found to be the hardest material existing on earth. Diamonds were quite rare and mostly found in very isolated areas. The mystique and myths surrounding diamonds and their discovery were closely related to people who had the fortunes needed to finance the search for diamonds. These stories were rife with rumors of glory as well as tragedy. Diamonds became symbols of strength and invincibility and were used to ward off illness and nightmares. Kings, queens, and nobility from around the world placed staggering wealth in caches of unique diamonds. *The Hope Diamond, The Star of India, The British Crown Jewels,* are all diamonds with historical prominence. Jewels such as these can be found in the great museums of the world. Men, women and children from all walks of life continue to visit these exhibitions in great numbers.

As the diamond trade evolved and production levels increased, diamonds became more affordable and available to a greater circle of society. They became a symbol of social status as well as becoming synonymous with romance, love and commitment. Today, those who find the allure and the beauty of diamonds irresistible buy more than 50 billion dollars of diamond jewelry annually. To meet these demands, exploration, mining and recovery of diamonds has become a significant industry. While the focus of diamond mining is on the gem industry, every size and quality of diamond is collected during the recovery process. About 65% of these diamonds, by weight, are destined for industry. About 80 million carats of natural diamonds are used each year in tools for every conceivable superabrasive application; and this ladies and gentlemen, is the theme of our discussion today.

EXPLORATION AND MINING

The first step in bringing diamonds to market is finding them. The process of locating diamond-bearing ore is both time consuming and costly. Historically, it was also dangerous. Adventure and perseverance combined with luck and courage were necessary attributes that enabled certain individuals to arrive at unique situations and places that most people clearly would avoid, even knowing the outcome could bring them vast fortunes. Today, with the advent of satellites and airplanes, the search for and discovery of diamondiferous areas has become more a function of technology rather than adventure. Areas containing diamond are identified by a rock formation known as kimberlite, a bluish rock that exists in pipes leading from ancient volcanoes. These pipes have been found throughout the world, in Africa, Canada, South America, Russia, and Australia. Several million years ago, formations of carbon deposits were exposed to intense heat and pressure in the bowels of the earth, causing the carbon to crystallize into diamond. This ore, or kimberlite, was carried up from deep below the earth's surface by volcanic eruptions. In certain places, the pipes emptied part of the kimberlite onto the earth's surface; in other places, rivers may have washed portions of the ore out of the pipes into riverbeds that eventually emptied into the ocean. The ore mined from kimberlite pipes plus surface findings known as alluvial deposits, as well as the runoff of diamonds down rivers and into oceans, are where the world's supply of rough diamonds comes from.

Once a diamond area has been identified, the diamond content and approximate average dollar value is evaluated to determine if mining that particular area will be commercially viable, as diamond recovery is very costly. Approximately 20 million pounds of earth must be mined, screened and processed to recover one pound of diamond. In mining the oceans, either dams are erected so the sand can be sifted and moved to find these precious stones, or boats equipped with dredging machinery sift through the ocean floor. Whether it is open pit mining or

digging deep into the earth, the requirements of organization and technology call for great commitment to the projects. Finally, after all the calculations are done, and the machinery is brought in, production begins; hopefully, the end result will justify the expense and efforts involved. The yield of diamonds and its market value must bring a return to those who successfully manage and market the productions in which they have invested.

The companies that control any particular mine determine the channel those diamonds take to market. DeBeers is the leading diamond mining and marketing group in the world. There are, of course, other producers who market diamonds and help maintain supplies and balance. As an example, Australia's Argyle Diamond Company is one of the world's leading diamond companies. Diamonds mined and marketed in Australia have a strong presence in the world market. This particular production contains predominantly lower quality brown diamonds, but also contains whites, yellows and an unusual range of pink stones. The 1999 production from the Argyle mine appears to be in the neighborhood of 25 million carats. Our understanding is that the mine peaked at 40 million carats in 1998. As with all natural resources, yields tend to decline with time and further evaluations must be made to determine if production can be maintained and/or increased through additional investment at an economically viable level. This may entail the sinking of a shaft to convert from open pit to underground mining.

Another new diamond producing area is here in Canada. After many years of exploratory work, a new area is being developed. There are new hats and old hands searching, evaluating, building, financing and mining. In 1999, over 400 million US Dollars of rough diamonds were recovered and sold. Large mining groups such as DeBeers and BHP are leading the way in developing this expanding new source of diamonds.

CATEGORIZATION, EVALUATION AND DISTRIBUTION

As we noted, there are approximately 125 million carats of diamonds mined per year. This amount has increased by about 25% over the past 10 years. Most of this production goes through the marketing channel of DeBeers. Recently, several producers have been marketing directly to diamond centers.

We discussed the Australian production earlier. The major market for the Australian production is the Indian polishing market. India has a substantial cutting center in the cities of Bombay and Surat. Large and small firms are able to capitalize on the low cost of labor to produce polished diamonds at affordable prices. These diamonds are used in inexpensive jewelry sold throughout the world. It should be noted that, although India is a low cost labor center, the industry has evolved with modern factories, good working conditions and fair labor practices. This industry employs about 800,000 people making it an essential industry within India's manufacturing community.

Regardless of which way diamonds move to market, they go through a standardized process of cleaning and evaluation. They are first cleaned, sized and categorized into very broad ranges. Then, the producers evaluated them based on current market conditions. The country of origin normally does an independent evaluation to ensure that it receives fair value for its' resource. If the producing company does not market the production directly, they may sell the production through tender offers to some of the worlds leading diamond firms or they may have contracts with DeBeers for part or all of their production. If they do, these diamonds will be evaluated in the country of origin and exported to DeBeers' Central Selling Organization in London. There, they are categorized and stratified into homogeneous packets which are offered for sale on a five week cycle. Local dealers then further categorize the diamonds into smaller parcels.

We turn our attention now to industrial stones, which is our particular and greater interest. The primary responsibility of the industrial dealer

is to be a reliable supplier of classified material for specific tools. It is his job to produce these materials in a consistent and orderly manner, which can be repeated time and time again -- clearly a manufacturing operation. Industrial diamond dealers are committed to buy, categorize and inventory these industrial diamonds. When diamond tool manufacturers and end-users design products, they must be confident that the industrial dealers will support their requirements and can economically produce the raw materials required. As a group, the dealers in natural industrial diamonds have a keen sense of social responsibility to the manufacturing community. They take this responsibility seriously.

As with synthetic diamonds, PCD, and other superabrasive materials, natural diamond is a relevant and viable product. There are many instances wherein natural diamond is not only the preferred product, but also the only product to use. For reasons ranging from higher productivity to acquiring the best finish, from tools that allow the greatest repeatable tolerances, to tools that hold up under the most difficult working conditions, natural diamond is the choice.

Another aspect of natural industrial diamonds is the availability of a wide array of sizes, shapes and qualities. This gives great economic flexibility to the tool fabricator or designer in offering the end-user a suitable product for virtually any superabrasive application. The ability to design a product that can meet varied price levels, allows the end-user to obtain tools that produce the best cost/productivity ratios possible. Behind all this lies the need for continuity of supply. This is the province and responsibility of competent and well financed industrial dealers.

NATURAL DIAMOND TOOLS AND MARKETS

We have reviewed how diamonds are mined and brought to market.Let us look at the tools and the various applications to see why this market needs a revitalized image. We all know that the producers and distributors of synthetic diamonds have promoted their products vigorously, part of which includes end-user education. This has overshadowed the market for natural diamonds during the past 25 years. Still, if we examine the tool industry, it becomes self evident that natural diamonds remain the product of choice for many applications. Let us look at the various tools and uses where natural diamonds continue to play a dominant role in today's industries.

I. Diamond Dressing Tools

Natural Diamonds are the most effective and efficient material for the dressing of conventional grinding wheels. This is primarily true because of the formation of natural diamond and the vast range of qualities available. Firstly, the shape…the octahedron and dodecahedral structure with closed edges which come together to form the strong points required for single point dressing applications cannot be substituted competitively. Additionally, each diamond, because of its natural geometry, can have as many as six usable points. Users can opt for a range of tools from single use tools, with a stone having only one useable point, to tools with stones which can be re-set to use all 6 of the available points. The fact that it is a single crystal adds to the diamonds structural integrity, giving continuous dressing action while maintaining strength throughout its life. By choosing the correct size, quality, and number of settable points, the

end user will be able to dress the wheels properly and obtain the best productivity at the lowest cost.

We can look at a few examples that will illustrate how the application dictates which type of diamond should be used. For dressing thread grinders, very sharp points and angles are required to enter the narrow grooves on the wheel; clearly, the design of the tool calls for octahedral or even sharper crystal type diamonds. This gives the operator the ability to dress very sharp angles. For high production situations, the design will call for a high quality stone that will hold up under repetitive use. For lower levels of productions, the user may save on cost by using an appropriately chosen, lower priced stone.

For wheels made of materials tougher than standard abrasives, such as the ceramic wheels used in some very tough applications, a dodecahedral shaped diamond offers great strength and durability. There is more material surrounding the point of a dodecahedral than the point of an octahedral, consequently reducing the wear rates. The experienced diamond tool manufacturer understands the need for a stone with significant durability and designs the tool based upon this criterion. The number of usable points as well as the overall quality of the stone will be a function of the expected workload.

There are other types of dressing tools that use multiple stone configurations to obtain the advantage of natural diamond in dressing applications. Elongated materials can be set up in various configurations for specialized blade tools. Lower priced diamonds may be used in various types of "cluster tools", even lower priced Congo cubes and rounds as well as other low range materials are in demand for inexpensive "throw away" type tooling.

All of this shows that there is great flexibility in natural diamond dressing tools, from the standpoint of performance as well as cost. For dressing applications, natural diamond has the characteristics that make it the preferred material.

II. Form Tools For Truing and Dressing Applications

Although Polycrystalline diamonds as well as single crystal synthetics have impacted this market, natural diamond remains a prominent player.

The tool designer who works with natural diamonds has a great variety of formation, size and quality of natural diamonds from which to choose. Let us look at the various natural formations available:

 Triangles (Window and Pillow Type)

 Long Stones (Flat and Full Bodied)

 Egg Shapes (Flat and Full Bodied)

 Round Shapes

 Octahedron Shapes

 Flat Shapes (Varying thickness)

Form dressers are designed for truing and dressing formed grinding wheels. The tolerances of the tool are critical to obtain good manufacturing processes. Ultra fine, clean diamonds are selected and polished by skilled diamond cutters to precise tolerances for the most critical applications.

Medium quality diamonds may be chosen and cut to acceptable tolerances when the design calls for less stringent specifications yet requiring a tool that stands up under high production conditions. Lower quality diamonds are called for in the design of typical, utility type tools. In these situations, cost of the stone may be the over riding factor; however, the requirements of a superabrasive tool can still be met with a quality product when the diamond form, size and quality are correctly matched to the application.

III. Shape Tools for Cutting Applications

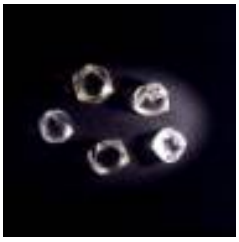
This area of application is clearly the one which has been most affected by man made products and other new technologies. The effect has been positive in that the availability of many types of superabrasive products has broadened the field of usage and expanded the overall superabrasive cutting tool market throughout the world.

PCD, PCBN, Single Crystal Synthetics and CVD products all have proven effective in many new as well as traditional areas for cutting tool applications. Nonetheless, manufacturers and users still find a broad range of applications where natural diamond is the optimum product. The finished cutting edges of PCD, PCBN and CVD products are inherently limited by the fact that they are multi particle products. CVD products have, so far, also been limited in their maximum thickness as well as limited by problems with adherence to the substrate.

Both natural diamonds and single crystal synthetics are used where high magnification, chip free cutting edges are required. Yet, the use of single crystal synthetics may sometimes be questionable, as many end users have determined that tool life may be inconsistent and that natural diamond, under similar conditions, will outperform single crystal synthetics. The available range of quality, size, shape, thickness and other characteristics found in natural diamonds gives great flexibility and choice to the end user and the tool designer. The "one quality, one price" of synthetics tends to limit the end users choice.

Again, we see that in many applications, natural diamond is the product of choice.

IV. Diamond Dies for Wire Drawing



In every conceivable application from electronics to construction, wiredrawing dies are the essential tools used to produce the billions of miles of wire drawn throughout the world. For applications of drawing non-ferrous metals, which require ultra fine finishes, diamonds are used as the cutting, or drawing material. In particular, in today's high tech world, ultra fine wires are required in enormous quantities and the demand for diamond dies has exceeded the expectations of many.

In fact, it was believed that the advent of PCD and single crystal synthetics would eliminate the demand for natural diamond. Although single crystal synthetics have been on the market for a few years now, and have entered some niche markets, producers, end users and suppliers continue to have strong demand for natural diamond dies. PCD has helped to expand the market for diamond dies replacing carbide dies for larger sizes and improving productivity dramatically. The continuing demand for natural diamond stones can be directly related to better performance from naturals plus the great flexibility in pricing and sizing that naturals provide. For obtaining high finish and for drawing fine sizes, natural diamond continues to be the material of choice offering the highest quality with the greatest productivity.

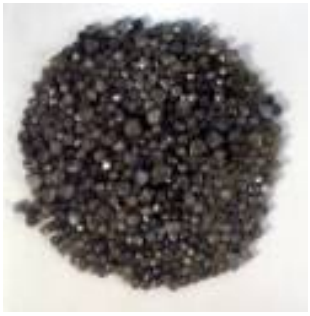
In some cases where PCD had made great in-roads, particularly for larger size dies, natural diamonds have made a comeback. In certain applications, some materials present in PCD have caused problems during the wire drawing process. One example of this is "sparking", which can cause the lubricants to ignite. This of course translates into down time and losses. The purity of natural diamond and its single crystal structure are the important characteristics allowing it to work unhindered in these applications. The revival of demand for larger size natural die-stones is effectively the result of definitive problems that arose in the use of alternative products.

For the making of natural diamond dies, the wire die manufacturer selects a high quality diamond, flattens both sides with parallel faces, sets the stone in a hard metal blank, drills through and polishes the center of the stone creating the critical form and tolerances required by

the wire manufacturer. Of course, this is a serious over simplification of a complex and critical process. With natural diamond dies, the producer will design the tool based on the size and type of wire to be finished, enabling them to determine the dimensions of the stone required. The diamond must be clean and uniform. Other characteristics will be taken into account when the toolmaker is selecting the appropriate diamond. This is individual to the company's process and adds flexibility of price according to the specifications of the application. With this, the die maker can be highly competitive, tailoring products to meet the demands of their customers. In turn, this enables the wire producer to meet the needs of industry at the most cost-effective levels while ensuring high quality products.

We are confident that, for the wire die industry, natural diamond dies are well suited to meet industry demands and will continue as an essential superabrasive material for many years to come.

V. Diamond Drill Bits



Diamond drill bits are used in mineral and oil exploration, mining, and construction. They are an excellent example of products that achieve results possible only with superabrasives.

Whether searching for minerals and metals, or, tapping the great oil reserves of the world, diamond bits are used to drill through the rugged earth efficiently, reducing expensive downtime for drill rigs. In the construction industry, where repetitive drilling of hard materials is commonplace, diamond drill bits are normally used. Prior to the early 1980's, natural diamond stones were used in surface set bits for exploration and mining. These bits are made by hand setting select diamonds in a mold, which is then filled with powdered metal and heated to form the diamond bit. The bits are then used, and a process

started which involves reclaiming the natural diamond from used bits, resetting the usable stones, and returning the bit to the user. The entire process, from hand setting to reclaiming used bits, to the bookkeeping for diamond reclamation, is an expensive process. Consequently, most hand set bits were replaced with either PCD blanks or bits made with either natural or synthetic mesh.

This is clearly an area where the usage of natural diamonds has been heavily affected; however, natural diamonds continue to be used, although at a lower level of consumption and price than in the days before alternative products were available. The availability of inexpensive natural diamonds allows bit manufacturers to exploit the potential of naturals by using naturals exclusively or mixed with synthetic products. Thus, manufacturers can produce bits that increase the efficiency of the drilling process.

In exploration and mining, the drilling conditions determine whether whole natural stones or processed diamonds are used. In construction, impregnated bits are made utilizing natural as well as synthetic mesh.

For the drill industry as a whole, the use of natural industrial diamond continues to be important in achieving maximum productivity levels.

VI. Grinding Wheels, Rotary Dressers, Impregnated Tools

This group of tools is used in many types of engineering applications. Natural diamond is often the raw material of choice when manufacturing various types of impregnated tooling used in dresser applications. The strength of the natural crystal and the cutting and friability properties of natural diamond, provide the best characteristics in many of these applications. Consequently, in manufacturing rotary dressers, natural diamonds, both processed and unprocessed, are the main material used. Where additional strength is required, such as in critical sections of the rotary dresser, natural diamond crystals are used to give added strength to the wheels.

Natural diamond powders are used to obtain ultra fine finishes and for fine grinding. The producers of these natural materials process, crush, categorize and size each product into the many grades, which are used in today's superabrasive industry.

VII. Specialized Applications

Diamonds are intrinsic to the manufacture of certain types of high precision tools and knives. The single crystal continuous structure, combined with the purity, stability, strength and integrity of natural diamond provides the best possible choice of material for use in new and evolving technology. Diamond knives are used in surgical procedures and for slicing and sampling of various materials, including human tissue. Diamond nozzles are used in water jets for specialized cutting applications. In high-tech industries such as the manufacture of fiber optic lines as well as certain precise etching applications, no other material has the repeatable characteristics of natural diamonds. Heat sinks, specialized diamond windows, guides, hardness testers, and ultra precision cutting tools are but a few more of the specialized applications where natural diamonds excel. If more attention and thought is applied to this field, surely tool manufacturers will be able to extend and increase the range of tools made with natural diamonds.

Natural diamond is a modern product for building the future.

CONCLUSION

As we look around us here in Vancouver, we see that the superabrasive industry is alive and vibrant. From our preceding discussion, we know that the role of natural diamond in today's superabrasive industry is also alive and vibrant. The supply of naturals is consistent and sure, and prepared by dedicated and professional suppliers who give the tool manufacturers and end users the confidence required when they opt for natural diamond.

We know from our own experience of more than 70 years, that natural industrial diamond is a wonderful material, providing cost effective and efficient products for many applications, both standard and high-tech. We are confident this will be so for many years to come as the manufacturing community continues to search for economical tooling with which to maximize its capabilities while improving the bottom line. The development of new products and the enhancement of older products are up to you, the leaders in tool manufacturing and designing.

It is up to us - the purveyors of natural industrial stones backed by the diamond mining community- to ensure the continuity of supply as we have done for so many years. We must increase users' awareness of the possibilities and advantages inherent in using natural diamonds. We can do this through education and through improving the performance and variety of tooling available.

Natural diamond products in the new millennium must and can increase productivity while decreasing cost.

Thank you for your time and attention.

COMPARISON OF	**NATURAL**	**SYNTHETIC MONOCRYSTAL**	**PCD**
PRODUCT TYPE	SINGLE CRYSTAL	SINGLE CRYSTAL	MULTI CRYSTAL
AVAILABLE SIZES	FULL RANGE	LIMITED	FULL RANGE
AVAILABLE QUALITIES	FULL RANGE	LIMITED OPTIONS	SPECIFIC GRADES
AVAILABLE PRICES	FULL RANGE	LIMITED OPTIONS	LIMITED OPTIONS
CUSTOMIZATION	HIGHLY FLEXIBLE	LIMITED FLEXIBILITY	VARIES BY PRODUCT
STABILITY OF SUPPLY	EXCELLENT	IMPROVING	EXCELLENT

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