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Administrative Problems in the Production of Diamond Dies

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Boston University
Administrative Problems in the Production of Diamond Dies

Respectfully submitted by Andre G. Chambre
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on March 1, 1960.
This thesis was prepared under my supervision and approval is hereby indicated.

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Second Reader
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Introduction

Purpose and Scope of Thesis

Perhaps the strongest motivating force which prompted the author to undertake this study was the widespread ignorance and lack of information concerning the subject on the part of business men and people in general. This situation appears extremely unfortunate in view of the paramount importance and necessity of the product not only for the manufacture of wire but also indirectly for the production of most any article whether it be a simple household good such as a light bulb or a complicated military weapon of the inter-continental ballistic missile variety.

It is hoped that this thesis may serve as an aid to the diamond die producer in his day to day struggle for survival and also as an introduction and guide to those individuals who will in the future join the ranks of the industry. In order that these objectives may be realized, the study will strive to reveal and discuss a number of major administrative problem areas that are commonly found in die manufacturing enterprises. These problems have at times proven to be especially troublesome due to the traditional practice of having the leadership function performed by individuals who while being technically proficient are totally lacking of formalized training in scientific methods of management.
To be reckoned with in the writing of this work is the decided lack of information and data on a trade-wide basis. Although this does present a formidable obstacle, it is in the hope of contributing to the removal of this barrier that the study has gained additional incentive. In subsequent chapters reference will be made wherever possible to reliable sources; but due to the scarcity of these, reliance will also have to be made upon the author's own brief experience in this industry. It is felt that far from being a weakness, this in effect adds a special impact to the work by taking it out of the world of pure theoretical and academic research investigation and placing it into the arena of practical reality.

The thesis will use as its structural basis the very famous definition of 'management' by Henri Fayol as: "the function of planning, organizing, commanding, co-ordinating, and controlling." The administrative problems to be discussed are classified under these major managerial activities somewhat arbitrarily but for the specific purpose of introducing order into the text and thereby make possible a logical presentation of related material. The point of departure is an attempt to establish a sales forecast with due consideration given to the factors which affect consumer demand. The problem of distribution to fulfill customer needs is then studied together with an analysis of the controversial import.
A shift in emphasis is made to production and the combination of men, materials, and machines into a working unit. The manufacturing processes are outlined and brought up to date by the mention of revolutionary new methods and techniques. At this juncture consideration is given to service requirements that the die manufacturer must be prepared to meet. The lack of industry wide standards makes the subsequent discussion on quality control especially pertinent. Since costs are vital to the successful business enterprise, a section has been included on reclamation of diamond powder and salvage of die stones. The matter of inventory control and valuation is then taken up with special attention given to the difficulties of maintaining an adequate stock-on-hand. The concluding chapter attempts to tie in the divided parts of the study into a unified whole by means of a general summary and the incorporation of several carefully selected cases and personal experiences.

It might be well to state at this point that the word thesis as used in this text is not to be construed in the popular sense of establishing and proving a particular hypothesis. The purpose here is rather to discuss a number of managerial problems and consider their full meaning and significance. Although in this instance these problems are applied to a specific industry it is well to keep in mind that they do have a correlation to many other business situations.
Definition and Description of the Subject

The most common reaction on the part of the average layman to the mention of the words wire-drawing diamond dies is a questioning gaze accompanied by the query: "What are they?". In all justice it must be admitted that this observation should not be totally unexpected. Diamond dies belong to a group of industrial goods which traditionally have had little publicity or glamor associated with them. Furthermore, the use of the word 'die' has been employed to identify so many and varied manufacturing tools that when used by itself it seldom transmits a clear and precise meaning. That is perhaps why one ordinarily finds the word preceded by a descriptive adjective such as blanking, stamping, extruding, or the like.

A wire-drawing die is a tool employed in the manufacture of wire whereby a metal is constricted and shaped to desired specifications by being pulled through a carefully drilled hole in a blank whose substance is harder than the metal being drawn. The most common types of material used to make wire-drawing dies are carbide and diamond although quartz, steel, ruby and sapphire have also been used.

Ideally, the harder the die composition the better it is from a wear resistance point of view. One method of determining the relative hardness of materials is by comparing

*See Appendix I.
The effects that various grinding abrasives have on them.

In the following table the abrasive action of diamond on some of the major types of material that have been used for dies has been fixed at one hundred.

Table I.

<table>
<thead>
<tr>
<th>Abrasive Material</th>
<th>Diamond Die</th>
<th>Hard Metal Die</th>
<th>Ruby Die</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond Grain</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Boron Carbide</td>
<td>0.5(0.6)</td>
<td>60</td>
<td>66</td>
</tr>
<tr>
<td>Crystallized Boron</td>
<td>0.5(0.2)</td>
<td>48</td>
<td>---</td>
</tr>
<tr>
<td>Silicon Carbide</td>
<td>0.5</td>
<td>22</td>
<td>17</td>
</tr>
<tr>
<td>Aluminium Oxide</td>
<td>---</td>
<td>4</td>
<td>---</td>
</tr>
</tbody>
</table>


The ideal wire-drawing die, a diamond die, is manufactured according to rigid specifications and the drilling consists of a number of shapes or parts. The bell or primary cone is located at the entering side of the die. It consists of a wide flaring of the die hole in conical fashion. Its purpose is to guide the metal into the die while at the same time permitting the lubricant in the die boxes of the wire drawing machines to be allowed into the die hole. That portion of the die referred to as the reduction or secondary cone is immediately adjacent to the bell. It is in this area that the cross section of the metal is reduced to its desired size. This is accomplished by means of constriction and elongation rather than cutting or trimming. The bearing of the die is located adjacent to
the reduction. Its function is to maintain the size of the die hole. The relief consists of a slight countersink to eliminate the sharp right angle that would otherwise be present at the exit end of the bearing. The back cone insures the free and uninterrupted release of the drawn wire.

Figure I

Magnified (x125) Photograph of a Diamond Die

Source: Taken by author through an American Optical Microscope with Polaroid Camera Attachment.
Origin and Development of Diamond Dies

The first wire-drawing dies are believed to have been used about 1400 A.D. There is little factual data in the archives of history on this subject which perhaps is an indication that their coming into being was gradual and evolutionary. Early accounts, however, do make mention of "a piece of iron two or three fingers wide, rather thinner, pierced with two or more rows of holes." Other than this, descriptions and information are practically non-existant.

It was with the introduction of water and steam power in wire drawing that the die came into its own as an essential and intrical part of manufacturing. As the demand for wire increased and power became more generally employed, the need for durable and standardized dies became pressing. For this purpose chilled iron and steel dies were developed and improved. These were somewhat limited because of their relative softness in comparison to the material drawn. It is significant to note, nonetheless, that the basic shape originated at about this period of history has not radically changed since then.

Dies using a harder and more resisting drawing element than chilled iron or steel alloys are known to have been used in Europe during the nineteenth century. There is evidence that sapphire and ruby dies entered into the production of gold braid for woven products. Apparently however, all but the most progressive wire manufacturers
shied away from the use of diamond because of its expensive nature.

With the passage of time there was a continual increase in the demand for harder wire and the speeds of drawing machinery accelerated greatly. These conditions made it imperative to employ diamond since it alone had the necessary hardness characteristics to produce economical long runs without frequent interruptions due to breakdowns and wear. In the late 1800’s and early 1900’s the majority of wire mill operators had become thoroughly convinced of the superiority of the diamond die and its use in wire manufacture was all but universal.

Its position remained unchallenged until about 1928 at which time was introduced the carbide die. Carbides became practically an overnight success principally because of their cheapness relative to diamond. It was common knowledge that they were not nearly as wear resistant but it was felt that the price differential more than made up for this deficiency. At present most wire mills use carbide dies for the drawing of larger size wire. However, it has not as yet been possible to drill carbides much under .004" and, therefore, diamond dies are relied upon almost exclusively for the drawing of small diameter wire.

It must not be inferred from the above that diamond dies are a thing of the past and that their day of oblivion is imminent. Rather the trend has constantly been towards
the use of progressively finer wire. The need for smaller diamond dies has been substantially increased in recent times by the many technological and electronic advances. In fact the demand has exceeded the capacity of the die producer who finds himself limited by his inability to drill holes finer than .0002". Wire under this size must be manufactured by lengthy and expensive laminating processes. Here then is a promising potential market whose eventual exploitation will depend upon further research and development by diamond technologists.
Chapter One
Planning - the Selling Function

Market Analysis

A fundamental business principle is that the selling function be given top priority. This issue not only from its close relationship to the realization of the basic profit motive but also because sales act as a kind of metronome in establishing and regulating the tempo or pace to be followed throughout the other operations of the enterprise. The ideal procedure is to calculate over-all market potential and from this derive a sales quota broken down into territorial units. The resultant serves as a goal to be attained and as a basis on which to figure production schedules and financial budgets. It also provides a measuring yard stick to be used in evaluating actual performance versus potential capacity. In view of the many advantages that this type of procedure has to offer one may rightly question why it is not employed by any of the diamond die producers.

The method of sales management most commonly found in the die trade can best be termed as very superficial and unscientific. Typically, the sales manager who is often also the general manager and principal salesman obtains or formulates a list of the total wire mills in the United States. An excellent such compilation is available annually from the publishers of Wire and Wire Products which contains the
names of the domestic wire mills, their geographic location, their product line, and identification of the principal buyers. From the master list the names of those mills which are known to be firmly committed to competition or who for some other reason do not qualify as potential customers are eliminated. A check mark is placed next to present customers and the remaining prospects are screened and evaluated on the basis of financial status, reputation, type of wire drawn and other such factors. For this purpose the sales manager will have recourse to data such as wire industry sales statistics, reliable publications of the Thomas Register and Moody's Industrials variety, information from present customers and competition, etc. In final analysis, however, the greatest weight in arriving at an appraisal is placed upon personal feeling and knowledge stemming from years of experience in the field. After arriving at a nucleus of prospective new business, a further judgment is made as to which names are worth the trouble and expense of visiting personally and which can be adequately solicited through letters and advertising.

It can be readily concluded that the above method does not produce accurate or even economical results. Many costly sales visits are made that do not produce tangible results. Conceivably, many other calls are not made that might prove very profitable. Furthermore, the lack of accurate forecasts render efficient production control impossible.
Scheduling must of necessity be done on an intermittent job order basis which causes re-occurring periods of slack and rush activity.

The above outlined method of sales management is, however, a practical alternative and in fact the only possible approach that can be taken under the circumstances. The establishment of a more precise market potential pre-supposes the availability of certain basic information. The direct data method, for instance, relies upon sales statistics of the entire market broken down into area percentages. The corollary data method is based upon the figures of products which parallel each other. In the multiple factors method the analyst selects a group of market potential indicators and combines them into one index series to measure the relative potential of a product.

The diamond die industry is notably devoid of the essential information needed for precise sales forecasting. The situation is further aggrieved by the fact that the diamond die is at least three and often four places removed from the ultimate consumer. Consequently, efforts to formulate a correlation to parallel products or general economic indexes are futile. Also the inadvisability of relying upon specific indicators as in the multiple factors method is borne out by the following statement:

It seems that the output per die varies greatly for the different wire producers. This may be due to
quality, mainly the shape of the die, and also polish, or to the more or less perfected method of drawing. Speed, lubricant, etc. are influencing factors.

Before passing on to other considerations it does not seem inappropriate to suggest that improvement and refinement in market analysis is attainable. The diamond die manufacturers have available to them the facilities of the Industrial Diamond Association to which many are members. Furthermore, the wire manufacturers' trade associations have continually shown a great deal of interest in the field of wire-drawing dies. It is quite possible that either of these groups could be prevailed upon to undertake surveys and studies to facilitate efficient sales management. That the present hit or miss method has been allowed to exist for so many years is to no one's benefit or credit.

Selling Policies and Procedures

The exigencies of competition have influenced, altered, and overridden many a sound business decision. In very few instances has this occurred with greater frequency than in the diamond die industry. Caught in the middle of a barbarous competitive jungle, the die manufacturer has found no alternative but to adopt regrettable short-run policies. He has, for instance, had to reduce his gross margin on profit to a level where the slightest error or miscalculation can mean the difference between profit or loss. To illustrate, a .001" size die which during the early
1940's sold for anywhere between sixty to eighty dollars at present lists for approximately only twenty dollars.

The extreme intensification of competition that has developed in this business appears to stem chiefly from the fact that there is in reality almost no distinguishing characteristics among the various brands of dies. This is true despite the customarily followed practice for each manufacturer to make sensational claims of superior workmanship and quality. That such claims have little justification is demonstrated by the following British experiment:

In order to determine fairly each company's individual practice die producers, and the wire industry agreed on identical sets of dies to be produced by each company. Each set was coded and judged by all participants. One of the startling results was that in at least one case a participant condemned his own dies in strong language as entirely unsatisfactory. It became apparent that generally dies were considered bad which very likely would have been found acceptable had the judge known who made them and vice versa.

The wire mill purchasing agent is fully aware of the arch rivalry that exists in the trade and he naturally presses his advantage to the fullest in demanding favorable concessions. In order to sell his dies many a manufacturer has succumbed to the temptation of employing so called tricks of the trade such as disguising a reduction of carat weight per die stone, under-cutting the price of the present supplier; and/or cunningly obtaining the good graces of the die shop superintendent who usually issues purchase requisitions.
This is not to deny that there are a few notable examples of companies which have survived and prospered solely on the basis of reputation, dependability, and reliability of service. However, the reader is cautioned not to infer that in this regard the exception proves the rule.

The principal salesman of a company is ordinarily a top executive who carries with him the prestige of his position and who has the authority to transact on-the-spot agreements. This is particularly significant in view of the fact that published quotations issued by die manufacturers are not the least bit meaningful since the list price is invariably subject to a multitude of special discounts and deals. Most companies also make use of brokers carrying a complete line of related goods and operating on a ten to fifteen percent commission. These find their most favorable usage in remote areas or where they have an "in" with a particular buyer. Terms of sale are customarily 2% ten days, net thirty. All merchandise is returnable upon inspection for full credit or replacement.

Product Diversification

Rather than lose out on an important segment of the die market, most diamond die producers have in recent times embarked upon a policy of product diversification. The combination of diamond and carbide die lines is a natural one from both a distribution and manufacturing point
Wire-drawing dies regardless of their composition find their way into the wire mill through the door of one and the same purchasing agent, in most cases. Presumably this buyer would rather deal with a single source who is able to satisfy his total requirements rather than with many different individuals each carrying only a limited line of goods. To the die manufacturer the cost of selling two lines is not appreciably greater than merely selling one product since no additional new expenses are incurred except those for advertising. There is, of course, also a slight increase in the time spent in the buyer's office.

From the viewpoint of manufacturing, the same machines and equipment can sometimes be used for the drilling of both carbide and diamond dies. Furthermore, a diamond die driller has no difficulty working on carbide dies since the same skills are required except to a much lesser degree. The similarity between the two products extends to the point that the same abrasive, diamond powder, is used on both types of dies during the polishing operation.

A few diamond die companies have followed a much more extreme policy of product diversification than that which is mentioned above. An Eastern concern, for instance, was actively and profitably engaged in the manufacture of diamond oil burner nozzles until the early nineteen fifties. Also a mid-Western firm has had some success in dove-tailing
its die line with a vegetable canning operation. A few other organizations sell diamond powder and diamond tools as an aside on a low turnover special order basis.

The Controversy Over Imports

The question of domestic versus foreign manufacture of diamond dies has implications that go much beyond the usual International Trade considerations. At stake in this instance is the actual defensive security of the nation. Diamond dies are essential to the production of war weapons and since the days of World War II have ranked very high on all government listings of strategic goods.

Prior to 1939 the entire demand for small size diamond dies was satisfied by European imports. It was at about this time, with the outbreak of global hostilities, that the United States was completely shut off from its source of supply. As the nation's industries tooled up for war production there was created an acute shortage of dies. In frantic efforts to alleviate this bottleneck the government was forced to spend huge amounts of money and time in developing production techniques and in financing fabricating plants. In time a domestic manufacturing industry was built-up which ranked second to none from both a quality and quantity basis. Nonetheless, it became painfully clear that the pre-war procurement policies had been very short-sighted and that the country had been fortunate to solve the crisis
without suffering greater injury.

It seems to be universally true that although lessons are hard to learn they are easily forgotten and it was not long after the end of the war that once again practically all small size diamond dies were being imported from Europe. Cognizant of the post-war turn of events, the government has frequently expressed concern over the availability of dies in the event of a national emergency. After considerable deliberation it decided to purchase a stockpile of small dies which would satisfy estimated needs for three years. As a consequence of this decision contracts were issued in 1958 for an unspecified amount of small diamond dies. These contracts were awarded to both domestic and foreign manufacturers with a guarantee that at least fifty percent of total requirements would be purchased from American producers.

To the American wire drawer the foreign made die has always had an irresistible attraction because of its relatively lower price notwithstanding the tariff. In attempting to explain this price differential it is to be noted that cost of materials remains constant throughout due to the monopolistic conditions which govern their use. It is also found that while production methods do vary somewhat on the international level differences also exist on the local scene but none of these are so significant as to cause substantial cost discrepancies in and by themselves.
More important in explaining the price differential is the incompatibility of wage levels. Whereas, for instance, an American diamond driller will make anywhere between $1.70 to $2.50 an hour, the average Frenchman doing the same work will only earn approximately fifty-five cents.

In relation to the import question the government decision to stockpile diamond dies raises a number of issues. Although the purchase contracts make provisions for inspection there has not yet been devised a method to distinguish between foreign and domestic dies. It is not completely outside the realm of possibility that American firms might purchase European dies and re-sell them as domestic. Such a proposition might appear extremely tempting since American suppliers are allowed premium prices for their dies. The probability of such an occurrence seems even more proximate in view of the fact that the production of small dies is very difficult and conceivably the skills required are beyond the capabilities of some of the companies who have received contracts.

Regardless of the veracity of the above implications, it is obvious that the United States is dependent on foreign sources since it was found necessary to purchase at least partial requirements from abroad. This situation is discouraging not only because of the strategic value of dies but also because some of these suppliers are not being very conscientious in their trading policies. It is quite likely
that the Soviet Union is also stockpiling and being supplied from these very same sources.

It's very likely the Russians have the same thing in mind. Both Switzerland and Sweden are buying large quantities of such dies from other European countries. Switzerland, for one, has no need for such quantities because it does little wire drawing, yet its purchases have been so large that for the first time in years U.S. importers are finding deliveries delayed.

A very practical solution to the import controversy would be the curtailment of imports until such a time that it becomes clearly established that the American diamond die industry is truly independent and self-sufficient. This would, for one thing, obviate the need for federal stockpiling which is certainly an expensive procedure. This suggested solution is not extreme in any sense of the word and in fact such an eventuality was foreseen by our legislators in the writing of the amended Anti-Dumping Act of 1921 which provides remedy after an investigation:

to determine whether an industry in the United States is being, or is likely to be, injured, or is prevented from being established, by reason of the importation into the United States of a class or kind of foreign merchandise which the Secretary of the Treasury has determined is being, or is likely to be, sold in the United States or elsewhere at less than its fair value.
Chapter Two
Organizing - the Factors of Production

Purchasing the Raw Materials

Industrial diamond for the manufacture of dies is bought on the basis of appearance, orientation, and weight. Proper selection of die stones is a difficult art and can best be done by the expert possessed of skill and experience. It behooves management, however, to have at least a working knowledge of the subject since industrial diamond and powder comprise the largest cost of production and strongly affect the quality of the finished product. Furthermore, the price fluctuations existing on the diamond market make timely purchasing a prime objective.

In the procurement process the die maker is presented with a lot of industrial diamonds from which he is to pick and choose. The stones are examined by eye loop and by microscope with a polarized light. The first step is to segregate all those stones which have obvious flaws such as carbon spots, cracks, fissures and internal pits. A recognized authority, Paul Herz, recommends that the following types of stones be eliminated: those having two enlarged crystal faces; showing single or multiple twinning, whether partial or not; showing slip planes, sharp edged stones with flat crystal faces; showing dull, frosted or corroded appearance; showing colour; blue-white stones; showing dull, grey, blackish or
murky appearance; multi-colored stones; stones with uneven distribution of colour; coated stones; partial or total skin coloration; stones with a rind; rippled, crinkled, corrugated or etched skin; glassy appearance; cubes.

Another reputed source, Paul Grodzinski, takes a less rigid approach and cautions that the above suggestions although excellent are not to be regarded as absolutes. He appears to lean towards the British specifications (BS 1168 and 1393) which specify that:

The diamond (when viewed at x10 magnification), shall be substantially clear and substantially free from internal stress, inclusions and fissures. Polycrystalline stones shall not be used, and twinned stones (macles) shall not be used for dies below 0.0008 inch or for dies used for hard metals. The diamond should preferably be oblate spheroidal, dodecahedral or octahedral in shape, but miscellaneous angular stones are acceptable.

A safe middle-of-the-road position seems to be somewhere in between these two extremes. To insist on the enth degree of perfection will mean a very lengthy selection procedure and practically all the stones within each lot will be found objectionable. On the other hand, simply to state that the stone shall be substantially clear and free from flaws leaves a great deal of ground uncovered. Furthermore, the use of macles under any circumstances is not generally recommended.

Much has been written relative to considerations of orientation in die stones.* In practice there is considerable

* See Appendix I
latitude of preference as between cubes, dodecahedron or octahedron formations.

Selection is generally made according to the case of manufacture and with a view to the minimum loss of diamond material in drilling. Therefore stones of tabular habit, such as distorted rhombic dodecahedral or octahedra, are preferred. Well-formed octahedra are not liked owing to the large amount of material that has to be removed for flattening. On the other hand, flattening of cube and dodecahedral faces is easier than that of octahedron faces, unless flat diamond shapes are used which do not need flattening. Macles (i.e. triangular diamonds with a naat running right through) may be useful for dies unless the actual bearing is not situated in the critical "naat" zone. 15

An important factor to consider in selection is the carat weight of the stone in relation to the expected diameter of the finished die. It is almost an invariable occurrence that whenever die men get together to talk over common problems the discussion will at that time when all other conversation runs dry turn to the establishment of universal carat weight standards for die stones. These parleys have on the whole been ineffectual since it is all but impossible to control the weight of a stone once it has been set in a die mount. Indications are at present and have been in the past that carat weight per die varies considerably from proposed standards the trend being towards the disguised use of the smallest possible stone.
### Table II
Proposed Carat Weight for Die Stones

<table>
<thead>
<tr>
<th>Diamond Die Size Range</th>
<th>Weight in Carats</th>
<th>Diamond Die Size Range</th>
<th>Weight in Carats</th>
</tr>
</thead>
<tbody>
<tr>
<td>.00039-.003</td>
<td>.18</td>
<td>.0361-.0403</td>
<td>.75-.85</td>
</tr>
<tr>
<td>.0031-.007</td>
<td>.20</td>
<td>.0404-.0453</td>
<td>.90-1.00</td>
</tr>
<tr>
<td>.0071-.0113</td>
<td>.25</td>
<td>.0454-.0508</td>
<td>1.00-1.15</td>
</tr>
<tr>
<td>.0114-.0142</td>
<td>.28-.30</td>
<td>.051-.057</td>
<td>1.20-1.35</td>
</tr>
<tr>
<td>.0143-.0179</td>
<td>.33</td>
<td>.0571-.064</td>
<td>1.40-1.55</td>
</tr>
<tr>
<td>.018-.0225</td>
<td>.40</td>
<td>.0641-.072</td>
<td>1.60-1.75</td>
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<tr>
<td>.0226-.0253</td>
<td>.50</td>
<td>.0721-.0808</td>
<td>1.80-2.00</td>
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<tr>
<td>.0254-.0285</td>
<td>.55-.60</td>
<td>.081-.0845</td>
<td>2.00-2.25</td>
</tr>
<tr>
<td>.0286-.032</td>
<td>.60-.65</td>
<td>.0846-.091</td>
<td>2.25-2.50</td>
</tr>
<tr>
<td>.0321-.036</td>
<td>.65-.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


The problems of procurement in regard to diamond powder are somewhat different than those discussed above. The principal considerations are not with the selection of material, which has been pretty well standardized, but rather with the choice between alternatives to make or buy. The topic is especially pertinent since diamond powder is used in very large quantities for production purposes and makes up an important part of the purchasing budget.

As a generalization it can safely be stated that the greater majority of die manufacturers rely upon industrial diamond dealers for at least a portion of their diamond powder requirements. New, or in trade terms, virgin powder is necessary for the performance of most drilling operations.

Under many circumstances it would be impractical for the die...
maker to devote excessive amounts of time to the fulfillment of his abrasive needs. However, external sources are expensive and it is in the interest of economy that they be used sparingly.

The die producer can make his own powder by crushing diamond with mortar and pestle and then grading the particles. This can be made to serve as an outlet for sub-standard and unsellable die stones which are a natural and expected consequence of any production effort. Cost estimates usually provide for a scrap percentage and assigns the expense to production overhead. Therefore, the conversion process by which this scrap is made into usable powder results in pure profit after deduction of labor costs.

The Controversy Over Pre-production Preparation

Opinion varies between manufacturers and customers and among manufacturers themselves as to how much preparation should be given to the rough industrial diamond before it is allowed to enter into the production process. Preparation in this sense refers to the operations of flattening and lapping. By flattening is meant the abrading of two parallel and opposing surfaces so that the diamond will lay perfectly flat during the drilling. This is necessary so that the hole does not deviate from the perpendicular in which it is being drilled. Lapping means the polishing of a facet or surface of the diamond that is perpendicular to the flattened ends.

* See Page 70
Its purpose is to make possible the full examination of the drilling located in the interior of the stone. Appropriately it is termed the window.

Flattening can be done either by a bruting or polishing operation. The former method is now discussed since the latter is subsequently to be taken up in regard to lapping. Briefly, the diamond is located on the rotating spindle of the small hand lathe and firmly secured with shellac at approximately the center of the chuck disc. Through the use of a splint (small piece or chip of diamond) held tightly in pliers, contact is made with the exposed surface of the stone. By exerting a certain moderate amount of pressure while at the same time moving the hand from the center outward the splint wears away the surface and a flat is produced. The diamond is then removed and cleaned. The same operation is repeated on the opposite and parallel side by reversing the position of the stone.

Figure 2

Hand Lathe for Bruting of Diamond Dies

Source: Adapted from Grodzinski, Paul: *Diamond Technology* (London, N.A.G. Press Ltd., 1953), P. 92
The polishing of the window is done on a lapidary machine. Although these come in varying designs a fairly common type is illustrated below. In this operation the stone is held in a clamp - (tang and dop) - and the facet to be polished is pressed against a revolving wheel or scaife. The grain of the diamond should be at right angles to the polishing direction. The wheel is impregnated with diamond powder and eventually wears away the diamond leaving a smooth transparent surface.

Figure 3
Common Type of Lapidary Equipment

revolving spindle  ->

scaife
Bench

1-tang
2-dop
3-diamond
4-impregnated diamond wheel


The controversy over how much preparation is necessary to give to the rough industrial diamond before it is entered into production expresses itself in terms of whether the diamond should be mounted before or after the drilling process. A mount is a metallic blank which completely
encompasses the diamond except for the upper and lower most surfaces. Before they can be used in the wire mill all dies must be mounted so that they can be held onto the drawing equipment. Almost universally, the bigger size dies are mounted before being drilled since the production process is not too exacting and since the hole is sufficiently large to be clearly visible and inspected from either of the terminal ends. In the smaller sizes most European manufacturers prefer to drill the diamond without a mount as they believe this to be the only suitable way to make a top quality product. This necessitates flattening so that the workpiece can be precisely positioned and lapping to enable accurate work-in-process inspection through the window. On the other hand, the traditional American school of thought has been that the techniques used for bigger dies is adaptable to even the most critical sizes. This method eliminates the need for the preparatory operations.

To the author who at one time specialized in the drilling of the very smallest dies, the American stand on this question is untenable. The drilling operation for fine dies is very delicate and requires a great deal of care and dexterity. This is true regardless of what method is used, be it mechanical or electric. In any case the needle which is basic to the work must be ground to a fine tapered point many times thinner than the human hair. The slightest

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pressure or vibration can destroy it. When this happens the hole not only gets plugged up but there exists a strong possibility that permanent injury may also be caused to the drilling and the area immediately adjacent to it. Furthermore, the drilling in each die progresses a little differently and presents its own peculiar problems. This is a consequence of the fact that diamond is a product of nature, the result of chemical combination, in which each specimen possesses varying characteristics of structural crystallization and hardness. To make a good die numerous allowances must be made for these individualities which can only be determined by frequent optical inspection of work-in-process. It seems only reasonable in view of the difficulties outlined above that the driller should be freed from any and all unwarranted encumberments such as lack of visibility, difficulty of access, etc. Yet these encumberments are direct results to be coped with in drilling pre-mounted diamonds.

It is interesting to note that at the outset of its negotiations for the purchase of diamond dies just three years ago, the United States Government was not at all interested in acquiring mounted dies. The reason set forth was that the dies to be purchased were chiefly within the small size range that could best be inspected in their natural state. After considerable pressure was exerted by domestic manufacturers the government was prevailed upon to alter its position and accept mounted dies. However, the National
Stockpile Purchase Specifications state that:

Each die shall have a flat surface ground and polished for a window which shall be perpendicular to the entrance and exit surfaces of the die. The window shall be large enough to permit viewing the secondary cone, bearing, relief, not less than one-third of the entrance cone next to the secondary cone, and not less than one-third of the exit cone next to the relief.

Each lot of mounted dies that draws satisfactory test wire shall have not less than ten percent of the dies unmounted for further inspection and testing.

The above quote clearly implies that for control purposes the mount which surrounds the diamond is nothing short of a nuisance. It also points out that a good die should have a polished window to permit complete inspection. In conclusion, then, somehow it doesn't seem logical to mount a diamond, then drill it, then unmount it for inspection, and then mount it again to make it usable for wire drawing. Unquestionably, the simpler process would be to drill the die, inspect it, and then mount it.

**Personnel Considerations**

One of the main problems of personnel administration for the die manufacturer is the difficulty of attracting competent young individuals to rejuvenate the work force. The experience where a young worker is hired, trained, and then quits at that point when he was just beginning to pay for himself has happened all too frequently to be called unexpected. This kind of training procedure is expensive
and beyond the means and resources of the ordinary die maker.

Some factors to consider in connection with this situation is the relatively lower wages paid by the industry as compared to other available jobs, the high degree of concentration and skill required, and the rather static working conditions that tend to develop devoid of any appealing recreational and social programs.

Another major trouble spot concerns itself with the older worker. The veteran with the advancement of age tends to seek additional security under various forms. He will, for instance, become reluctant to show a younger person any of his special skills. He will also heatedly oppose any technological improvements and the purchase of newer and better machines which might tend to disrupt the status quo.

In his attempt to show that he has not lost any of his skill, vision, and dexterity he will overtax himself and become quarrelsome and impatient.

An issue which cuts across all age limits is that of recognition and status. Traditionally, the governing factors in employee relations have been the closeness that exists between owner or manager and the worker and the long standing acquaintances between worker and worker. The good die man takes great pride in his work and resents to an extent the organizational hierarchy that must exist in the shop. The selection of foremen or supervisors carries with it the implication of superior ability and the basis for the
choice may not be accepted by all concerned. The friction that may arise as a consequence is intensified by the smallness and close relationship of the group.

An important area in which little has ever been done by the die industry is that of time and motion study. The feeling has always been that the work is highly specialized and that output depends on many variable factors that cannot be fully controlled. Although this attitude does have some justification it has not contributed to higher efficiency or increased productivity. On routine operations such as, for example, the polishing of a cone there appears to be an "average time" that exists in relation to a certain quantity of dies even though specific ones in the group may vary greatly as to workability, hardness of diamond, etc. Standard times could possibly be developed through the use of weekly production records kept on each employee. A fair work load would seem to be equal to what a particular man has been doing over a period of time such as the past six months. This average output might be set at slightly below par since the purpose of the new wage system is to remedy an inefficient situation. All that output over and above the pre-determined quota would be paid for at preferred rates of increasing proportions attractive enough to serve as strong motivators. Perhaps the best system to use would be the guaranteed piece work plan so that the less skilled workman and the one who runs into a series of difficult dies would be afforded some protection.
Another point to be made in regard to personnel administration is that it is to management's great advantage to see to it that all workers in the shop are as versatile as possible. Since the workforce is small the absence or quitting of a key person can seriously disrupt production and lose orders especially during rush periods. There should, ideally speaking, always be someone ready and prepared to step in should such a situation occur. When each individual can do the other person's work it is found that there is much less opportunity for anyone to hide certain petty secrets and to exploit exclusive specialization in a particular function. In some past instances the tendency for certain individuals to regard themselves as irreplaceable experts has led to general disharmony and lack of cooperation.

Production Facilities and Working Conditions

Classified under the heading of adequate working conditions and plant facilities are such factors as cleanliness, good lighting, sufficient supply of tools at each work bench, accurate measuring and visualizing instruments, regular maintenance of machinery, and vibration-free work areas. All of these are essential pre-requisites to the attainment of a satisfactory degree of productivity from the workforce. There necessity stems principally from the precise and intricate nature of the work to be performed.

Cleanliness pre-supposes some sort of program by
which it is established that all floors will be swept at regular intervals and that benches will be kept in order and dusted. Usually the newest employee inherits this responsibility until he earns full worker status. At that time the shop hands will take turns doing this menial chore. Most important in this regard is that all open viles of diamond powder be covered and that critical equipment (lenses, micrometers, etc.) be protected from foreign elements.

An overhead fluorescent lighting system of sufficient illumination is gaining increasing popularity in die shops. The older system of having individual lamps at each bench has a number of disadvantages. For one thing these lamps are cumbersome and the post is forever in the way. They often produce a sharp glare which reflects off the drilling needle and make the grinding operation extremely tedious. Further, the workman when inspecting work-in-process with an eye loop will place the diamond in direct allignment with the light and the intensely bright background is harmful to the eyes.

Each workman tends to regard the tools he has at his bench as his own property and gives them special consideration. It becomes annoying and disturbing for him to have a colleague constantly borrowing something and perhaps not bringing it back. The borrower loses a substantial amount of time roaming about the shop and stopping at every station to see if there is anything which he can use. In view of
these facts it seems advisable to place at each bench all the necessary apparatus that the workman will need in the course of his work day and to make him solely responsible for them.

The eye loop is to the die man what the eraser is to the secretary. However, these give only limited magnification and excessive reliance should not be made on them. Some drilling machines are built so as to be able to be equipped with special microscopes over each drilling head. Although these have not gained wide acceptance for practical reasons they do offer some obvious advantages. As a minimum each work area should have at least one microscope centrally located and its frequent use should be encouraged.

All machines have to be well lubricated and in top working order to insure that quality standards are achieved. This requires a carefully thought out plan of preventative and routine maintenance for all moving parts. At least once annually all drilling equipment must be checked to insure that all rotating needle spindles are in true alignment with the die holders. Maintenance is best done during the slower periods which invariably occur during a business cycle.

Vibration from motors and transmission drives make it impossible to drill small diamond dies and difficult to polish, measure, and inspect any dies regardless of their size. One method of combatting vibration is to set up the work benches on specially constructed concrete foundations. Also all pulleys and drives must be kept off of and away from
bench mounts and should themselves be solidly secured so as to cause a minimum of trouble. It has sometimes been found advantageous to place the most delicate equipment in the basement of the building because of its more rigid construction.

Other problems arise if the shop is a completely open area. Some drilling processes are perhaps unique to a particular company and considered somewhat secretive. These must usually be segregated by special partitions. Also the mounting operation causes some discomfort because of the heat which it produces. This area is often made separate and kept well ventilated.

It is only the most careless of production managers that will want to leave thousands of dollars worth of diamond lying unattended in the shop. A control and distribution center is an absolute must. It should be equipped with a safe or vault that is never allowed to remain open without good reason. All work-in-process must be carefully accounted for and the distribution of diamond powder should be an important responsibility of the foreman.
Chapter Three

Commanding - the Line Production

Mechanical Drilling Process

An often heard axiom is that top management is primarily concerned with administrative matters and need not possess any degree of technical proficiency. While this statement is perhaps generally valid it does not hold true in some specific instances. One such exception is the diamond die industry. Here the typical organization is very small and the chief executive is in direct contact with all the major operating divisions. He serves a dual function in that he not only establishes the broad company policies but is also of necessity actively engaged in the execution of these plans. Furthermore, because of the highly technical and specialized nature of the business, efficient administration pre-supposes a working knowledge of the fabricating activities.

The physical appearance of a finished diamond die has already been described in the Introduction. Of interest now is how form utility is given to the raw industrial diamond.

Figure 4

Raw Diamond to Finished Die

Source: Author
The two basic machines used in the drilling of small diameter diamond dies are the small hand lathe and the single-head horizontal drilling machine. The first of these has already been described and repetition at this time would be superfluous. The latter machine is virtually unknown to the layman and some explanation is therefore necessary.

Figure 5

Single-head Horizontal Drilling Machine

Source: Adapted from Grodzinski, Paul: Diamond Technology, (London, N.A.G. Press Ltd., 1953), P. 537

The above machine is operated by centering a steel needle on the rotating spindle (a). This is done by placing the needle in the aperture of the spindle and melting shellac about it while permitting the spindle to turn slowly. The sliding bar (b) rides in grooves on the chassis and is made to reciprocate by contact with the extension of the eccentric cam (c). Adjustable screw mechanism (d) regulates the rate of
reciprocation. There is also an adjustment to control the length of travel. The spring (e) supplies a constant push effect on the sliding bar keeping it in constant contact with the eccentric cam and also affects the drilling action by introducing pressure onto the diamond. The diamond is centered on the extreme end of the bar and it makes contact with the drilling needle according to how the bar itself moves. Essentially the drilling process is a matter of transposing the shape of the grinding needle into the diamond. To this end the needle is ground at frequent intervals and is shaped according to the desired shape of the hole.

With reference to figure 4 previous explanations have been given concerning steps one (flattening) and two (lapping). Step three (spotting) is usually done immediately following the flattening operation. The same equipment is used. The only variation in the work being that instead of moving the splint from the center outward it is kept in the center as much as possible and only slight hand movements are used. The dimensions of the spotting depend on the thickness of the stone and the desired size of the finished die. The work progresses relatively fast in this operation in comparison to subsequent drilling steps and therefore the deeper the initial penetration the less is over-all drilling time other things being equal. In general the tendency seems to be towards the making of too small rather than too large an initial cavity.
One of the main purposes of the spotting is to facilitate the centering of the stone in subsequent drilling operations. Since the majority of these operations are to be performed on the horizontal driller it might be well to digress at this point in order to explain how a diamond is centered on to this machine. The stone is first secured on to the approximate middle of the sliding bar with shellac. The shellac is then heated so as to render it pliable and the bar is advanced towards a pre-ground needle which fits into the spotting or hole in the diamond. The stone is kept in contact with the needle until the shellac cools and hardens. The sliding bar is then returned to its original position and it is assumed that the diamond is centered.

Step four of the diagram refers to the drilling of the primary cone. This work is initiated after the stone has been cleaned and inspected for possible cracks or flaws that may have developed during the spotting. The diamond is centered on to the horizontal drilling machine as outlined above and a thick grade of diamond powder is placed on the needle. The eccentric cam is adjusted so as to produce approximately 500 reciprocations per minute. The spring is advanced so as to exert a comparatively strong pressure on the diamond. The needle is ground very short with an extremely sharp conical tapper. It is allowed to wear until the conical shape disappears, at which time it is again ground. In successive grindings the needles are lengthened slightly
and the tapper becomes more gradual. This process is continued until the desired length of the primary cone is attained. This will take varying amounts of time depending on the cutting action of the powder and the amount of oil that has been mixed in with it, the characteristics of the machine, and the hardness of the diamond. Before progressing to step five the primary cone is given a rough polish. This is done by simply weakening the cutting action of the powder through the addition of a greater amount of oil to the mixture. The stone is then removed, cleaned and inspected.

The secondary cone (step five) is a little more difficult to drill. After the diamond has been centered, the reciprocation rate and spring pressure reduced; work is ready to begin. At this stage a finer grade of diamond powder is used. The needle is ground with a cylindrical point which tappers into a conical shape. The purpose of the straight piece is to open up the stone and the conical end blends in the hole with the primary cone. As the work progresses downward and successively thinner needles are used, more frequent re-grindings become necessary. On the last few needles the amount of wear that is allowed to take place on the conical part of the needle is negligible. After completion of the reduction the drilling is cleaned and even finer powder is used to give a preliminary polish to the area.

The bearing is now ready to be drilled. It should
be emphasized at the outset that this operation is much easier to describe than it is to perform. The stone is cleaned thoroughly and inspected for shape, depth, and possible flaws that have developed as a consequence of the above operations. It is then secured on the sliding bar by means of bees wax and accurately centered. The rate of reciprocation, amount of travel, and spring pressure are adjusted so as to have an almost unnoticeable effect on the diamond. The needle is ground with a long cylindrical piece whose diameter determines the finished size of the die. Because of its thinness it wears very rapidly and has to be frequently re-ground. Very fine powder is used in this operation. The drilling action, consequently, proceeds very slowly. After many days of diligent labor the bearing should attain the desired length—anywhere from 75 to 100 percent of width—and is ready to be polished.

In step 7 (counter-sinking) the die is placed on a small hand lathe. It has to be precisely centered so that the back will meet the bearing right on the nose. Unless it does the die will not draw good wire. Such a deviation is called high-sidedness and can only be remedied by shortening the bearing and enlarging the size of the die. The diamond is centered on the lathe by holding a needle in the front end of the drilling and revolving the disc until the shellac cools and solidifies. This is very delicate and skilled work and requires much experience and practice.
The difficulties it presents are too numerous to even enumerate here. Nonetheless, after the stone is properly centered the exit cone is made by chipping away the diamond with a splint. This work is quite similar to that of spotting.

The relief (step eight) can be drilled in two ways. The preferred method is to continue the above operation until the bearing is reached. The other way is to again place the stone onto the horizontal drilling machine and proceed drilling until both ends of the die meet. In either case the difficulty is to determine that precise moment when relief and bearing are joined. When this occurs all drilling activity must cease immediately at the risk of wearing away a good deal of the bearing and increasing the size of the die substantially. One trick that is commonly used is to insert a liquid in the front drilling and watch for it to flow out the back. This serves as an aid but is not infallible since many a time the die will become plugged up and the liquid will not flow freely even after the ends are joined. In the performance of this work there is as yet nothing that has been found to replace skill, diligent effort and frequent optical inspection.

The emphasis up to this point has been placed on the production of the small size dies. These dies are in the .000" size range and it is preferable to work on them while the stone is unmounted. A few words are in order at
this time concerning the drilling of the larger size dies which are usually mounted before entering the production process. The work to be done on these is not nearly as critical, difficult, or time consuming although the same general principles apply.

The spotting is done on a small hand lathe which has already been referred to a number of times. The only variation is that the lathe is equipped with a chuck to hold the casing. There is no centering problem provided that the mount runs true.

In the drilling of the primary cone, reduction, and the bearing a multi-head vertical drilling machine is used. This machine works relatively fast and saves on labor and overhead costs because of its compactness. The needles are similar to those previously described except that they are proportionately bigger.

In counter-sinking there is no centering problem since the die fits right into the chuck. The making of the relief is not as exacting as it is in small dies since the bearing is much larger and will not be increased as rapidly should the counterdriller fail to stop at the precise moment when the two ends of the drilling are joined.

Before concluding this section on the mechanical drilling process, it should be stated that management must not be led to believe that there is only one set method of doing an operation. In practice there exists a considerable
difference of procedure among workers. This is not necessarily to be interpreted as a fault and undue interference by an efficiency expert might do more harm than good. Experience is a very valuable teacher and lessons learned through years of practice can add considerably to a driller's worth. There is a problem which arises in connection with the training of new men since these are assigned to different instructors as they progress. In this case a consistent drilling procedure should be followed throughout but those unconventional 'tricks' which are picked up here and there along the way should not be completely excluded.

Mounting

A diamond die in its natural state is very small and difficult to handle. Therefore, a casing is used to give the die workable dimensions and uniformity. Further, wire-drawing machinery is so designed as to operate only with a die of standard size. It is claimed by some that the mount reinforces the diamond and gives the die longer life.

Figure 6

Steps in the Mounting Process
The usual types of blanks used for mounting are brass, steel, and monel. The first step is to make a well in the blank as in step B. This can be done on a lathe by the manufacturer or the blank is sometimes purchased already machined. Next a guide hole is drilled in the back side to permit the centering of the die once the front end is closed in. This is done by placing the die, top down, in the well and inserting a small mandrel through the back aperture and primary cone of the die. Since diamond comes in different shapes and sizes there will be some variation as regard the depth of the stone within the casing but slight changes do not materially affect the drawing ability of the finished product. The mounting blank is now ready to be placed on a brazing stud and a metallic disc is pressed on top of the diamond to prevent the spletter used in subsequent operations to flow into the die hole. The mount is heated with a gas and air blow torch until red hot. Spletter and flux are then melted about the area so as to fill the space surrounding the diamond. The work is then allowed to cool after which it is centered on a lathe from the back opening. The circumference of the mount is made concentric by turning down the blank until it runs true. The work is then chucked from its outside diameter and the entrance and exit of the mount is bored out in conical fashion so as to allow free passage of the wire in the drawing operation.

There are two principal difficulties that have
constantly re-occurred with mounts. These stem from the terrific amounts of heat and pressure to which the die is subjected during the wire pulling. On occasion the stone has pulled right out of the setting and it has sometimes been lost or badly damaged in the process. Another cause of trouble has been the tendency of some stones to shift position and become out of center.

Much effort has been devoted in research to combat these undesirable occurrences. One improvement has been that:

The diamond die blank is set inside a ring in a soft aluminium receptacle with a depression in the bottom of the receptacle for the die blank, and with a thin cylindrical wall which is folded inwards and pressed downwards by a punch so as to force the metal into intimate contact with the diamond and the ring holding the receptacle. Diamonds mounted in this way will seldom break during the drilling and usually do not shift from their central position in the holder.

Other recent improvements have centered about the design and construction of electric furnaces and hydraulic presses to replace the old-fashioned methods of clamping and heating. These permit the mounting of more dies in less time and also have improved the quality of the settings.

New Methods and Techniques

In that span of time from the invention of the diamond die to the beginning of World War II the industry had been completely stagnant in regard to research and development. It was not until the war crisis was reached
that improved methods of drilling were discovered. Much impetus in this direction was given by the United States Bureau of Standards and the War Production Board.

Perhaps the most significant advancements have been those that concern themselves with the application of electric current to the drilling of diamond either by electrolytic or dry electric processes. The following diagram illustrates the time saving that can be obtained in theory at least by a combination of these two processes as compared to the conventional mechanical method described previously:

\[ \text{Figure 7} \]

\textbf{Comparison of a Combined Electric and Electrolytic Drilling Process to the Conventional Mechanical Method.}

A. Preparing blank: cut and polish faces and windows.
B. Forming pilot hole: drilling primary pilot (dry electric).
C. Countersinking: mechanical countersinking.
D. Pilot extension: drilling pilot extension (dry-electric).
E. Finishing the bell: Mechanical countersinking
F. Starting secondary cone: electrolytic drilling coarse.
G. Finishing secondary cone: electrolytic drilling fine.
H. Blending: blending and polishing reduction.
I. Back opening: a) Lapping to open; b) Lapping to open; c) Drilling through (preferred).
J. Polishing: reaming as with fine wire and fine diamond dust.
K. Relieving: countersinking as with blunt drill and fine diamond dust.

A. Bruting flat
B. Bruting starting hole
C. Pecking primary cone
D. Pecking secondary cone
E. Bruting and pecking back
F. Relief and smoothing of bearing
Besides substantial time-savings there are many other advantages that accrue from the newer methods such as reduction of skill and attention by the operator. "A further advantage is that the diamond powder consumption is considerably reduced; this is of particular importance as it is usually calculated that for producing a die hole about four times the weight of the diamond itself is consumed."  

Principally, the dry electric method is a process of drilling whereby a series of high voltage discharges of electricity are emitted at that point where the drilling needle (composed of platinum and iridium for conductivity and heat resistance) and the diamond blank come together. The discharges cause a burning away of the diamond and thereby produce a hole. Caution must be taken to insure that the diamond does not become so hot as to turn 'frosted' since this renders it completely useless. The hole that is produced by this method is rough and irregular. Consequently, it usually requires some mechanical re-finishing.  

In the electrolytic method the diamond and needle are placed in a rotating bowl containing a conductive fluid and a secondary electrode to complete the circuit. A constant voltage current is applied between the needle and the diamond and a drilling effect takes place. This method is slower than high voltage drilling but considerably faster than the mechanical process. It is used principally to drill the smaller parts of the die.
A method of much more recent vintage than the above is the chemical heat process developed in Germany.

In the heat method the hole through the diamond is produced with the help of acid which burns into the crystal. A V2A-steel box serves as an oven, with a double-walled quartz-glass lining containing molybdenum heating wires. The diamond is clamped on a sintered aluminium shank projecting from the bottom of the oven. The process can be watched through quartz glass windows. The 'boring tool' is a quartz glass spray which ejects acid on to the diamond through a 0.1 to 0.35 mm diameter opening. The distance between the spray end and the diamond surface to be worked is a few tenths of a mm. During the process hydrogen is brought to the diamond through a porous aluminium tube. A temperature of 900 degree C. is reached after about one minute from the positioning of the diamond and the release of the hydrogen, and the acid can then be released to burn the diamond.

Improvements have also taken place in other phases of diamond die production indirectly related to the drilling operation. Among the more noteworthy of these is a centering device developed by the General Electric Company of England. It is particularly useful for counter-drilling of the exit cone. Essentially, it is a microscope with a substage which is equipped with a rotating die holder. The holder has adjustable screws so that the diamond can be placed in any position under the cross hairs seen in the field of the microscope. A small lamp throws a beam of light through the hollow spindle and illuminates the diamond. To countersink the stone is placed in the holder with the drilled end downward. The tip of the bearing is visible and appears as
a dot. This dot is lined up with the cross hairs and kept in place by the adjustable screws. Once centered in this manner the countersinking operation is carried out in the usual manner by the use of a splint. This is possible since the substage is capable of being moved 45 degrees to a horizontal position. When in this location it is connected to a fractional horsepower motor and rotated at high speed. Although this system has much to recommend it, the author has learned from experience that unless the diamond is very transparent the bearing will not show through very clearly. In order to use this machine, therefore, the diamond should be flattened by polishing on a lapidary rather than bruted on the hand lathe.

A significant advance has been made in the area of die cleaning. Previously this was done by such methods as; bathing the stone in a cleaning solution such as benzene, by means of a thin dowl stick, by blowing out the hole with an air hose, or by boiling the stone in acid. Recently an ultrasonic machine has been developed which cleans the die by emitting very rapid vibrations from a transducer. The machine can clean a number of dies at one time, is easy to operate, works on even the very smallest dies, and does the job in a relatively short amount of time. There is also an electrolytic method which has been developed especially for fine dies when all other cleaning attempts fail. Essentially, an electric current is made to contact the hole in the hope
of burning out the impurities. 21

A great many improvements have been made in optical equipment. Many of these will be discussed in a subsequent chapter on quality control. There is, for example, the Profilescope for studying the shape of the die as well as other types of comparitors.

Common Servicing Problems

To the consumer the buying motive second only to price and quality considerations which influences the purchase of a particular brand of dies is the service offered by the manufacturer. Service in this instance refers to the re-conditioning and polishing of worn dies. It is particularly important to the customer because of the high original purchase price. Some wire drawers are able to get three to four times the original wear of a die by having it re-worked to progressively larger sizes.

On occasion wire men have abused their service privileges by letting a die get in such poor condition before having it repaired that the re-cutting operation becomes almost as time-consuming and tedious as the original drilling work. Although die producers have not been in a very good position to make strenuous objections to such practices there is a limit beyond which they should not go. For instance, the height of insult is reached when a wire manufacturer purchases dies from a low cost and cheap source
and then sends these very same dies to a more reputable firm to have them re-conditioned.

The material to be discussed here should not be viewed as entirely separate from that which precedes it concerning the drilling operation. Before a drilled die can be marketed it must be polished to a high mirror finish and any shape imperfections must be removed. The work performed to this end is quite similar to the servicing operation, and therefore, both are treated jointly.

A diamond die is an intricate tool and any slight deviation in shape can seriously hamper its usefulness. The following is a pictoral representation of some of the more common difficulties that can develop. This list is not meant to be exclusive since to treat all the possibilities would be a thesis in itself.

Figure 8

Common Servicing Problems

[Diagram of common servicing problems]

Source: Author

The first three drawings represent faults most often found in servicing of worn dies while the latter three are more common to newly drilled stones.

Rings result from excessive wear and affect the
quality of the wire drawn through the die to a greater or lesser degree depending on where they are located. Those in the primary cone are not nearly as serious as those in the reduction or bearing since the wire has less contact in this area. In repairing this type of damaged die the area about the rings is leveled off so as to alleviate the sharpness between the grooved and normal surfaces. Needles are ground so that they fit the injured area and powder of varying coarseness is used depending on the depth of the rings. The machine used in this operation should have an up and down rubbing motion rather than the typical straight downward action of the driller.

A die that has had its bearing completely deformed has drawn far too much wire. To repair such a die will greatly increase its original size. The new size will approximate the diameter of the former hole at about mid-point in the reduction. In this case the usual procedure is to put the die on a wire polisher. On this machine a wire coated with diamond powder is repeatedly passed through the die. The wire is made to move up and down in the drilling and eventually produces a straight bearing by wearing away and enlargening the lower half of the reduction. The die is then placed on conventional polishing equipment and the approach angle is blended.

High-sidedness can occur almost anywhere that different parts of the drilling come together. In wire
drawing it is not uncommon to develop high-sidedness where the reduction and bearing are joined. This is the area which is subject to the greatest pressure and the one which invariably will wear first. Depending upon the degree of sharpness, the die can be fixed either by simple blending of the angle or by a complete enlargening of the cone and reduction. The operation is quite similar to that of drilling and need not be explained in greater detail.

Fault number four is another example of high-sidedness. Where such a condition occurs in the drilling process the cause is usually that the workman did not properly center the diamond on the drilling machine before beginning to work on the reduction. Using the secondary cone as a point of reference for centering, the top portion of the die is enlarged and proportioned.

An off-center back is frequently encountered in small size dies because of the great deal of skill and finesse required to set up the stone in the counter-sinking operation. It is almost impossible to repair such a die without sacrificing some of the bearing. The usual method is to place the die on a horizontal drilling machine and to center it using the tip of the bearing as a reference point. The difficulty is that in some cases the diameter of the bearing is so minute that the needle entered from the sharp relief angle breaks on contact with the stone. If and when the die is centered properly the procedure is to
blend in and enlarge the back cone until it becomes properly alligned.

A bearing which deviates from the perpendicular was practically unknown until the advent of electric drilling. However, with the widespread use of this newer method it has become a significant problem. The difficulty is that in order to bring the die in proper allignment it must be centered from the tip of the bearing. In a fine die the needle is so thin that it can hardly be made to suffer the strain of descending into the slightly curving hole. Once the die is centered the upper half of the drilling is broached out so as to re-form the die into a funnel shape.
Chapter Four

Controlling - the Quality, Cost, and Output Factors

Quality Control Methods

The die man at times appears to be possessed of a dual personality. On the one hand he demands that dies be purchased solely on a quality basis and that price considerations be given second billing. On the other he claims that the quality of the die should be determined only be means of obsolete equipment and in fact denies that there is any absolute judging criteria or standards.

A recent article written by the Die Committee Chairman of the Industrial Diamond Association concluded by saying in substance that: "the wire industry can make a tremendous contribution to diamond die quality by a willingness to pay a fair price for a good die and disregard competitive price cutting." This statement is very well put and certainly to the point. However, it does conflict with an earlier section of the article which states:

Commercially perfect dies should be inspected with microscopes, up to, but not exceeding 30 power on the fine sizes, (.0015" and smaller), and on the larger sizes up to 10 power. Any die which is to pass examination through a more powerful lens or which is produced to any special specifications should be considered a custom-made die."  

Without intending any dispersions towards the writer of the article who was merely acting as the voice of the committee
members, it does appear inconsistent to conclude that quality should be the sole basis for purchasing and yet in the same breath to deny to the buyer the use of adequate means to determine quality. It must be remembered that ten power is the magnification of the ordinary eye loop and this instrument leaves much more to the imagination than it actually reveals.

Another interesting point is that the die industry has never been able to agree on a meaningful set of standards. Yet, "The remarkable thing is that despite the absence of industry-wide standards for diamond dies, there has developed a considerable uniformity of practice." In fact dies produced by different manufacturers are so similar that: "It became apparent that generally dies were considered bad which very likely would have been found acceptable had the judge known who made them and vice versa." One may justly wonder, then, whether the lack of standards is the result of a hopeless dilemma or if it is a deliberate policy. The author is of the opinion that die makers realize full well that there is in actuality little product differentiation in the industry and yet not wanting to be reduced solely to price competition they strive to create an image of uniqueness and individuality about their respective die lines. The word quality is used generally only in a very nebulous sense and merely as a selling point.

This backward attitude taken by die manufacturers is unfortunate and indications are that it has not greatly
impressed the wire mill purchasing agent. Neither has it been able to stem the onrushing tide of progress in the measuring and visualizing equipment field. Microscopes, for example, have been improved to give excellent clarity at 300 power. These come equipped with filar attachments, optional lighting arrangements, interchangeable dual or single eye viewing, etc. One type is equipped with an inclinable tube and illuminator which when adjusted correctly permits a whole series of diamond dies to be inspected without further change.

The British Iron and Steel Research Institute of London has come up with an inspection device called the Profilescope which is creating somewhat of a small revolution in this field.

The instrument is based on a very simple principle in which a narrowly divergent light beam passes through the die placed on a tilting table, on to a screen placed below. When the die is horizontal a small bright circle of light is seen, outside which is a first dark band, and then a narrow band of light, all three being concentric. The innermost circle is due to direct illumination through the die hole and the outer to internal reflection from the tapered region of the die. Any changes in taper show up as additional concentric light circles, one for each change in taper, while a gradual change in types causes a wider band of light. Scoring shows as light radial lines radiating from the center circle. The effect may be intensified by tilting the die.

To measure the die angle, the die is tilted, when the outermost circle of light distorts to a heart-shaped image; by sufficient tilting, the cusp or peak at the top of the heart may be made to touch the innermost circle. The operator now uses a scale
adjusting screw to move the angle scale until the die diameter appears against the pointer. He then tilts the die in the opposite direction until the cusp touches the center spot on the opposite side. He can now read off the total die angle against the pointer. Measurement of the die angle takes about twenty to thirty seconds.

Batch quality control of the die profile is even simpler. If tolerance limit markers are placed on the instrument scale the die angle can be checked without the need for exact measurements and standard images can serve as criterion of surface finish.

Among other notable European innovations is a microscope with a special eyepiece that makes possible quick and easy comparison of tapers by pull-back against an angle scale. To this has recently been added a roundness tester which is equipped with a projection screen and is said to permit quick and reliable check of die diameters in two 90 degree positions.

A less recent but very reliable method of determining the diameter of a small diamond die is by weighing samples of wire which it draws. The torsion balances used for this purpose are very accurate. In measuring the diameter of a .0035 inch diameter they are only subject to variations of 15 millionth of an inch.

The method is best explained with reference to application in drawing a specific kind of wire since with various metals different assumptions have to be made. As applied to copper the density of wire is said to be 8.84 gm/cm³ at 20°C. One meter is computed to equal 39.37 inches. One pound is taken to be the same as 453.59243 grams.
following formula is then derived:

\[ W = \frac{d^2 \times \pi \times 8.39 \times \left(\frac{\text{39.37}}{\text{39.37}}\right)^3}{100} \]

\[ W = 114.418275 \times \frac{d^2}{39.37} \]

\[ W = \text{grams per inch of wire length} \]

\[ d = \text{wire diameter in inches} \]

This formula makes it possible to compute the weight of a known length of any diameter wire. The average diameter of a wire produced by a die could now be determined by weighing measured lengths. This operation is performed for all the gage sizes in common use according to the established progression of the series. The results are placed on a master card and used as a reference in future computations.

Table III

<table>
<thead>
<tr>
<th>Wire Diameter Limits-Inches</th>
<th>Length or turns of sample</th>
<th>Sample Weight-Mg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.0045</td>
<td>.00500</td>
<td>.00595</td>
</tr>
<tr>
<td>.00445</td>
<td>.00450</td>
<td>.00445</td>
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<tr>
<td>.00415</td>
<td>.00420</td>
<td>.00425</td>
</tr>
<tr>
<td>.00395</td>
<td>.00400</td>
<td>.00405</td>
</tr>
</tbody>
</table>

Source: Moyers and McLeod; Weighing Samples of Wire to Determine Accurately the Hole Size of Fine Gage Diamond Dies. Wire and Wire Products. Vol. 32, No. 10. October 1957. P. 1275

One difficulty that arises with the computation of weights is that variations occur as between hand and machine drawn wire. To overcome this problem special equip-
ment can be used. At Western Electric a unique wire puller was improvised.

To overcome this problem in the die shop a simple hand powered wire drawing machine was made. This consists of a die holder, a pulling capstan and a measuring wheel driven together. Diameters of the refinished diamond die are checked on the machine by drawing a wire of the next larger gage through the die opening. It is then wrapped around the capstan and fastened to the measuring wheel. The sample is taken by turning the measuring wheel the number of turns as specified on the master chart for the gage size being checked. A slot in the measuring wheel is provided so that the turns of wire are cut simultaneously. This provides several lengths of wire exactly the same length. The number of samples or total length of samples wires varies with the diameter. By doing this, sample weights are produced that fall within the range of the precision balance used for weighing the sample. 30

Most of the inspection equipment described so far finds its best area of usage in final inspection. There is needed, however, a series of in-process checks to insure that the die is being produced according to desired specifications. This is all the more true in view of the fact that once a die develops a crack or serious flaw it becomes scrap and to keep working on the stone after this point is a complete waste of money. Also to be kept in mind is that dies in the small size range are valued according to the diameter of the bearing. The smaller the hole the more is its worth. The workman, therefore, must have accurate measuring instruments at his bench to constantly check that bearing dimensions are being maintained to minimum tolerances.

The eye loop is an indispensable tool to the drilling
process. It gives the workman a rough idea of how the work is progressing although many details are not clearly defined. After many years some workmen get so used to the loop that they prefer it to the microscope which they consider to be solely an instrument for amateurs and apprentices. It is interesting to note that the majority of these workers have had to wear strong spectacles. The difficulty with eye loops is that as the magnification is increased the loop has to be held closely to the workpiece. There is a point that is reached where it is impossible to further approach the lens to the workpiece without bumping into it. This point is somewhere around ten power magnification. The design and construction of eye loops has improved and they now come with graduated scales and comparator etchings which are a great aid in estimating approximate dimensions of the work.

The barrel or screw type micrometer is a fast and accurate instrument to determine the diameter of the bearing. To use it a wire slightly bigger than the size of the hole is pulled through the die and then measured. The same instrument is also used as a comparator to determine the roundness of the hole by taking a number of readings at various points on the wire. The variations in the reading is the degree of out-of-roundness. In shops having numerous micrometers it has been found necessary to make sure that all of them were set to give the same readings. This instrument
is accurate to within .0001 inch. However, some micrometers within a group seem to be constantly either under or over the nominal size and this has caused difficulties in final inspection.

Cost Control

In diamond die production those variable costs which offer the greatest opportunity for possible economy are raw materials, abrasive consumption, and direct labor. With the latter not too much control is possible beyond adequate supervision since workers are paid on an hourly rate which is determined chiefly by local and competitive wage levels. The nature of the work does not lend itself to a cut and dry definition of a 'fair day's work' and there is considerable fluctuation in daily output. There are a few areas, however, in which a cost-conscious management will want to look into. One of these is the popular shop practice whereby all machines are shut off during the lunch break. Workmen usually claim that it is dangerous to leave the work unattended since the needles may become worn and out of shape and may perhaps injure the die. This is true if the period of in-attention is extremely long. In most cases, especially in polishing operations, the rate of wear for such an occurrence is longer than the half hour lunch recess. If the workman sees to it that all needles are re-ground just prior to lunch, there is no valid reason why the machines cannot be left on and unattended for the half hour. The point being made here may
seem on the surface to be rather trivial but actually the time wasted by this practice adds up to almost one working month a year per worker. Another savings can be obtained by running certain machines on a continuous twenty-four hour basis. Although most die companies have only a single day shift certain drilling operations such as the primary cone in big sizes take days of routine drilling with little re-grinding of the needle necessary. The machines used to work on these dies can be left on throughout the evening and night provided that they be well lubricated and in good working order.

The cost of industrial diamond represents thirty to fifty percent of the selling price of the finished die. Yet a die which develops cracks or flaws during the drilling process is in most instances unsellable and becomes worth even less than the raw diamond from which it is made. The only possible salvage value that can be obtained is by conversion of the diamond into powder. This is done by means of the mortar and pestle principle. When done by hand the operation takes about thirty minutes to complete. The crushed pieces that are produced are not immediately utilizable as a drilling abrasive.

It is essential that the crushed particles be graded so that each category contains particles of uniform size. This is because each grade depending on its coarseness can only be used for certain types of work. For example, very fine particles are used for polishing operations while
coarser grades are used for drilling. If both fine and large particles were allowed to be mixed together the result would be that if the powder were used for drilling the work would progress slower than if just coarse abrasives were used. On the other hand, if the ungraded mixture were used for polishing the die surface would be severely scarred by the coarser grains.

The usual method for grading powder is through sieves-(screens)-whose mesh corresponds to commercial powder standards. The diamond particles fall through the openings in the sieves which are used in decreasing sizes. Most diamond die drilling, however, is done with what is called sub-sieve powder. That is to say that the particles are finer than the smallest commercially available sieves. The grading process must then be carried out even further.

The sedimentation method is generally recommended for this purpose. It operates on the principal of Stokes' Law which demonstrates that:

1.) The rate of fall of a particle can be reduced by increasing the viscosity of the liquid, and vice versa;
2.) The rate of fall of a particle increases rapidly with its size, because it is proportioned to the square of its radius;
3.) The lower the density of the liquid the higher the speed of fall and vice versa.

Ordinarily olive oil is mixed with the particles and the solution is allowed to stand for varying amounts of time, after which the oil is poured into another receptacle. In
successive repetitions there is left at the bottom of the mixture progressively finer residual which is removed and properly labeled. No standard time factor exists for each step in the sedimentation process but rather practice differs with each manufacturer. The following suggested procedure appears to be fairly reliable as a guide:

Table IV

<table>
<thead>
<tr>
<th>Grade</th>
<th>Time</th>
<th>Grade</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>3 min</td>
<td>Four</td>
<td>2 hours</td>
</tr>
<tr>
<td>Two</td>
<td>10 min</td>
<td>Five.</td>
<td>5 hours</td>
</tr>
<tr>
<td>Three</td>
<td>20 min</td>
<td>Six</td>
<td>24 hours</td>
</tr>
</tbody>
</table>


Other methods of grading sub-sieve powder are the air flow, fluid-flow, and centrifuging method but these are not universally used for one reason or another.

In regard to possible abrasive consumption economy the emphasis is to be placed not on its reduced employment for drilling but rather on the reclamation and re-utilization of used powder in preference to newly purchased dust. It has been estimated that in the sludge formed during the grinding operations there can be from one to eight carats of diamond per pound. At current market prices this does represent a sizable sum of money.

Reclamation of used diamond powder presents other
difficulties beside those connected with grading and sedimentation discussed above. It must first be separated and freed from that matter in which it is found; e.g. sludge, oil, cleaning solutions, wiping rags. A very logical procedure for the removal of impurities is outlined in the following six steps.

1.) Degreasing with organic solvents for heavy oil or grease contamination. The sample is heated with carbon tetrachloride or trichlorethylene and washed several times with the solvent.

2.) Magnetic separation. A magnet covered with cloth is placed in a beaker of liquid which also contains a mixture of diamond powder and iron or steel. The mixture is stirred and the metallic particles cling to the magnet which is then removed from the beaker.

3.) Sulphuric acid and nitric acid treatment to remove carbonaceous material. The powder is placed in a cup with either one of these acids and is brought to a boil to increase the effect.

4.) Aqua regia treatment to remove metallic contamination. This removes contaminants such as bronze, copper, monel, etc. If alcohol is added to the acid combination a violent reaction is produced. This is a good way to increase the action but it should not be tried by the apprentice.

5.) Caustic/nitrite fusion for removal of carbides, silicates, etc.

6.) Bisulphate/fluoride fusion for elimination of alumina.

To be effective the waste control program has to
receive the support of the workmen. They must willingly cooperate by using proper die cleaning techniques and be meticulous in saving used powder that has collected on rags and in cleaners. Also to be mentioned is the fact that the cutting edges of the reclaimed particles may have been dulled by their prior use. Therefore, such powder often finds its best area of usage in re-polishing and finishing operations.

**Inventory Control**

It is very important to the successful diamond die manufacturer that he be able to give immediate delivery on rush orders. Hardly a day goes by that he does not receive a call from a frantic purchasing agent asking that a shipment be sent right away. The ability to meet such requests is the basis for many a sale and it demands good inventory control.

Generally a perpetual inventory system is recommended. There are commercially available paper systems which greatly reduce the time and effort of keeping the records up to date. These are well worth the price provided that a company has sufficient turnover to warrant their use.

A common practice among manufacturers is to maintain a stock of semi-finished dies. These dies, either mounted or unmounted, have been drilled but are not completely finished or polished. When orders come in the semi-finished die smaller than but closest to the desired finished size is worked up to meet specification. This makes possible a
considerable saving in manufacturing time and also frees working capital which would otherwise be tied up in a less flexible inventory. It also aids production planning which in the absence of sales forecast is done on the basis of orders received and inventory levels.

Most companies have also found it desirable to maintain a stock of finished dies. These are sorted according to quality and size and classified accordingly. There is no great problem in regard to mounted dies since the size and the results of inspection can be easily written on the metallic blank. There is a good deal of difficulty, however, with unset stones because they are troublesome to handle and not easily identifiable. Practice varies as to the method of storage. Some companies combine similar dies in a plastic vial or envelope on which is written the size, the general quality, and the number of stones contained therein. The preferred method would seem to be the use of small cellophane envelopes, one for each stone on which is marked information peculiar to that stone alone.

One of the chief disadvantages of having to carry a complete stock of finished dies is the large amount of duplication that has to be allowed for within each size. For instance, a customer may want a 001" die with a one and seven eighth monel casing or with an inch and one eighth mount or then again perhaps he may want the die in one inch brass. Furthermore, the specifications for this same die
may call for a long bearing for hot drawing or a short 50% bearing.* These variations multiplied by the number of sizes that must be kept in stock amounts to a huge financial outlay.

A problem which has been encountered by most die manufacturers is how they can best move low turnover items. Over a period of time there is amassed in the stock a number of inferior quality dies. These are usually allowed to remain in the inventory from year to year simply because no one knows exactly what to do with them. This is unfortunate in view of the fact that they are collecting additional charges on which no return will ever be realized. A practical procedure to follow would be to enforce periodic inspection of inferior dies to determine whether they will be re-worked, sold as seconds, or crushed into powder. Immediately after the decision is made steps should be taken to see that it is promptly carried out.

Most die manufacturers valuate their inventory on the last in first out basis. One reason for this is the ever present hope of realizing an immediate return on price fluctuations of the raw industrial diamond market. It also serves as a hedge against continued inflation. There is no hard and fast rule which tells management exactly how large an inventory it should carry. To maintain to minimal a stock means possible loss of sales and generally dis-satisfactory service. Too large a stock can mean a serious loss in case some sizes become obsolete and can even spell

* See Appendix II
the failure of the entire enterprise from lack of working capital. Much depends on the judgement of management in regard to prediction of future business activity and market trends.
Significance of Management

The typical diamond die concern is a small business organization. The average workforce totals about thirty shop employees supplemented by perhaps two office clerks, an assistant manager, and the general manager. The latter individual holds the key to the company's success and the entire operation bears a strong imprint of his personality. This is due largely to the fact that he is in direct contact with all the activities of the enterprise. That is why perhaps that competition and customers think of a particular die company not in terms of a distinct corporate body having separate existence in and of itself such as, for instance, a General Motors or a G.E. but rather the company is thought of in terms of Mr. So and So, General Manager.

An example which illustrates this thought is the case of a now defunct diamond die company formerly operated in New York City. This company was owned and managed by an energetic man who thought nothing of spending twelve to fourteen hours a day at work. He had worked his way up through the shop and still spent too much time with the drilling machines and not enough with managerial functions. At any rate the company had a small but reliable clientelle based on long term acquaintances and these enabled the attain-
ment of a modest annual profit. In the early 1950's the owner who was advancing in years became less enthusiastic about the business and put it up for sale. It was bought by a larger New Jersey outfit who paid somewhat more than the actual worth of the physical assets. The feeling was that many of the company's customers would make the transition to the new management, some of whom offered interesting possibilities for future sales. The new owners took painstaking care to insure these customers that the same standards and workmanship would be offered and in fact set up a separate division for their convenience. Despite these efforts and even though the New Jersey company enjoyed a better reputation, could offer dies of at least comparable if not superior quality, to say nothing of more prompt delivery and service; at the end of two years only three of the dozen or so top customers were ordering regularly. The only likely conclusion that could be reached from this case was that the personal element which disappeared with the retirement of the former owner could not be replaced by a simple transferral of title.

The Pitfalls of Subjectivism

Perhaps as an adjunct to the "one man show" type of leadership which dominates the industry is a characteristic subjectivity. This is seen in the initiation of policy decisions based almost entirely on personal judgment and hunch. It is evident in the lack of trade-wide data on which
to trace changing trends and future predictions. The many short-range expedients which turn out to be long range blunders are also a manifestation and result of this characteristic. Subjectivism has carried over into the production area where it has prevented the establishment of universal standards and practices. Without a yardstick with which to compare the ideal versus the actual it becomes difficult to determine exactly which dies are good and which are bad. Purchasing, therefore, becomes based on tangible price considerations rather than nebulous and unproved platitudes about quality. This leads unavoidably to bitter price competition and undercutting. Such conditions not only make all die makers in general less prosperous but also forbode the eventual bankruptcy of many conscientious but not quite so unscrupulous companies. The policy of allowing cheap foreign imports to flood the American market has not made the die producer's struggle for survival any easier but no group action has ever taken place to block this undermining of the domestic market.

A case in point concerns itself with an American importer who had a reputation for good small size dies. These he bought in France and sold at relatively high prices in this country. The firm was actively seeking the business of a big Newark, N.J. wire-drawer whose purchasing agent happened to be a woman. For some un-fathomable reason not much headway was ever made with this account.
The importer also sold small size dies to a nearby competitor who was allowed a discount because he purchased in quantity and did not require special mountings. This buyer subsequently mounted the dies, put his name on the casings, and re-sold them at just above cost. This competitor was likewise interested in the Newark wire-drawer and did in fact get the majority of the business. The purchasing agent insisted that his dies were vastly superior to the importer's who eventually stopped dealing with both the customer and the other supplier. Reportedly the wire mill is now buying dies directly from Europe at a decided price advantage.

A Plan of Action

In conclusion it would seem most advisable for management to take a broad long range view of the entire business picture. In the past the tendency to concentrate totally on a small segment within the whole has often had unfortunate consequences. The industry should take a more positive attitude and join together towards the solution of common problems. There should be a united single purpose effort in the protection of markets from foreign pirates, in the establishment of fair and equitable prices, in the search for new application and uses. Diamond die manufacturers should march together towards the heights of progress and technological developments that will open the gates to greener pastures. Then and only then will the industry gain that degree of integrity and stature that will enable the members to partake of an economic prosperity and well-being that they can and should enjoy.
Appendix I

Structural Aspects of Diamond

It is common knowledge that diamond is the hardest known natural mineral. Few individuals, however, understand what makes diamond have this characteristic. According to a leading diamond technologist:

The hardness of the diamond is largely due to the fact that great energy is required to liberate one or more carbon atoms from their tetrahedral surroundings, since this involves the breaking of several bonds and disruptions of their symmetry, which is essential in valence-bond crystals.

Figure 9

The Structure of a Diamond Cell

Diamond crystallizes in the cubic system. The arrangement of the carbon atoms in an elementary cell is characteristic, and other solids having a similar arrangement are said to have the diamond structure. In such materials the binding force between the atoms are of the valence type. They have the important property of showing pronounced preferred directions in space. The carbon atoms in the diamond lattice each have four nearest neighbors arranged tetrahedrally around the central atom, the four bond directions being thus arranged symmetrically in space.

Much has been written concerning the best orientation to seek in drilling a diamond die. In practice there
exists no uniformity of method.

Of fifty British made diamond dies recently examined by x-ray methods, the majority had the drawing axis near the two point direction, many were three point, but only one was anywhere near the four point direction which has been claimed as the ideal direction to give maximum die life. 37

Figure 10

Possibilities for Placing the Hole in a Diamond Crystal

Perpendicular to an Octahedron face
Perpendicular to an Rhombic-Dodecahedron face
Perpendicular to a cube face


Opinion seems to vary greatly as to the effect on the wear resisting ability of the diamond that is caused by drilling the die hole in any particular plane. Some contend that the effects of orientation are completely offset when a die is set in a metallic mount. On the other hand others believe that the wear resistance is increased up to 67% by drilling in a particular plane. A group of noted experts who studied this problem came to the conclusion that the hole is preferably placed perpendicular to an octahedral plane. 38

37
38
39
40
Figure 11
Comparison of the Effects Which Result From Drilling a Die
in a Particular Plane

A hole drilled perpendicular to a cube face is bounded by cube and rhombic-dodecahedral planes. Wear will occur mainly in the rhombic-dodecahedral planes which will eventually give the appearance of a square.

A hole drilled perpendicular to a rhombic-dodecahedral plane is surrounded by all three types of planes. Wear will occur mainly in the cube planes and appear as an oval.

A hole drilled perpendicular to an octahedral plane is surrounded by rhombic-dodecahedral planes, all wearing at a uniform rate.

It is supposed that in wearing these planes give way to octahedral planes of which those marked 0 will wear because of their unfavorable orientation with respect to the drawing direction.
Appendix II

The Ideal Diamond Die.

It is difficult to think of a perfect die shape without reference to the purpose for which the die is to be used. The profile varies with the type of wire to be drawn. Soft metals—(copper, silver, gold, aluminium)—are drawn through dies having a very short bearing. The term applied here is cold drawing. Medium hard metals such as bronze, nickel, brass, and some steels demand a somewhat longer bearing. The hard metals—(nickel-chromium, hard steels, tungsten and molybdenum)—must be drawn with dies having up to 100% bearings.

The fact that there is a number of variations in die shape does not preclude the establishment of standards. Perhaps a step in this direction has been taken by the issuing of the National Stockpile Purchase Specification, P-67-R, July 16, 1958. Section 3 states:

a. The entrance and exit surfaces of the die shall be plane and parallel.

b. The minimum thickness of the die between the entrance and exit surfaces shall be 0.040 inch.

c. Each die shall have an entrance or primary cone, a secondary cone, a bearing, a relief, and an exit or back cone. The center line or axis of the cones, bearing, and relief shall be the same straight line, which shall be perpendicular to the entrance and exit surfaces of the die.

d. Each die shall have a flat surface ground and polished for a window which shall be perpendicular to the entrance and exit surfaces of the die. The window shall be large enough to permit viewing the secondary cone, bearing, relief, not less than one-third of the entrance cone next to the secondary cone,
and not less than one-third of the exit cone next to the relief.
e. The axis shall be in the center of the die stone, in order to assure maximum utilization in redressing.
f. The distance from the axis to the exterior surface of the finished die, on a plane parallel to the entrance and exit surfaces, shall be not less than 2.5 x (diameter of bearing).
g. The primary cone shall have an included angle of not less than 30 degrees (or a minimum angle of 15 degrees with the axis). The secondary cone shall have an included angle of from 12 to 20 degrees (or an angle of from 6 to 10 degrees with the axis). The entrance cone shall be blended into the secondary cone and the secondary cone shall be blended into the bearing.
h. The length of the secondary cone shall be not less than 0.005 inch.
i. The bearing shall be cylindrical in shape. The rated size of the die shall be to the nearest fifth decimal point.
j. The length of the bearing for hot drawing shall be not less than 90 percent or more than 125 percent of the diameter of the bearing.
k. The length of the bearing for cold drawing shall be not less than 50 percent or more than 75 percent of the diameter of the bearing.
l. There shall be an exit or back cone which shall have an included angle of not less than 80 degrees (or a minimum angle of 40 degrees with the axis). There shall be a well-rounded relief between the bearing and exit cone.
m. All ridges formed when the hole is drilled shall have been removed. The secondary cone, the bearing, and the relief of the finished die shall be highly polished to a mirror finish.
Bibliography

1.) Fayol; Henri. General and Industrial Management. (1916) (Sir Isaac Pitman and Sons Ltd. 1949)


5.) Lewis; Kenneth B; Op. Cit. P. 69


8.) Calculated from current price lists.


10.) War Production Board: The W.P.B. Reports on Diamond Dies. Wire and Wire Products. Vol.20 No.3 March 1945 P.224

11.) Comparison based on wages received by author in 1956-57.


21.) Grodzinski; Paul: Op. cit. P.904


32.) Grodzinski; Paul: Op. cit. P.343


