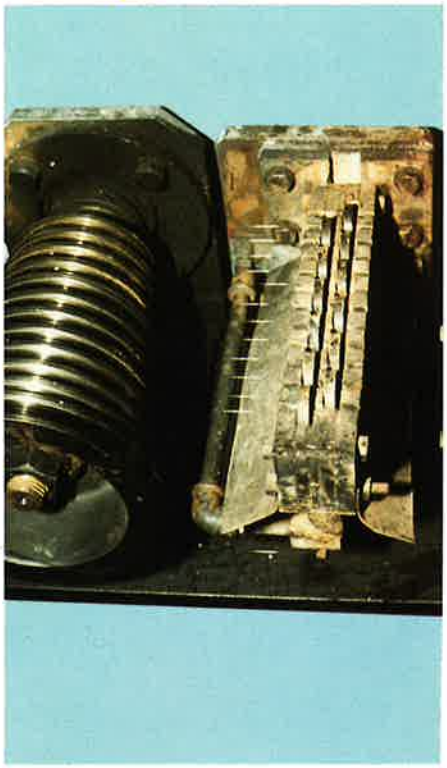

# Diamond Wire-drawing Dies

TUNGSRAM

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# SELECTION OF ROUGH DIAMONDS

TUNGSRAM wire-drawing dies are diamond products manufactured with up-to-date methods. These are the best choice for high quality wire drawing. Their use makes wire production economic and improves wire geometry, surface features and the mechanical properties of the end product.
The first thing in ensuring high quality for our products is the selection of the right rough diamond.
Perfect diamonds are colourless and clear.
Coloured diamonds contain contaminants (e.g. iron oxyde, copper oxyde, cobalt, etc.) which enter the crystals in the early stages of their formation. These colours vary from bluish-white to dark brown, however, occasionally black diamonds can be seen.
Diamonds exhibit highly varying features. Not only individual crystals differ in both structural and mechanical properties, but also the same diamond may have portions with significant discrepancies (e.g. in the case of inclusions).
TUNGSRAM, relying on its own experiences gained during several years in this industry, uses in standard mounts only superior, clear, colourless or yellowish-white natural monocrystals that are free of inclusions and of secondary strains (though recently polycrystalline diamonds of other manufactures, namely those of other leading houses are also offered in our mounts).
The high quality of our monocrystalline diamonds is warranted, among other methods, by selection using polarized light under microscope. This test is repeated after boring.
Consequently, the constant high quality of our diamond drawing dies is ensured. Anisotropic diamond features are respected in boring and in choosing the direction of the bore.
Of the critical properties, the most striking ones are susceptibilities to cracks in different cristallographic directions and to wear appearing in dependence upon similar directions.
Theoretical crystallographic considerations and our practice in the industry of wire drawing suggest for the bore perpendicular (or near to perpendicular) directions to the natural octahedral facet. To this effect,

**Fig. 1**
Rough diamonds

rough diamonds selected for drawing dies are subject to careful orientation and X-ray diffraction methods are applied for testing.
The risk of breaks and cracks is reduced to a minimum and both long life and highly constant dimensions are warranted by this care.

**Fig. 2**
Cutting of diamonds

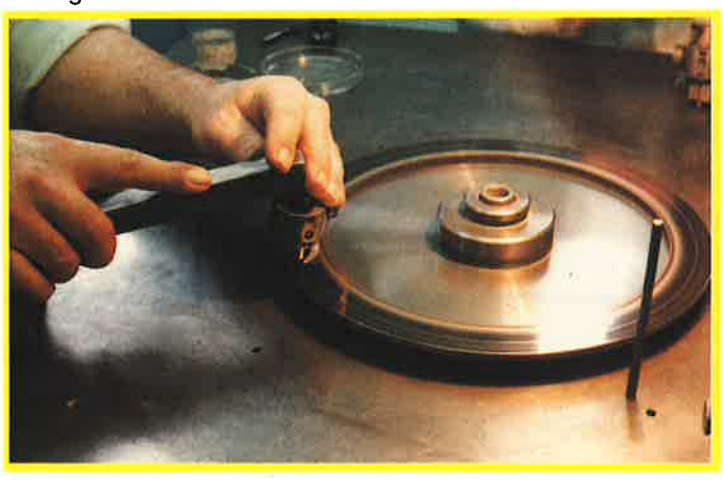


**Fig. 3**
Direction of the bore
in octahedral diamonds

# PROFILE OF THE BORE

Diamond drawing dies are precision tools. In wire drawing, the drawn material passes through a die the diameter of which is less than that of the material to be drawn. Adequate profiles of the bore are defined by the working conditions and by the properties of the drawn material. The quality of the wire produced and the longevity of the die both depend mainly upon the profile shown in Fig. 4.

Every part of the die profile is significant, as they influence the wire quality produced using the die in question, and as they act upon the longevity of the die itself. The performance of the die can be attributed mainly to factors such as the choice of the reduction angle and like the amount of reduction in diameter, though deficiencies in the smooth transition of profile sections and in the concentricity of the same, have their impact on the ovality and curliness of the wire drawn.

In Fig. 5 and 6 the typical profile patterns of bores used for the drawing of soft and hard materials are shown, respectively. The value of the reduction angle $2\alpha$ is 18° to 22°, for soft materials and 10° to 14° for hard materials. Actual values for the angles are chosen to suit the specifications of our customers.

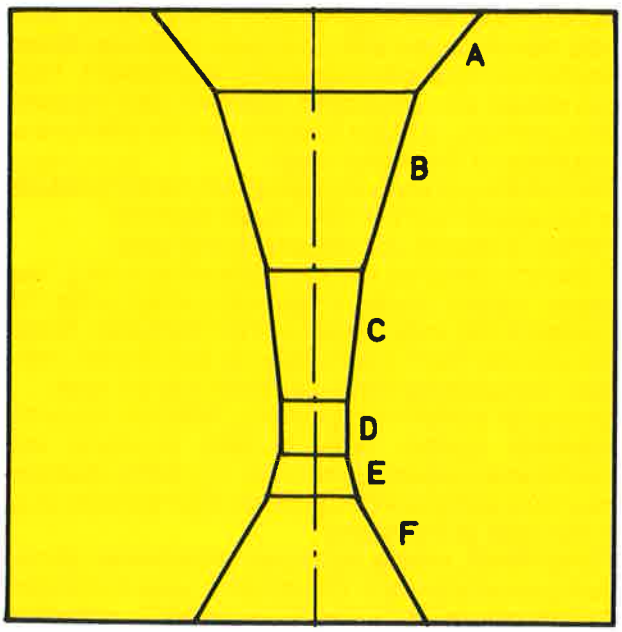



**Fig. 4** Profile of the bore
A—opening bell/entrance
B—approach
C—reduction zone
D—bearing
E—back relief
F—exit

**Fig. 5**
Profile for soft materials

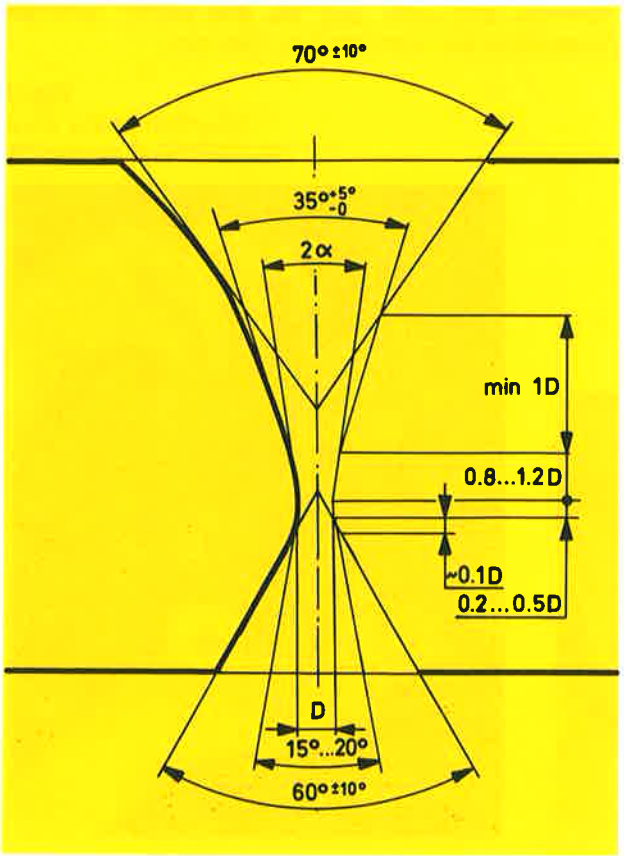
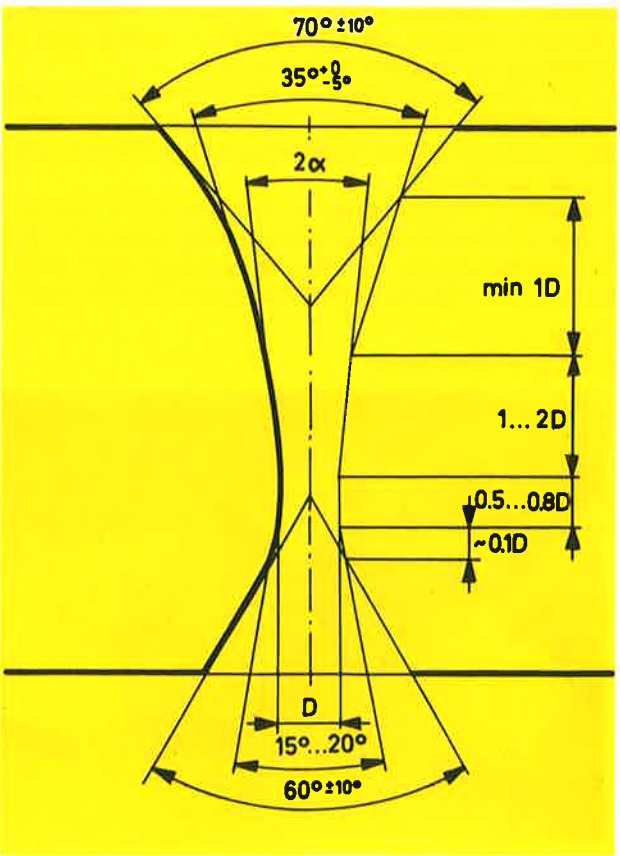



**Fig. 6**
Profile for hard materials



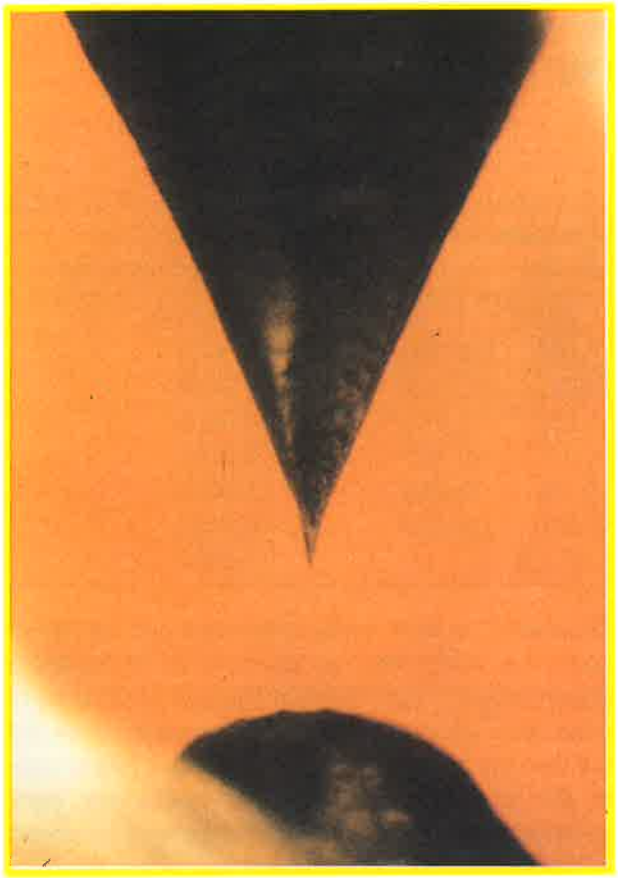


**Fig. 7**
Semi-finished bore shape produced using laser

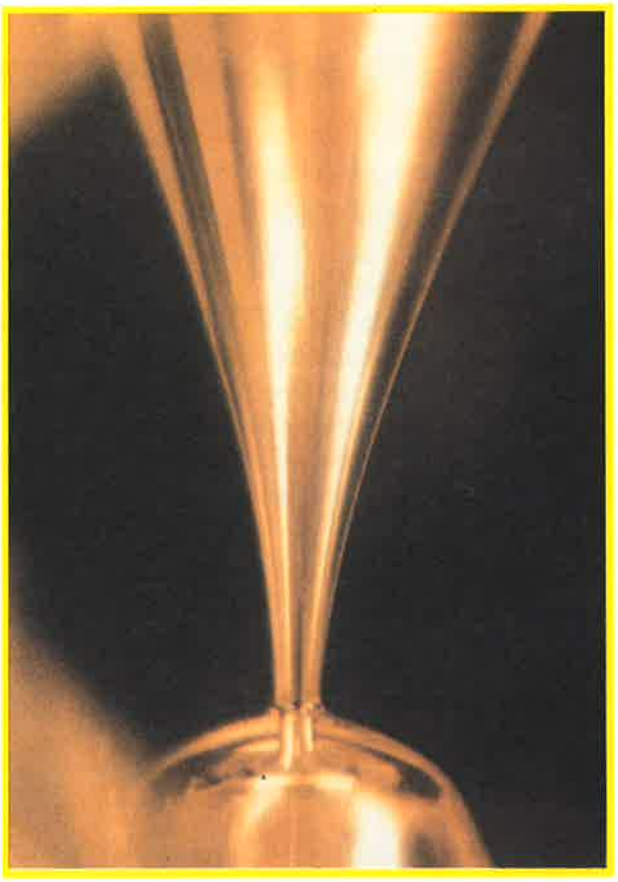


**Fig. 8**
Bore shape in a diamond die

Die profiles have been developed starting with theoretical considerations. Experience has shown the way to economic aspects, namely dies can be re-bored repeatedly though bore-hole diameters are increased each time by re-boring and repolishing. Special requirements in particular cases can be respected in designing profiles, your particular specifications for the following, will enable us to provide you with the best die for your special objectives:

— diameter of the bore/bearing;
— diameter tolerance;
— mounting dimensions;
— quality and hardness data of the material you intend to produce;
— initial diameter of the inlet wire;
— machine specifications whether multistep or single drawing machines are used;
— if multistep, subsequent reduction rates;
— drawing speed;
— drawing temperature;
— lubricant specifications.

TUNGSRAM-made die bores are mirror-polished in the reduction zone, the bearing and the exit, giving superior wire surface quality in the production and resulting in the prolongation of die life. The other profile parts are provided with fine polish. Our special mirror polishing methods, the use of advanced tools and the high technical skills of our experts warrant excellent results.

**Fig. 9**
TUNGSRAM-made wire-polishing machine for die boring

## TOLERANCE ON THE DIAMETER OF THE BORE

Die bore sizes can be tested mainly in three ways:
— the diameter of a sample drawn through the die is tested using a micrometer,
— the electric resistance of a defined length in the sample drawn through the die is tested,
— the weight of a defined length in the sample drawn through the die is determined.

The standard tolerances of TUNGSRAM-dies are comprised in the following table:

| Diameter of the bore in mm | Tolerance on diameter in mm |
|---|---|
| ≤0.020 | 0.015×D |
| 0.020 . . . ≤0.025 | 0.0003 |
| 0.025 . . . ≤0.050 | 0.0004 |
| 0.050 . . . ≤0.075 | 0.0006 |
| 0.075 . . . ≤0.100 | 0.0008 |
| 0.100 . . . ≤0.200 | 0.0015 |
| 0.200 . . . ≤0.350 | 0.0020 |
| >0.350 | 0.0030 |

On special request, other tolerances can be agreed upon, e.g. tolerances can be confined to deviations only in positive or in negative direction. (As far as no other specifications are received from our customers, our dies are manufactured with negative tolerances.) In the case of peculiar strict tolerances being specified, please indicate the desired testing method, as results obtained with different methods may exhibit discrepancies. (In our tools, tolerances on the roundness of the bore, if they do not exceed bore size tolerances, are admitted.)

## DIE MOUNTING

In wire drawing, high radial strains can arise in the die bore, which can damage brittle, fragile diamonds if they are not supported by cases. Good supports cause preliminary strains in diamonds to resist drawing strains.

In addition, local overheating is eliminated by the thermal conductivity of the case, if its material is chosen carefully.

TUNGSRAM diamonds are sintered, in compliance with the above conditions. The perpendicularity of the die bore axis to the entrance and exit plane of the mounting, as well as the concentricity of the bore in the case are warranted by our special sintering method.

In designing our die cases, the specifications of our customers are considered.

## HANDLING AND CHECKING OF DIES

When using our dies, please be sure that the wire runs without a break straight through the dies and that the wire lubrication and the heating or cooling units operate efficiently. If the wire surface becomes rough in the production, this defect may be due to the failure of the die. Do not omit to replace defective dies!
Inspect, maintain and repolish dies regularly! Take special care of the correct profile in reboring!

For testing of dies in maintenance, up to bore diameter 150 $\mu$m, monocular microscopes with magnification by 100 . . . 150, and above bore diameter 150 $\mu$m, high luminance stereomicroscopes with a magnification of 40 are recommended.

## POLYCRYSTALLINE DIAMOND WIRE-DRAWING DIES

Spatial anisotropies in the mechanical and physical properties of monocrystals may be drastic features in dies, namely their resistance to wear varies in each crystallographic direction. Large, precious diamond monocrystals used for the drawing of thick and/or very hard wires are in addition brittle and can soon break in normal operating conditions. Tungsten carbide cores are rather soft and wear away easily, frequent replacement is inevitable because of the variation of wire diameters produced and also the quality of the wire surface is inferior to that of wires drawn with diamond dies, though they require less performance from the machinery. To overcome all these difficulties, polycrystalline diamond dies have been developed by General Electric. These are produced by sintering small diamond particles, that achieve spatial homogeneity in wire production. Another advantage is the use of synthetic diamonds in wire manufacture, whereby the hegemony of natural diamonds in the industry is broken.

Diamond sintering is a rather complex process involving the use of high pressures and high temperatures. A wide range of polycrystalline diamond dies has been developed by General Electric under the brand-name COMPAX, of which the main types are shown in the subsequent table, with indications concerning size ranges for different uses. These latter data give valuable information also for reboring.
Polycrystalline diamond dies owe their extraordinary success on world markets to a quite special economy in their use, they constitute an improvement resulting in superior wire quality as compared to that obtained with former methods. Though they are available at higher prices than natural diamonds for the same size range, their life is prolonged to its multiple. E.g. the following data are warranted for COMPAX dies (without full details):

| Material | Wire size | Relative life |
|---|---|---|
| Aluminium | 0.64 ... 2.6 mm | 3 times better than natural diamond |
| Copper | 1.84 ... 4.6 mm | 200 times better than hard metal |
| Copper | 0.40 ... 2.05 mm | 10 times better than natural diamond |
| Tinned copper | 0.50 ... 1.45 mm | 8 times better than natural diamond |
| Nickel | 0.33 ... 1.45 mm | 10 times better than natural diamond |
| Tungsten | 0.18 ... 0.62 mm | 4 times better than natural diamond |
| Molybdenum | 0.38 ... 1.02 mm | 70 times better than hard metal |
| Molybdenum | 0.18 ... 1.02 mm | 5 times better than natural diamond |
| Steel with copper coating | 0.17 ... 0.96 mm | 4 times better than natural diamond; 20 times better than hard metal |
| Carbon steel | 0.17 ... 1.05 mm | 36 times better than hard metal |
| Stainless steel | 0.41 ... 1.6 mm | 6 times better than natural diamond |
| Chrome-nickel steel | 0.23 ... 0.91 mm | 5 times better than natural diamond |
| Structural steel | 1.55 ... 3.2 mm | 40 times better than hard metal |

**Fig. 10**
High yield automatic ultrasonic boring machine for polycrystalline diamonds

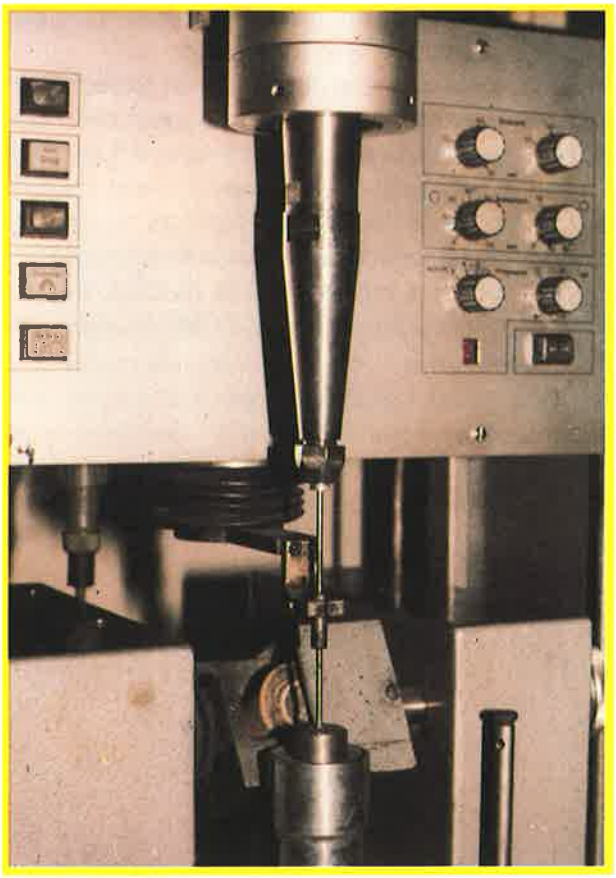
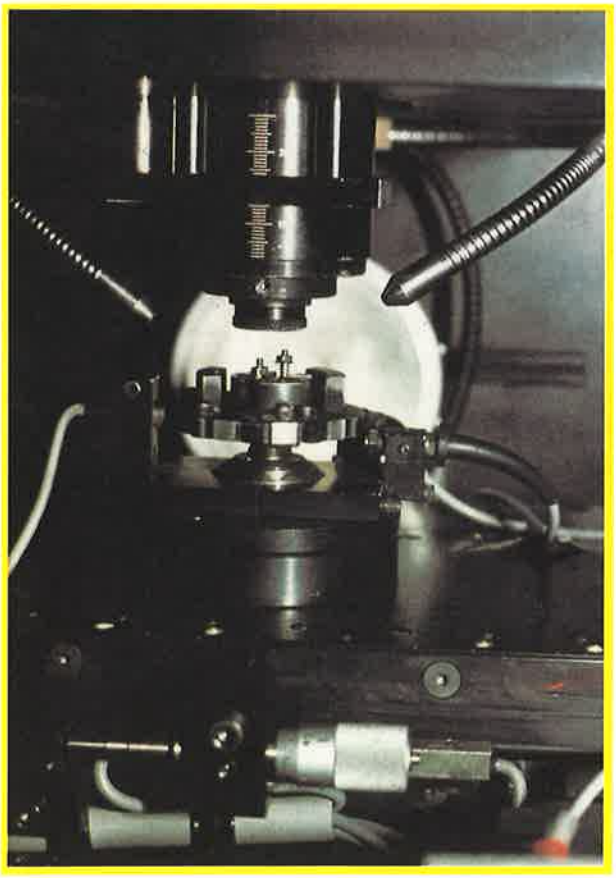
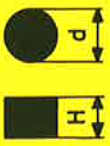


**Fig. 11**
Diamond boring with laser method



# COMPAX* blanks

| Product No. | Product configuration | Rating values (mm) | | | | | Explanation |
|---|---|---|---|---|---|---|---|
| | | Outside diameter, D | Diamond diameter, d | Diamond thickness, H | Hole diameter | | |
| | | | | | for soft wire | for hard wire | |
| 5120 | | sector 90° | 0.90 | 0.85 | 0.120 . . . 0.400 | 0.120 . . . 0.300 | |
| 5235 | | 3.99 | 1.5 | 1.5 | 0.120 . . . 0.800 | 0.120 . . . 0.600 | |
| 5430 | | 8.12 | 2.4 | 2.3 | 0.300 . . . 1.300 | 0.250 . . . 1.050 | |
| 5435 | | 8.12 | 3.5 | 2.9 | 0.700 . . . 2.200 | 0.500 . . . 1.350 | |
| 5530 | | 13.65 | 5.1 | 3.8 | 1.300 . . . 3.300 | 0.900 . . . 1.850 | |
| 5535 | | 13.65 | 6.4 | 5.3 | 2.200 . . . 4.600 | 1.300 . . . 2.600 | |
| 5735 | | 24.13 | 12.9 | 11.6 | 3.300 . . . 7.600 | 1.800 . . . 5.800 | |
| 5010 | | — | 3.2 | 1.0 | 0.120 . . . 0.600 | 0.120 . . . 0.400 | |
| 5015 | | — | 3.2 | 1.5 | 0.120 . . . 1.000 | 0.120 . . . 0.600 | |
| 5025 | | — | 5.2 | 2.5 | 0.500 . . . 2.000 | 0.250 . . . 1.100 | |


* General Electric's registered trade-mark

**Fig. 12**
Polycrystalline diamond wire-drawing dies

Needless to say, in recent years other Houses succeeded in developing and selling polycrystalline diamond dies, similar to the ones produced by COMPAX, as regards technical characteristics. The high technicity of our methods helped us in developing special techniques for polycrystalline diamond die manufacture when facing international competition. TUNGSRAM's reputation is enhanced by this new achievement.

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