



Black Diamond
Drilling Services Australia

BD Drill

Cemented Carbide

www.bddrill.com.au



BD Drill Black Diamond Drilling Services Australia Pty Ltd

The Three Advantages

To meet the international upscale market demands for high grade cemented carbide on products of high air pressure DTH bit, tricone bit and top hammer drill bit, Black Diamond Drilling Group has established a specialised Cemented Carbide Section in December of 2015. With a strong foundation of drilling working conditions and extensive knowledge of bit manufacturing and TCI configurations. BD Drill has specialised in researching and manufacturing super strength and toughness cemented carbide geologic and mining tools. The following is a brief introduction of the advantages of our cemented carbide.

Innovation Oriented

- Cemented Carbide Section adheres company's innovation-oriented concept to utilizes the unique advantages on professional, precise, and deep in drilling industrial, create a new business model in cemented carbide customization for drilling tools.
- BD Drill has a group of senior engineers with rich experience in the research and development of cemented carbides and a group of senior technicians who have been working on carbide producing 20 to 30 years.
- We have imported the most advanced production and inspection equipment from Germany, Japan and other countries to constantly improve the production process and enhance the ability of the new technology utilizations.

Superior Quality

- **Raw materials supplier:** The suppliers of tungsten carbide we are working with are German wholly owned manufacturer, the raw materials are also manufactured by professional manufacturers to ensure the hi-grade performance of raw materials supplied.
- **Quality Control:** By adopting the most advanced production technology and quality control system in Europe ensures the products quality is always high.
- **Accurate Inspections:** Precision is the highest level for superior cemented carbide products. Our company has imported the most advanced physical performance testing equipment from Japan and Germany, the testing results are accurate. At the same time, our cemented carbide testing standard is higher than the GB Standard and the Industrial Standard.

Customised

"Customized for special applications to provide the best carbide solution" is the characteristic concept of BD Drill, combining the accurate ability controlling of end-user's requirements in the drilling industry to meet the different requirement from different customers. Manufacturing the products with its high quality and better suitability to provide professional personalized service and good interaction to maximize the performance in its specific work conditions.

What is cemented carbide?

Cemented carbide was invented by the German Mr. Schroter in 1923, It is a kind of insoluble compound basis with metal hardness (hard phase) and the metal as binder (metal phase) by powder metallurgic method made high strength and high wear resistant material. WC-Co cemented carbide is composed by WC hard phase and Co bonding phase, the hard phase result in cemented carbide's wear resistant characteristic, the binder phase result in toughness. This composition of normal cemented carbides has the characteristic of contradictory properties, good toughness inverse to poor wear resistance, good wear resistance inverse to poor toughness.

Basic features of cemented carbide.

- 1 – High hardness and high wear resistance, especially at higher temperatures still has high hardness means the red hardness feature.
- 2 – High elastic modulus, good rigidity.
- 3 – High compressive strength.
- 4 – High chemical stability and high resistance to acid corrosion.
- 5 – Low expansion coefficient.
- 6 – Low fracture toughness.

Application of cemented carbide.

Commonly known as "the teeth of industry", cemented carbides are widely used as cutting tools, impact tools, wear-resistant and corrosion-resistant parts, and play an important role in cutting, geological exploration, mining, oil drilling, mould manufacturing and other industries.

Microstructure – Phases in cemented carbide manufacturing.

1. **HARD PHASE:** The hard phase of WC-Co cemented carbide is WC phase with microstructure of hexagonal system, belong to unequal axis crystal system. The dissolution and precipitation are directional in liquid sintering, which makes the geometrical shape of WC particles and size in difference, appear in angle angular, result in an uneven stress distribution, stress concentration, and affecting the toughness of cemented carbide. The angle of WC phase can be improved by heat treatment to rounding off status, so that stress concentration can be reduced, and toughness can be improved.
2. **BONDING PHASE:** The bonding phase of cemented carbide is Co phase, which has two structures of HCP and FCC. To add rare earth elements in Co that can improve the strength & toughness of the bonding phase, and adding of a small amount of ruthenium, i.e. Co-Ru binder, can stabilize the hexagonal structure of Co in high temperature and increase the toughness and wear resistance of cemented carbides at the same time, and greatly improve the anti- collapsing ability of the carbide blade.
3. **DECARBURIZATION PHASE:** In the sintering process of cemented carbide, due to the lack of carbon in raw materials or decarburization in sintering medium, part of tungsten dissolved in the cobalt phase cannot form WC. The part of cobalt atom participates in forming W-Co-C ternary compound or W-Co binary compound, this kind of compound named decarburization phase.
4. **NON-CARBON COMPOUND:** It also known as free carbon or graphite inclusions, when nest-shaped gathering or schistic small pores are observed by microscope from grinding sheet, that is non-carbon compounds. The main reasons for reacting non-carbon compound are: a. The total carbon content in raw materials is too high; B. Too much carbon content from padding; C. The products in the boatpan are closed to the graphite boatpan wall; D. Dewaxing, pre-sintering, sintering process out of control, etc.



Microstructure Parameter

GRAIN SIZE: The grain size of carbide phase is one of the most important features of cemented carbide. In the production of cemented carbide, the grain size of carbide must be controlled in addition to carbon content controlling. The comparison method is often used in production to compare the most characteristic part of the grinding sheet with the standard pictures of known grain size.

The grain size as usual is based on the grain size of cemented carbide products. The German standard is commonly used, and the grade is divided according to the following standards:

Level	Grain Size
Nanoscale	0.1~0.3 μm
Ultrafine	0.3~0.5 μm
Extrathin	0.5~0.9 μm
Fine	1.0~1.3 μm
Intermediate	1.4~2.0 μm
Medium Rough class	2.1~3.4 μm
Rough class	3.5~4.9 μm
Ultra Bold	5.0~7.9 μm

CARBIDE CONTIGUITY: Carbide contiguity is the proportion between interface in carbide and entire surface, its value depends on the amount of cobalt contained, sintering time and temperature which has important role to carbide mechanical properties.

THE MEAN FREE PATH OF BONDING PHASE: The cobalt layer thickness between hard phase and two particles is an important parameter, the changing of cobalt content and particles size along with thickness of cobalt layer which can be represented by mean free path.

POROSITY: The size of porosity is a significant symbol for cemented carbide's quality. The existing of pore greatly reduced strength and other properties of carbide, the single black point with sharpness border in size 5-40µm can be observed by 100-fold magnification microscopes that is pore. Porosity is proportion percentage of pore in a field.

Pore level		The pore size
A00		Class A pores not found
Level A	A02	<10µm
	A04	
	A06	
	A08	
Level B	B02	10-25µm
	B04	
	B06	
	B08	
>25µm		25-75µm
		75-125µm
		>125µm
Serious contamination		Too many holes

Parameters of cemented carbide.

CARBON AND OXYGEN CONTENT: Carbon and oxygen play an important role in cemented carbide. Carbon is the life of cemented carbides, and existence of oxygen affects carbon. One oxygen atom will consume 0.75 carbon atom. The carbon content in WC powder includes total carbon content and free carbon content, the total carbon content and free carbon content are measured by mass method. Oxygen is a microelement with low content. Usually, the analysis of oxygen content of powder is to analyse the total oxygen content of powder, including adsorbed oxygen and combined oxygen.

DENSITY: The density of cemented carbides is usually measured by water drainage method. According to Archimedes theory, the buoyancy of carbide in water is equal to the mass of the water discharged by carbide sample. The density of WC-Co cemented 3 3 carbide is usually 14.3g/cm -- 15.0g/cm.

HARDNESS: The hardness represented the AXility of against deformation resistance. The hardness of cemented carbide represents as Rockwell A hardness HRA and Vickers hardness HV, Vickers hardness has higher accuracy than Rockwell hardness.

Rockwell Hardness and Vickers Hardness Comparison Table

HV10	HRA	HV10	HRA
1900	93.5	1350	89.3
1850	93.1	1330	89
1800	93	1250	88.5
1750	92.5	1200	88.1
1700	92.3	1150	87.6
1680	92	1100	87
1650	91.7	1050	86.4
1600	91.5	1000	85.7
1560	91	980	85.5
1500	90.5	950	85
1430	90	900	84.3
1400	89.9	870	84
1370	89.5	800	83.5

BENDING STRENGTH: Cemented carbide is kind of fragile material, when examine the strength of carbide through tension test, it is hard to get accurate data due to the great influence of sample mounting accuracy. Therefore, the strength of carbide is usually evaluated by measuring the transverse fracture strength, which is called bending strength.

FRACTURE TOUGHNESS: The fracture toughness of cemented carbide is the ability of resistance of crack development and the ability of materials to resist fragile cracking.

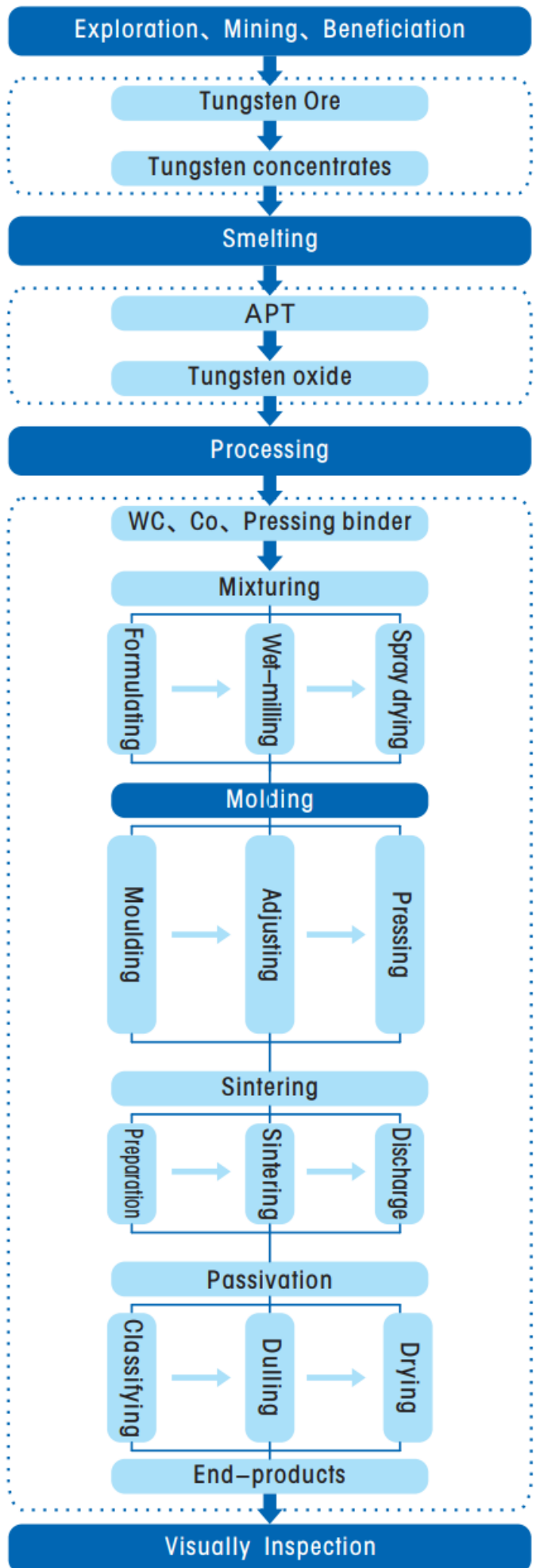
COERCIVE FORCE: Cemented carbide is characterized by ferromagnetic materials due to its inclusion of cobalt, a ferromagnetic substance. After the cemented carbide sample is magnetized in the DC magnetic field to the technical magnetic saturation status, remove the external magnetic field, and there is still some magnetism in the cemented carbide. To make the sample completely demagnetized ($M=0$), a magnetic field in the opposite direction must be added. The magnetic field intensity in this direction is the coercive magnetic force to be measured. The coercive force H_C is measured in KA/m; it is the amount of the reverse magnetic field applied to reduce the magnetic strength of the sample to zero.

MAGNETIC SATURATION: Magnetic saturation of cemented carbides (MS) reflects the relative content of the bonding phase in the carbide, thus determining the content range of magnetic materials such as cobalt, nickel and iron in the product and indirectly reflecting the carbon content in the sample. The relative magnetic saturation calculation formula of cemented carbides is as follows: $M (%) = \frac{e}{W} \cdot K$ -- correction coefficient, e -- the relative saturation magnetization strength measured in the carbide, and W -- the actual cobalt content of the carbide. The content of carbon and impurity in the carbide is estimated after the magnetic saturation value of cemented carbide is measured.

Grade Table

Main physical and mechanical performance indexes of each grade					
Grade	Density (g/cm ³)	Hardness (HV30)	Coercive force (Ka/m)	Grain size (um)	TRS (MPa)
306-G01	14.95	1460	12.6	Intermediate	≥3200
306-G02	14.95	1440	11.6	Intermediate	≥3200
306-G03	14.95	1500	13.2	Intermediate	≥3200
206-S01	14.95	1460	12.6	Intermediate	≥3200

Production process



The shape of carbide



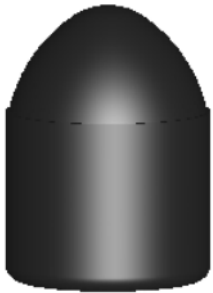
Domed / Spherical Button

Domed / Round Buttons are usually used as gauge buttons of DTH Bits, they are suitable for very abrasive and very hard formations.



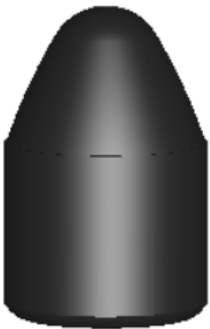
Sharp Ballistic Button

Sharp Ballistic Buttons are usually used as front buttons of DTH bits for soft formations where fast penetration rates are possible and button breakage is minimal.



Semi-Ballistic Button

Semi-Ballistic Buttons are usually used as gauge buttons and front buttons of DTH Bits, suitable for medium abrasive and hard formations.



Ballistic Button

Ballistic Buttons are usually used as front buttons of DTH Bits, suitable for medium abrasive and medium hard formations. They can also be used as gauge buttons if the rock is soft.



Flat Button

Flat Buttons are usually used as protection buttons to reduce wear on rubbing surfaces of DTH Bits.



Double Dome Button

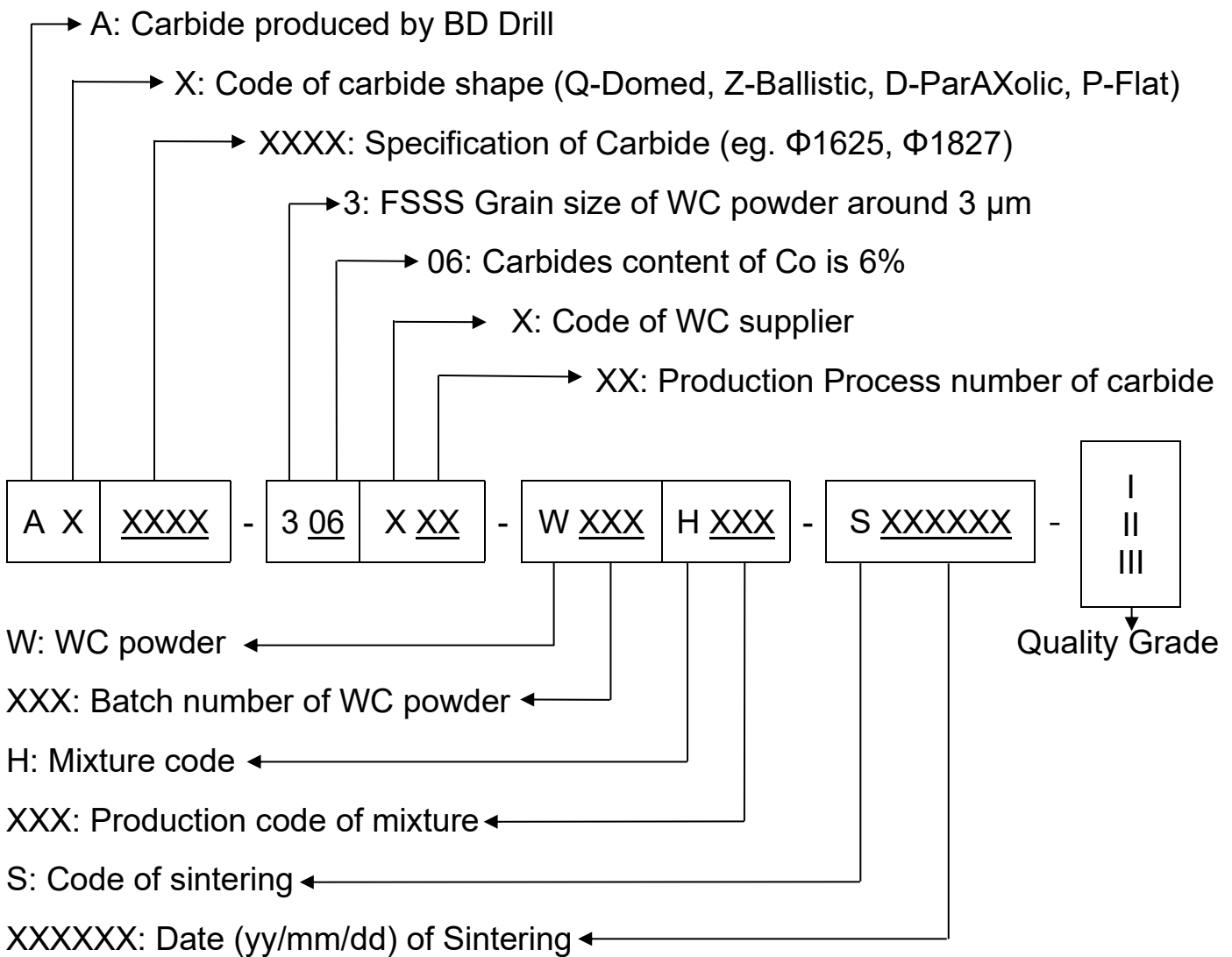
Double Dome Buttons are usually used for drilling hard rock, they can provide longer life span 20-40% in premise of re-grinding carbide.



Chisel Button

Chisel Buttons are used in tricone bits for drilling medium-hard formation with the higher penetration rate.

Carbide Naming Principle

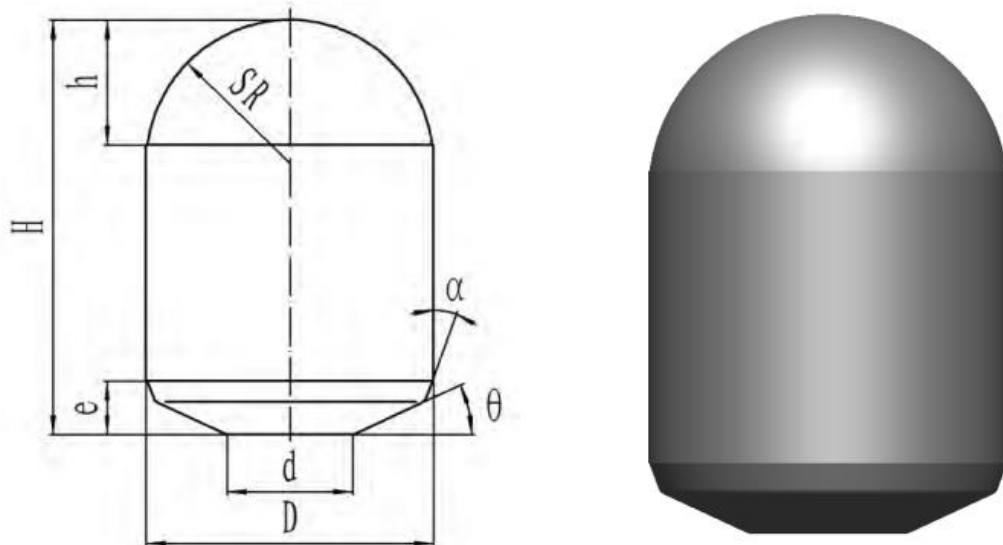


Example: AQ1625-306G01-W103H001-S171013-I

Specification of Products

Domed Button

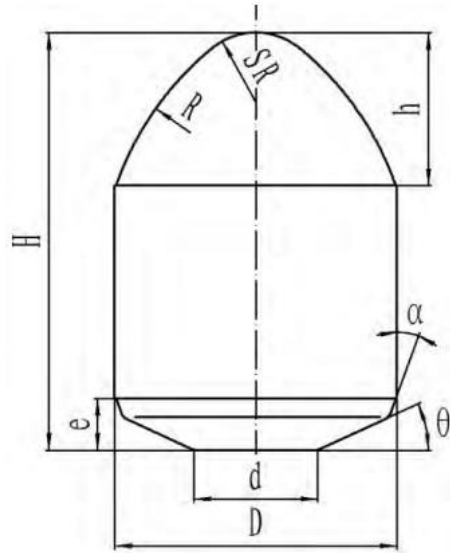
Domed button is mainly used as the gauge button of drill bit suitable in drilling high abrasive and extremely hard formation.



Type	D		H	h	SR	e	d	α	θ
	Finished Diameter	Blank Diameter							
AQ0913	9.15 ± 0.005	9.25 ± 0.10	13	3.40	4.70	1.80	3.50	20°	25°
AQ1015	10.15 ± 0.005	10.25 ± 0.10	15	3.42	5.40	1.90	3.50	20°	25°
AQ1116	11.15 ± 0.005	11.25 ± 0.10	16	4.51	5.70	2.15	3.50	20°	25°
AQ1218	12.15 ± 0.005	12.25 ± 0.10	18	4.93	6.17	2.30	4.00	25°	20°
AQ1320	13.15 ± 0.005	13.25 ± 0.10	20	5.27	6.70	2.40	5.00	25°	20°
AQ1422	14.15 ± 0.005	14.25 ± 0.10	22	6.00	7.17	2.68	5.00	20°	20°
AQ1523	15.15 ± 0.005	15.25 ± 0.10	23	6.50	7.66	2.80	5.50	20°	20°
AQ1625	16.15 ± 0.005	16.25 ± 0.10	25	6.90	8.17	2.90	6.00	20°	20°
AQ1726	17.15 ± 0.005	17.25 ± 0.10	26	7.07	8.70	3.10	8.00	25°	20°
AQ1827	18.15 ± 0.005	18.25 ± 0.10	27	7.90	9.13	3.35	8.00	20°	25°
AQ1928	19.15 ± 0.005	19.25 ± 0.10	28	8.00	9.69	3.60	8.00	20°	25°
AQ2029	20.15 ± 0.005	20.25±0.10	29	8.40	10.30	3.40	8.00	20°	20°

Semi-Ballistic Button

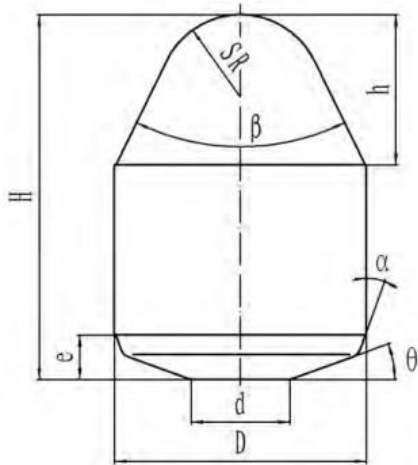
Mainly used as gauge button and front button of bit suitable for medium abrasive and hard rock formation.



Type	D		H	h	SR	R	e	d	α	θ
	Finished Diameter	Blank Diameter								
AD0913	9.15 ± 0.005	9.25 ± 0.10	13	5.00	2.40	11.00	1.80	3.50	20°	25°
AD1015	10.15 ± 0.005	10.25 ± 0.10	15	5.50	3.00	12.00	1.90	3.50	20°	25°
AD1116	11.15 ± 0.005	11.25 ± 0.10	16	6.70	3.00	12.00	2.15	3.50	20°	25°
AD1218	12.15 ± 0.005	12.25 ± 0.10	18	7.00	3.20	13.00	2.30	4.00	25°	25°
AD1320	13.15 ± 0.005	13.25 ± 0.10	20	7.20	3.27	15.54	2.40	5.00	25°	20°
AD1422	14.15 ± 0.005	14.25 ± 0.10	22	7.73	3.53	16.67	2.68	5.00	20°	20°
AD1523	15.15 ± 0.005	15.25 ± 0.10	23	8.60	3.80	17.00	2.80	5.50	20°	20°
AD1625	16.15 ± 0.005	16.25 ± 0.10	25	9.00	4.00	18.00	2.90	6.00	20°	20°
AD1726	17.15 ± 0.005	17.25 ± 0.10	26	9.20	4.30	19.00	3.10	8.00	25°	20°
AD1827	18.15 ± 0.005	18.25 ± 0.10	27	9.70	4.50	20.00	3.35	8.00	20°	25°

Ballistic Button

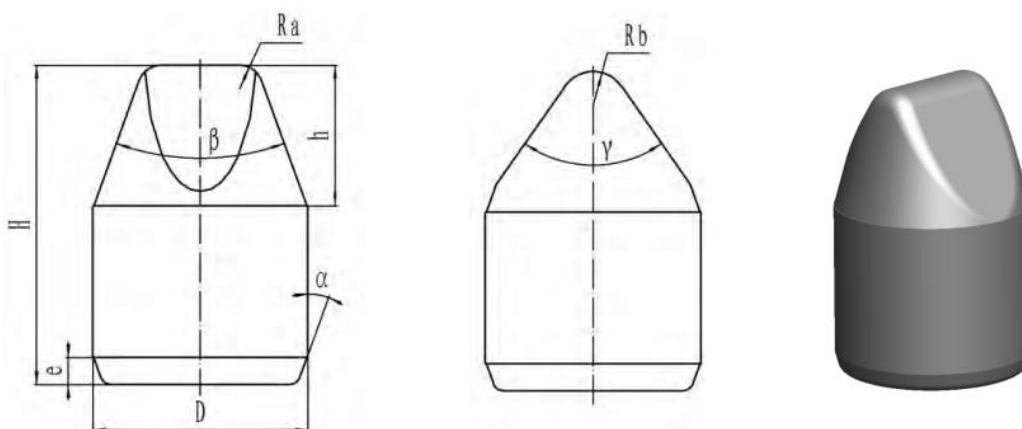
Mainly used as middle button of bit, suitable for medium abrasive and hard formation. Can also be used as gauge button in case of drilling in soft formation.



Type	D		H	h	SR	β	e	d	α	θ
	Finished Diameter	Blank Diameter								
AZ0913	9.15 ± 0.005	9.25 ± 0.10	13	4.55	3.00	50.00	1.80	3.50	20°	25°
AZ1015	10.15 ± 0.005	10.25 ± 0.10	15	6.15	4.00	52.00	1.90	3.50	20°	25°
AZ1116	11.15 ± 0.005	11.25 ± 0.10	16	6.18	4.00	52.00	2.15	3.50	20°	25°
AZ1218	12.15 ± 0.005	12.25 ± 0.10	18	6.95	4.00	55.00	2.30	4.00	25°	20°
AZ1320	13.15 ± 0.005	13.25 ± 0.10	20	7.91	4.00	55.00	2.40	5.00	25°	20°
AZ1422	14.15 ± 0.005	14.25 ± 0.10	22	7.70	5.00	55.00	2.68	5.00	20°	20°
AZ1523	15.15 ± 0.005	15.25 ± 0.10	23	9.10	5.00	52.00	2.80	5.50	20°	20°
AZ1625	16.15 ± 0.005	16.25 ± 0.10	25	8.90	6.50	60.00	2.90	6.00	20°	20°
AZ1726	17.15 ± 0.005	17.25 ± 0.10	26	9.20	6.50	60.00	3.10	8.00	25°	20°
AZ1827	18.15 ± 0.005	18.25 ± 0.10	27	10.30	6.00	56.00	3.35	8.00	20°	25°
AZ1928	19.15 ± 0.005	19.25 ± 0.10	28	10.80	6.50	56.00	3.60	8.00	20°	25°
AZ2029	20.15 ± 0.005	20.25±0.10	29	11.20	6.80	60.00	3.40	8.00	20°	20°

Chisel Button

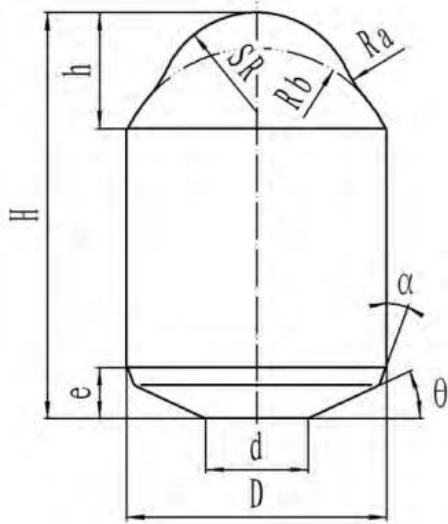
Chisel buttons are used in tricone bit for drilling medium-hard formation with the higher penetration rate.



Type	D		H	h	Ra	Rb	e	α	β	γ
	Finished Diameter	Blank Diameter								
AX0912	9.15 ± 0.005	9.25 ± 0.10	12	6.20	2.00	1.90	1.80	18°	45°	70°
AX1014	10.15 ± 0.005	10.25 ± 0.10	14	6.50	2.10	2.00	1.80	18°	45°	70°
AX1114	11.15 ± 0.005	11.25 ± 0.10	14	6.80	2.10	2.00	1.80	18°	45°	70°
AX1216	12.15 ± 0.005	12.25 ± 0.10	17	7.10	2.20	2.10	2.00	18°	45°	70°
AX1317	13.15 ± 0.005	13.25 ± 0.10	17	7.90	2.40	2.20	2.10	18°	45°	70°
AX1419	14.15 ± 0.005	14.25 ± 0.10	19	8.90	2.60	2.30	2.20	18°	45°	70°
AX1520	15.15 ± 0.005	15.25 ± 0.10	20	9.30	3.00	2.50	2.20	18°	45°	70°
AX1622	16.15 ± 0.005	16.25 ± 0.10	22	10.20	3.00	2.60	2.30	18°	45°	70°
AX1823	18.15 ± 0.005	18.25 ± 0.10	23	10.50	3.00	2.80	2.40	18°	45°	70°
AX1924	19.15 ± 0.005	19.25 ± 0.10	24	10.80	3.00	3.00	2.50	18°	45°	70°

Double Dome Button

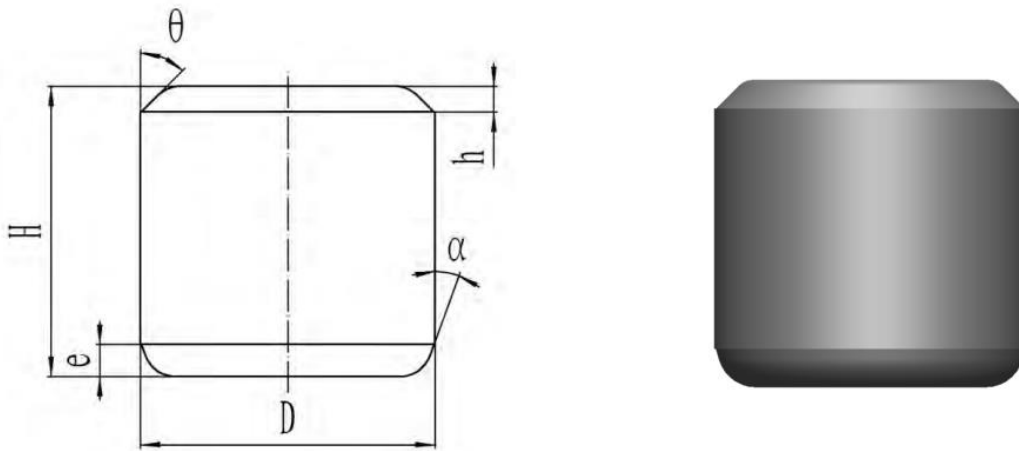
Double Dome buttons are usually used drilling in hard rock, it can provide longer life span 20%-40% in premise of re-grinding carbide.



Type	D		H	h	SR	Ra	Rb	e	d	α	θ
	Finished Diameter	Blank Diameter									
AN1218	12.15 ± 0.005	12.25 ± 0.10	18	5.20	3.50	8.00	6.35	2.30	4.00	25°	20°
AN1320	13.15 ± 0.005	13.25 ± 0.10	20	5.65	4.00	8.50	6.80	2.40	5.00	25°	20°
AN1422	14.15 ± 0.005	14.25 ± 0.10	22	6.05	4.00	9.00	7.35	2.68	5.00	20°	20°
AN1523	15.15 ± 0.005	15.25 ± 0.10	23	6.67	5.00	10.00	7.95	2.80	5.50	20°	20°
AN1625	16.15 ± 0.005	16.25 ± 0.10	25	7.09	6.00	10.00	8.90	2.90	6.00	20°	20°
AN1726	17.15 ± 0.005	17.25 ± 0.10	26	7.50	6.50	10.00	9.50	3.10	8.00	25°	20°
AN1827	18.15 ± 0.005	18.25 ± 0.10	27	8.16	7.00	10.00	10.10	3.35	8.00	20°	25°
AN1928	19.15 ± 0.005	19.25 ± 0.10	28	8.56	7.50	10.00	10.60	3.60	8.00	20°	25°

Flat Button

Flat buttons are usually used as protection buttons in bit side to reduce the wear on surface of Bits.



Type	D		H	h	e	α	θ
	Finished Diameter	Blank Diameter					
AP0807	8.15 ± 0.005	8.25 ± 0.10	7	0.58	1.10	15°	45°
AP1008	10.15 ± 0.005	10.25 ± 0.10	8	0.67	1.29	18°	45°
AP1109	11.15 ± 0.005	11.25 ± 0.10	9	0.50	1.50	18°	45°
AP1212	12.15 ± 0.005	12.25 ± 0.10	12	1.20	1.76	18°	45°
AP1414	14.15 ± 0.005	14.25 ± 0.10	14	1.40	2.36	18°	45°
AP1616	16.15 ± 0.005	16.25 ± 0.10	16	1.50	2.00	18°	45°

1. We can provide cemented carbide with blank size and with accurate size.
2. Accurate size cemented carbide can be confirmed, tolerance is controlled between +/- 0.005mm, roughness is $\sqrt{0.4}$
3. We can customise the cemented carbide button according to the customers requirement on different size of diameter, length, shape of carbide head and carbide bottom.



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