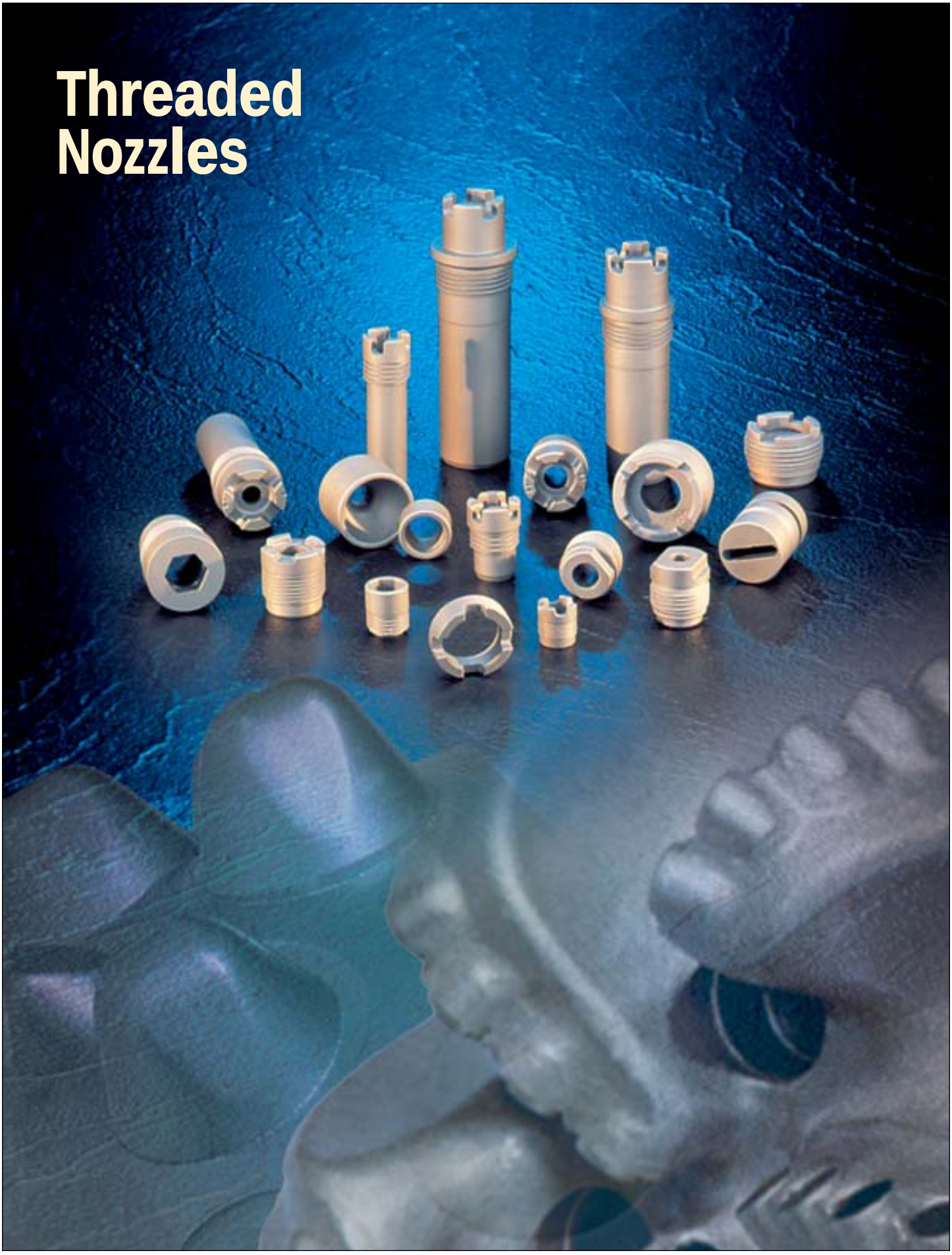
Specialty Nozzles and Diamond Bit Accessories

ATI Firth Sterling
Allegheny Technologies

Threaded Nozzles



Firth Sterling is a quality supplier of tungsten carbide rockbit products for all drilling applications and in all types of bits. The carbide components of a rockbit are not just another product for ATI Firth Sterling — they are our ***only*** products.

ATI Firth Sterling manufactures nozzles and threaded nozzles in a wide selection of style and size combinations to meet our customer's exacting specifications. Our nozzles are produced from a variety of field tested grades each designed to provide the best combination of toughness and wear resistance possible for designs requiring high torque capacities.

Engineering nozzles to a customer's exacting specifications using Pro-E® and Solid Edge® software systems is just the first step in ATI Firth Sterling's manufacturing process. Our state of the art equipment includes precision presses designed in-house to maintain accurate size control for ATI Firth Sterling products. High pressure sinter HIP furnaces control carbon and porosity to ensure the highest quality part possible. CNC OD grinders, thread grinders and a fully equipped tool room, have given MPD a reputation for service and responsiveness.
The result of this fully integrated, turnkey operation is a precision ground, high quality, cost competitive nozzle.

Rotary Tricone Bits

ATI Firth Sterling offers a standard nozzle brochure with information on the hydraulics of roller cone bits and nozzle designs. Please ask your sales representative for a copy.

Polycrystalline Diamond Cutter Bits (PDC)

Diamond bit nozzles are commonly arranged with one or several nozzles at the inner end of each blade, with the intention of cleaning that particular blade. Field and laboratory studies have proven this to be the most effective configuration, although bit dynamics is a continuing area of rapid change and improvements. The size and configuration of the nozzles are critical to effective cleaning of the bit surfaces. ATI Firth Sterling manufactures a large variety of standard nozzles, threaded nozzles and specialty nozzles to ensure maximum flow, and therefore, maximum cleaning action. Working with your bit design engineer's ideas, ATI Firth Sterling can produce those ideas in carbide, giving each new bit design a performance advantage.

ATI Firth Sterling provides the following information to be used as a guideline only, any error is purely unintentional & we recommend that all values and information be verified independently of this information.

Hydraulics of the PDC Bit

PDC bits (as with all bits) are most effective when the correct weight on the bit, correct mud pressure and flow rates are used, and rotational speed is properly controlled. PDC bits are usually equipped with some type of nozzle system. With the cost of a PDC bit at 5 to 15 times more than a roller cone bit, the hydraulics of the bit becomes a key component of efficient operation and economics.

In all types of drilling, the rock is fractured, gouged or scraped by the bit. The main function of the drilling fluid is to remove the cuttings from the bottom of the hole through the annular space between the drill string and the hole wall and then to the surface. The drilling fluid is channeled through nozzles to clean the face of the bit. In applications where air or gas is used, a steel nozzle may be acceptable. When drilling with mud or some other type of liquid or abrasive fluid, a tungsten carbide nozzle is needed to give maximum bit performance.

The hydraulics of the diamond bit are critical in ensuring its economic success, which means that the drilling mud must successfully clean the cutting elements, avoid clogging or balling up the bit, as well as cooling and lubricating the cutters. Pneumatic hole flushing with air or some other gas does not cool or lubricate the bit well enough and is, therefore not suited to diamond drilling. Drilling mud, whether water or oil based, is the preferred medium for the task. Drilling mud is abrasive and tungsten carbide nozzles are most efficient in resisting the abrasive action of the mud.

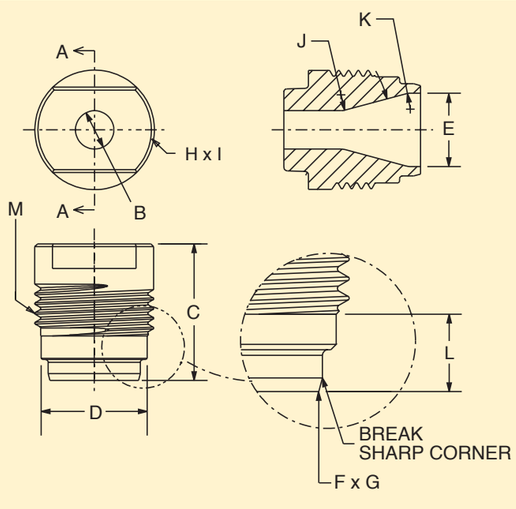
The shape of the diamond bit can have an impact on how the bit performs and the nozzle system must be matched correctly to the design of the bit. For diamond bits, hydraulic horsepower per square inch (HSI) can also have a dramatic impact on bit performance.

ATI Firth Sterling manufactures a broad range of styles and sizes of specialty nozzles, the following pages show some of the available sizes.

Threaded Nozzle Cross Reference

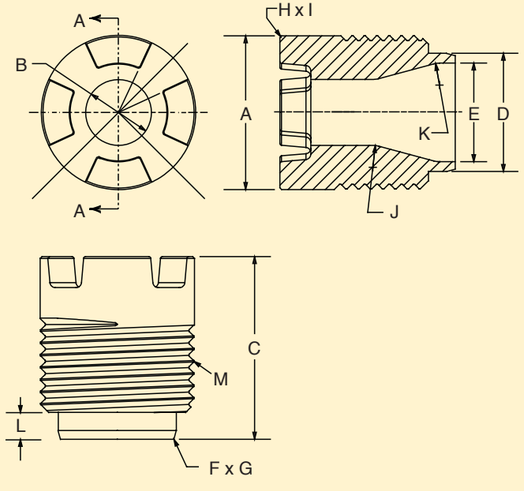
Style	Dim	Cap Top										Castle Top																								Inverse Castle Top	
Major OD	"A"	.875						1.000				.562		.625		.750			.805				.875		.880		.945		1.000		1.090		1.173		1.385		.869	
OAL	"C"	1.000						1.125				.625		.625		.445	1.065		1.065		1.211		.688		1.080		1.000		1.210		3.095		3.801		4.418		.668	
Minor OD	"D"	.776						.900				.520		.579		.643	.634		.634		.835		.750		.776		.830		.804		.881		1.008		1.134		.750	
Bell Side ID	"E"	.500		.562		.562		.600		.804		.438		.438		.500	.500		.500		.500		.625		.562		.688		.688		.700		.745		.745		.438	
Threads	"M"	7/8-14UNF-2A						1.00-14UNS-2A				9/16-32UN-2A		5/8-32UN-2A		3/4-12UN-2A	3/4-12UN-2A		3/4-12UN-2A		3/4-12UNF-2A		7/8-12UN-2A		7/8-14UNF-2A		15/16-16UN-2A		1.00-14UNS-2A		1.00-12UNF-2A		1.125-12UNF-2A		1.250-12UNF-2A		7/8-12UN-2A	
Drawing Number		TNZ0001		TNZ0009		TNZ0011		TNZ0002		TNZ0010		TNZ0012		TNZ0013		TNZ0007	TNZ0014		TNZ0004		TNZ0005		TNZ0006		TNZ0015		TNZ0017		TNZ0016									
ID Radius	"J"/"K"	0.350	0.350	0.125	0.125	0.125	0.125	0.150	0.150	0.125	0.125	Varies	0.250	Varies	0.250	.125	.125	0.500	0.500	0.500	0.500	0.500	0.500	0.062	1.000	0.125	0.125	Varies	Varies	0.125	0.125	N/A	5°	N/A	5°	N/A	5°	0.062	1.000
		Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle	Length	Angle
Bell Side Chamfer	"F"/"G"	0.050	15°	0.050	15°	0.050	15°	0.050	15°	0.050	15°	0.025	20°	0.025	20°	0.030	45°	0.055	15°	0.050	15°	0.050	45°	0.095	20°	0.015	45°	0.050	15°	0.040	20°	0.050	15°	0.127	20°	0.090	20°	0.093	20°	0.015	45°
Orifice Side Chamfer	"H"/"I"	0.020	45°	0.040	45°	0.040	45°	0.020	45°	0.040	45°	0.010	45°	0.010	45°	0.020	45°	0.015	45°	0.015	45°	0.015	45°	0.030	45°	0.015	45°	0.015	45°	REF	REF	0.015	45°	0.030	45°	0.030	45°	0.030	45°	0.015	45°
Bell Side Length *(Below Threads)*	"L"	0.325	N/A	0.325	N/A	0.254	N/A	0.375	N/A	0.375	N/A	0.104	N/A	0.140	N/A	0.120	N/A	0.310	N/A	0.310	N/A	0.310	N/A	0.456	N/A	0.198	N/A	0.325	N/A	0.200	N/A	0.155	N/A	1.931	N/A	2.377	N/A	2.994	N/A	0.178	N/A
Orifice Size	"B"																																								
Blank						YES				YES							YES		YES		YES		YES			YES				YES				YES							
6/32"																																									
7/32"																														YES											
8/32"																														YES											
9/32"		YES		YES		YES		YES*		YES											YES				YES		YES		YES		YES								YES	
10/32"		YES		YES		YES		YES*		YES							YES		YES		YES				YES		YES		YES		YES		YES		YES				YES	
11/32"		YES		YES		YES		YES*		YES							YES		YES		YES				YES		YES		YES		YES		YES		YES				YES	
12/32"		YES		YES		YES		YES*		YES		YES					YES		YES		YES				YES		YES		YES		YES		YES		YES				YES	
13/32"		YES		YES		YES		YES*		YES											YES				YES		YES		YES		YES		YES		YES				YES	
14/32"		YES		YES		YES		YES*		YES							YES		YES		YES				YES		YES		YES		YES		YES		YES				YES	
15/32"				YES		YES		YES*		YES											YES				YES		YES		YES		YES		YES		YES					
16/32"				YES		YES		YES*		YES							YES		YES		YES				YES		YES		YES		YES		YES		YES					
18/32"										YES																YES		YES		YES		YES		YES		YES					
20/32"																												YES		YES		YES		YES		YES					
22/32"																												YES		YES		YES		YES		YES					

ATI Firth Sterling adds new sizes and styles weekly. Please check with your sales representative or customer service at (800) 899-1234 for availability. Nozzle prints furnished upon request.
*Some tooling available at time of printing, please inquire on status.




Cap Top Threaded Nozzle


Castle Top Threaded Nozzle



Hydraulic Horsepower per Square Inch (HSI)

Hydraulic Horsepower per square inch (HSI) is an indirect measure of how well the mechanical energy expended at the bit is being assisted by the circulating mud. As cuttings and heat are generated, both must be removed from the bit. The correct level of hydraulic horsepower accomplishes the cooling and cleaning, as well as offering a certain amount of lubrication. HSI is simply the value of the hydraulic energy expended at the bit divided by the projected area of the hole in square inches. Please note that impregnated diamond bits run at a lower Hydraulic horsepower due to the total flow area (TFA) in the bit design (discussed on the next page).

DRILLING RATE (ft/hr)		Hydraulic HSI
0 – 2	(0.0 – 0.6 m/hr)	0.5 – 1.5
2 – 4	(1.8 – 1.2 m/hr)	1.5 – 2.0
4 – 6	(1.8 – 1.2 m/hr)	2.0 – 3.0
6 – 10	(1.8 – 3.0 m/hr)	2.5 – 3.0
10+	(3.0 m/hr)	3.0 – 3.5

Hydraulic energy, as defined here, is the hydraulic horsepower shown as a function of flow rate and bit pressure drop. Hydraulic energy in diamond bits has a direct correlation between bit life and performance. For soft formations, a high HSI is necessary for cutting removal and cooling of the diamonds with the emphasis on cutting removal. As drilling conditions get more difficult, HSI values will decrease and the emphasis shifts to diamond cooling. Annular fluid velocity needs to be high enough to lift the drill cuttings out of the hole. This requirement sets the minimum fluid circulation rate.

The flow rate can be measured as follows:

$$Q = 1.41\ CA\sqrt{\frac{\Delta P}{S_g}}$$

Where

Q = flow rate (gpm, m^3/s)
C = flow coeffiecent (C=0.80 for sharp edged orifice, or C = 0.60 for square-edged orifice)
A = area of orifice opening (in^2, m^2)
$\Delta P = P_2 - P_1$= pressure drop across orifice (psi, kPa)
S_g = specific gravity of flowing fluid

Fluid Velocity

Fluid velocity is a function of flow rate and the area and is another way of determining the capability of the hydraulic system to cool the diamonds and clean the bit. Normal fluid velocities range from 150 to 300 ft/sec (46 - 91 m/sec) in most drilling applications. The fluid velocity provides momentum and fluid movement on the diamond.

The basic equation for fluid velocity, including friction and nozzle losses is,

$$u = \sqrt{1+fL/D+K} \quad * \sqrt{2*P/rho*32.2*144}$$

Where

u = velocity, fps
fL/D = friction loss
K = nozzle loss
P = pressure drop, psi
rho = fluid density, lbm/ft3
32.2*144 = conversion factors

A sudden increase in standpipe pressure (and pump pressure) during drilling is occasionally the result of a plugged nozzle. If this causes no other problems and the bit continues to drill without a change in the rate of penetration at the same parameters, it should be noted but drilling can continue. Plugging of more than one nozzle is usually more serious and the bit may have to be pulled from the hole for cleaning. A sudden decrease in pump pressure followed by a small, continuing decrease indicates that fluid erosion has resulted in the loss of at least one nozzle. Assuming there are no problems with the pumps or other related surface equipment, the bit should be pulled. No attempt should be made to repair the bit on site.

ATI Firth Sterling has provided this information as a guide for the bit engineer only as an aid in nozzle design. It is not meant as a field manual, all inclusive or as a final guide in bit design or usage. Any information which may be incorrect or inaccurate is purely by accident. Verification of all information shown in this guide is incumbent on the bit designer and manufacturer.

TOTAL FLOW AREA (TFA) OF STANDARD NOZZLES (INS^2)

Nozzle Orifice Size		NUMBER OF NOZZLES 1	2	3	4	5	6	7	8	9	10
7/32"	# 7	0.038	0.075	0.113	0.150	0.188	0.226	0.263	0.300	0.338	0.376
1/4"	# 8	0.049	0.098	0.147	0.196	0.245	0.295	0.344	0.393	0.442	0.491
9/32"	# 9	0.062	0.124	0.186	0.249	0.311	0.373	0.435	0.497	0.559	0.621
5/16"	# 10	0.077	0.153	0.230	0.306	0.383	0.460	0.537	0.614	0.690	0.767
11/32"	# 11	0.093	0.186	0.278	0.371	0.464	0.557	0.650	0.742	0.835	0.928
3/8"	# 12	0.110	0.221	0.331	0.442	0.552	0.663	0.773	0.844	0.994	1.105
13/32"	# 13	0.130	0.259	0.389	0.519	0.648	0.778	0.907	1.037	1.167	1.296
7/16”	# 14	0.150	0.301	0.451	0.601	0.752	0.902	1.052	1.203	1.353	1.503
15/32"	# 15	0.173	0.345	0.518	0.690	0.863	1.035	1.208	1.381	1.553	1.726
1/2"	# 16	0.196	0.393	0.589	0.785	0.982	1.178	1.374	1.571	1.767	1.963
17/32"	# 17	0.249	0.497	0.746	0.994	1.243	1.491	1.740	1.988	2.237	2.485
9/16"	# 18	0.249	0.497	0.746	0.994	1.243	1.491	1.740	1.988	2.237	2.485
19/32"	# 19	0.277	0.554	0.831	1.108	1.384	1.661	1.938	2.215	2.492	
5/8"	# 20	0.307	0.614	0.920	1.227	1.534	1.841	2.148	2.454	2.761	
21/32"	# 21	0.338	0.676	1.015	1.353	1.691	2.029	2.368	2.706	3.044	
11/16"	# 22	0.371	0.742	1.114	1.485	1.856	2.227	2.599	2.970	3.341	
23/32"	# 23	0.406	0.811	1.217	1.623	2.029	2.434	2.840	3.246	3.652	
3/4"	# 24	0.442	0.884	1.325	1.767	2.209	2.651	3.093	3.534	3.976	

As nozzle diameters become smaller, it is recommended that drill pipe screens be used to avoid plugging the nozzle orifices.

Total Flow Area (TFA)

The total flow area (TFA) for the mud represents the minimal sectional area for the passage of fluid across the bit face. For a surface set diamond bit the total flow area is the sum of the cross sections of all the waterways and the cross sectional area between the diamonds at the nose of the bit. This section will get smaller during the run of the bit; however, the TFA will stay the same for the life of the bit. These surface set diamond bits are used successfully with most types of mud. Although oil-based muds can reduce penetration for tricone bits and to some extent, surface set diamond bits; however, for PDC bits, they increase penetration and bit life through better chip removal.

The flow area of a PDC bit can be adjusted by a series of nozzles designed to give a pressure drop and hydraulic horsepower compatible with the rig pump capacity, the mud circulation and the output needed for the entire drilling phase. At any given flow rate, the choice of an increased TFA will reduce the fluid velocity at the exit end of the nozzle. Jet impact is the force at which the fluid exiting the nozzle hits the hole bottom. This impact force, which is primarily a function of the fluid speed and weight of the mud, is determined when the pressure drop at the bit is roughly 50 percent, or slightly less, of the pump pressure at its maximum. The hydraulic power is at its maximum when the pressure drop at the bit is sixty- five percent (or slightly less) of the pump pressure.

Wear Components for Bits

ATI Firth Sterling provides our customers with a wide selection of rock bit wear components. Gage bricks, nozzle extensions & wear sleeves, thrust surface buttons, and substrates ready for diamond coating are only a few.

ATI Firth Sterling supplies gage bricks unground in a wide variety of sizes ready for brazing. We offer a selection of stock sizes in our proprietary grade, “HAR”. This grade is 7.5% cobalt with a R_A hardness of 91.2 and is specifically designed to resist rubbing wear. Some stock sizes are also offered in MPD2C. Due to a higher cobalt content, this grade has more transverse rupture strength for applications which have less wear and more breakage potential.

ATI Firth Sterling supplies nozzle sleeves and wear extensions to customer design specifications. These are generally supplied finished ground to tight tolerances and can be manufactured in a variety of grades, depending on the erosion wear resistant characteristics required.

Gage Bricks

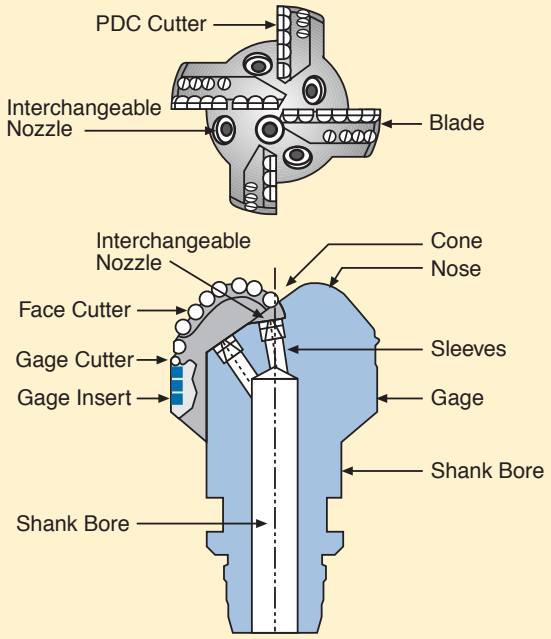
Nozzle Sleeves

Thrust Buttons

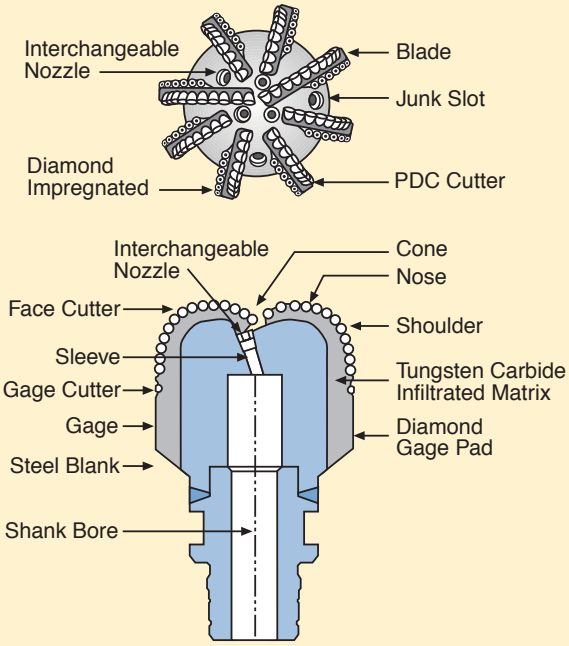
Substrates

ATI Firth Sterling manufactures substrates ready for diamond coating. Our ProE® and Solid Edge® modeling capabilities allow for complex part design and tooling manufacture. Our Engineering group is available for concurrent design consultation through all phases of your project. Our grade offerings allow for a broad selection of carbide options in even the most difficult of applications. Our fully equipped in-house tool room can make your design a reality.

Bit Nomenclature



Steel Body Bit Nomenclature



Matrix Bit Nomenclature

GAGE BRICKS

ATI Firth Sterling offers Gage Bricks in a wide variety of sizes to suit every bit design. Gage Bricks are used as wear pads or gauge protection on PDC bits to prevent erosion or wear of the cutter.

Thickness	*X*	*Width*	*X*	*Length*
1/32	X	3/4	X	1
	X	1	X	1-1/2
1/16	X	1/4	X	1/2
	X	1/4	X	3/4
	X	1/4	X	1
	X	3/8	X	1
	X	1/2	X	1/2
	X	1/2	X	3/4
	X	1/2	X	1
	X	3/4	X	3/4
	X	3/4	X	1
	X	1	X	1
	X	1	X	1-1/2
.080	X	1/4	X	1
	X	1/2	X	1
1/8	X	1/4	X	1/2
	X	1/4	X	1
	X	1/4	X	1-1/4
	X	3/8	X	3/4
	X	3/8	X	1
	X	1/2	X	1/2
	X	1/2	X	1
	X	3/4	X	3/4
	X	3/4	X	1
	X	1	X	1
	X	1	X	1-1/2
	X	1-1/4	X	1-1/4
.135	X	1/4	X	1
3/16	X	1/2	X	1/2
	X	1/2	X	1
	X	1/2	X	1-1/4
	X	1/2	X	1-1/2
	X	3/4	X	3/4
	X	3/4	X	1
	X	1	X	1-1/2

Stock grades HAR (some sizes available in MPD2C)

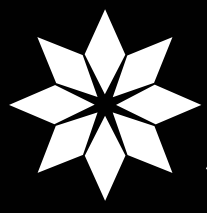
DIAMOND MATRIX POWDER & BINDER

Diamond matrix powder and binders are used for drilling, coring, and mining bits which require a high resistance to erosion and abrasive wear. These bits can be set with diamond substrates, surface set diamonds, or impregnated diamonds that provide the cutting action. ATI Firth Sterling manufactures a broad range of precisely blended powders and binders offering the strength and stability you require for all types of matrix diamond bits.

ATI Firth Sterling's powders are produced by melting tungsten metal and tungsten monocarbide (WC) together, forming a eutectic composition of WC and W2C. This melt is then cast and rapidly quenched to form extremely hard solid particles with a fine crystal structure. The solids are crushed and classified to various mesh sizes producing the cast carbide component of ATI Firth Sterling powder. Adding additional constituents, a precisely blended and metallurgically tested dry sintered matrix powder is produced. During bit manufacture, this powder is combined with our binder alloy, which comes in various blend combinations, and sintered together with the matrix powder to form a stable, highly wear resistant and abrasion resistant material.

A matrix bit provides excellent surface properties, with a high resistance to fluid erosion. The erosion resistance can be increased by increasing the volume percentage of tungsten carbide in the powder. The percentage of tungsten carbide affects the transverse rupture strength of the tungsten carbide and limits the mechanical stresses that the material will sustain, especially in shock loading conditions. Therefore, it is critical to determine the optimum percent tungsten carbide necessary for your specific type bit.

ATI Firth Sterling manufactures field-tested powders and when combined with our binder alloys, produces the optimum in penetration rates and bit life. Your ATI Firth Sterling salesman can help you select the most suitable grade for your application.



ATI Firth Sterling

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