Technical Reference Section: Flow

Velocity-based Flow Measurement Technologies

All of the flow sensors featured in the +GF+ SIGNET catalog belong to the broad category of velocity-based flow measurement devices. This vast offering includes paddlewheel, electromagnetic, vortex, in-line rotor, and turbine flow sensors. Principles of operation vary considerably for each type, but some very important installation considerations are common throughout. The following discussion plus the general selection guidelines at the front of the catalog should help the user choose the appropriate sensor type and obtain optimal flow measurement results.

All manuals, data sheets, and additional helpful information are available at **www.gfsignet.com.**

Fully Developed Turbulent Flow

Velocity-based flow sensors depend on fully developed turbulent flow for accurate and repeatable measurements. Fully developed turbulent flow occurs in Newtonian fluids with a Reynolds Number (Re) greater than 4,500. Low flow rates, viscous liquids, and large pipe sizes make fully developed turbulent flow more difficult to achieve. The opposite is also true. That is, for a given set of conditions, simply reducing the pipe size to increase the local flow velocity will produce a higher Reynolds Number.

Note: Vortex sensors require higher minimum thresholds than paddlewheel sensors.

Re: Reynolds Number

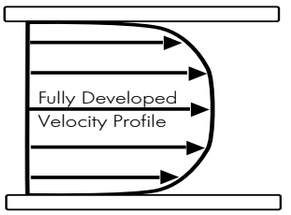
$Re = 3{,}162.76 \times Q \times Sg/(\mu \times ID)$

where: Q = Flow Rate in US GPM
Sg = Specific Gravity
μ = Dynamic Viscosity in Centipoise (cP)
ID = pipe inside diameter in inches

OR

$Re = DN \times V/\nu$

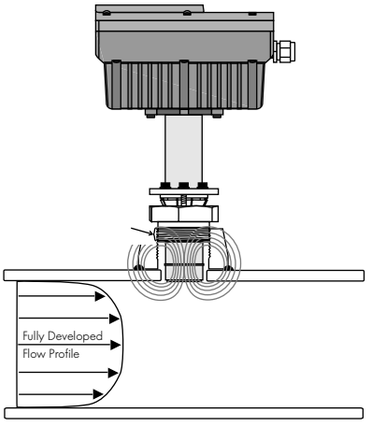
where: DN = pipe inside diameter (m)
V = flow velocity (m/s)
ν = kinematic viscosity (m^2/s)
(ν of water = 1×10^{-6} m^2/s)



Principles of Operation

- **Electromagnetic** flow sensors, like +GF+ SIGNET's Models 2550 and 2560, operate on Faraday's principle of electromagnetic induction, and have no moving parts. As fluid (must be conductive) moves through the magnetic field produced at the sensor tip, a voltage occurs that is directly proportional to the fluid velocity. Internal electronics then convert this voltage into a frequency and/or a 4 to 20 mA output. +GF+ SIGNET electromagnetic flow sensors are insertion-style, suitable for use in a wide range of pipe sizes.

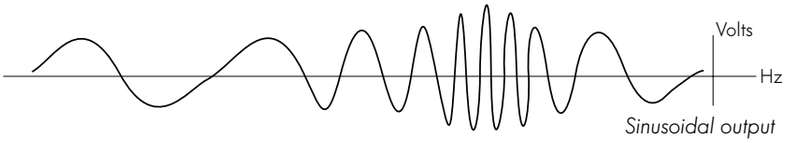
2550 or 2560



Technical Reference Section: Flow

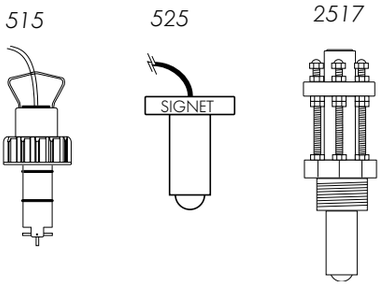
Principles of Operation (continued)

- **Paddlewheel** flow sensors are insertion devices, mounted perpendicular to the piping system, and rely upon the energy in the flow stream to spin a rotor (paddlewheel) around a stationary shaft. Most paddlewheel flow sensors utilize rotors with magnets embedded in each blade. The magnets are typically used either in conjunction with a coil internal to the sensor housing to produce a sinusoidal output (self-generating, non-powered sensors), or to trigger an internal electronic switch to produce a square-wave output (transistor-type, powered sensors). Either way, the resulting frequency is directly proportional to the fluid velocity.



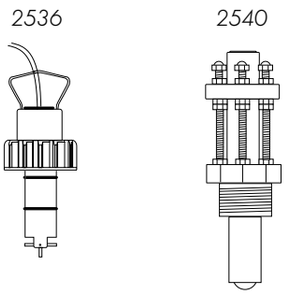
Sinusoidal output

1) Sinusoidal sensors output a signal typical of self-generating, non-powered paddlewheel sensors such as the Model 515, 525, or 2517. The frequency and amplitude (voltage) both vary directly with flow rate.

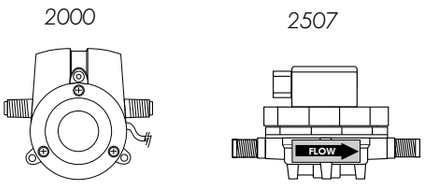


Square wave output

2) Transistor-type sensors output a signal typical of powered sensors such as the Model 2536, 2540, and all other +GF+ SIGNET powered flow sensors with frequency output.



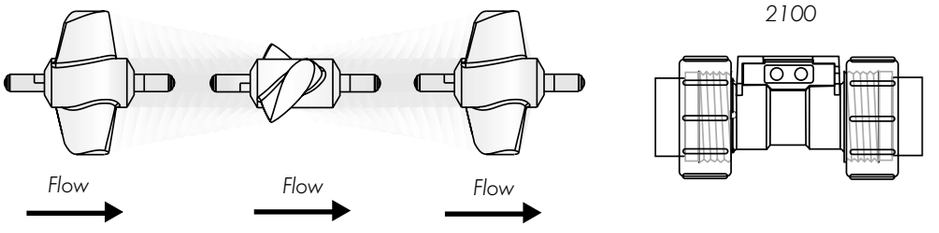
- **In-Line Rotor** flow sensors like the +GF+ SIGNET Models 2000 and 2507 are similar to paddlewheel sensors, except the rotor is positioned in a flow cell. These types of sensors have a transistor-type output signal and are able to measure lower flow rates.



Technical Reference Section: Flow

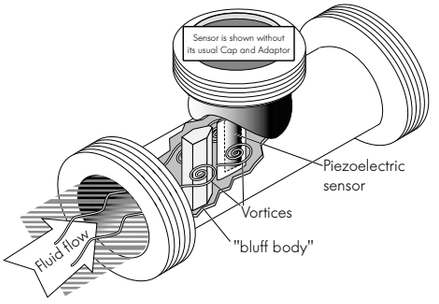
Principles of Operation (continued)

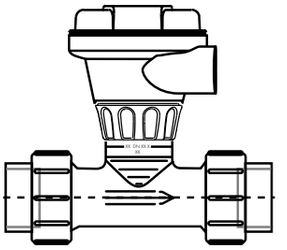
- **Turbine** flow sensors are full-bore devices designed for low-flow measurements. +GF+ SIGNET Model 2100 is offered in 6.4 mm and 12.7 mm (1/4 in. and 1/2 in.) line sizes. Many self-aligning end-connector options are available for installation simplicity and application versatility. Similar to paddlewheels, they rely upon the energy in the flow stream to spin a rotor (turbine). The difference is that the shaft is in the center of, and parallel to, the flow stream. The velocity of the fluid spins the turbine for detection by external electronic circuitry, producing a transistor-type square wave output with a frequency directly proportional to the flow rate.



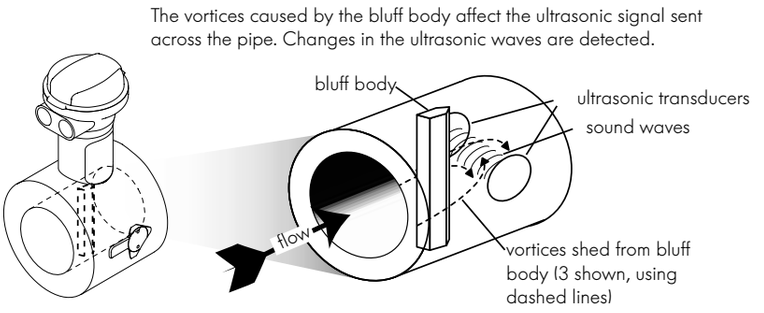
- **Vortex** flow sensors have no moving parts and utilize a naturally occurring phenomenon in which whirling masses of liquid, or vortices, are shed downstream of a stationary object within a flow stream, and at a rate directly proportional to the velocity of the flow stream. Each vortex causes a local pressure fluctuation that can be detected. +GF+ SIGNET Models 7000 and 7001 Vortex Flow Sensors, sizes DN 15 to DN 50 (1/2 in. to 2 in.), develop vortices around a narrow bluff body and direct them to an encapsulated piezoelectric sensor. +GF+ SIGNET Model 7002 Vortex Flow Sensors, sizes DN 80 and DN 100 (3 in. and 4 in.), utilize a state-of-the-art ultrasonic technique for detecting vortices shed by a bluff body. Factory calibration and electronic conditioning produce an extremely accurate and reliable output that is strictly proportional to the fluid flow rate.

Model 7000/7001Vortex Flow Sensors DN 15 to DN 50 (1/2 in. to 2 in.)





Model 7002 Vortex Flow Sensors DN 80 and DN 100 (3 in. and 4 in.)



Technical Reference Section: Flow

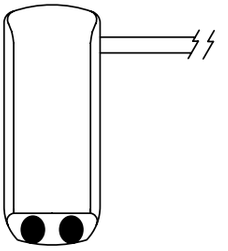
Principles of Operation (continued)

- **Ultrasonic Doppler** sensors have a transducer that emits an acoustic signal which penetrates the fluid flow and is returned after reflecting from particles and air bubbles within the flow. The difference in frequency is proportional to the stream velocity.

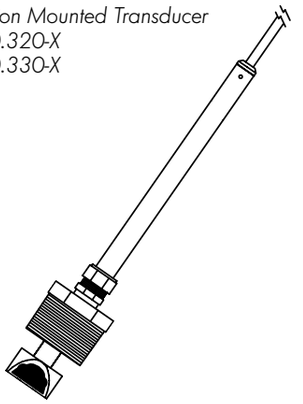
  In full or partially full pipes, the velocity of the flow stream varies markedly across the cross-section of the pipe. Typically, velocity is zero along the wall of the pipe and increases to a maximum at or about the center of the pipe. The +GF+ SIGNET 3300 instrument receives reflected frequencies from particles moving at these different velocities and then calculates the average velocity of the stream.

  Depth is measured with a ceramic-based pressure transducer integrally mounted in a surface mount velocity sensor.

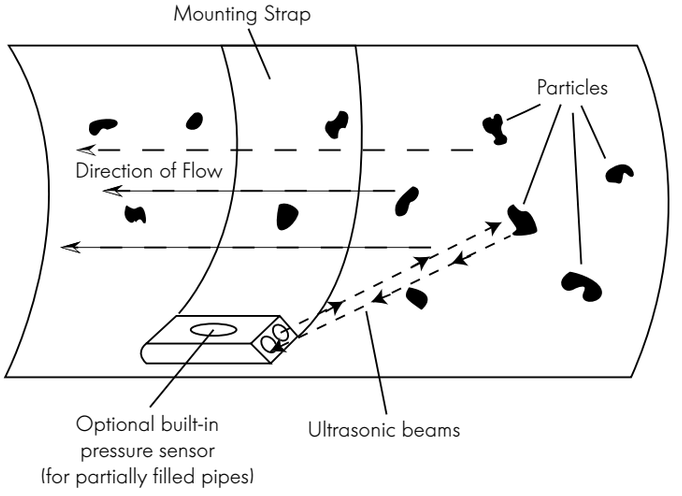
Strap Mounted Transducer
3500.31X-X



Insertion Mounted Transducer
3500.320-X
3500.330-X



View of Cross-Section of Typical Pipe Installation



Technical Reference Section: Flow

Flow Range Charts (GPM)

Paddlewheel and Electromagnetic Sensors

+GF+ SIGNET Models 515, 525, 2517, 2536, 2540, 2550, 2560
GPM Flow Rates for DN 15 to DN 450 (1/2 in. to 18 in.) pipe sizes

MIN/MAX Flowrates in Gallons per minute (GPM)

			Insertion Paddlewheel				Electromagnetic	
	Pipe Size (in.)	Pipe Size (mm)	3-2536-XX 3-8512-XX	3-2540	P51530-XX 3-8510-XX	P525-X 3-2517	3-2550	3-2560
Velocity Range			0.3 to 20 fps 0.1 to 6 m/s	0.3 to 20 fps 0.1 to 6 m/s	1 to 20 fps 0.3 to 6 m/s	1.6 to 20 fps 0.5 to 6 m/s	0.3 to 20 fps 0.1 to 6 m/s	0.3 to 20 fps 0.1 to 6 m/s
	0.5	d20/DN15	0.3 19	0.3 19	1 19	1.6 19	- -	0.3 19
	0.75	d25/DN20	0.5 34	0.5 34	1.7 34	2.7 34	- -	0.5 34
	1	d32/DN25	0.8 54	0.8 54	2.7 54	4.4 54	- -	0.8 54
	1.25	d40/DN32	1.4 94	1.4 94	4.7 94	7.4 94	- -	1.4 94
	1.5	d50/DN40	1.9 127	1.9 127	6.4 127	10.1 127	- -	1.9 127
	2	d63/DN50	3.2 210	3.2 210	10.6 210	16.8 210	3.2 210	3.2 210
	2.5	d75/DN65	4.5 300	4.5 300	15 300	24 300	4.5 300	4.5 300
	3	d90/DN80	7 461	7 461	24 461	37 461	7 461	7 461
	4	d110/DN100	12 794	12 794	40 794	63 794	12 794	12 794
	5	d140/DN125	19 1247	19 1247	63 1247	100 1247	19 1247	- -
	6	d160/DN150	27 1801	27 1801	91 1801	144 1801	27 1801	- -
	8	d225/DN200	47 3119	47 3119	156 3119	250 3119	47 3119	- -
	10	d280/DN250	74 4915	74 4915	246 4915	393 4915	74 4915	- -
	12	d315/DN300	105 6977	105 6977	349 6977	559 6977	105 6977	- -
	14	d400/DN350	127 8432	127 8432	422 8432	- -	- -	- -
	16	d450/DN400	166 11015	166 11015	551 11015	- -	- -	- -
	18	d500/DN450	210 13942	210 13942	698 13942	- -	- -	- -

Based on Sch 40 metal pipe (ASTM); values will vary due to pipe material, size, and schedule

Vortex Sensors

+GF+ SIGNET Models 7000 and 7001
GPM Flow Rates for DN 15 to DN 50 (1/2 in. to 2 in.) pipe sizes

	GPM											
Velocity Range	0.5 to 4 meters/sec 1.64 to 13.12 feet/sec				0.4 to 4 meters/sec 1.31 to 13.12 feet/sec				0.3 to 4 meters/sec 0.98 to 13.12 feet/sec			
	Pipe Size (in.)	Pipe Size (mm)	Pipe Size (in.)	Pipe Size (mm)	Pipe Size (in.)	Pipe Size (mm)	Pipe Size (in.)	Pipe Size (mm)	Pipe Size (in.)	Pipe Size (mm)	Pipe Size (in.)	Pipe Size (mm)
Sensor	0.5	d20/DN15	0.75	d25/DN20	1	d32/DN25	1.25	d40/DN32	1.5	d50/DN40	2	d63/DN50
Materials	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
PVDF	1.32	10.48	2.36	18.94	3.11	31.12	5.60	55.89	7.07	94.24	11.30	150.64
PP	1.32	10.48	2.36	18.94	3.11	31.12	4.79	47.86	5.68	75.74	9.15	122.03
PVC Sch 80	1.13	8.42	2.02	15.25	2.63	25.21	4.94	47.86	5.11	66.35	8.61	112.36
PVC Metric	1.39	11.21	2.49	19.93	3.36	33.67	5.42	54.23	6.28	83.71	10.10	134.66

See page 206 for Flow Range Charts for sizes DN 80 to DN 100 (3 in. to 4 in.)

Technical Reference Section: Flow

Flow Range Charts (LPM)

Paddlewheel and Electromagnetic Sensors

+GF+ SIGNET Models 515, 525, 2517, 2536, 2540, 2550, 2560
LPM Flow Rates for DN 15 to DN 450 (1/2 in. to 18 in.) pipe sizes

MIN/MAX Flowrates in Liters per minute (LPM)

			Insertion Paddlewheel				Electromagnetic	
	Pipe Size (in.)	Pipe Size (mm)	3-2536-XX 3-8512-XX	3-2540	P51530-XX 3-8510-XX	P525-X 3-2517	3-2550	3-2560
Velocity Range			0.3 to 20 fps 0.1 to 6 m/s	0.3 to 20 fps 0.1 to 6 m/s	1 to 20 fps 0.3 to 6 m/s	1.6 to 20 fps 0.5 to 6 m/s	0.3 to 20 fps 0.1 to 6 m/s	0.3 to 20 fps 0.1 to 6 m/s
	0.5	d20/DN15	1 72	1 72	4 72	6 72	- -	1 72
	0.75	d25/DN20	2 129	2 129	6 129	10 129	- -	2 129
	1	d32/DN25	3 204	3 204	10 204	17 204	- -	3 204
	1.25	d40/DN32	5 356	5 356	18 356	28 356	- -	5 356
	1.5	d50/DN40	7 481	7 481	24 481	38 481	- -	7 481
	2	d63/DN50	12 795	12 795	40 795	64 795	12 795	12 795
	2.5	d75/DN65	17 1136	17 1136	57 1136	91 1136	17 1136	17 1136
	3	d90/DN80	26 1745	26 1745	91 1745	140 1745	26 1745	26 1745
	4	d110/DN100	45 3005	45 3005	151 3005	238 3005	45 3005	45 3005
	5	d140/DN125	72 4720	72 4720	238 4720	379 4720	72 4720	- -
	6	d160/DN150	102 6817	102 6817	344 6817	545 6817	102 6817	- -
	8	d225/DN200	178 11805	178 11805	590 11805	946 11805	178 11805	- -
	10	d280/DN250	280 18603	280 18603	931 18603	1488 18603	280 18603	- -
	12	d315/DN300	397 26408	397 26408	1321 26408	2116 26408	397 26408	- -
	14	d400/DN350	481 31915	481 31915	1597 31915	- -	- -	- -
	16	d450/DN400	628 41692	628 41692	2086 41692	- -	- -	- -
	18	d500/DN450	795 52770	795 52770	2642 52770	- -	- -	- -

Based on Sch 40 metal pipe (ASTM); values will vary due to pipe material, size, and schedule

Vortex Sensors

+GF+ SIGNET Models 7000 and 7001
LPM Flow Rates for DN 15 to DN 50 (1/2 in. to 2 in.) pipe sizes

	LPM											
Velocity Range	0.5 to 4 meters/sec 1.64 to 13.12 feet/sec				0.4 to 4 meters/sec 1.31 to 13.12 feet/sec				0.3 to 4 meters/sec 0.98 to 13.12 feet/sec			
	Pipe Size (in.)	Pipe Size (mm)	Pipe Size (in.)	Pipe Size (mm)	Pipe Size (in.)	Pipe Size (mm)	Pipe Size (in.)	Pipe Size (mm)	Pipe Size (in.)	Pipe Size (mm)	Pipe Size (in.)	Pipe Size (mm)
Sensor Materials	0.5	d20/DN15	0.75	d25/DN20	1	d32/DN25	1.25	d40/DN32	1.5	d50/DN40	2	d63/DN50
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
PVDF	4.98	39.66	8.94	71.70	11.76	117.78	21.18	211.56	26.76	356.70	42.78	570.18
PP	4.98	39.66	8.94	71.70	11.76	117.78	18.12	181.14	21.48	286.68	34.62	461.88
PVC Sch 80	4.29	31.86	7.63	57.73	9.97	95.43	18.70	181.14	19.35	251.12	32.57	425.29
PVC Metric	5.28	42.42	9.42	75.42	12.72	127.44	20.52	205.26	23.76	316.86	38.22	509.70

See page 206 for Flow Range Charts for sizes DN 80 to DN 100 (3 in. to 4 in.)

Technical Reference Section: Flow

Flow Range Charts (GPM and LPM)

In-line Rotor and Turbine Sensors

+GF+ SIGNET Models 2000, 2100, and 2507
GPM and LPM Flow Rates

		GPM		LPM	
Model and Size:	**Description**	**Min**	**Max**	**Min**	**Max**
3-2000-1X	Micro Flow - Low	0.030	0.700	0.110	2.600
3-2000-2X	Micro Flow - High	0.300	3.200	1.130	12.110
3-2100-XL and -31 Kits	Turbine Low - 1/2" Tubing	0.100	1.000	0.380	3.800
3-2100-XL and -32 Kits	Turbine Low - 3/8" Tubing	0.100	1.000	0.380	3.800
3-2100-XL and -33 Kits	Turbine Low - 1/4" Tubing	0.100	1.000	0.380	3.800
3-2100-XL and -34 thru -38 Kits	Turbine Low - 1/2" Pipe	0.100	1.000	0.380	3.800
3-2100-XL and -40 Kit	Turbine Low - 1/2" Flare	0.100	1.000	0.380	3.800
3-2100-XL and -41 Kit	Turbine Low - 3/8" Flare	0.100	1.000	0.380	3.800
3-2100-XL and -42 Kit	Turbine Low - 1/4" Flare	0.100	1.000	0.380	3.800
3-2100-XH and -31 kits	Turbine High - 1/2" Tubing	0.800	10.000	3.000	38.000
3-2100-XH and -34 thru -38 Kits	Turbine High - 1/2" Pipe	0.800	10.000	3.000	38.000
3-2100-XH and -40 kit	Turbine High - 1/2" Flare	0.800	7.000	3.000	27.000
3-2507.100-2V	Mini-Flow - 2mm Insert	0.106	0.740	0.500	2.800
3-2507.100-3V	Mini-Flow - 3mm Insert	0.198	1.123	0.750	4.250
3-2507.100-4V	Mini-Flow - 4mm Insert	0.330	1.585	1.250	6.000
3-2507.100-6V	Mini-Flow - 6mm Insert	0.792	3.170	3.000	12.000

Vortex Sensors

+GF+ SIGNET Model 7002
GPM and LPM Flow Rates for DN 80 (3 in.) sensors

At this velocity:		**the flow rate will be:**		**and the current output will be:**	**and the frequency output will be:**	
m/s	**ft/s**	**lpm**	**gpm**			
0	0	0	0	4.00 mA	0 Hz	Below 0.2 m/s, the output is 4.0 mA
0.1	0.33	28.64	7.57	4.00 mA	~1.9 Hz	
0.2	0.66	57.28	15.13	4.80 mA	4.6 Hz	
0.5	1.64	143.2	37.83	6.00 mA	12 Hz	
1	3.28	286.4	75.67	8.00 mA	23 Hz	
1.5	4.92	429.6	113.5	10 mA	35 Hz	
2	6.56	572.8	151.33	12.00 mA	47 Hz	
2.5	8.2	716	189.17	14.00 mA	58 Hz	
3	9.84	859.2	227	16.00 mA	70 Hz	
3.5	11.48	1002.4	264.83	18.00 mA	82 Hz	
4	13.12	1145.6	302.67	20.00 mA	93 Hz	
Beyond 4 m/s, the current output is 20.00 mA						

+GF+ SIGNET Model 7002
GPM and LPM Flow Rates for DN 100 (4 in.) sensors

At this velocity:		**the flow rate will be:**		**and the current output will be:**	**and the frequency output will be:**	
m/s	**ft/s**	**lpm**	**gpm**			
0	0	0	0	4.00 mA	0 Hz	Below 0.2 m/s, the output is 4.0 mA
0.1	0.33	43.4	11.47	4.00 mA	~1.9 Hz	
0.2	0.66	86.8	22.93	4.80 mA	3.8 Hz	
0.5	1.64	217	57.33	6.00 mA	9.4 Hz	
1	3.28	434	114.66	8.00 mA	19 Hz	
1.5	4.92	651	171.99	10 mA	28 Hz	
2	6.56	868	229.33	12.00 mA	38 Hz	
2.5	8.2	1085	286.66	14.00 mA	47 Hz	
3	9.84	1302	343.99	16.00 mA	56 Hz	
3.5	11.48	1519	401.32	18.00 mA	66 Hz	
4	13.12	1736	458.65	20.00 mA	76 Hz	
Beyond 4 m/s, the current output is 20.00 mA						