# SPINNER SELECTION GUIDE

## Introduction

Sondex manufactures a wide range of spinner flowmeters. This document provides general information to help select the correct spinner tool for the job.

## Types of spinner tools and their applications:

### Caged Fullbore Spinners

These flowmeters fold down to tool OD while running through tubing & passed restrictions; on exiting to the casing the spring-loaded cage opens allowing the impeller assembly to unfold. In this way a large impeller can be passed through small diameter tubing. CFB spinner shafts are mounted on roller bearings and the spinner threshold velocities are very low. In casing, it is recommended generally to run the largest possible spinner, maximizing cross-sectional coverage of the wellbore, to obtain the best data.

CFB tools are available with cages and impeller assemblies appropriate for particular casing sizes. Note that the impeller assembly may be changed for a smaller one, which may be advantageous in, for instance, rugose open hole completions.

**3 arm Caged Fullbore Spinners, CFBxxx**

The 3 arm CFB has rollers at the pivots of the arms and thus presents less friction when running in hole. With only three arms the exposure of the impeller to the well fluids is maximized, which helps to minimize the threshold velocity, but this reduces the protection of the spinner from damage. To protect the impeller whilst running through tubing and associated jewelry, run a spacer tool (such as a temperature tool) between the CFB and the roller centralizer above; this will help to keep the CFB centralized as it passes through items of varying diameter, such as GLMs, where the CFB may partially open.

**6 arm Caged Fullbore Spinners, CFBxxx**

The 6 arm CFB was developed to protect the impeller from damage and to provide greater centralising force in highly deviated and horizontal wells. This does reduce the exposure of the spinner to the flow and the anti-wear hardening on the springbow arms will have an increased friction effect so more weight may be required to descend in highly deviated wells.

**Alternative mechanisms for CFBs**

- **Downflow:** The Sondex CFB impellers fold downward. In high rate injection wells (fluid velocity more than ~240fpm) the downward flow will tend to fold down the impeller reducing log quality. To prevent this, the CFBs may be fitted with downflow impeller assemblies which only close in response to action by the tool's closing mechanism. Note that 9 5/8in CFB are fitted as standard with downflow spinner assemblies, due to the size of the blades.

- **Solid Shaft:** Sondex CFB impellers have restricted range flexible joints; this is to minimise the risk of damage if an obstruction is met. At higher flowrates (above about 500 fpm or 25 RPS) there is a tendency for the flexible joint to oscillate; to avoid this, a solid shaft may be fitted to the flowmeter.

- **Fitting smaller impellers:** If there is risk of damage or more clearance between the impeller and casing is required, it is possible to fit a smaller impeller assembly to the CFB. Note though that if changing impellers that the impeller closing spring must be the correct length.

- **Repairs to CFB impellers:** The Sondex CFB impellers are supplied as balanced 4 blade assemblies, with flat blades; if the impeller is not too badly damaged and the welding on the blade is not cracked, bent blades may be hammered back flat.

## Continuous Spinner Flowmeters

### Continuous Spinner Flowmeter, CFSxxx

These spinners are designed for logging in tubing or sand-screened wells. The impeller rotates continuously and is supported by roller bearings at each end of the shaft. If the tubing diameter permits, a spinner larger than the diameter of the tool body should be run to improve exposure to the well fluids. Sondex flowmeters are protected from side impact by having a solid shroud, optional ported shrouds are available. The impellers are helical which may give better results, particularly in viscous fluids. If there are problems of plugging with debris it is possible to fit a smaller diameter impeller to give more clearance between the impeller and the tool body.

### Continuous Jeweled Spinner Flowmeter, CFJxxx

These spinners are designed for logging in high fluid velocity fluids, such as in gas wells, as the impeller is more like a turbine, has a lower pitch than the CFSs and is capable of going to higher revs. The impeller rotates continuously and the shaft is supported by jeweled bearings at each end. If the tubing diameter permits, a spinner larger than the diameter of the tool body should be run to improve exposure to the well fluids. Sondex flowmeters are protected from side impact by having a solid shroud, optional ported shrouds are available. If there are problems of plugging with debris it is possible to fit a smaller diameter impeller to give more clearance between the impeller and the tool body. In wells with sand production, there should be less likelihood of jamming with jeweled bearings than with roller bearings.

### In-Line Spinners, ILSxxx

The downhole environment is not well known in terms of debris, scale build up etc that may affect spinner data so it is wise to run a back up spinner in the string, whenever possible, as standard practice.

In-line spinners have an electrical feedthrough to enable other PLT tools to be run below; this allows spinner profiles of both tubing and casing to be logged in a single run. Particularly in high profile wells or where there is danger of fouling (such as in horizontal wells) the in-line spinner should be run as a back-up. If the tubing diameter permits, a spinner larger than the diameter of the tool body should be run to improve exposure to the well fluids. Sondex flowmeters are protected from side impact by having a solid shroud; ILS housings with 3 removable side doors are now available to allow greater exposure to the fluid flow, particularly when using the tool in wells with scale contamination. In situations of anomalous downward flow, (see below), the data from the ILS can be better than that from the CFB, probably because it has smaller coverage.

### Diverter Flowmeters, DBTxxx

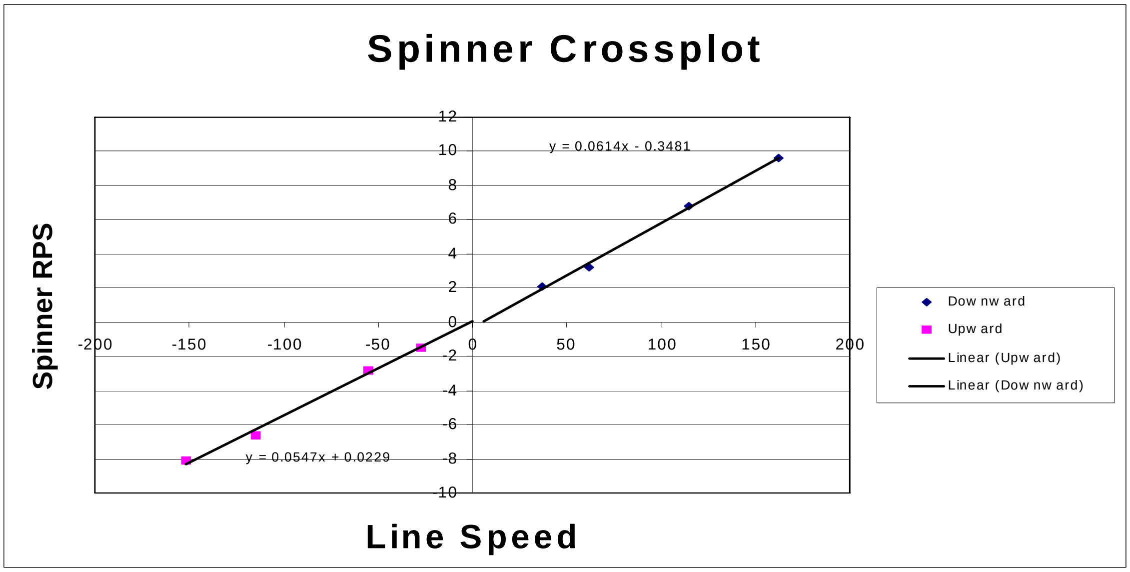
Spinner flowmeters measure flowrate in terms of fluid velocity. When the flowrate of a well is low and the casing diameter is large the fluid velocity can be very low. For example a flowrate of 200 bbls per day in 7” casing is equivalent to a fluid velocity of 3.5 fpm. Thus, if there are, say, 3 zones contributing to this total then it may be difficult to evaluate a very accurate flow split. The solution is to reduce the effective tubing diameter by using a diverter flowmeter which opens an ‘umbrella’ cone downhole and channels all the flow through the small ID of the spinner housing. For a 1 11/16” diverter flowmeter the spinner housing ID is 1.49” so for a 200 bbls/d well, fluid velocity is now 64 fpm instead of 3.5 fpm. This flowrate is easily measured by the internal CFS spinner which has a threshold velocity of 7 fpm. Another reason to use a diverter flowmeter is to negate the effect of anomalous downward flow in multi-phase inclined wells (see below) by diverting all the flow through the spinner. In this way better fluid identification may also be achieved by the mixing of the phases.

Diverter flowmeters are opened and closed in response to signals from surface or, for the memory diverter flowmeter, power interruptions. Because all the flow is being channeled through a small restriction there is a pressure differential across the tool which tends to exert an upward force. The tool is supplied with charts to determine the lift force and thus the weight needed to counteract this lifting. The Sondex tools have built in safety features relating to battery voltage and user defined maximum pressure differential.

**Calculation of Fluid Velocity from Spinner data.**

With the exception of the diverter flowmeter which is calibrated from known response and threshold, spinner flowmeters are calibrated downhole in a static portion of the well. This consists of recording spinner RPS at different downward and upward line speeds to establish a response slope and intercept.

This is an example of a 'spinner cross-plot' to determine response slope and intercept.




Typically throughout the industry the **response slope** is in RPS per fpm and the intercept is fpm, or the equivalent metric units. The intercept is known as the **threshold velocity** or lowest flow velocity required to start the spinner rotating. The threshold velocities in this case, where the lines intercept the x-axis i.e. at zero rps, are +5.4 fpm for downward passes and –0.4 fpm for upward passes; the positive and negative threshold velocities are not necessarily equal. Similarly, the upward response slope may be different (shallower) to the downward response slope. This is because when logging up the tool body is shielding the impeller to a certain extent.

Sondex nominal response slopes for different impeller types are listed below. The CFB impellers have a nominal response slope of 0.05 RPS per fpm, equivalent to a 4" pitch [calculated from 12/(60*impeller pitch in inches)]. The response slope and threshold *will* vary with fluid type and downhole conditions which is why it is important to perform a spinner calibration for each well (and ideally each zone during flow).

Using the calibration slope and intercept, we can calculate the apparent fluid velocity that the spinner sees after correction for line speed. We subtract line speed as it is contributing to the fluid velocity that the spinner sees. If we were logging up we subtract a minus line speed therefore we effectively add line speed to the apparent flow.

**To calculate apparent flow: Apparent Flow (fpm) = (RPS/Slope + Threshold) – Line Speed.**

Apparent flowrate is flow where the spinner measures it in the centre of the tubing. This must then be corrected to average flowrate using a correction factor. For turbulent flow and depending on the impeller size compared to the pipe diameter this factor can range from 0.75 to 0.9, the industry accepted value is 0.83. Fullbore spinners in casing tend to have a correction factor of about 0.85-0.90.

**To calculate average flow: Average Flow (fpm) = Apparent Flow x Correction Factor**

If we know the casing or tubing ID we can convert flow in fpm to bbls/day:

**To calculate flow in bbls/day: Average Flow (BPD) = Average Flow(fpm) x 1.4 x Casing ID"^2**

For example:

A typical slope for a CFB is 0.05 RPS per fpm and intercept (threshold) 2.5 fpm. Thus if we are in 7" casing (nominal ID 6.3") and we record 15 RPS at a downward line speed of 30 fpm:

Flow (fpm) = (15/.05 + 2.5) – 30 = 272.5 fpm

Average Flow (fpm) = 272.5 x 0.83 = 226.2 fpm

Flow (BPD) = 226.2 x 1.4 x 6.3^2 = 12,569.0 BPD

Remember that this is *downhole* flowrate and will need converting to surface rates using PVT properties.

**Threshold Velocities**

One measure of a spinner's sensitivity is its threshold; generally, the lower the threshold the better the tool. This threshold value is used in the calculation of fluid velocity and in low fluid velocity wells can become significant. Estimated threshold velocities for gas at 2000psi are listed but note that the threshold values in gas will vary with well pressure.

Assuming the bearings are in perfect condition the threshold velocity and response slope are related to the density and viscosity of the well fluid. Without major test facilities it is hard to measure the actual threshold velocities but the following is based on experience with Sondex tools in water and in the field light, clean oil.

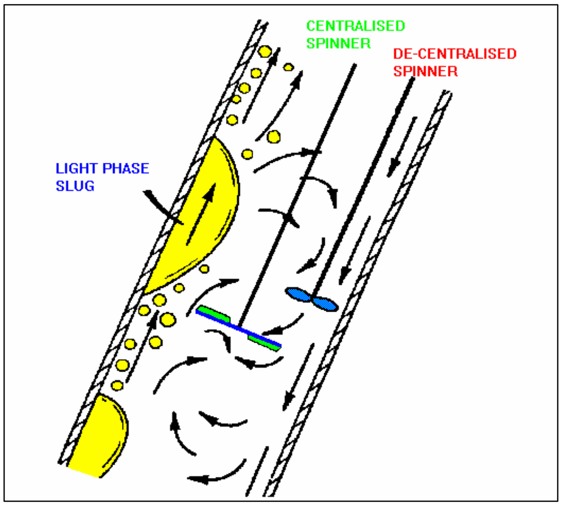
The thresholds listed are based on responses in water. Add about 0.5 fpm for light oil and 2.5 fpm for heavy oil. For gas it will depend upon the pressure, the higher the pressure the lower the threshold (as density increases). For gas add typically an extra 5-10 fpm for pressures around 2000 psi. In reality it is best to perform a downhole calibration as slope will also change with fluid type. The experience with heavy oil was in Egypt recently where a log showed a considerable shift in threshold in heavy oil. When logging low fluid velocities the threshold change can make a difference to the appearance of the logs which could be mistaken for anomalous flow. For 1 11/16" CFS/CFJ/ILS add an estimated 2 fpm as these tools have small impeller diameters. The 1 11/16 CFS and CFJ may also be less responsive when flow is downward past the tool and the tool body tends to shield the impeller. For similar reasons the 1 11/16 In Line Spinner may show a different slope at high fluid velocities.

Because there are so many variables (density, viscosity, spinner diameter etc) it is only possible to give guideline threshold velocities, as follows:

| | Water | Light Oil | Heavy Oil | Gas (2000 psi) |
|---|---|---|---|---|
| CFB | 1.8 - 2.5 fpm | 2.3 - 3.0 fpm | 4.3 – 7.0 fpm | 7.0 - 12.5 fpm |
| CFJ | 3.5 - 5.5 fpm | 4.0 - 6.0 fpm | 6.0 - 10.0 fpm | 8.5 - 15.5 fpm |
| CFS | 5.0 - 8.0 fpm | 5.5 - 8.5 fpm | 7.5 - 12.5 fpm | 10.0 - 18.0 fpm |
| ILS | 5.0 - 8.0 fpm | 5.5 –10.0 fpm | 7.5 - 14.5 fpm | 12.0 - 20.0 fpm |

**Anomalous CFB Responses**

The most common anomalous response is in multi-phase deviated wells where flow tends to stratify and the light phase (oil or gas) flows on the high side of the wellbore. The upward movement of the light phase bubbles displaces water back around the bubbles while moving upwards, and also cause eddying, as illustrated here.




The result is that the spinner will display an anomalous downward negative flow. This phenomenon is more pronounced in 2 phase flow than in 3 phase flow which tends to be more turbulent. .

It is possible in a static column of water to calculate the *theoretical* downflow of water around the bubbles as the light phase bubbles up the well.  We need to measure light phase holdup (from density or capacitance) and estimate light phase slip velocity.

For example:

Light phase holdup = 0.2, heavy phase holdup = 0.8. Slip velocity = 30 fpm.
Superficial velocity of light phase = 0.2 x 30 = 6 fpm
Apparent velocity of heavy phase = -6/0.8 = -7.5 fpm

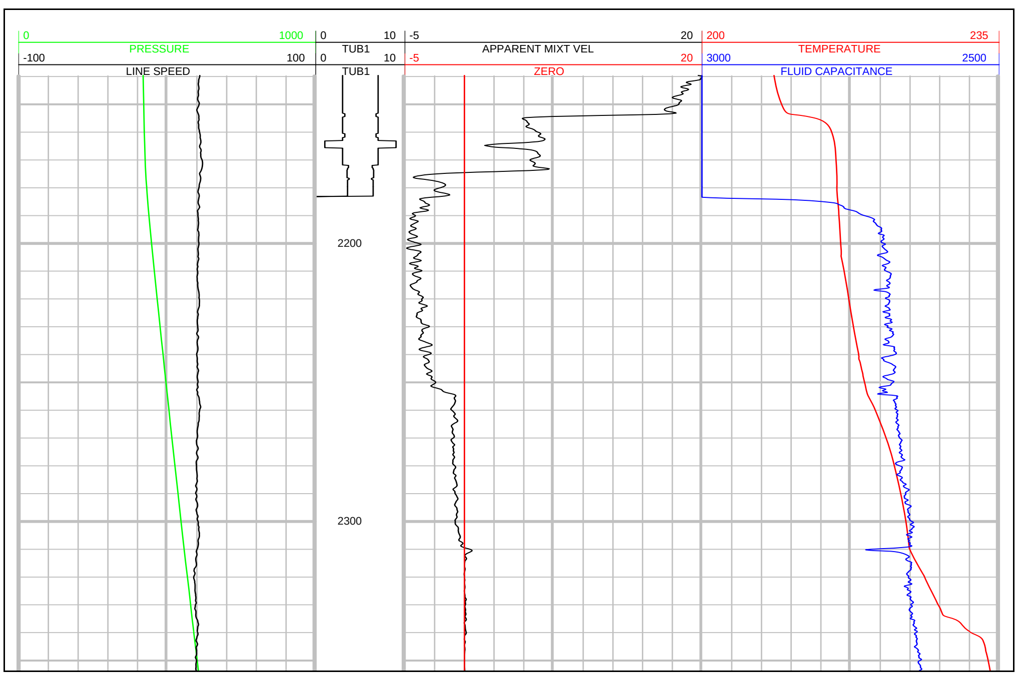
The spinner would show the apparent heavy phase flow as -7.5 fpm.  In reality though, the values for apparent negative flow are much higher than this as the upward flow of the light phase induces eddying.

Assuming that the true heavy phase flow is zero (light phase bubbling up through a static heavy phase column) an *estimate* for the true light phase superficial velocity:

Superficial Velocity light phase = holdup light phase x slip velocity light phase x 0.5.

The correction factor, 0.5, is because the turbulence (which is not factored into the slip velocity estimation) tends to retard the light phase, but this value is only an estimate.  The interpreter may elect to use a different correction factor.  If a centre measuring holdup tool (e.g. nuclear fluid density or capacitance) is being used the measured holdup should be at its maximum, i.e. at the perforations or just above, before the oil disappears to the high side of the hole.  For this case it may be better to calculate superficial light phase = holdup light phase x slip velocity only (to take into account that a centralised fluid ID tool may not show the true holdup).

This is an example Production Log showing anomalous negative spinner response (the red line is zero mixture velocity):




Looking at the spinner data only it looks like a downward cross-flow.  However, the temperature and capacitance curves show that flow is upward - this is a flow of oil bubbles up through a water column. Note that when the flow enters the tubing the velocity is higher and the water is lifted out of the well.

Apparent downflow will occur in an oil/water well where the fluid velocity is < 70fpm.

**An option in this well would be to run a diverter flowmeter which will give good results as all the flow is forced through the small flow path past the impeller.**

**SONDEX SPINNER STATISTICS**

| TOOL | BODY DIAM ins | Spinner Blade OD ins | Shroud Hsg ID ins | Pitch ins/rev | Pitch RPS/fpm |
|---|---|---|---|---|---|
| **Caged Full Bore Flowmeter 6 arm & 3 arm mechanical sections** | | | | | |
| CFBMxx (4 1/2 in csg) | 1 11/16 | 2.60 | N/A | 4.0 | 0.050 |
| CFBMxx (5 in csg) | 1 11/16 | 3.15 | N/A | 4.0 | 0.050 |
| CFBMxx (5 1/2 in csg) | 1 11/16 | 3.30 | N/A | 4.0 | 0.050 |
| CFBMxx (7in csg) | 1 11/16 | 4.24 | N/A | 4.0 | 0.050 |
| CFBMxx (9 5/8 in csg) | 1 11/16 | 5.50 | N/A | 4.0 | 0.050 |
| (all 9 5/8in CFBM are fitted with downflow impellers, as standard) | | | | | |
| **Continuous Flowmeter Spinner** | | | | | |
| CFSMxx (1 1/2 in shroud) | 1 3/8 | 1.220 | 1.290 | 4.0 | 0.050 |
| CFSMxx (1 11/16 in shroud) | 1 11/16 | 1.402 | 1.490 | 4.0 | 0.050 |
| CFSMxx (2 1/8 in shroud) | 1 11/16 | 1.772 | 1.935 | 4.0 | 0.050 |
| **Continuous Flowmeter Jewelled Bearing Spinner** | | | | | |
| CFJMxx (1 11/16 in shroud) | 1 11/16 | 1.402 | 1.490 | 5.6 | 0.036 |
| CFJMxx (2 1/8 in shroud) | 1 11/16 | 1.772 | 1.935 | 7.0 | 0.029 |
| **In-Line Spinner** | | | | | |
| ILSxxx (1 11/16 in shroud) | 1 11/16 | 1.402 | 1.490 | 5.6 | 0.036 |
| ILSxxx (2 1/8 in shroud) | 1 11/16 | 1.772 | 1.935 | 7.0 | 0.029 |
| **Diverter Basket Flowmeter Tool** | | | | | |
| DBTxxx (1 11/16 in shroud) | 1 11/16 | 1.402 | 1.490 | 5.6 | 0.036 |
| DBTxxx (2 1/8 in shroud) | 1 11/16 | 1.772 | 1.935 | 7.0 | 0.029 |

**Fullbore Spinners Minimum Working Diameters**

Caged Fullbore Spinners fold down to pass restrictions & through tubing and open when in the casing to perform the log. This opening and closing is made by mechanical linkages to the cage surrounding the spinner. For each pipe size there is a limited reduction in diameter that is tolerated before the spinner assembly closes; this is to ensure that the blades are closed quickly to avoid damage (& possible loss of log data) and to avoid indefinable log anomalies where the blades may be partly open.

| CFBMxx (3 & 6 arm) | | Minimum ID | Spinner assy | Spinner assy OD |
|---|---|---|---|---|
| 1 11/16in | *x 4 1/2 csg* | 3.80in | pn 1872 | 2.60in |
| 1 11/16in | *x 5 csg* | 4.20in | pn 1870 | 3.15in |
| 1 11/16in | *x 5 1/2 csg* | 4.60in | pn 1871 | 3.30in |
| 1 11/16in | *x 7 csg* | 5.90in | pn 1842 | 4.24in |
| 1 11/16in | *x 9 5/8 csg* | 8.50in | pn 1894 | 6.08in |
| **CFBMxx (3 arm)** | | **Minimum ID** | **Spinner assy** | **Spinner assy OD** |
| 1 3/8in | *x 4 1/2 csg* | 3.80in | pn 13939 | 2.60in |
| 1 3/8in | *x 5 csg* | 4.20in | pn 13908 | 3.15in |
| 1 3/8in | *x 5 1/2 csg* | 4.60in | pn 13937 | 3.30in |
| 1 3/8in | *x 7 csg* | 5.90in | pn 13932 | 4.24in |