PC-PUMP® Points to Consider

March 2007

This document contains a list of details regarding the use of C-FER's **PC-PUMP**® software that all users should be aware of. These are based on questions asked and problems reported by **PC-PUMP** users, as well as on observations by C-FER staff. Most of these are in the *User Guide*. This document is intended as a reminder of some of the important (and often not obvious) points which should be kept in mind when using **PC-PUMP**. Please note that these comments are as of v2.68. Some of these may change for future releases or may be different in earlier versions.

1. General Considerations

- If a window has an ***OK*** button, you must use it to close the window, saving the entered data—if you click on ***Cancel*** or the ***X*** at the top right corner, your changes will not be saved. Windows without an ***OK*** button, however, are closed using the ***X*** at the top corner, and the changes are saved. (Only the *Wellbore Geometry* window falls in this category.)

- The energy cost, as reported by **PC-PUMP** (when the drive equipment is specified), is based on the power consumption and the price of electricity as set in the *Defaults* tab in the *Preferences* window, which can be changed on a case-by-case basis in the *Prime Mover* tab of the *Surface Equipment Selection* window. The default value is $0.05 per kilowatt-hour, but this can be changed. This covers only power use and does not consider other power costs such as demand charges or power factor penalties. Different power companies will assess these in different ways. Note: if your Windows International settings have a currency unit other than dollars, **PC-PUMP** will use that. In this case, when **PC-PUMP** is installed or first used, it will ask you to enter the default value; this value can be changed at any time, as described above.

2. Equipment Specification

- The Kelly Bushing Offset is the difference between the wellhead and the point from which geometry surveys are measured (the Kelly Bushing on the drill rig). Entering this value incorrectly will result in predictions of wear locations being incorrect.

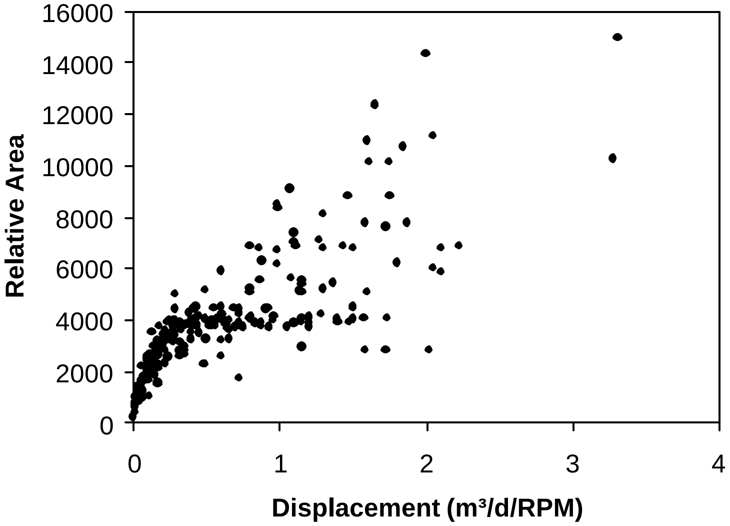
- If you haven't specified a pump seating depth, you will not be able to use the "fill to surface" method of rod selection, since **PC-PUMP** will think that the pump is at the surface and that no rods are needed to fill the rod string to surface. C-FER recommends always entering the wellbore geometry (when applicable), Kelly Bushing offset, mid-perforations depth and the pump seating depth first in any analysis.

- In pump selection, entering the proper values for the volumetric efficiency and the friction torque can be very important, depending on what results you are trying to achieve. These should be as close as possible to the values expected in steady state operation in the well and can be very different from values measured in a bench test using water. The default values set by C-FER are 100% for the volumetric efficiency and 80 ft·lb for the friction torque, and may not be appropriate for many cases. These defaults can be changed in the *Preferences* window, and the existing default can always be overridden in the *Pump Selection* window.

- Be careful entering the electric motor efficiency and power factor for surface drive motors. The efficiency should be entered as a percentage (0-100), while the power factor should be entered as a decimal (0-1).

- The efficiency and power factor of electric motors can change substantially depending on the loading of the motor. For downhole drive systems, **PC-PUMP** can calculate appropriate values once the motor performance curves are known. However, this is not the case for surface drive systems. For surface drive systems, efficiency and power factor values specified as input are not changed by **PC-PUMP** as a function of motor load. Note that the load rating of a motor changes with the electrical frequency, and this also is not considered when determining if a surface motor is overloaded. In addition, because **PC-PUMP** calculates only steady-state conditions, it will not determine if a selected motor is capable of starting the pump or not.

- The actual pump to be used should be specified whenever possible. It is not sufficient to select a pump with a similar displacement and rated pressure, because the axial load depends on geometry factors which are not directly related to the displacement of the pump. Axial load has an effect on rod loading, drivehead loading (and bearing life), and wear calculations. The chart below shows the effective area that is used by **PC-PUMP** to calculate the axial load versus the displacement for a number of single-lobe pumps in the **PC-PUMP** database. Note the large variation in area for pumps of similar displacement, especially at larger displacements.



- Thrust bearing life calculations are commonly done in two different ways, either based on a life of 1 million revolutions or 90 million revolutions. The ISO standard (used by **PC-PUMP**) uses the 1 million revolution method, while some major bearing manufacturers (e.g. Timken) use the 90 million revolution method. With either method, the minimum life that 90% of bearings are expected to have can be calculated using the following equation:

$$L_{10} = \left(\frac{C}{P}\right)^{\frac{10}{3}} \cdot \frac{B}{N}$$

where C is the bearing rating (in N or lbs), P is the bearing load (N or lbs), B is a constant (1.902 for ISO method, 171.2 for C_{90} method), N is the speed (RPM), and L_{10} is the life (in years) expected to be exceeded by 90% of the bearings. The C ratings for the two methods are compared as:

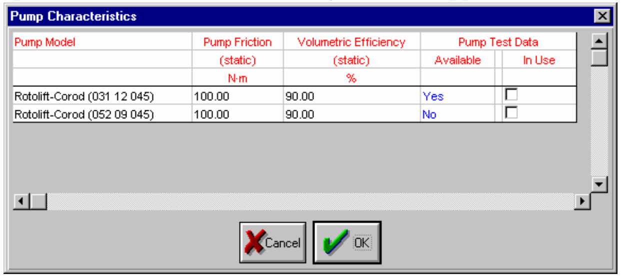
$$C_{ISO} = C_{90} \times 3.857$$

Either calculation method will give the same result, if used properly. For example, a bearing with an ISO rating of 3000 lb, operating under a load of 1000 lb at 100 RPM, as calculated using the B coefficient for the ISO method will have a life of 0.74 years. The C_{90} rating for this bearing is 777.8 lb, and the life, as calculated using the B coefficient for the C_{90} method, is also 0.74 years. However, errors have occurred because the C rating for one method was used with the B constant for the other. Users should be aware of the differences when comparing bearing ratings. The thrust bearing ratings displayed in the *Drive Equipment Specification* window in **PC-PUMP** are based on the ISO method and not the method used by some bearing manufacturers. Comparisons should be made appropriately.

- **PC-PUMP** requires that the wellbore geometry extend below all equipment entered. If the survey does not extend into the region of the well where the pump and/or perforations are located, you will have to enter an extrapolated survey point (or points) below them.

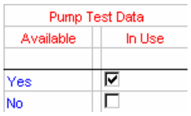
- If you have an open hole completion, **PC-PUMP** will assume the diameter of that section is the same as the lowest casing in the well. Alternatively, you may specify casing in the open hole section, even though it does not actually exist, in order to be able to specify the diameter.

- If you wish to enter a bench test and have **PC-PUMP** calculate the appropriate volumetric efficiency and friction torque, please be aware that the pump may not behave the same in the well as it does on the bench. If you have accounted for this and still wish to use a test result in the **PC-PUMP** calculation, you must turn on this feature. Simply entering the bench test data is not sufficient. After the test data has been entered, and all the other equipment has been specified, you must go to the *Analysis* window and click on the Pump Model: button (located in the equipment selection area above the ***Calculate*** button. When you click on the ***Pump Model*** button, the following window appears:



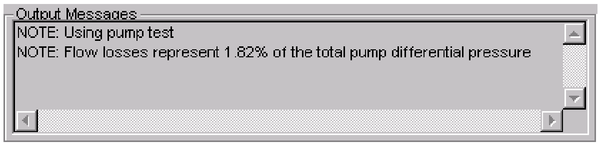
Pump Model	Pump Friction	Volumetric Efficiency	Pump Test Data	
	(static)	(static)	Available	In Use
	N·m	%		
Rotolift-Corod (031 12 045)	100.00	90.00	Yes	☐
Rotolift-Corod (052 09 045)	100.00	90.00	No	☐

In this case, two pumps have been selected, and test data has been entered for one (the 031 12 045). In order to specify that this test data is to be used in the calculation, you must turn on the appropriate check boxso that it looks like this:



Pump Test Data	
Available	In Use
Yes	☑
No	☐

When a test is being used, a message will appear to that effect in the output messages box (*Analysis Outputs* window):



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NOTE: Using pump test
NOTE: Flow losses represent 1.82% of the total pump differential pressure
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3. Fluid Properties

- In single-phase mode, and when the advanced viscosity feature is ***not*** being used, the single value of viscosity entered must correspond to the **total liquid viscosity**, not simply the oil viscosity. This simple calculation mode should not normally be used in wells with viscous oils. If the oil viscosity is very low or if there is a high water cut, the temperature effects are small overall, and this simple mode can be used. If the advanced viscosity mode is used, enter total fluid viscosity as a function of temperature if the water cut effects section is not in use. If the water cut section is in use, enter only the oil viscosity as a function of temperature.

- In single-phase mode, **PC-PUMP** gives you the ability to set the tubing and casing fluid densities separately. This feature is not often needed but occasionally can be useful. For example, a well with a high water cut that has been operating for a reasonable period of time will have the oil separate from the water in the annulus above the perforations or pump intake, whichever is higher. In this case, the casing density should be set to that of the pure oil, while the tubing density should be set to that of the full mixture.

- Be aware that the effect of water cut on total fluid viscosity is complex. A water-in-oil emulsion can have a viscosity much greater than the oil viscosity. If the water cut is below 75%, great care should be taken in entering the viscosity into **PC-PUMP**. At higher water cuts, an emulsion is most likely oil-in-water, with a viscosity not much different from that of water alone. The only way to determine for certain if an emulsion will form and what its viscosity will be is to test the fluids in a lab. The water effect section of the advanced viscosity mode in single phase flow allows you to have **PC-PUMP** calculate the effective viscosity based on the viscosity of water and oil and on the water cut. You have the choice of using just a simple interpolation or a built-in emulsion correlation. The default emulsion correlation assumes that the emulsion switches from water-in-oil to oil-in-water at a water cut of 60% and that the viscosity at 60% water (water-in-oil) is 8.67 times the viscosity of the oil alone. Above 60% water cut, the emulsion is assumed to have the viscosity of water. Caution: these values will be different for different types of oils and can change drastically with the addition of small amounts of certain chemicals.

- While **PC-PUMP** does consider the weight of sand in calculating the density in the Single Phase – Specify Composition mode, it does not consider the effects of the sand on the total fluid viscosity, nor does it evaluate whether the fluid can carry the sand out of the wellbore. The Sand Settling calculator (available through the Windows Start menu or from the button in the Auxiliary Calculations section of the Analysis Outputs window) can assist in determining how quickly sand settles down in the tubing—it is important that the velocity of the fluid moving up the tubing be **significantly** higher than the velocity the sand settles down at.

- In multiphase mode, the user specifies BS&W cut. The multiphase correlations use this to determine both density and viscosity, but these calculations assume that the entire BS&W cut is essentially water and the effect of sand being present is negligible. If this assumption is invalid, there will be some error in the results.

- In multiphase flow, a large number of properties (e.g. solution gas, bubble point, viscosity, gas compressibility) are calculated from correlations based on parameters like the API gravity of the oil and the pressure and temperature. The correlations used by **PC-PUMP** are from the literature, and the sources are listed in the *User Guide*. Be aware that they may not be representative of all oils. The accuracy of these correlations may be reduced in some cases, particularly in heavy oil. **PC-PUMP** will print a warning for any multiphase case with an API gravity less than 15°. Note that you do have the option of entering dead oil viscosity test data—this removes the reliance on this correlation and is highly recommended in heavy oil cases. **PC-PUMP** gives you the ability to select different correlations for some of these properties. Selecting one of these correlations, however, requires knowledge about which of these correlations most suits the properties of the oil from your fields.

4. Operating Conditions

- **PC-PUMP** allows you to specify operating conditions without entering IPR data (but just fluid level, for instance). This should be done with care. A common use of **PC-PUMP** is to determine if a particular well can increase production by increasing the speed (or using a larger pump). **PC-PUMP** can help with this analysis by determining if the new rate will overload the rods or result in a wear or fatigue problem (among other things). However, if the IPR is not specified, **PC-PUMP** cannot by itself consider the effects of the increased drawdown of the well (unless you actually change the entered value for the fluid level or producing pressure to correspond to the increased flow rate). Note that increased drawdown results not only in increasing loading, it may also result in larger amounts of gas going through the pump, causing lower volumetric efficiency, for instance.

- Know that the casing head and tubing head pressures (CHP and THP, respectively) are important when doing a **PC-PUMP** analysis. Cases have occurred when a pump was sized only to produce fluid to surface, and when the back pressure at the wellhead was considered, the pump was undersized. The THP is the pressure at the wellhead at the operating flow rate. In some cases, the flow rate won’t have a large effect on the THP, and in other cases it may. The casing is sometimes vented to atmosphere. However, in many cases it is connected to the flowline (through a check valve). In which case, the CHP should be set equal to the THP.

- Accuracy in specifying the fluid level (or IPR) is always important (in that it affects the overall hydrostatic pressure on the pump), but it is particularly important in multiphase cases. As flow is increased, the producing pressure will decrease. This will cause more gas to break out of solution, and the volume of the free gas will also increase. If the pump is not located below the perforations, some of this gas will be forced through the pump, thereby reducing its efficiency. Too much gas through the pump can have a substantial negative effect on the pump life. (Note: while the fluid level normally drops in the well as producing pressure decreases, it is possible in gassy wells for the opposite to occur.)

- The temperature gradient is the temperature gradient of the fluid in the tubing at the operating flow rate, expressed as a temperature per unit of vertical depth. Note that it is **not** the geothermal temperature gradient. This flowing temperature gradient should be smaller than the geothermal gradient. The option exists in **PC-PUMP** to enter the flowing wellhead temperature instead of the gradient.

5. Flow Calculations

- Flow friction losses from the perforations to the pump intake are calculated in the current version of **PC-PUMP**. (In v2.1, only the hydrostatic gradient was calculated and not the flow losses; flow losses were only considered in the tubing.) This is not important in many cases, particularly if the pump is located above the perforations and is driven from surface. In other cases, however, it can be very important. In some cases, the pump is located below the perforations and there is very little clearance between the casing and the pump; if there is a high flow rate or high viscosity, the flow losses can have a drastic effect on the results. Downhole drive systems will frequently suffer from high flow losses, as they tend to have high flow rates and the downhole motor is usually a larger diameter than the pump, leading to a smaller flow passage. Note that **PC-PUMP** does not consider the flow effects of a no-turn tool or tubing anchor below the pump. If the pump is seated below the perforations, the fluid will have to pass by the anchor to reach the pump intake. Some anchors have a fairly small flow area, which could cause problems in high viscosity or high flow rate situations.

- In the *Defaults* tab of the *Preferences* window, there is a check box labelled “Use Rod String in Flow Loss Calculations”. This check box should normally be turned on. If it is turned off in surface drive calculations, **PC-PUMP** will calculate the flow losses as if the rod string was not there. (Note that a rod string must still be specified.) This feature was added in v2.1 so that users could simulate downhole drive situations before the downhole drive module was added to the software. If you have the downhole drive module, GFER highly recommends that you do not turn this check box off. **PC-PUMP** will then consider the effects of the rod string in surface drive cases and not consider a rod string in downhole drive cases. When this option is turned on, **PC-PUMP** will print an output message with the results of every calculation, reminding you that it is turned on.

- **PC-PUMP** has a “Calculate Free Gas Separation” option and also an option to specify the free gas separation separately for when the intake is above or below the perforations. When the calculate option is turned on, the program will use 100% separation when the intake is above the perforations. This assumption is normally reasonable, unless there is a high velocity of fluid in the annulus at the perforations (e.g. if there is a very high flow rate or if there is a narrow clearance between the tubing and casing). If a lower value for free gas separation is desired, you must turn off the calculate option and enter a value manually. The calculate option works best in wells where the pump is near vertical and is centralized in the casing—in significantly deviated wells, or in cases where the pump is off to one side of the casing, the calculated free gas separation may be less accurate—a manually entered value may be preferable in such cases.

- In downhole drive systems, you have the option of calculating thermal effects—by turning on the check box labelled “Perform Motor Heating Analysis”. Many ESP manufacturers recommend that there be a minimum of 1 ft/s flow velocity past the motor in order to remove heat generated by the motor. While this criterion is usually adequate in light oil or in high water cut wells, it may be insufficient in heavy oil, where the flow regime is likely to be laminar. Using this calculation will give you a better idea of whether motor overheating is a potential problem in your well. Also, if you are using an advanced viscosity calculation (always recommended in heavy oil) and have this feature turned on, **PC-PUMP** will consider the effect of the heat transferred to the fluid from the motor on the temperature of the fluid and therefore on the viscosity—in some heavy oil cases, a viscosity reduction can be realized, leading to a power reduction.

6. Rod/Wear/Fatigue Calculations

- **PC-PUMP** considers only steady state. It is important to note that the effects of transients (e.g. start-ups, or slugs of sand/gas/water) are not considered. It is unwise to design a rod string such that the calculated effective stress is very close to (or above) the yield stress of the rods. This would make transient conditions not considered by **PC-PUMP** very likely to result in rod string failure.

- You can perform a space-out calculation in **PC-PUMP** by opening the Rod Loading/Deflection graphs after clicking on the ***Calculate*** button in the *Analysis* window (Click on Rod Loads/Defl.). The tab on the furthest right in this window is for space-out. When you click on the *Space-Out* tab, a window appears asking if you wish to consider thermal effects. If you decide to do this, turn on the check box in the window and then enter *the average temperature of the rod string in the well at the time the space-out is done*. The space out graph shows the rod extension due to operating stretch, rod weight and thermal extension (if selected). The minimum space-out is the maximum operating stretch (plus thermal extension if applicable).

- A major problem in analyzing deviated wells is the survey interval. In many cases a 30 metre survey interval is used, and only a portion of the well (below the kick-off point) is surveyed. Vertical wells are often not surveyed at all. Previous C-FER research work indicates that widely spaced surveys often hide doglegged sections which are worse than the survey would indicate and that supposedly straight sections of wells are sometimes corkscrewed or contain other deviations. If a survey which has insufficient spacing is entered in **PC-PUMP**, and the software predicts that the well is marginal in wear or fatigue, the actual field conditions may be worse (possibly even much worse) than **PC-PUMP** would indicate. Similarly, users have had fatigue or wear problems in wells which were supposed to be vertical, only to discover later that the well was drilled very poorly.

- Severe doglegs are not the only indicator of possible problems with wear and fatigue. Some types of shape can be worse than a plain dogleg, even if the actual measured dogleg severity is not as severe. **PC-PUMP** is capable of analyzing these cases. (One example of a bad well is one which starts vertical, deviates out in one direction, and then drops into the production zone—an S-shaped well.)

- A problem suffered by several operators in eastern Alberta (and into Saskatchewan) involves reliable operation for a very long time, suddenly changing to frequent failures due to broken rotors or rod fatigue. One possible cause of this type of failure is a casing deformation due to shear or subsidence in the reservoir. This would not have been detected during the initial survey and the long initial run of the pump. Because of the nature of gyro surveys, it is possible that such a survey would not identify the problem even if the gyro tool runs through the damaged interval. A survey which measures the inside diameter of the pipe (such as with a caliper tool) may be more capable of discovering this type of problem.

- Rod/Tubing wear calculations in **PC-PUMP** do **not** consider wear on the rod body, but only on the tubing. In some cases, rod body wear can be significant. (Some people have been known to run a larger diameter rod string in high-wear parts of the well to allow for increased rod life.) Note that for standard rods, all the contact is assumed to occur on the couplings/centralizers and rod guides, and not on the rod body. Wear on the couplings is not normally going to have a large effect on the rod string strength. However, in some cases (and all the time in Corod strings) the rod body can actually contact the tubing and then rod wear may be an issue.

- **PC-PUMP** considers the spin-through centralizers and rod guides to give zero wear on the tubing wall. Wear internal to the guide or coupling is not considered.

- **PC-PUMP** only has wear coefficients for steel couplings on steel tubing and for urethane coated couplings on steel tubing. Other materials may have different coefficients. The only way to determine the correct coefficients is through lab testing or careful analysis of field data. Also, the coefficients used in **PC-PUMP** are based on field results in western Canada. They may have reduced accuracy in other regions.

- **PC-PUMP** does not consider the burst pressure of tubing. Normally, any production tubing will have a burst pressure capacity that is greater than the discharge pressure of a **PC-PUMP**, so this is not of great concern. However, a pipe wall thickness that is reduced by corrosion or wear may cause the tubing to burst. Note that in **PC-PUMP**'s wear calculations, the results are given in terms of wall percentages—failure will result at some point **less than 100%** wall thickness loss, due to loss of pressure capacity of the tubing.

- Corrosion is not considered in **PC-PUMP**. The presence of steel rods and tubing in a medium which may contain water, brine, CO_2, H_2S, acid or other chemicals means that corrosion will be a virtual certainty. Corrosion will lead to reductions in tubing wall loss and rod diameter. Tubing wall loss from corrosion is normally not a major concern unless the corrosion is especially severe or is in conjunction with tubing wear. Rod diameter loss can be significant—the rod's ability to withstand axial load is a function of the square of the diameter, and its ability to withstand torque is a function of the cube of the diameter. If the rod is loaded close to yield, a small amount of corrosion may lead to rod yield and eventually failure. Fatigue life can also be greatly reduced by the effects of corrosion.

- **PC-PUMP** does not consider the effects of erosion on tubing wall loss. The sand cut specified in the tubing wear calculation only affects the rate of wear at the contact areas. High sand flow rates in areas such as constrictions (where the flow velocity is increased) or severe dog legs (where the sand impinges on a surface) can lead to tubing wall loss (or rod diameter loss) which will not be predicted by **PC-PUMP**.

- **PC-PUMP** does not consider vibration effects in contributing to rod/tubing wear. The eccentric motion of the rotor in the pump causes the bottom of the rod string also to move in an eccentric manner. This has the potential of causing vibrations in the rod string—in some cases these vibrations are sufficient to cause the rod string to contact the tubing wall with significant force, even in vertical wells.

- It is standard practice in designing PCP systems that no rod guides, centralizers or couplings are placed near (usually within one full rod length of) the pump. This is to ensure sufficient flexibility in the bottom of the rod string to absorb the eccentric motion of the pump rotor. Failure to do this can result in high wear rates or short fatigue life of the rod string near the pump. In extreme eccentricity cases, connections have broken. **PC-PUMP** does not consider these factors in its calculations—the user must be aware of this when designing and evaluating the rod string. **PC-PUMP** will give a warning message if a rod that is less than six feet long is placed immediately above the pump.

7. Backspin Calculations

- The backspin module is capable of some very complicated calculations but is limited in use at present because there is very little data presently available on the performance of brakes. Note that you can turn off the brake calculation in the backspin calculations to determine how the backspin would progress if there were no brake on the drivehead, or if the brake had failed. Simply turn on the "Brake Disengaged" switch on the *Analysis* tab of the *Backspin* window. In this case, no brake data needs to be specified. All the other data does, however, need to be specified.

- When using the backspin module, first specify the brake information, if it is available. Then click on the ***Refresh Specifications*** button. This fills in much of the information that is input in the *System Configuration* and *Analysis* windows in the main part of **PC-PUMP**. The only remaining information to specify is the surface equipment friction torque and the sheave sizes. Enter the sheave sizes. Then click on the ***Inertia Defaults*** button to have **PC-PUMP** determine the appropriate inertia for the sheaves, motor and bearing/gear box. These are default values based on standard equipment types. If you have access to the actual values (especially if you are using exotic equipment, such as a solid sheave), you should enter these instead. The surface equipment friction torque is the last value which must be specified—it refers to friction in the bearings (in the motor and drivehead) and stuffing box.

- When specifying the seized pump torque for the seized pump backspin case, the value entered should be the amount of torque stored in the rod string when the backspin starts. Normally this will depend on the setting of a shutdown switch on the electric motor. To assist you if you do not know what this value will be set at, **PC-PUMP** has a torque calculator. Click on the ***Torque Limits*** button to access this. Note that the values calculated within this window are not automatically transferred to the seized pump torque input. This calculator will help you determine what the maximum torque of the rod string is and what the torque of the electric motor operating at full power and rated speed is. Note that the maximum torque of a NEMA B motor is twice the torque available at rated power and speed.

- The surface equipment friction torque in the backspin calculation should never be left as zero. If a backspin scenario for a seized pump is run with the brake disengaged, the surface equipment is the only source of friction which can remove energy from the system (other than some effects of rod/tubing friction, which are non-existent in vertical wells, and a very small effect of fluid friction on the rods). In other words, the rod string will spin back and forth indefinitely if there is no friction. Due to a numerical effect, the calculation will tend to be slightly unstable in this case—**PC-PUMP** will actually report that the rods will spin faster and faster with each oscillation. Even a small amount of surface equipment friction, say 0.5 Nm (0.4 ft·lb), specified will normally remove this numerical instability.

Multiphase Flow Calculations

The multiphase calculation capability has improved somewhat in each version of **PC-PUMP** from v2.1 to v2.68. For example, in v2.1, in multiphase flow you had to specify the flow rate and fluid level, if there was no IPR specified, and either the flow rate or producing pressure, if there was an IPR specified. In more recent versions, you have the option of entering either the flow rate or the pump speed and either of the producing pressure or the fluid level, if there is no IPR specified, or any one of the four, if there is an IPR specified.

Other enhancements to the multiphase flow routines include the ability to calculate conditions that generate an annular flow pattern in the tubing. v2.1 would give an error if this condition was encountered (normally with high GORs).

It is also now possible to run a multiphase case in **PC-PUMP** when the oil's API gravity is less than 15°. However, note that the correlations used to determine the fluid properties were not designed to work with low gravity oil, so some errors may be introduced. **PC-PUMP** will print a warning message whenever the API gravity is less than 15°. You can, however, improve the accuracy of any multiphase calculation by using the advanced viscosity feature. By entering the dead oil viscosity data into **PC-PUMP** directly, you remove the error generated by using a correlation for this. You still have to depend on correlations to determine the live oil viscosity and other properties required in multiphase flow calculations, though, so the warning message will still appear if the API gravity is less than 15°.

Heavy oil, in particular, can have dead oil viscosity quite different than what would be calculated by common correlations. The figures below show some dead oil viscosity data from oil samples collected in the Lloydminster-Elk Point-Cold Lake area of eastern Alberta and western Saskatchewan at 20°C (Figure 1) and 30°C (Figure 2). They also show results calculated with some correlations. Of these, only the deGhetto correlation was designed for use with heavy oils, but it was based on oil samples obtained from the Mediterranean, Africa and the Persian Gulf. Note that in **PC-PUMP** v2.61 and earlier, the Ng & Egobah correlation was used, unless data is input using the advanced viscosity feature. Starting in **PC-PUMP** v2.62, users have the option of selecting one of several different correlations, but the Ng & Egobah correlation is the default.

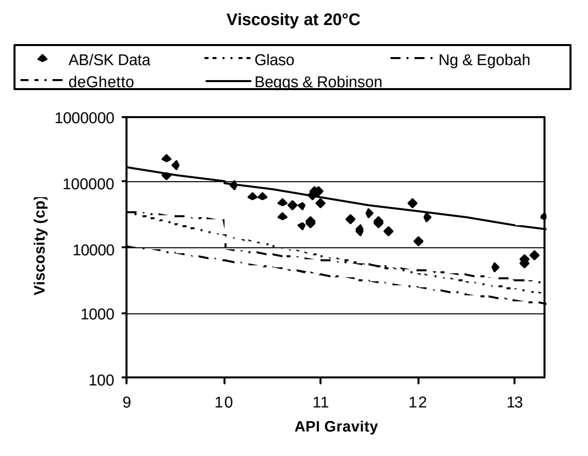

Figure 1.

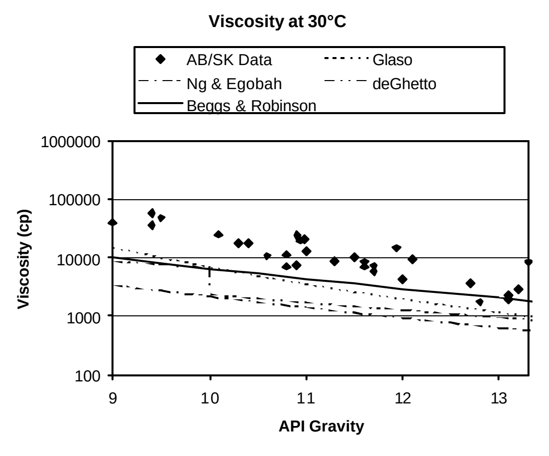

Figure 2.

Clearly, none of these correlations is adequate through a wide range of API gravity and temperature when used for calculating dead oil viscosity of western Canadian heavy oil. It is particularly important to notice that even for oils of the same gravity taken from the same approximate area, there is a large range of measured viscosities. This is why C-FER strongly recommends the use of the advanced viscosity feature.

PC-PUMP® Minimum Inputs (surface drive case)

The following is a list of the *minimum* data required to run a reasonably accurate **PC-PUMP** analysis. There are some other data which can be entered if available but which will normally have only a small effect on the results. If any of the data below is unavailable, the **PC-PUMP** user will have to guess at what input value to use. If this must be done, C-FER advises a sensitivity analysis be done to determine how much of an effect a bad guess would have on the results. Note that the minimum inputs vary depending on each of the different fluid properties and operating conditions options.

- Survey (if well is not vertical)
- Kelly Bushing Offset (vertical height of KB above surface)
- Pump seating depth
- Mid-perforations depth
- Pump model, with friction torque and volumetric efficiency expected at reservoir conditions
- Casing and tubing diameter and weight
- Rod string: diameter and grade, coupling type, guide type and spacing, if applicable
- Specification of surface drive equipment is optional, but if you do wish to specify it (in order to have **PC-PUMP** calculate its performance) the following equipment must be specified:
  - Drivehead model
  - If belts are used: belt/sheave ratio (or sheave sizes) and efficiency
  - If hydraulics are used: hydraulic pump model and hydraulic motor model
  - Electric motor power, # of poles, efficiency and power factor
- The simplest single-phase case involves specifying the following total fluid properties (i.e. effects of any water must be considered):
  - Density
  - Viscosity
- Alternatively, the following can be specified for a single-phase case:
  - API gravity
  - Water and sand cuts
  - Viscosity
- In single phase, there is the option of specifying further information about how the viscosity of the fluid changes with temperature, shear rate, water cut, or any combination of these. This is particularly important to specify in heavy oil.
- Multiphase flow calculations require a minimum of the following data:
  - API gravity
  - Water cut
  - GOR
  - If the pump or tail joint intake is located above the perforations, an estimate of the proportion of free gas entering the pump is required.
- In multiphase, there is the option of entering the dead oil viscosity as a function of temperature. This should be done whenever possible, and should always be done for oils with an API gravity less than 15°.
- In the simplest operating mode, an IPR is not specified. In this mode you must enter:
  - Desired pump speed or fluid rate
  - Estimated fluid level or pressure at perforations (at the given flow rate or pump speed).
- Accuracy will normally be increased if IPR data is available, depending on the type of calculation being done. There are different types of IPR which can be entered into **PC-PUMP**, which require different inputs.
- If an IPR is specified, only one of the following is required: pump speed, flow rate, fluid level, producing pressure (at perforations).
- Tubing head and casing head pressures must be entered
- Bottomhole temperature (i.e. at perforations) and flowing temperature gradient (or flowing wellhead temperature) must be entered. However, these will only affect the results in multiphase cases or in single-phase cases for which the viscosity is specified as a function of temperature. (They are also required if a space-out calculation is done with thermal effects considered.)