Pumps 'n Pipeline (PnP) v1.4

User Manual

By

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Software Program Revision Record

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1.1	27/10/2016	PnP v1.1. issued for use	Ralph Brevet	Simon Burgmans
1.2	31/08/2017	Included new features as part of PnP v1.2, i.e. clay balls, booster pump location, rainbowing und under water pump	Ralph Brevet	Simon Burgmans
1.3	29/01/2018	Tick marks for flows <1 m³/s fixed. Probing position of mouse cursor instead of probing nearest data point in graphs.	Ralph Brevet	Simon Burgmans
1.4	28/02/2019	Added functionality: • Yield stress; • Hydraulic particle sizes and distribution; • Nett Positive Suction Head required; Made some GUI improvements	Ralph Brevet	Simon Burgmans

Document Revision Notice

This is a managed document. All copies of this document preceding this release are obsolete and shall be destroyed.

This Pumps 'n Pipeline (PnP) v1.4 Help document is:

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3	28/02/2019	included text for new functionality in PnP v1.4	Simon Burgmans	Ralph Brevet Grace Dennis	Simon Burgmans

Table of Contents

1   Overview

1.1   General Information

Pumps 'n Pipeline (PnP) estimates suction and discharge production for any dredging or mining equipment that hydraulically transports soil like materials. PnP is a generic and powerful tool, but is still simple and intuitive to use, with a Graphical User Interface (GUI) derived from decades of estimating experience. PnP can accurately and robustly estimate any production for dredging or mining equipment using a unique collection of empirical relationships based on decades of field measurements.

Although extensive literature on hydraulic transport is available, all this information complicates the practical production of estimates. Literature is often very specific and includes many hidden model scale effects and sub-optimisations. To overcome these issues, PnP only applies empirical relationships which have proven themselves in the field.

PnP can be used to support:

- Designing pump-drive systems and pipeline configurations
- Determining equipment feasibility for projects
- Estimating suction and discharge production
- Selecting gear(s) or, for example, the rainbow nozzle diameter for a project
- Evaluating performance of pump-drive systems

PnP's GUI interface consists of five tabs, which provide the user with an easy overview. The five tabs are:

- Pumps
- Pipeline
- Mixture
- Diagrams
- Results

All PnP's input parameters use SI units (see section *1.3* for more information) and all input fields show the SI unit. For some input parameters, standard values or ranges are provided thus ensuring calculations are realistic.

PnP can estimate production for most projects even though the following constraints have been built-into the application to ensure it is user friendly:

- A maximum of three pumps in series can be entered

  More pumps can be entered when pumps are in series, if the pumps' characteristics are summated and entered as one pump.

- No increase of viscosity due to mud or clay is taken into consideration

- The impeller diameter or number of vanes are not included as variables

  However, this can be easily done by manipulating the pump characteristics with the affinity laws.

In addition to PnP, i2D has at its disposal PnP Expert, an open-source program not available to the public that overcomes the constraints mentioned on the previous page, and can be used on less typical, special, advanced projects. PnP Expert is not constrained by a graphical user interface and is thus very flexible, fast to customise and easy to integrate with other estimation tools. Both PnP and PnP Expert are developed alongside each other in two different computer languages to ensure results are mathematically correct.

If you have any questions, comments, ideas or feedback on PnP please contact i2D via the contacts page www.in2Dredging.com/contact or at support@in2dreding.com.

1.2   Introduction

As previously mentioned, PnP's GUI includes five tabs. The first 4 tabs allow users to set the values for the input parameters to be used by the application. Once the application has run its calculations using the values inputted by the user, the results of the calculations are presented on the last tab, the *Results* tab.

The *Results* tab displays several graphs, which allows users to check the input deck and displays the suction or discharge production results. The calculations are run by clicking the **Calculation** button located on the program's *Toolbar* (the button has a calculator icon) or by pressing the **F9** shortcut key on the keyboard. If no user input errors are encountered by the application, the results are displayed on the **Results** tab. If the application returns an input error message, users will be required to either enter missing data or to modify the data entered in the input box specified in the error message.

Users are unable to input field values that are outside the standard logical data range. If the graphs returned on the **Results** tab are out of range, users can tweak the values they entered on the **Diagrams** tab to bring the graphs within range.

Once the application has run, the Project file with its inputted values and results, can be saved as a *.pnp file onto the file system by clicking the **Save Project** button on the *Toolbar*. The Project file can be reopened at a later stage by clicking the **Open Project** button on the *Toolbar* and selecting the required *.pnp file from the file system.

Similarly, users can open or save a pump's specifications into a *.pmp file and build their own pump database. For further information on this feature, please refer to section *2.2: Pumps Tab*.

Detailed help on PnP's use and functionality can be found in later sections of this document. Press **Crtl + F1** on the keyboard or select **Help/PnP Document** from the *Menu Bar* to reopen this document.

1.3 Abbreviations

CSD   Cutter Suction Dredger

GUI   Graphical User Interface

i2D   in2Dredging Pty Ltd

NPSHr   Nett Positive Suction Head required

PnP   Pumps 'n Pipeline

RPM   Revolutions per Minute

SI   Système International (International System of Units)

TSHD   Trailer Suction Hopper Dredger

UWP   Under Water Pump

1.4 Getting Started

You can download a demo version of PnP v1.4 from the PnP [web page](#).

The demo version allows for unlimited use of PnP v1.4 over a trial period of 30 days. This demo version is fully functional except for the *Pumps* tab, which has been disabled.

To acquire a licensed version of PnP v1.4, users need a licence key, which can be obtained in the following manner:

1. Pay for the licence key online.
2. A link to the latest PnP licensed version will then be sent to you via email.
3. Download and install the PnP licensed version using the link provided.
4. Send the *Registration Number* and *Username* to [support@in2Dredging.com.](#)
5. An *Unlock Code* will be sent to you from [support@in2Dredging.com](#) to unlock the licensed version of PnP.

Once you have installed the licensed version of PnP, you can reliably estimate suction and discharge production. A sample Project file called example.pnp is also provided with the PnP application to get you started faster.

2   PnP's GUI and Functionality

2.1 Toolbar

The *Toolbar* is located above the tabs and it contains the standard program buttons such as New Project File, Open Project File, Save Project File, Print Project and Run Project.

Project files have a *.pnp extension.

2.2 Pumps Tab

The *Pumps* tab's screen is used to enter pump specification data. On this screen, it is possible to select up to three pumps in series. PnP has the three pumps constraint because most projects only use a maximum of three pumps. However, i2D can perform calculations using an unlimited number of pumps with its PnP Expert tool.

Each dredge pump's specification data entered on the *Pumps* screen, can be saved to a *.pmp file for reuse in the future. Over time, the saved *.pmp files essentially form a pump database, which can be used to quickly retrieve pump specification data.

Figure 1: Pump Specification Input Panel

The *Pumps #1 Specification* and *Pump #2 Specification* panels depicted in *Figure 1* above, are explained overleaf. Only the *Pump #1 Specification* and *Pump #2 Specification* panels are explained as these panels are more or less identical to the *Pump #3 Specification* panel.

2.2.1 Name Fields

The *Equipment* and *Pump* fields at the top of the *Pump Specification* panel are used to identify the equipment and type of pump being specified in subsequent fields on this panel. The names entered in this field are at your discretion, however, example naming conventions are:

- Equipment field: CSD 01 – for Cutter Suction Dredger 01
- Pump field: UWP – for Under Water Pump

2.2.2 Open Pump File and Save Pump File Buttons

All data entered in the *Pump Specification* panel pertaining to a particular pump, can be saved to the file system by clicking the **Save Pump File** button located next to the *Equipment* field, and has the standard Windows *Save* icon. The Pump Specification file has a *.pmp extension.

To open a previously saved Pump Specification file, click the **Open Pump File** button, which is also located next to the *Equipment* field and has the standard Windows *Open* icon, and select the required *.pmp file.

An empty pump specification file can be opened to clear all the fields at once. A pump without specifications is not considered in the calculations.

Pump #1 is at the suction inlet end and must always be specified. Pump #2 must be specified if Pump #3 is specified.

2.2.3 Constant Power and Constant Torque Radio Buttons

Select either the **Constant Power** or **Constant Torque** radio button to indicate whether your pump engine generates constant power or constant torque.

A pump driven by an electrical engine typically generates constant power when the pump load on the engine reaches the nominal power. On the other hand, a pump driven directly by a diesel engine typically generates constant torque. It is best to acquire the engine's specifications, as these usually indicate the pump engine's revolutions versus torque.

2.2.4 Power Nominal [kW] Field

The nominal power value entered in this field is the maximum power of the engine on the shaft. The hydraulic power is limited by the entered nominal power depending on the pump's efficiency.

The nominal engine power may decrease due to various reasons. Therefore, ideally a torque and a Revolutions Per Minute (RPM) measurement should be taken regularly to check the engine's performance.

2.2.5 RPM Nominal [1/min] Field

The nominal RPM value entered in this field should match the RPM value used to obtain the pump regression coefficients. See sections *2.2.8* and *2.2.9* below for further information on pump regression coefficients.

2.2.6 RPM Minimum [1/min] Field

The minimum RPM value is typically set as 70 to 80% of the previously entered nominal RPM value.

2.2.7 RPM Maximum [1/min] Field

The maximum RPM value is typically set to 120% of the previously entered nominal RPM value.

This field is disabled when the **Constant Torque** radio button is selected, as the maximum RPMs of a dredge pump directly driven by a diesel engine are the same as the nominal RPMs.

2.2.8 Head Regression Coefficients (kPa) Fields

The three head regression coefficients, entered in fields **C1**, **C2** and **C3**, describe a second order polynomial.

$$y = C1 + C2 * x + C3 * x^2 \hspace{3cm} (1)$$

The coefficients can easily be calculated by using the curve fitting equation (1) above with water operating points. A minimum of three points, but ideally at least five operating points, are used to fit the polynomial curve.

In the above equation, *x* is the discharge in m^3/s and *y* is the manometric head in kPa.

2.2.9 Efficiency Regression Coefficients [–] Fields

Efficiency is defined as hydraulic power divided by engine power.

The three efficiency regression coefficients, entered in this second set of **C1**, **C2** and **C3** fields, describe the same second order polynomial as shown in equation (1) above.

In this case, however, *x* is the discharge in m^3/s and *y* is the dimensionless efficiency [-].

2.2.10   NPSHr Regression Coefficients [-] Fields

The three NPSHr regression coefficients, entered in this third set of **C1**, **C2** and **C3** fields, describe the same second order polynomial as shown in equation (1) on the previous page.

In this case, however, *x* is the discharge in m³/s and *y* is the Nett Positive Suction Head required (NPSHr) [-].

It is not mandatory to enter values for NPSHr regression coefficients. Furthermore, these coefficients can be provided only for Pump #1. In addition, NPSHr calculations can be made separately for Pump #2 and Pump #3 as the coefficient results are only shown in the *Suction Performance* graph and do not influence any other results.

Please note that these coefficients can be saved as part of a pump's *Pump Specification* file.

2.2.11   Pipeline Length from Pump #1 [m] Field

Specified in this field is the pipeline length from the previous pump. For Pump #2 you specify the pipeline length to Pump #1, and for Pump #3 you specify the pipeline length to Pump #2.

2.3 Pipeline Tab

Figure 2: Pipeline tab used to enter pipeline specifications

The *Pipeline* tab's screen is divided into six sections, all of which are described below.

2.3.1   General Section

2.3.1.1   Wall Roughness [mm] Field

The *Wall Roughness* field is typically set to 0.04 mm. This relatively high value takes into account the impact of the flanges that are typically present in pipelines.

2.3.2   Suction Side Section

In this section of the panel, values are only entered for Pump #1's suction side.

2.3.2.1   Diameter of Suction Line [m] Field

Used to set the diameter of the suction line.

2.3.2.2   Suction Pipeline Length [-] Field

Used to set the total length of the pipeline at Pump #1's suction side.

2.3.2.3   Friction Loss Water [–] Field

This field is used to set friction losses in the suction pipeline. Typical local friction losses in suction pipelines at the suction side are provided in the *Table 1* below.

Description	Friction Loss [-]
Accelerating water or mixture	1.0
Inlet	0.5
Drag of cutter head (also soil dependent)	0.7 - 7.0

Table 1 Typical friction losses at the pipeline's suction side

Significant friction losses in the suction pipeline can affect the pump's performance.

2.3.2.4   Friction Loss Mixture [–] Field

Used to set the friction losses in the suction pipeline depending on soil mixture. The soil mixture could increase the local friction losses.

Typical friction loss values for a Trailing Suction Hopper Dredger (TSHD) and a Cutter Suction Dredger (CSD) are between 1 and 2.

2.3.3 Discharge Side Section

The discharge side starts upstream of Pump #1.

2.3.3.1 Diameter of Discharge Line [m] Field

Used to set the diameter of the discharge pipeline.

2.3.3.2 Discharge Pipeline Length [-] Field

Used to set the length of the pipeline upstream of Pump #1.

2.3.3.3 Friction Loss Water [-] Field

This field is used to set friction losses in the discharge pipeline when in water. Typical local friction losses in the discharge pipeline are provided in *Table 2* below.

Description	Friction Loss [-]
90-degree bend	0.5
T-piece	1.2
Rubber hoses, man holes, straight Y-piece	0.05

Table 2: Typical friction losses in the discharge pipeline

2.3.3.4 Friction Loss Mixture [-] Field

This field is used to set additional friction loss in the discharge pipeline due to the soil mixture.

2.3.4   Vertical Distances Section

Pictorial definitions for the vertical distances used in this section's fields are provided in the diagram on the *Pipeline* tab.

Please note that the vertical positions of Pump #2 and Pump #3 are ignored in PnP.

In addition, in a vast majority of projects, the incoming pressure for Pump #2 and Pump #3 is not relevant, or not a concern, and therefore it is ignored as a production limitation in PnP. However, i2D can perform more detailed calculations with PnP Expert if the incoming pressure of Pump #2 or Pump #3 is of concern.

2.3.4.1   Suction Depth [m] Field

Used to enter the vertical distance between the inlet (e.g. cutter head or drag head) and the water level.

2.3.4.2   Waterline Pump Axle Depth [m] Field

This field is used to enter the vertical distance between pump axle level and water level.

The waterline pump axle depth only affects suction production.

2.3.4.3   Geodetic Height [m] Field

Used to enter the vertical distance between the water and outlet levels, e.g. the vertical distance of the rainbow nozzle or outlet from the sand fill.

2.3.5   Rainbow Nozzle Section

Setting the fields in this section allows you to include the friction loss of the discharge pipeline's rainbow nozzle in the calculations.

2.3.5.1   Include Rainbow Nozzle Checkbox

If this checkbox is ticked, the rainbow nozzle resistance is included in the calculations and, the reach of the rainbow beam is calculated and shown in the *Pump and Pipeline Characteristics (QHL-Diagram)* graph.

2.3.5.2   Nozzle Diameter [m] Field

This field is used to set the rainbow nozzle's diameter. Note that the rainbow nozzle's diameter value must be smaller than the discharge pipeline's diameter value.

2.3.5.3   Nozzle Angle with Horizontal [deg] Field

This field is used to set the angle of the nozzle from the horizontal. This value is then used to calculate the reach of the rainbow beam.

2.3.6 Underwater Pump Section

The underwater pump section fields have been provided to help estimate the extent to which vacuum limits the suction production in shallow water.

2.3.6.1 Include Underwater Pump Checkbox

If this checkbox is ticked, the **Waterline Pump Axle Depth** value entered in the *Vertical Distances* section is overwritten with a calculated figure based on the values inputted in this section.

2.3.6.2 Length of Ladder or Dragarm [m] Field

Used to enter the length of the ladder or the drag arm. The length measurement is taken from the hinge to the suction mouth of the cutterhead or the heel of the drag head.

2.3.6.3 Location of UWP Axle Length [m] Field

This field is used to enter the location of the Underwater Pump's (UWP) Axle length. This length measurement is taken from the hinge to the UWP's axle.

2.3.6.4 Hinge above Waterline [m] Field

Used to enter the vertical height of the hinge from the waterline.

A negative value is entered in this field to indicate that the hinge is below the waterline.

2.4 Mixture Tab

Figure 3: Mixture tab used to enter mixture specifications

The *Mixture* tab's screen is divided into two sections, namely the *Mixture Specification* and the *Particle Size* sections, both of which are described below.

2.4.1 Mixture Specification Section

2.4.1.1 Mixture Density [kg/m³] Field

The *Mixture Density* value entered in this field should be between the *Water Density* value and the *In-situ Density* value.

The *Mixture Density* value set in this field is utilised in the *Pump # Range Diagram* provided on the *Results* tab. A range of mixture density values between the Water Density and Mixture Density values, incremented by 100kg/m³, are applied throughout the operating points calculations.

The mixture density value applied in this field can be related to the maximum production generated at, for example, the drag head, suction head, cutter head or in the hopper.

2.4.1.2 Water Density [kg/m³] Field

This field is used to set the water density of water. Seawater typically has a density of 1025kg/m³.

2.4.1.3 In-situ Density [kg/m³] Field

In the *In-situ Density* field, soil density values for unstirred and fully saturated soil samples are entered. Typical in-situ soil density ranges are given in *Table 3* below.

Soil Description	In-situ Density [kg/m³]
Silt, mud and clay	1.3 – 2.2
Sand	1.8 - 2.0
Gravel	2.0 - 2.1
Rock	2.0 - 2.7

Table 3: Typical in-situ density ranges

The production (in-situ m³/hr) values displayed in the graphs on the *Results* tab are given for In-situ densities.

2.4.1.4 Lump Density [kg/m3] Field

The *Lump Density* field value is used to allow for clay balls in the soil.

The *Lump Density* value entered must be smaller than 2,650kg/m³ to accurately estimate the effects of clay balls. If no clay balls are formed, enter the lump density as a value greater than 2,650kg/m³.

2.4.1.5 Solids Density [kg/m³] Field

This field is used to enter the solids density of soil particles.

The solids density of sand particles is typically 2,700kg/m³. Clay or peat particles may have a lower solids density, while rock particles may have a higher solids density.

2.4.1.6   Shape Factor [-] Field

Enter values in this field to allow for the shape of various soils.

Various soil shape factor values have been provided in *Table 4* below.

Soil Description	Shape Factor [-]
Clay balls	1.0
Silica sand	0.7
Intact shells	0.5
Crushed shells	0.3

Table 4: Typical soil shape factor values

2.4.1.7   Temperature [deg C] Field

Enter the water temperature in this field. The temperature must be given in degrees Celsius.

2.4.1.8   Yield Stress [Pa] Field

This field is used to enter the yield stress of clay mixture, mud, or slime. The yield stress must be given in Pascals.

Yield stresses below the critical yield stress do not allow the mixture to move easily. Yield stress is measured with a viscometer and can significantly affect the production rate.

2.4.1.9   Atmospheric Pressure [kPa] Field

In this field, enter the atmospheric pressure, given in kPa. The default value is 101.325 kPa.

The atmospheric pressure figure entered in this field only affects the *Suction Performance Pump #1* graph.

2.4.2   Particle Size Section

This section is used to set particle size(s). In this section, users can select either the *Determining Particle Size* or the *Particle Size Distribution*.

It has been determined that the most accurate production estimates for mixtures coarser then 1,000 μm can be obtained by entering the entire particle size distribution.

2.4.2.1   Determining Particle Size [μm] Field

The determining particle size can be calculated using the following equation (2):

$$dmf = \frac{D_{10}+D_{20}+D_{30}+D_{40}+D_{50}+D_{60}+D_{70}+D_{80}+D_{90}}{9} \qquad (2)$$

If the *Particle Size Distribution* (PSD) is not defined, then the *Average Particle Size* (D_{50}) can be applied as a best estimate.

2.4.2.2   Particle Size Distribution [μm] Fields

If the *Determining Particle Size* is larger than approximately 1,000 μm, then higher, less conservative, discharge productions can be estimated by entering the entire *Particle Size Distribution* (D_{10} to D_{90}).

2.5 Diagrams Tab

The *Diagrams* tab is divided into 4 sections, namely the:

- Calculation Parameters section;
- Display Parameters section;
- Show Labels section; and
- Calculation Step Sizes section.

Figure 4: Diagrams tab used to set diagram specifications

The *Diagrams* tab's above-mentioned four sections are described overleaf.

2.5.1 Calculation Parameters Section

2.5.1.1 Maximum Discharge [m³/s] Field

This field is used to set the Maximum Discharge value. The Maximum Discharge figure determines the domain of the calculation, which is between zero and the entered value.

The discharge is displayed on various graphs' horizontal axes.

2.5.1.2 Minimum Vacuum [kPa] Field

The *Minimum Vacuum* figure entered in this field is the lowest production parabola drawn in the *Production Limitation (PrQ Diagram)* graph.

The limiting vacua are calculated when the NPSHr regression coefficients are provided for Pump #1 (see *Section 2.2.10* for further information). The limiting vacuum is shown in the *Suction Performance Pump #1 (NPSHrQ-Diagram)* graph. This graph can be read and used to define the vacuum range.

The *Limiting Vacuum* value depends on the NPSHr, the mixture density and the pump's engine's RPMs. Therefore, the limiting vacuum does not easily allow for vacuum ranges that apply to certain working areas of the pump.

If the NPSHr of the pump is not known, then the typical limiting vacuum range for a pump can be used, which is between 50 - 80kPa depending on the design of the pump and its RPMs.

2.5.1.3 Maximum Vacuum [kPa] Field

The *Maximum Vacuum* figure entered in this field is the highest production parabola drawn in the *Production Limitation (PrQ-Diagram)* graph.

The previous section (i.e. *Section 2.5.1.2*) provides guidance on determining the vacuum range.

2.5.1.4 Maximum Pipeline Length [m] Field

The Maximum Pipeline length value entered in this field is displayed on the horizontal axis of the *Discharge Production Limitations (PrLd Diagram)* graph.

2.5.2 Display Parameters Section

Please note that the values entered in this section only affect the scales of the graphs' axes.

2.5.2.1 Maximum Head [kPa] Field

The *Maximum Head* value entered in this field determines the *Pump # Range Diagram* and the *Pump and Pipeline Characteristic (QHL Diagram)* graphs' **Head (vertical)** axis.

2.5.2.2 Maximum Power [kW] Field

The *Maximum Power* value entered in this field determines the maximum limit for the graphs' **Power (vertical)** axes.

2.5.2.3 Maximum Production [in-situ m³/hr] Field

The *Maximum Production* value entered in this field determines the maximum limit for the **Production (vertical)** axes of the *Production Limitations (PrQ Diagram)* and the *Discharge Production Limitation (PrLd Diagram)* graphs.

2.5.2.4 Minimum Efficiency [%] Field

The *Minimum Efficiency* value entered in this field determines the minimum limit for the **Efficiency (vertical)** axes in the *Pump # Range Diagram* graphs.

2.5.2.5 Maximum Efficiency [%] Field

The *Maximum Efficiency* value entered in this field determines the maximum limit for the **Efficiency (vertical)** axes in the *Pump # Range Diagram* graphs.

2.5.3 Show Labels Section

The tick boxes provided in the *Show Labels* section are used to select whether to show labels or not on the graphs specified in this section. The labels, if selected, indicate mixture densities.

2.5.4 Calculation Step Sizes Section

This section contains optional input fields, that allows users to adjust the calculation's default step sizes, if the default values are not showing the required results.

For instance, the default mixture density step size is 100kg/m³. However, when pumping very poor mixtures in a long discharge pipeline, for example, a more appropriate mixture density step size may be 50kg/m³, as this latter step size would provide results with more definition.

2.6 Results Tab

The calculation results are displayed as six different graphs on the *Results* tab. The required graph can be selected from a dropdown menu provided on the *Results* tab.

When the project has been calculated, and assuming no input errors were encountered, PnP automatically displays the *Results* tab. To run the project simulation, either select the **Calculator** button located on the *Toolbar* or click the **F9** shortcut key on the keyboard.

All graphs can be queried by clicking the **left mouse** button on a point of interest. This causes a box to appear that provides numerical values, including symbols and units, selected from the point of the cursor arrow. An example is shown in *Figure 5* below.
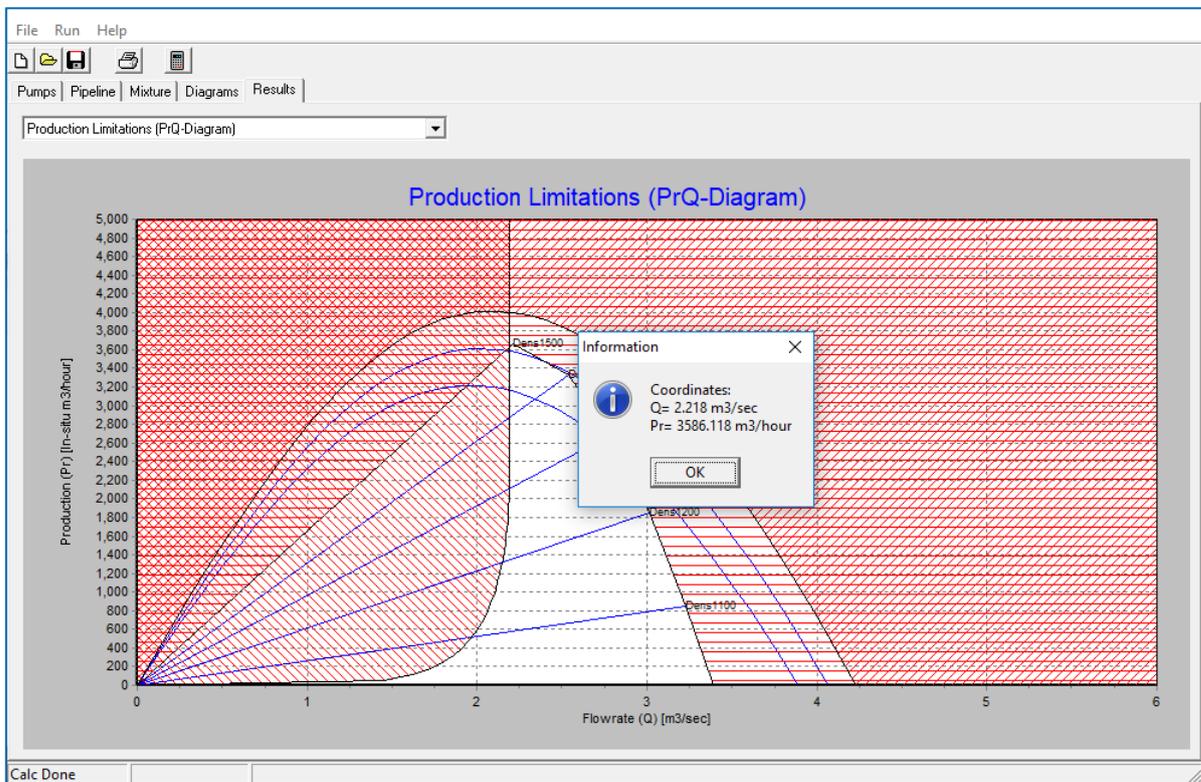
Figure 5: Information box from a specific point in a graph

2.6.1   Pump # Range Diagram

The *Pump # Range Diagram* consists of three graphs:

- Top graph: Charts discharge [m^3/s] versus power on the shaft [kW]
- Middle graph: Charts discharge [m^3/s] versus efficiency [%]
- Bottom graph: Charts discharge [m^3/s] versus manometric head [kPa].

The scale of these graphs' axes can be set and modified on the *Diagrams* tab.

These *Pump # Range* graphs can be used to understand the pump characteristics for the specified mixture density and RPM range. The RPM range is from minimum to maximum.

In order to obtain quick and accurate results, it is recommended that these pump range graphs be checked for possible input errors before proceeding to the estimation phase.

2.6.2   Pump and Pipeline Characteristic (QHL-Diagram) Graph

The *Pump and Pipeline Characteristic (QHL-Diagram)* graph charts the characteristics of the pumps and pipeline. If three pumps are specified, i.e. Pump #1 and Pump #1 + Pump#2, then a summation of all the pumps is displayed. The intersection of the pumps and the pipeline characteristics, or the operating points, are presented in the graph.

The graph charts a range of mixture densities against specific pipeline lengths to determine whether the pumps chosen for the project can pump the specified mixture through the specified pipeline.

For example, the pipeline could be too long thus the number of specified pumps must be reduced so that intersection points between the pumps and the pipeline characteristics can be determined.

If the **Include Rainbow Nozzle** checkbox was selected on the *Pipeline* tab, then the horizontal range of the rainbow beam is also charted for each operating point.

2.6.3   Suction Performance Pump #1 (NPSHrQ-Diagram) Graph

The *Suction Performance (NPSHrQ-Diagram)* graph charts the **Nett Positive Suction Head required (NPSHr)** and the **Limiting Vacuum**.

The NPSHr curves are shown for the pump's *RPM Minimal* and *RPM Nominal* values, which were entered on the *Pumps* tab.

The Limiting Vacuum curves are shown for the *RPM Minimal* and *RPM Nominal* revolutions, as well as for water and mixture densities, values for which were entered on the *Mixture* tab.

The *Limiting Vacuum* range used in this graph can be entered in the *Diagrams* tab *Minimum* and *Maximum Vacuum* fields (see *Sections 2.5.1.2* and *2.5.1.3* for further information).

2.6.4 Production Limitations (PrQ-Diagram) Graph

The *Production Limitations (PrQ Diagram)* graph shows all the limitations of the submitted project at once. This graph essentially presents the critical components for making a project successful and shows:

- **Critical discharge for the largest pipeline diameter, typically on the suction side**

  The velocity in the pipeline must stay above the critical velocity to avoid a bed of solid material forming in the pipeline. Typically, one would want to prevent the formation of a solid bed in the pipeline to reduce the possibility of unnecessary pressure losses.

  A discharge below the critical velocity is hatched red on the graph.

- **Vacuum production parabolas for a specified range of vacua**

  Production above the vacuum range is not possible and is to be avoided because the pump starts to cavitate and rapidly loses its efficiency.

  The area above the maximum vacuum parabola is hatched red on the graph. In addition, the graph only displays the vacuum production for Pump #1, as it is only applicable to Pump #1.

  Ensure your vacuum parabolas are accurate by entering NPSHr regression coefficients for the first pump and values in the Minimum and Maximum Vacuum fields (see *Sections 2.5.1.2* and *2.5.1.3*) based on the *Suction Performance (NPSHrQ Diagram)* graph.

- **Operating points for a range of mixture densities**

  The operating points are an outcome of the pump-drive system and the number of pumps specified.

  The area outside the viable operating points is hatched red on the graph.

  Maximum production is displayed above the red hatched area on the graph. The intersection of the critical discharge with the working point parabola, or vacuum parabola, normally indicates maximum production.

  At minimum mixture velocity, *minimal pressure* is lost due to the lack of velocity and *Optimum Pressure* is lost due to optimum mixture density.

2.6.5 Discharge Production Limitation (PrLd-Diagram) Graph

The *Discharge Production Limitation (PrLd Diagram)* graph charts the *Pipeline Length* versus *In-situ Production*. It charts the *maximum discharge production* for the specified mixture density range and maximum discharge pipeline length.

This graph indicates whether the project is feasible with the specified pumps, pipeline and mixture. Depending on the returned results, the user might have to reconsider, for example, the pump-drive systems intended to be used, whether a booster pump may be needed, or even if alternative equipment needs to be used on the project.

2.6.6 Pipeline Pressure Profile (LHm-Diagram) Graph

The *Pipeline Pressure Profile (LHm Diagram)* graph charts the *Pipeline Length* versus *Atmospheric Pressure*. The pressure profile is only shown, if the mixture density value provided on the *Mixture* tab, has an operating point on the *Pump and Pipeline Characteristic (QHL-Diagram)* graph.

The pressure profile charted on this graph is typically used to position a booster pump. The booster pump must have enough incoming pressure to avoid cavitation and the outgoing pressure must be below design pressure.

2.6.6.1 Incoming Pressure

A lower limit of 100kPa + is typically used to avoid cavitation.

If NPSHr regression coefficients have been entered, more accurate calculations can be made as to whether the pump's incoming pressure is sufficient by comparing the limiting vacuum results from the *Suction Performance (NPSHrQ-Diagram)* graph with the incoming pressure.

2.6.6.2 Outgoing Pressure

To avoid exceeding the pump's design pressure, the incoming pressure must not be too high because the outgoing pressure may then exceed the pump's design pressure, or the pressure generated by gland water pumps.

3   Conclusion

Once a pump's power usage and production are well defined with the help of PnP, it is then possible to develop accurate and robust cost estimates and/or schedules for projects.