STEAMFIELD MANAGER - RESOURCE CONSENT REPORTING AND LONG-TERM STEAMFIELD MANAGEMENT.

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SUMMARY – The management of a geothermal power plant can be significantly different to most other power projects. Firstly, the fuel supply and the working fluid form an integral part of the operation, rather than being brought in from outside. Secondly, initial fuel and fluid properties are often poorly understood, making accurate observation of long-term trends essential. Furthermore, the project may attract substantial resource consent reporting requirements. Steamfield Manager is specifically designed to manage this unique geothermal data environment. It has a hierarchical relational database structure that provides both a short-term and a long-term perspective, allowing the program to manage normal operational processes, as well as looking after data over years or even decades. Besides maintaining detailed records of each steamfield configuration, Steamfield Manager is able to make thermodynamic, network, revenue and other calculations, to generate resource consent reports, and to monitor long-term trends, both above ground and within the geothermal reservoir.

1 INTRODUCTION

Large amounts of data are generated from a typical geothermal development, especially with the trend to automated electronic measurement instruments. Much of this data is used to manage day-to-day operations, ensuring that the correct quantity and quality of steam is delivered to the power station and the equipment is functioning correctly.

Access to reliable monthly or yearly data is absolutely essential for good geothermal project management. Unfortunately, the operational data collected for process control does not easily scale to longer time periods, which are typically 3 to 6 orders of magnitude greater than measurement intervals. The sheer quantity of operational data demands some time-averaging process to reduce it to manageable proportions. The required long-term data is often not measured directly, but must be derived fkom other measurements. Any processing must be robust, able to provide reliable results even when data is missing, instruments are out-of-service and configurations have changed.

To achieve both short-term and long-term capability, Steamfield Manager has been designed with two complementary data structures, one to handle operational data measured at arbitrary time intervals, and the other to record data on a strict daily basis, for long-term management. The operational data is collected from measurement points (or tags), whereas the daily data represents physical quantities (such as temperature, pressure, flow) from objects within the steamfield. The relationships between the points and the objects, and between operational and daily data, the calculations and the network connections are defined in the steamfield configuration, the controlling hub of the program.

Steamfield Manager is written in Delphi and is built on a modem client-server database, SQL Server. The program has a similar style to and interoperability with other geothermal software developed by PB Power, namely GDManager and WELLSIM (Anderson,2000). In common with these other programs, Steamfield Manager is fully unit-aware, with data storage in SI units but allowing data entry and presentation in measurement units of choice.

2 OPERATIONAL DATA

Steamfield Manager accepts any time-dependent operational data, provided it can be defined by three quantities: the measurement point identifier, the date and time of measurement, and a numeric value. This data can be entered manually, imported from files in a range of formats, or directly from a database server, such as a DCS or SCADA system.

The properties of the measurement point, including the type of measurement, measurement units and valid data range are defined separately. As data is entered into Steamfield Manager, various automated checks can be performed, to ensure that the data is as reliable as possible. These checks may duplicate those performed by the data-gathering system, but are considered necessary because of the focus on good-quality long-term data. Unfortunately, operational control systems tend to flag a data value only if it triggers alarms rather than being incorrect for some other reason. Manual and graphical inspection and editing is also possible.
The checks include the following (possible causes in brackets):

- Values out of range (instrument malfunction)
- Null values (instrument malfunction)

- Invalid points (not defmed in configuration)
- Duplicate values (data imported twice)
- Values out of tolerance (malfunction elsewhere)

Steamfield Manager can also "thin" data, rejecting values that do not vary significantly from a preceding value, with the provision to specify a maximum time interval with no data. A final feature is the ability to insert pre-filled records for measurement points that are not included in the imported data set, as a prompt for manual data entry.

The attributes, such as temperature, mass flow or power, which are available for each object, are defined by user-defined properties of the underlying object base types. Besides "owning" daily data, objects use directed connections (parent → child) to define the relationship between different parts of the steamfield.

There are many advantages to separating operational data collected from measurement points from daily data related to objects. For example, field operations staff see the data as it comes in from the field, and as calculated for the past few days. Steamfield and reservoir managers, interested in long-term data, see it from the point

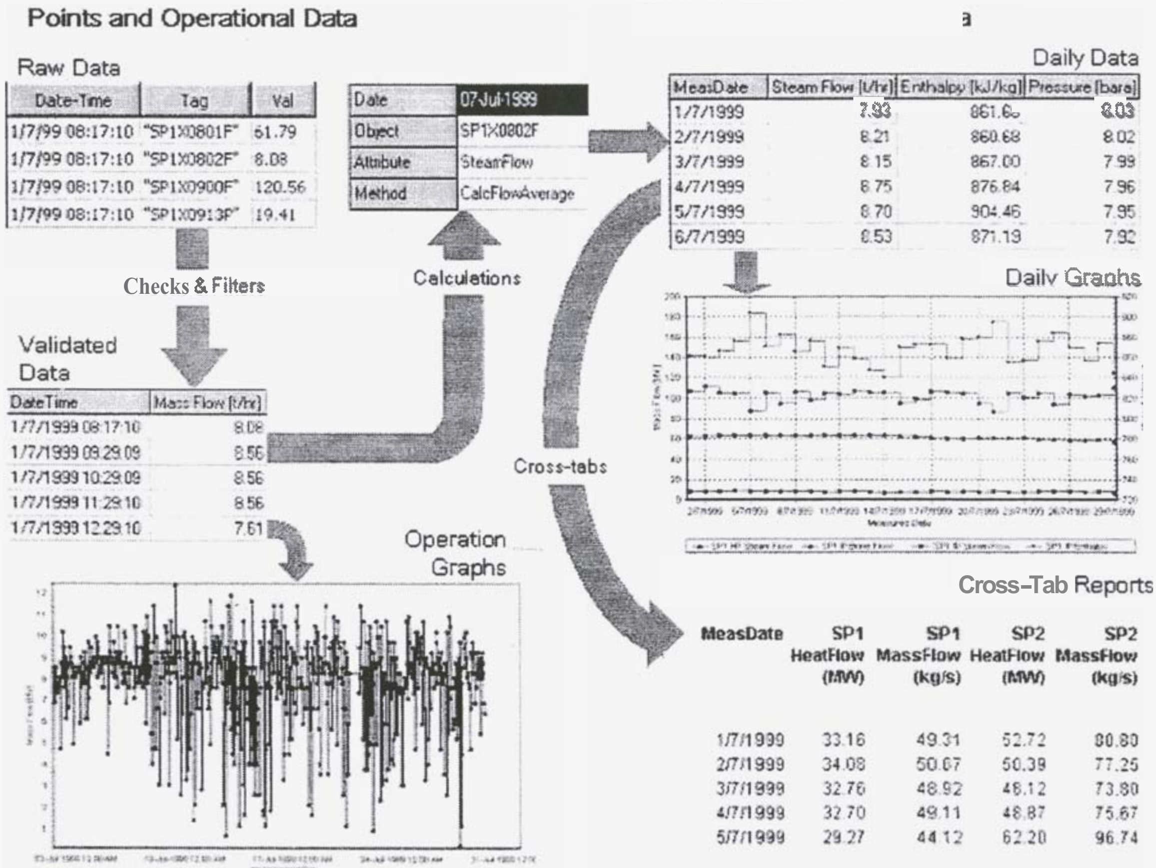

Figure 1. Steamfield Manager data flow diagram, showing operational data validation and presentation on the left and long-term daily data graphs and reports on the right. The two data sets are connected by the calculations specified in the current configuration.

After the automated and manual checks, the imported data can be validated and accepted into the steamfield database, ready for further processing to generate the daily data for long-term storage and analysis. At this point, all data is converted from the measurement units specified for each point to SI units.

3 DAILYDATA

In Steamfield Manager, daily data belongs to steamfield objects, such as wells, separators and generators, and not to the measurement points.

of view of objects and quantities they are familiar with, and do not need to learn about measurement points, SCADA systems, transducers, etc. Moreover, a dual system provides additional flexibility, allowing measurement instruments to be modified or upgraded without affecting the presentation of the long-term data.

Even more important, however, is the ability to calculate daily data that is not directly measured (e.g. enthalpy), and have a place to store this information. Furthermore, object inter-connection allows network calculations, such as propagating flows to parent or child objects, and summing flows at branch points. This enables the program to calculate flows and enthalpies around separator complexes and to partition flows from contributing wells, thus generating a comprehensive data set **fiom a** few critical measurements.

Figure 1 shows a schematic data flow diagram from raw data on the left through to long-term data on the right.

4 CONFIGURATIONS

At the heart of Steamfield Manager is the steamfield configuration. This is a record of the complete steamfield layout, tracking every change as it is made. It includes all the objects in current use, the connections between them, separator configurations and associated measurement points. This information is presented in a "live" screen layout schematic (Figure **2)** , where not only configuration details but also current data can be instantly obtained from the screen.

To obtain correct results, it is often necessary to ensure that the calculations are made in a particular order. For instance, before the enthalpy is calculated at an object, the steam and brine flows must be calculated from orifice plate measurements. For this reason, each calculation is assigned an action level (priority) to prevent the calculation from being called until the appropriate data is available.

Whenever new observation data is imported, or if any modification is made to the steamfield configuration, all affected dates are marked as requiring calculation. The calculation procedure then operates on the whole steamfield, to ensure that new results are correctly propagated through the entrire network.

4.2 External Parameters

Many calculations also require external parameters; for instance, flow calculations fiom orifice plate measurements use orifice plate and pipe diameters. Furthermore, many of these

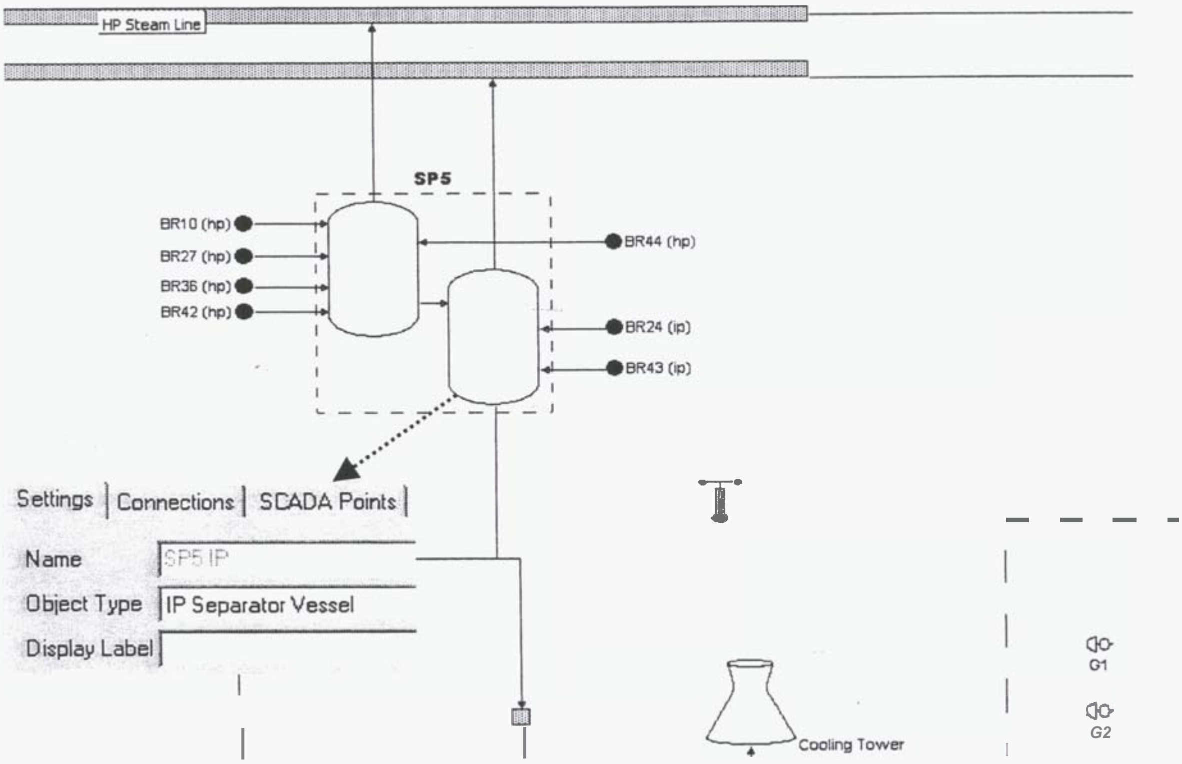

Figure **2** Part of live steamfield schematic, showing the current steamfield layout at a specified date. The layout can be designed on-screen, with object details readily available as shown. When in operation, daily data can also be presented graphically.

4.1 Calculations

The configuration is also used to specify all the calculations, both those made on operational data collected from the measurement points and also the network calculations that use the daily data. Calculation procedures are stored externally to the program in dynamic link libraries (DLLs), and are readily extendible by the user.

parameters are not constant but occasionally change. These parameters are made available in user-specified tables which include the measurement point or object name and the date and time when the parameter became valid.

Calculations that reference external parameters automatically choose the latest value ***before*** the date being calculated, thus ensuring the most up-to-date results.

5 A WORKED EXAMPLE

To show the versatility of Steamfield Manager, an example of calculations around a separator station is presented below. In this example, gas and salt concentrations are assumed to be negligible, so that the calculations use pure-water steam tables. However, if periodic measurements of gas and salt concentrations were included in the parameter tables, appropriate calculations can be developed to use these.

The separator, S1, is made up of a high pressure vessel, HP1, fed by three wells W1, W2 and W3 and a low pressure vessel, LP1 fed by two wells, **W4** and W5 (Figure **3).** The brine line fiom LP1 divides, with one branch to the brine feeder (BF1) and the other to the holding pond (PO1).

The following parameters are assumed to be available.

- Deliverability coefficients, CO to C3, (assuming cubic equation) for wells W1 to w5
- Pipe and orifice diameters for **steam** line at HPDP1
- Pipe and orifice diameters for brine line at BFDP1
- Totaliser rollover value at PT1

Table 1 Points and measured parameters.

Object	**Point**	**Quantity Measured**
W1–W5	WHP1–WHP5	Wellhead pressure
HP1	HPSP1	Separation pressure
HP1	HPDP1	Steam line orifice differential pressure
LP1	LPSP1	Separation pressure
BF1	BFUP1	Brine line upstream pressure
BF1	BFDP1	Brine line orifice differential pressure
PO1	PT1	**Holding** pond totaliser (total mass)

Measurement points and measured quantities are listed in Table 1., and calculations are called in the order shown in Table 2.

This example shows that orifice plate measurements on brine and steam lines, together with separator and wellhead pressures, allows the complete calculation of **flows** and enthalpies around the separator station. In this case, the total flow from all the wells was assumed to match the total **flow** from the separator station. In reality, enthalpy information from the wells may allow the matching of flows within each separator vessel.

While it may not be immediately clear from Table **2,** the real strength of Steamfield Manager is that it is not necessary to individually define all the components of a calculation. For instance, if another well is connected to a separator station, procedures such as Sum_parent and Normalise would function correctly, with the new well automatically included provided connection data had been specified.

6 RESOURCE CONSENT REPORTING

Steamfield Manager can easily calculate attributes such as flows and enthalpy for any object in a steamfield. It is a short step, therefore, to generate monthly reports containing this information for reguatory agencies, using the special Cross-Tab reporting function.

Cross-tabs allow the user to assemble data from completely different sources (for instance, steam flow from the steam line, generated power from the power plant and ambient temperature from a meteorological station) into a single report.

Available tools within the cross-tab reporting module include the ability to define and select groups of objects, to generate summary values such as sum, average, maximum and minimum, and to include user-defined calculated fields. Unlimited report formats can be saved and retrieved, so that it is a simple process to select the appropriate format, specify a date range, and generate the correct report.

Export functions allow the data to be sent electronicallyto regulatory agencies if required.

7 LONGTERM MANAGEMENT

As Steamfield Manager can generate reliable daily average data for any object within the. steamfield, it is the ideal tool for medium-term and long-term steamfield management. These include both above-ground conditions as well as changes within the geothermal reservoir. Besides the reporting tools already described, all data can be selected and presented graphically – often a much more effective way to observe slow changes than any reporting method.In particular, tools to partition flows from a number of wells feeding a common separator allows the generation of reliable production histories from individual wells. This has significant implications for more detailed reservoir simulation and reservoir assessment.

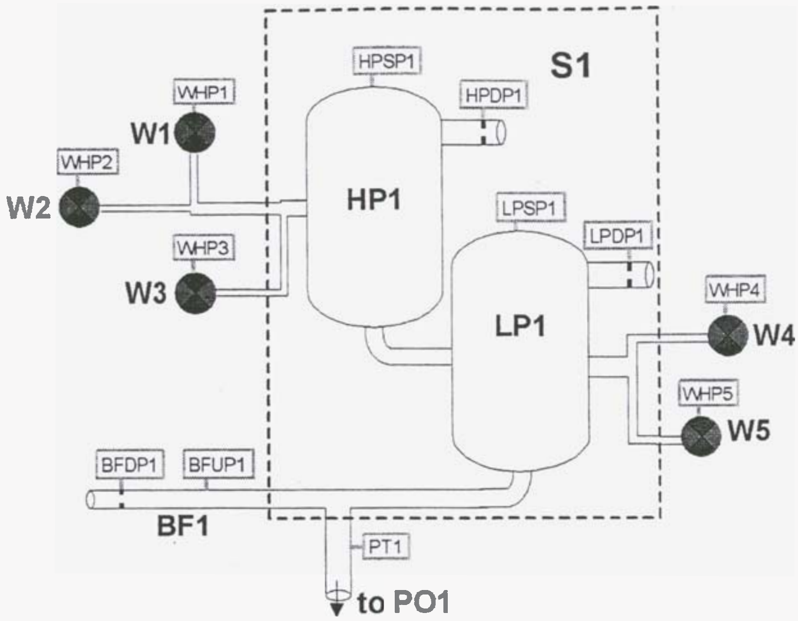

Figure 3 Measurements around a typical separator station. Measurement points are indicated by grey rectangles, with objects labelled in bold type.

Table 2. Calculations called around a typical separator station

Calculation	Source	Target	Attrribute	Comment
Totaliser_flow	PT1	PO1	Brine Flow	Converts mass increase to daily mass flow
Orif_brine_flow	BFUP1, BFDP1	BF1	Brine Flow	Converts time-paired point data to flow, and calculates daily average flow
Orif_steam_flow	HPSP1, HPDP1	HP1	Steam Flow	Converts time-paired point data to flow, and calculates daily average flow
Orif_steam_flow	LPSP1, LPDP1	LP1	Steam Flow	Converts time-paired point data to flow, and calculates daily average flow
Average	WHP1–WHP5	W1-W5	Pressure	Converts point data to daily average pressure for each well
Sum–child	LP1	LP1	Brine Flow	Sums flows of child objects (BF1, PO1) to obtain flow for parent object
Enthalpy	LP1	LP1	Enthalpy	Calculates enthalpy from steam flow, brine flow and pressure
Dual–massflow	S1	S1	Total Flow	Sums steam flows and low pressure brine flow from a separator complex
Well–flow	W1 – W5	W1-W5	Total Flow	Uses pressure, deliverability coefficients to calculate flow from each well
Normalise	S1	W1-W5	Total Flow	Adjusts well flows pro-rata to equal total separator flow
Sum_parent	HP1	HP1	Total Flow	Calculates flow from sum of flows from parent objects.
Brine–flow	HP1	HP1	Brine Flow	Calculates brine flow from difference of total flow and steam flow
Enthalpy	HP1	HP1	Enthalpy	Calculates enthalpy from steam flow, brine flow and pressure
Dual–enthalpy	S1	S1	Enthalpy	Calculates overall enthalpy of a dual-flash separator complex.

8 CONCLUSIONS

Steamfield Manager has been designed to solve data management requirements unique to a geothermal development by incorporating a dual-level time management structure. This allows the collection of operational data for short-term management as well as long-term data for management of slowly-varying changes.

The configuration-based approach facilitates network calculations so that a comprehensive data set for all objects can be generated from a limited number of measurements. A structured data entry process, coupled with filtering and validation, means that reliable information for resource consent reporting and long-term management is always available.

9 ACKNOWLEDGMENTS

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10 REFERENCES

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