MINE CLOSURE: TRANSFORMATION OF DEFUNCT LIABILITY INTO PROFITABLE ASSET

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Chris Grobbelaar and Matthew Handley

Say how?

- The new environmental laws place stringent, and sometimes costly, requirements for environmental rehabilitation and maintenance on mining companies after mine closure
- The cost of these requirements could be ameliorated or even turned into sustainable profit if resources available in old and new mines could be harnessed
- The "free" natural resources, namely heat, air, water, and gravity can be used in any mine to:
  Produce electricity; Purify polluted mine water
- A novel thermohydraulic process using the above free resources has been formulated and tested to evaluate its potential to meet the seemingly impossible goal of turning a defunct mine into a profitable portfolio

The method was developed for the systematic integration of **thermodynamic and hydraulic power generation** in a closed loop system availing itself to recirculation. Recycling provides the facility to reach 100% efficiency in inverting **heat into electric power**. The system lends itself to low temperature operation, applying a refrigeration system to drive the power generation system. Consequently the heat input to the refrigeration system avails the consumption of heat energy at lower temperatures, enabling the inversion of presently **rejected heat into electric power.**

Abstract

Mine closure is normally recommended when production cost exceeds mineral earnings. Mine income can be improved by selling mine heat as electric power in contrast to the present system of cancelling the burden of heat by water, power and freezing. A new system of freezing was developed to invert mine heat into electrical power in the underground without the expense of disposing the heat into the atmosphere. The generated electrical power can be sold at daytime when the tariff is high, or alternatively according to the power remuneration. Normally electric power generation is driven by heat. In the new system the power generation is driven by a freezing system consuming reject heat at the minimum or fitting temperature.

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Introduction

A nominal new type of power station consists of three columns connected at top and bottom, a low level sump, a liquid elevating pump in the sump, a fluid driven motor and power generator in or above the sump and a heat input system at the top or anywhere in the layout. A mini-model was built and it yielded confirming test results as illustrated in the diagrams.

If the operating temperature is below the temperature of the surround, part of or all heat may leak into the system. The system is filled with at least two fluids systems and may simply consist of water and air as allowed for by the inspector of mines.

As illustrated the liquefied sump contents is pumped to the top of the system through one of the three columns and sprayed into the second column. The third column contains gas or vapour or simply air. The liquid sprayed from the first column increases the density of the fluid in the second column. The density difference and pressure difference between the fluids in the second and third columns cause fluid rotation, which drives the power generating motor.

The invention operates in closed loops and the only surround changing factors are heat input and power output. Note that the properties of the material in the second column is **not a linear function and contains the sum of the hydraulic energy** plus the thermodynamic energy of the gaseous components, approximating an **exponential curve of column height.**

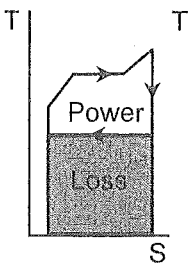

Figure 1

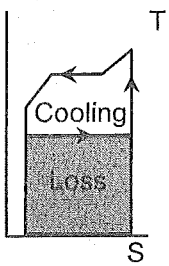

Figure 2

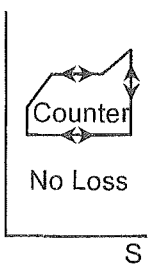

Figure 3

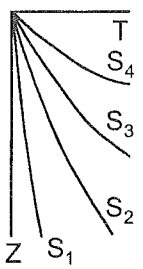

Figure 4

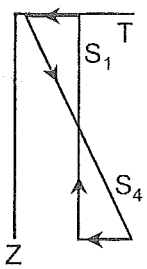

Figure 5

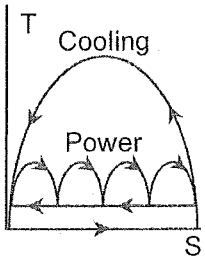

Figure 6

Thermodynamic countercycles

The spread of thermodynamic explanations includes T-S representations. This means the graphic representations are displayed on axes of temperature and entropy. The latter is a **mathematically calculable** presentation of thermodynamic disorder. The beauty of the display is that

- horizontal lines display latent heat, and vertical lines display work input
- output as shown in the power generating cycle shown in figure 1. If th
- direction of flow is reversed as in figure 2 it represents a refrigeration cycle.

Countercycle operation represents the superimpositioning of two cycles, for example figures 1 and 2 added together to obtain figure 3. The beauty of this superimpositioning is that the **losses** in figures 1 and 2 **cancel one another.**

Combination of thermodynamics and hydraulics to get Thermo-hydraulic power

Depth is normally displayed vertically and denoted by z as shown in figure 4. Displays of one or more fluids in entropy values, denoted by s, are shown in figure 4. If two curves of the display in figure 4 are selected and fitted according to internal energy values, figure 5 is obtained. This figure shows that **internal heat energy** can be **recirculated** by combining gravitational forces with thermodynamic law applications.
The information in figure 5 can be displayed as shown in figure 6. Four power cycles are driven by one refrigeration cycle. The sum of the work output of the four-power cycles is more than the input of one refrigeration cycle.

Basis of operation

Heat energy is a condition of state. It can be generated from fuel. In a mine heat originates from the virgin rock temperature as released by mine activities.
In a mine shaft with no fluid circulation, no heat transfer from the rock and adiabatic heat conditions, the temperature and pressure increase with depth into the shaft as a result of the **stacking effect** of the matter in the column. If no matter is contained e.g. absolute vacuum, no stacking occurs. If matter is contained the **pressure at a depth z** below the top is the product of density times gravitational acceleration times the depth increment. Under constant gravitational acceleration the pressure increase is proportional to the **changing density of the fluid** column contained in the shaft. The pressure at the bottom of the shaft is obtained as the incremental sum of, or the integral, and is **not a linear function**. The exponential final pressure consists of:

a. the starting pressure at the top of the shaft

b. the sum of increments of pressure (or the integral of)

$$\delta P = \delta \rho g \delta z = \frac{g \delta z}{\delta V} \quad \text{or} \quad z = \frac{\Delta(PV)}{g}$$

where ρ is the density (which is a function of z), g is the gravitational acceleration, z is the increment of the shaft depth or column height and v is the unit volume or the inverse of density. Gravitational work **per unit of mass** is equal to gz.

As a result of the pressure increase with depth, the temperature of shaft contents increases according to the thermodynamic properties of the fluid, i.e. the **fluid** filling material.

The combination of temperature and pressure of many substances are tabulated. Formulae for the mathematical calculating of the material properties are also available. The actual properties are significantly **material related**. Examples of incremental property calculations had been done for selected types of fluids.

The unit heat capacity of any water exceeds that of rock.

In stead of hoisting reject heat to surface, the new method captures any disposable heat as input heat to produce electric power. The generation of electric power causes

mine and water cooling. The electric power may be consumed or sold to create mine income. The new method can be driven faster than the production of unwanted heat. This causes an office class of climate. A winter class climate may be produced by overproduction to invite more heat, to advance manual labour production **as well as** to increase the power production. Each mine dominates it's own capacity to deliver heat energy. The production of heat from mines varies from zero before mining to more than 50-megawatt at large and active mines.

According to the new method the **available** heat energy can be inverted into electricity, all day or any part of the day. Power production is instantly modifiable and controllable.

If the global condition in the mine is inverted to a winter class of climate the temperature of a mine or it's water, air and ore can be reduced at will to say 5°C to economise on the power production as well as labour output.

The essence of operation

The layout of the power generating system lends itself to underground positioning i.e. ground surface occupation is not demanded and dormant mine openings reduce construction cost.

The system operates by applying novice techniques under conditions where **the second law of thermodynamics does not apply,** in conjunction with a number of common operations and techniques. The capacity and efficiency of the layout may be selected at will.

The system is supreme in reversing the development of the heat shield surrounding the earth. At desert coasts the system may create inhabitable country areas. If no input fuel is required all the associated eco care problems created by firing are prevented.

Heat collection from a reject heat source avails one input heat exchanger, which is comparable to conventional ones. Cheap thermodynamic fluids and chemicals may be applied. Fluids are conserved.

Nineteen test observations on the mini-model were analysed. The results show that vapour density changes, doubled the wattage delivered by the model as shown in figures 7 and 8.

The invention is based on the scientific facts that:

- the **temperature** of heat energy **can be increased** as normally exposed by weather forecasting. Thermodynamics show that heat upgrading can be expedited.
- Countercycle applications show that heat leakage can be productively accommodated to increase the heat mass of the system. Leakage is therefore a profit and not a loss.

- Recirculation can increase the efficiency to convert heat into electric power up to 100% efficiency.
- The system is not perpetual motion nor applying a breach in natural laws – it only applies the concise application of the laws of nature;
- Analyses showed that the system operates as a global refrigerator, which must be supplied with heat energy to reach a stable state of condition;

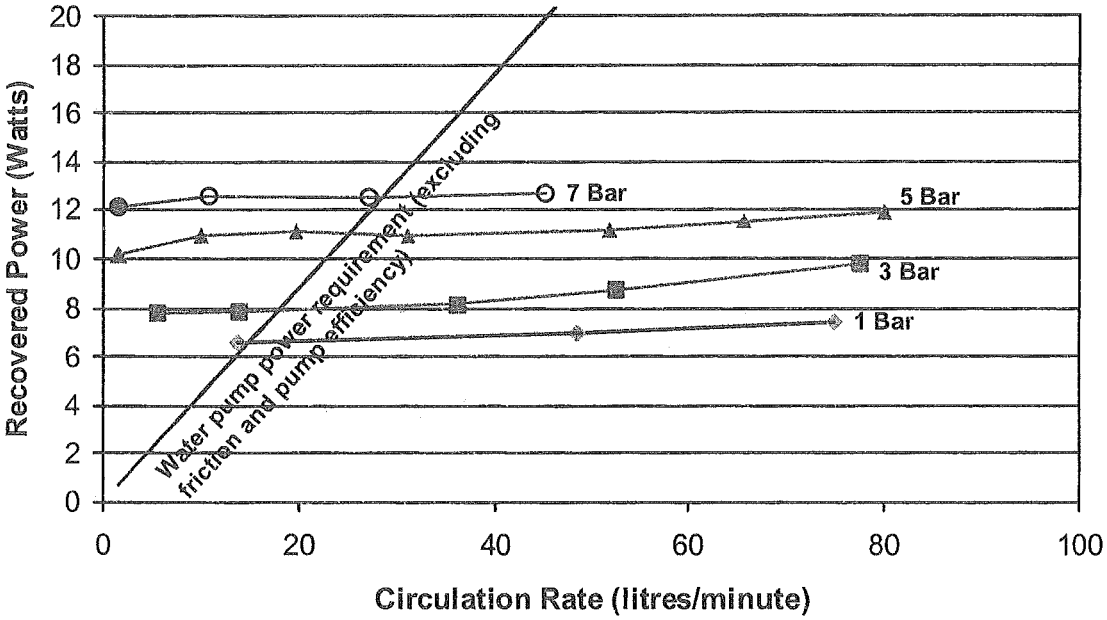

Figure 7: Output by small-scale experimental model

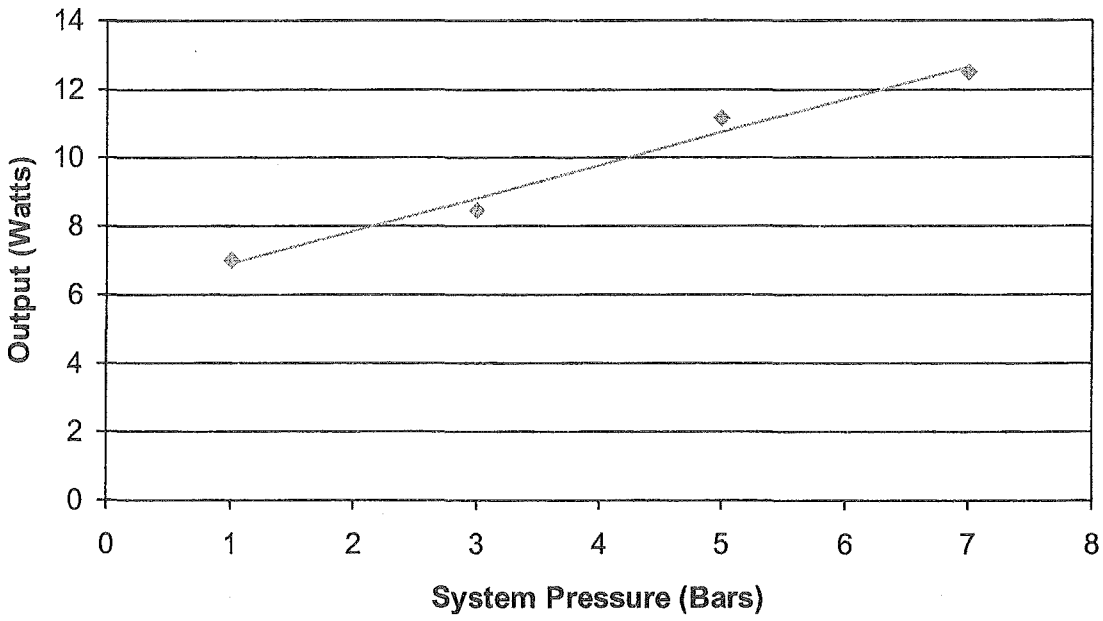

Figure 8: Output versus System Pressure (or density)

The application of the invention involves several variables:

- hydraulic process relates to an elevation difference
- thermal upgrading depends on adiabatic compression, which is a progressive cumulative factor of elevation change
- the inversion action is accelerated by chemical and catalytic action
- turbine action must accommodate liquid and gas action
- the layout size involves fluid density levels.

Extended Application

Obviously further model tests have to conducted to examine:

1. trebling the power delivery by conventional thermal power stations without burning more fuel and power delivery by conventional nuclear power stations without more nuclear reactions;

2. inverting the heat of seawater into power to the extent that ice or drinking water is produced on top of the power delivered;

3. inverting mine heat into electrical power.

4. mines pumping water can derive more power from the heat of the water than the power needed for pumping the water.

5. the exponential effect of elevation change (in say a 200 m high model);

6. optimisation in the chemical and catalytic action (in say a 20 m high model

which is not attached to a mine and does not require the approval of the Inspector of Mines);

7. the examination of dual fluid turbines which had been used elsewhere.

Other benefits of process

- Extend the life of SA's coal and uranium reserves by augmenting electricity generation using a countercycle process
- Remove the need for nuclear plants and nuclear waste disposal
- Generate electricity from heat in sea water, thereby spreading SA's and the world's, generation capacity over a wider geographical area
- Reduce power generation demand for water

Conclusions

- A countercycle heat flow process can provide power and refrigeration at the same time with reduced losses when compared with current single cycle technology
- This process can be applied in mine shafts for electricity generation and water purification through freezing
- The process is applicable to producing mines where electricity generation and refrigeration would offset or exceed mine requirements partly or completely, depending on size of plant.

EXAMPLE 1

As an alternate of purchasing 50 000 m^3 of water per day and purchasing 20 Megawatt of power to cool a mine, the new system provides for recirculating stope water, rejecting contamination and producing 20 Megawatt power for sale or consumption.

EXAMPLE 2

The Koeberg Nuclear Power Station is located on the Western Cape coast to apply cold water at the Augullas coast to condense the boiler steam for recirculation. The effect of the luke warm reject water on sea life has been studied.

If Koeberg power station is closed down and replaced with a thermo-hydraulic power station the latter may produce more power from the heat of the seawater and on top, it can produce potable water for drinking on freezing the seawater for the removal of excessive sea salt.

During 2001 the power produced by Koeberg power station amounted to 10718623 megawatt hours (MWh) of power. Assume the temperature of **seawater** is 15°C and latent heat for freezing is 335 kJ/kg. To produce one kilogram ice the heat to be extracted from the seawater requires the removal of 335 + 15 x 4.187 = 397.8 kJ per kilogram ice.

The heat equivalent to produce 10718623 MWh electricity to equal the power

production of Koeberg power station by freezing sea water into ice, at rate of 397.8 kJ/kg ice, means that 265000 cubic meters of water per day can be leached from the ice. The potable water production to equal the Koeberg power production amounts to 265000 m^3 water per day and can be chlorinated to be available for domestic consumption.

The closure of Koeberg power station will reduce the risk of small children living nearby from developing cancer. (Tertius Harmse)

EXAMPLE 3

This example is calculated from the tabulated values of the thermodynamic properties of fluids and catalysts.

Assume the power generation unit fits in a 543 meter deep shaft column. The en-circulating shaft lining of 3 meter internal diameter withstands a working fluid pressure of up to 6 mega pascal (60 bar). The 3 m diameter column may contain inside it a 2 m diameter power generation column and a 0,5 meter diameter liquid conveyance column at internal pressure **differentials** of 1.5 and 5.5 mega pascal (15 and 55 bars) respectively. The fluid flow velocities are 3.0, 2.4 and 2.7 meters per second respectively in the of three individual columns of 3.0, 2.0 and 0.5 meter diameter. The system must be fitted with a heat exchanger at the best elevation for cooling the mine working water to say 5°C. It may consist of a cluster of say 50 mm diameter pipes extending in a haulage for cooling mine ventilation air or water and yield up to 18.7 mega-joules heat per second (4.5 mega-calories per second). A power generation system must be fitted to generate 18.7 megawatt electric power.

With a smaller **column length** of 100 metres the power yield will be 3.4 megawatt. Available wind charger dynamometers may be applied to produce megawatts of power.

If the encirculating shaft column diameter is increased from 3 to 6 m the 543 m column will yield 74.8 megawatt and a 100 m column will yield 13.8 megawatt.

The power station yield may be reduced according to demand. The temperature of the cooled surround may be **chosen at will** and may be different from the assumed 5°C temperature in the example. If the operating temperature choice is say -20°C and arrangements are made for **freezing of the heat exchanger** the system may be applied to produce potable water from the ice.