The Convector Generator - Revised and Restructured

Introduction

The Convector Generator (an earlier paper on this website - November 2003) describes a new method for the generation of electricity using natural gas as fuel. Natural convection alone is used for the combustion unit and separately for the closed turbine gas circuit. It has some similarities to the condensing gas boiler and should have a comparable efficiency. It is the author's assertion that the convector generator allows conversion of the heat of combustion of natural gas into electricity with over 90% efficiency.

To date 32 replies have been received to the earlier paper – 8 positive/encouraging, 10 negative and 14 neutral. The main objections of critics have been:

(1) to draw attention to the second law of thermodynamics and the Carnot theorem with its maximum efficiency of $\Delta T/T$ for the conversion of heat into mechanical energy.

(2) to point out that the entire history of air engines is that they are rather cumbersome – large in dimensions for low power output.

I will answer both points. Critics are wrong on (1) – the Carnot limit does not apply to the configurations devised. But I concede substantially on (2). A Restructured Convector Generator is proposed that is compact, power-packed and ultra efficient.

Comments on (1)

The configurations proposed are driven by convection currents and involve energy cycles at constant volume. For the conversion of heat into electricity in the turbine gas circuit, there is no exhaust gas and no energy sink. The driver is gravitation. The energy conversion method proposed is different in kind to classical thermodynamic cycles. The proof of the Carnot theorem involves disposal of energy at the lower temperature into an energy sink. In modern heat engines, large quantities of energy are likewise lost in the exhaust gases. In the Convector Generator, there is efficient and virtually complete energy recovery from exhaust gases in the open combustion cycle. The turbine gas circuit is closed and involves just natural convection – there are no pumps or fans – it is driven simply and only by GRAVITATION. This is a force unknown to Carnot cycles and unused in any of today's heat engines. The energy cycles involved in these proposals mirror three instruments from 19^{th} century physics – Joule's thermoscope (see website July 2003), Crookes' otheoscope and Bennett's Convection Mill. Each of these has an anomalously high efficiency for the conversion of light into mechanical energy. Carnot theorem predictions for these instruments are wrong by five or six orders of magnitude. It is the author's assertion that the energy conversion processes involved driven by natural convection and operating in an enclosure at constant volume allow conversion of heat into mechanical energy with a theoretical efficiency of up to 100%. Carnot does not apply.

Comments on (2)

Air engines have a history of being large and cumbersome. The author concedes that this may also be the case for the configurations proposed earlier for the Convector Generator. In the second half of this paper new configurations are proposed that involve placing the turbine very close to the upper surface of the combustion chamber. This will allow rapid transfer of heat. Also the combustion cycle, the turbine gas circuit and the energy recovery section are all brought into one housing which is compact. An indicative calculation suggests that the Restructured Convector Generator of height 10 metres and external diameter 20 metres will comfortably generate 100 MW and may have a capacity of up to 2000 MW. This would give a power density comparable to or better than today's gas turbine power stations.

This paper has been written with the hope that some or several individuals in university research departments, industrial companies or energy research institutes will decide to initiate research work to test and develop the proposals. There is no intellectual property constraint – the ideas are original and I have no intention of applying for patents. I would be very grateful for any comments. [E-mail address: williams.a(AT)globalwarmingsolutions.co.uk]

Revised Convector Generator

In the earlier paper on the Convector Generator, arguably the most promising configuration proposed was the vertical arrangement (Figure 6 – of November 2003 paper). This is now modified to provide a COLD section to the turbine gas circuit and to give the most efficient energy recovery possible from flue gases. The revised configuration is shown in Figure 1 on Page 3.

There are three main sections:

- the combustion chamber where natural gas burns using preheated incoming air. The combustion circuit is open and at atmospheric pressure and driven simply by natural convection.

- the turbine chamber which has a vertical axis turbine driven by the rising current of warm gases. It is suggested that an inert gas such as nitrogen or carbon dioxide be used in this closed cycle at a pressure of 10-100 atmospheres to provide large heat capacity.

- the energy recovery section where combustion products transfer their residual energy to incoming air in a countercurrent heat exchanger. This will also allow condensation of water vapour from the flue gases.

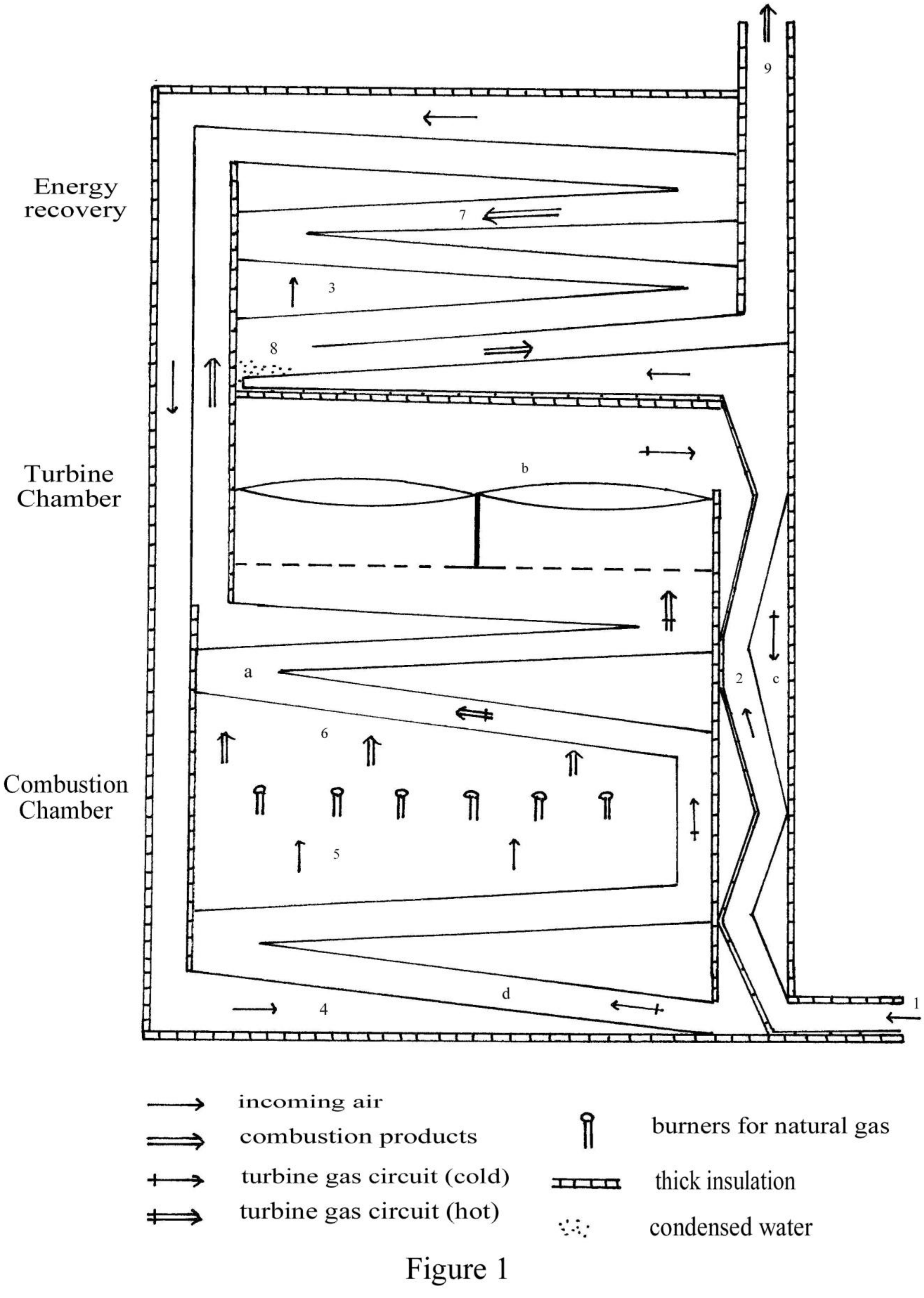

Energy recovery
Turbine Chamber
Combustion Chamber
9
7
3
8
b
a
2
c
6
5
4
d
1
incoming air
combustion products
turbine gas circuit (cold)
turbine gas circuit (hot)
burners for natural gas
thick insulation
condensed water

Figure 1

Incoming air enters the configuration at (1) and recovers energy from the leaving condensate. As it climbs the vertical section at (2) it takes up heat from the cold section of the turbine gas circuit. It then passes through the energy recovery unit (3) where it absorbs energy from the flue gases. The prewarmed incoming air now travels to the bottom of the combustion chamber at (4) where it transfers some of its energy to the turbine gas circuit. The incoming air there takes part in combustion (5). The combustion products rise (6) transferring over 90% of the heat of combustion to the turbine gas circuit. Combustion products then travel through the energy recovery unit (7) where they transfer their residual energy to incoming air. Exhaust gases should be sufficiently cooled for water vapour to condense at (8). The condensate runs to ground level whilst the remaining exhaust gases leave the chimney at (9). The entire combustion system is driven by natural convection – there are no pumps or fans. The process of combustion – the creation of warm gases which rise is effectively the driver of the system. This draws in ambient air no matter how tortuous a route we create. The speed of combustion is simply controlled by the rate of inflow of natural gas to the burners.

For the turbine gas circuit, the energy of combustion is transferred to the turbine gas in the heat exchanger pipes at (a). It is vital that this energy transfer has high efficiency, ideally around 90% and this is why it is suggested that the turbine gas be at a pressure of 10-100 atmospheres, to provide a much higher heat capacity than the combustion air circuit. The hot turbine gas rises and impacts on the turbine at (b). Energy transfer to the turbine is partly due to the velocity of the convection current that flows right around the gas turbine circuit. But the major component is simply molecular collisions in the gas between (a) and (b) that shuttles the additional heat from molecule to molecule in the layers between (a) and (b). When these hot molecules impinge on the turbine they cause rotation. There does not need to be any mass movement from (b) via (c) and (d) to (a). There will however be a circuit available for turbine gas to flow from above (b) to (c) where it is cooled by incoming air. This provides an 'energy sink' for the turbine gas circuit – but the energy is not lost to the convector generator – it is recycled by the incoming air. The turbine gas then flows from (c) to (d) where it is warmed by the preheated incoming air for combustion at (4). For the turbine gas circuit, every heat exchange opportunity enhances convection currents in the clockwise direction in the configuration drawn – at a/6, b, c/2 and d/4. The turbine gas circuit is a closed cycle at constant volume; it is the author's belief that such an energy cycle has a theoretical efficiency of up to 100%.

When we consider Figure 1 as a whole, all energy losses or inefficiencies are reabsorbed and recycled within the system. The final losses to the environment will be

- in the flue gases
- in the condensate
- through the external walls

It is the author's assertion that the Revised Convector Generator will have an efficiency comparable to the condensing gas boiler. It will convert the heat of combustion of natural gas into electricity with an overall efficiency of over 90%.

Restructured Convector Generator

A criticism generally levied against all air engines is that they are large and cumbersome for low power output. The author concedes this could be a problem with the Convector Generator. The critical problem is the efficiency of heat transfer from the combustion products to the turbine gas circuit. Ideally the turbine should be at the minimum possible distance from the site of combustion. In Figure 1 this is achieved by placing the turbine chamber immediately above the combustion chamber with as little pipework as efficient heat transfer allows. A second question arises in reducing size – is there a radically different way of merging the three chambers into two or even to one so that all processes take place in one compact structure? Both points are considered in this section.

The author has made a detailed study of the origins of thermodynamics and the work of arguably, the two greatest experimental physicists of the 19th century, Joule and Crookes. Joule is well known for the heating effect of an electric current and more importantly, for establishing the mechanical equivalent of heat. He is called the father of thermodynamics and largely credited with the discovery of the first law. Very significantly however, Joule did not believe in the second law proposed by his close associate Thomson, Rankine and Clausius.[1] Crookes is best remembered for his invention of the radiometer which was the first demonstration of the conversion of light into mechanical energy. He published the results of hundreds of experiments on the radiometer with many very imaginative variations. Midst that wealth of detail, he also invented an instrument that he called the otheoscope [2] (Greek, *otheo*, I propel) (Figure 2).

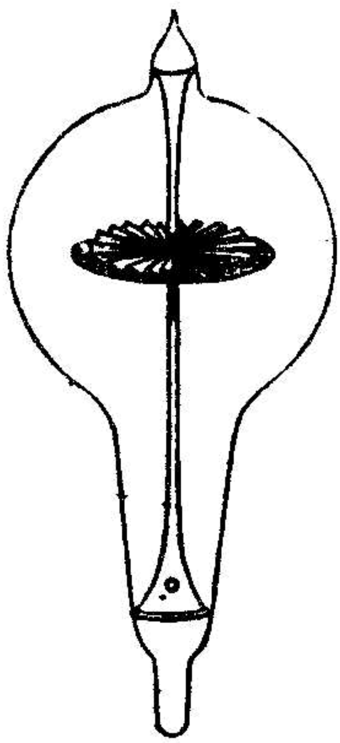


Figure 2

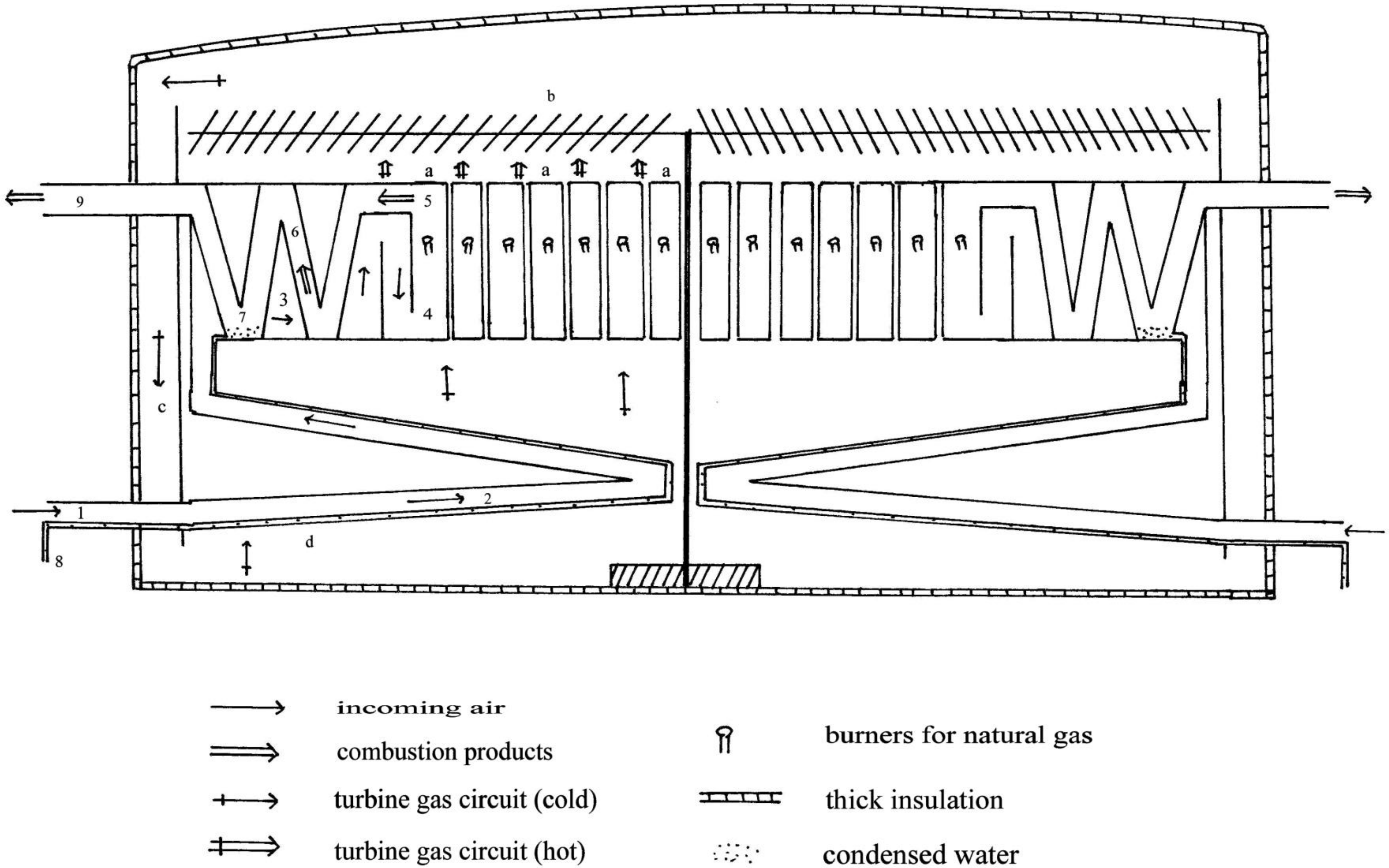
Crookes writes, “A more sensitive form of this construction is made by having a fixed copper plate lampblacked on the upper side, and making the vanes of mica for the sake of lightness. The vanes are as numerous as can conveniently be put together and being set at an angle, the pressure from the copper plate drives them round with great speed when set in action with even a faint light.” In the figure there are 16 vanes set at an angle of 45° and delicately suspended so that the lower edge of the vanes is about a millimetre from the fixed copper disc. Crookes emphasises the importance of this minimum separation, “Whilst experimenting with the otheoscope it was found that, for a given exhaustion, the nearer the reacting surfaces were together the greater was the speed obtained.”

The author has taken careful account of Crookes’ findings in 1879 and the need to devise a more compact arrangement. A new configuration is proposed for the Restructured Convector Generator with substantial changes to the design of the turbine and with all three major chambers in one housing (Figure 3 on Page 7).

The outer structure is heavily insulated. The combustion chamber (CC) is of cylindrical shape with hundreds of vertical channels to allow flow outside in the turbine gas circuit. The burner compartments are interconnected at the upper and lower levels so that incoming air enters at the base and combustion products leave at the top. The energy recovery unit (ER) forms a concentric annulus around CC – it prewarms incoming air and allows condensation of water from the flue gases. The turbine has a central vertical axle with electrical generation at its base. The turbine blades should be of heat resistant material, angled at 45° to the horizontal and should shade the entire area of CC and ER and be placed as near as possible to their upper surface. The turbine would resemble a Trent engine or steam turbine. The volume surrounding these structures and under the dome is filled with an inert gas, perhaps nitrogen or carbon dioxide at a pressure of 10-100 atmospheres to provide large heat capacity. The turbine gas is in a closed system whereas the combustion chamber is open to the atmosphere. Both operate entirely by natural convection – there are no pumps or fans.

Incoming air enters the configuration at (1) where it takes up heat from the condensate pipe. It then travels through the heat exchanger at (2) where it cools the turbine gas. It then enters the energy recovery section (3) where it takes up energy from the combustion products. The prewarmed incoming air enters the combustion chamber at (4) and takes part in the combustion of natural gas. Combustion products rise (5) and transfer about 90% of the heat of combustion to the turbine gas circuit.

The combustion products then pass through the energy recovery unit at (6) surrendering most of their residual energy to incoming air in this countercurrent heat exchanger. Water vapour condenses from the flue gases (7) and leaves via the condensate pipe at (8). The flue gases leave the configuration at (9). This entire cycle is driven by natural convection with no pumps or fans. The driver is combustion which produces hot gases which rise drawing ambient air into the system. Energy output is governed by the amount of natural gas provided for combustion.


b
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4
c
1
2
d
8
incoming air
combustion products
turbine gas circuit (cold)
turbine gas circuit (hot)
burners for natural gas
thick insulation
condensed water

Figure 3

The turbine gas circuit is a closed system containing an inert gas at 10-100 atmospheres pressure. Heat transfer takes place through the upper sections of the vertical channels in the combustion chamber and from its upper surface at (a). It is suggested that the turbine gas be at high pressure to provide large heat capacity so that 90% of the heat of combustion is transferred to the turbine gas at around the level of (a). The hot turbine gas rises striking the turbine blades at (b) causing rotation. The region between (a) and (b) has layers of molecules that are in collision with the upper levels of the combustion chamber and with the turbine blades. When they strike the combustion chamber they rebound with higher velocity taking up the extra energy. This additional velocity is shuffled along the layers of molecules between (a) and (b). As fast moving molecules strike the turbine blades, they lose their excess energy causing rotation. The overwhelming majority of energy transfer, combustion gases to turbine takes place in this region (a) to (b) via a shuttle of molecular collisions with no great mass movement of turbine gas. There will however be some passage of turbine gas in a convection current b → c → d → a → b …

At (d) the turbine gas current is cooled by incoming air. This provides a COLD section or ‘energy sink’ for the turbine gas circuit. But the energy transferred is not lost to the Convector Generator. It is recycled as prewarmed incoming air. The turbine gas is then drawn through the channels in the combustion chamber completing its cycle. Again there are no fans or pumps. All movement in the turbine gas circuit is by natural convection. There is no energy lost in the expansion of the turbine gas and no discharge to the environment. It is the author’s assertion that in this ‘energy cycle at constant volume’ conversion of heat into electricity has a theoretical efficiency of up to 100%.

When we consider the configuration in its totality the only energy losses are

- in the flue gases at (9) after maximum energy recovery
- in the condensate at (8) where incoming air recovers energy
- through the outer structure which should be very well insulated

It is the author’s assertion that the Restructured Convector Generator will have an efficiency comparable to the condensing gas boiler. The Carnot efficiency limit does not apply to this system. The heat of combustion of natural gas will be converted into electricity with an overall efficiency of over 90%.

Capacity of the Restructured Convector Generator

Let us assume that the structure depicted in Figure 3 has the following dimensions:

combustion chamber diameter	10 metres
convector generator external diameter	20 metres
convector generator height	10 metres
distance top of combustion chamber to turbine	1 metre
pressure of gas in turbine circuit	10 atmospheres
temperature rise for gas molecules as they impact on upper surface of combustion chamber	100°C

Consider that all of the critical energy transfer takes place in the region (a) to (b). Each gas molecule on impact at (a) acquires an energy $k\Delta T$ where k is Boltzmann's constant.

Volume of gas in region (a) to (b) $\pi r^2 h$ r = 5 metres h = 1 metre

$$\text{volume} = 3.14 \times 5 \times 5 \times 1 = 78.5 \text{ cubic metres}$$

The Gram Molecular Volume – one mole of gas at ambient temperature and one atmosphere pressure occupies 24 litres and contains N molecules where N is Avogadro's number

78.5 cubic metres of gas at 10 atmospheres pressure will contain

$$\frac{78.5}{24} \times 10^3 \times 10 \text{ N molecules}$$

$$3.27 \times 10^4 \text{ N}$$

If each of these molecules collects $k\Delta T$ of energy on single impact, the total energy transferred is

$$3.27 \times 10^4 \text{ Nk}\Delta T$$

But Nk = R the gas constant $R = 8.314 \text{ Joules K}^{-1} \text{ mol}^{-1}$ and $\Delta T = 100$

Thus total energy transferred is $3.27 \times 10^4 \times 8.314 \times 100$

27×10^6 joules

Let us consider that all the molecules in this band (a) to (b) collide with the upper surface of the combustion chamber once every second. Thus the total energy transferred is

27×10^6 joules/second

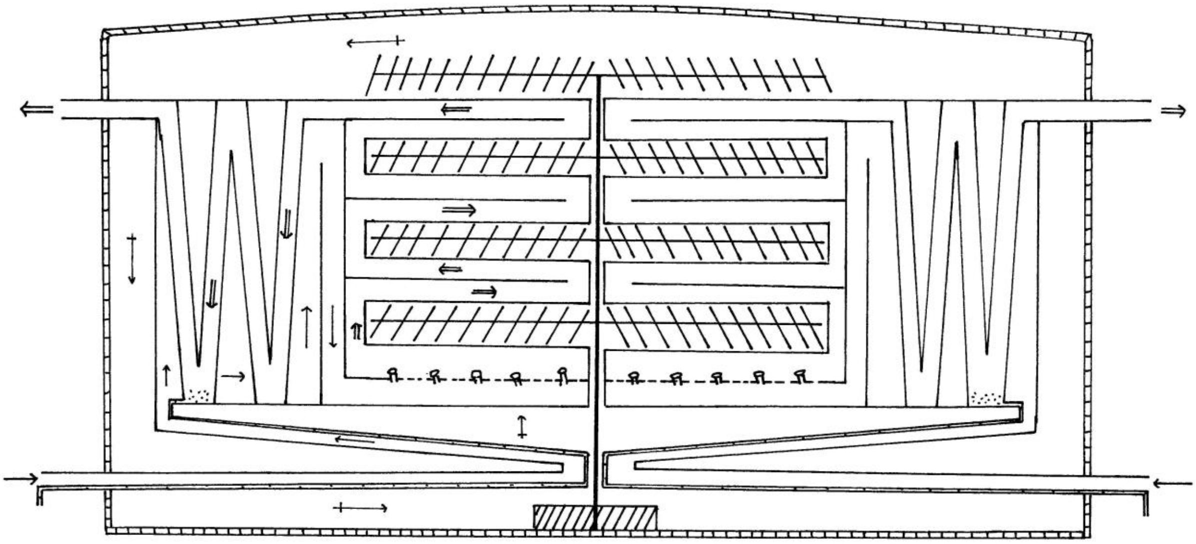
or <u>27 Megawatts</u>

But the root mean square velocity of oxygen molecules at 300°K is 483 metres/second. Thus if energy transport (a) to (b) is the dominating heat transfer mechanism, the gas molecules in this region can be involved in energy transport from the combustion chamber to the turbine over 100 times/second. Thus the potential capacity of the above configuration is up to <u>2700 MW</u>.

Convector Generator – Restructured, Compact and Ultra Efficient

The author has a slight concern that the configuration depicted in Figure 3 could allow hot gases to accumulate above the turbine and cold gas to stagnate in the lower regions. This could be the case if heat transfer was overwhelmingly from (a) to (b) and if there was only a minor role for the convection current circuit a $\rightarrow$ b $\rightarrow$ c $\rightarrow$ d

An alternative configuration is proposed (Figure 4) with a 'Christmas Tree' configuration of turbine blades.



Key as previously

Figure 4

The combustion chamber is divided into four layers with natural gas burners only at the lowest level. Combustion products rise but are channelled through a pathway that allows maximum heat transfer opportunity from the surfaces of the combustion unit to the turbine gas. The four series of turbine blades have a common axle. Transfer of energy will be greatest at the lowest level but successive layers will add to the torque, cooling the combustion products as they rise. The energy recovery section and the choice and pressure of the turbine gas are as previously. The configurations shown will ensure there is no overheating in the dome of the structure. The number of layers and of turbine sections could be increased to 5-10 which should ensure ultra efficient stripping of energy from the combustion products. The capacity of the system will be as previously and the author asserts that there will again be conversion of heat into electricity with an overall efficiency of over 90%.

References

[1] James Joule – a biography Donald S L Cardwell, Manchester University Press, 1989 [ISBN - 7190 3479 5]

[2] Philosophical Transactions of the Royal Society, London, 1879, Vol 170 pp88-163