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VN-H POWER GENERATION LTD

ROUND 3 IFA DUE DILIGENCE PACK

Elettra Produzione S.r.l 50MW Power Plant in Piombino now **Mothballed**

This pack is issued to IFA's who, in the understanding of the directors of VN-H Power Generation Limited, work with Certified High Net Worth Individual clients for the purposes of the Financial Services and Markets Act 2000 (Financial Promotion) Order 2005. These are defined as persons with annual income of not less than £100,000 or who have capital assets, excluding their house and pension, of at least £250,000 and who have a signed a 'High Net Worth' certificate**.**

This Due Diligence pack has been designed to help advisors carryout sufficient research to assist in meeting their obligations for compliance under FCA regulations on investment advice

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A "Sophisticated investor" is one who has a current certificate signed by an authorised person to the effect that he or she is sufficiently knowledgeable to understand the risks associated with the type of investment described by the Information Memorandum and who has signed, within the period of twelve months ending on the date of this document, a statement that he or she is qualified as a Sophisticated Investor in relation to such investments and accepts that he or she may receive financial promotions which have not been approved for the purposes of section 21 of the FSMA.

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The attention of IFA's is drawn to contents of page 6 of this document entitled "Summary of Risks".

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The Company or any other person shall construe nothing in this document as the giving of investment advice. The Revenue Projections, shown are purely illustrative and constitute a forecast of the possible market opportunity only.

IFA's are encouraged to conduct their own due diligence into the terms of this offer and the investment opportunity.

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Project Summary

Having successfully met the Stage 1 & 2 Project development milestones, VN-H Power Generation Ltd, (VN-HPG) is raising a further £315,000 of funding to continue development of the Electro Hydrogen Generator technology ("EHG") and to monetise the technology through licensing agreements with major Natural Gas Turbine Generator manufacturers and Power Station operators. The manufacturers are under significant pressure from operators to produce 'clean' and more fuel efficient' generating plant following the decision of governments around the world to reduce allowed CO_2 emissions and encourage increased fuel efficiency. Failure on these levels for the manufacturers would result at best in loss of market share, or worse, no sale of equipment. For the existing operators, the choice is even simpler; reduce and clean up, or shut generation down, because after allowance fees and fines it will simply not be commercially viable. *This is clearly evidenced by E.On's closure of their €400m, 3-year old Gas-fired plant in Bavaria and many others throughout Europe.*

EHG technology in this application will deliver a device designed to produce Hydrogen from the power generator waste energy streams. The Hydrogen produced is then compressed and stored onsite, (for future use) or fed directly to the gas turbine component of the generation plant and co-fired with Natural Gas. The Hydrogen introduced increases the burn efficiency of the gas turbine and then replaces conventional fuel with a corresponding percentage (of Hydrogen). *Thus, by co-firing with a low-cost, onsite produced, 'clean fuel', purchasing less CO_2 allowances and less natural gas, plants that are not economical today, can continue to operate, and newer more efficient plants can operate even more economically.*

VN-H Power Generation Ltd negotiated a globally exclusive development Licence in December 2012 allowing it to utilise existing *intellectual property and patents registered in 27 countries*, to develop and monetise the technology within the Gas Turbine Power Generation market.

The EHG uses a unique combination of centrifugal force, magnetic force and conventional electrolysis, which when combined produces a more efficient level of Hydrogen generation. The technology's capability was demonstrated under laboratory conditions whilst being developed in Russia by respected scientists. Dr Fulcieri Maltini on behalf of the UKTI witnessed the experiments and hydrogen output.

The data was further validated by an International peer science review team in the UK prior to its recognition in April 2011 by the UK Trade and Industry ("UKTI") as a *Technology of Exceptional Global Potential, being led by a Professional Management Team* and thus its subsequent development in the UK. (Copy UKTI certification available upon request)

Following Stage 1 testing, the unit has a proven and witnessed efficiency in excess of 95%.

VN-HPG is led by a *UKTI recognised Professional Management Team* working with a '*Technology of Exceptional Global Potential*'. (UKTI – United Kingdom Trade & Industry.)

VN-H Power Generation Ltd is positioned to leverage industry expertise at world-renowned companies together with specialist scientific teams. In November 2012, it obtained an expression of interest from Siemens AG Energy Sector - Fossil Power Generation Division and Energy Solutions for the role as joint developer – integrator and test-bed provider subject to further testing and design metrics being met. Siemens Industrial Turbo Machinery AB and Infraserv Höchst KG recently announced the successful conclusion of tests carried out by the Svenskit Gastenknist Centre AB on "Co-firing with hydrogen in industrial gas turbines". This study has led to Siemens and Infraserv Höchst rating the Siemens SGT- 700 & SGT 800 gas turbines suitable for 15% co-firing with hydrogen.

Advanced Assurance from HMRC for inclusion in the Enterprise Investment Scheme has been granted.

An IP Development Licence in relation to the 'Decomposition of Water', patent family deriving from International patent application number PCT/RU03/000413 and registered in 27 countries, was negotiated *(at an initial stage 1 cost of £50,000)* with the beneficial owner *Viridis Navitas IP Ltd* to complete the development programme.

Current Position:

The Company raised £150,000 via an SEIS New Founder Share Holder offer that closed 'over-subscribed' on the 8th of February 2013. The project commenced on the 25th March 2013 with proceeds of the raise being used by the Company to secure the exclusive development Licence for EHG use within the Combined Gas Turbine Power Generation market and to commission a report from Newcastle University referencing upward scalability constraints together with predicted scalable output quantity metrics.

Based upon the EHG3 and new prototype EHG4-M, this report provides the "Energy Equation" i.e. a predicted cost of scaled production "energy in vs energy out" or efficiency as described in kWh terms.

As a benchmark, in April 2005 under laboratory conditions In Moscow, Dr Maltini recorded that the EHG 3 model produced 21.2 – 24.6 standard litres of hydrogen per hour when driven by an electric motor at speeds between 4,500 & 8,000rpm using a 30% concentration of sulphuric acid electrolyte.

The latest conventional alkali Proton Exchange Membrane (PEM) electrolyser in the industrial sector is approximately 69% efficient at scale, i.e. 500kw – 1MW. Dr. Maltini's report, (based on the Russian science and data provided) *suggests that the Russian EHG3 had an efficiency of approximately 91%*. The main focus for Stage 1 was to provide supporting evidence and data for this efficiency claim.

The Stage 1 confirmation report author is Keith Scott - Professor of Electrochemical Engineering at the School of Chemical Engineering and Advanced Materials within Newcastle University. Quoting from the report, he states:

"The best performance was achieved with the sulphuric acid electrolyte based EHG tests. A peak hydrogen production rate at an equivalent current of 71 Amps and an energy consumption of 36 kWh/kg was obtained which is superior to that for water electrolysis. *The average energy consumption for the short-term tests is comparable with those for standard water electrolysis".* This means that the EHG is more efficient, and therefore potentially a more competitive technology than the existing alkali based electrolysers, i.e. it costs less to produce the same amount of hydrogen as existing technologies.

"Qualitatively increased rotation rate appears to improve hydrogen production rate as does an increase in temperature. At a rotation rate of 1000rpm the current enhancement above background current was some 8A, compared with an enhancement of some 29A at a rotation rate increase from 1000 to 2250 rpm. This indicates an exponential type of increase in production rate with increase in rpm, rather than a non-linear increase". This indicates that the technology's output and efficiency can be significantly improved when scaling it.

"Based on the thermoneutral potential of 1.41 V the minimum energy consumption is 37.5 kWh/kg. Thus, an efficiency approaching 100% is indicated."

The above is caveated with *"This data should be used with caution due to the short-term duration of the tests and the inherent assumptions in the calculations. There is clearly a need to perform more detailed tests under stable operating conditions to verify the performance observed so far."*

Stage 1 Milestone/deliverable: A detailed report on the efficiency, scalability and output metrics.

Stage 2: The company originally had a fundraising target of £1,150,000 to deliver the following:

1. A series of stage revised EHG-M units each larger than the previous unit with continuous improvement
2. A set of industry accepted independent test reports confirming optimal and increasing hydrogen output for each EHG
3. A set of draft design drawings for a fully characterised EHG matched to the 10% co-firing fuel requirements of an existing Combine Cycle Gas Turbine Generation plant being driven by an industry standard steam turbine, power take-off drive, or electric motor.

NOTE

In July 2014 post publication of the Stage 1 success, VN-HPG Directors started discussions with various large manufacturers of heavy duty centrifuges interested in acquiring a manufacturing and licencing deal for the EHG technology. A comprehensive commercial and technical dialogue was entered into with Thomas Broadbent & Sons, one of the UK's largest centrifuge manufacturers. Promotion of the funding-round was temporarily suspended pending negotiations and possible beneficial commercial results, as the amount to fundraise would change significantly, and the Directors wanted to protect the investor's, and their own, share dilution position. During this process, all major challenges involved with centrifuge design were examined and all possible alternatives for a design solution that would facilitate the EHG's specific technical requirements explored. The process, of putting together the VN scientific, engineering, design, IP and commercial resources to create a solution from a 'blank sheet of paper' and understanding in detail what didn't work from our Russian colleague's results, resulted in the new EHG design, and completely negated the need for a manufacturing partner at this stage. It also helped to substantiate a project development plan that would not affect the shareholder value, nor impose any constraints on the commercial proposition or its flexibility of delivery to make money for shareholders.

In August 2015, as a result of the delays incurred, and to ensure that no opportunity to improve the projects prospects for success had been overlooked, the Directors reviewed every aspect of the project, re-investigating, re-evaluating and where required, adjusting the plan to benefit the following: Timeline, Cost Reduction, Manageability and Control, Security and Potential Supplier Risk.

Where appropriate previous supplier or partnership arrangements were amended, or changed completely when beneficial in one or more of the aforementioned areas. This, and information gleaned from the scaling design work mentioned in the previous and following paragraphs, led to a significant reduction in the development capital estimated to be required for Stage 2, lowering the fundraise requirement from £1,150,000 to £600,000, therefore avoiding greater investor dilution.

As mentioned in the above paragraph, in parallel with the negotiations and to keep momentum in the project, the Directors decided to commission the design for a larger scalable version of the EHG. This was actioned in June 2015 and carried out in parallel utilising funds raised at that time.

This has delivered the following:

1. A completely new series of EHG designs
2. A prototype manufactured and assembled
3. A series of technical workshops held to provide engineering adaptations and design updates
4. Preliminary mechanical longevity testing
5. Preliminary alkali electrolyte testing with initial on-target results achieved.

A significant proportion of the initial raise remains, sufficient to build further scaled iterations of the EHG, for more testing and development.

As a result of these deliverables, additional reduction in project and technology risk and to ensure existing Investors derive maximum value from these activities so far, the Directors closed Stage 2 funding at £290,000 on the 19th May 2016

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Stage 3 Development Programme – On Offer

Stage 3: **Now Open and will be financed by a 3rd round funding of £315,000 via the issue of a further 42 shares and will by building and testing further scaled EHG's deliver:**

- 1 x Industry accepted independent test report showing optimal and increasing hydrogen output throughout the stages (Provided by Intertek Tickford & Professor Keith Scott of Newcastle University)

- 1 x Set of draft design drawings for a fully characterised EHG used either singly or in a series, matched as a minimum to the 10% co-firing fuel requirements of an GE PGT10b gas turbine operating in a Combined Cycle Gas Turbine Generation plant being driven by an industry standard steam turbine, power take off drive, or electric motor

- 1 x signed 'Option to Purchase' contract for the Elettra Produzione S.r.l owned 50MW CGT Power Plant in Piombino, Italy.

Stage 4 Development Programme

Stage 4: Financed by a 4th round raise of £6,400,000 via the issue of a further 640 shares or research and development funding if appropriate or available. (Budgetary figures only)

Delivering:

- The purchase of the Piombino Power Plant together with operating finance for 24 months
- 1 x Set of integration drawings for the EHG waste energy drive system
- 1 x Pre-commercial EHG unit for trial and testing.
- 1 x Set of negotiated supply contracts for 3 x subsequent EHG builds and installation of same, complete with timeframes and delivery service level agreements
- 2 x EHG unit integrated drive systems installed for commercial operation at the Piombino Plant.

The design will be focused on the GE PGT10b gas turbine. Consisting of a waste heat / steam driven fully characterised Electro Hydrogen Generator, producing hydrogen and co-firing it with conventional fuel. We will initially fit the EHG to one of the GE PGT10b 11.25MW multi-fuel industrial gas turbine which are capable of burning a mixture of natural gas and other gases at a 60/40 ratio, providing the plant with a targeted 10% fuel replacement capability and 10% plant reduction in CO_2 emissions, as proof of concept. Once the first EHG unit is deemed to be operating successfully a further unit will be commissioned and installed.

Timings and Costs

Stage 3 will take place over a 12-month period with costs estimated at £283,000 including a stage 2 payment *(£50,000 being 20% of the full cost of £250,000)* of the negotiated development Licence fee. *Note: All Legal, Accountancy and 3rd Party costs as indicated on Page 24 of the IM (estimated at £29,500) will be made before project commencement. Project expenditure at £283,000 includes a 10% overrun/contingency fee.*

Stage 4 will take place over a 24-month period with costs estimated at £5,792,000 including a final payment (£150,000 being 60% of the full cost of £250,000) to complete the purchase of the development Licence fee. *Note: All Legal, Accountancy and 3rd Party costs as indicated on Page 24 of the IM (estimated at £608,000) will be made before project commencement. Project expenditure at £5,792,000 includes a 10% overrun/contingency fee.*

Summary of Factors to deliver success for VN-HPG Ltd

1. Legislation is forcing the power generation industry to continuously reduce CO2 emissions. This is forcing manufacturers and operators to build and operate low/no emissions plant. Therefore, any solution that assists or delivers on those reductions will very likely become a commercial success.

2. Professor Keith Scott has been retained by VN-HPG to deliver the scientific development and scalability, and assist in the integration of the solution into existing processes and technologies. His background, experience and R&D skills in this area are second to none worldwide, in this field.

3. Mick Avison, Technical Director for this development programme, has been involved in all aspects of the power generation industry and has recently managed over 250MW of Combined Cycle Gas Turbine, (CCGT) generation plant it Italy, and prior to that Programme Managed the development and build of a 400MW CCGT power plant in Portugal. This experience coupled with Mick's commercial pragmatism, and track-record on execution of large and complex projects will ensure the delivery of this programme.

4. The VN-HPG management team operate on 'equity for services' agreement with no salary costs. This means that the company has very low OPEX and this again helps to reduce project and investor risk.

5. VN-HPG pay a fixed £5k pa admin fee, this covers all monthly/annual accounting, fiscal reporting, VAT returns, Shareholder administration and daily administration. This very low cost for the services mentioned will assist the company's financial stability.

6. As a result of the two previous points the majority of money raised is applied directly to the project delivering further proofs, prototypes, IP, knowledge/know-how and equipment that will accelerate the companies progress to invoiced sales.

7. Using Universities, the scientific community and industry specialist outsource suppliers on fixed-price, fixed-deliverable contracts underpinned with quality metrics and Service Level Agreements means that VN-HPG is able to predict and control costs, quality and timelines.

8. The VN-HPG licence model delivers profitable revenues without the need for extensive company scaling and monetary requirements. Furthermore, this makes a potentially disruptive solution complementary to the goals and strategies of most Governments and Industrial manufacturers, i.e. to reduce CO2 efficiently, and create local jobs and taxation.

9. Working with existing manufacturers and industry process specialists opens up more potential for R&D funding, thereby reducing potential share dilution, and increases the possibilities for licencing and/or JV agreements and/or a trade sale for investor exit.

10. The solution has the potential to produce more than the target 10% replacement Hydrogen for the Gas Turbine plant. It is proposed that the excess Hydrogen produced will be sold, potentially increasing the EBITDA, and increasing the opportunity for the trade-sale exit route.

11. Breaking the project down into smaller funding rounds with measurable targets helps to reduce project risk. Furthermore, significant reductions in funds required for Stages 2 and 3 through careful project planning and supplier management has significantly reduced investor dilution.

Summary of Risk Factors

The Company's Stage 2 business development involves a degree of risk, inasmuch as:

1. An investment in the Company is speculative because, although it has access to a substantial amount of research and data compiled regarding the EHG project, and has a full IP exploitation Licence granted by the IP owner, the EHG has been proven to produce hydrogen in laboratory and test facilities only. Whilst the engineering being utilised to enable the EHG to be driven by waste energy within the Gas Turbine environment is 'industry standard Turbine Drive technology' it has not been used to drive an EHG to date. Therefore, there is a possibility that the process may not deliver the desired results and the project could fail

2. Although best endeavour has been used to verify all the scientific research and data the Company is relying on for this project, it may transpire not to be reliable

3. The market uptake for an EHG type product is unproven. The project's success is driven by legislation that forces the Generation Industry to continuously reduce emissions in the face of perpetually rising fuel costs. This is forcing manufacturers to build 'low emission' and 'fuel-efficient' machines, however there is no guarantee that the EHG will become the industry's 'preferred' solution

4. Estimates of potential value and costs may not be reliable inasmuch as:

   - The potential Licence income values are illustrations based on available comparable industry information
   - The estimates are subject to market input variables that cannot be determined until the unit is developed and ready for market,
   - The illustrations of potential income value in this Information Memorandum may, accordingly, not be reliable despite the Directors best efforts to judge them accurately.

Enterprise Investment Scheme

A condition of HMRC's approval of EIS is that the conditions relating to the Company and its trade have to be complied with throughout the three-year period following the issue of the Shares. Although it is the intention that the Company's activities should qualify under the EIS, if the conditions are not complied with, the Company would have breached the EIS legislation and EIS income tax relief would be withdrawn.

How Tax Relief Mitigates the Financial Risk

EIS Information

The summary below provides an *indicative guide* to the tax implications stemming from an investment in VN-Hydrogen Power Generation Ltd and is based on current understanding of UK tax law and practice. *It does not set out all of the rules or regulations that must be adhered to and should not be interpreted as the provision of tax, legal or financial advice.* Investors are strongly recommended to seek independent professional advice on the tax consequences of acquiring, holding and disposing of EIS qualifying Shares before proceeding with an investment into the Company.

The Round 3 fundraise has been structured with the intention to enable investors to claim EIS reliefs on the amount of their subscription, as described below. The amount and timing of these reliefs will depend on the individual circumstances of each investor and may be subject to change in the future. The illustrations included in this section are for indicative purposes only and should not be construed as forecasts or projections of the likely performance of the Company.

In order to access the tax reliefs described it is necessary to be a UK resident taxpayer and subscribe for EIS qualifying Shares. The summary below gives only a brief outline of the available tax reliefs and assumes that an investor is an additional rate taxpayer.

EIS Tax Relief:

Highlights

- An individual can invest annually up to £1 million in EIS companies and obtain a tax credit equal to 30% of the cash investment.

- For EIS it is possible to invest up to £1 million in 2013/14 and carry back £1 million to 2012/13, provided certain conditions are met.

- Certain types of trade do not qualify for EIS relief. These include certain financial activities, property development, hotels and providing legal or accountancy services.

- A 'disqualifying arrangements' test has been introduced to exclude VCTs, EIS or SEIS that do not invest in qualifying companies and are set up solely for the purpose of giving investors tax relief.

The following sections analyse the main features:

- Income tax credit on the amount invested and when it may be withdrawn
- The capital gains tax exemption and/or utilisation of capital losses on the disposal of the shares
- Deferral relief, provided the relevant conditions (explained below) are met and
- Business Property Relief (BPR) from inheritance tax (IHT), where certain conditions are met.

EIS Income Tax Relief:

- Income tax credit at 30% of the amount invested in subscribing for new shares (maximum annual investment of £1 million).
- By election, where an EIS investment is made in one year it can be treated as though it was an investment made in the immediately preceding tax year, subject to the overall limit for that year.
- Dividends paid on EIS shares are taxable.

- Where the EIS shares are sold within 3 years, the EIS investor receives value or an option is placed over the shares, then the EIS tax credit is clawed back.
- The claw-back amount is the lower of:
  - Original income tax credit; and
  - 30% x sale proceeds received (only applicable if sold for a loss)
  - There can also be a claw-back if the company loses its EIS status within 3 years.

EIS Capital Gains Tax (CGT) Relief:

- An EIS investor is entitled to exemption from CGT on a disposal of those shares, provided he has held them for three years. Therefore, any growth in value is effectively tax-free.

EIS Relief for Capital Losses on Disposals:

- Relief is given for allowable losses arising on the disposal of the shares against either income of the tax year of disposal (or of the previous tax year) or chargeable gains, provided all the relevant conditions referred to below are met.
- Any income tax relief obtained under EIS, which was not withdrawn, reduces the capital loss.

EIS CGT Deferral Relief:

- The tax due on a gain on any asset can be deferred by subscribing for shares in EIS qualifying companies, in a period beginning one year before and three years after the disposal of the original asset.

Business Property Relief:

- Shares in EIS companies held for at least two years will normally qualify for 100% BPR for IHT purposes.

EIS Conditions:

For EIS purposes, both the investee company invested and the investor need to meet certain conditions:

Conditions to be met by the company:

- The company's gross assets must not exceed £15 million immediately before the shares are issued and £16 million immediately afterwards

- The Investee Company must be unquoted when the shares are issued and there must, broadly, be no arrangements for it to become quoted. A company admitted to AIM will not be regarded as quoted for these purposes

- The Company must exist to carry on a qualifying trade (i.e. conducted on a commercial basis with a view to making profits; and the trade does not include, to a substantial extent (20% or more), excluded activities such as property development, leasing, dealing in land, shares and/or commodities etc.)

- The company must not be a 51% subsidiary of another company

- The Company must not have any subsidiaries that are not 51% subsidiaries

- The issuing company must either be a UK resident company carrying on a trade in the UK or be an overseas company with a UK permanent establishment carrying on a trade

- The Company must not be in financial difficulty
- The Investee Company must have fewer than 250 full-time employees
- The Investee Company cannot raise more than £5 million in total over a 12-month period under the EIS and the VCT scheme.

Conditions to be met by the investor:

The key conditions are as follows:

- The subscription must be in newly issued, ordinary shares and paid for in cash, as well as being for genuine commercial reasons and not for tax avoidance purposes
- To retain the income tax relief and to be exempt from capital gains tax, the shares must be held for at least three years
- The investor must not be connected for EIS purposes with the company. Investors who are connected with the company cannot claim income tax relief but may still qualify for capital gains tax deferral relief
- An investor will be connected with the company if he, either on his own or with associates, possesses or is entitled to acquire more than 30% of the issued share capital, voting power or assets of the company or any subsidiary on a winding up
- An investor will also be connected if he or she is an employee of the company or its group. They can be directors provided they meet certain conditions. An investor must not receive any amount of remuneration as a director that is excessive in comparison to the services performed. Relief will be withdrawn if the investee company, or a person connected with the company makes a payment to the investor (which is not "insignificant") up to one year before, and three years after, the share issue.

Exit Strategy & Potential Investor Returns

Exit Strategy and Potential Returns for Round 3 Subscribers

The Directors plan an Initial Public Offering of the shares in the company between 2018 and 2021 or at such time as the Directors believe a significant multiple on initial investment may be achieved for subscribers.

No guaranteed forecast can be given of the likely or potential returns to Subscribers upon the successful delivery of the project. Therefore, given current market uncertainties, allowances have been made for a broad spectrum of returns. On the basis of Market Research carried out by VN-HPG, the cost of electricity generation using NG in the target sector is estimated currently to be £234 billion pa. Of this, we are proposing that 10% be replaced by EHG generated hydrogen, providing a market opportunity of ***£23 billion pa.***

The 670 or so New Generator sales made each year incur another £12.48 billion in fuel costs, thus providing a further ***£1.25bn pa market opportunity***.

The business model uses Platts pricing of gases produced, discounted by 50% and assumes 10% of the turbines fuel requirement being replaced with hydrogen produced by the installed EHG.

The 'equipment installed' revenue assumptions through the period 2018 to 2022 are based upon a minimum 20% retention of gross replacement gas revenue by way of licencing fees, plus Design & Consultancy income of £1m per unit targeted at 8 unit designs pa. (4 x new turbine models & 4 x Refurbished existing models).

The balance of revenue (80%) provides for hardware, installation and equipment O&M costs. VN-HPG is budgeting for fixed annual operating costs of £4.2m in 2020 rising to £5.2m in 2021, £6.2m from 2022 and £7.2m from 2023, and £6m from 2024 onwards. Variable costs of £3.2m pa are primarily for Design and Consultancy services that will be outsourced. There is potential to substantially reduce the outsource costs if insourcing is considered a more strategic option.

The P&L projections when producing Hydrogen & Oxygen at the 50MW Piombino plant, co-firing 10% of the total produced and selling the balance, delivers a potential EBITDA of €88M per year, compared to an €8M per year loss prior to closure.

See below for potential investor returns:

Round 3 Potential Returns to Investors table –

Round 3 Example Investment of £50,000 = 6.6 Shares						
				Potential Return on Investment		
Year	Gross Income	EBITDA	Sales Projections	P/E	P/E	P/E
				7	10	12
2020	£9,168,287	£4,968,287	Scenario 1	£107,259	£153,228	£199,196
2021	£14,429,275	£9,229,275	Scenario 2	£199,249	£284,641	£370,034
2022	£21,536,586	£15,336,586	Scenario 3	£331,098	£472,998	£614,897
2023	£29,503,822	£22,303,822	Scenario 4	£481,512	£687,875	£894,237
2024	£35,503,391	£29,503,391	Scenario 5	£636,942	£909,918	£1,182,893

This shows projected returns of between 2 and 23 times initial investment. Assuming the shares are held for a minimum of 3 years, these return is exempt from Capital Gains Tax.

Management Track Record

Scientific Advisor

Prof. Keith Scott, is Professor of Electrochemical Engineering at the School of Chemical Engineering and Advanced Materials, Newcastle University.

Research activities include:
Electrochemical power sources: fuel cells, batteries, microbial and biological fuel cells
Electrochemical environmental engineering, photochemical processes, Membrane materials and membrane separations.

Research Interests are:
Fuel cells, power sources and energy systems,
Electrocatalysis
Electrochemical systems and engineering,
Reaction engineering, catalytic reactors
Membrane separation processes and membrane reactors

Research themes & Projects:
Alkaline Polymer Electrolyte Fuel Cells (http://www.ncl.ac.uk/ceam/research/project/2639)
Project Leader(s): Prof Keith Scott

An Oxygen Electrode for a Rechargeable Lithium Battery.
(http://www.ncl.ac.uk/ceam/research/project/2656)
Project Leader(s): Prof Keith Scott

Enhanced Fuel Cell Flexibility (http://www.ncl.ac.uk/ceam/research/project/2646)
Project Leader(s): Prof Keith Scott

SUPERGEN III - Fuel Cells: Powering a Greener Future.
(http://www.ncl.ac.uk/ceam/research/project/2638)
Project Leader(s): Prof Keith Scott

To develop a potential energy self-sufficient process to treat waste and waste water using Microbial Fuel Cell (http://www.ncl.ac.uk/ceam/research/project/2708)
Project Leader(s): Prof Keith Scott

Directors:

Mick Avison is a highly experienced Senior Executive Manager, with a reference-able track record in the development, construction, operation and management of power generation projects and businesses (renewable and conventional energy) in Europe. Mick has significant knowledge and experience of Private Equity and Commercial Banking Finance and Risk Management.

He has particular skills in the development of renewable projects, particularly the negotiation and management of EPC contracts for the construction of Power Plants, fuel supply and Power Take Off agreements (PTAs) together with operation and maintenance contracts. Mick also advises private institutions on energy related issues and asset management.

This expertise has been gained in a number of professional and commercial roles over the last 28 years. Aged 54, his skills mix reflects core training as an engineer, leadership roles in Joint Venture companies and blue chip power generation companies.

Since 2004, Mick has provided independent practitioner and advisory services to private investors, government agencies and independent power companies.

Mick was instrumental in the contract restructuring of the Elettra business in Italy, resulting in a successful €170m refinancing in 2007 and went on to manage their power business in Italy comprising 230MW of CCGT power plant utilising industrial producer gases to co-fire the gas turbines. Mick has also developed wind, biomass and solar projects in the EU working with a strong network of contacts.

Mark Gilmore is a founding Director of Viridis Navitas Capital Partners Ltd *(the sponsor of EHG)* and a highly motivated, tenacious and achievement orientated individual who has constantly delivered on business, margin and project targets throughout his career.

Be it participating in successful IT start-ups, or working within a 'FTSE 500' company, Mark brings more than 20 years successful operating experience at senior and executive sales management level to VN-HPG.

Mark's most recent corporate role was managing COLT Managed Services strategic markets region (6 countries and 27 employees). In his last year, he delivered over £30m in revenues (118% against target) and nearly £13m of new business bookings (122% against target). This achievement was coupled with the process of transitioning the pre-sales technical architects, with corporate incentive structures to technical consultants holding personal incentive schemes.

Prior to this Mark held a number of senior Business Development roles including; Dimension Data for over 4 years, significantly exceeding revenue, bookings and margin targets in each of the 4 years he was there; GTS Carrier Services; and TGNS S.A.

In between these roles, Mark started Big Picture Interactive, a brand new digital multimedia and interactive web company and took the company from start-up to over £1m turnover in the first year, and prior to that converted an antique shop into a pub and restaurant and ran it for 2 years before exiting.

David Newman is also a founding Director of Viridis Navitas Capital Partners Ltd *(the sponsor of EHG technology)* and another highly commercial, innovative and success driven individual. He is also an entrepreneur with a strong electronic, electro-mechanical, automotive and heavy engineering background.

Following 10 years of military service operating throughout the world, David spent the next 10 learning the commercial realities of international business by apprenticing himself to the most successful business owners and companies he could find. During this time, he was tasked across a broad range of industries including, leisure, entertainment, automotive, telecoms, advertising and IT. His corporate roles have included: Project Management, New Business Procurement, Financial Restructuring, Technical Creation and Support, IT Solution Creation & Delivery, Training Program Creation & Delivery and Change Management.

In 1999 he formed his own Telecoms consultancy and later that year created Trans Global Network Services, the world's first global fibre optic leasing operator.

After successfully exiting TGNS in 2002 with annual revenues of $27m, David accepted the role of Commercial advisor to the then Maltese Minster of Finance, The Right Hon Mr John Dalli.

There he formed part of a 3-man team charged with redesigning the Countries FDI programme, agencies and Industrial Estate Management.

Successful completion of this project delivered a 'step change' in Government attitude toward FDI procurement, Business Promotion and even its own work force, pre-the Country's accession to Europe.

In 2004 David continued his career by taking on international consultancy roles within the restructuring IT and telecoms sector and later within the emerging renewable energy industry.

He returned to the commercial 'start-up' market place in 2008, designing and building an "outsourced" Credit Management and Cash Collection business for top 50 London accountancy practice, Simmons Gainsford LLP. SG Credit Management was initially created to assist SG client's post-recession but today has exceeded that brief. The business currently manages annual cash collections in excess of £16m and is currently working with a major UK High Street bank delivering its services to their customers. David successfully exited the company in 2012.

In mid-2009, David was invited to lead the design team in building an 'algae to fuel' Photo Bio Reactor for a US project. In mid-2010 working with the same US affiliates, he went on to manage the design and build of an innovative 'oleophilic membrane' crude oil recovery rig. With support from the US Department of Energy, the machine was deployed in the Gulf of Mexico and trialled as part of the Deep-Water Horizon clean-up operation.

In September 2010 David joined forces with Mark and formed Viridis Navitas Capital Partners Ltd (VN-CP) specifically to target the renewable energy start-up funding gap experienced by inventors, engineers and scientists alike.

The above-mentioned experiences have allowed David to build up a broad network of contacts throughout Governments and industries alike that he leverages to the benefit any company he works with.

Understanding the financial risk versus reward balance for investors, as a 'real' investor himself, he brings an unusual but extremely useful skill set to the company.

Since inception VN-CP has delivered 10 successful funding rounds for platform technology application spinouts raising in excess of £2M via HMRC Advanced Assurance Seed Enterprise Investment Schemes & Enterprise Investment Schemes.

Secretary and Treasurer

Steven Strauss is a Chartered Accountant and Fellow of the Institute of Chartered Accountants in England and Wales. Steven read Economics at the London School of Economics, gaining a BSc Honours Degree in 1981, studied for his articles and qualified in 1985 receiving an associate membership of the Institute of Chartered Accountants in England and Wales later in that year.

In addition to work in the tax field, Steven has also had a significant amount of commercial experience, advising and consulting corporate entities on a wide range of matters.
Steven has been a Director of an Australian Stock Exchange Quoted company and is currently Chairman of an International payments solution company and Company Secretary to VN Capital Partners.

Related Renewable Project Success

VN Automotive Ltd – The team at VN-HPG Ltd. is common to a number of leading edge renewable technology start-ups where Government legislation and incentives are driving the adoption of CO_2 reduction solutions across industries worldwide. It is recognised by the UKTI as a professional management team working with projects of exceptional global potential, the first of which was the development of an Electro Hydrogen Generator for the automotive, static generator and commercial vehicle market. Here the team generated significant success using the same set of basic principles of business operation now being used in VN-HPG, i.e. clear and transparent principles of operation as described on page 5 of this document.

The team has raised over £1m in VN Automotive Ltd, delivering the scientific and engineering proofs used in the development of an embryonic automotive solution to prove the following:

1. The most efficient Hydrogen production technology currently in development – currently over 95%
2. The most flexible method of production using waste energy streams
3. Proof of potential scalability for specific markets.

The solution has now moved to the production of a proof of concept and a working prototype. These will demonstrate the effectiveness of the solution and potentially enable the company to licence the technology to the automotive, static generator and commercial vehicle markets with full commercialisation in 2017/18.

FAQ's for VN-H Power Generation

What is the minimum investment?

£10,000.

What are the fees?

The company pays distribution charges of up to 6% of the funds raised to introducers and intermediaries. There are no annual 'fund management' fees, neither are there any success fees.

What are the management team salaries?

The management team do not draw salary until the company is commercial and in a position to make sales, in this case after the successful completion of Stage 3, and with its first invoice for a licence contract. The management team is incentivised by their respective equity stake in the company, and therefore their goal is completely aligned to that of any investor, i.e. a profitable exit generating a significant multiple return on investor funds.

What are the projected returns on my investment?

Dependent upon company P/E, market penetration and carbon credits price at the time of commercialisation, between 2 and 23 times your original investment. See page 28 of the IM for more detail.

How will the company make money?

By designing and licencing the technology to Gas Turbine Generator manufacturers for New and existing Gas Turbine Plants, and to Power Generation plant operators and owners through retro-fit solutions. See pages 21, 25 to 27, pages 60 to 62 and Schedule 5 of the IM for more detail

When will, the company make money?

2020. See pages 21, 25 to 27, pages 60 to 62 and Schedule 5 of the IM for more detail.

What is the exit strategy for Investors?

An IPO of the company between 2019 and 2022 or sooner if market conditions and company financials allow, or a trade sale if available earlier and it provides a suitable return for investors and management. An MBO will be an alternative exit for Investors assuming business conditions are suitable. VN HPG would also like to offer Investors an independent exit through Asset Match, see http://www.assetmatch.com.

How big is the market opportunity?

In 2020 the estimated addressable 'New' target market opportunity will be £1.24bn. In 2020 the estimated addressable 'Retro-fit' target market opportunity will be £23.4bn. Therefore, the total estimated addressable market in 2020 will be £24.6bn. See pages 50 to 53 of the IM for more detail

Why does the market opportunity exist?

There are a number of factors involved, including but not limited to; Current EU legislation enforcing CO2 reduction in the Fossil Fuel Power Generation with fines to punish polluters, slumping electricity prices and overcapacity. See first 4 pages of IM for more detail.

What is the competition?

The nearest comparable technology is Proton Electron Membrane Electrolysis, (PEM).

How does VN –HPG compare with PEM Electrolysis?

The VN HPG solution is much more flexible as it has the intrinsic ability to scavenge waste pressure and heat to produce hydrogen, or it can utilise electricity if it is surplus to requirements. Furthermore, the EHG is proven to be over 95% efficient compared to the PEM's 70%. See page 53 of the IM for more detail.

What is unique about this solution?

- The flexibility of production by the intrinsic ability to scavenge waste pressure and heat, as well as to use electricity if necessary to produce hydrogen.
- The proven efficiency rating of the solution, i.e. over 95%. See pages 20, 21 and Schedule 6 of the IM for more detail.

How proven is the technology?

The technology has been proven in the laboratory, industry test-bed and witness tested by Professor of Electrochemical Engineering, Keith Scott of Newcastle University. Professor Scott has also produced an efficiency report, proving the technology's rating at over 95% efficient. See Schedule 6 of the IM

What are the main risks in this company and how will VN HPG mitigate them?

Whilst the technology has been demonstrated in the laboratory, it has yet to be fully tested and so this leaves uncertainty as to the full market potential and scalability of the solution.

Mitigation – By working sequentially, VN HPG provides continuous and further proofs, validation and recyclability rates of the solution and its application before progressing to the next stage.

Market adoption – whilst the company is already in discussions with major manufacturers regarding integration into existing technologies, this is no guarantee of successful licence sales.

Mitigation – by working with manufacturers at the development stage VN HPG opens the possibility for manufacturer-funded R&D. This is a low/no cost funding option that further proves the solution without dilution of shareholders.
One additional benefit is that it opens the possibility to a trade sale as an alternative to an IPO.

Market protection – Some Governments may wish to protect their domestic markets by favouring particular solutions.

Mitigation – VN HPG has support from UKTI for this solution and will leverage this position with UK based Operators and Manufacturers to get their buy-in. Furthermore, the VN HPG licence model lends itself to encouraging Governments to buy-into it, as the main economic benefits of jobs, taxes and environmental are still there. See pages 61 & 62 of the IM for more detail

What are the IHT benefits of EIS?

It is strongly recommended that Investors take independent advice on this prior to investing.
After 2 years, any investment in SEIS or EIS is IHT exempt.

What is the likelihood in any of the fundraising rounds not being fully subscribed? What will happen if this is the case?

VN H Power Generation has already raised over £440K from existing VN Investors. In the history of the management team and existing companies, most of the fundraising activities have been oversubscribed. Furthermore, as the company takes on new investors the fundraising activity becomes more straightforward as current experience is proving that a high level of previous investors, i.e. Previous investors in other VN companies, are subsequently investing in following investment rounds and spreading further investments across the VN company portfolio.

Do the dilution percentages include the issue of the planned share options?

Yes. See page 24 to the IM for more detail

Are the dilution percentages guaranteed? Is there anything to prevent the company from issuing more shares than in the plan to raise further capital, thereby diluting the existing shareholders further?

The forecast dilution of shareholders is not guaranteed. However, in the experience of previous projects and fundraises this has not happened. One of the benefits of having the management team as equity participants is that their incentive is to ensure, as far as is possible, that dilution does not happen above the percentages forecast. In the unlikely event that this was required, the management team would communicate with investors the options at that time, and hold a shareholder vote to resolve the issue.

Project development expense is forecast at £6.4m in total for the final (4th) Round, which is a substantial project. How certain is the company that it will be completed in time for you to launch commercially in 2020?

This is based on the management teams experience of similar projects, timelines and developments using the same or similar 3rd party suppliers, and this underpins the team's complete confidence in these time and budgetary forecasts. The team has not missed forecast development or delivery budgets in past projects and companies, so have a demonstrable track-record in this respect.

Having demonstrated the ability to significantly reduce the capital required to deliver the same Stage, the VN HPG management team reduced the Stage 2 & 3 budget from £1.15m down to £600K, to deliver the same outcome, and as a consequence reduce Investor dilution by the same proportion in this stage. See page 5 of the IM for more detail.

How will you meet the additional capital requirements if it has not been completed on time?

As the company, does not have any salaried management, or employees, and the fact that all subcontracted projects and developments have fixed-price and time dependent deliverables on service-level based contracts, means that there will be no additional capital requirements.

Can you explain the actual business model in more detail? What exactly is the product that the company will be selling and how will it be sold?

The company plans to licence the solution to manufacturers of Natural Gas fired power generators to reduce their Natural Gas fuel bill, by replacing it with Hydrogen, and reduce their CO_2 emissions bill as a result of using a replacement fuel that does not emit CO_2 when burnt, with the model working as follows:

- VN-HPG will charge the manufacturer for design and consultancy services
- The manufacturer will integrate, build and commission the plant for the operator under a 20-25-year contract of supply
- The manufacturer will charge the power station operator an annual fee for the provision, maintenance and support of the based on a percentage of the fuel and emissions savings, e.g. 10% replacement fuel = 10% CO_2 reduction
- VN-HPG will retain 20% of the annual charge it made to the operator, as a licence fee VN-HPG is targeted on both 'New build' gas turbine plant and retro-fit
- The target for 'New build' plant design is 5 of the 5-7.5MW gas turbines per year, (based on Siemens market share of New Gas Turbine sales)
- The target for 'Existing' plant builds is 35, (based on Siemens market share of existing Gas Turbine plant)
- The manufacturer is targeted to build and commission 35 retrofit plants per year, as part of their Operations & Maintenance schedule for existing plant. See pages 18 to 20 and pages 50 to 53 of the IM for more details.

Can you explain the forecast revenue figures and EBITDA? In particular, where is the OPEX, and how much is it?

The EBITDA figure is a function of the invoiced sales of the company less fixed and variable costs and of the company. In the case of 2020 there is forecast to be an ongoing OPEX of £4.2m and variable cost of £3.2m. This variable cost is due to the use of 3rd party suppliers for the design services. It is intended that the use of these types of supplier will be reduced as the 'predictability' of future design requirements becomes clear, and these services can be brought in-house to reduce cost. There is a full breakdown of the forecast EBITDA on pages 68 & 69 of the IM.

The OPEX is forecast to be as follows:
2020 – £4.2m
2021 – £5.2m
2022 – £6.2m
2023 - £7.2m
2024 - £6m.

The first year of forecast revenue is 2020, in which year the company expects to achieve invoiced sales of £9.2m.

Where is the expense of achieving, and implementing these sales?

See the answer to the above question and Schedule 6 of the IM.

How long is it estimated that this process of negotiating these sales will take?

The process of negotiating contracts of this nature is forecast to take place throughout 2018, with conclusion by 2019. This is based on the management teams experience in negotiating, closing and finalising the legal details on contracts of similar values and complexity.

To what extent have the estimated sales prices, sales volumes and speed of orders been based on research with potential customers?

This contractual framework and commercial mechanism has been discussed in with a number of manufacturers that could be potential customers, and in greater detail with potential end-user/operators of Gas Turbine power generation in Europe.

What are the risks associated with the EIS conditions being broken?

The main risk associated with this is an exit of the company before the 3-year share holding period is over. Though not forecast, and unlikely, this will potentially give rise to a 'claw-back' of investor tax reliefs, and a capital gain issue for investors.

However, the overall effect on Investors would mean a very significant return to investors, even when taking into account the loss of reliefs and resultant CGT, which of course can be potentially mitigated in other HMRC pre-approved SEIS or EIS VN companies.

What patents does the company own?

VN-HPG owns a globally exclusive development licence for use within the Worldwide Natural Gas Power Generation industry, allowing it to utilise existing and future intellectual property and patents to develop and monetise the technology within the aforementioned market. See Schedule 4 of the IM for more details.

Is there a short video that will summarise the opportunity and why it exists?

Yes, please go www.vn-cp.co.uk

What if I have other questions about the opportunity, what should I do?

Either put your questions in an email, or request a call from us in order to have a telephone conference or meet with one of the management

Strictly Confidential

Apeendix (1) VN-HPG IFA Due Diligence Advisory Pack

Report on EHG Tests carried out for

VN-H POWER GENERATION LIMITED
4th Floor 7/10 Chandos Street
Cavendish Square
London
W1G 9DG
United Kingdom.

Author: Professor Keith Scott, Professor of Electrochemical Engineering

School of Chemical Engineering & Advanced Materials

Contents

The report relates to work carried out on the:

EHG Feasibility

The overall objectives for the project are for the theoretical, and subsequent test data supporting theory for the scalability of the EHG technology.

Objective 1— Phase I- Feasibility Study

To carry out a study with the objectives:

To assess the EHG process and the H_2 production units functionality and capability. This will be achieved by inspecting the Intertek Tickford Automotive test facility unit and from discussions of the facility with relevant personnel at Intertek Tickford and from VN-HPG and by assessing relevant documentation.

Summary

This report examines data produced by the EHG test rig located at the Intertek Tickford site. Tests were performed with a KOH based electrolyte and a sulphuric acid electrolyte. In the case of the KOH electrolyte an imposed “electrolysis” current was applied. EHG tests with an alkaline electrolyte gave at best current equivalents of 5 Amps and energy consumptions, which are some ten times greater than that for water electrolysis. With an imposed “ electrolysis” current the best (peak) currents with the imposed currents were around 18.5 Amps, at an imposed current of around 3.5 A. A similar performance was achieved with the alkaline electrolyte with and without an imposed current. The best performance was achieved with the sulphuric acid electrolyte based EHG tests. A peak hydrogen production rate at a equivalent current of 71 Amps and an energy consumption of 36 kWh/kg was obtained. The average energy consumption for the short term tests are comparable with those for standard water electrolysis.

1.0 Introduction

This report examines data produced by the EHG test rig located at the Intertek Tickford site. The test rig is based around the operation of a two electrode cylindical reactor which under rotation produces hydrogen from the decomposition of water. The application of a magnetic field may potentially improve the rate and efficiency of hydrogen generation.

The data was collected during two tests periods in March 2013 and July 2013 (between the period 02/07/2013 to 04/07/2013) using electrolyte solutions of aqueous KOH and H_2SO_4.

The Initial understanding of the EHG cell/reactor concept is that essentially the device relies on electricity generation through rotation in a magnetic field. The electric field produced is then effectively pushed through an electrolyte solution whereby in contact with electrodes, electrode reactions are induced; one of which is notably hydrogen evolution. An additional feature of the device is that the rotational fluid motion augments the electrochemical reactions at either or both electrodes.

2.0 Analysis Methods of Gas Production Rates

The gas output from the hydrogen generation EHG device is measured from a hydrogen analyser as the percentage of gas (%H) in the exhaust stream and the exit flow rate, *v*. The exit flow will consist of a mixture of the inert carrier gas (N_2) and H_2 and O_2 generated, including water vapour (with small amounts of mineral acid or alkali used as electrolyte). This assumes that the EHG cell reactions are merely water decomposition.

The H_2 gas flow is the $F_H = \%H \times v/100$ (1)

The moles of H_2 is determined from the gas law at the temperature (T) and pressure (P) of the exit gas stream:

$n_H = PV/RT$ (2)

the molar flow of hydrogen is thus:

$N_H = P\,F_H/RT$ (3)

To assess the EHG H_2 gas production, a comparison can be made with respect to the performance of an electrolyser. The equivalent current required to produce the gas flow can be determined from Faraday's law of electrolysis. This law, simply presented states that for zF coulombs of charge passed 1 mole of hydrogen is produced. In the case of hydrogen production z = 2.

The charge (Amp seconds) required to produce n_H moles of hydrogen is $= zFn_h$

The current required to produce hydrogen at the rate N_H ,

$I = z\,F\,N_H$ (4)

Combining equs. (1) to (4) gives

$I = z\,F\,(P/RT)\,(\%H\ v/100)$ (5)

The typical gas outlet temperature in the EHG rig is 18.5 ^oC (291.8 ^oK), F = 96485 C/mole, R = 8.314 J $(mole\ K)^{-1}$ = 8.314 10^{-5} m^3 $(mole\ bar\ K)^{-1}$

Therefore $I = 79.54\ 10^5\,(P.\ \%H\ .v/100)$ (6)

Where P is in bar and hydrogen flow is in m^3/s

With the EHG hydrogen flows in units of standard litres per minute (slpm)

$$I = 79.54\ 10^5\ (P.\ \%H\ .\mathit{v/100})\ /[10^3\ .\ 60]$$

$$\mathbf{I\ =1.326\ \ (P.\ \%H\ \mathit{v})\ \ \ (Amps)} \qquad \mathbf{(7)}$$

2.1 Comparison with Electrolysers for Hydrogen Generation

For the production of hydrogen other than from hydrocarbon and oxyhydrocarbon compounds, eg. methane steam reforming, the only commercial technology operated at a significant scale is water electrolysis. Water electrolysis uses direct current electrical energy to form hydrogen and oxygen. Decomposition of water requires a practical minimum of 1.41 volts (the thermoneutral potential) based on thermodyamics. This voltage falls with an increase in temperature. In practical operation, voltages required are higher to overcome electrode polarisation (activation overpotentials) and internal electrolyte resistance. Thus for example practical alkaline electrolysers operate at voltages of the order of 1.8-2.0 V, depending upon electroyser design, operating conditions and materials for electrodes and separators. Thus electrical efficiencies based on the ratio of the thermodynamic minimum and the practical voltages are of the order of 70-78 %. [Note that in some cases the standard water decomposition potential is used, i.e 1.21 V]. The voltage of operation determines the Energy Consumption of the electrolysis.

2.2 Energy Consumption

The energy efficiency of the test rig can also be determined and compared with that achieved by an electrolyser. Based on only the energy input in rotation, as the first approximation ,

i.e rotor power = $V_R\ I_R$

Where V_R and I_R are the rotor voltage and current respectively.

The energy consumption (EC) of the EHG rig is = Power/ N_H (Ws $mole^{-1}$)

For hydrogen; EC = Power/ (2 N_H) (kWs kg^{-1})

= Power/(7200 N_H) (kWh kg^{-1})

From equation (4) N_H = I /(z F)

Hence EC = Power/(7200) (z F /I) = **26.8 Power/I** (8)

[note that a kg hydrogen has approximately the energy equivalence of 1.0 US gal of petrol]

In electrolysis, with a cell voltage E_{cell}

Energy consumption (EC) = z F E_{cell} / (3600 M {CE}) [kWh/kg]
C.E. is the current efficiency as a fraction, which is assumed = 1.0

Typical values fo hydrogen: (molar mass, M = 2, F= 96485 [As/mole], CE = 1.0)

z = 2, E_{cell} = 1.8 to 2.0 V. EC = 2x96485x1.8/(3600x 2) = **48.24 to 53.6 kWh/kg**

2.3 Electrolyser production rate

In electrolysers the rate of hydrogen production is measured in terms of the current density, i.e current per unit cross sectional area of the electrode, as discussed above. Thus it is possible to make a comparison of the EHG test rig with that of an electrolyser based on the equivalent current density, i.e the equivalent current produced per unit cross sectional area of the electrodes, S:

$$j = I/S$$

Note that an alkaline electrolyser operates with a current density of a single cell of between 2000 to 5000 A m^{-2}.

In the present EHG cell the cross sectional area of the rotor is around 100 cm^2. Hence an equivalent current (hydrogen production rate) of 1 Amp represents an equivalent current density of 100 A m^{-2} and an equivalent current of 20 Amps a value of 2000 A m^{-2}. Hence at such hydrogen generation rates the EHG would require a similar electrode area as an electrolyser. This comparison does not consider aspects of cell stacking, where it may be suitable to consider the performance based on volume also.

3.0 Observation from March Test data

The tests with caustic electrolyte were performed initially with the cell not rotating and then followed by applying rotation. The background equivalent current was 3.0 Amps. On rotation, at 2000 rpm, the equivalent current increased to 3.4 Amp.

4.0 Data Analysis of Test Observations

Test data gas output pressures are only a few thousand kPa above atmospheric gauge pressure (1.01 bar) hence we assume that all pressures are atmospheric, which gives generally a slight underestimate of performance of a few percentage. The equivalent current from equ. (7) is thus

$$\mathbf{I} \quad = \quad \mathbf{1.34} \ \ (\mathbf{\%H}\ \boldsymbol{v}) \quad (\mathbf{Amps})$$

In the following, the test observations and data, as presented in the Appendix are analysed. Calculations of equivalent current, I, are included in Table 1, as a spreadsheet.

4.1 KOH Electrolyte EHG Tests

At the test set up of time 9.15, the background equivalent current (referred to current for future reference) was of the order of 0.9 A. This is presumably due to corrosion effects although direct evidence for this is needed. The accumulation of solid deposits and decolourisation was an indicator of this although there was no apparent visual damage to the EHG cell.

At time 12.20 current increased on rotation to a maximum of 1.44 A, i.e an increase above background current of approximately 0.5 Amp. This may have been an outcome of some physical gas release due to rotation or/and due to the centrifugal field effect on the EHG. Increase in temperature to 90^{o}C caused a significant increase in %hydrogen. Currents at the %H measured are some 4 and 3 Amps above background. However the increase in gas output may have been a result of the much reduced gas solubility at 90 ^{o}C. It was observed that the gas production decreased after this; which concurs with the effect of a decrease in solubility of hydrogen as the amount of dissolved hydrogen would decrease with time causing a decrease in hydrogen desorption rate.

An increase in rotation from 2000 to 3000 rpm caused an increase of some 0.5 A compared with an increase of only 0.1 A when the rotation rate was increased from 1000 to 2000 rpm.
Considering briefly the energy consumption (EC) with alkaline electrolyte. Motor currents applied during rotation were of the order of 0.4 Amp. Assuming a 240 V DC supply the motor power used was 96 W. Using equation (8) for energy consumption:

$$EC \quad = \quad \mathbf{26.8\ Power/I}$$

Hence with a current equivalent of 4 Amps, the EC = 643 kWh/kg, which is a factor of 10 greater than water electrolysis.

4.2 EHG with electrolysis mode of operation

With the EHG operated in electrolyser mode, the background current was low at around 0.7 Amp. Introduction of an electrolyser current caused an initial large increase in the current (hydrogen production) of 20 Amp, which fell to 4.5 Amp, although the electrolyser current was recorded at 0.5 A (time 18.17).

There was a considerable variation in hydrogen production with currents varying between 3 to 10 Amp, with the EHG rig under rotation of 2000 to 3000 rpm. The applied electrolyser currents were typically around 2 to 3 A.

The EHG test system during the electrolyser mode tests was exhibiting significant dynamics with current pulsing and cell pressure variation. Such dynamics will affect the hydrogen production dynamics and may explain why the measured hydrogen production currents are often well above the actual electrolyser currents applied to the EHG cell. However it may be that imposing a centrifugal field (in conjunction with a magnetic field) has enhanced the hydrogen production above that predicted from the electrolyser current imposed. One way of checking this would be to integrate (over time) the hydrogen production rate and compare this with the integrated electrolyser current with time, i.e. accumulated charge passed.

The best (peak) currents with the imposed currents were around 18.5 Amps, at an imposed current of around 3.5 A.

Thus an enhancement of some 15 Amp maximum was achieved for the "electrolyser" system. The typical enhancement was of the order of 10 Amp which is roughly in agreement with that achieved without an imposed current. Thus a similar performance was achieved with the alkaline electrolyte.

4.3 EHG Tests with Sulphuric Acid

Tests of the EHG cell with sulphuric acid (30% aqueous solution) were performed after the electrolyser tests but with no imposed current. In addition to production of hydrogen and oxygen from water electrolysis, it is possible that sulphate can be oxidised to persulphate at high sulphate concentrations. This effect may influence performance but is not quantifiable in the present test system, without detailed analysis.
On start up of the EHG cell without rotation, large quantities of hydrogen were produced, with equivalent currents of the order of 17- 43 Amps at temperatures of around 60 ^oC. These are large amounts of background hydrogen which is potentially a result of corrosion. This has subsequently been potentially attributed to corrosion of internal stainless steel springs which can result in hydrogen production through the sacrificial oxidation of the steel.

Rotation of the cell caused a large increase in currents of up to 71 Amp at 2250 rpm. However at this point the cell tests had to be stopped after 5 minutes of operation and thus it is not certain whether the very large increase in hydrogen was due to the EHG cell dynamics. Notably this performance was achieved after the cell exhibited an apparent "exotherm" with the EHG cell electrolyte exit temperature some 2.6 ^oC above the inlet temperature. Such an effect would normally be associated with large Ohmic heating in an "electrolyser" mode, due to high current passing through the cell.

A 71 Amp current value is good when compared with the production capabilities of alkaline electrolysis, i.e. an equivalent current density of some 7000 A m^{-2}, cf. electrolysers at up to 5000 A m^{-2}. The measured values of approximately 40 Amps compares well with current electrolyser technology. However this data does not allow for background currents which is difficult to absolutely quantify.

There is no real quantifiable trends in the effect of rotation on performance. Qualitatively, an increased rotation rate appears to improve hydrogen production rate as does an increase in temperature. At a rotation rate of 1000 rpm the current enhancement above background current was some 8A, compared with an enhancement of some 37 A with a rotation rate increase from 1000 to 2250 rpm. This indicates an exponential type of increase in production rate with increase in rpm, rather than a non-linear increase; although caution is advised in this assessment.

4.4 Efficiencies and other observations from the test data.

The recorded rotor currents in EHG tests without applied electrolysis are of the order of milliAmps and as such suggest hydrogen production is not associated with current flowing in the external circuit between the EHG anode and cathode.

Motor currents applied during rotation are of the order of 0.4 Amp. Assuming a 240 V DC supply the motor power used is 96 W. Using equation (8) for energy consumption

$$EC = \mathbf{26.8\ Power/I}$$

At a current of 71 Amps this gives an EC = 36 kWh/kg and indicates that an energy consumption at least comparable with electrolysis is possible.
Based on the thermoneutral potential of 1.41 V the minimum energy consumption is 37.5 kWh/kg. Thus an efficiency approaching 100% is indicated. This data should be used with caution due to the short term duration of the tests and the inherent assumptions in the calculations. There is clearly a need to perform more detailed tests under stable operating conditions to verify the performance observed so far. The data does not allow for background currents. However taking values of current of 37 Amp (which allows for background current) gives EC =69 kWh/kg and efficiencies (compared to electrolysis) of around 50%; approaching those of electrolysis.

5.0 Conclusions and Recommendations

EHG tests with an alkaline electrolyte gave at best, current equivalents of 5 Amps and energy consumptions, which are some ten times greater than those for water electrolysis.

With an imposed " electrolysis" current the best (peak) currents with the imposed currents were around 18.5 Amps, at an imposed current of around 3.5 A. Thus an enhancement of some 15 Amp maximum was achieved for the "electrolyser" system and a typical enhancement of the order of 10 Amp. A similar performance was achieved with the alkaline electrolyte with and without an imposed current.

The best performance was achieved with the sulphuric acid electrolyte based EHG tests. A peak hydrogen production rate at a equivalent current of 71 Amps and an energy consumption of 36 kWh/kg was obtained, which is superior to that for water electrolysis. The average energy consumption for the short term tests are comparable with those for standard water electrolysis.

5.1 Recommendations

It is recommended that following the re-build of a new EHG test cell and rig that tests with sulphuric acid electrolyte be performed. These tests should be carried out with varied rotation rates up to the maximum possible, e.g. aound 5000 rpm. The tests should be conducted to a point where a reasonable steady state of hydrogen production is achieved, of the order of 1 hour for each condition investigated (temperature and rpm). In addition the accumulated hydrogen production rates should be recorded to enable energy consumption and performance in general to be better assessed over the campaign of the test. This is because of the gas solubilities and electrolyte conductivty and mass transfer of gases will vary with changes in temperature and rotation rate. Measurements of any current flowing between the two EHG electrodes should be made to check for the effects of induced current from the magnetic field. This should be done with an external electrical circuit which has a low resistance. The potential difference between the two electrode terminals should be measured.

In addition to examining the effect of operating variables with sulphuric acid electrolyte, examining the influence of sulphuric acid concentration (10% and 40%) should be considered. An alternative acid to sulphuric acid, which has a larger ion size, e.g. methane sulphonic acid, should be considered.

Such electrolytes have been effectively used in other electrochemical cells to improve electrode catalysis. In addition the larger ionic size of the methane sulphonate should make it more susceptible to a combined rotation and magnetic field; potentialy providing faster ion transport and interfacial electrode charge accumulation. If appropriate, tests which also include the use of an imposed "electrolysis" current should be considered.

The influence of the magnetic field should be examined by dis-engaging the magnets from the EHG cell.

Longer term considerations should be given to investigating the EHG cell design, its scalability and the materials used, for electrodes and any catalysts. Investigation of the gas and liquid flows through the cell should be considered from practical and fundamental aspects.

Notes:

Status Report on Electro Hydrogen Generation (EHG) carried out by VN- H POWER GENERATION LIMITED. 12th January 2017

Summary

This report describes the development work of an electro hydrogen generation (EHG) system for the production of hydrogen from the application of a rotating electrode system within a magnetic field. The system design was based on data generated from the previous development programme using a small scale single cell system. The report gives details of the flow circuit components, the drive train and sealing system for the new EHG cell.

1.Background.

The principle of operation of the EHG is that by rotating electrodes and an associated electrolyte in a magnetic field, at right angles to the direction of rotation, creates an electrical potential difference and thus the ability for current flow (orthogonal to both the magnetic field and direction of rotation) and thus for electrolysis to occur. The electrolysis can typically be the decomposition of water which produces hydrogen gas (and oxygen).

The efficiency of the device is believed to be improved through supply of external waste heat and operation at moderately high temperatures, e.g. ca. 60 °C.

2. Previous Feasibility Tests.

The previous test work on EHG1 has demonstrated the feasibility of using a combination of rotational force with a magnetic field to generate hydrogen from both concentrated aqueous acid and alkaline electrolytes on a small scale. The test rig was based around the operation of a two electrode cylindrical reactor (see Fig 1 schematic), of short length (H = 2cm) which under rotation produced hydrogen from the decomposition of water on the inner surface of the external electrode. However, although electrochemically, high rates of hydrogen were generated, over short time scales, of an order of magnitude similar to more conventional electrolysis using external voltage/current supply, the test data produced was limited due to engineering problems of the rig associated with the rotation mechanical mechanism, seals and materials scaling and corrosion. Ultimately this test system failed mechanically.

3. Phase 2 programme.

One of the limitations of the EHG1 was the electrode area available, in a unit volume of the system, and consequently the rate of hydrogen generated per unit volume (sometimes referred to as the space time yield (STY, kg m^{-3} h^{-1}). To increase the STY essentially requires introducing more electrode area in the available space, which can be achieved by using an array of so-called bipolar electrodes. (noting that increasing the electrode diameter reduces the area per unit volume}. Thus EHG2 was designed on the basis of a stack of relatively large bipolar, rotating, flat disc electrodes, with a central hole for positioning of the EHG rotor and magnets, as shown in Fig. 2. The electrodes in this system rotate in the plane of the discs as opposed to EHG1 in which the electrodes surface was at 90 degrees to the direction of rotation. However in both systems the lines of magnetic field strength, rotational force and any subsequent potential field are all orthogonal; complying thus with theoretical requirements of the EHG operating principle (Fig. 3).

To support the operation of EHG2 required detailed engineering design of rotational components, seals, electrical contacts and electrodes.

3.1 Status of EHG2 test programme.

The work carried out in the test period concentrated on the design and commissioning of the EHG2 and the flow, mechanical and electrical systems.

3.1.1. EHG2 design with a variable number of rotating bipolar disc electrodes.

The device consists of an array of a maximum of 17 rotating electrodes, positioned around a central shaft which has access for fluid flow at the bottom. The electrolyte flow passes into the rotating shaft and flows out between the spaces between each bipolar disc electrode. Permanent magnet rings are positioned (north and south poles facing one another) on the inside and outside of the disc (annular) electrodes. The bipolar disc electrodes function during electrolysis by virtue of an induced potential gradient, normal to the surface, causes one side to act as a cathode (e.g. for hydrogen generation) and the other side to act as a anode. Current flows through the complete stack via stationary electrodes positioned at the top and bottom inner surfaces of the EHG2.

3.1.2 Design specification and manufacture of electrodes.

For water electrolysis it is beneficial to reduce the required voltage for hydrogen and oxygen evolution by using electrocatalysts. Stainless steel is not an ideal material for electrolysis in acid, e.g concentrated sulphuric acid electrolytes as it has no electrocatalytic activity and may potentially corrode. Electrodes for the EHG need to be non-magnetic, have high electrical conduction, to be mechanically strong and be chemically resistant to a range of electrolytes. This EHG2 hydrogen generator is designed to be used with, concentrated sulphuric acid, concentration potassium hydroxide and methane-sulphonic acid and sodium chloride electrolyte. The latter gives the option to produce sodium hypochlorite as an alternative to oxygen, the former being an important disinfectants used in a number of environments for water treatment, for example in power stations. State of the art bipolar disc electrodes were designed based on a chemically stable titanium sheet coated with a thin electrocatalyst cathode layer on one side and a thin electrocatalyst anode layer on layer on the other side.
A stack of stainless steel electrodes has been designed and built for the EHG.

3.1.3 Design of main rotation drive for EHG2 stack testing.

The EHG1 failed mechanically due to the rotor only being fixed in place at the bottom location. EHG2 was designed to be fixed in place at both the top and bottom of the unit. Preliminary tests with an external motor and pulley drive proved to be inefficient, generating large amounts of heat and temperatures and had limited rotation rates. This drive system for the EHG2 rotor was replaced with a direct drive motor fixed to the base of the EHG rotor.
The direct drive resulted in a redesign of the motor-drive configuration to initially prove the concept, and then a subsequent set of design adjustments resulting in a robust, flexible and reliable drive mechanism capable of dealing with the very large torque requirements without failure. Subsequent testing proved the new drive setup, and the impact on the reliability was immediate. The rig was able to reach up to nearly 2300rpm, though this was not a constraint

on the drive mechanism, rather the electric motor power and internal EHG design. The direct drive has been specified to reach speeds of up to 5000 to 6000rpm.

3.1.4. Test rig design

Design of test rig with efficient gas engagement and fluid recirculation and accurate hydrogen and oxygen gas analysis is essential for EHG2 testing. A requirement for EHG2 operation is to avoid a build-up or gas (two phase gas liquid mixture) in the recirculation loop, which requires the introduction of efficient gas liquid separation. A flow circuit with electrolyte heating and temperature control, gas disengagement and on-line hydrogen and oxygen flow and compositions sensors has been designed and commissioned. The gas-liquid separator functioned in an effective manner; separating the gases from the liquid after the EHG2 and thus preventing gas re-entering the flow circuit. Gas analysers have been calibrated and provide high accuracy for both hydrogen and oxygen composition measurement in the generate product gas stream.

3.1.5. Design and specification of robust seals for fluid containment.

Retaining liquid integrity of the EHG2 during operation is critical for long term operation. Preventing electrolyte loss through the point of contact of the rotating central rotor and the EHG2 stationary body requires seals that can tolerate strong acid and alkali at moderate temperatures and the friction produced between the two surfaces. This required evaluation (both mechanically and chemically) of a number of sealing options.

The first set of seals designed and fabricated by Fluorocarbon Company Ltd. of Hertford, (see attached schematic –Figure 4) was a lipped seal made from a mixture of PTFE and a polyamide filler to reduce the heat effect on the PTFE. Some heat-effect testing was performed by Fluorocarbon, though it was limited and was only done in air, not with electrolyte, up to 60C. This version failed soon after filling the EHG with water and rotating the shaft at relatively low speeds. The following version included an energised spring design, incorporated into the original design, made from Hastelloy, but again this failed after the introduction of electrolyte to the EHG and on commencement of rotation. The final version was a PTFE graphite mix. Various degrees of longevity of the seals resulted, but none were successful in completely sealing the bottom of the EHG shaft. It also became clear that any filler that was too abrasive would start to wear the seal journal, and so after more investigation into potential alternative suppliers. Erks Seals were tried with an off-the-shelf solution, but this also failed. AllSeals Inc of California designed a simpler more robust solution, (see schematic of seal 2; Figure 5) which consisted of a PTFE and Ekanol, with a light loaded canted coil spring seal with a hastelloy spring. AllSeals also suggested a hardness and surface finish for the seal journal to ensure electrolyte-tight integrity. As a result of this recommendation a supplier was found that could deposit a ceramic coating to the surface and hardness requirements onto the Ti shaft without altering the overall dimensions, to ensure that the EHG could be rebuilt without any 'Fitting' issues or leaks. This seal and surface treatment on the TI was tested at various temperatures with water prior to full testing with electrolyte and was watertight. Subsequently, with both acid and alkali at temperatures up to 45C the seals also proved to be electrolyte-tight.

3.1. Conclusions

Design, commissioning and initial testing of EHG2 has been carried out and has resulted in the following achievements:

EHG2 bipolar stack tests showed electrical integrity during using both an array of stainless steel (non-magnetic) electrodes and coated titanium electrodes.

Electrode materials research identified a suitable Ti metal substrate that could be coated with electrocatalyst for hydrogen and oxygen evolution (and chloride electrolysis) by thermal decomposition, that was compatible with acidic, alkaline and chloride electrolytes. Disc electrodes were manufactured with mechanical tolerance, after thermal treatment, suitable for use. The EHG2 was successfully mechanically tested with the array of bipolar, coated Ti electrodes.

A direct drive system has been specified and successfully mechanically tested for operation and rotation of the EHG2 at rates of 2300 rpm with a design capability of 5000-6000 rpm.

A flow circuit with electrolyte heating and temperature control, gas disengagement and on-line hydrogen and oxygen flow and compositions sensors has been designed and commissioned.

A seal system based on has been identified and evaluated under the relatively short term tests carried out so far.

Figures.

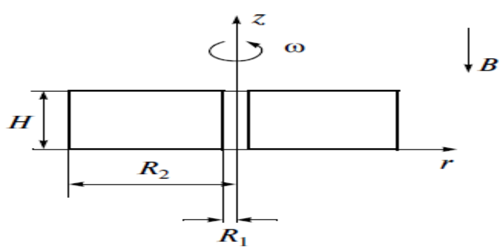
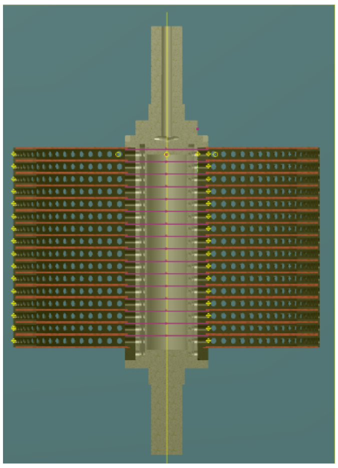


Figure 1. Schematic of EHG1. Electrodes of length H= positioned at radial positions R_1 (3 cm)and R_2.(15 cm). Magnetic field in direction B. Rotation around coordinate z.



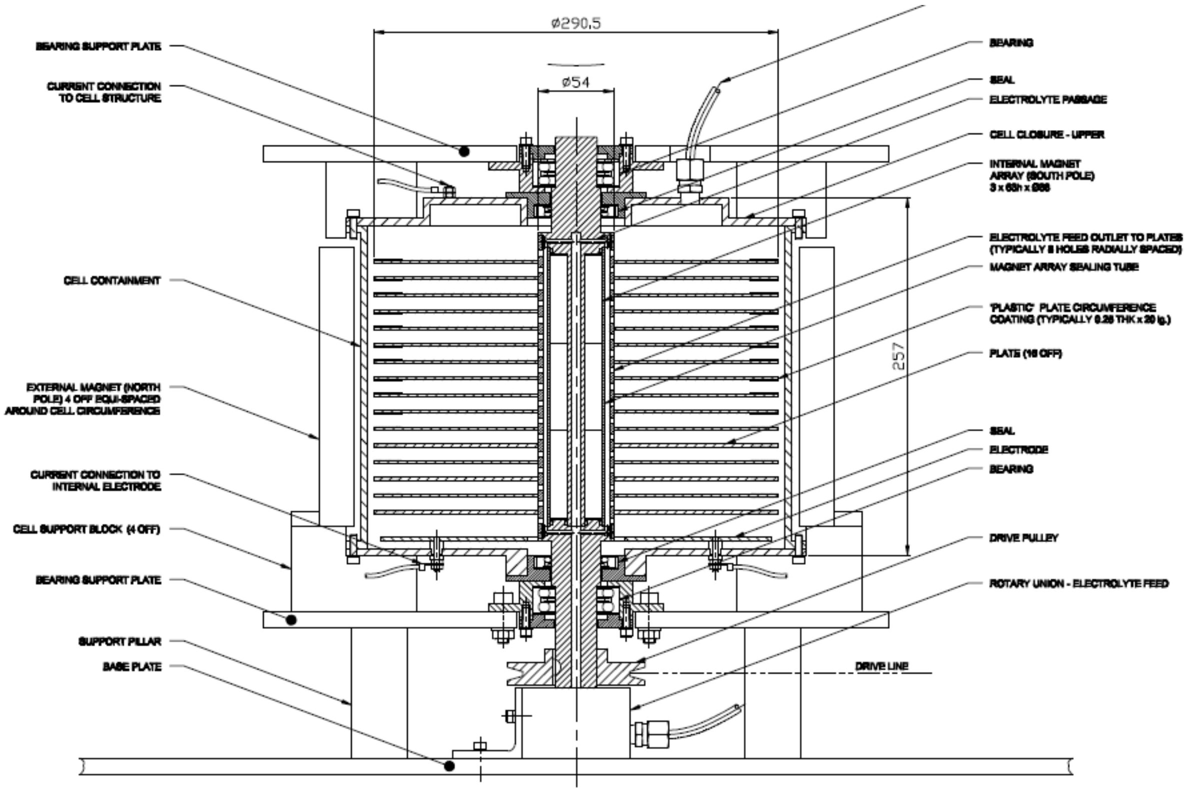


Figure 2. Schematic of electrode disc stack around central rotor. Scale diagram of EHG 2

Disc inner diameter = 5.4 cm; outer diameter =29 cm.

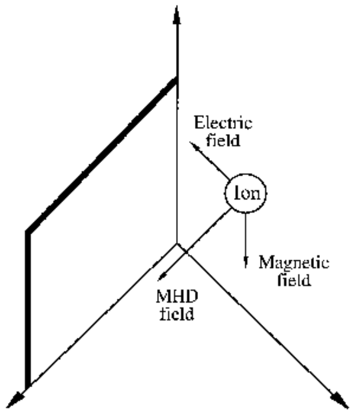


Fig 3. Schematic of lines of force fields for EHG operation. Ionic movement is generated in a medium by the coupling of an electric and a magnetic field. The direction of movement is perpendicular to the fields. The resulting force action along the solid surface generates flow at the interface

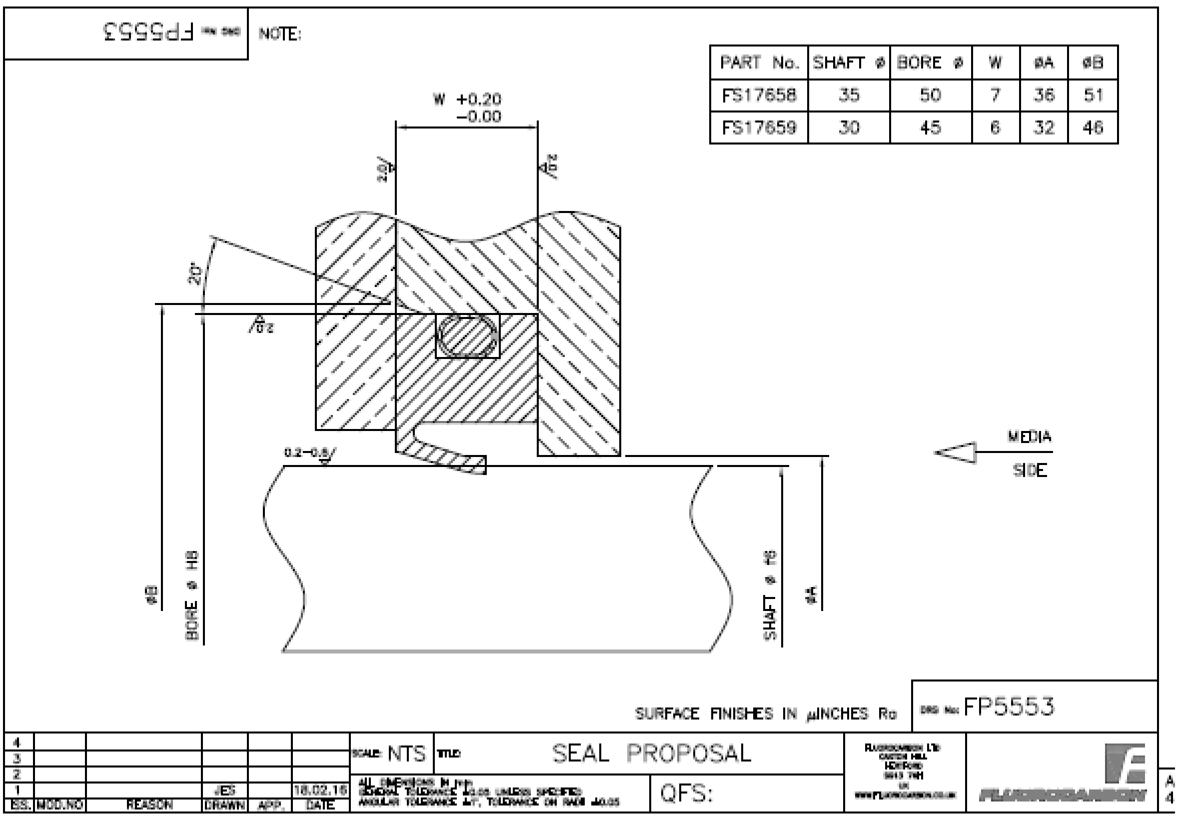


Figure 4. Schematic of Seal 1.

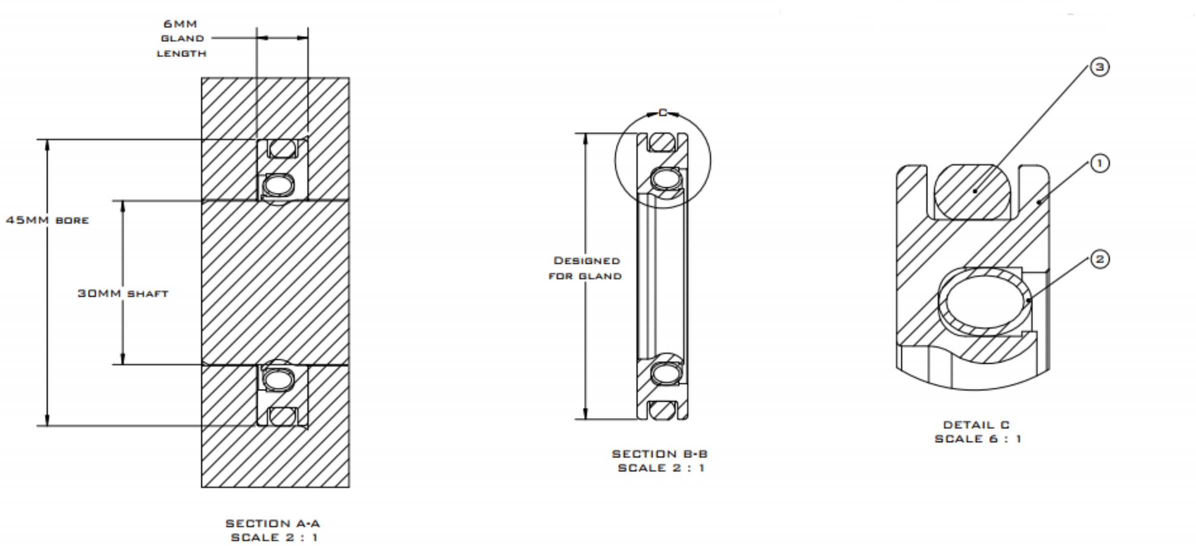


Figure 5. Schematic diagram of seal 2.

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