C.En
Stand For Clean Energy

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15th May 2009

Academician Prof. E.P. Velikhov
President
RRC Kurchatov Institute
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RUSSIAN FEDERATION

Dear Sir,

Re: C.En Technology and Development

It was my great pleasure meeting with you at your home some two years ago. I recall my great impression of the talks and lectures given that day. Moreover, I recall your encouragement of both Moshe and I to extensively pursue this very unique project, a project which we have been developing 'till this day, and which today more than ever shows increasing promise.

Over these few years the Scientists from both Moscow State University (MSU) and the RRC Kurchatov Institute have proven their marked ability. The theory behind this project, which forms the very basis of our project, was elaborately written up by members of the Kurchatov Institute. In addition experiments were conducted at MSU. Unfortunately, due to the lack of advanced facilities development of the technology began to stall after some time. Following suggestions by members of both the MSU and Kurchatov Institute we had decided to try and find advanced facilities more suitable to our specific experimentation.

Some time before I had started working with C.En, I was fortunate enough to receive a mercator professorship from the DFG of Germany. During this time I had developed close relations with some of the top scientists and management of the BAM Federal Institute for Materials Research and Testing (http://www.bam.de/index_en.htm). After the demonstration of our preliminary results, as well as after lengthily negotiation, we were able to secure further experimentation and development of C.En Technology at the well equipped, world leading BAM facilities.

Following the original ideas you had presented to Moshe some years ago (and later to Moshe and I at your home two years ago) and working together with a team of highly skilled scientists at BAM, C.En is able to develop the ground-breaking theories developed at the Kurchatov Institute into an advanced and ground-breaking technology.

The various achievements that C.En has made at BAM thus far are outlined in the below essay -"Summary of C.En's Main Developments and Achievements" (achievements are further detailed in appendixes 1, 5 and 6).

In addition, I had recently spoken with both the Vice-President (Prof. Dr.-Ing. Thomas Böllinghaus) and President (Prof. Dr. rer. nat. Manfred Hennecke) of BAM and they informed me that they would be honored if you could visit The BAM Federal Institute, in Berlin, Germany. If this is possible BAM will issue you an official Federal invitation.

Again I would like to thank you greatly for your foresight and initiative, as well as your continuing support of this project.

Yours Sincerely,

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Summary of C.En's Main Developments and Achievements

The central ideas and theory behind C.En's technology were developed by members of the Kurchatov Institute. These have been outlined by Prof. N.K. Zhevago and Prof. V.I. Glebov in their article "Hydrogen Storage in Capillary Arrays" published in the *Journal of Energy Conversion and Management* in 2007 (please see Appendix 3). Initial experimentation and development of the technology took place at Moscow State University (MSU). An official MSU Report, issued in August 2008, outlines the various achievements made (please see Appendix 4).

In February 2008 the German Federal Institute for Materials Research and Testing (BAM) began its "Storage of Hydrogen in Capillary Arrays" project. A number of official BAM Progress Reports have documented the continual development of C.En's technology thus far. A summary of these progress reports is presented below (Appendix 5 provides the December 2008 and March 2009 Official BAM Federal Institute Progress Reports)

Facilities and Experimentation at the BAM Federal Institute

Beginning in February 2008 a new test set-up was built and further modified in order to enable kick-off experiments of hydrogen filling and releases. A fixed "Standard Operating Procedure" (SOP) was further developed. Basic steps of this procedure included: the preparation of test tubes with alloy and glass capillaries; the development of a filling process with fixed rates; the closing procedure of the capillaries; the pressure release process with fixed rates and the determination of hydrogen storage amounts in experiments.

During this initial period the analysis of experiments was further standardized so that the volume of hydrogen stored in capillaries is now determined by its release into a vacuum. Within this, the solubility of hydrogen into different materials was considered.

Furthermore, it is important to note that during this period first acquisitions were completed for new valves pressure resistant up to 3000 atm at room temperature.

Over time and in accordance with the SOP a new system was developed which enabled experimenters to place hydrogen in a storage vessel at certain pressures and then to close the capillaries with a special alloy. First tests were not very successful as it was found that single arrays of glass capillaries were very sensitive to shocks, vibrations and stresses caused by the filling and release procedure. However, with the implementation of the newly established SOP and the completion of a new test-stand no further arrays were damaged during testing.

The new set-up was assembled in a special safety room especially built to test the pressure resistance of single capillaries in relation to their wall thickness and diameters. As the original capillaries were not able to withstand high pressures and to fulfill the targets of the projects, two German companies were found which delivered capillaries of high quality and high pressure resistance. Those capillaries didn't break at pressures up to 500atm.

Current Results

With the completion of a specially built state of the art laboratory the C.En developed system ensures the safe infusion, storage, and controlled release of hydrogen gas, under storage pressures of up to 1200 bar.

Storage tests conducted demonstrate a gravimetric storage capacity of about **33 wt%** and a volumetric capacity of **28 g/L**. This was determined at a comparative low pressure of *only* 400 bar. These results are significantly higher than the actual published storage capacities for other storage systems. Results have already surpassed the US Department of Energy's 2010 gravimetric target, and are expected to meet all of the DOE's 2015 target in the near future.

A first prototype was prepared by filling one single capillary with 200 atm hydrogen, this was enough to run a small model car with a fuel cell for approximately 90 seconds. This prototype shows that the concept of hydrogen storage in capillary arrays is of a trendsetting nature which will be very useful in broad fields of energy related applications.

Focus of Development

On the basis of these results current focus lies on the increasing of hydrogen storage pressure while decreasing the thickness of the capillary walls leading to a loss of weight and to higher gravimetric storage capacities. This will be of great interest to all prospective applications.

BAM is currently in the process of creating a further two prototypes in order to demonstrate the function of the hydrogen storage system for multiple applications. The second prototype will be of a small capillary array existing of about 20 to 50 single glass capillaries. This small bundle will be connected to a fuel cell and will deliver sufficient energy to any electronic device. The third prototype will consist of a storage container with multiple capillary arrays and therefore thousands of single capillaries. The various uses of this storage system are only limited by the form in which it is provided to the end-user.

The principles of hydrogen storage in capillary arrays have been firmly established. The development of a final storage system is only a question of engineering. The system can be optimized in many ways to achieve the most economical system for a variety of applications.