



Research Article

# A Technique for Making Nuclear Fusion in Solids

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## Abstract

A technique is described for making nuclear fusion at room temperature by compressing a powder mixture comprising a deuteride and catalytic material. The result is explosive beyond known chemical reaction for the materials..

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*Keywords:* Nuclear fusion, Solid state

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## 1. Introduction

It is understood worldwide that efforts must continue to develop nuclear fusion as an energy source. One process involves inertial confinement fusion wherein a pellet of deuterium and tritium fuel is compressed strongly by lasers, see <https://lasers.llnl.gov/science/icf>, <http://www-lmj.cea.fr/en/experimental/index.htm>. This and other techniques are being pursued in order to prevent a global warming catastrophe and the riotous consumption of the remaining oil.

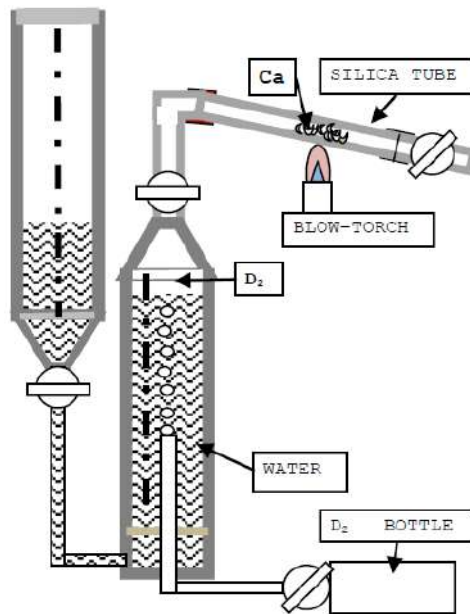
A significant number of established trustworthy scientists have pursued cold fusion [1], and published papers in the proceedings of 18 International Conferences on Condensed Matter Nuclear Science and elsewhere [2–4]. However, a problem of reproducibility remains, and the absence of expected fusion products like neutrons and  $\gamma$ -rays is puzzling. Experiments point to some obscure new phenomenon involving serendipitous trace catalysts.

In this paper it will be claimed that by strongly compressing a deuteride and catalyst mixture, one type of nuclear fusion has been induced (E.B., private communication). Repeatability is no longer a problem, and there should be a way of making this process commercially viable using inertial confinement in particular.

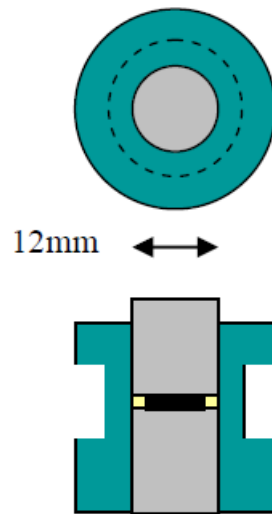
Section 2 describes current experimental techniques to produce nuclear reactions. Section 3 covers experiments with hydride in place of deuteride. Section 4 describes different mechanical designs. Section 5 offers explanations for the chemical processes involved. Section 6 proposes ways to develop a commercial energy generator. Section 7 summarises the work, and ends with a note of caution.

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**Figure 1.** Apparatus for preparation of calcium deuteride from calcium turnings and deuterium gas.



**Figure 2.** Original compression cell design consisting of two chrome steel roller bearings in a steel sleeve with solder seal to contain the fuel powder and gases.

## 2. Experimental Methods

The techniques developed for demonstrating the claimed nuclear fusion are on a small scale, but generate strong explosions. Many varied experiments have been performed in order to understand the effect and gain reproducibility.

### 2.1. Fuel preparation

First of all, a quantity of calcium deuteride was produced by heating calcium turnings in a flushed-out closed silica tube containing deuterium gas supplied by a manometer assembly, see Fig. 1. The used volume of deuterium was measured in order to estimate the final purity of the calcium deuteride at around  $\text{CaD}_{1.75}$  as if some CaD was also produced. The lumps of  $\text{CaD}_{1.75}$  were then ground to a fine powder with mortar and pestle, and thoroughly mixed with similar weights of red phosphorus and manganese powders, to yield the “primary fusion fuel”. Typical particle sizes of the powders have been in the range 20–75  $\mu\text{m}$ , while the weight proportions of the ingredients have been varied around 1:1:1.

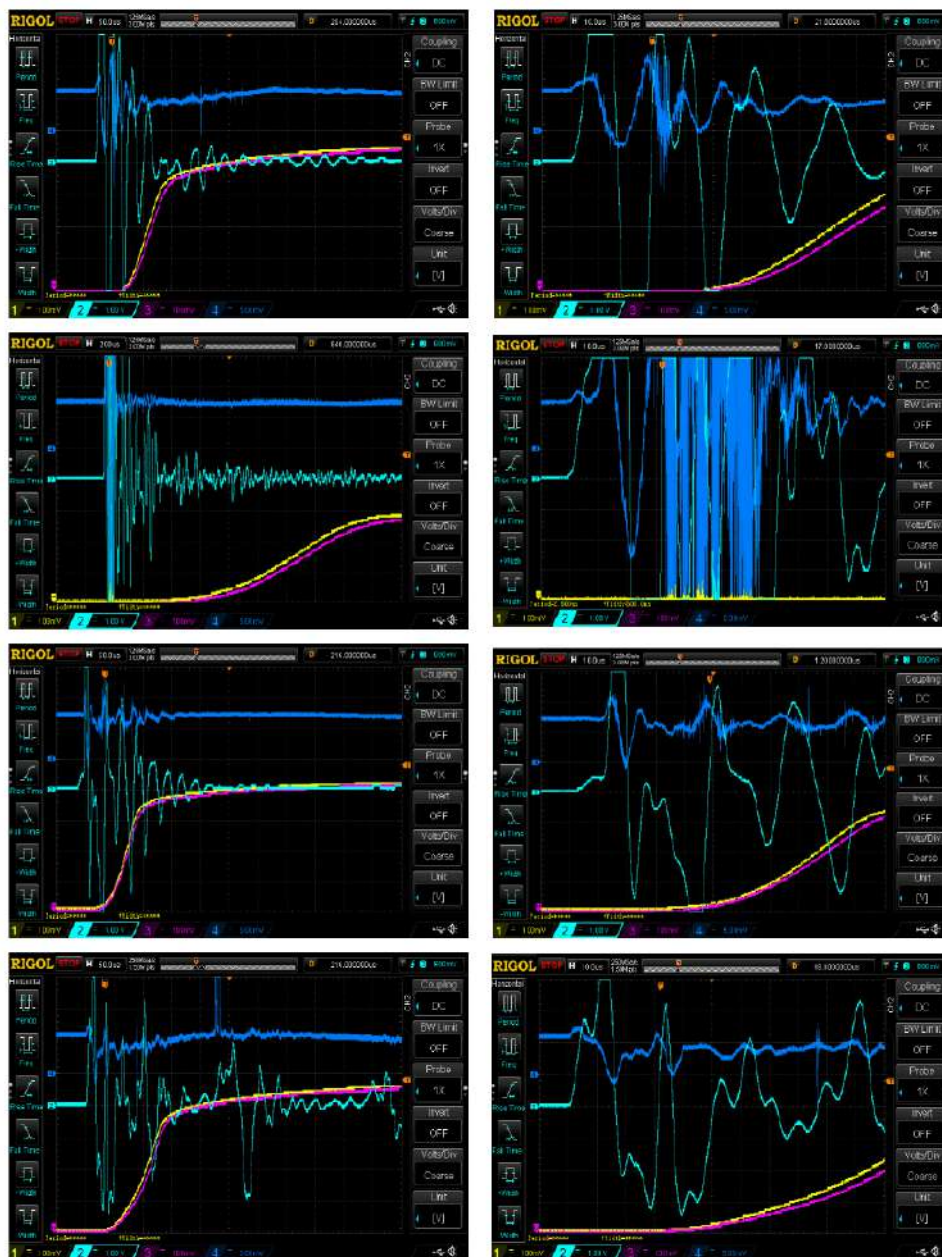
Subsequent experiments using the deuteride of magnesium, strontium, barium, lithium and sodium in place of calcium deuteride have also provided results, suggesting that efficient deuterium fixation is the key necessity. Likewise, other transition metals have been found to work in place of manganese to some degree; as was confirmed by mixing the calcium deuteride and red phosphorus with each one of the following powders: scandium, titanium, vanadium, chromium, iron, cobalt, nickel, copper, zinc, yttrium, zirconium, niobium, molybdenum and cadmium. By inference, a metallic particle surface is required, with its high electron density and ionic lattice.



**Figure 3.** Two typical results of fusion ignition, wherein the local gas pressure has forced a wedge of steel downwards through the lower bearing, splitting it apart. One of the wedges is shown at top left, and sitting on the appropriate bearing in the lower views. It is triangular in cross-section, roughly 4 mm  $\times$  1 mm  $\times$  2 mm deep.



**Figure 4.** Oscilloscope traces for one very strong explosion, shown at 50 and 5  $\mu$ s/division temporal resolution (use zoom 200% to view details). Blue trace is the load-cell output showing how the press applied load at 20 tons is increased above 40 tons by the explosion lasting only for 8  $\mu$ s, followed by total fall-off and strong mechanical ringing. Turquoise trace is the output from the piezo-accelerometer, which was attached to the side of the cell until it burst. Yellow trace illustrates the response of the direct view photodiode to the debris ignition, and red trace the output from the photodiodes with UV scintillators. There is some cross-talk between the four channels because of amplifier overload. The over-exposed video camera recording of the bright explosion flash was viewed through a 12 mm thick shatterproof polycarbonate window; see Fig. 9 for mechanical layout details. The photodiodes, shown with wires attached mounted in the centre of the polycarbonate window, view through a hole but are protected from flying debris by a stainless steel mesh. Picture width corresponds to 200 mm  $\times$  120 mm high.



**Figure 5.** Four examples of explosions at medium (*left*) and high (*right*, 10  $\mu$ s/division) resolution showing random variability in their characteristics. Experiments Nos. 244, 246, 248 and 273.



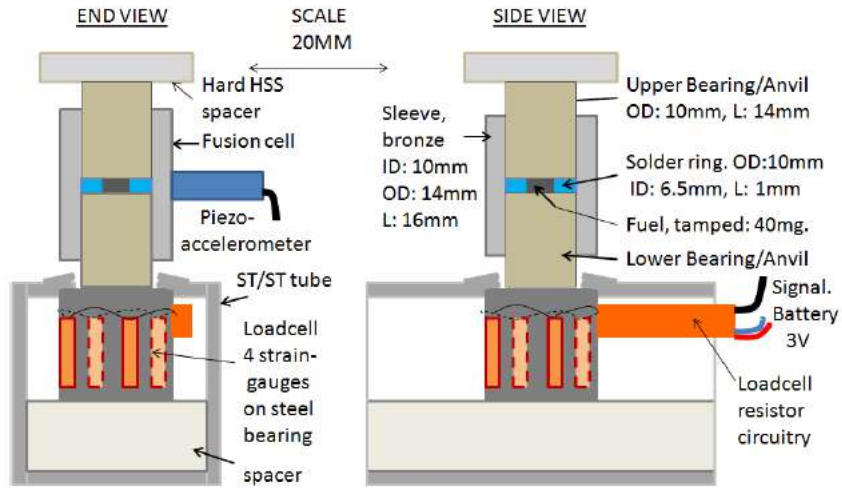


Figure 6. Fusion cell on canister load-cell assembly

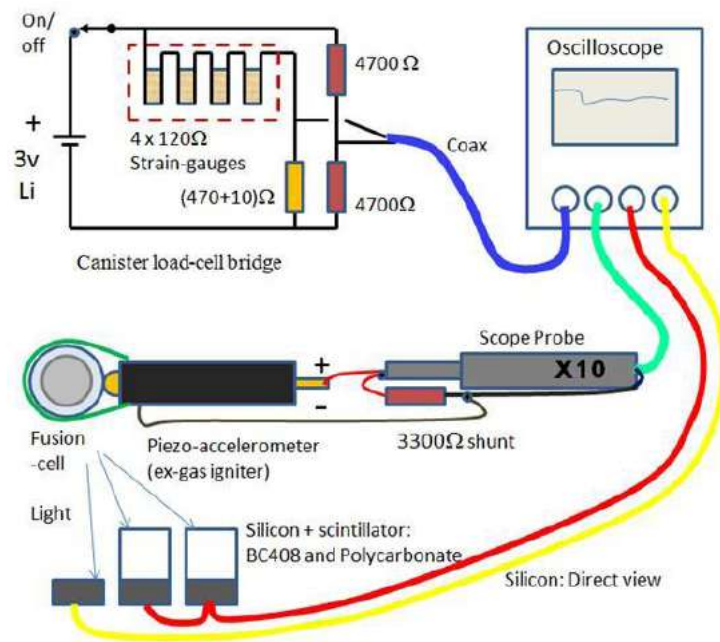


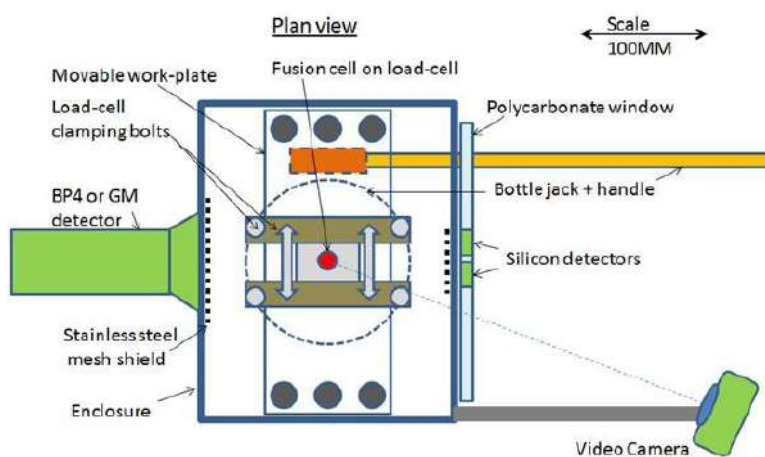
Figure 7. Circuit diagram for Canister load-cell bridge, Piezo-accelerometer (ex-gas igniter), and Silicon detectors (one direct view, two with scintillators).



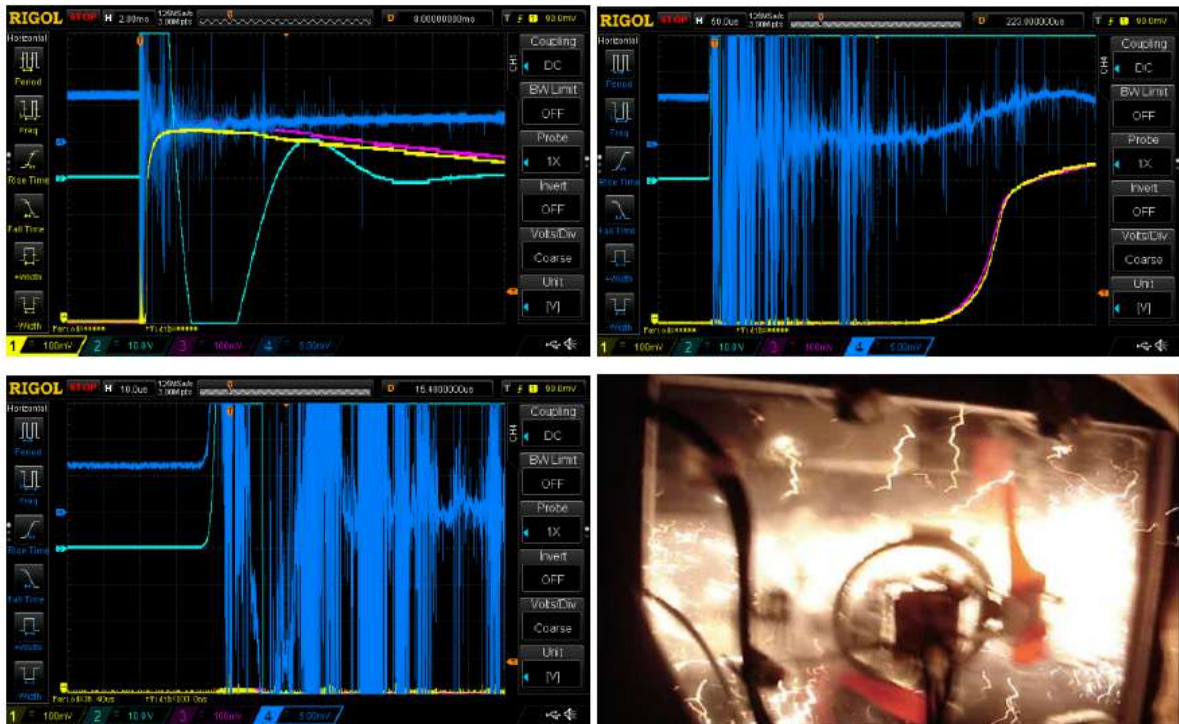
**Figure 8.** *Left:* photograph of bottle-jack press assembly. *Right:* close-up view of fusion cell standing on load-cell assembly (Fig. 6), which is securely clamped to the movable work plate (Fig. 9).

## 2.2. Early experiments

In the first experiments, about 200 mg of the primary fuel powder was put in a compression cell which consisted of two EN31 chrome steel roller bearings (12 mm × 12 mm) as anvils in a mild steel sleeve, sealed with a lead/tin solder



**Figure 9.** General assembly.

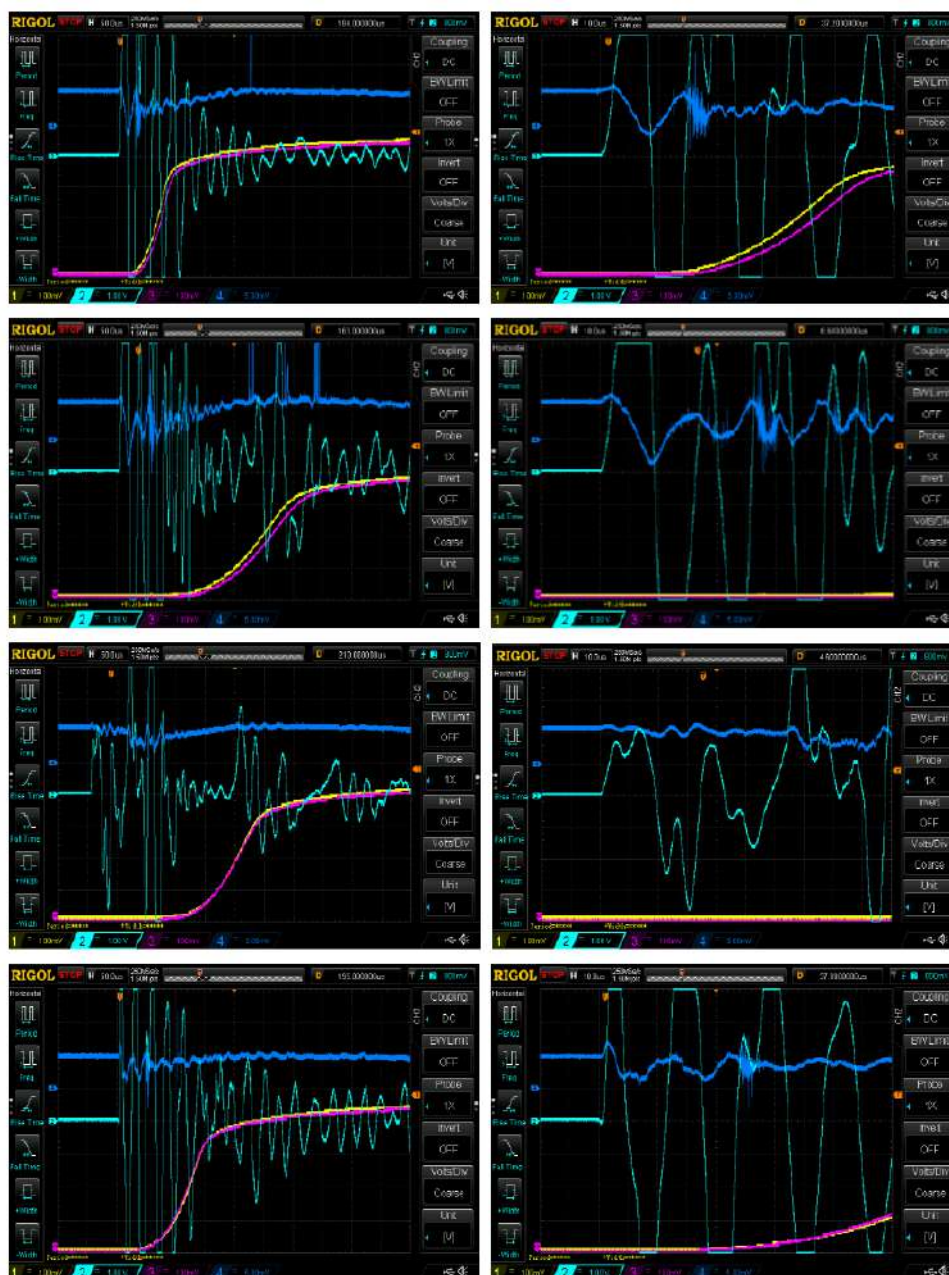


**Figure 10.** Calcium hydride in place of calcium deuteride: Oscilloscope traces for one strong explosion at low (2 ms/division), medium (50  $\mu$ s/division), and high (10  $\mu$ s/division) temporal resolution. Blue trace is the load-cell output showing how the applied load at 20 tons increases rapidly to more than 40 tons during the explosion, which lasts only for 10  $\mu$ s, followed by load fall-off and mechanical ringing as the cell disintegrates. Turquoise is the output from the piezo-accelerometer attached to the side of the cell until it bursts. The blast propagates for 200  $\mu$ s before the hot ejected debris can ignite in the air, as detected by the photodiodes: yellow trace illustrates the direct view photodiode output, and red the photodiodes with UV scintillators. The video snapshot includes burning tracers which reveal shaking of the assembly. The photodiode detector assembly with wires attached is mounted in the centre of the polycarbonate window as usual, see Fig. 9. Experiment No.196.

ring to contain generated gases, see Fig. 2. When this cell was subjected to a vertical force of 30 tons in a press, the powder was formed into a hard solid disc, but no ignition occurred. The force was then removed so that a thin steel wedge could be placed underneath, before re-applying the force gradually. As a high force level was approached this time, it appeared that some shear occurred within the fuel pellet such that localised hot-spots [5–7] in the shear-plane ignited a chemical exothermic reaction which enabled the fusion process within the enclosed pressurised environment, causing an explosion in the cell.

Figure 3 illustrates two examples wherein the generated gas pressure (ionised deuterium and phosphorus) was great enough over a 1 mm  $\times$  4 mm surface area to create a cutting wedge of steel which immediately cleaved the roller bearing anvil into pieces. As soon as the bearings were cracked enough within the cell, the process ceased because the gases were able to escape through the cracks. This means that the process is not susceptible to run-away in this configuration.





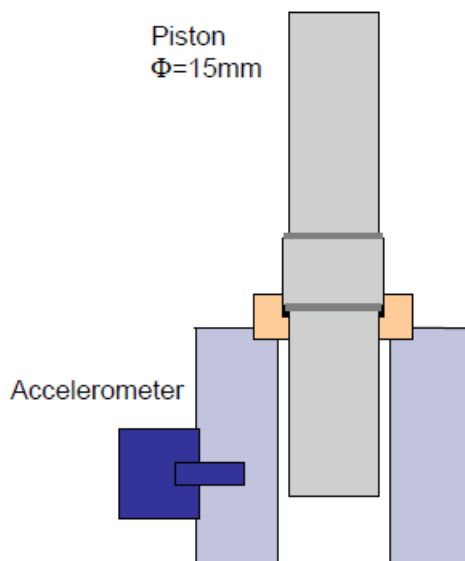
**Figure 11.** Four more experiments with weaker explosions, using calcium hydride in place of calcium deuteride. Oscilloscope traces shown on the left at  $50 \mu\text{s}/\text{division}$  and on the right at  $10 \mu\text{s}/\text{division}$  temporal resolution. Experiments Nos.282, 284, 285 and 288.



**Figure 12.** Debris from four strong explosions using calcium deuteride and calcium hydride, which shattered the anvil bearings in three cases and the upper HSS spacer in two cases.

### 2.3. Current experiments

The latest experiments have employed smaller roller bearings as anvils within a bronze sleeve such that near axial compression is adequate without the tilting wedge, see Section 2.5 and Fig. 6. Typically, 40 mg of fuel is now used per cell. The compression and explosion reaction force have also been monitored by means of a canister load-cell placed beneath the fusion cell and a piezo-accelerometer clipped to the side. When the reaction is great enough, the local pressure may dent and fracture or cleave the bearing surface. Sometimes the bearings are noisily shattered by the shock-wave. Extracted bearings show blast marks radiating from the hot-spot position. One good example given in Fig. 4 shows these forces and also the explosion flash monitored by UV-enhanced silicon photodiodes (Centronic OSD35-7XCQ). The actual fusion may only last for  $8 \mu\text{s}$  before it breaks the anvils or cell wall enough for gases to escape. The relatively long interval of  $400 \mu\text{s}$  before the flash begins indicates that the flash is due to combustion of hot expelled fuel debris (phosphorus, deuterium) in atmospheric oxygen, after the blast wave has subsided. That is, the fuel debris does not by itself burn exothermically. This delay interval is found to be shorter when the cell sleeve and corresponding blast are less strong. Thus the actual ignition of fusion, lasting only  $8 \mu\text{s}$ , is not detected by the



**Figure 13.** Long shear cell consisting of a case-hardened steel piston with shoulder in a shaped steel sleeve to contain the fuel powder.

photodiodes. An over-exposed video camera snapshot of the very bright flash is shown. When a sleeve is able to resist bursting, there may be no flash at all because the expelled debris is cooled by the inner surface of the sleeve as it squeezes past.

Four more experimental results are presented in Fig. 5 showing that the strength of explosion is variable, although it tends to increase with applied force. In each case, the explosions occur at pressures greater than 15 tons/cm<sup>2</sup> but unpredictably as the pressure is further increased towards 30 tons/cm<sup>2</sup>. The hotspot parameters must govern this process. Sometimes there is no immediate explosion, and then the applied force is held at 30 tons for 2 min before releasing and re-applying.



**Figure 14.** Enlarged view of two typical results of fusion ignition wherein the explosion gas pressure has broken pieces off the piston shoulders, in order to escape upwards.

#### 2.4. Search for nuclear debris

An extensive effort has been put into the search for any nuclear particles emitted by the explosion, but none has been found for sure. Detectors with stainless steel mesh screening were located at 10 cm from the fusion cell and repeatedly subjected to the blast which ultimately ruined a BP4 beta-probe, a ZP1401 GM tube and a ZP1610 proportional counter. In addition, neutron activation was sought many times using indium, lithium, copper, niobium, titanium, aluminium, and vanadium. These materials were placed inside the cell with the fuel then collected with the debris and tested for radioactivity, but none was detected.

#### 2.5. Detailed design features

For other investigators to confirm this work, some detailed practical design information is included in Figs. 6–9. Many configurations have been tried but currently the fusion-cell shown in Fig. 6 is good for ignition under near axial compression up to 30 tons force. The cell consists of two hardened (60–67 Rockwell Scale) chromium AISI 52100 steel roller bearing anvils inside a sintered bronze sleeve. The bearing ends are pre-roughened with coarse sandpaper in order to grip the fuel powder to cause shear within the bulk fuel. It is understood that during initial compression, the malleable solder ring (pre-formed from 1.6 mm diameter solder wire) is squeezed inwards so as to compress the fuel powder. Then as the compression force is increased, the sleeve bulges due to outward pressure from the solder, while the fuel is crushed generating internal shear friction hot-spots wherein the fusion occurs. The cell lower anvil sits upon a canister load-cell (a 16 mm × 16 mm steel roller bearing with 4 strain-gauges wired in series) to measure the applied axial compression and explosion reaction force. This load-cell is held in place by the pre-formed square stainless steel tube housing. Figure 7 shows circuitry for the strain-gauges, the piezo-accelerometer, and silicon diodes, coupled directly to the oscilloscope. A general side view photograph of the press with its bottle-jack and strong location clamps for the fusion-cell assembly is shown in Figs. 8(a,b). The corresponding plan view schematic, with overall safety enclosure and detectors is shown in Fig. 9.

### 3. Experiments with Calcium Hydride

Experiments have also been done using calcium hydride in place of calcium deuteride, and unexpectedly found to produce good explosions, see Figs. 10 and 11. Can it be possible that the Coulomb force between the freed hydrogen protons is screened within the hot-spots, leading to deuterium production and energy release?

For both hydride and deuteride, many experiments have emitted weak ignition reports as the applied load is increased above 15 tons, but the strong explosions occur over 25 tons such that the anvil bearings are dented, cracked or well shattered. Sometimes a small wedge is found in the debris, which was the root cause of an anvil splitting in half directly under the source of ignition. Figure 12 illustrates four extreme cases of explosion debris in which the anvil bearings and/or HSS spacer happened to shatter. On average, a 32 ton bottle-jack only survives for 15 experiments because the fast explosion shock-wave damages its input valve before the internal overload valve can operate.

### 4. Other Cell Designs

Another type of cell design which easily produced the required shearing action is shown in Fig. 13. The fuel powder was put around a case-hardened steel piston rod with a shoulder that compressed the powder as it was pushed through a shaped mild steel sleeve. Upon applying several tons of force, shear in the powder produced hot-spots wherein ignition of fusion broke many pieces off the rod shoulder, see Fig. 14. This allowed the local gas pressure to subside and prevented the fusion from progressing. Clearly, extreme pressure pulses must have been generated to do this amount of damage on hardened steel. Inspection of the steel sleeve adjacent to the hot-spots revealed a melted appearance.

Other methods of inducing fusion with this fuel have been tried, and need further experimentation. For example, externally heating the pressurised cell sleeve caused it to split open and show the burnt interior as a sign of fusion. Therefore, heating the fuel in a container pressurised with deuterium may be one way of producing controlled fusion for energy generation.

## 5. Proposed Chemical Processes

First of all, phosphorus, calcium and manganese compounds have catalytic properties [8–10]. For example, some primary fusion fuel ( $\text{CaD}_{1.75} + \text{P} + \text{Mn}$ ) was heated in a test tube and found to decompose readily yielding deuterium gas.

It is hypothesized that chemical and nuclear processes occur within the compressed fuel shear-plane hot-spots [5–7], which are high pressure plasma regions up to 1000 K. Here, ionised manganese and phosphorus may combine exothermically, yielding 104 kJ/mol of MnP [11]. Nearby calcium deuteride, bound by 180 kJ/mol during its production [12], may now be dissociated by energetic phosphorus ions. Deuterium is thereby freed and calcium phosphide formed exothermically at 543 kJ/mol [12], adding further energy to the hot pressurised plasma. Under pressure, freed deuterium atoms will occupy interstitial positions between surface atoms of manganese grains [13] where they are dynamically constrained while being bombarded by energetic deuterons in the plasma. At the same time, bombardment by energetic free electrons adds to the environment of manganese conduction/valence electrons and results in enough screening of the Coulomb force to enable fusion of the free and constrained deuterons.

To support this theory, the transition metal powders listed earlier in Section 2.1 were found to behave like manganese in producing explosions; and deuterides other than calcium were also successful. However, no activity could be induced when pre-formed manganese phosphide was substituted for the elemental manganese and red phosphorus powders. As might be expected, there was no activity in control experiments employing a (Ca + P + Mn) mixture, or dry  $\text{Ca}(\text{OH})_2$  powder.

This has proved to be a self-restricting technique and there is a residue of unconsumed fuel around the cell after the explosion because the fuel confined alone does not burn easily. A sharp smell of impure phosphine is always apparent.

## 6. Further Developments

The experiments described above are clearly limited to fusion demonstration only, to prove it is possible in the solid state. For commercial energy generation we need a continuous high energy process, as already tried by various groups [14]. A pellet of fusion fuel would be compressed and heated by powerful laser beams, or heavy-ion beams, or electron beams, or a Z-pinch cell. An alternative process for continuous energy generation may be to heat the source compound in a controlled manner.

When trying these different techniques, the fuel compound could be varied by substituting other chemical elements in part, to get a controllable reaction. For example, calcium hydride has already been substituted for the deuteride and produced explosions.

## 7. Conclusion

A large number of experiments have been conducted with powdered material comprising a deuteride and catalyst. The technique is understood in terms of pressurised shearing hot-spots within which exothermic chemical reactions facilitate enough Coulombic screening for nuclear fusion of deuterons. Even a mixture of hydride and catalyst produces explosions, so this is a noteworthy phenomenon. In a separate paper, theoretical models will propose how soft X-rays are generated and convert to heat in the material. From an engineering point of view, this discovery may be developed immediately using inertial confinement or other techniques [15].



Safety shielding has been necessary in all experiments with pressurised solid state compounds. The manual compression technique used here is slow enough to allow time for the fusion gases to escape. Impact techniques might strongly confine the gases, resulting in a dangerous fusion avalanche [5].

### Acknowledgements

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