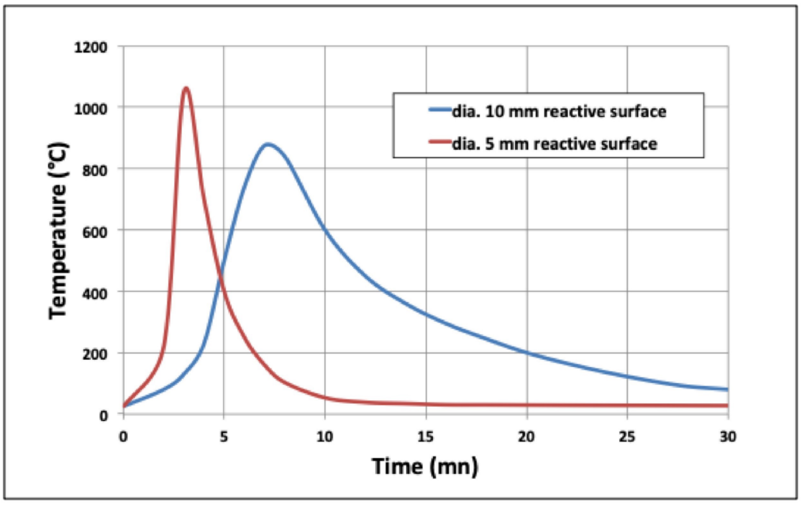

Figure 3. Temperature evolution at the surface of different diameter rods – Initial deuterium loading ratio: $x = 0.9$.

The model was adapted for a 3D spherical configuration. In the case of a 10 mm diameter sphere with a deuterium loading ratio $x = 0.9$ the calculated peak temperature is 982°C instead of 875°C for a 10 mm diameter rod, and the peak is reached after 3 min instead of 7 min. Although the calculated values cannot be considered precise, the relative magnitude is probably meaningful.

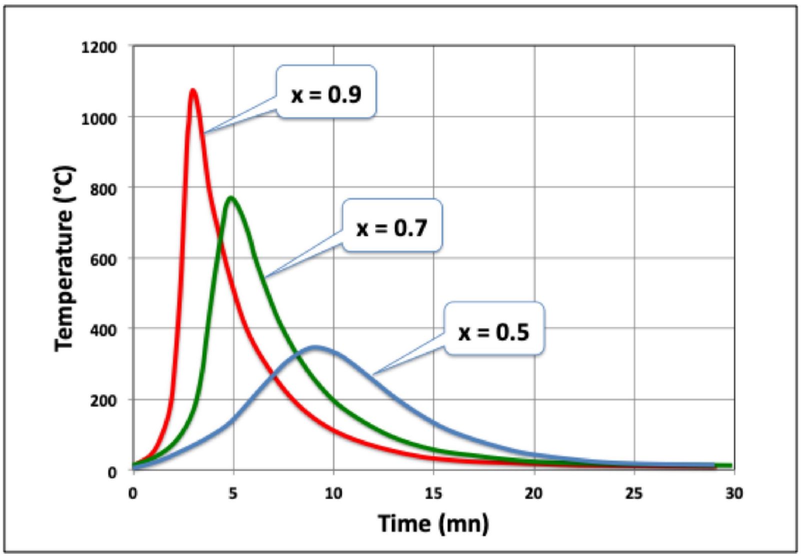

Figure 4. Influence of the initial deuterium loading ratio – Rod diameter: 5 mm.

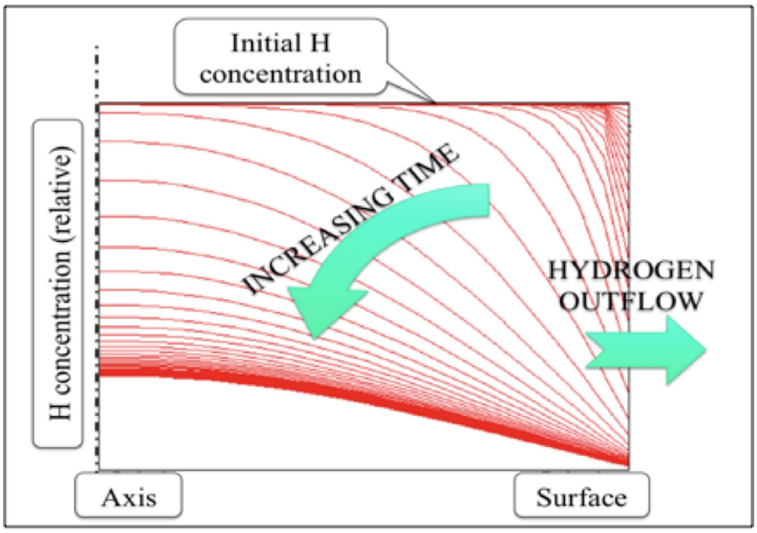

Figure 5. Example of evolution of the local deuterium content with time – Diameter: 10 mm. D distribution plotted every 30 s.

5. Conclusions of the Simulation

The model confirms what has been observed: A palladium sample loaded with hydrogen (or deuterium) can heat up when it is exposed to the air. The gas diffuses out of the metal and reacts at the surface with oxygen. The reaction increases the temperature of the metal. The higher temperature enhances diffusion, so that the process is

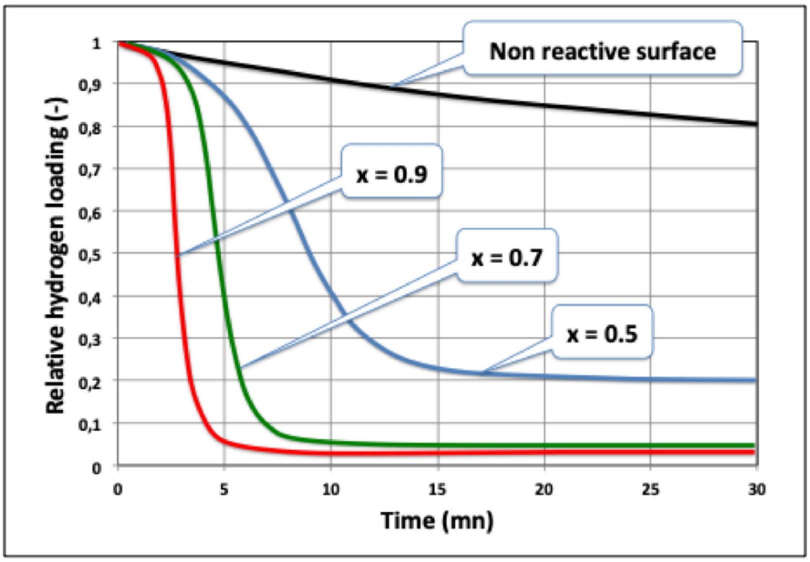

Figure 6. Ratio of the inventory of deuterium to the initial one. 10 mm diameter rod.

auto-accelerated. The reaction slows down once the hydrogen is depleted.

It remains to be clarified if the catalytic nature of the Pd is able to trigger the reaction of all the gas atoms coming to the surface or only a fraction of them, and if other conditions are necessary. Small samples heat up faster than large ones. The maximum temperature increases with the initial loading and the final hydrogen content left after cooling is lower. Cylinders and spheres react in a similar fashion, but the desorption is faster in 3D configuration (spheres) than in a 2D one (cylinders). Cubes being also a 3D configuration probably have the same behavior as spheres. The model is a simple one, so that the results presented here should only be considered as indicative.

6. Speculative Scenario to Explain the Meltdown that Occurred at Fleischmann and Pons Laboratory in 1985

In March 1985, Fleischmann and Pons were conducting an electrolysis experiment with a cathode made of a 1 cm cube piece of palladium. The cell exploded. There was no direct witness of the event that occurred at night during a weekend. This is acknowledged in the original Fleischmann and Pons paper [10]:

We have to report here that under the conditions of the last experiment, even using D_2O alone, a substantial portion of the cathode fused (melting point 1544°C), part of it vaporized, and the cell and contents and a part of the fume cupboard housing the experiment were destroyed.

Charles Beaudette describes the scene in his book [11]: *An early experiment consisted of a one-centimeter cube of palladium suspended in a flask of heavy water containing dissolved lithium metal*

Kevin Ashley was a graduate student of Pons in the chemistry department. He witnessed the scene the morning after the meltdown. This one morning I walk in, the door is open and Pons and Fleischmann are in the room with Joey. The lab is a mess and there is particulate dust in the air. On this lab bench are the remnants of an experiment. The bench was one of those black top benches that was made of very, very hard material. There were cabinets under one end of the bench, but the experiment was near the middle where there was nothing underneath. I was astonished that there was a hole through the thing. The hole was about a foot in diameter. Under the hole was a pretty good sized pit in the concrete floor. It may have been as much as four inches deep.

Because such damage requires a large amount of energy, it is often discussed within the CMNS community that this event was a strong evidence of nuclear reactions in this type of experiment. See for instance [12,13].

Another scenario is proposed here. This is admittedly a speculative one because there is no evidence left after so many years to prove it is correct. The experiment involved electrolysis "*in a flask of heavy water*" (see Fig. 7A). Electrolysis produces a stoichiometric mix of hydrogen and oxygen. This gas is highly explosive. In a previous paper, the author analyzed an explosion that occurred during a similar experiment [14]. The explosion can take the form of a rather benign deflagration. Under some circumstances, a phenomenon called Shock Wave Amplification by Coherent Energy Release (SWACER) transforms the explosion in a violent detonation able to develop shock wave pressures in excess of 40 bar. It is here supposed that the quantity of explosive gas contained in the cell was sufficient to detonate (Fig. 7B). The shock wave is stronger along its travelling path than on the other directions. If the shock wave was directed downwards it may have contributed significantly to the damage of the bench.

Once the cell was destroyed, the cathode fell on the bench, covered by debris from the explosion. It is further speculated that the palladium cube started to heat up, following the process explained above. The piece of metal kept hot for several minutes, sufficient to burn a hole in the bench, if it was not already broken by the explosion (Fig. 7C). All debris fell and accumulated on the floor, some covering the glowing piece of palladium. The concrete floor was subjected to a thermal shock during several minutes. In this scenario, the concrete may have exhibited some blistering (Fig. 7D). Further investigation could determine the relationship between the heat input and the extent of blistering. It is interesting to note that the large bas-relief at Stone Mountain near Atlanta was carved in granite via the use of oxy-fuel burners [15]. In this case the oxy-fuel burners produced sustained heating. It might be instructive to do some

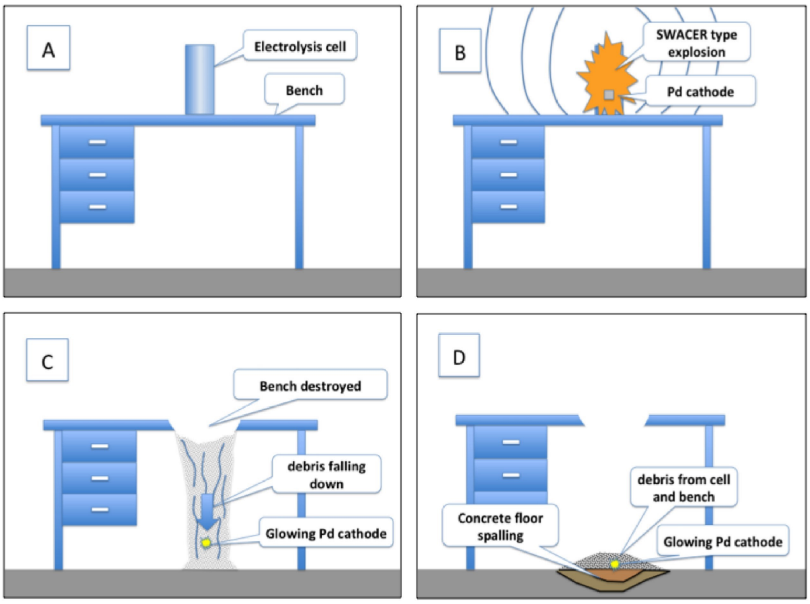

Figure 7. Potential scenario of the Fleischmann and Pons explosion event (A) Experimental setup, (B) SWACER type explosion in the gas phase of the cell, (C) debris on the floor and Pd self-heating and (D) spalling of the concrete floor.

tests to check if a piece of glowing metal can have similar effects.

7. General Conclusions

Palladium cathodes loaded with hydrogen or deuterium can heat up once exposed to air. Such events are rare but have been observed by several researchers. The simplified numerical model shows that temperature levels in accordance with the experiences can be attained. The process requires that the hydrogen present at the metal surface react readily with the oxygen from the air. The metal catalytic activity is the key that triggers the reaction (or fails to trigger it).

The combination of a detonation in the gas phase of the cell and of the self-heating of the palladium piece of metal may offer an alternative explanation of the event that occurred at Utah University in 1985 when Fleischmann and Pons were conducting an electrolysis experiment with a 1 cm cube palladium cathode.

Acknowledgements

The authors thank Jean-Paul Bibérian, Melvin Miles and Edmund Storms, who shared their experiences with us, as well as Nicolas Armanet for his input with valuable information regarding palladium hydrides.

Post-scriptum

The authors acknowledge they were tempted by David French to do this study. Unfortunately, David passed away on December 2, 2018. His co-authors want to dedicate this work to his memory.