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PATTERNS OF FAILURE IN COLD FUSION EXPERIMENTS

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ABSTRACT

Although reproducible cold fusion experiments continue to be difficult to achieve, analyses of these experiments offer preliminary suggestions on improving yields and reliability.

INTRODUCTION

Deuteron-deuteron fusion remains elusive in conventional systems because electrostatic repulsion makes close approach unlikely to the requisite few Fermi separation that only exists for kinetic energies 0.1 MeV or temperatures >100 million degrees Kelvin. Nonetheless, laboratories in over 15 countries[1] have reported replication of non-plasma ("cold") fusion[2] using heavy water alkaline solutions with platinum anode and palladium cathode[2-10] and for light-water electrolytic or gas systems with nickel cathodes and gold, nickel or graphite anodes[11-18]. Excess power ratios of 30-1000%, peak energy densities of 1-15 megajoules per cm^3 palladium and peak power densities of 100-2000 Watts/cm^3 Pd have been reported. Light water nickel cathodes systems produce excess heat at lower power levels [1-7 Watts/cm^3 Ni/H_2O] but with a rapid onset consistent with nickel's deuteron diffusive properties. Each watt of excess heat requires ~10^{12}-10^{13} fusion events per second out of a total sample population of perhaps ~10^{20}-10^{22} candidate nuclei. Therefore, only a very small fraction of the interstitial population is involved at any time. The lattice links to the nuclei through s-orbital coupling [heralded by the Mossbauer effect]. We believe that localized low temperature Bremsstrahlung may further facilitate such coupling via the optical phonons (~32-48 millieV; which result from the small mass of the deuteron in the heavier Group VIII metal lattice). Given the weak couplings linking the lattice to the nuclei through s-orbital coupling [heralded by the Mossbauer effect], we believe that localized low temperature Bremsstrahlung may further facilitate such coupling via the optical phonons (~32-48 millieV; which result from the small mass of the deuteron in the heavier Group VIII metal lattice). They may permit the non-ionizing radiation pathway to satisfy the momentum requirements, as eventually the acoustic phonons contribute to the observed excess enthalpy. The ash, helium-4[4,5,10] [and tritium[3,6,8,9,14-16]] have been found to be linked with the excess heat [and low energy low intensity x-ray emission ~10 keV] and the former generated in quantities consistent with the observed excess heat for the deuterium palladium systems; consistent with a nuclear origin of these reactions.

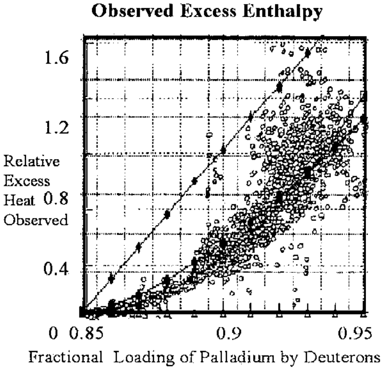

Figure 1 - Form Factor of Fusion and Excess Power as a Function of Loading

The scatter points [open data symbols] are the output from a palladium heavy water electrolysis experiment [after M. McKubre (1993)]. An inflection in the output as a function of loading only begins at loadings equal to ~0.85 D/Pd. These points represent the excess power-loading curve. The three curves for linear, 1.5 power, and quadratic function of total loading [after Swartz (1997)].

Table I - PATTERNS OF FAILURE IN COLD FUSION EXPERIMENTS
(and Possible Suggestions)

SOME FALSE POSITIVE ERRORS	
Driving Below Noise Level	Thermal Waveform Reconstruction
Errors of Energy Storage	Must Rule Out
Differential Pathlength, including time variation, and or with gas stream	Thermal Waveform Reconstruction
Vertical Flow Calorimetry	Avoid, or correct
Chemical Reactions, Phase Change	check, quality control

SOME FALSE NEGATIVE ERRORS	
Erroneous paradigm	Check hypothesis a priori
Failure with use of sliding average	Check hypothesis a priori
Failure to correct for mass transfer	minimize by use of V * I for input
Errors of Power Delivery	optimal operating point
Insensitivity to enthalpy generated	systems not robust
Insensitive Thermometry	pretesting

SOME TRUE NEGATIVE ERRORS	
Errors of Loading - subthreshold	control loading; codep.
Inactive Samples ab initio	pretesting, electrochemical and activity testing
Inactive Samples post-loading	pretesting, alloys
Contamination Issues	common problem, not all material issues resolved
Nonperiodic material	? possible coherence length
Insufficient Loading	common failure frequently not measured
Loading Rate Issues	incorrect face on loading, control loading rate, and loading rate ratio
Removal of Phonons for coupling	avoid flow calorimetry, energy drain systems
Biphasic Response to Power Drive Optimal Operating Point	common failure - Q1D loading model
Material breakdown	?Alloys, pulsing, heat removal

SOME TRUE POSITIVE ERRORS	
Amplification of Effects	avoid vertical flow calorimetry
Impact of Open Systems	add in gas phase loss

SOME OTHER POSSIBLE ERRORS (more than 1 category)	
Systematic Errors	Chemical controls
Errors of Paradigm	Check hypothesis *a priori*
Sampling Below Nyquist Level	Increase sampling rate
Time-variant Diffusion Pathlengths	Precheck
Inadvertent Mass Transfer	Check Absorption issues
Errors of Calibrations	Thermal Waveform Reconstruction
Errors of Thermometry	Preselection
Errors of Calorimetry - Heat capacity, barriers, changes during experiment	Inclusion
Errors of Heat Transfer	Careful Planning
Errors of Calorimetry - Barrier Heat Uptake	Check of Thermal, Absorption issues
Errors of Calorimetry - Time Variations	Careful Planning

Despite increased metallurgical, nuclear and theoretical understanding[19-25], the desired reactions are not easy to accomplish and can destroy the material in which they are sought. Patterns of failure of cold fusion experiments can be divided into physical issues such as sample activity, loading achieved, ambient noise power, paradigm used, and possible material degradation. Alternatively, the issues can be categorized as in Table 1.

ISOTOPIC LOADING

Many "negative" results are due to inadequate loading or loading flux ratio (ratio of the first-order loading flux rate to that for gas evolution which competes against the loading). This occurs because D-Pd systems only produce excess heat when the cathode is loaded[21,26] to an atomic ratio greater than ~0.85 (Figure 1). Such full loading of the metals with isotopic fuel appears to one *sine qua non* for some of these processes; insufficient loading is a common true negative failure. Inactive samples, which cannot be loaded because they "leak" gas, appear to account for many of the failures.

The electrode bulk not only must be crack free but also must not crack during loading even when the volume expands by ~6% or more. These cracks are invisible until heralded during bubble leakage. Material factors leading to routine failure include contamination, use of fractured small domain metals, and improper material handling techniques.

OPTIMAL OPERATING POINTS

Optimal operating points (the peak of the biphasic response of the observed excess power to the input electrical driving power) for nickel light water and palladium heavy water systems have been reported[17,18]. Driving with electrical input power beyond this peak (optimal operating point) yields a typical falloff of the observed power ratio for increasing input power or current levels toward a power gain ratio of 1 and less.

In nickel systems with anodes of nickel, gold, and graphite[17,18], this optimum operating point (biphasic) action appears to be the generalized behavior for the generated excess heat. Several years of our investigations of these nickel light water systems has revealed a more reproducible excess enthalpy by electrically driving these systems at their optimal operating point. Furthermore, optimal operating points appear to be generalized behavior for hydrided solid state fusion systems comprised of palladium-heavy water, codepositional, and also independent nickel plated systems. Figure 2 shows the relatively narrow loci of optimal operating points for the various systems

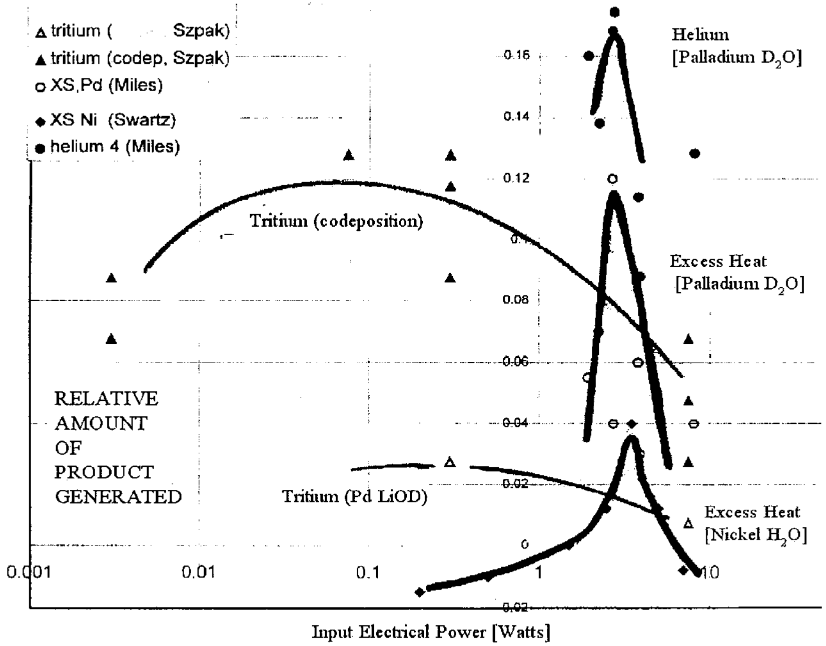

Figure 2 - Biphasic Nature Of Excess Heat And Nuclear Ash As A Function Of Input Power

The Biphasic Character of excess Power [watts] as a function of applied input current may be possibly be seen. The data is an output plot of excess heat, or nuclear ash (He-4, tritium) production as a function of input power. The figure represents the superposition of many separate experiments. The vertical axes are relative and do not indicate absolute values between the experiments. The curves connect the operating points in each group of experiments. The horizontal axis represents the electrical levels toward a power gain ratio of 1 and less. In nickel systems with anodes of nickel, gold, and input power and is logarithmic. Excess enthalpy data [nickel, light water] after Swartz., helium data [palladium. heavy water] after Dr. Miles, Bush and Johnson; codeposition with LiOD and tritium production after Szpak and Mosier-Boss.

including excess heat and ash production as a function of input electrical power and represents the superposition of many separate experiments. The horizontal axis represents the electrical input power and is logarithmic. The vertical axes are relative and do not indicate absolute values between any of each cohort of experiments. The nickel light water data is from Swartz[17,18]; the palladium heavy water data are from Miles[4,5] and Szpak[6].

What could be the origin? The biphasic response may be the result of competitive processes. One is the falloff in output of the sample beyond the peak output for higher input drive levels due to isotope loss secondary to gas electrolysis. Other possible theoretical reasons for the biphasic effect include variations in the loading flux ratio[17,23-25], development of a phase change[20], or catastrophic changes to the material[17].

The optimal operating point for the desired reactions is important for several reasons. First, it may account for some of the widespread difficulties in observing the phenomena because some of the failure to reproduce the cold fusion may have occurred from driving the systems inadvertently or unintentionally outside of the optimal operating point manifold. Second, the obtainable peak maximum output appears to define a sample's characteristics with a decrease from the peak due to suboptimal drive conditions. Therefore, we use the peak power gain for each electrode/configuration obtained by driving at the optimal operating point to characterize samples. Some (nickel fibrex in light water) have low excess enthalpy even at the optimal operating peak (maximum excess heat ~0.40-2) whereas other have more (nickel spiral versus gold) demonstrated power gains of ~3-9.

AMBIENT NOISE LEVEL POWER

There have been many improvements in semiquantitative calibrations[27-29], calorimetry[17,30,31], noise[32] and other[33,34] analysis. There should be routine measurement of background noise power levels in all cold fusion (and other purported over-unity) experiments because it improves the quality of the derived information and may rule out false positive indications of over-unity which can be artificially produced. Figure 4 shows this by driving a system[32] with input power of magnitude less than the average noise power. This obviously will yield an output at, or slightly above, the original noise level. This false "over-unity" occurs because the computed yield of "over-unity" is defined as the energy in the noise spectrum and output energy divided only by the input energy.

Our work focuses upon the role of phonons in these reactions, and some of our preliminary research suggests that massive removal of phonons dampen the reactions perhaps by changing the coupling of the nuclear reactions to the lattice. figure 4 shows an inactive reactor which nonetheless demonstrates the appearance of a false positive in the time range of ~50-100 minutes. At those times the input power level was below the noise power level producing the appearance of false positive "excess heat" (** in the figure, upper left). This false positivity of more than "300%" is important yet avoidable.

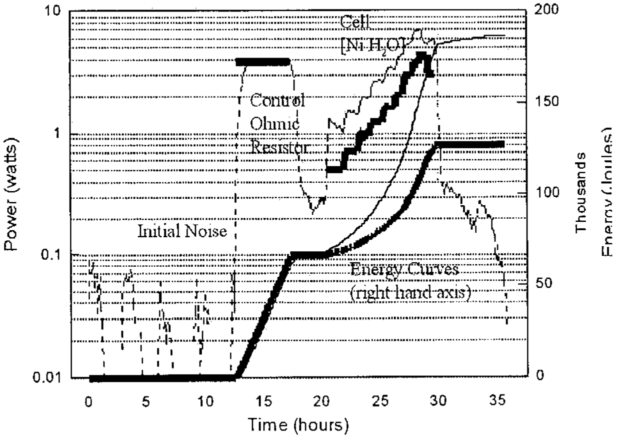

Figure 3 - Excess Heat in Nickel Light Water Electrolytic System
Four curves show input (thicker) and output energy and power for a cell with gold anode and six spiral nickel cathodes (cathodic area 28 cm^2, volume 0.35 cm^3, H_2O). To the lower left is thermal noise ~90->60 milliwatts extending until the control pulse at about 12 hours. Following that, cells response with excess heat contrasts both ohmic, and other metal, controls.

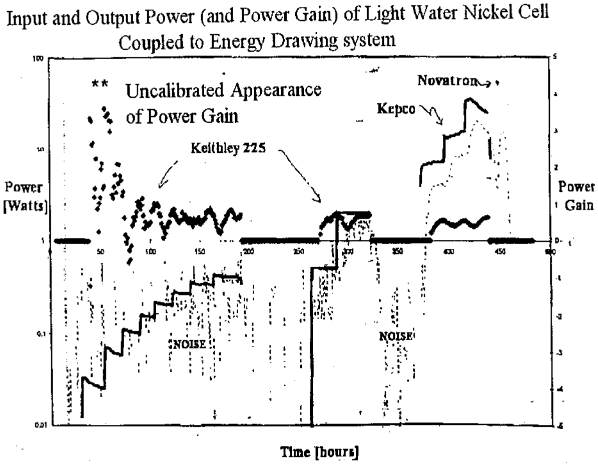

Figure 4 - Inactive Cold Fusion Setup Showing False Positive
"Phonon-drained" light water system [nickel cathode, gold anode] using several power supplies [Keithley 225 current source, Kepco voltage source, Novatron power source]. Three curves showing input electrical power (watts; solid step functions), detected output power (dashed thinner curve), and power gain (thick curve to be read of right axis). The latter is the overunity factor (right axis; solid large dots and solid wavy lines).

ERRORS IN ALGORITHM

Several false negative reports are due to incorrect paradigms[33,35-37]. Some (e.g. the Phase-II, and the sliding windows algorithm) methodologies are flawed because they mask any constant [steady-state] excess enthalpy. These are avoidable errors of technique. They occur only when a new paradigm is not sufficiently explored. In the worst cases, the paradigms used have not been sensitive to potential excess heat. Other flawed analyses can also either hide excess heat or amplify what is observed.

INACTIVITY OF SAMPLES

Although last to be covered, this is not the least important. Samples can have their peak obtainable power irreversibly destroyed by either loading or the desired reactions limited by the structural integrity of the material in which they occur. When the internal pressures exceed the energy needed[38,39] to create fresh new surfaces, leakage occurs and the sample becomes, at best, locoregionally inactive.

SUMMARY AND CONCLUSION

While no research paper can completely examine the matters considered here, a study of the patterns of failure must continue. The major errors involve material issues such as loading, leakage, contamination and failure to consider the optimal operating point. The need for ruling out energy storage and other controls remains obvious. Other errors include failure to consider noise power and the reliability of the algorithm used.

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