Journal of Electrochemistry

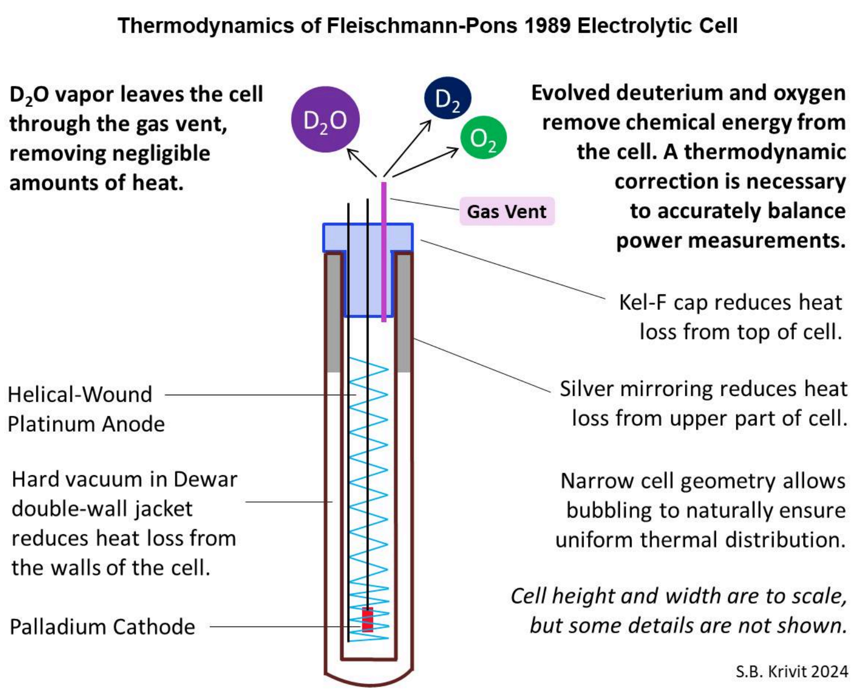
Volume 30 | Issue 2

2024-02-28

# Confirmation of Anomalous-Heat Report

Steven B. Krivit
*New Energy Times 369-B 3rd St. #556, San Rafael, CA, 94901*, steven3@newenergytimes.com

Melvin H. Miles




## Recommended Citation

Steven B. Krivit, Melvin H. Miles. Confirmation of Anomalous-Heat Report[J]. *Journal of Electrochemistry*, 2024 , 30(2): Article 4.
DOI: 10.61558/2993-074X.3424
Available at: https://jelectrochem.xmu.edu.cn/journal/vol30/iss2/4

VIEWPOINT

# Confirmation of Anomalous-heat Report

Steven B. Krivit [a,*], Melvin H. Miles [b]

[a] New Energy Times, 369-B 3rd St. #556, San Rafael, CA, 94901, USA
[b] University of La Verne (Retired), 1950 3rd St, La Verne, CA 91750, USA

Image courtesy of and copyright New Energy Times

Received 25 June 2023; Received in revised form 5 August 2023; Accepted 2 September 2023
Available online 9 October 2023

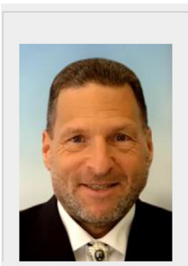
* Corresponding author, Steven B. Krivit, E-mail address: steven3@newenergytimes.com.

*https://doi.org/10.61558/2993-074X.3424*

**Abstract**

This study identifies, for the first time, critical calculation errors made by Nathan Lewis and his co-authors, in their study presented on May 1, 1989, at the American Physical Society meeting in Baltimore, Maryland. Lewis et al. analyzed calorimetrically measured heat results in nine experiments reported by Martin Fleischmann and his co-authors. According to the Lewis et al. analysis, each of the experiments, where calculated for no recombination, showed anomalous power losses. When we used the same raw data, our corrected calculations indicate that each experiment showed anomalous power gains. As such, these data suggest the possibility of a new, energy-producing physical phenomenon.

**Keywords:** Low-energy nuclear reaction; LENR; Excess heat



Steven B. Krivit is a publisher, author, and international speaker who has specialized in Low-Energy Nuclear Reaction (LENR) research since 2000. He has written four books about LENRs, and has been an invited contributor of journal and encyclopedia review articles about LENRs and their history. He is an editor of three reference books on nuclear energy research and has written more than 1000 news articles on nuclear science research. More broadly, Krivit is an expert in the analysis of science conflict.

Dr. Miles received a B.A. from Brigham Young University with a chemistry major and a Ph.D. from the University of Utah with a major in physical chemistry. He received a NATO postdoctoral award for research with Professor Heinz Gerischer. His scientific career includes 28 years as a research electrochemist with the Navy laboratory in China Lake, California. Dr. Miles also has 14 years of university teaching of chemistry and physical chemistry. His research has resulted in more than 300 publications and 20 patents.

## 1. Historical perspective

On April 10, 1989, a published journal article by Martin Fleischmann, Stanley Pons, and their collaborators at the University of Utah reported evidence of anomalous heat gains in a set of heavy-water electrochemical experiments using palladium cathodes. This indicated the possibility of a new energy-producing phenomenon [1,2].

On May 1, 1989, at the American Physical Society (APS) meeting in Baltimore, Maryland, Nathan Lewis criticized the Fleischmann et al. article and claimed that the same data indicated anomalous heat losses. Thus, according to calculations presented by Lewis et al., there was no evidence of a new energy-producing phenomenon [3]. Since then, that unpublished Lewis presentation has been used as the authoritative reference for Fleischmann et al.'s heat measurements instead of Fleischmann et al.'s own published papers [4,5]. Lewis et al. have never published their calculations of the Fleischmann et al. percent excess power values in a peer-reviewed journal. The Lewis et al. paper in *Nature*, submitted after the APS meeting, discussed only the failed Caltech experiments [6]. The Caltech team, in a paper published in *Science* in November 1989, discussed speculative ideas on the rate of power that Fleischmann et al. might have expected for their experiments. However, the Caltech team mentioned nothing about anomalous heat losses in the Fleischmann et al. experiments. Thus, they effectively withdrew the assertions about heat losses that Lewis had made in Baltimore [7].

## 2. Introduction

We have examined the data and calculations presented by Lewis et al. We find that the raw data they used for the Fleischmann et al. experiments are accurate. However, we report here for the first time that their calculations were performed incorrectly. When calculated correctly, using the same raw data, these data confirm, rather than disprove, the anomalous-heating effect. As a result, a possible new source of energy is indicated, with a potentially vast impact on energy science, technology, and the fields of chemistry and physics.

## 3. Why now?

Why is this new insight being reported only now, 35 years later? There are several reasons. First, with the exception of the Lewis et al. abstract, no official printed record of the Lewis′ presentation exists. Second, during his presentation, Lewis spoke so rapidly that an expert in electrochemistry would have had difficulty both critically evaluating the calculations he presented and detecting the errors. Third, the audience of primarily physicists likely would not have had the knowledge to detect the calorimetric calculation errors. Fourth, few people with knowledge of the subject matter would have had access to, as well as an interest in, examining the historical records. Many years ago, one of the authors, Krivit, went to the Cornell University's Cold Fusion Archive to view selected records there. Among these records were video footage of the Lewis presentation and copies of some of the Lewis APS slides. Krivit did not recognize the errors at that time.

In April 2023, Krivit analyzed a public document from the University of California, Berkeley, that described how Fleischmann and Pons used an inferior heat measurement technique [4]. The document said that they had "used a technique in which gasses were allowed to escape the fusion cell and then the amount of heat carried away by these gasses was estimated." This contradicted Krivit's understanding of the precision of the Fleischmann et al. experiments. The Berkeley document did not cite a source for that statement. However, while Krivit was viewing a copy of the Lewis APS video recording, he noticed that Lewis had speculated about the estimate of energy carried away by gases, similar to what was stated in the Berkeley document. Krivit compared the data table in the video to a photograph that he had taken of the same table in the Cornell archive. Based on his knowledge of the subject matter, the percent excess heat values seemed incorrect. In particular, he noticed that Lewis was displaying negative percent excess heat values.

Krivit was puzzled because he had never seen any previous discussion about Lewis' calculations. He contacted two people in the field who were experts in the history of the Fleischmann–Pons heat measurements: Jed Rothwell, the librarian of the LENR-CANR Web site, and Melvin Miles, a former colleague of Fleischmann. Neither expert was aware of the discrepancy.

Krivit also reviewed Charles Beaudette's book *Excess Heat* to determine if and how Beaudette had addressed the discrepancy [8]. On Page 73 of his book, Beaudette wrote about Lewis' APS presentation but did not mention Lewis' errors. Instead, Beaudette wrote about a critique Lewis had presented about Fleischmann et al.'s extrapolated projections.

In their 1989 paper, Fleischmann et al. provided three sets of power gain values: a) the most realistic power gain calculation, b) the most pessimistic calculation, and c) an optimistic and projected calculation. But they did not provide strong evidence for the third set of extrapolated calculations. Fleischmann et al. had overextended their claims in only the third set of values. The errors that we describe here by Lewis, however, relate to the first and second sets of power gain calculations.

## 4. Experiment

Fleischmann et al. employed electrolytic cells that were called open cells despite being closed at the top with a Kel-F solid cap. They were designed with a small vent hole with a glass tube to allow the evolved gases to escape. In contrast, with closed-cell electrolysis, the evolved deuterium from $D_2O$ (or hydrogen, if $H_2O$ is used) and oxygen remain in the cell. Instead, materials at the top of the closed cell are intended to facilitate the recombination of gases into $D_2O$ (or $H_2O$). Closed-cell calorimetry is not necessarily more accurate than open-cell calorimetry. This is primarily because closed-cell calorimetry can cause isolated hotspots where the recombination takes place, resulting in large thermal gradients. Such thermal gradients can contribute to inaccuracies in temperature measurement.

*Table 1. Reproduction of photograph of table presented by N. Lewis on May 1, 1989.*

"Raw data" from electrolysis of $D_2O$[a]

| Applied Current (I) mA | Applied voltage (E) V | Input Power (Pin = E*I) W | Heat Produced ($P_{out}$) W | $\frac{P_{out} - E*I}{E*I}$ % | $\frac{P_{out^T} - E*I_b}{E*I}$ % | Excess Heat Produced W |
|---|---|---|---|---|---|---|
| 0.1 cm rod | | | | | | |
| 25.13 | 2.84 | 0.0714 | 0.0402 | −44 | −54 | 0.0075 |
| 201.1 | 3.61 | 0.0726 | 0.495 | −32 | −43 | 0.079 |
| 1608 | 9.67 | 15.55 | 13.7 | −12 | −16 | 0.654 |
| 0.2 cm rod | | | | | | |
| 50.27 | 2.70 | 0.136 | 0.094 | −31 | −57 | 0.036 |
| 402.1 | 4.21 | 1.696 | 1.57 | −7 | −37 | 0.493 |
| 3217 | 8.25 | 26.5 | 24.6 | −7 | −19 | 3.02 |
| 0.4 cm rod | | | | | | |
| 100.53 | 2.91 | 0.293 | 0.291 | −1 | −53 | 0.153 |
| 804.2 | 4.84 | 3.89 | 4.40 | 13 | −32 | 1.751 |
| 6434 | 8.60 | 55.3 | 72.2 | 31 | −18 | 26.8 |

[a] Calculated from Tables 1 and 2 in paper by S.Pons, M. Fleischmann and M. Hawkins, J. Electroanal. Chem. 261 (1989) 301–308.
[b] $P_{out^T}$ =(E−1.54)*I (i.e.assuming no recombation of $D_2$ and $O_2$.

*Table 2. Correct excess-heat calculations, assuming no recombination.*

| Current Density $mA/cm^{-2}$ | Cell Current (I) A | Cell Voltage $E = 1.54+P_x/I*X_a$ V | Power Input ($P_{in}$) $(E\text{-}1.54)^a I$ W | Power Produced ($P_{out}$) W | Excess Power ($P_x$) W | Percent Excess Power ($\%P_x$) $P_x/(E\text{-}1.54)I$ % |
|---|---|---|---|---|---|---|
| 0.1 cm Rod | | | | | | |
| 8 | 0.0251 | 2.84 | 0.0326 | 0.0401 | 0.0075 | 23 |
| 64 | 0.201 | 3.61 | 0.416 | 0.495 | 0.079 | 19 |
| 512[a] | 1.61 | 9.67 | 13.07 | 13.7 | 0.654[a] | 5 |
| 0.2 cm Rod | | | | | | |
| 8 | 0.0503 | 2.70 | 0.058 | 0.094 | 0.036 | 62 |
| 64 | 0.402 | 4.21 | 1.074 | 1.57 | 0.493 | 46 |
| 512[a] | 3.217 | 8.25 | 21.6 | 24.6 | 3.02[a] | 14 |
| 0.4 cm Rod | | | | | | |
| 8 | 0.101 | 2.91 | 0.138 | 0.291 | 0.153 | 111 |
| 64 | 0.804 | 4.84 | 2.65 | 4.40 | 1.751 | 66 |
| 512[a] | 6.43 | 8.60 | 45.4 | 72.2 | 26.8[a] | 59 |

[a] These values were measured on 1.25 cm electrodes and rescaled based on 10 cm electrodes. Raw data, including values for $P_x$ and $X_a$, come from Tables 1 and 2 in Ref. [1]. $X_a$ is defined as: $X_a = P_x/P_{in} = P_x/(E - 1.54)\, I$.

Even though closed-cell electrolysis does not apply to the Fleischmann et al. results, those authors were aware that people might ask about the heat gain calculations if there had been undetected recombination. Additionally, because of the confusion introduced by the Lewis presentation about both cases — assumption of 0 % recombination as well as assumption of 100 % recombination — it will be useful for readers to understand both cases.

## 5. Computational details

In open-cell electrolysis, where enthalpy is measured calorimetrically, a thermodynamic correction is necessary to accurately balance power measurements. In the open-cell design, the evolved and escaping deuterium (or hydrogen) and oxygen take with them a specific rate of chemical energy from the cell. The thermoneutral potential for heavy water, $E_h = 1.54$ V, is the most straightforward way to make this correction. This power correction is expressed as $(E-1.54)\, I$, where $E$ is the cell voltage and I is the cell current in Amps. The term for input power to the cell is reduced by this value. The thermodynamic correction for any electrolysis reaction is determined by the enthalpy change for that reaction. This value can be calculated by using thermodynamic values found in sources such as the U.S. National Bureau of Standards Tables of Chemical Thermodynamic Properties. Because Fleischmann et al. were using open-cell electrolysis, they applied this thermodynamic correction to their computation of the input power rate. Alternatively, in closed-cell electrolysis, 100 % recombination is assumed, and the thermodynamic correction is not used.

Recombination of evolved gases at significant rates in open cells typically requires specific recombination materials. Fleischmann et al. had no such materials in their systems. Moreover, the researchers could detect whether any appreciable rates of recombination were occurring in their cells. This can be done in various ways, including the direct measurement of the rate of gases that escape the cell or simply the measurement of the $D_2O$ additions compared to the theoretical loss of $D_2O$ by electrolysis (−0.812 mL of $D_2O$ per day at $I = 0.100$ A). LENR experiments with fully submerged electrodes and correctly insulated wire leads have not reported significant recombination.

In addition to the dissociated $D_2$ or $H_2$ and $O_2$ leaving through the vent hole of an open electrolytic cell, some molecules of $D_2O$ or $H_2O$, as vapor, leave through the vent hole, taking with them a small amount of heat that is produced. In most cases, this amount is negligible at cell temperatures below 50° C to 60° C. However, if accounted for, the excess heat value would be even larger. Fleischmann and Pons addressed this matter on Pages 3−9 in the proceedings of the October 1989 National Science Foundation/Electric Power Research Institute (NSF/EPRI) workshop and on Page 313 of their 1990 paper [9,10].

Table 1 is a reproduction of a slide presented by Lewis at the APS meeting on May 1, 1989 [11]. Lewis obtained or derived all the raw data in the table from Ref. 1. The term $P_{out}$, (power out), represents the total heat produced by the electrolysis reaction. Alternatively, the term $P_{out^T}$ represents power out adjusted for the thermodynamic correction. A footnote reference (b) appears in the header of Column 6 but it is difficult to see. The footnote explains that Column 6 represents the percent excess heat in the case of 0 % recombination of the gases. Alternatively, Column 5, without the thermodynamic correction, is intended to represent the percent excess heat in the case of 100 % recombination of the gases. However, Column 6 simplifies algebraically to −1.54/E, and does not involve the excess power in its calculations. Moreover, this expression can never produce positive results for Column 6.

According to Lewis et al., experiments performed by Fleischmann et al. in the deuterium-palladium electrolysis system produced mostly negative values for percent excess heat. However, there are no materials in such a system that would cause endothermic reactions, and values for percent excess heat can never be negative in the D/Pd system, based on known science. The smallest possible value is zero. Therefore, any reported measurement of negative excess power indicates an error.

Further, Lewis et al. say that the reaction they calculated for 0 % recombination (which should result in a higher percentage of excess heat) generally results in a lower percentage of excess heat than the reaction they calculated for 100 % recombination. In Appendix A, we have provided an example of the calculations that produce the Lewis et al. results, using the first experiment, operated at 25.13 mA constant cell current.

## 6. Results

As shown in Table 2, when we perform the correct calculation for the case of 0 % recombination, we find that Fleischmann et al. measured positive percentages of excess power in each of the nine experimental runs. In Appendix B, using the first experiment, operated at 0.0251 A cell current, we have provided an example of the calculations that produce these correct results.

Although Lewis did not have access to it at the time of the 1989 APS meeting, Fleischmann and Pons presented a new set of excess-heat-producing experiments, and a set of control experiments to Lewis and other participants at the October 1989 NSF/EPRI workshop. The following year, Fleischmann et al. published a 58-page paper that was far more extensive than their eight-page preliminary note from 1989. This paper reported almost the same set of experiments as they had presented at the NSF/EPRI workshop.

## 7. Conclusion

The power values reported by Fleischmann et al. in the nine experimental runs, where calculated for no recombination, are calculated correctly, and each run shows the production of anomalous heat. When we accounted for all power going into and coming out of the system, these experiments produced net power that was about twice the power going in. Although the absolute net power in this D/Pd system is at the level of hundreds of milliwatts and does not immediately demonstrate a practical energy technology, neither did the anomalous heating effect that was initially observed by Pierre and Marie Curie that was, years later, found to be from nuclear fission. These newly recognized errors by Lewis et al. support the conclusion that Fleischmann et al. may have discovered a potential new source of energy as well as a new field of science, contrary to general understanding. This paper aims to correct the scientific record on this matter.

## Acknowledgements

We would like to thank Francis Tanzella and Dieter Britz for their thoughtful suggestions. S. Krivit would also like to thank Cynthia Goldstein and Michael Ravnitzky for their editorial support; and Bruce Lewenstein, who had the foresight to preserve this history.

## References

[1] Fleischmann M, Pons S. Electrochemically induced nuclear fusion of deuterium[J]. J. Electroanal. Chem., 1989, 261: 301−308.

[2] Fleischmann M, Pons S, Hawkins M. "Errata to 'Electrochemically induced nuclear fusion of deuterium,"[J]. J Electroanal Chem, 1989, 263: 187−188.

[3] Lewis N, Barnes C, Koonin St. Calorimetry, neutron flux, gamma flux, and tritium yield from electrochemically charged palladium in $D_2O$[D]. Baltimore, USA: American Physical Society, 1989.

[4] Gilet C, Stuart S, Casazza L. Cold Fusion: a case study for scientific behavior[M]. Berkeley, USA: University of California Museum of Paleontology, 2012.

[5] Briefing on low-energy nuclear reactions (LENR) research [D] USA: office of the ASD. (R&E) Research, 2016.

[6] Lewis N, Barnes C, Heben M, Kumar A, Lunt S, McManis G, Miskelly G, Penner R, Sailor M, Santangelo P, Shreve G, Tufts J, Youngquist M, Kavanagh R, Kellogg S, Vogelaar R, Wang T, Kondrat R, New R. Searches for low-temperature nuclear fusion of deuterium in palladium[J]. Nature, 1989, 340: 525−530.

[7] Miskelly G, Heben M, Kumar A, Penner R, Sailor M, Lewis N. Analysis of the published calorimetric evidence for electrochemical fusion of deuterium in palladium[J]. Science, 1989, 246(4931): 793−796.

[8] Beaudette C. Excess heat: why cold fusion research prevailed. 2nd. Ed. South Bristol, USA: Oak Grove Press, 2002.

[9] Fleischmann M, Pons S. Calorimetry of the palladium-$D_2O$ system[M]. Proceedings of the NSF/EPRI workshop on anomalous effects in deuterided metals. Washington, D.C. USA: Electric Power Research Institute, 1993.

[10] Fleischmann M, Pons S, Anderson M, Li L J, Hawkins M. Calorimetry of the palladium-deuterium-heavy water system[J]. J. Electroanal. Chem., 1990, 287: 293−348.

[11] Lewis N. Selected slides from American physical society meeting[M]. Cornell USA: University Cold Fusion Archive, 1989. p. 7−30.

# 异常热报告的确认

Steven B. Krivit[a,*]，Melvin H. Miles[b]
[a]New Energy Times, 369-B 3rd St. #556, San Rafael, CA 94901, USA
[b]University of La Verne (Retired), 1950 3rd St, La Verne, CA 91750, USA

**摘要**

本文首次确认 Nathan Lewis 及其合作者于 1989 年 5 月 1 日在美国马里兰州巴尔的摩举行的美国物理学会（APS）会议上所犯的关键计算错误。Lewis 等人分析了 Martin Fleischmann 及其合作者报告的 9 轮实验中的热测量结果，并报告在没有催化复合的情况下每轮实验都显示出异常的热功率损失。而本文使用相同的原始数据，经过正确的计算，再次确认每轮实验都显示出异常的功率增益。因此，这些数据意味着可能存在一种能产生能量的新物理现象。

**关键词：**低能核反应；LENR；超热

ERRATUM: In a diagram, we wrote "$D_2O$ vapor leaves the cell through the gas vent, removing negligible amount of heat. If Fleischmann and Pons had accounted for this loss, their excess-heat values would have been larger." In the body of our manuscript, we wrote "However, if accounted for, the excess heat value would be even larger." In fact, Fleischmann and Pons did factor this term into their calculations. This equation is found in Appendix 3 as Fig. A3.1 on page 330 of Ref. 10

ERRATUM: We wrote "When we accounted for all power going into and coming out of the system, these experiments produced net power that was about twice the power going in."

The correct statement is "“In the highest-percentage case, after properly accounting for the power-equivalent value of the electrolysis products leaving the cell, the combined thermal and fuel power output exhibited an excess of approximately 100% relative to the conventional electrochemical baseline for that operating condition, while remaining below the total electrical input power."

## Appendix A - Sample Calculations Used in Table 1

Column 1: Applied Current

$I$ = 8 x 3.1416 = 25.13 mA = 0.02513 A, where 3.1416 is the electrode area.

Column 2: Applied Voltage

$E$ = 1.54 + 0.0075/ (0.02513) (0.23) = 2.84 V

Column 3: Input Power

$P_{in}$ = 2.84 x 0.02513 =0.0714 W

Column 4: Heat Produced

$P_{out}$ = (2.84 - 1.54) (0.02513) + 0.0075 = 0.0402 W

Column 5: Percent Excess Power, 100% Recombination

($P_{out}$ - EI)/EI = (0.0402 - 0.0714)/0.0714 = - 0.437 or - 44 %

Column 6: Percent Excess Power, 0% Recombination

($P_{out}^{T}$ – E I)/E I = [(2.84 - 1.54) (0.02513) - 0.0714]/0.0714) = -0.542 or -54%

(This equation simplifies algebraically to "-1.54 / E" = -1.54/ 2.84 = -0.542 or - 54%)

Column 7: Excess power produced as reported by Fleischmann et al.

Notes:

1. From Ref. 1, $P_x$ = 0.0075 W and the percent of excess heat = 23% = 0.23 = $P_x/(E - 1.54)$ I which can be solved for $E$ as used in Column 2.

2. The electrode area is Pi x Diameter x Height. For this 0.1 x 10 rod, the 0.1 x 10 = 1.00; thus, this area equals the number Pi, which is 3.1416 for four decimal places, which seems to be what Lewis used to get his numbers.

## Appendix B - Sample Calculations Used in Table 2

Column 2: Cell Current

$I$ = 8 x 3.1416 = 25.13 mA = 0.02513 A, where 3.1416 is the electrode area.

Column 3: Cell Voltage

$E$ = 1.54 + 0.0075/ (0.02513) (0.23) = 2.84 V

Column 4: Input Power

$P_{in}$ = (2.84 - 1.54) (0.0251) = 0.0326 W

Column 5: Heat Produced

$P_{out}$ = (2.84 - 1.54) (0.0251) + 0.0075 = 0.0401 W

Column 6: Excess Heat

$P_x$ = 0.0075 W (as reported in Ref. 1)

Column 7: Percent Excess Power, 0% Recombination

The percent of excess power is given by 0.0075/0.0326 = 0.230 or 23%.

Note that this is Column 6/Column 4 or $P_x/P_{in}$ and uses $E_h$, the thermoneutral potential of 1.54 V