# EXCESS HEAT IN ELECTROLYSIS EXPERIMENTS AT ENERGETICS TECHNOLOGIES

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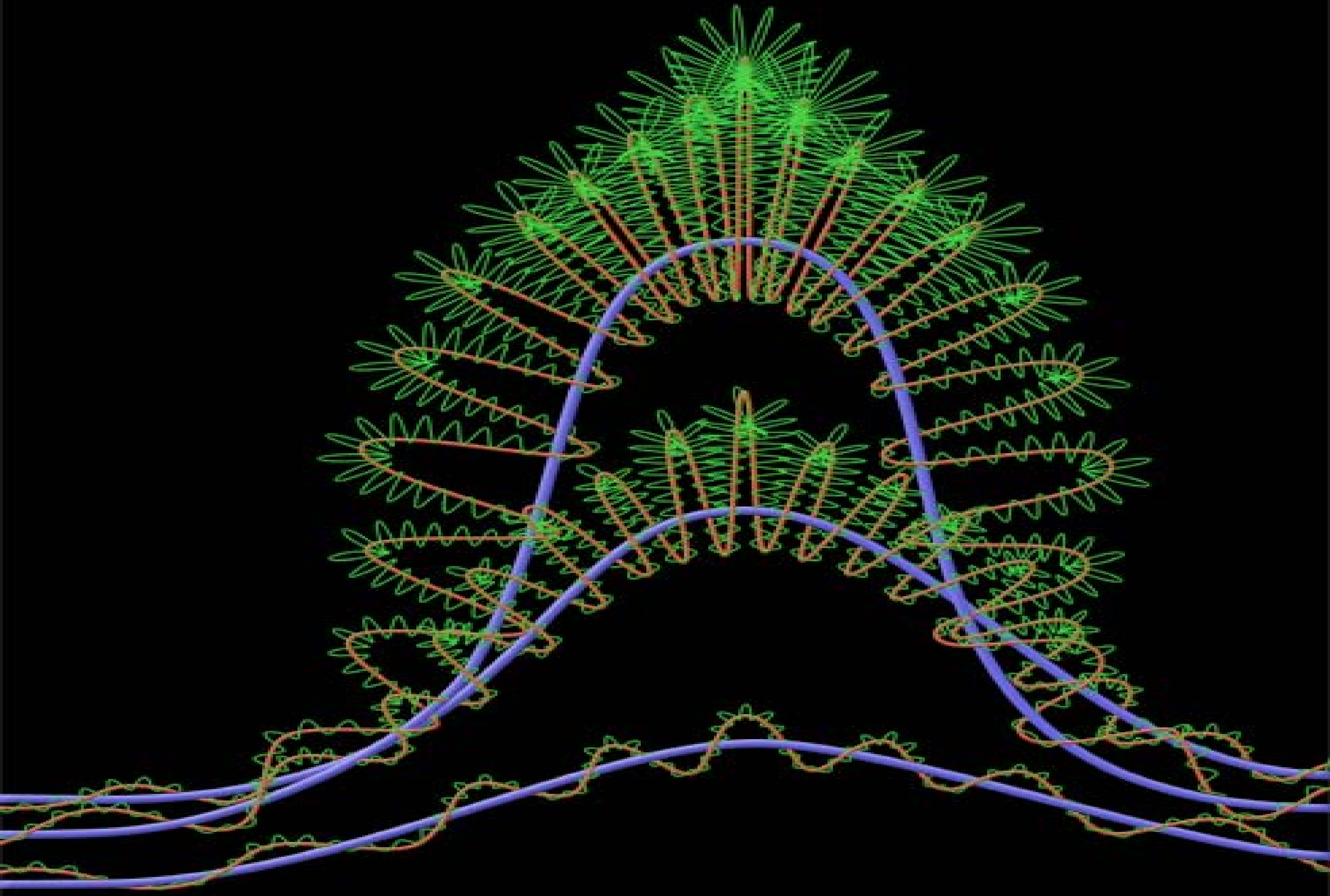
# CONTENTS

# PRESENTATION OBJECTIVES

1. **Review of SuperWave© principles**
2. **Review of Glow Discharge Experiments**
3. **Description of 3 ET electrolytic cell experiments that resulted in significant excess heat generation:**

| Experiment # | 56 | 64a | 64b |
|---|---|---|---|
| Cycle № | 4 | 1 | 2 |
| Loading time (s) | 80 | 5 | 16 |
| Excess heat (EH) (%) | 80 | 2500 | 1500 |
| Duration of EH (h) | 300 | 17 | 80 |
| Excess energy (EE) (MJ) | 3.1 | 1.1 | 4.6 |
| Specific* EH (W/g Pd) | 11 | 71 | 62 |
| Specific* EE (KeV/Pd atom) | 13.5 | 4.8 | 20 (24.8) |

* - pertaining to effective part of cathode ( 6 x 0.7 cm )



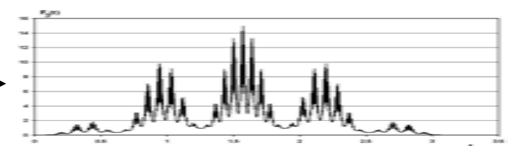
# EC are driving by SuperWaves

Operator

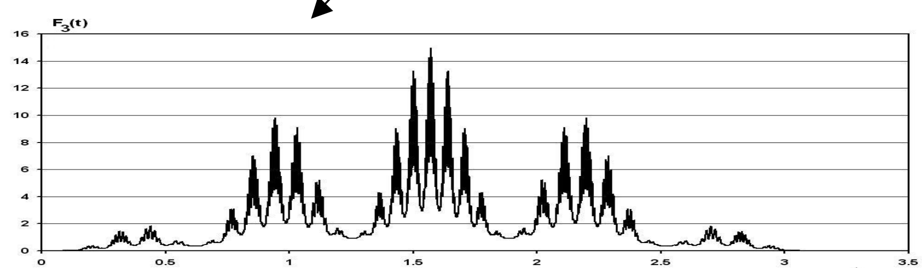
Parameters

set up

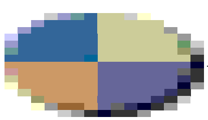
Superwave form signal generation using LabView software



Low current



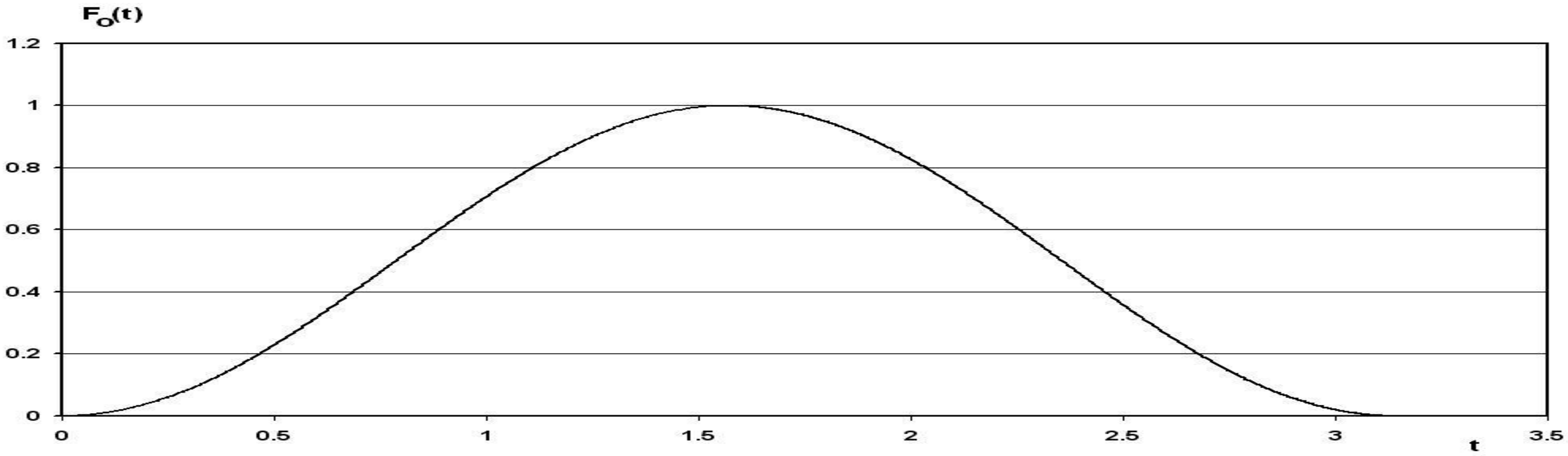

Current amplifier



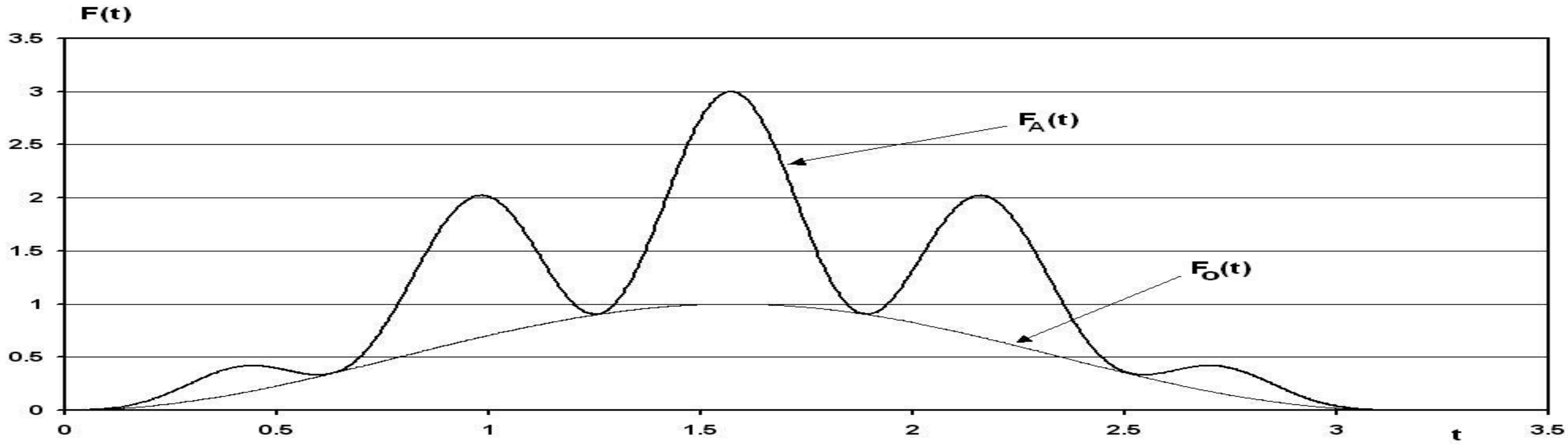
Experimental system

# SuperWaves formation principles

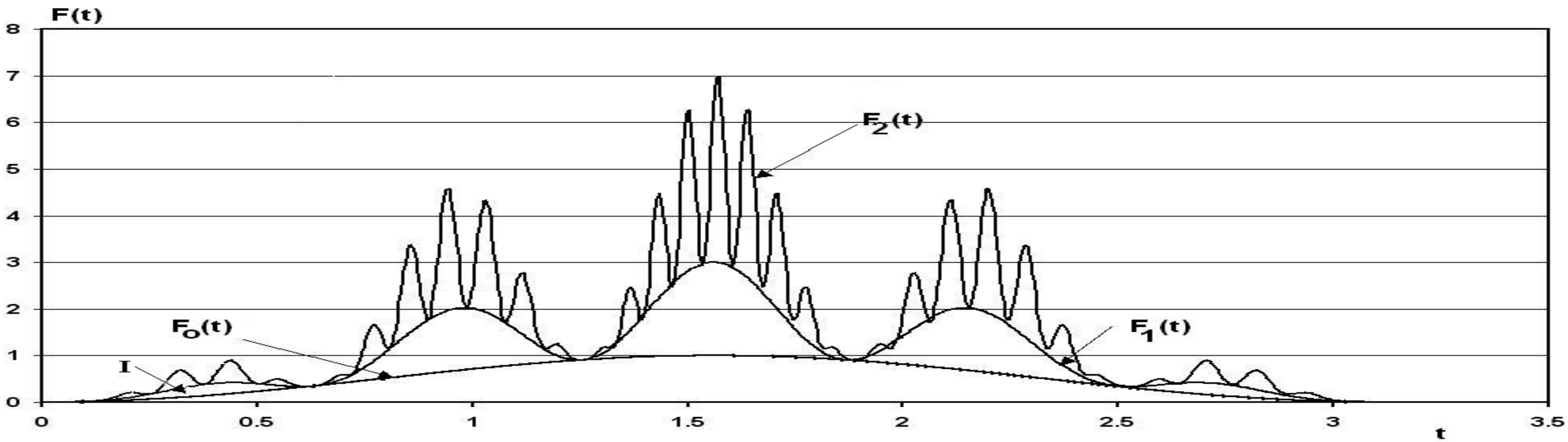
$$F_0(t) = A_0 \sin^2(\omega_0 t)$$



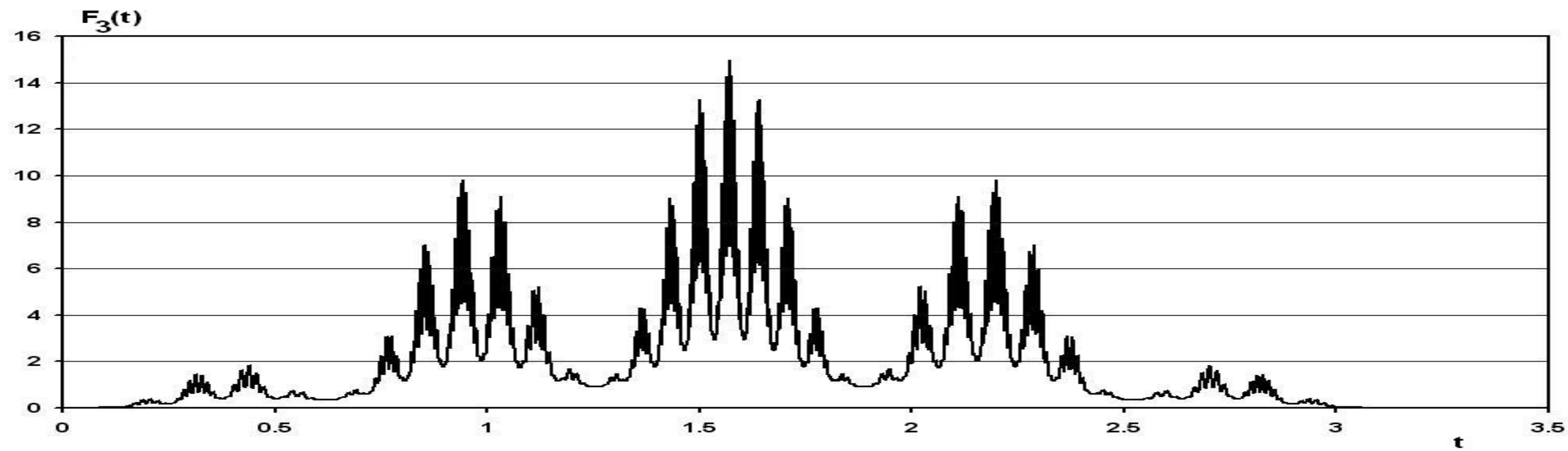

$$F_1(t) = A_0 \sin^2(\omega_0 t)(1 + A_1 \sin^2(\omega_1 t))$$



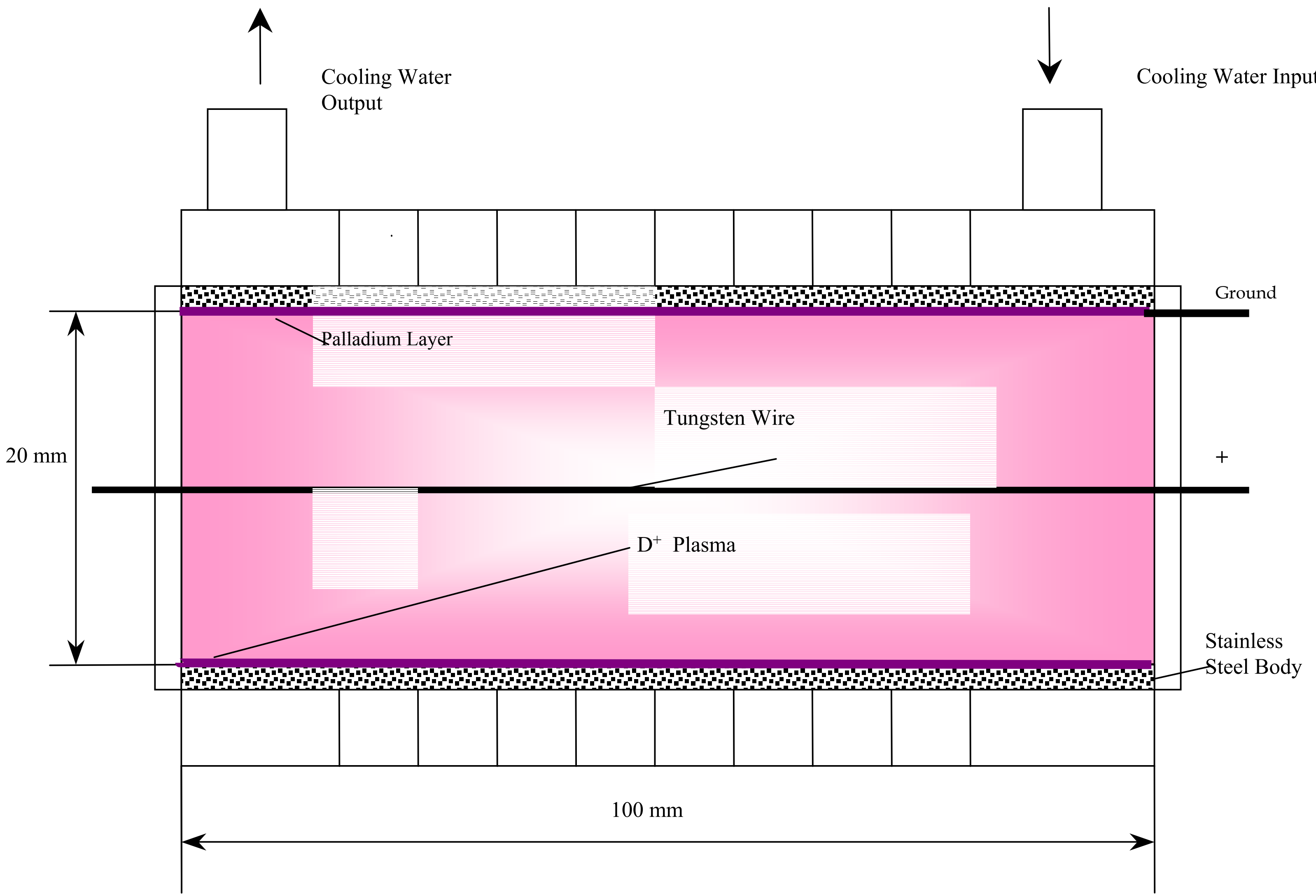
$$F_2(t) = A_0 \sin^2(\omega_0 t)[1 + A_1 \sin^2(\omega_1 t)(1 + A_2 \sin^2(\omega_2 t))]$$




$$F_3(t) = A_0 \sin^2(\omega_0 t)[1 + A_1 \sin^2(\omega_1 t)(1 + A_2 \sin^2(\omega_2 t)(1 + A_3 \sin^2(\omega_3 t)))]$$



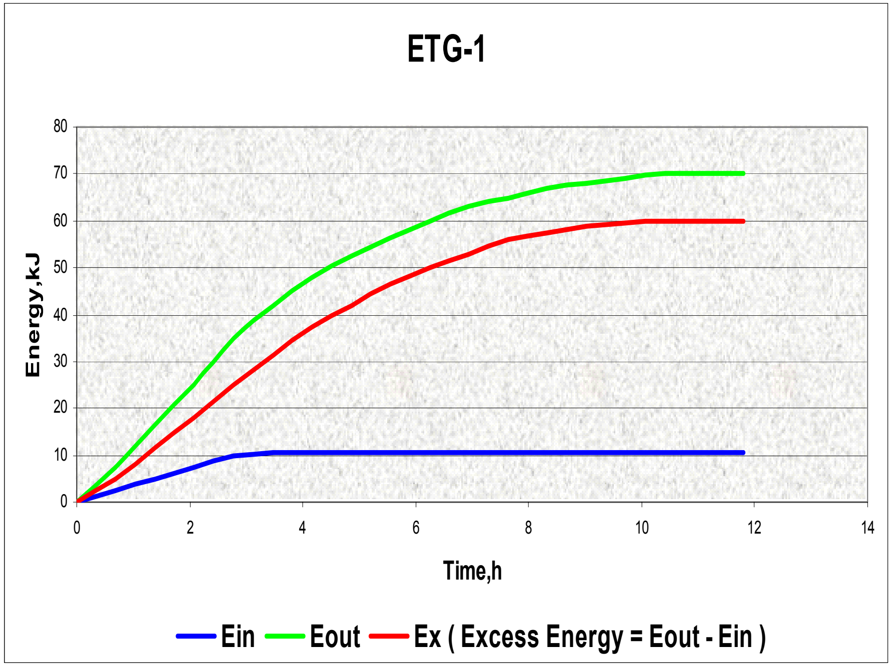
# Glow Discharge Cell

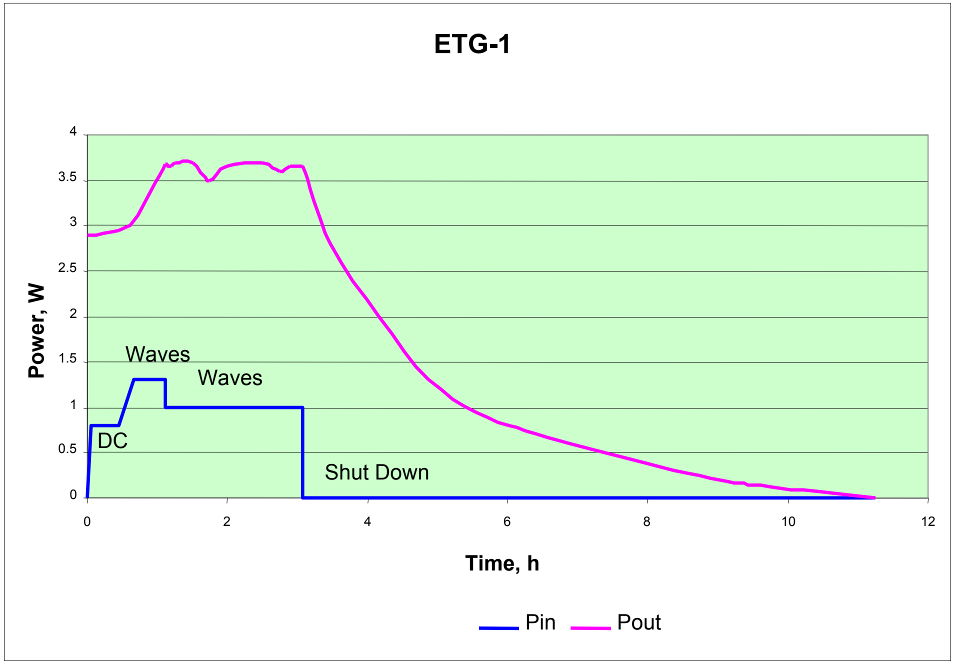



Conceptual Design

# Cell Assembly

# Experimental Results with thin Palladium film (about 1 μm) on Stainless Steel Body

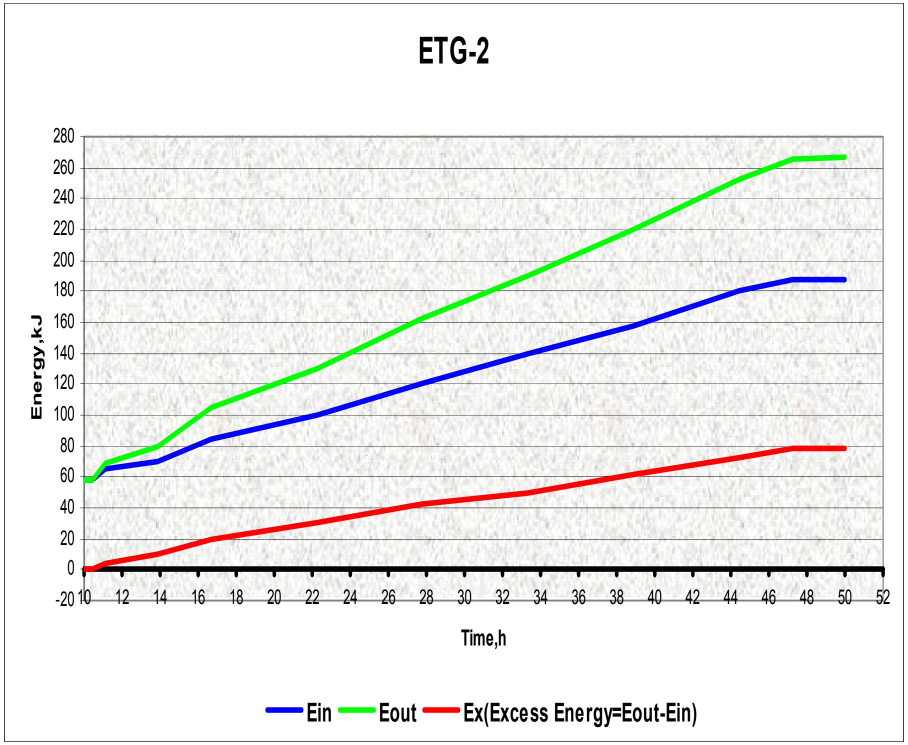


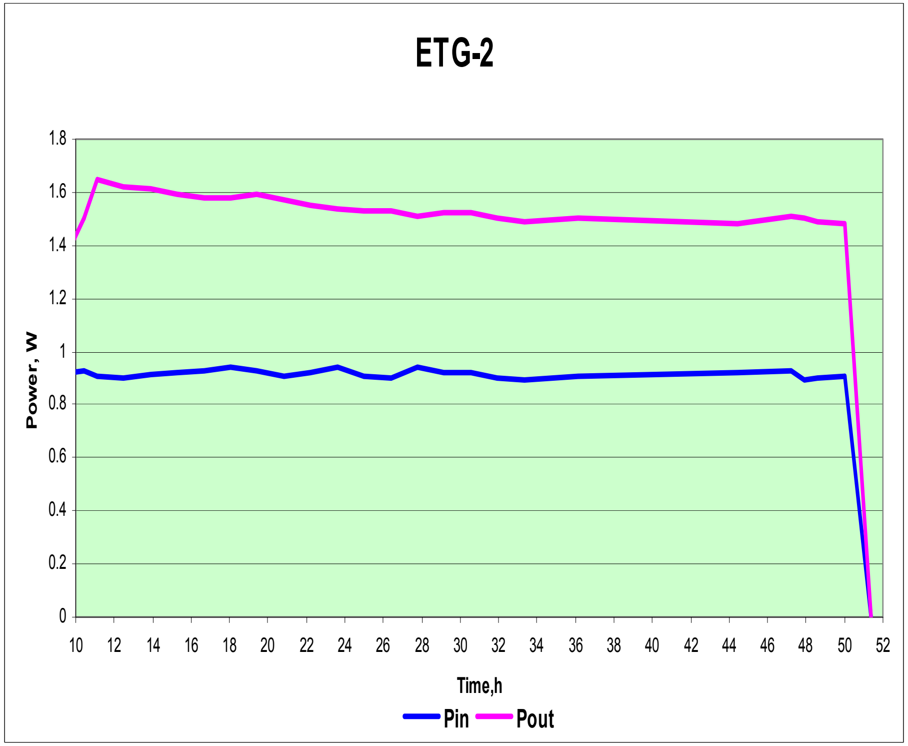




**Maximum Excess Power = 3.7 x Input Power**

**Total Excess Energy = 6.7 x Input Energy**

# Experimental Results with thick Palladium foil (100 μm)

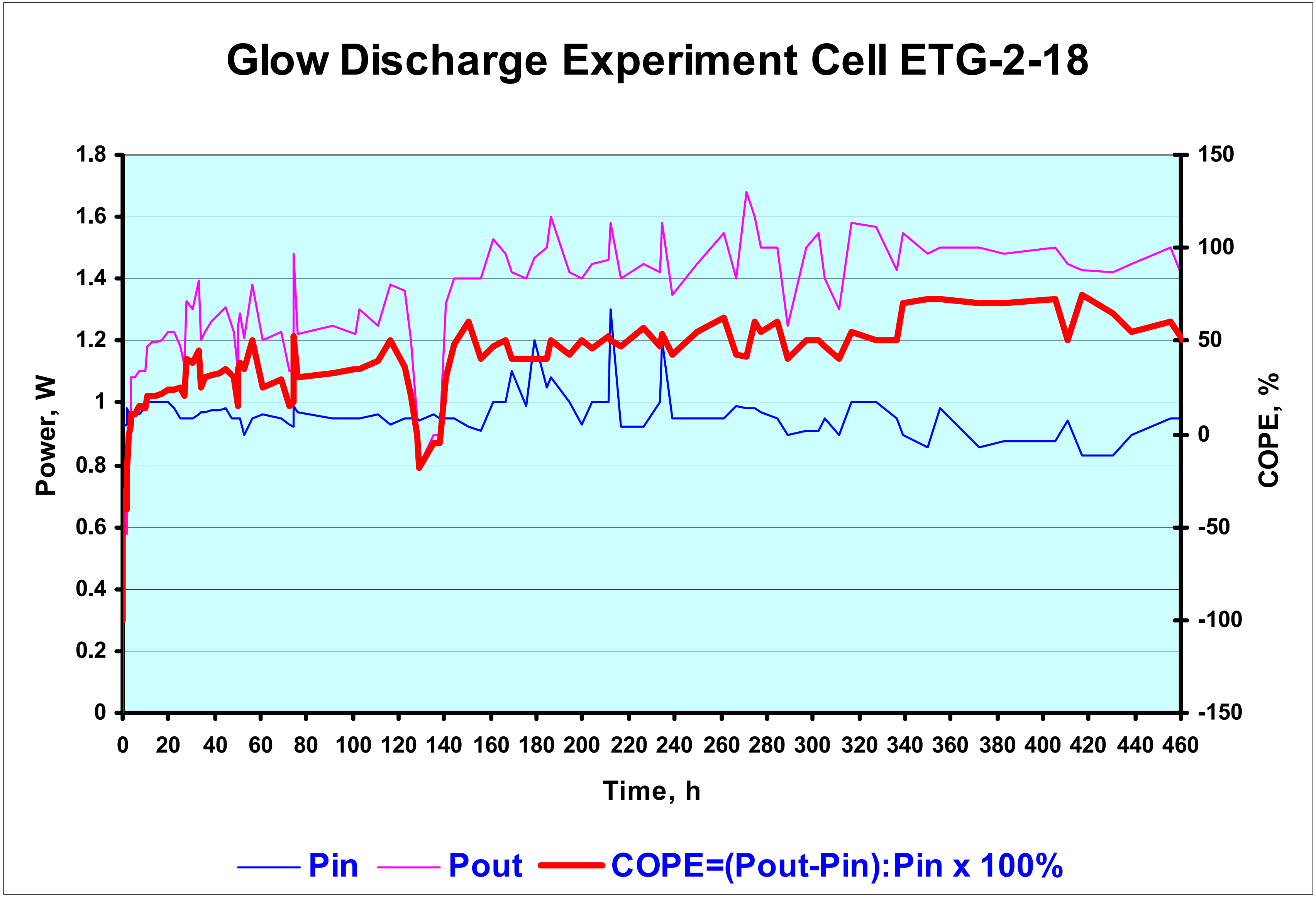


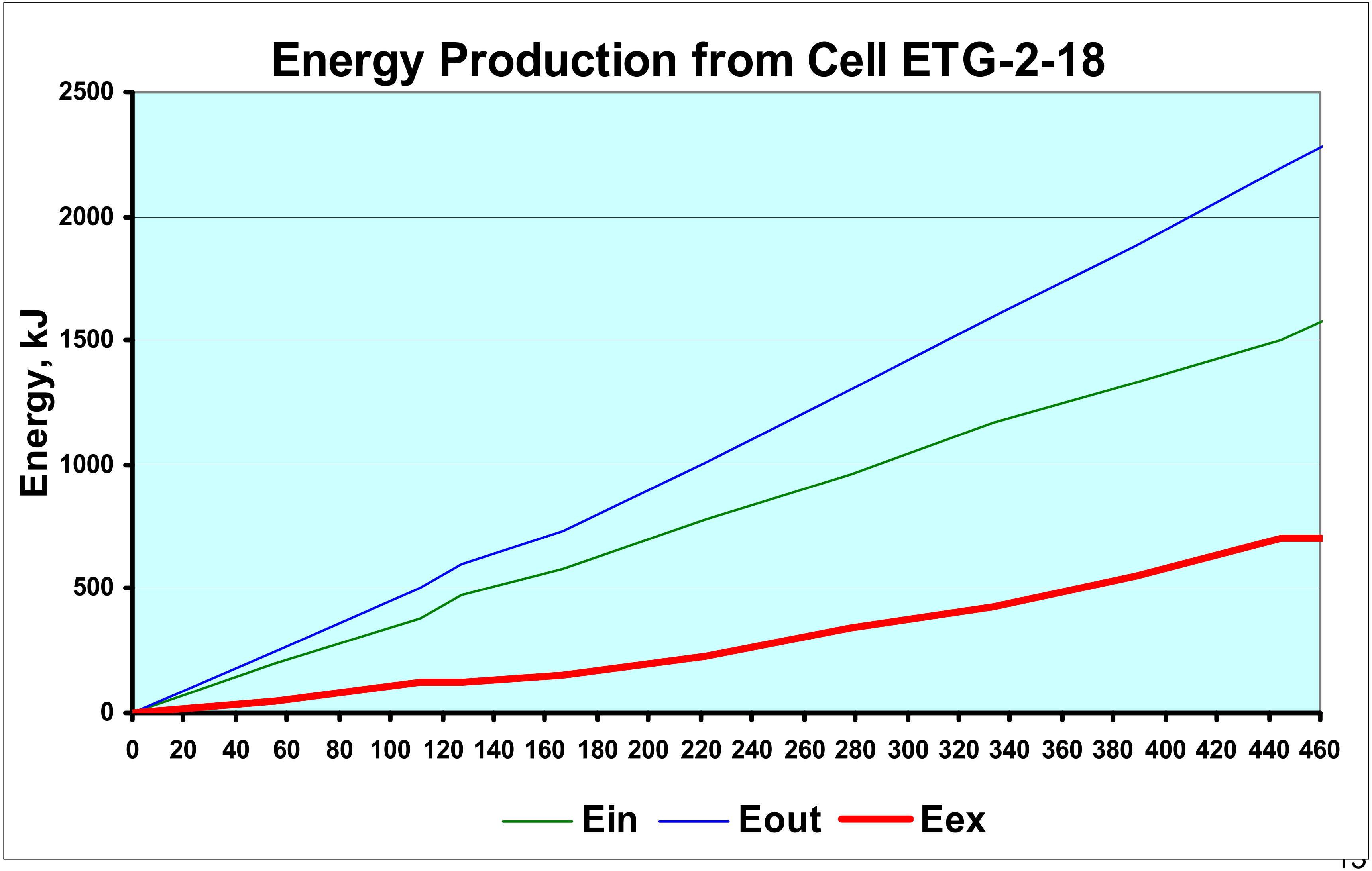

**Maximum Excess Power = 0.8 x Input Power**

**Total Excess Energy = 0.8 x Input Energy**

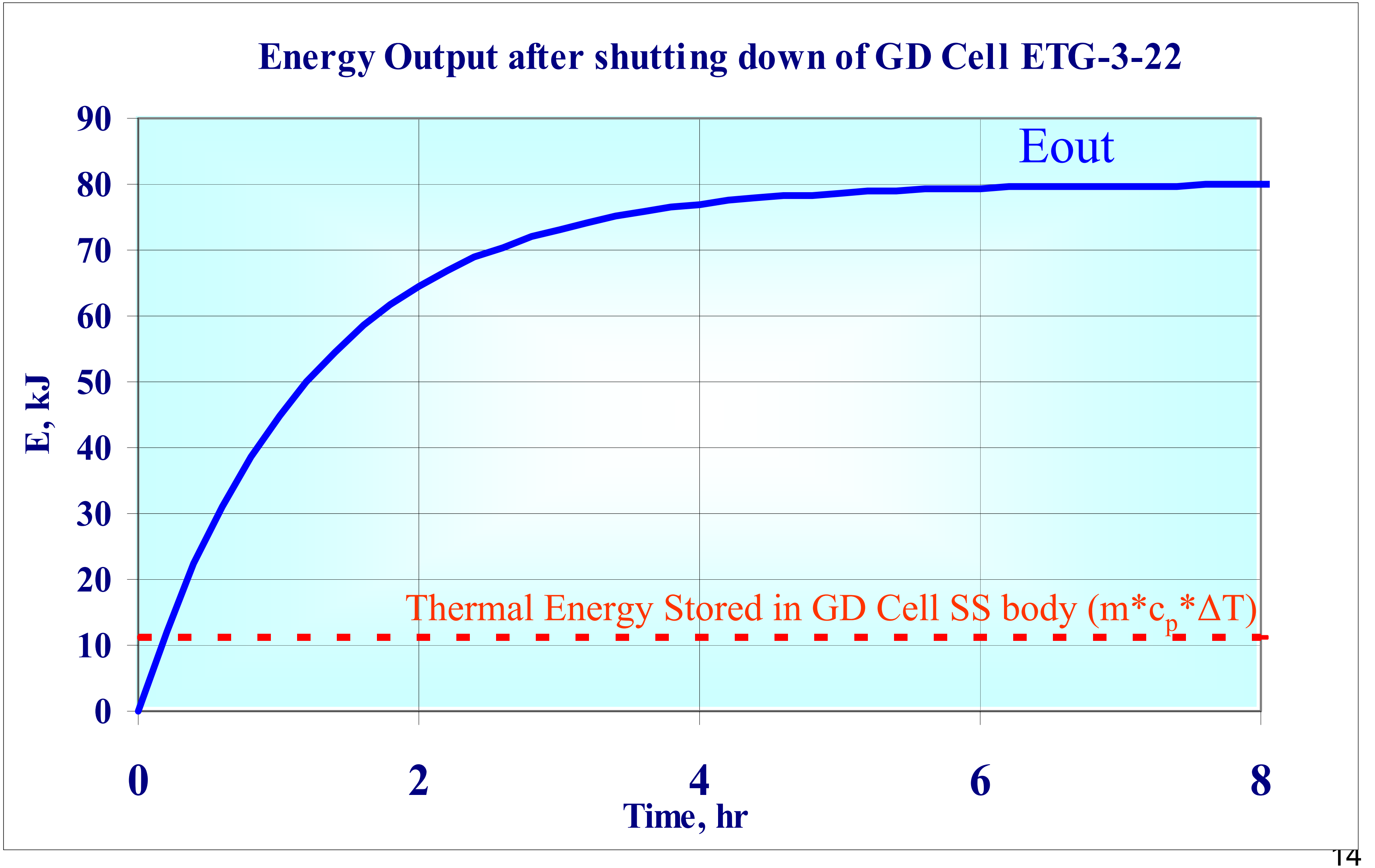
# Excess Heat Generation during 20 days



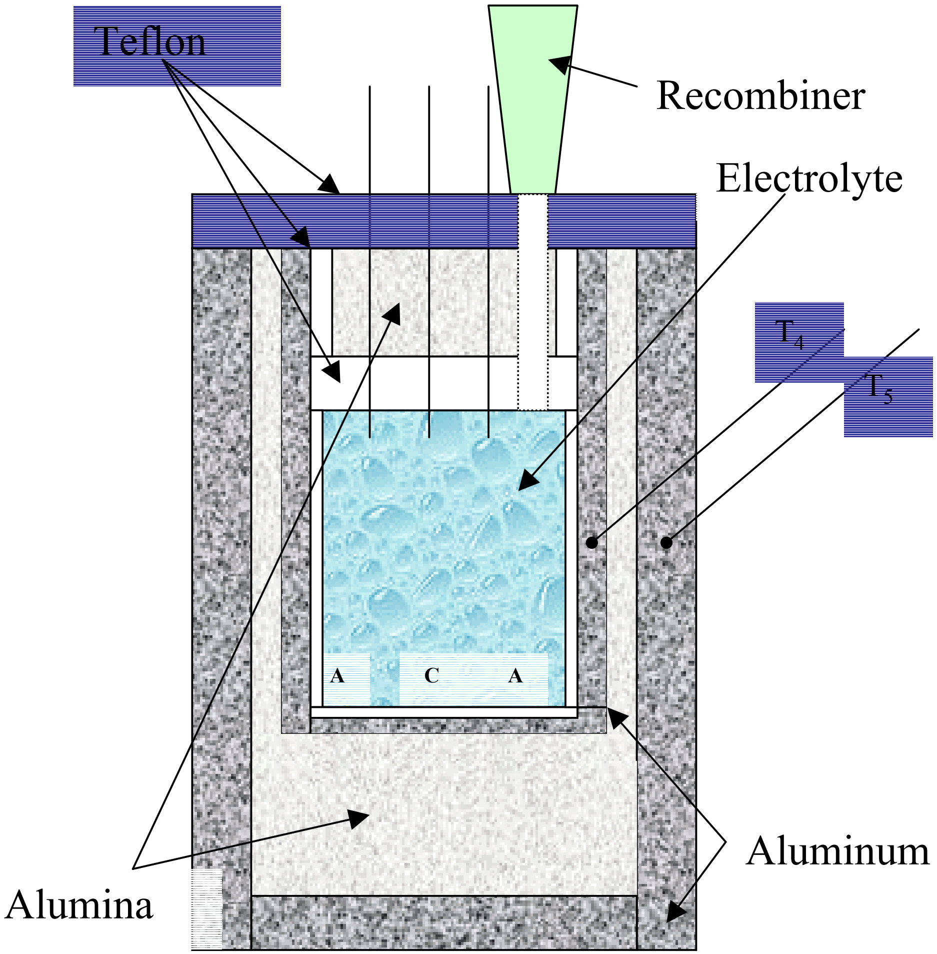
# Excess Energy during 20 days

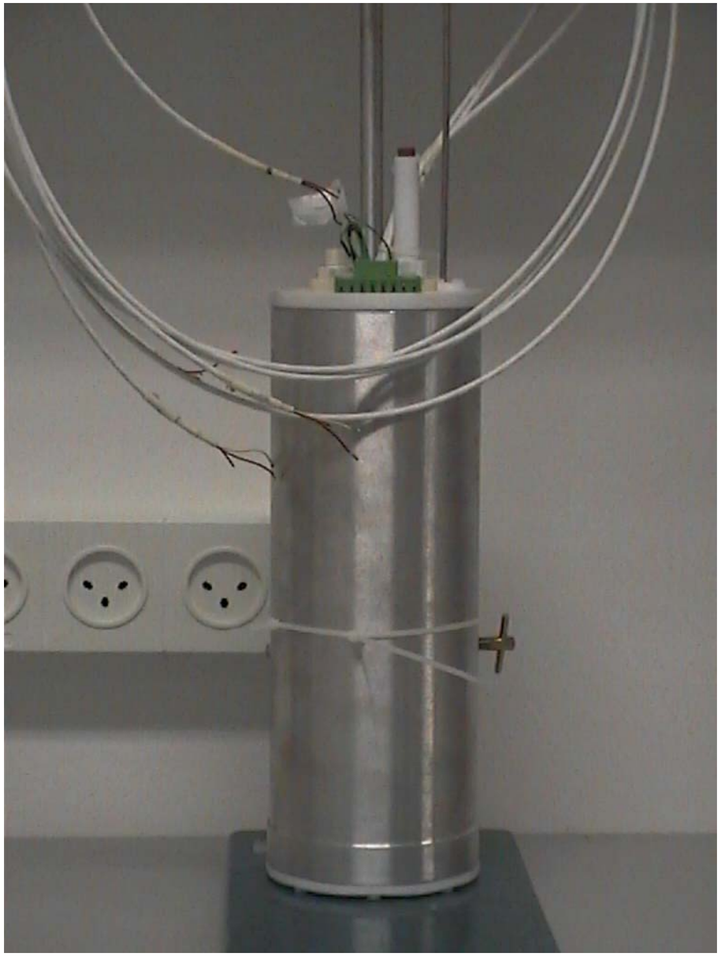


# "Heat After Death"



# ET Electrolytic Cell



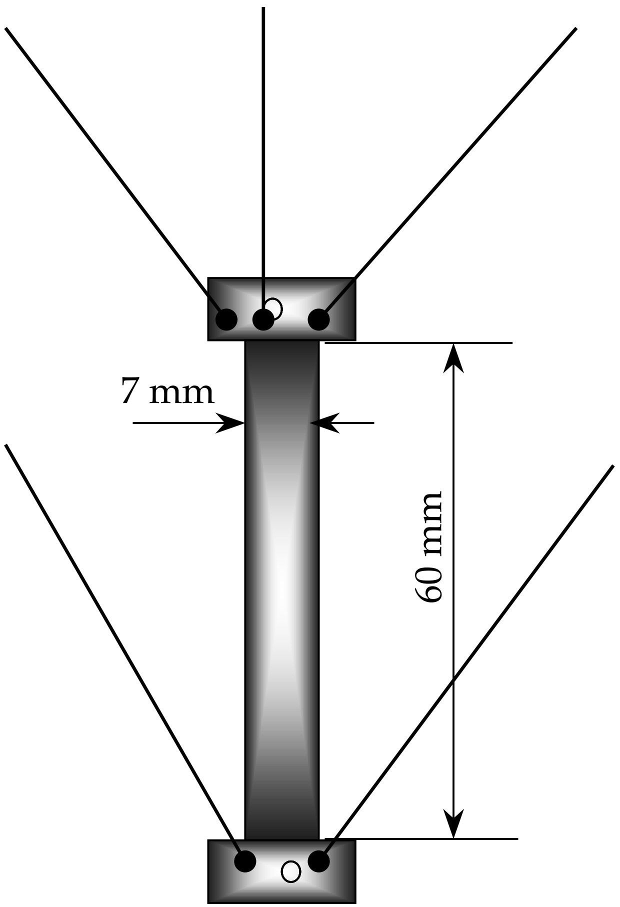
0.1M LiOD in low tritium content $D_2O$ (230 ml)

**EC is inside a Teflon beaker that is placed inside an isoperibolic calorimeter**

# Electrolytic Cell

Three cells are immersed in a constant temperature water bath of $+2.5^0C \pm 0.25^0C$

# Cathode & Pre-treatment




- 50 μm Pd foil, prepared by

  **Dr. Vittorio Violante** (ENEA Frascatti, Italy)
- Annealed at 870$^{o}$C in vacuum for 1h
- Etched:

  - in Nitric Acid 65-67%; 1 min

  - in Aqua Regia 1:1 water solution; 1 min
- Rinsed:

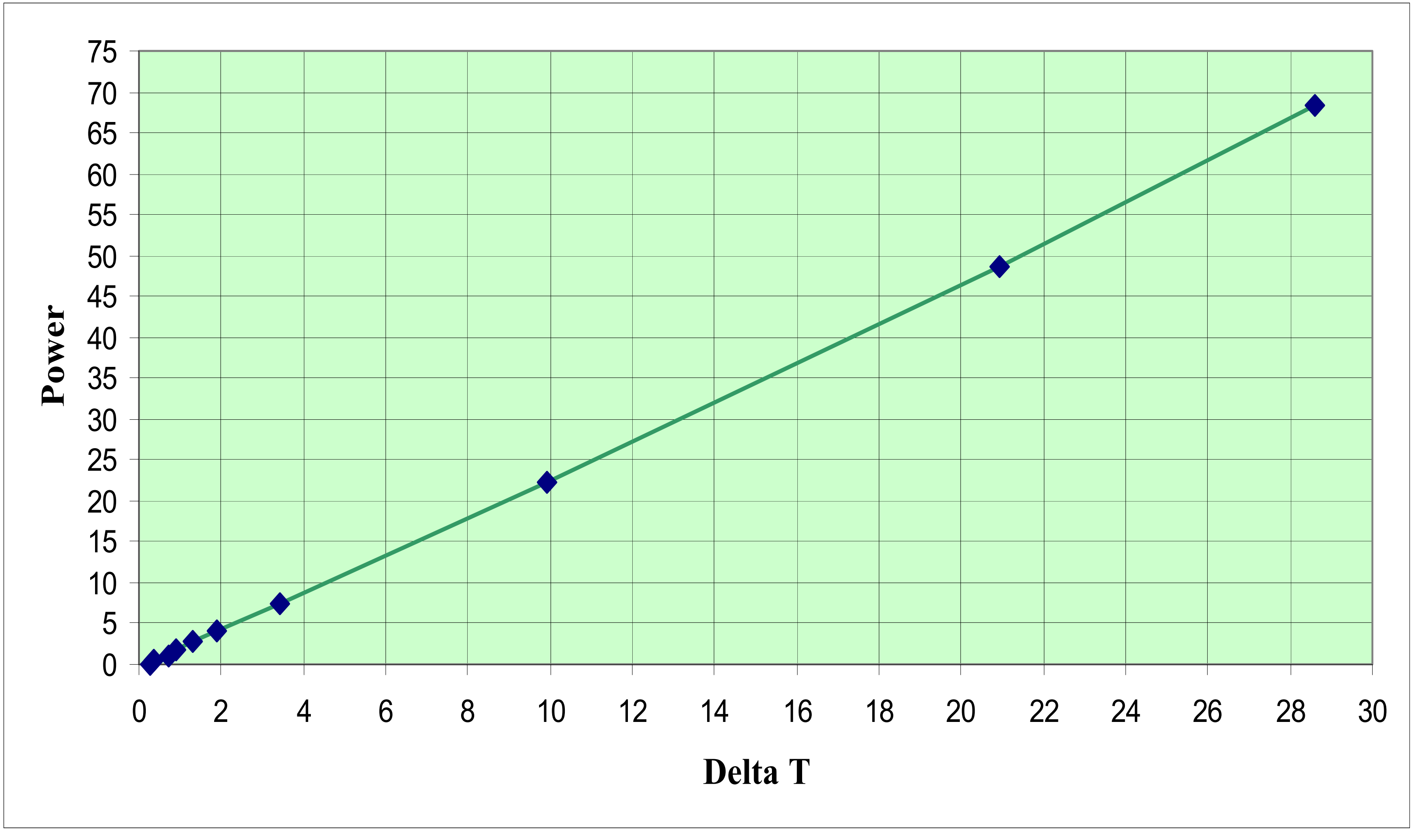
  - $D_2O$ four times

  - Ethanol 95% twice

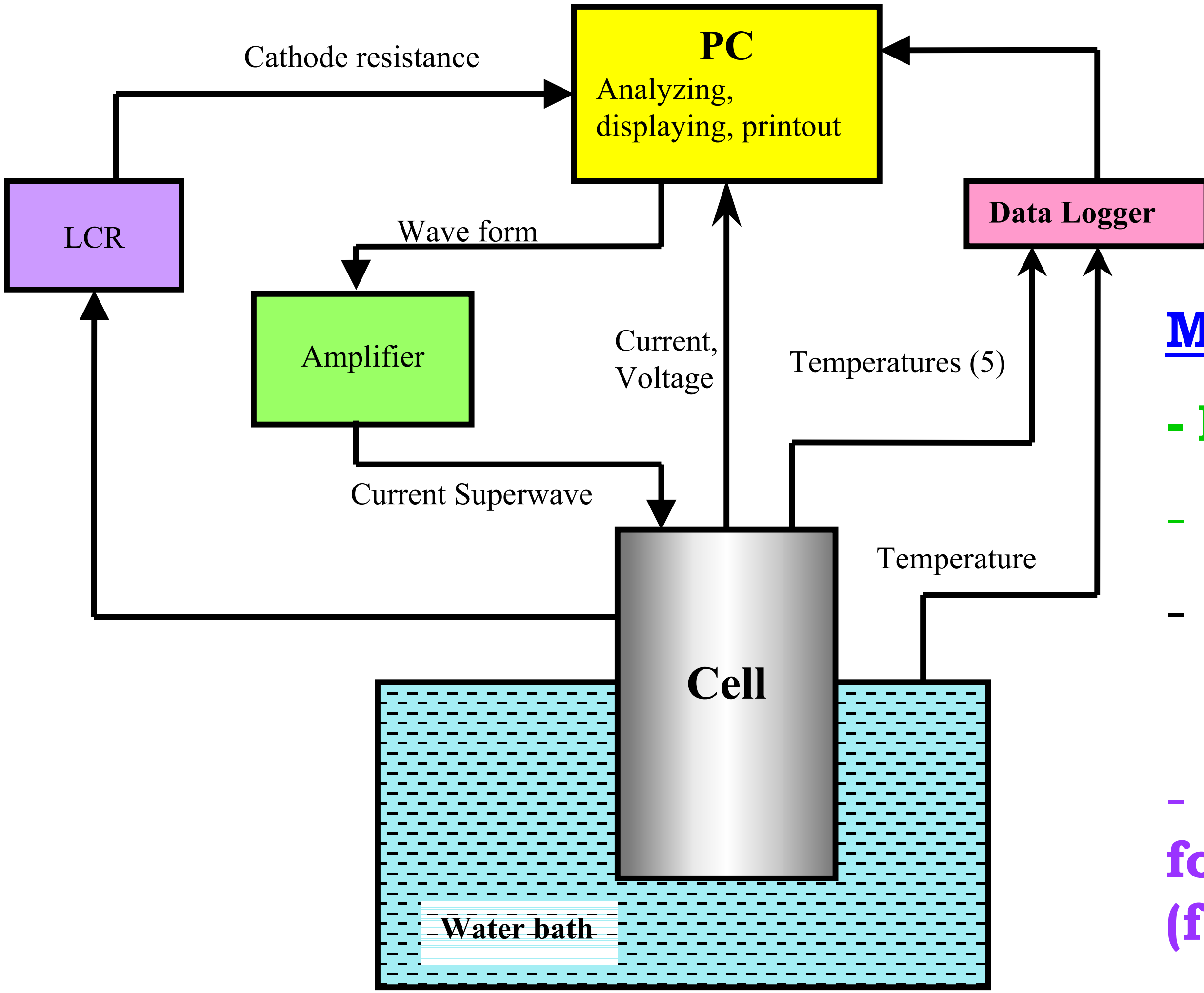
  - Ethanol Absolute once
- Dried:

  in vacuum at ambient temperature for 24 h

# Typical Calibration Curve for Electrolytic Cell Calorimeter



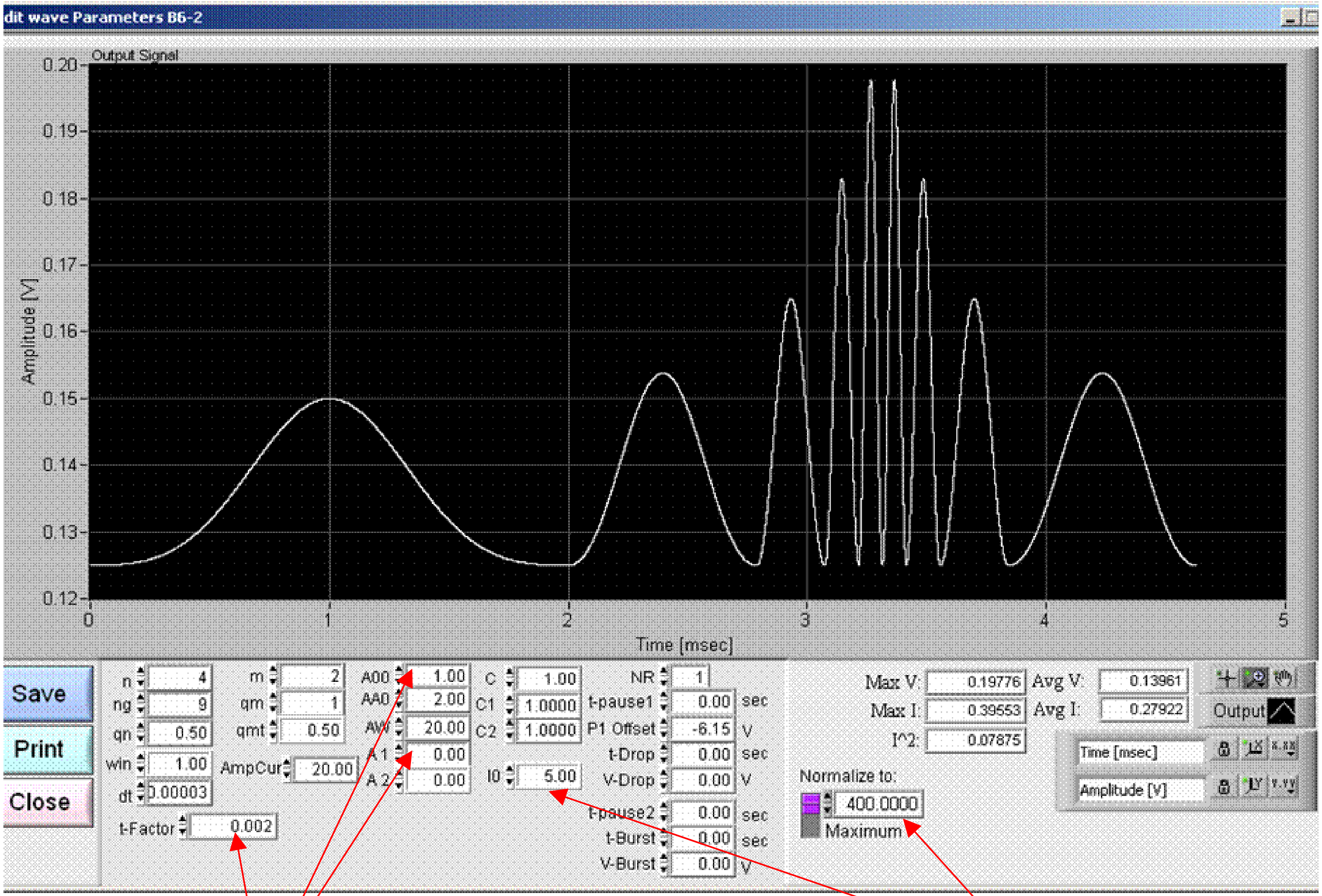
# Block diagram




**Measured Parameters:**

- **Input Current**
- **Input Voltage**
- **Wall Temperatures $T_4$ and $T_5$**
- **Resistance of cathode for monitoring loading (four probe AC method)**

# Study of Influence of Modulations on Loading

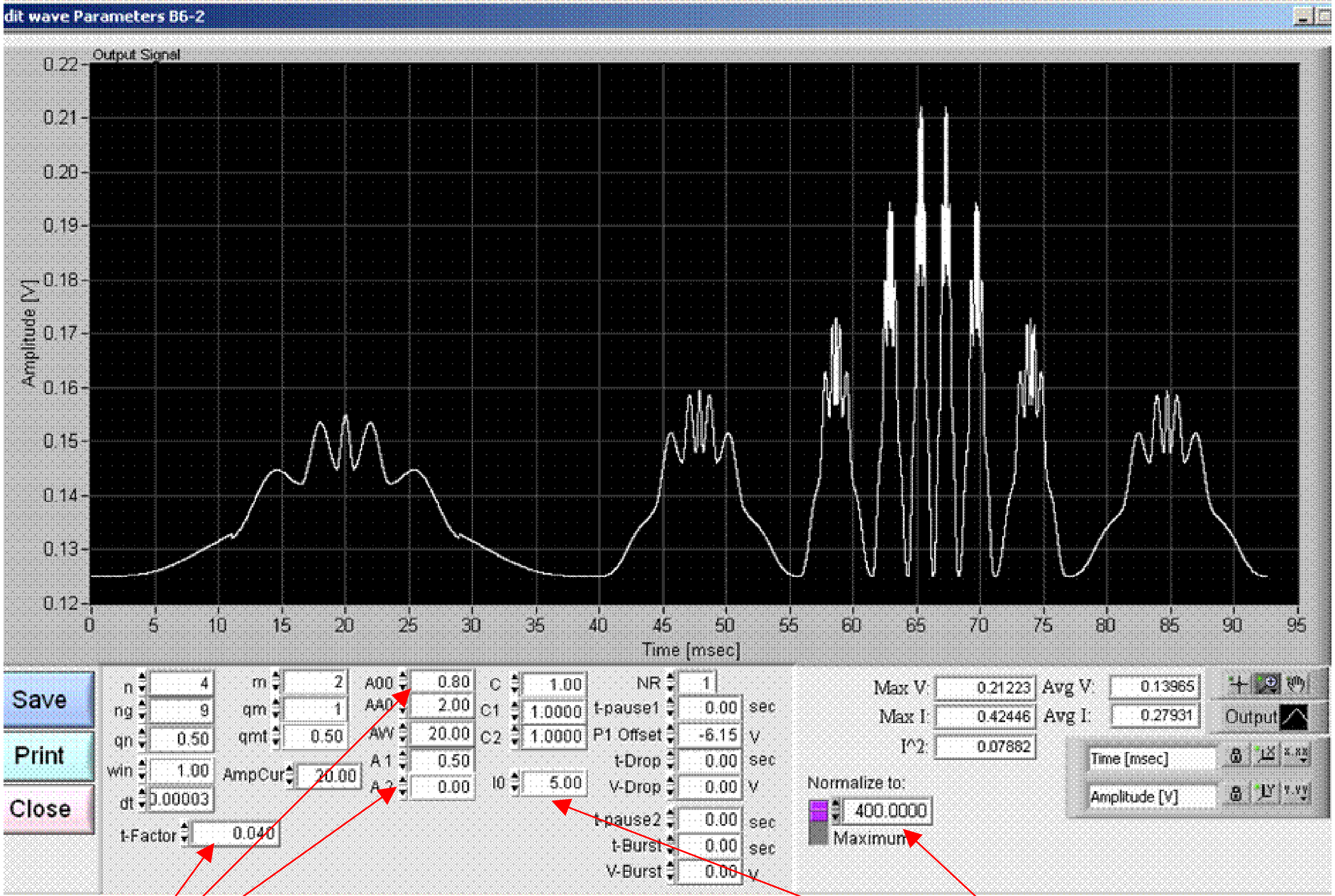



Changeable parameters

$1^{st}$ level of modulation

Constant parameters

# Study of Influence of Modulations on Loading

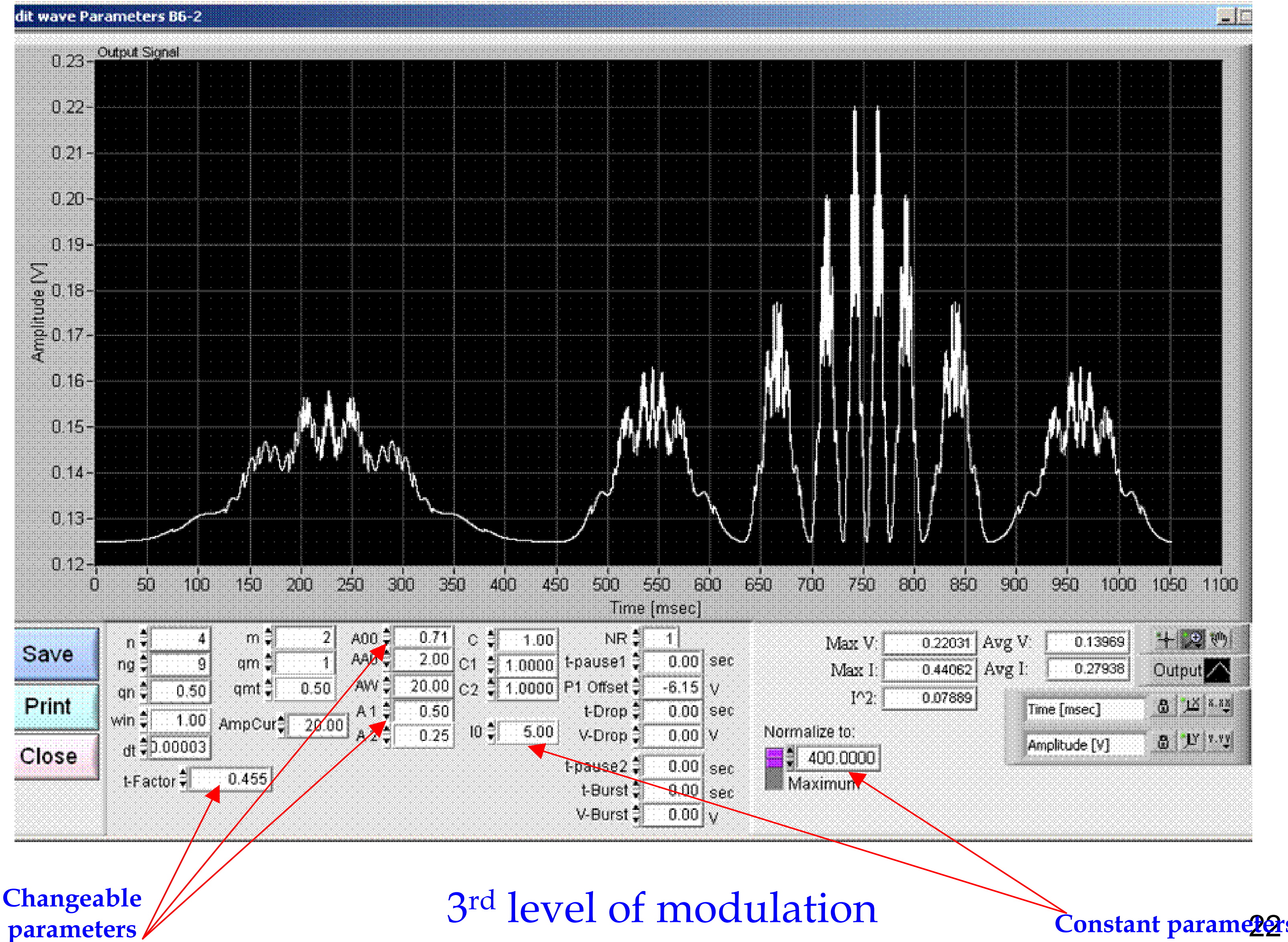



2nd level of modulation

Changeable parameters

Constant parameters

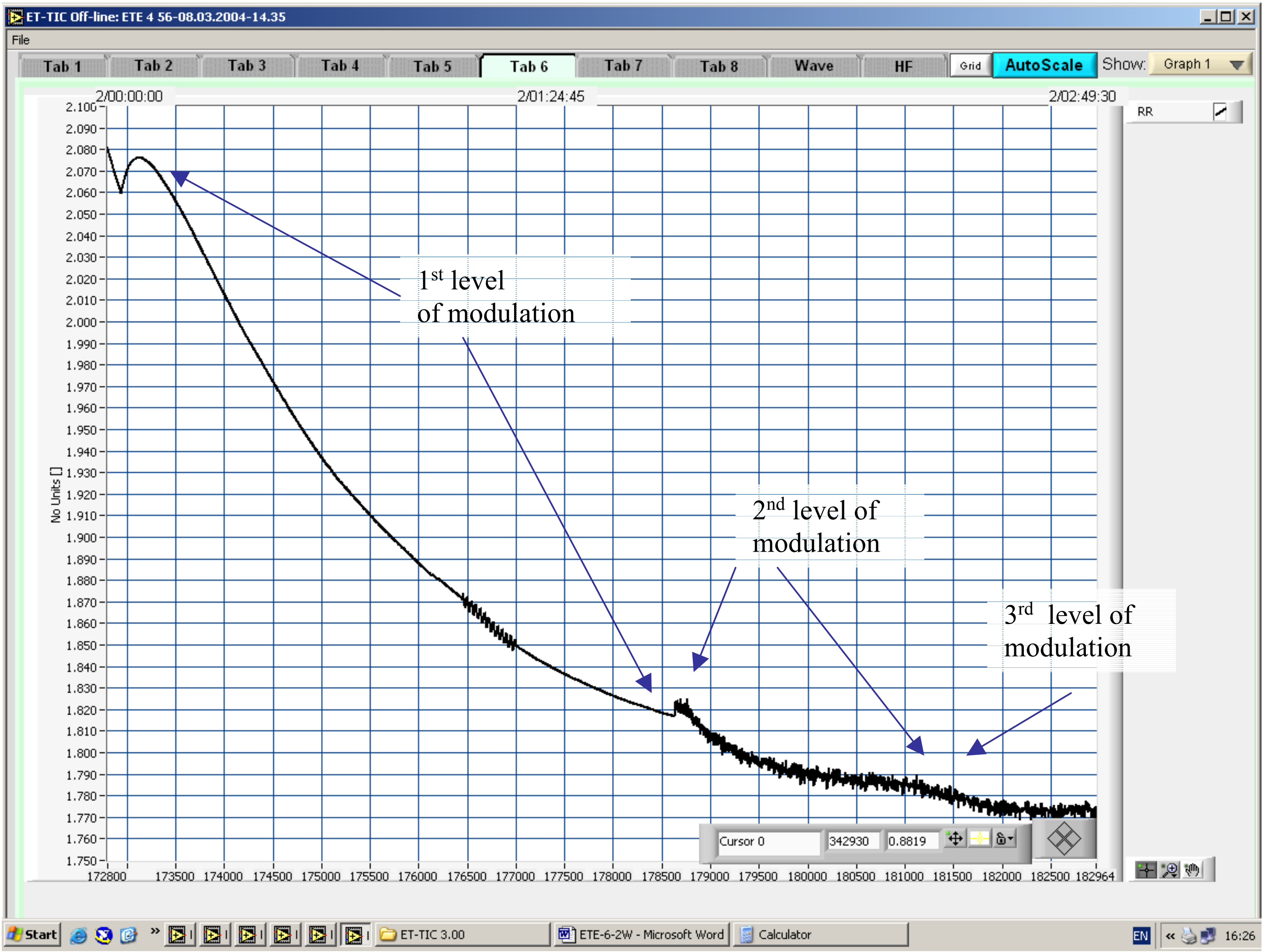
# Study of Influence of Modulations on Loading




3rd level of modulation

# Study of Influence of Modulations on Loading

1.

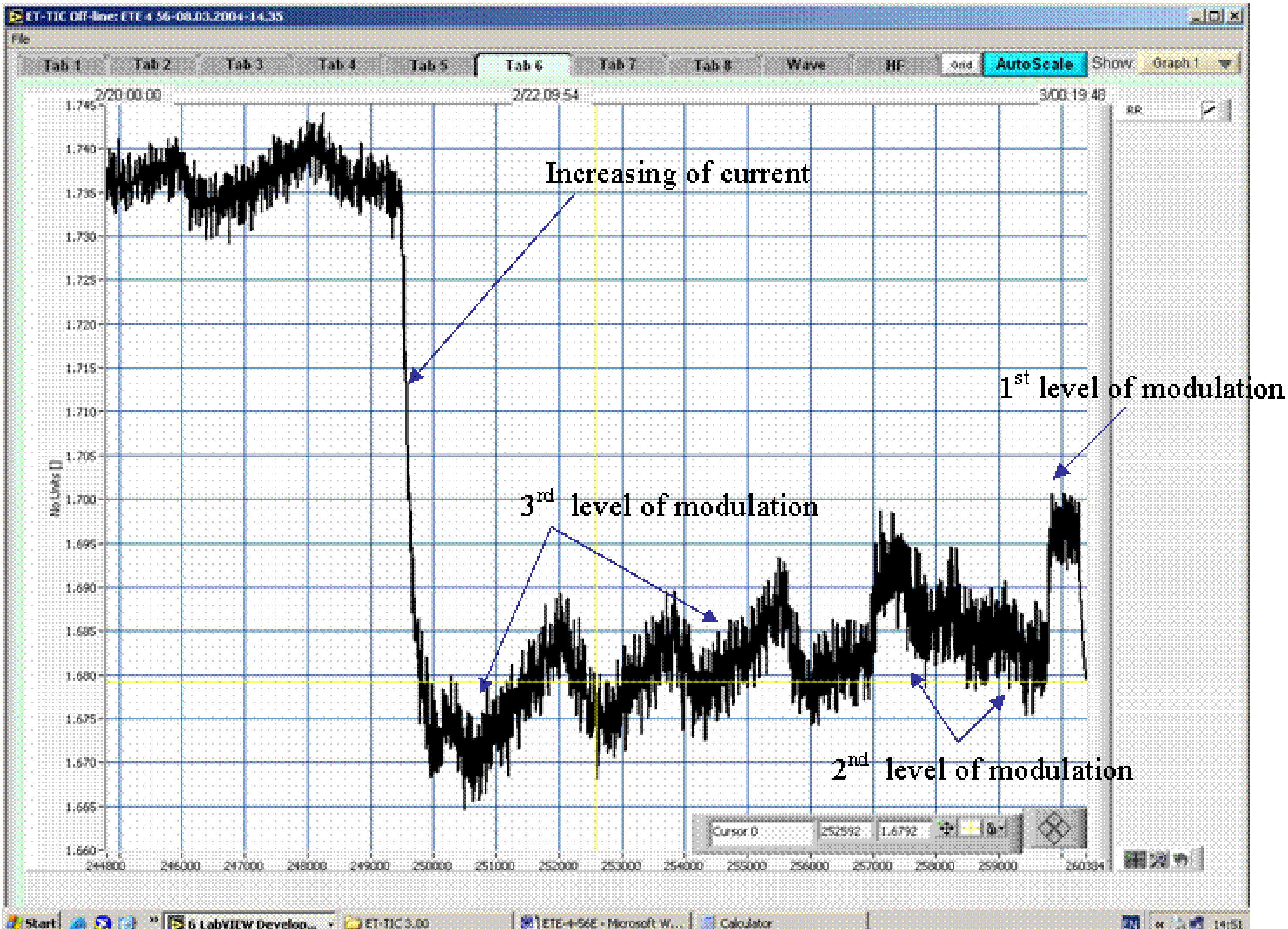





Of-line $RR_0$ versus time for Foil N$^0$56 (Dr.Violante)

# Study of Influence of Modulations on Loading

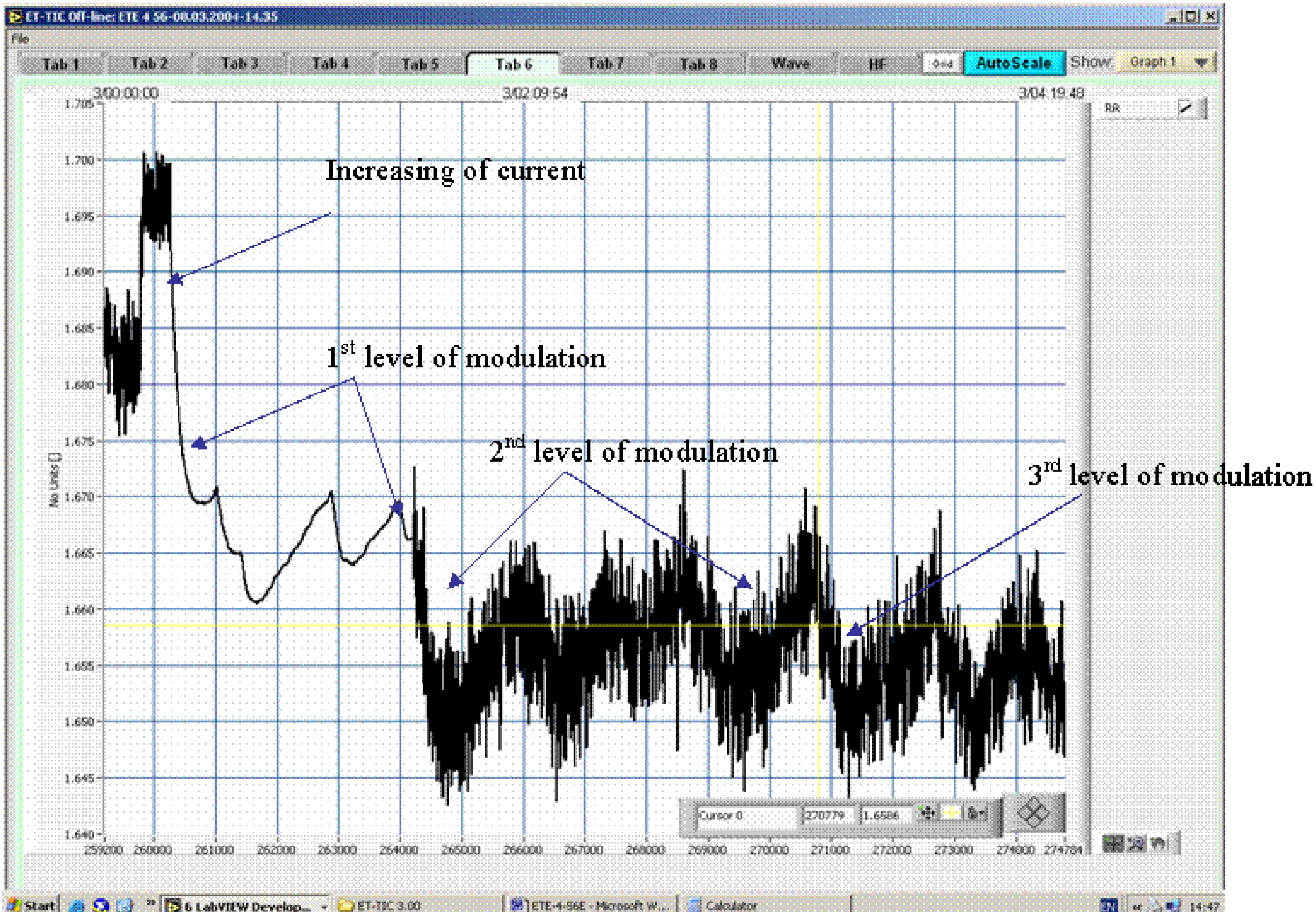
2.




Of-line $RR_0$ versus time for Foil N⁰56 (Dr.Violante)

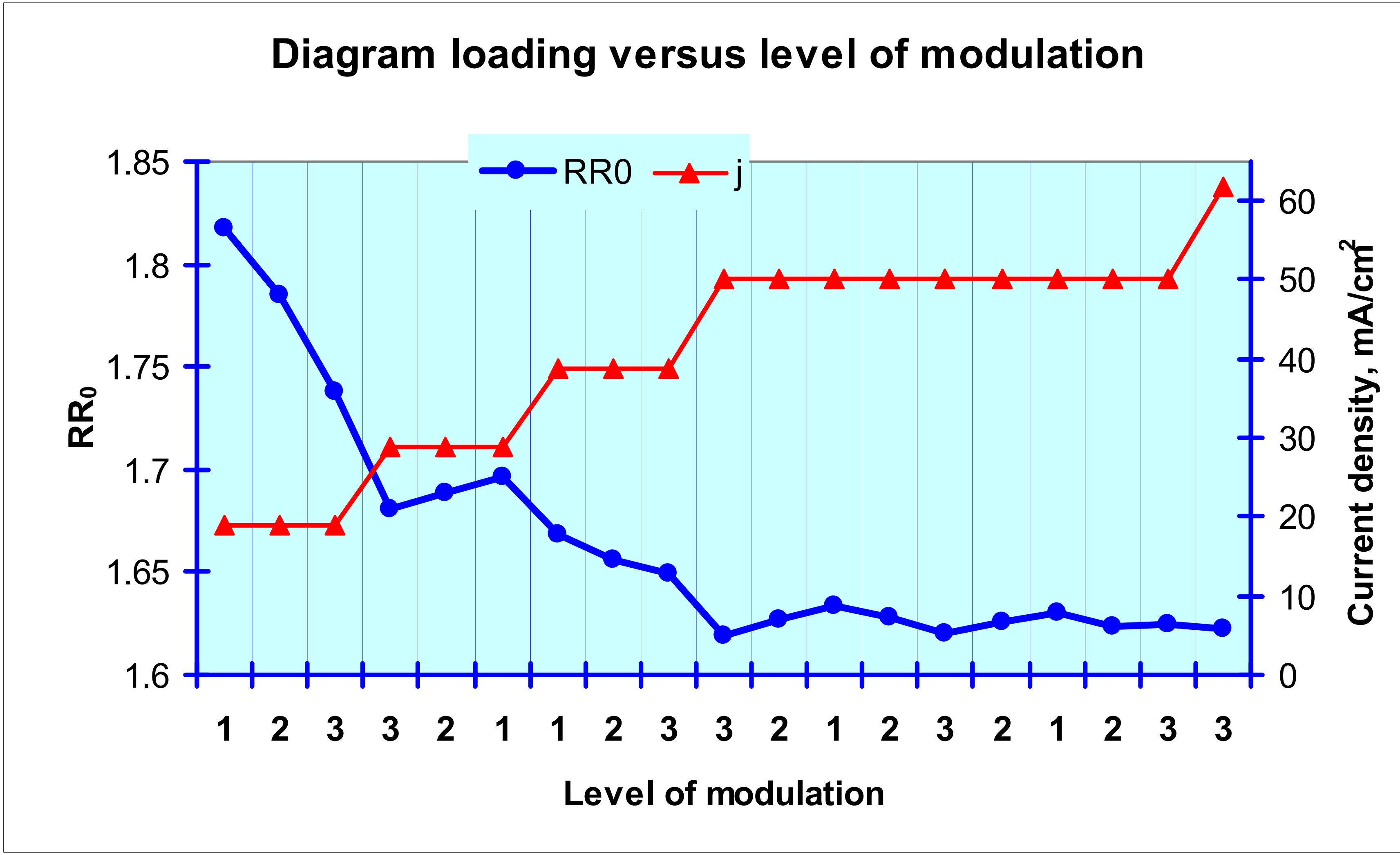
# Study of Influence of Modulations on Loading

3.



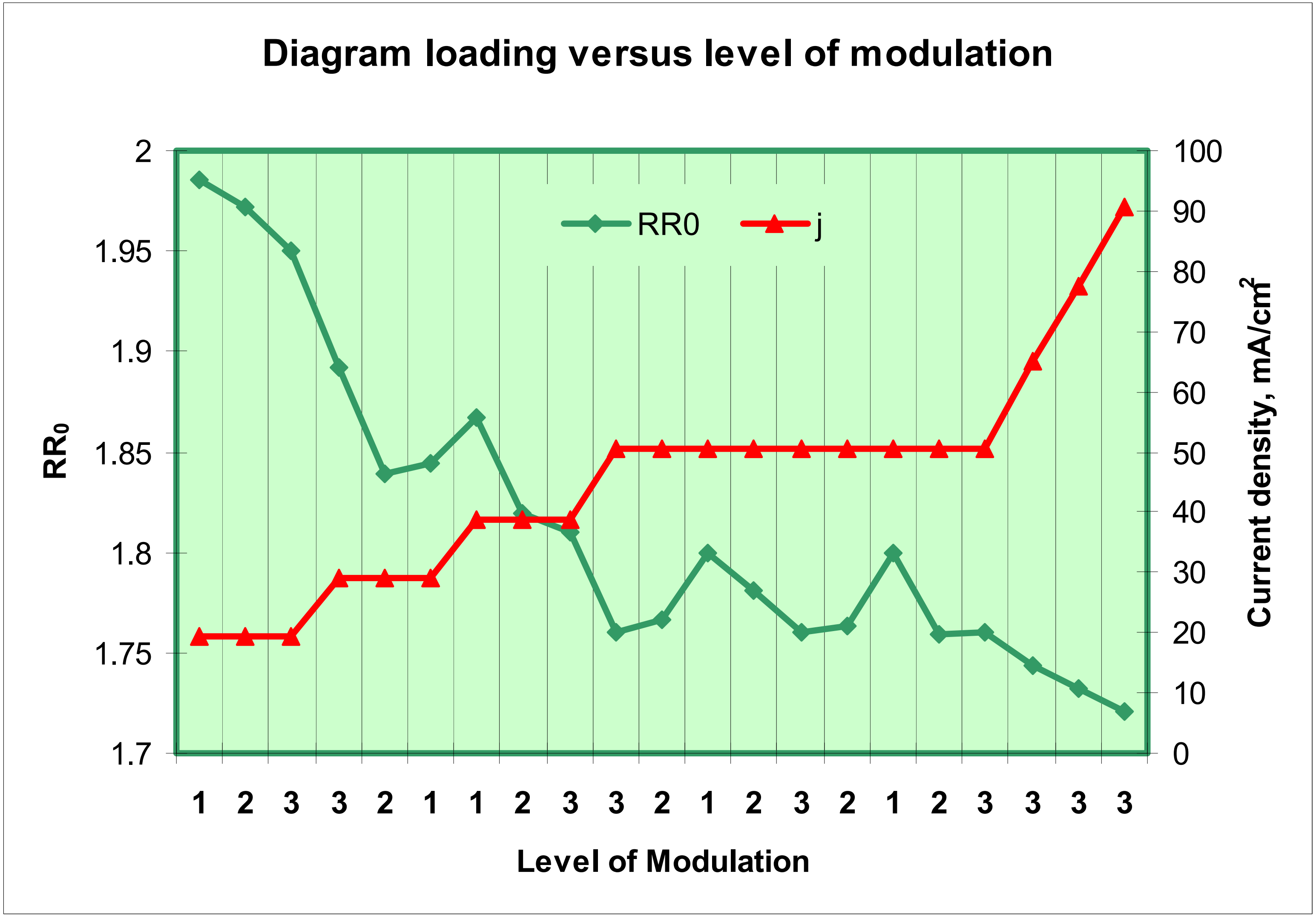

Of-line $RR_0$ versus time for Foil N$^0$56 (Dr.Violante)

# Study of Influence of Modulations on Loading



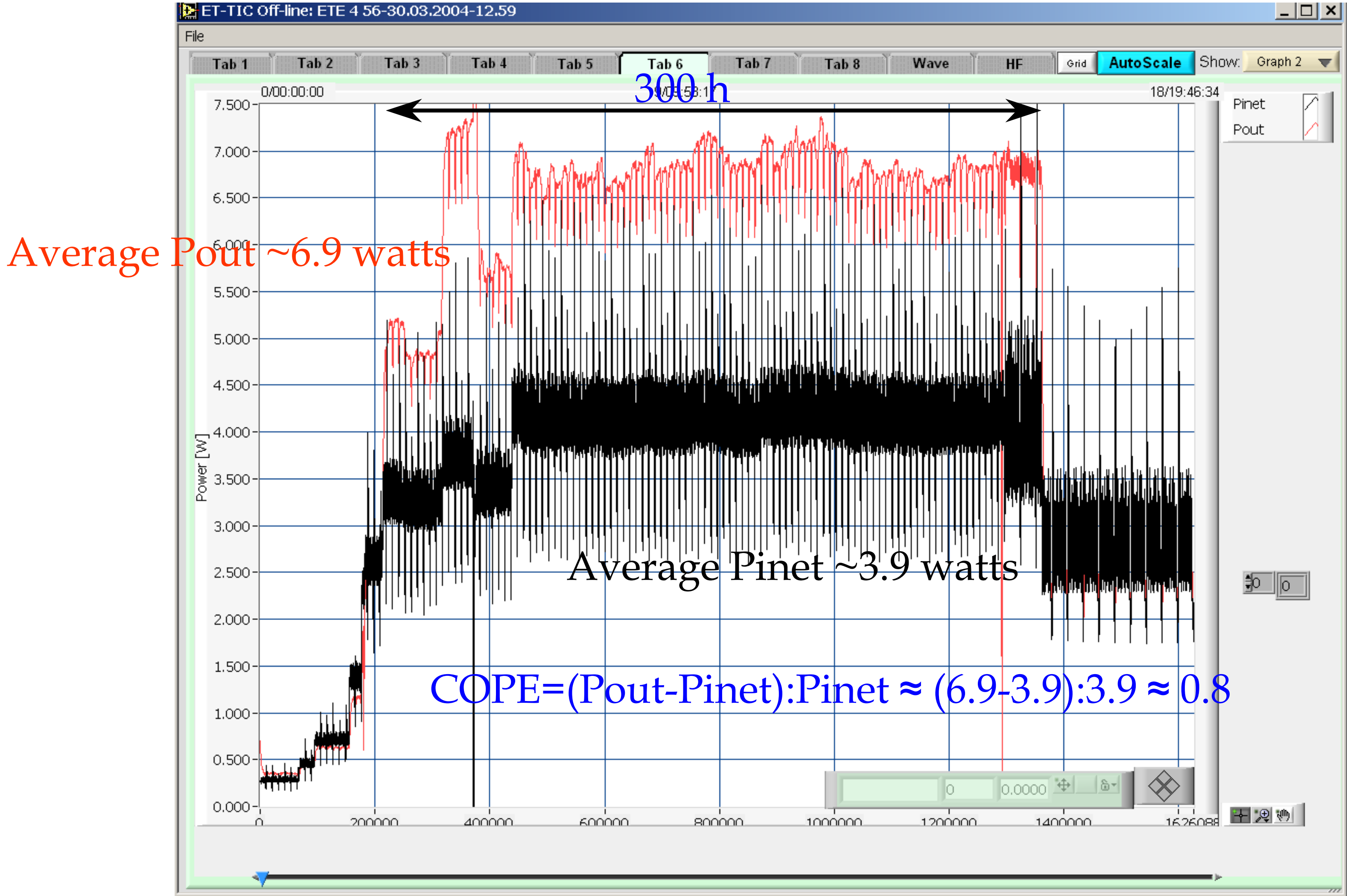

Foil N⁰56 (Dr.Violante)

# Study of Influence of Modulations on Loading



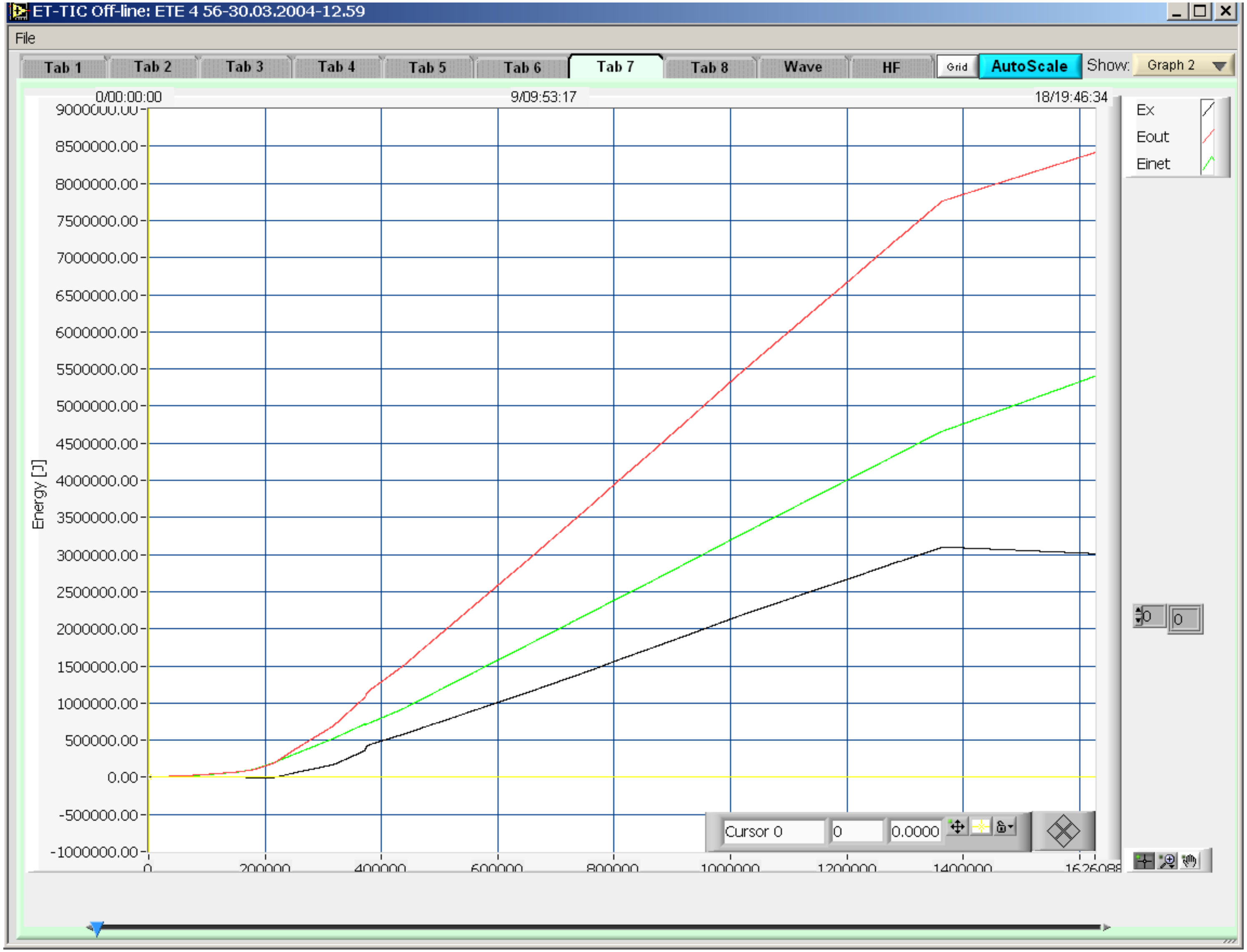

Foil N⁰51 (Dr.Violante)

# Excess Power; Exp. # 56



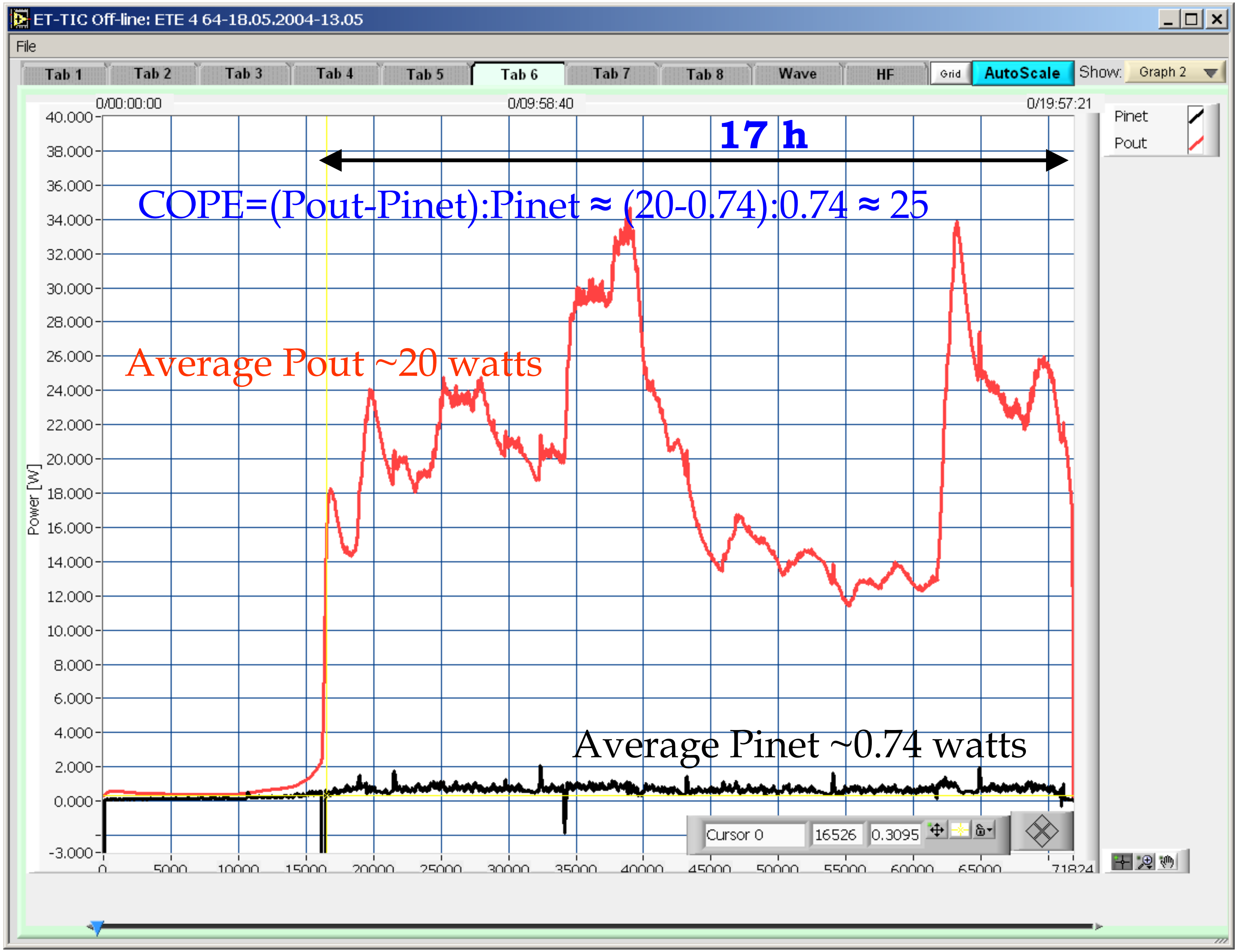

Excess Power of up to ~3.5 watts; Average ~2.7 watts for ~300 h

# Excess Energy; Exp. # 56



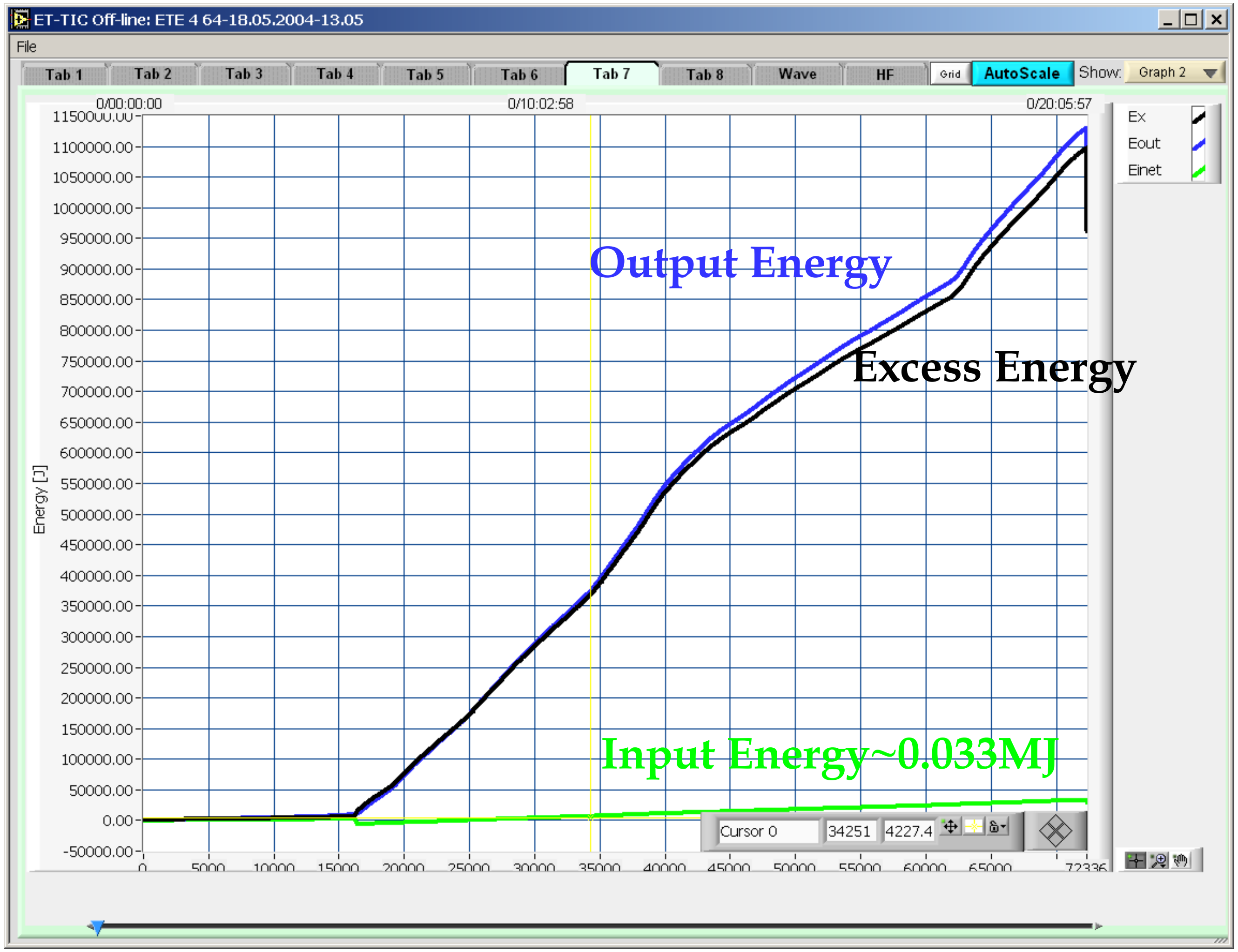

Excess energy of ~3.1 MJ

# Excess Power; Exp. # 64a




Excess Power of up to 34 watts; Average ~20 watts for 17 h

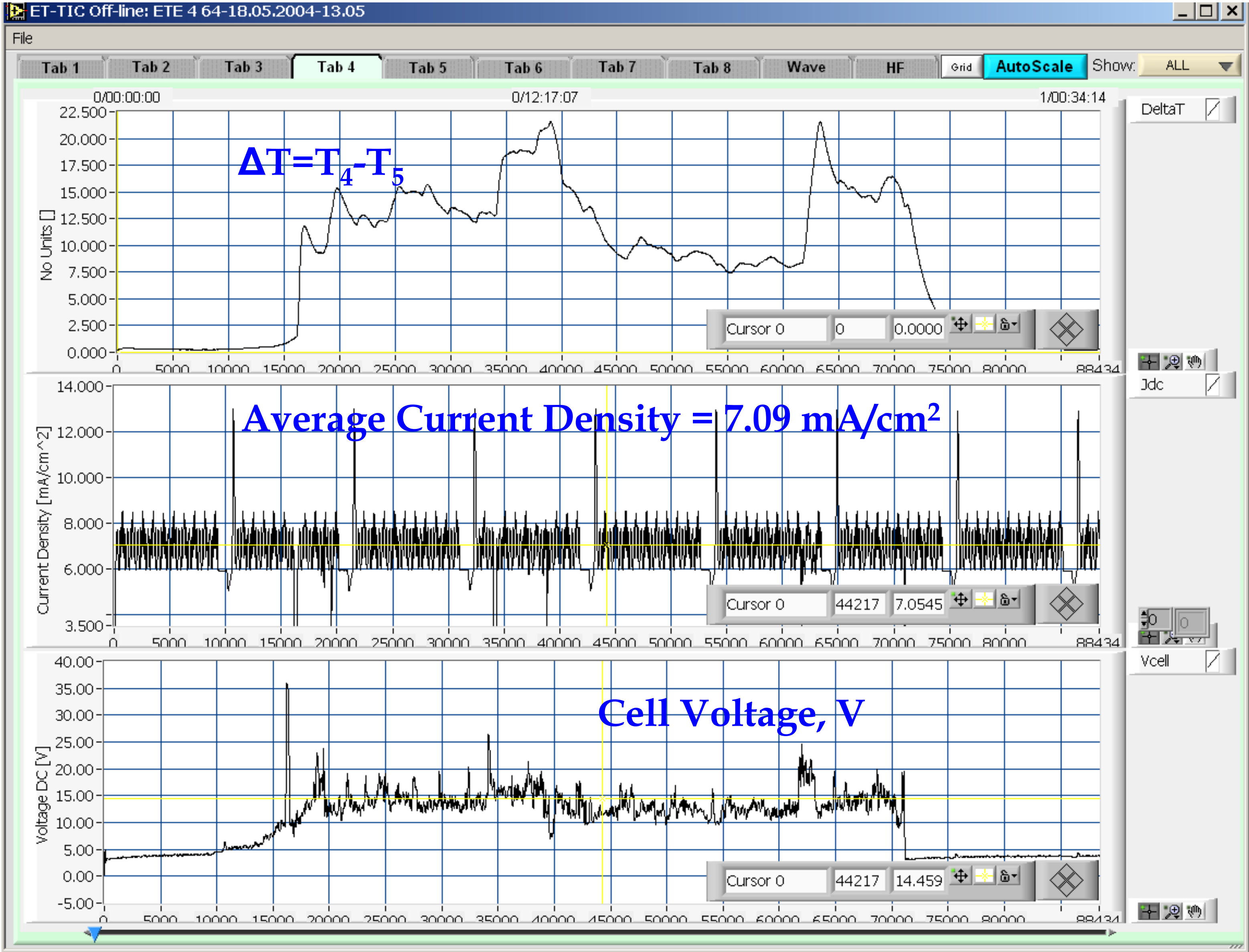
# Excess Energy; Exp. # 64a




Excess energy of ~1.1 MJ

# Temperature Evolution, Exp. # 64a

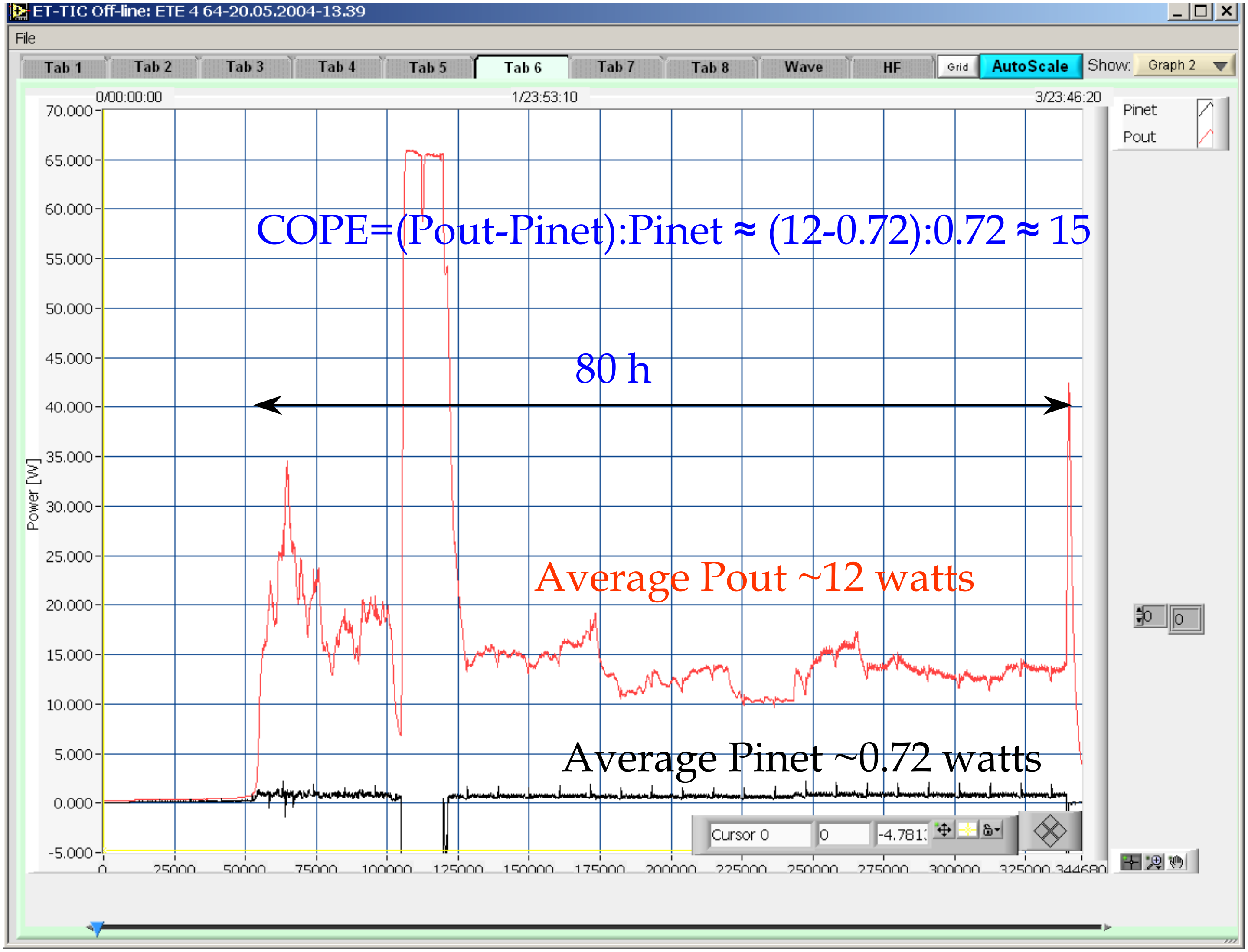
# Current & Voltage; EXP. # 64a



# R/Ro & Power; EXP. # 64a

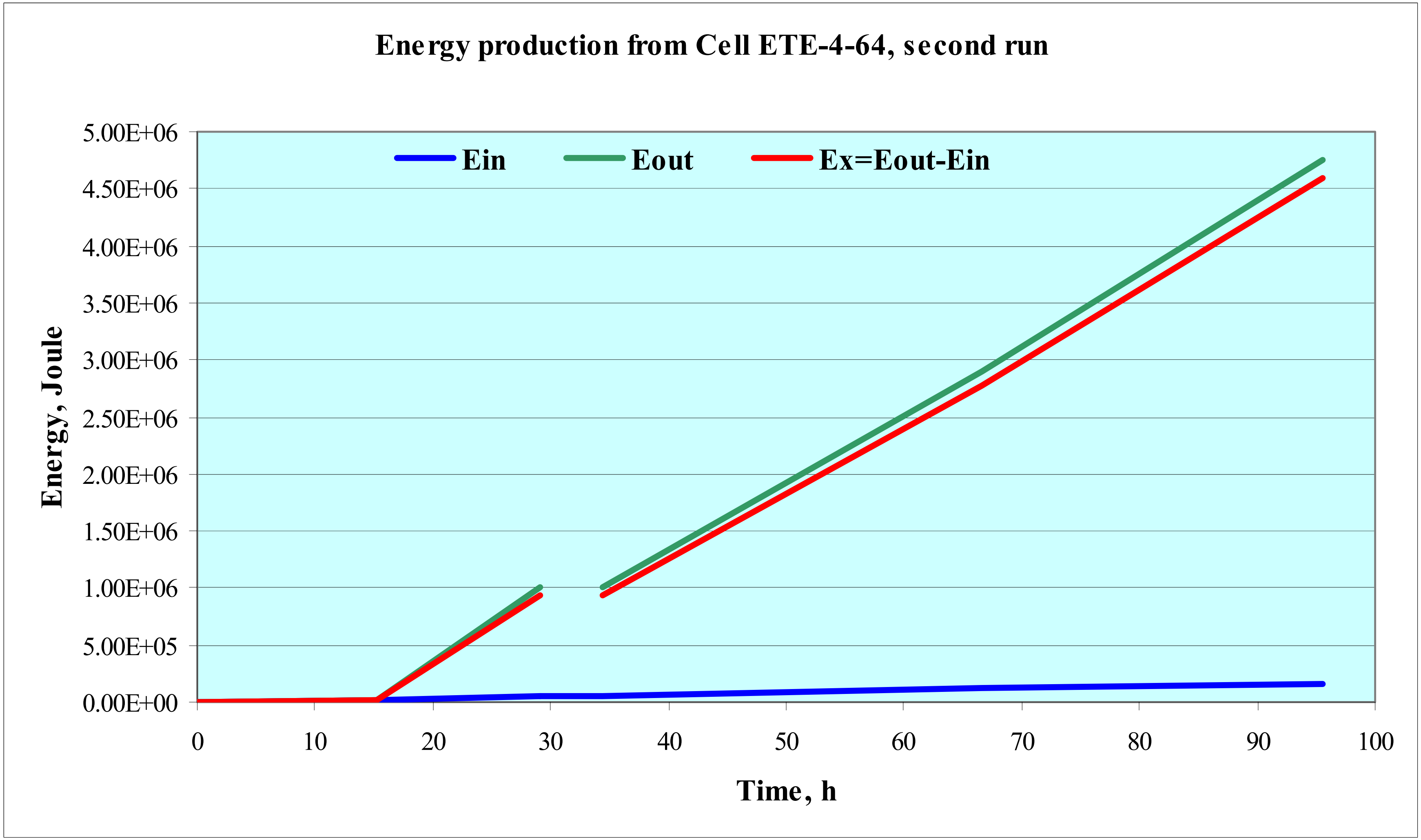

Loading is relatively low (~0.8)

# Excess Power; Exp. # 64b



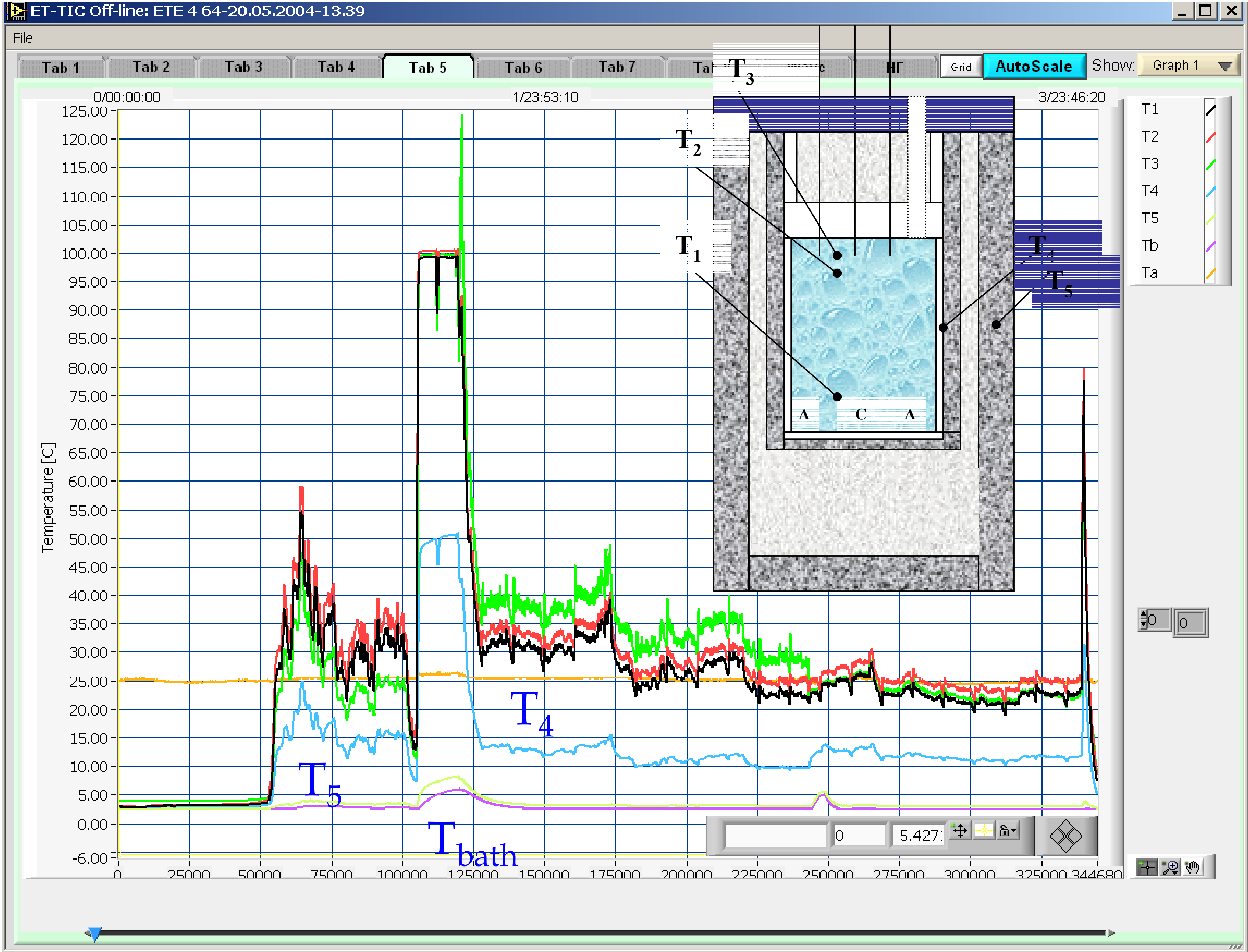

Excess Power of up to 32 watts; Average ~12 watts for 80 h

# Excess Energy; Exp. # 64b

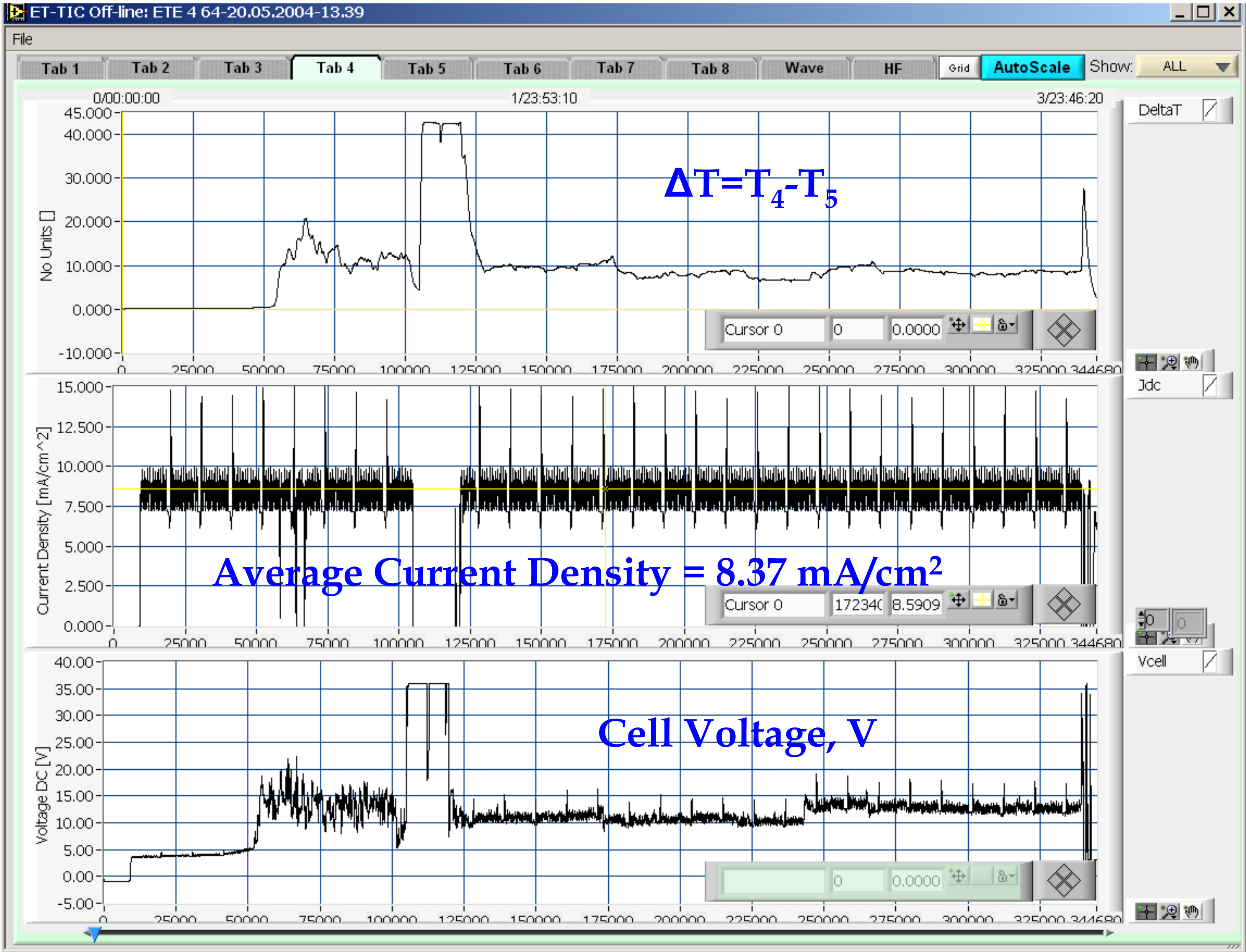



Excess energy of ~4.6 MJ

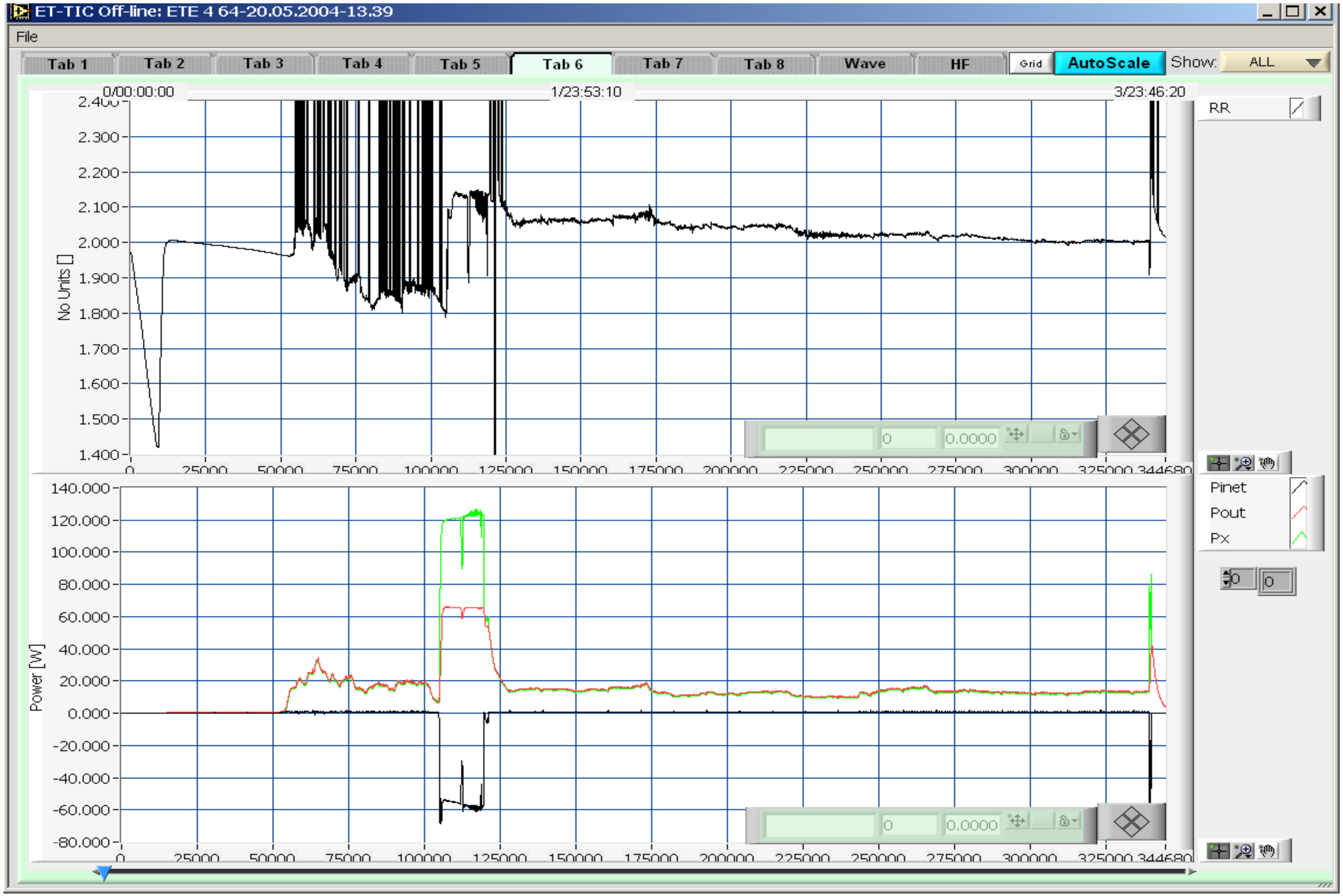
# Temperature Evolution, Exp. # 64b



# ΔT, Current Density & Voltage ; EXP. # 64b



# R/Ro & Power; Exp. # 64b




Loading relatively low (~0.8)

# Excess Tritium in # 64

- Tritium concentration measured at end of #64 analysis ~ 250% of reference
- ~625 $cm^3$ of $D_2O$ has been added to make-up for evaporation; initial inventory was 230 $cm^3$
- Assuming $TDO/D_2O$ evaporation rate ~ 1.0
- Estimated T effective concentration ~ 750%
- This amount of tritium corresponds to <1J – negligible as compared with the 5.7MJ excess energy generated.

# Material Analysis

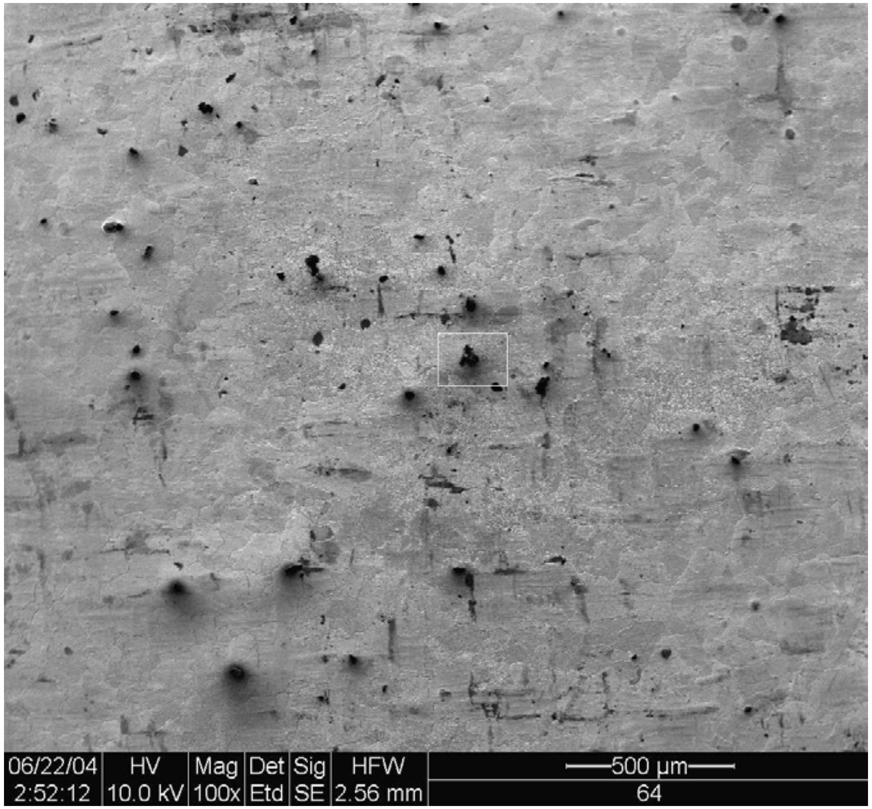
Diagnostics:

- Auger Electron Spectrometry
- Scanning Electron Microscopy-Energy Dispersive Spectrometry SEM-EDS
- Transmission Electron Microscopy (TEM)
- Secondary Ion Mass Spectrometry (SIMS)

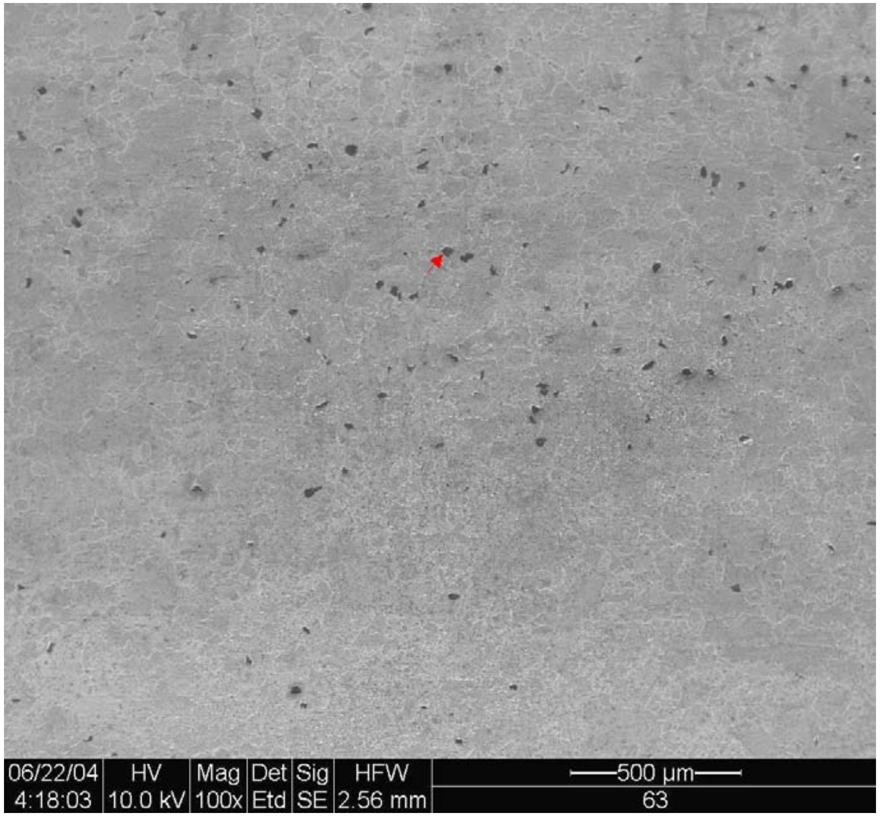
# Material Analysis # 64 vs. 63; SEM-EDS

Surface of Pd foil after rolling and annealing at 870$^0$C:

sample #64

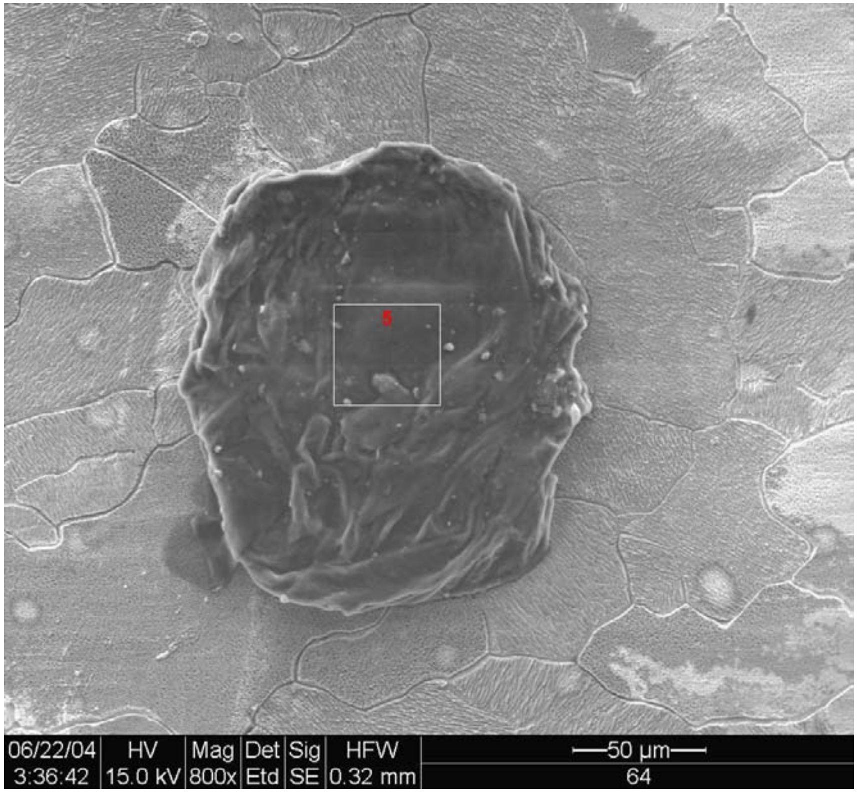



sample #63

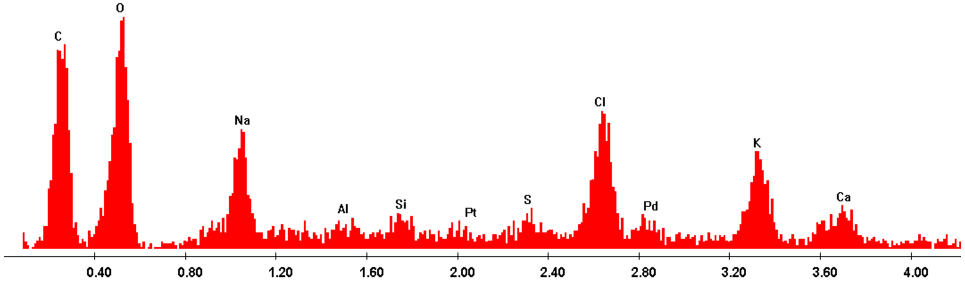


# View of Typical Black Spot on # 64 and its composition

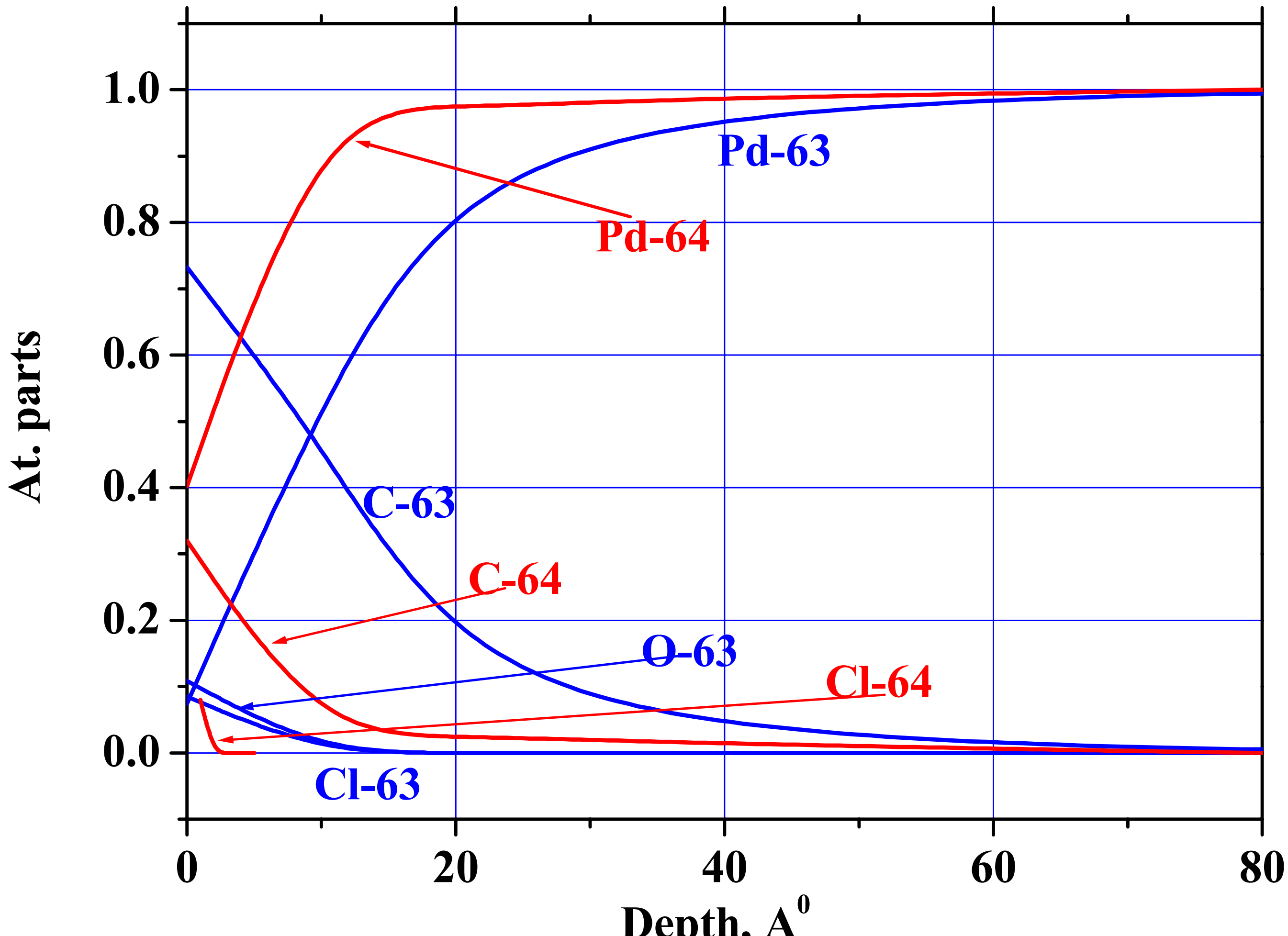
SEM-EDS




| Element | Wt % | At % |
|---|---|---|
| C | 35.77 | 52.48 |
| O | 26.19 | 28.84 |
| Na | 4.92 | 3.77 |
| Al | 0.43 | 0.28 |
| Si | 1.05 | 0.66 |
| Pt | 0.39 | 0.04 |
| S | 1.44 | 0.79 |
| Cl | 10.68 | 5.31 |
| Pd | 2.55 | 0.42 |
| K | 11.07 | 4.99 |
| Ca | 5.52 | 2.43 |
| Total | 100.00 | 100.00 |

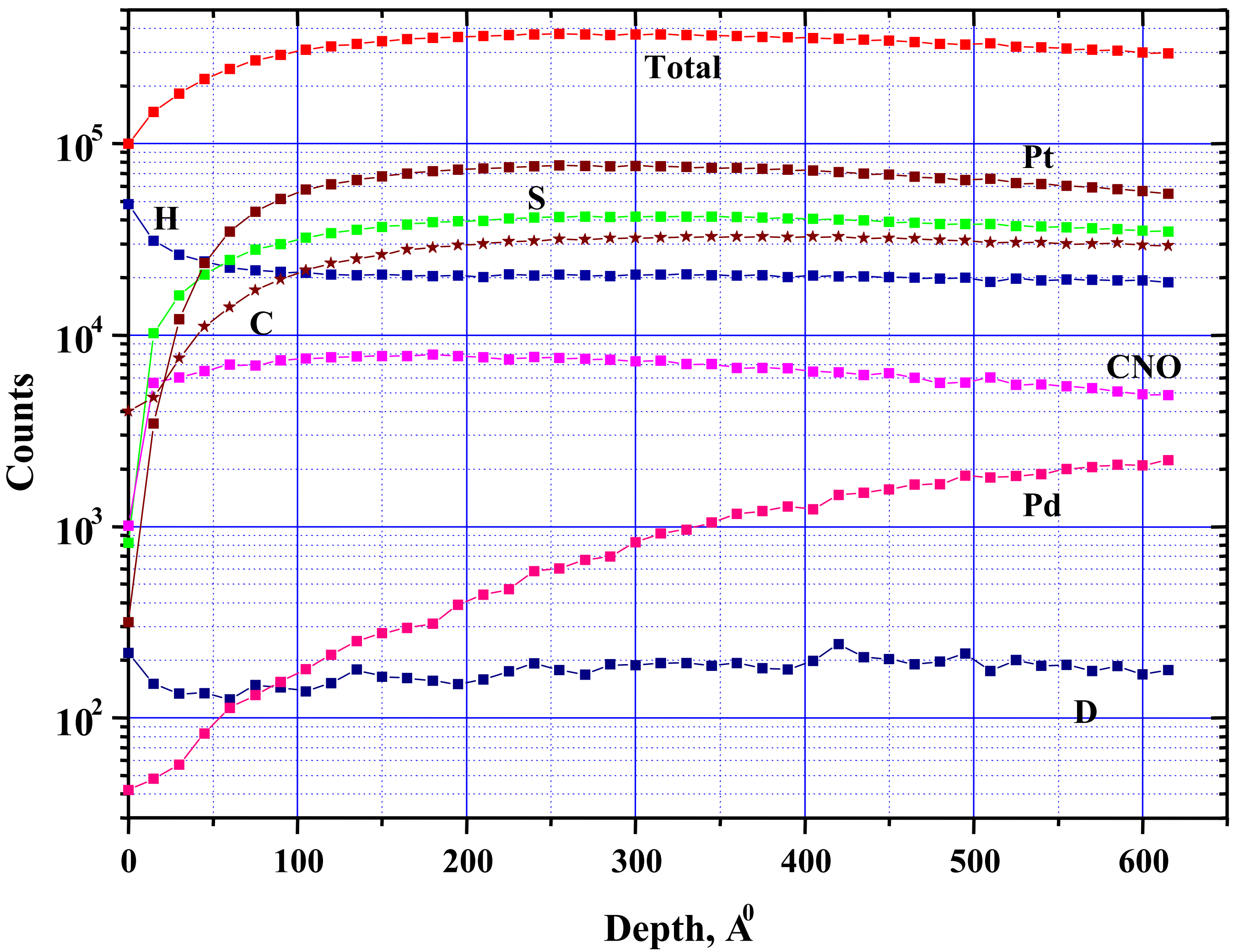


# AES profiles of Pd, C, O and Cl of Pd foils #63 and # 64

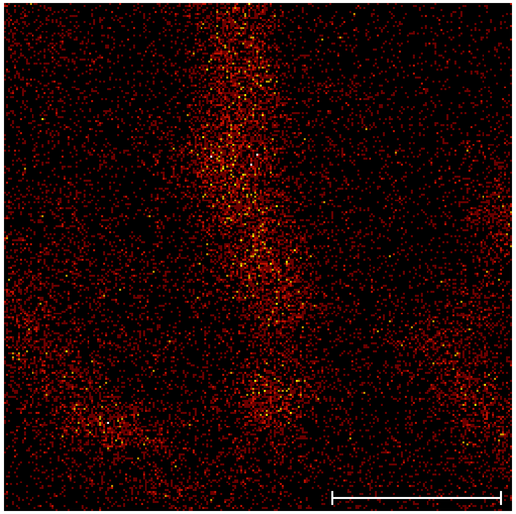



After etching in Aqua Regia

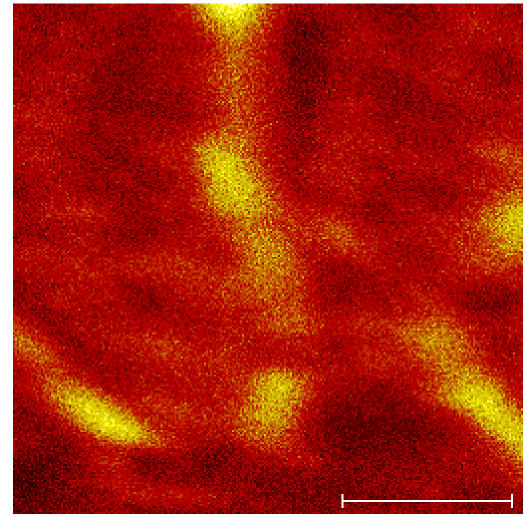
# Sample 64. SIMS depth profiling.



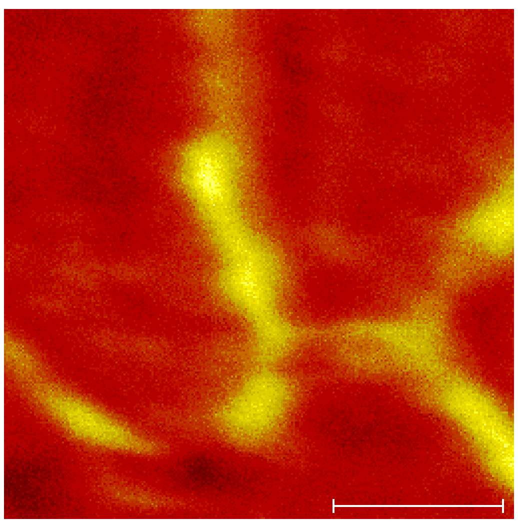
## Spatial distribution of selected isotopes measured by SIMS in #64
## a – D, b - $^{32}$S, c - total isotopes content, d - $^{195}$Pt.
## Scale bar - 30 μm.



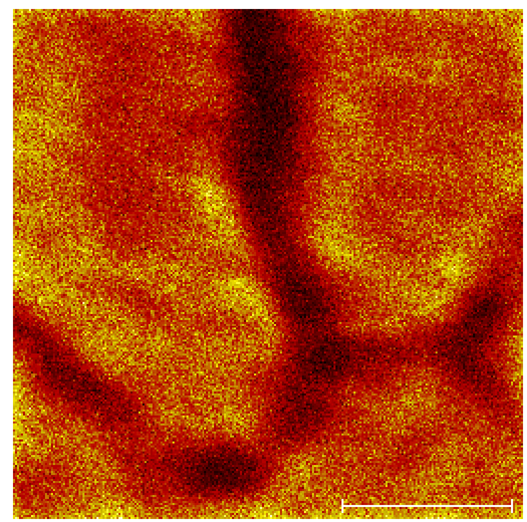
**a**



**b**



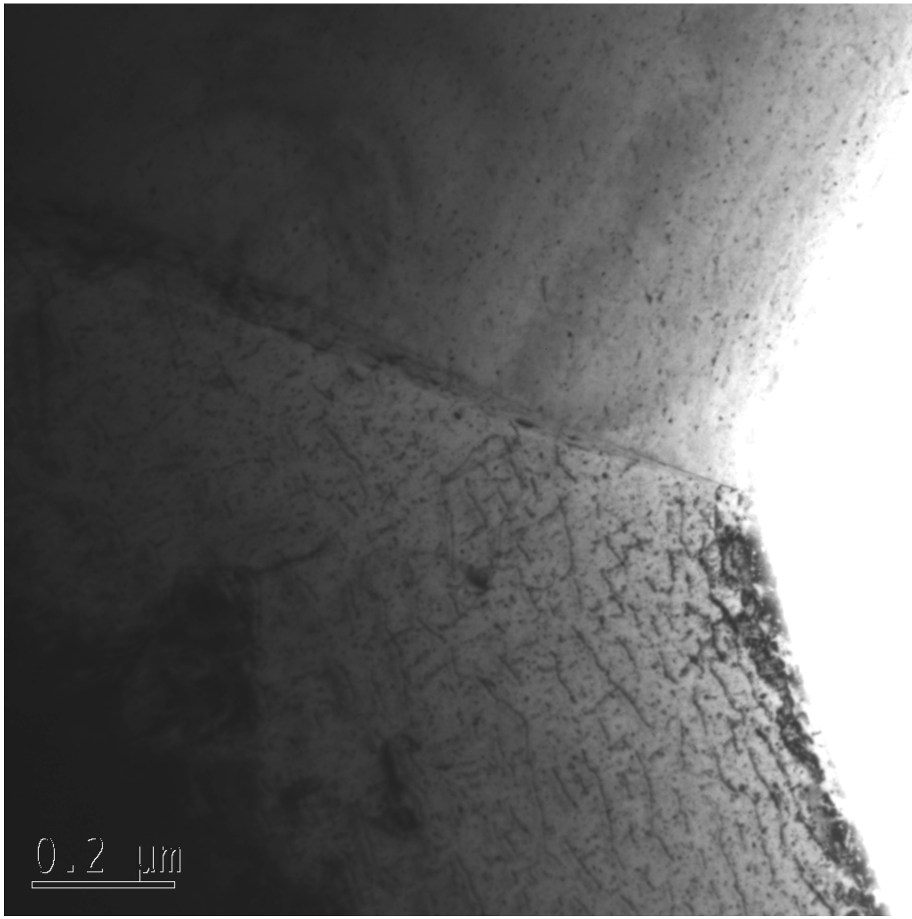
**c**

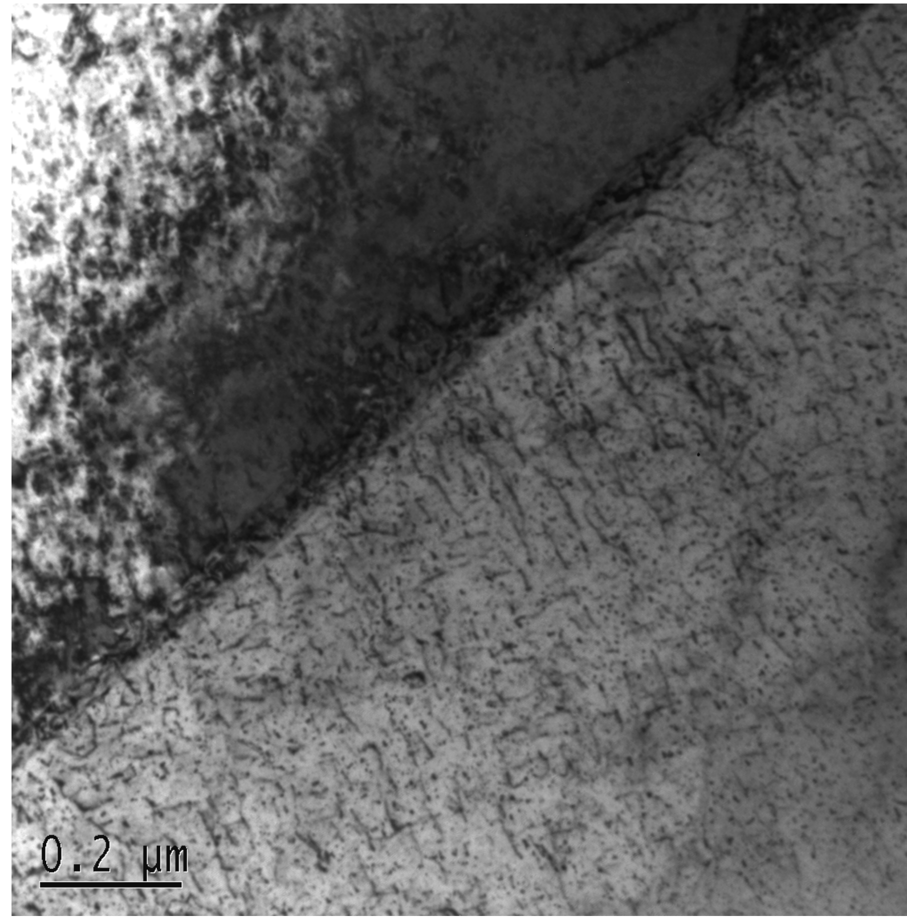


**d**

# The dislocations in Pd foils after annealing.

TEM




**Dislocation density**

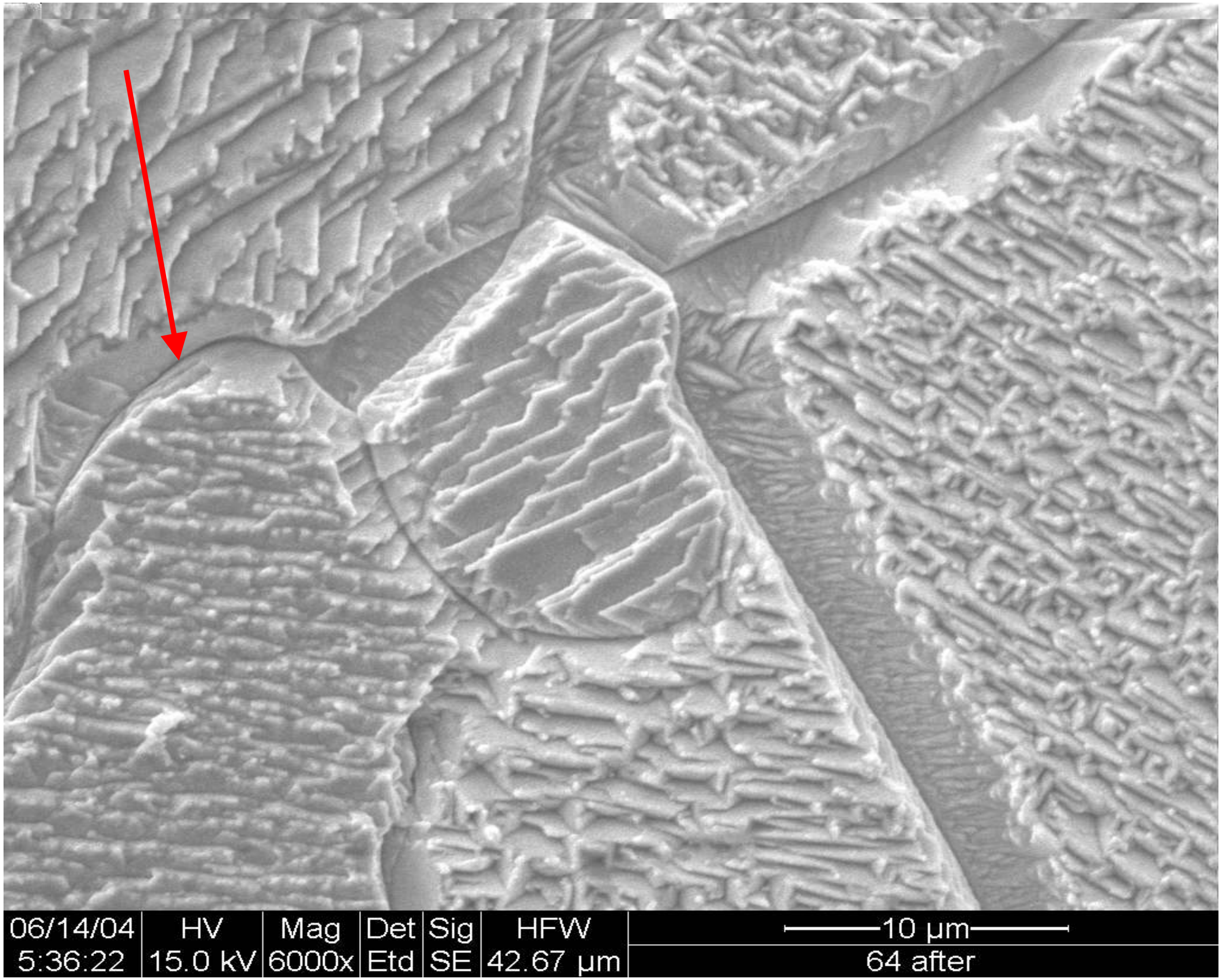
**#63**

**$3x10^{10}$, cm$^{-2}$**

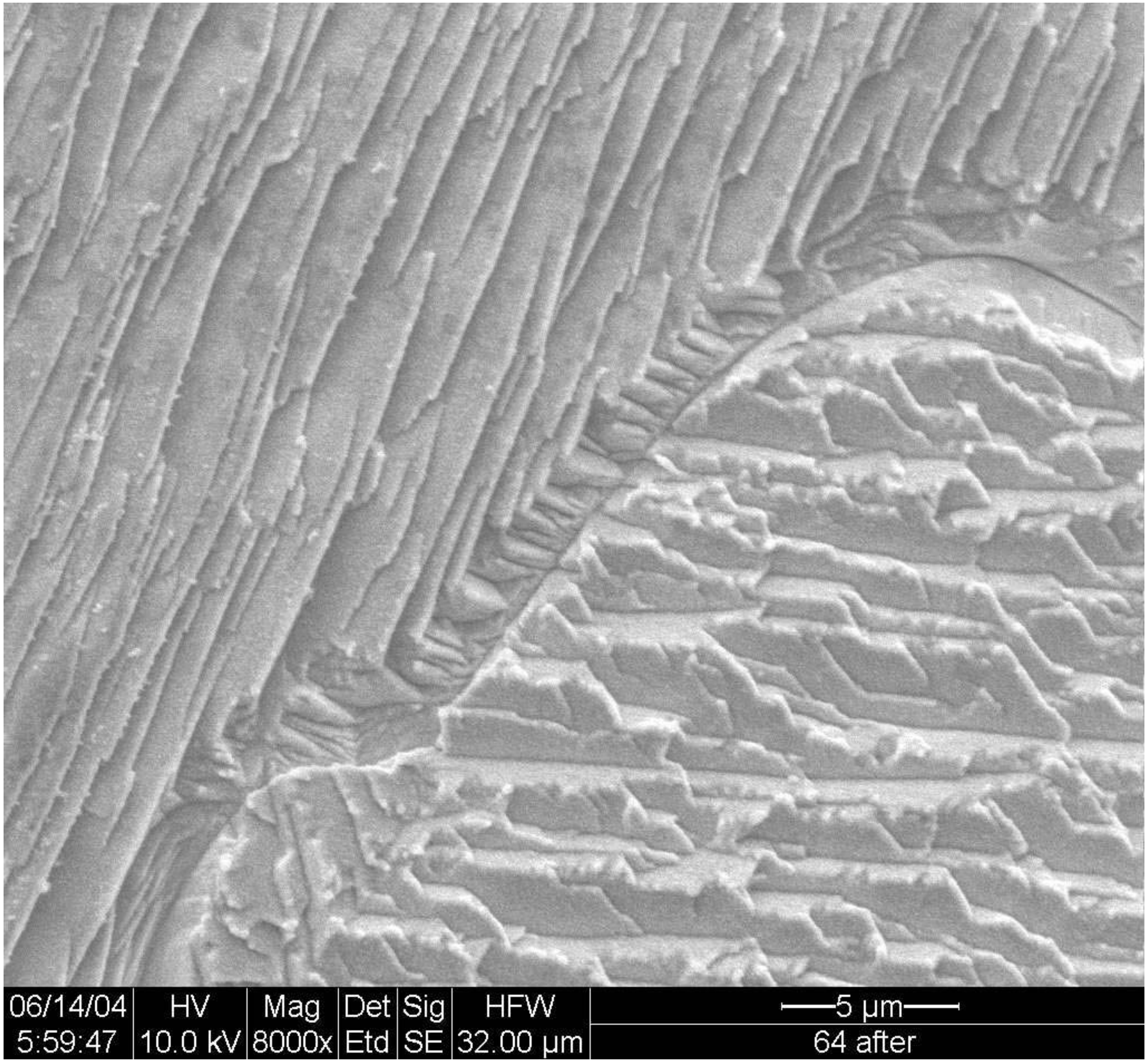
**#64**

**$6x10^{10}$, cm$^{-2}$**

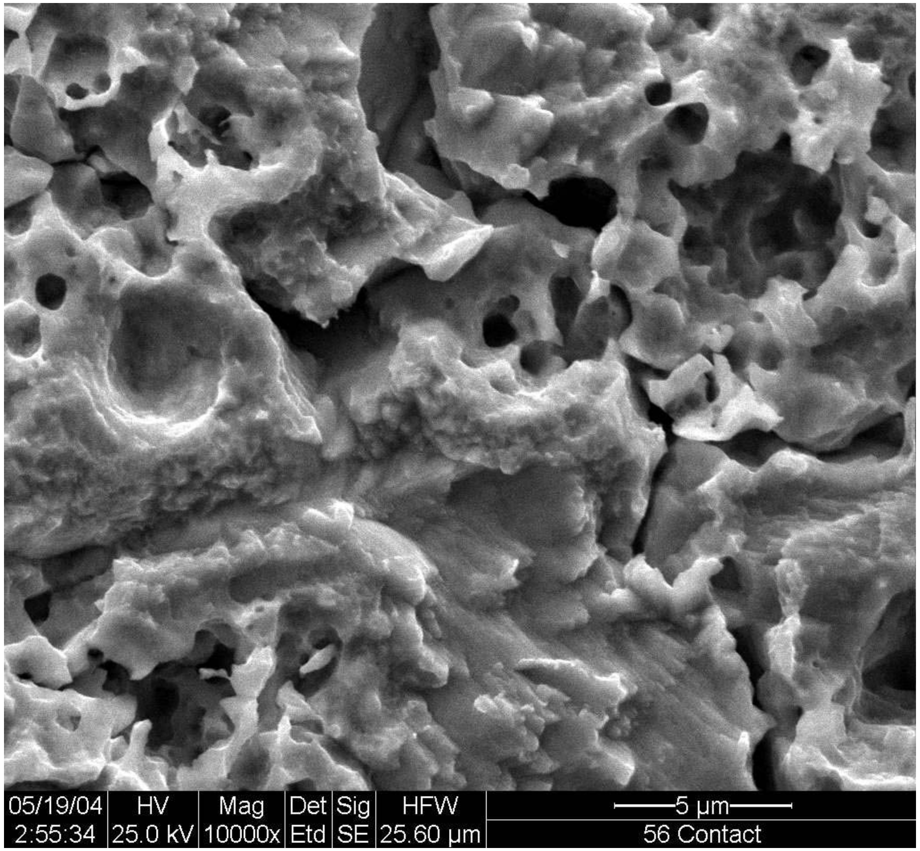
# Plastic deformation of Pd foil caused by D2 absorption. Planes of sliding (111) are visible. Sample #64

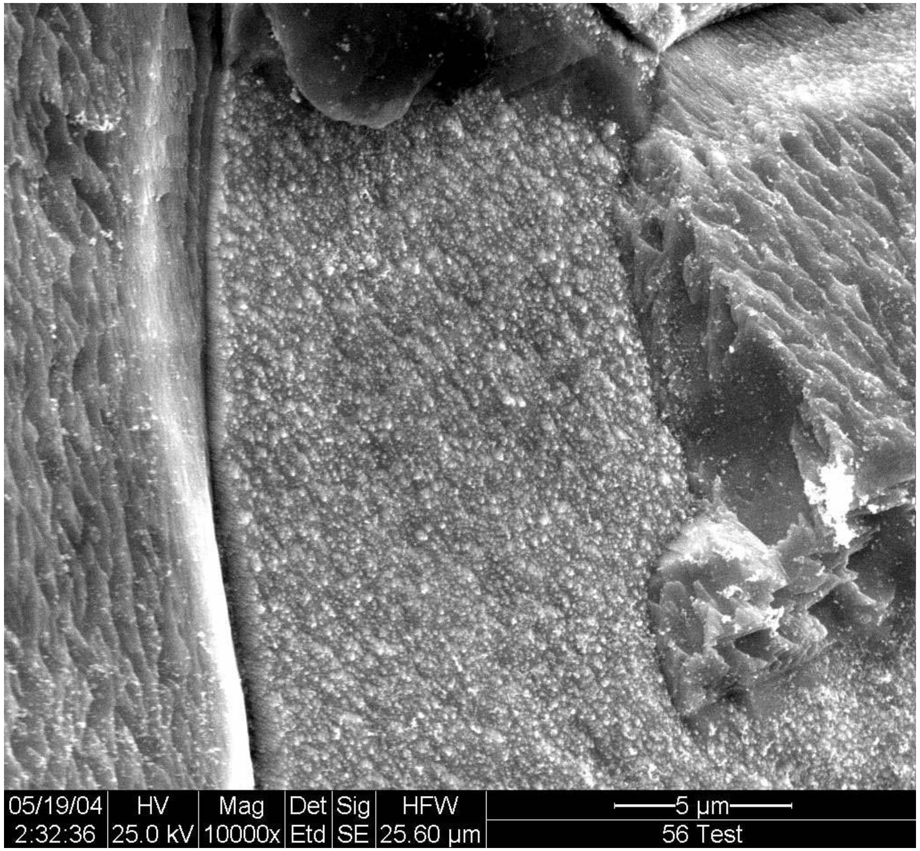


# The area that is shown in the previous picture by an arrow.



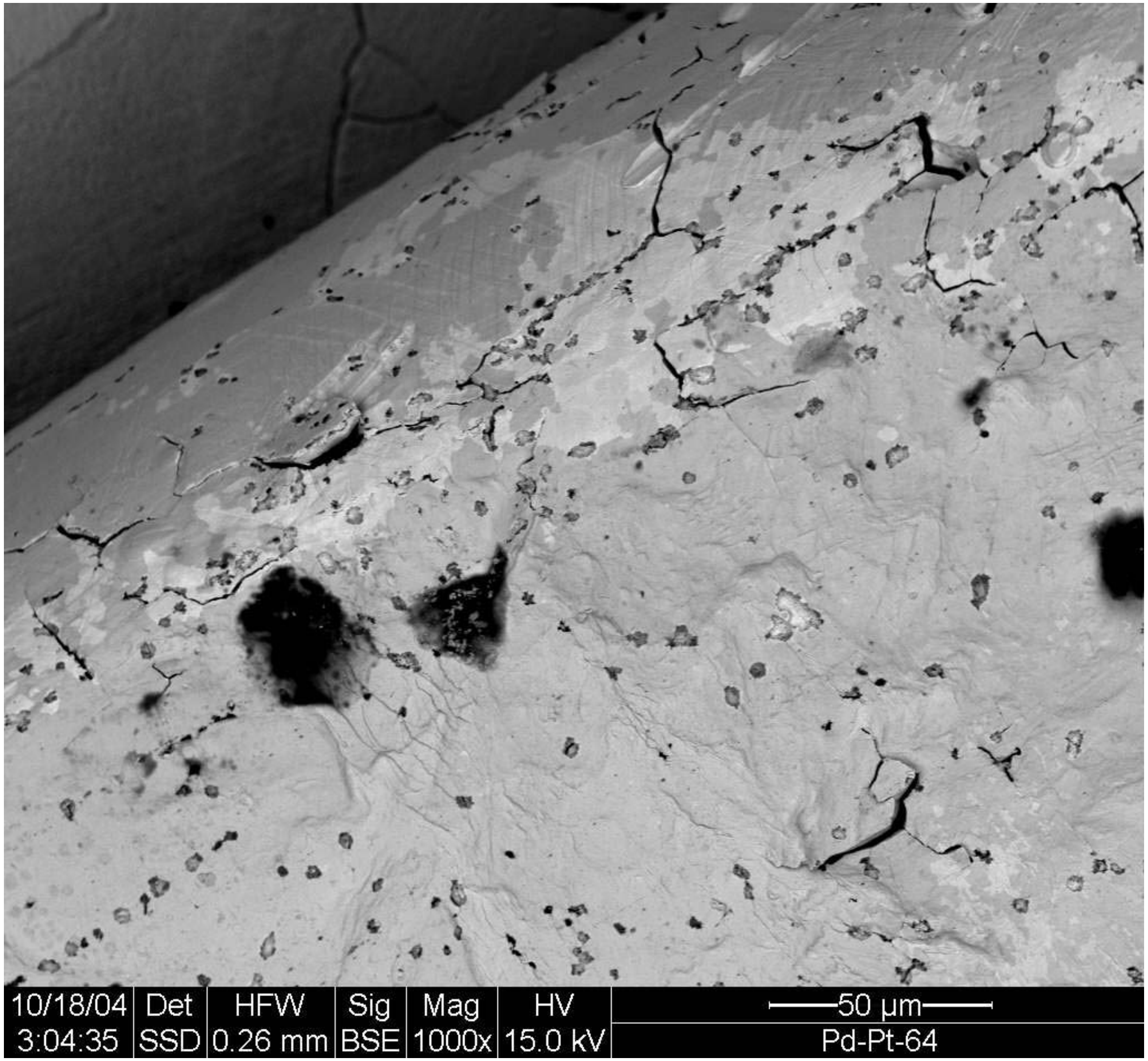
# Sample #56




**Contact area** **Working area**

# Brittle destruction of Pt Wire Sample #64



# Summary of Material Analysis

- Pd surface is covered at least with two types of impurities. The first one is a lubricant used at a rolling process with Pd during plastic deformation of the metal. The second one is a result of adsorption of air components by Pd surface.

- The lubricant stains are of various sizes and configurations and present on surface of all samples before and after the electrolysis.

- Annealing at $850^0$ does not fully remove the lubricant's components from Pd surface.

- The density of dislocations and the average size of grains in sample # 64 are twice higher, than in the reference sample.

- Nuclear reaction product can not be detected on surface zone due to high concentration of impurities. No He measurement has been attempted.

# SUMMARY

- Significant amount of excess heat has been generated in 3 experiments using 2 Pd foils.
- Dardik's modified SuperWaves have been used for current drive in all the three experiments.
- The average current density was relatively low: < **10 mA/cm$^2$**
- The maximum excess power was **2500%**. This range of excess power is suitable for commercial applications (although the operating temperatures were too low for such applications).
- The maximum excess energy generated with a single Pd foil is **5.7 MJ**.
- This corresponds to a specific energy of **24.8 KeV per Pd atom.**
- The highest average power density obtained is **~70 W/g Pd** (versus 20 to 50 W/g U in commercial fission reactors).

# SUMMARY (cont.)

- Significant increase in the tritium concentration in the electrolyte has been observed. However, the amount of tritium produced is negligible as compared with the excess energy generated.

- No measurement of He has been attempted.

- The Pd cathode surface was contaminated by what appears to be lubricant from the roller used for pre-treatment as well as impurities adsorbed from the air.