



COST – 529, WP Diagnostics and Modelling

What to measure in HID lamps:
view of a modeller

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Advances in HID lamp plasma modelling

- With the use of modern commercial software (Fluent, Femlab, CFD, ...), **2D and 3D non-LTE modelling** of high-pressure plasma **has become a matter of routine**.
- Considerable advances have been achieved in understanding and modelling the **interaction of high-pressure plasma with electrodes**.

In a few years, a **modelling of the whole system plasma-electrodes will be routinely performed** in a self-consistent way without any arbitrary theoretical assumptions (such as a prescribed current and/or temperature distribution over the electrode surfaces) or empirical parameters (such as near-electrode voltage drop).

Two approaches to measurements

- **Traditional approach: Measurements in “real” lamps**

Advantages

- Measurements give information directly on a device of interest.

Disadvantages

- Measurements are extremely difficult;
- There is no reliable way of re-scaling results to other conditions.

- **A new approach has become possible: “Standard” measurements in “model lamps”** in order to verify codes. Once having been verified experimentally, a code may be used for simulation of real lamps.

Advantages

- Measurements are not prohibitively difficult;
- Measurements may be performed on many parameters and in a wide range of conditions;
- Results can be ‘re-scaled’ to different conditions by means of a code.

Disadvantages

- Measurements results can be applied to real lamps only in an indirect way (through a code).

Standard measurements in low-current arcs

- **Plasma-electrodes interaction**

Extensive work has been performed in recent years, in particular, by the Bochum group and especially on cathodes. It has been found that the modern theory of current transfer to thermionic cathodes describes experimental data in the whole range investigated.

- **Bulk plasma**

Virtually no standard experimental information on the column of low-current high-pressure arcs is available! As a consequence, the state of the theory is far from complete.

Example: a model considered in some of the latest publications

$$R^+ = q^I n_e n_n \text{ (ionization by electron impact)}$$

$$R^- = q^R n_e n_i + q^C n_e n_i n_n \text{ (radiative recombination and three-body collisional recombination)}$$

q^R and q^C are expressed in terms of q^I by means of the equation

$$(R^+)_{\text{LTE}} = (R^-)_{\text{LTE}}$$

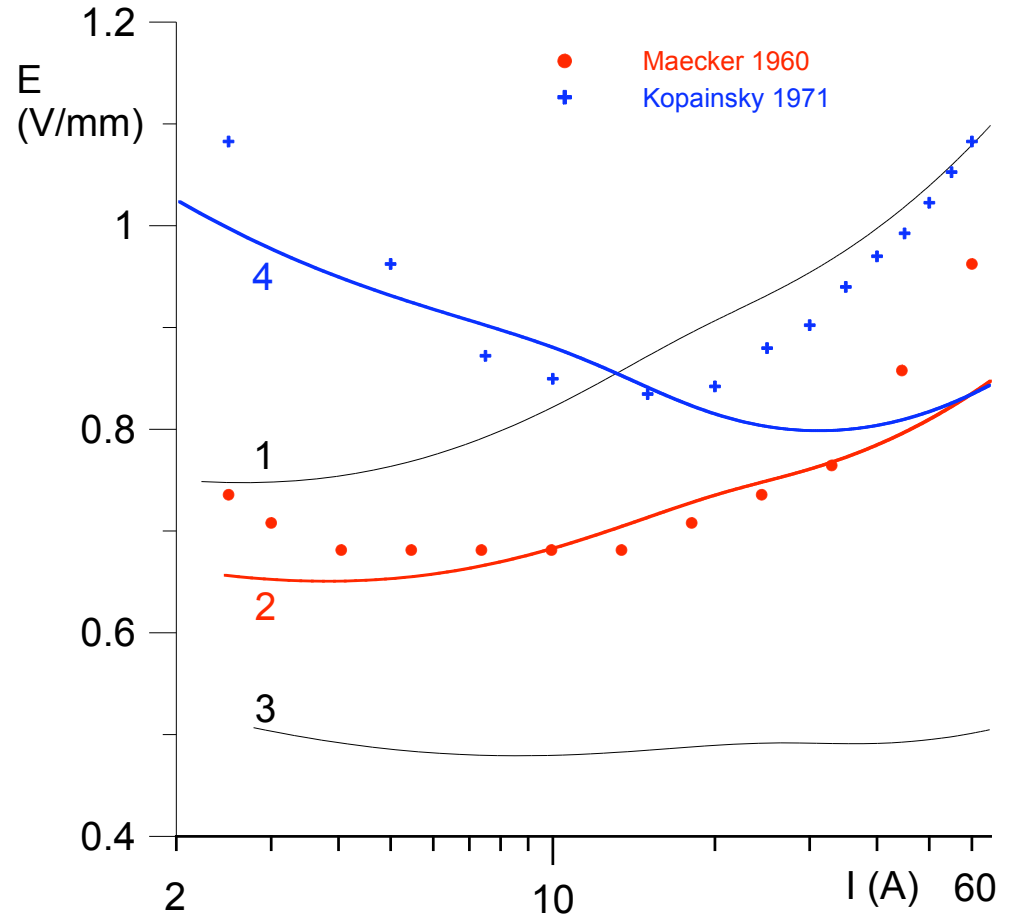
Standard measurements in low-current wall-stabilized arcs

- The simplest thing to work with is a **cylindrical wall-stabilized arc**.

Example: high-pressure Ar arc

What has been measured in this classic arc at low currents, apart from the current-voltage characteristic?

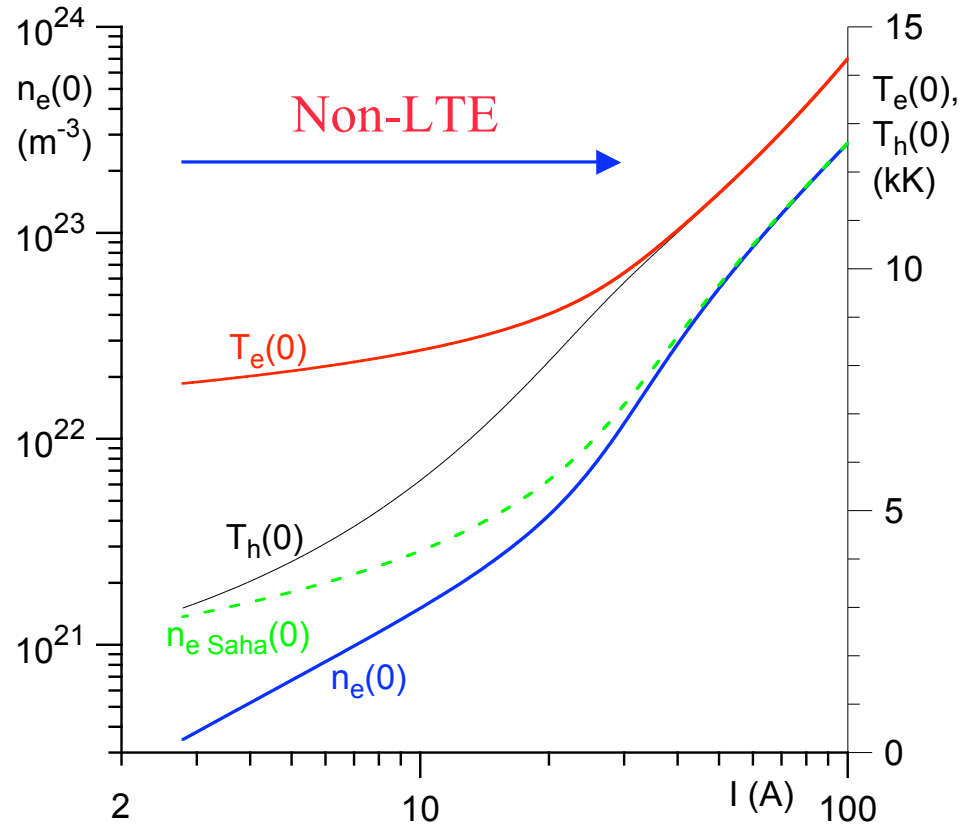
Nothing! (At least as far as I know...)



1: $R = 2$ mm, $p = 1$ atm. 2, circles: 2.5 mm, 1 atm.
3: 4 mm, 1 atm. 4, crosses: 2.5 mm, 3 atm.

Parameters on the axis of a low-current Ar arc

- There is a possibility that the column of lamp arcs is not in LTE.
- A comparison of standard measurements with the modelling will allow one, apart from checking the model on the whole, to check kinetic and transport coefficients (such as k_i , D_{ia}) used in the modelling.



The charged-particle density, the electron and heavy-particle temperature at the axis of the tube ($R = 4$ mm) vs. discharge current.

Conclusions

- Modelling is likely to become one of the main sources of information for a lamp designer in a few years, as it has become for designers in many other areas.
 - Examples of what can be calculated: $U(t)$, $T_h(x,y,z,t)$, $T_e(x,y,z,t)$, $\text{species}(x,y,z,t)$, $T_{\text{electrodes}}(x,y,z,t)$
 - Example of what cannot be calculated and must be measured in real lamps: contaminants
- Standard measurements in “model lamps” are badly needed for verification of codes!

How a modeller sees a standard lamp

- **There is no sense in testing a model on one experimental point!** _
A wide range of conditions is necessary.
 - **There is no sense in going to complex mixtures and/or AC before we can model one-species DC plasmas!** _ Standard regimes should include inert-gas and mercury plasmas without additives and DC power supply, for example
 - Hg, Xe, Hg+MH, Xe+MH with 1 A DC (or square-front AC several Hz)
 - Hg, Xe, Hg+MH, Xe+MH AC
 - Researchers working with lamps are encouraged to introduce **variations in any parameters, provided that the range investigated includes one of the standard regimes** (e.g., the current range 1-30 A is OK, the range 3-30A is not OK).
 - **The design must be suitable for diagnostics and modeling** (no ceramics, a simple cylindrical tube, large interelectrode distance in order that the plasma include a well-pronounced cylindrical column, one-piece electrodes).
 - If possible, the design should be that simple that universities or government labs be able to build and maintain a lamp (at least with Xe).
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