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Penning mixture experiments in an inductively driven lamp

Penning effect reduces the ignition voltage of inductively driven lamps, similar as in electrode lamps

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Motivation

Introduction to Penning ionisation

- "Penning effect" is accredited to Dr. Frans Michel Penning, who discovered that discharge potential in certain mixture percentages of Ne and Ar to be lower than in pure noble gases, due to creation of meta-stable states [3].
- Used in manufacture of neon gas-discharge lamps and flurescent lamps to lower ignition voltage.

Theoretical background

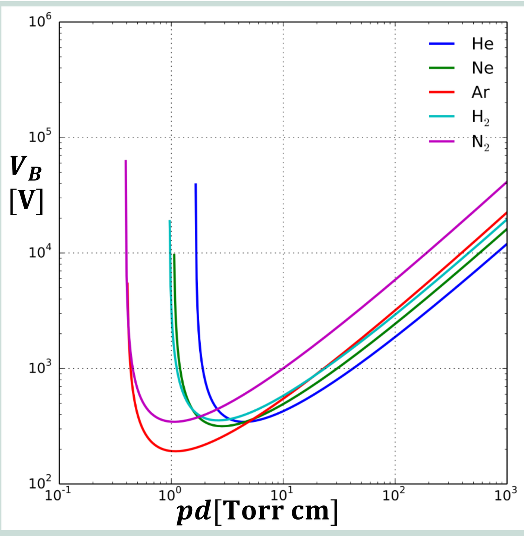
Shift of the Paschen minima

- Penning effect is prominent when a small percentage of argon is added to neon. A similar lowering was observed when a small percentage of neon was added to argon lamps.
- This is explained by the meta-stable effects present in both type of mixtures. Paschen curves are adapted to ICPs and the resulting curve is used to predict gas breakdown in an inductive lamp [6].

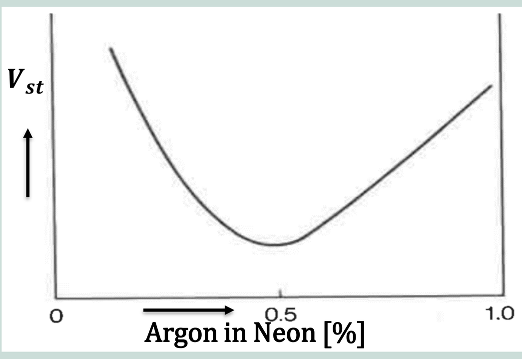
Paschen curves and Penning effect

- Paschen curves can be plotted for several gases from literature [5]. The empirical equation that gives us an estimation of breakdown voltage to start an arc, between two electrodes in a given gas as a function of pressure and gap length is:

$$V_B = \frac{B\,p\,d}{\ln(Apd) - \ln\left[\ln\left(1 + \frac{1}{\gamma_{se}}\right)\right]}$$



- Starting voltage (V_{st}) as a function of addition of argon (%) to neon (%) is plotted (Penning effect) [2]. The effect reverses once the percentage increases beyond a certain ratio.

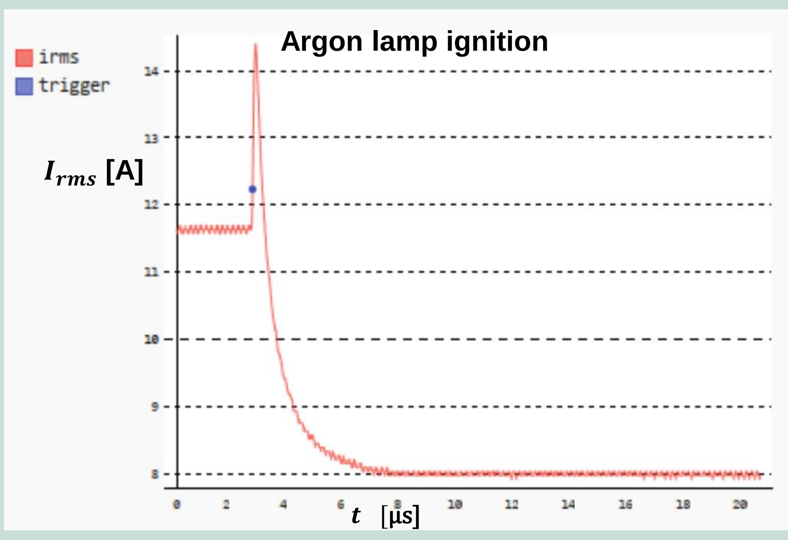


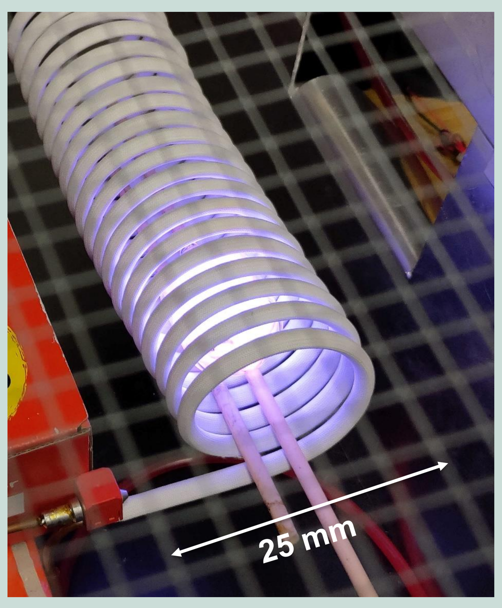
Experimental setup

- The setup consists of a high frequency inverter which drives a copper coil of $240\ \mathrm{mm}$ in length and 20.5 windings. The inverter operates at a frequency of about $3.125\ \mathrm{MHz}$ and adapts the frequency for current control.
- The input voltage to the inverter of the DC power supply is increased manually until the lamp ignites. As a result of the ignition, the controller notices a shift in the impedance of the lamp and records the lamp current at ignition time.
- We discuss our results of measured ignition currents of five different Penning lamps (length $60\ \mathrm{mm}$, diameter $40\ \mathrm{mm}$ and a starting gas pressure of $40\ \mathrm{Pa}$).

Lamp current during ignition of a pure noble gas lamp

- Plot of lamp current (I_{rms} [A]) of lamp (hot) during ignition. X-axis is timesteps of $2\ \mu\mathrm{s}$ and Y-axis is of $1\ \mathrm{A}$.
- The controller detected the ignition at the blue trigger point. It saved some data before and after the trigger event.
- This is an example of the plots from the controller that form the base for the result values in the table.
- Image (on the right) is a photo of a pure-gas lamp (argon) in operation during experiments.





Results and conclusion

- The data from the ignition experiments shown in the Table below shows that a 0.5% mix of neon in argon Penning mixture is useful in reducing the ignition current.
- This shows that the Penning effect of argon/neon pair in an inductive lamp setup helps in reducing the ignition current, similar to the argon/xenon pair in [4]. Any higher ratio of neon in argon and krypton in argon did not have a useful effect.

Lamp	Ar (%)	Ne (%)	Kr (%)	T (°C)	I_{rms} (A)
1	99.5	0.5	0	230	8.8
2	99	1	0	260	9.0
3	98	2	0	230	9.3
4	90	0	10	260	10
5	100	0	0	220	8.9

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