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THE BNL VOLUME H^- ION SOURCE*

Krsto Prelec
Brookhaven National Laboratory, Upton, NY 11973

SUMMARY

This paper is a progress report on the studies of the BNL volume H^- ion source. We have measured the H^- yield, I_H^-, and the ratio I_e/I_H^- as function of the size of the extraction aperture, strength of the conical filter field, size and position of the filament, and of the phase of the filament heating current. The H^- current density in the extraction aperture was lower for the largest aperture, while there was a broad maximum when the conical field varied. Position of the filament and the phase of the filament heating current are very important parameters.

INTRODUCTION

The BNL volume H^- ion source with a toroidal discharge chamber was described previously[1]; its design evolved from the idea of using a cup-shaped dipole field surrounding the extraction region of a tandem source[2]. There were two benefits expected from such a design: a better utilization of the discharge and a reduction in the beam emittance due to a full rotational symmetry of the source.

Studies of the source performance[3], using a 1 cm^2 extraction aperture, have shown that it is possible to extract more than 30 mA of H^- ions in 1 ms pulses, with a ratio of I_e/I_H^- between 20 and 30. The H^- yield measured as function of the arc current increases at first steeply with the arc current, but this is followed by a saturation region. If the arc current is held constant, the H^- yield as function of the extraction voltage increases again steeply at first, but at a certain voltage the slope becomes more gradual. The two parts of the characteristics are similar to space charge saturation and emission limited regions of many emitters of charged particles. The potential of the plasma electrode (PE) affected both, the H^- yield and the accompanying electron component. The H^- yield was usually the highest if the plasma electrode was floating, but at the same time the ratio I_e/I_H^- was also the highest. When the PE potential varied from its floating value through zero into the positive range, the H^- yield would decrease somewhat but the electron component would be reduced even more[3].

EXPERIMENTAL ARRANGEMENT

Figure 1 shows a cross section of the source. There are 11 cusp rings assembled from standard Sm Co magnets (6.25 mm diameter, 12.5 mm length) and placed on the inside of the flux return

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structure (iron). Opposite the extraction aperture, there is a Sm Co disc to create a conical dipole field around the source axis. Another paper[4] presented at this Symposium describes the mapping of the magnetic field. The cathode of the discharge consisted of a single loop of tungsten wire placed outside the conical dipole field. For lower arc currents (up to 150 A) a smaller loop (9 cm diameter) was sufficient, but for arc currents up to 400 A we had to use a loop of 16 cm diameter. Gas injection was pulsed, with the peak pressure in the range of 5 - 15 m Torr.

The H^- yield was measured as the voltage drop on a 100 Ω resistor in series with the Faraday cup; a strong dipole field in front of the Faraday cup served to deflect the electrons out of the beam. A standard current transformer served to measure the electron component. For the measurements of the emittance, the Faraday cup was replaced by a slit-and-collector type emittance device; a paper presented at this Symposium[5] describes the results of emittance measurements.

RESULTS

A. Effects of the size of the aperature

Three different apertures have been tried, 0.5 cm^2, 1 cm^2, and 1.87 cm^2. Figure 2 shows the optimized yield as a function of the arc current for the three apertures, at constant arc and extraction voltages and with a 16 cm diameter filament. The H^- yield from the largest aperture (1.87 cm^2) increases if a thin tungsten wire cross is mounted across the opening in the plasma electrode; there was no such effect with smaller apertures. The graphs on Fig. 2 show that the H^- yield increases linearly with the arc current up to a few tens of amperes; above about 50 A the increase is more gradual and the characteristics approach a saturation above 300 - 400 A. The H^- current density does not change much when the aperture changes from 0.5 cm^2 to 1 cm^2; however, there is a substantial reduction for the largest aperture, especially if there is no wire cross on the plasma electrode. Table I is a summary of the best H^- yields for the three apertures.

Table I

Aperture	I_{arc}	I_{H^-}	J_{H^-}	I_e/I_{H^-}
0.50 cm^2	300 A	15 mA	30 mA/cm^2	18
1.00 cm^2	400 A	35 mA	35 mA/cm^2	43
1.87 cm^2 (no cross)	300 A	33 mA	18 mA/cm^2	29
1.87 cm^2 (with cross)	400 A	48 mA	25 mA/cm^2	31

B. Comparison of the dipole filter and conical filter

In order to check the effectiveness of the conical filter, we have compared the source performance in the standard configuration (conical filter) with the performance when the Sm Co disc on the filament flange was removed and a linear dipole field established in the vicinity of the extraction aperture by mounting a few small permanent magnets on the plasma electrode. The latter configuration corresponds to those usually existing in tandem H^- ion sources. (In the absence of any dipole field, the extracted electron component was extremely high which limited the arc current to 10 - 20 A at most.) Figure 3 shows the optimized yield for the two dipole configurations, once for the larger filament loop and then for the smaller one. It is evident that in either case the conical dipole increases the yield by about 50%, for the same arc current.

C. Size and position of the filament

Figures 3, 4, and 5 show results of studies with filaments having different sizes and different locations with respect to the symmetry plane. First, a smaller loop (Fig. 3) had a better arc current efficiency; however, the arc current was limited to the region below 150 A because of a smaller emitting surface. While the position of the larger filament with respect to the symmetry plane was not critical, the smaller filament was more efficient if placed 1 cm closer to the filament flange (Fig. 4). Finally, even the diameter of the filament wire had an effect on the source performance: there seems to be an optimum for values around 1 mm diameter (Fig. 5). It is not clear what causes this effect, but any explanation would have to include the local magnetic field due to the arc current flowing through the wire (the heating current was interrupted during the pulse).

D. Strength of the conical field

By replacing the Sm Co magnet that produces the conical field with a small coil in the same location, we were able to study the yield as a function of the conical field. Figures 6 and 7 show the H^- yield and the ratio I_e/I_{H^-}, as function of the pulsed coil current, for several values of the arc current. The measurement was done both, with the filament heating current on or interrupted during the arc pulse. While there is a broad optimum in the H^- yield, shifting slowly toward higher values of the coil current with the arc current increasing, the electron load (or, the ratio I_e/I_{H^-}) depended strongly on the conical field. It should be noted that the best H^- yield and the lowest value of the ratio I_e/I_{H^-} do not occur simultaneously.

E. Direction and magnitude of the filament heating current

The effect of the filament heating current was discovered early in our studies. As the first step, a circuit was added to bypass the filament during the arc pulse, reducing in this way the filament heating current close to zero. With an ac heating, we were able to move the arc pulse over the full ac period and monitor the effect of the instantaneous value of the filament current. Figures 8 and 9 show the H^- yield and the ratio I_e/I_{H^-} as a function of the ac phase, for several values of the arc current. First, for the larger loop (Fig. 8) the H^- yield is higher for ac phases around zero crossings than around peak values of the filament current. There is a symmetry of both sets of curves with respect to peak values, but an asymmetry with respect to zero values. This observation is in agreement with earlier measurements when the yield depended on the direction of the direct current for filament heating. The source with the smaller loop shows a different behavior (Fig. 9). While there is still a symmetry with respect to the peak instantaneous values of the filament current, the asymmetry with respect to zero values is much more pronounced. This agrees again with observations that the H^- yield may be even slightly higher if the filament current (dc) is not interrupted during the arc pulse. Of course, this is not a general rule because the behavior can be different if the position of the filament loop with respect to the extraction aperture is changed. As it was the case with the effect of the wire diameter on the H^- yield (Fig. 5), the explanation this time will also have to include the local magnetic field due to the filament current and its relationship to the local cusp field.

CONCLUSIONS

The work described in this report represents a part of ongoing studies of the BNL volume H^- ion source with a torroidal discharge chamber. So far only minor variations from the original design[1] have been investigated, e.g., effects of the size and location of the filament. The source has performed well, very reliably and repeatedly, close to the AGS requirements. The data are still not complete, there are many features to be explained and understood and more substantial changes of the original design to be explored (e.g., different cusp configurations; a properly designed extractor; better pumping of the region around the extractor to reduce stripping losses of H^- ions; etc.). We can, however, conclude that it is not possible to optimize the source performance with respect to several criteria simultaneously, among them the arc power efficiency, gas consumption and the ratio I_e/I_{H^-}. Figure 10 shows, to illustrate this point, the ratio I_e/I_{H^-} vs I_{H^-} for many operating conditions of the source. It is evident from data like these that there is a broad range of combinations of source parameters and that the selected operating regime will be a certain compromise.

REFERENCES

1. K. Prelec, Proc. European Particle Accelerator Conference, Rome, June 1988, p. 1327.
2. K. Prelec, J.G. Alessi, A. Kponou, A. McNerney, Proc. Second European Workshop on Production and Applications of Light Negative Ions, Palaiseau, France, March 1986, p. 31.
3. K. Prelec, Proc. 1989 Particle Accelerator Conference, Chicago, March 1989 (to be published).
4. C.R. Meitzler, this Symposium.
5. J.G. Alessi, this Symposium.

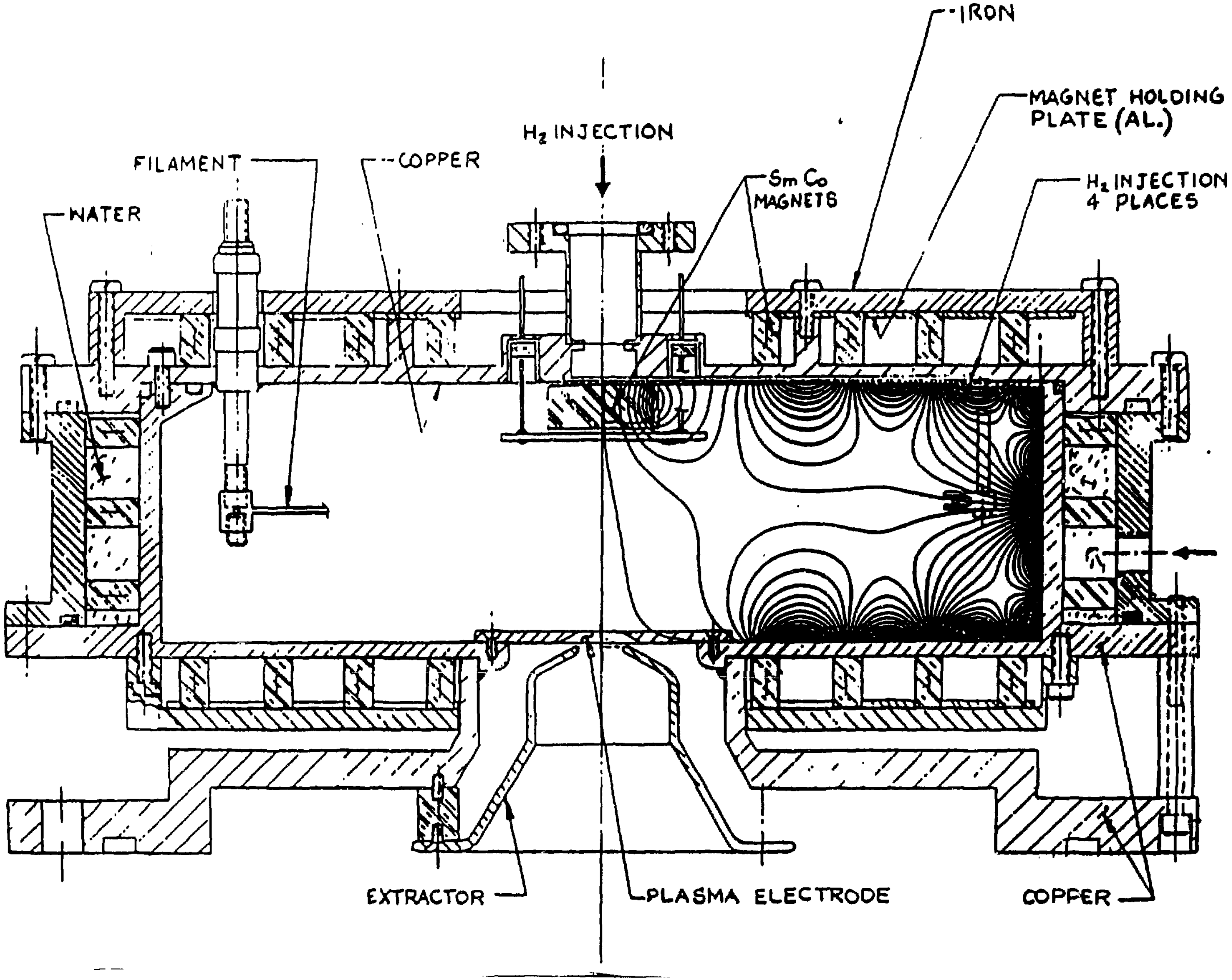

Fig. 1 Cross section of the source.

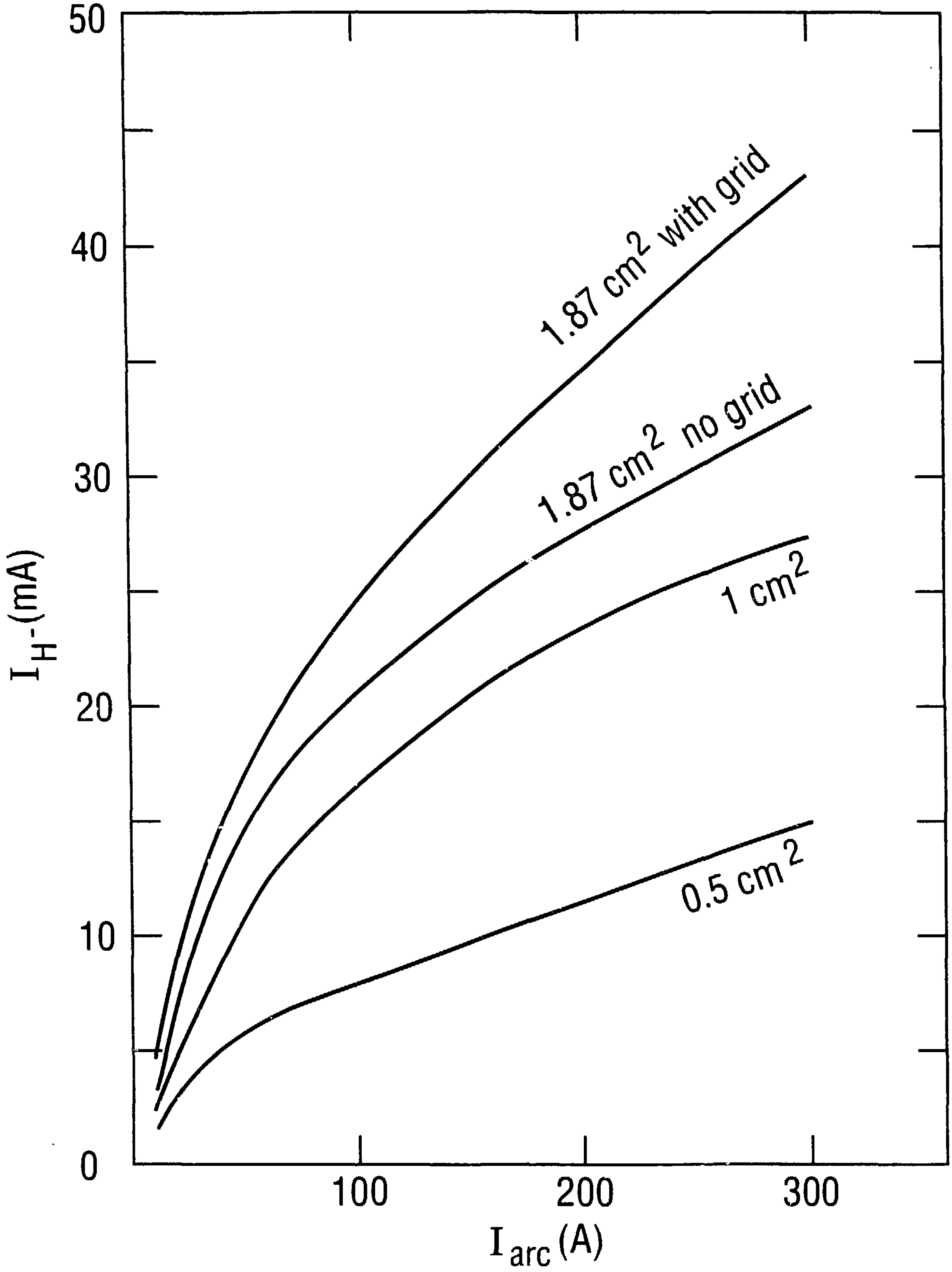

Fig. 2 H⁻ yield as function of the arc current, for several apertures.

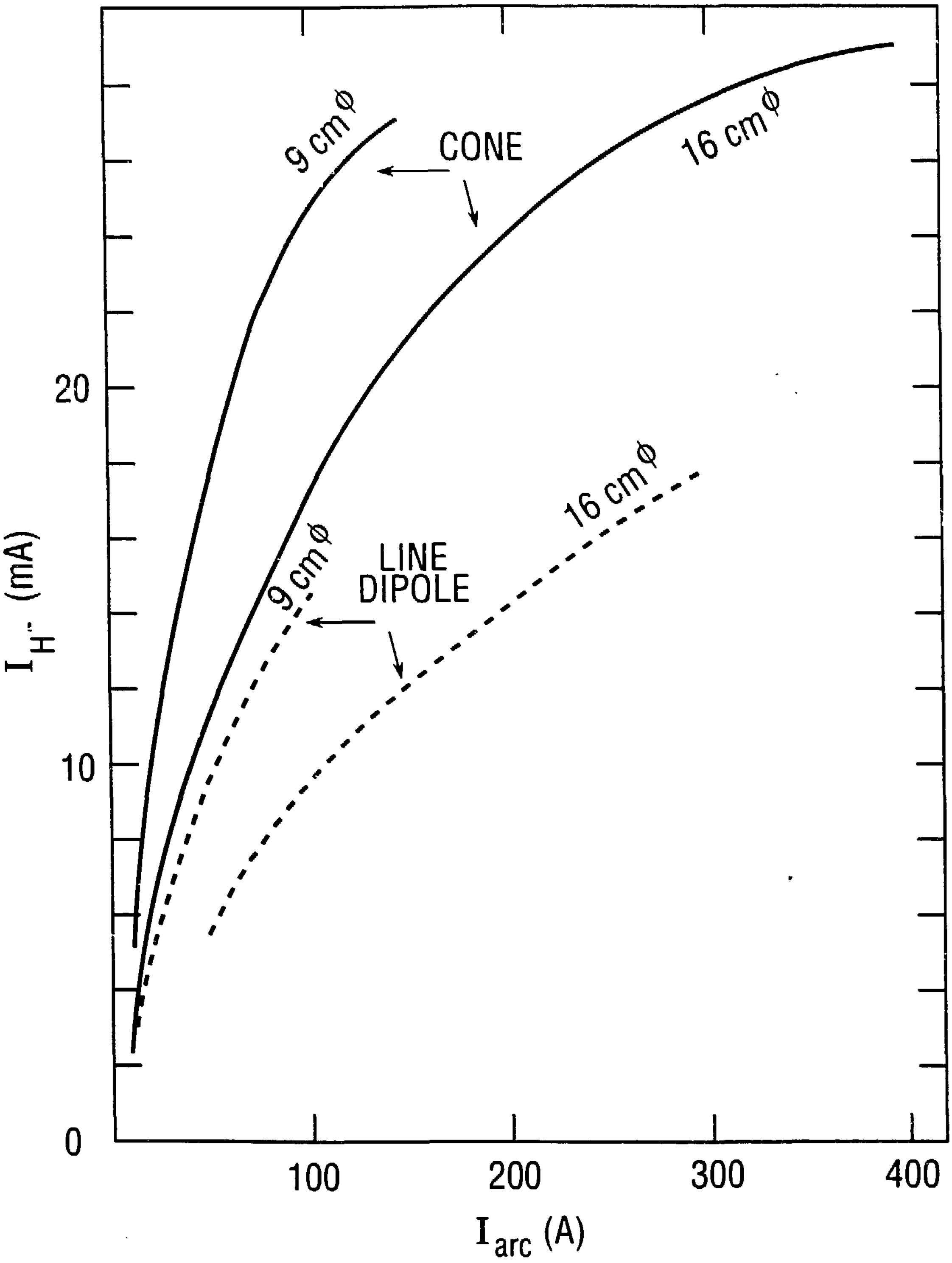

Fig. 3 H⁻ yield as function of the arc current comparing different filaments and filter field configurations.

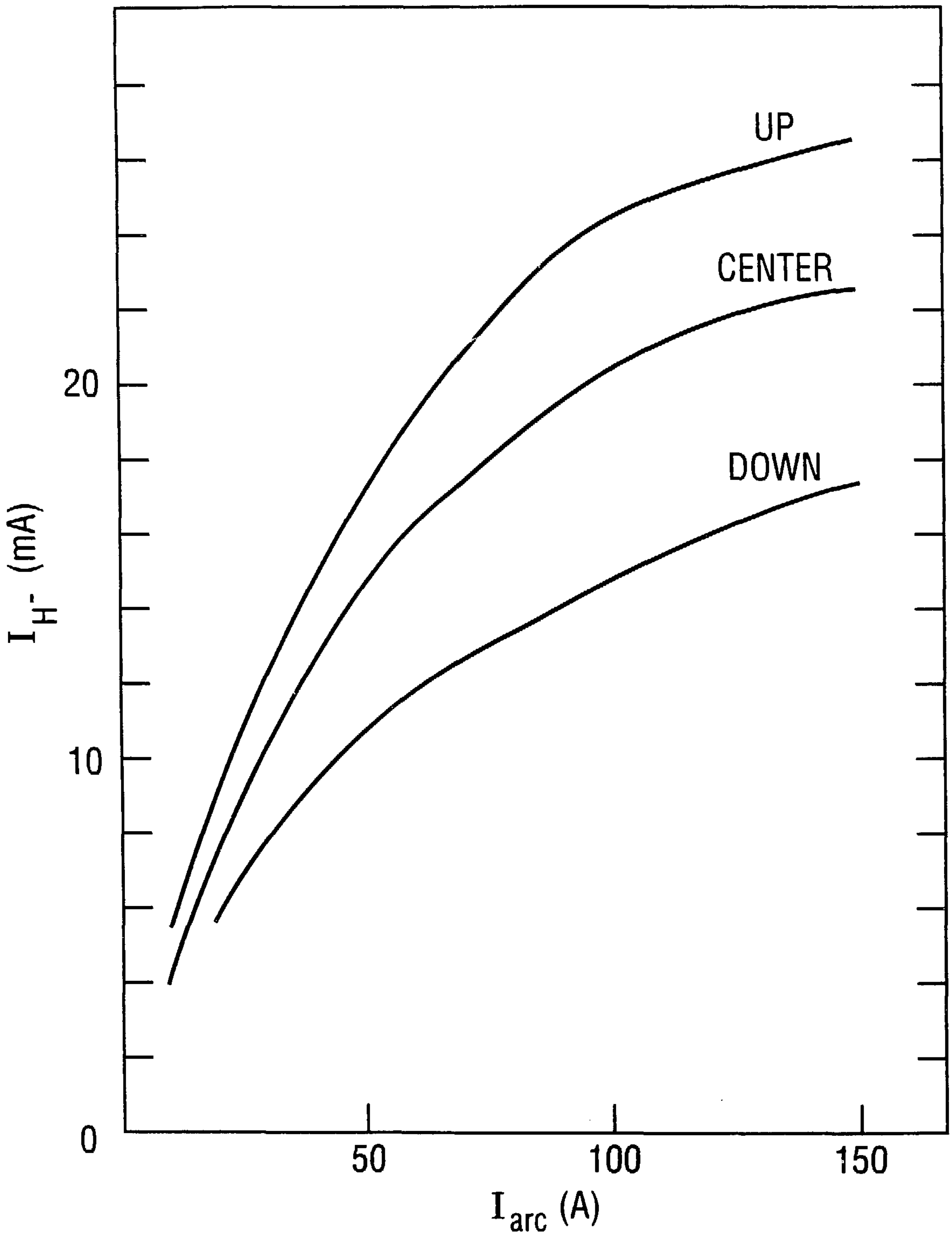

Fig. 4 H⁻ yield as function of the arc current for several positions of the filament.

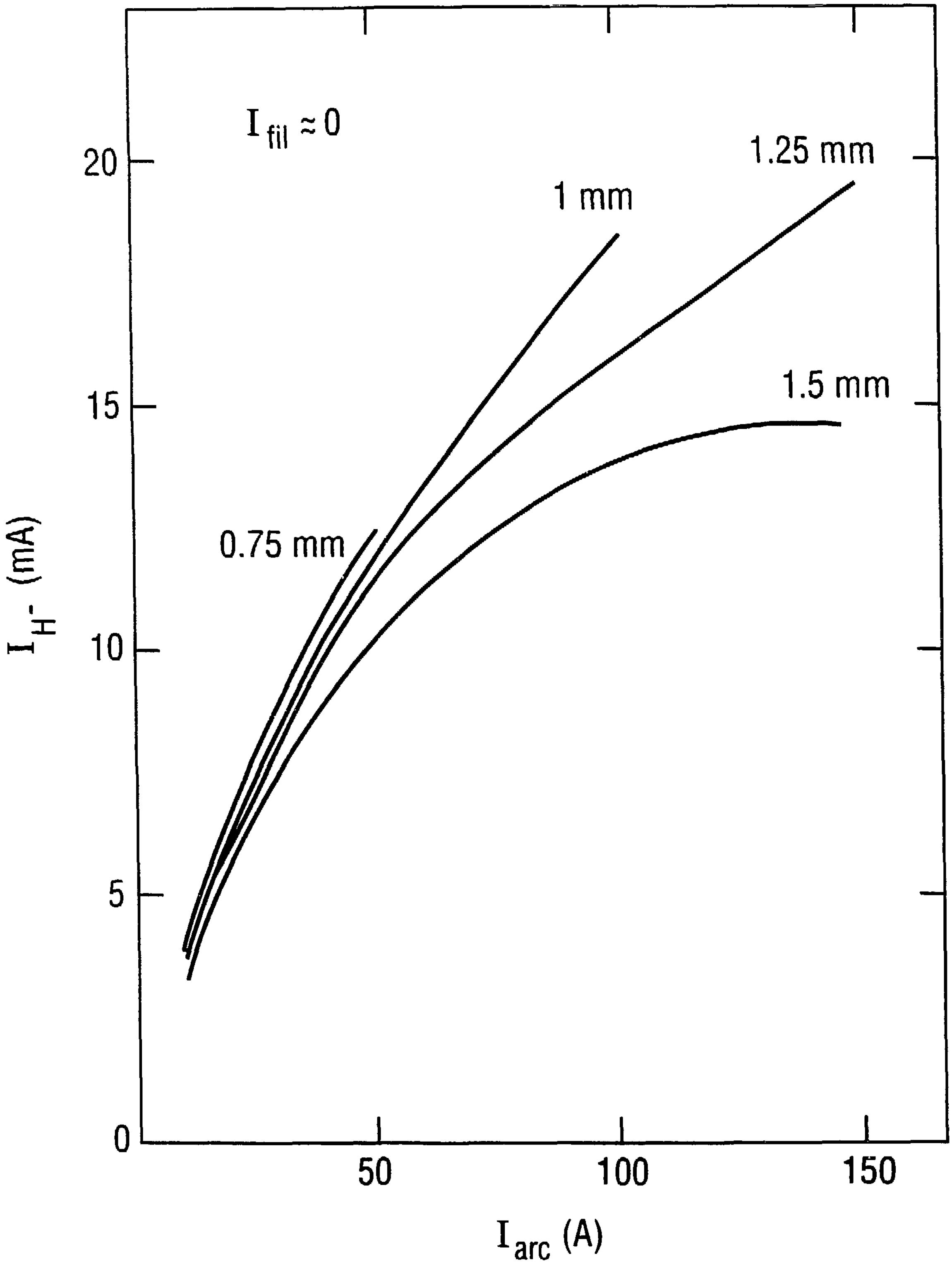

Fig. 5 H^- yield as function of the arc current for several values of the filament wire diameter.

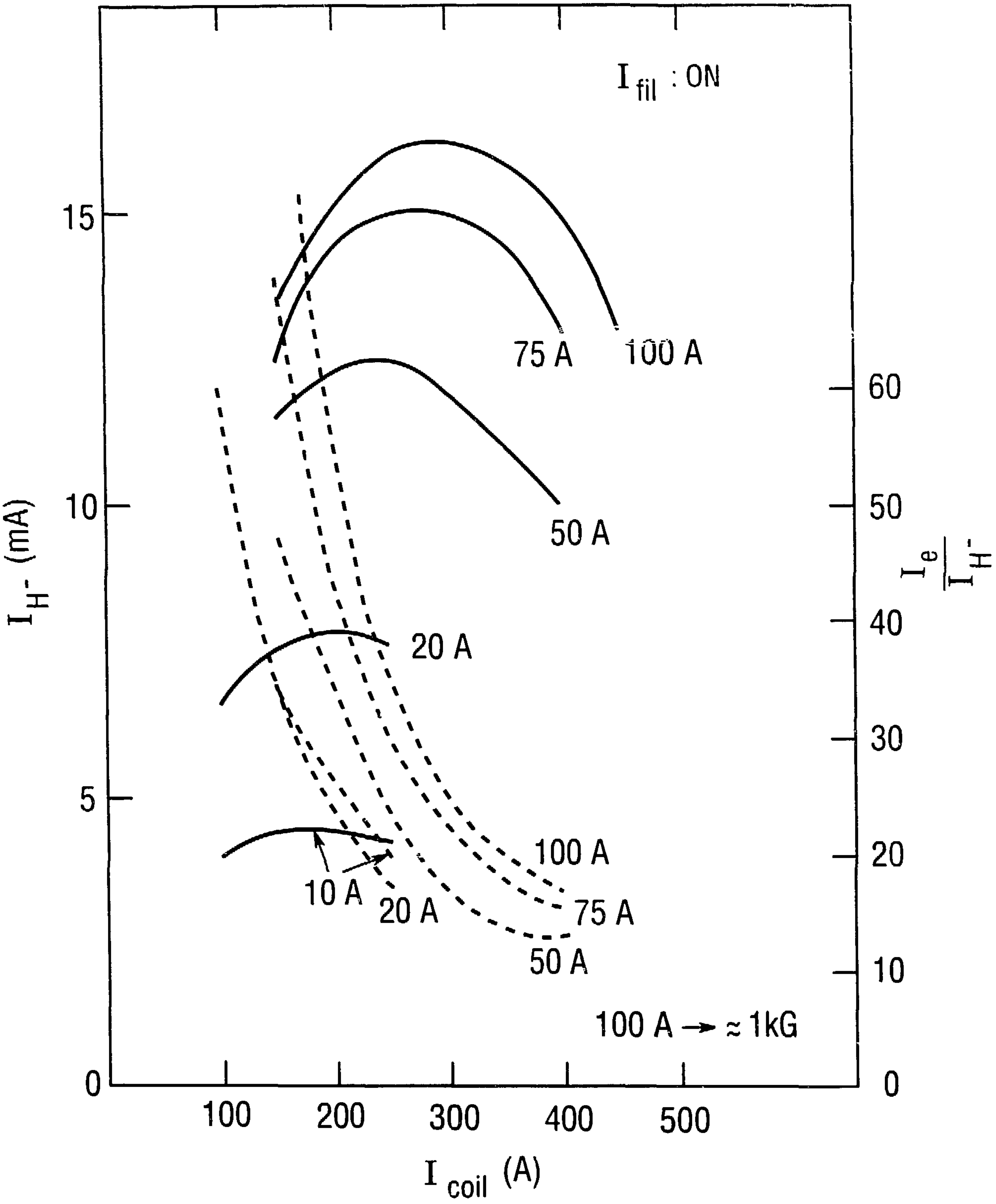

Fig. 6 H^- yield (full lines) and the ratio I_e/I_{H^-} as function of the conical field strength for several values of the arc current; I_{fil} ON.

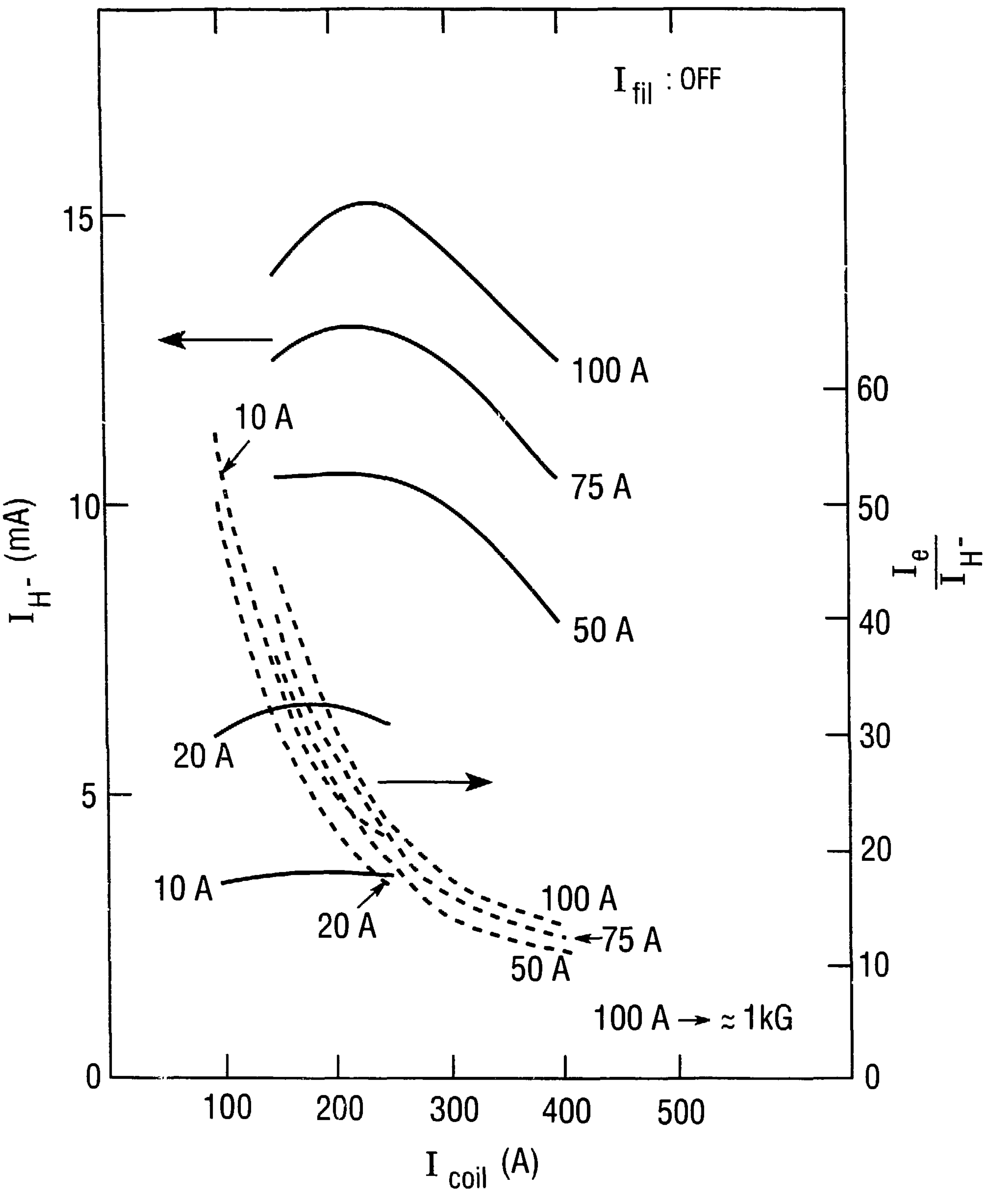

Fig. 7 H^- yield and the ratio I_e/I_{H^-} as function of conical field strength; I_{fil} OFF.

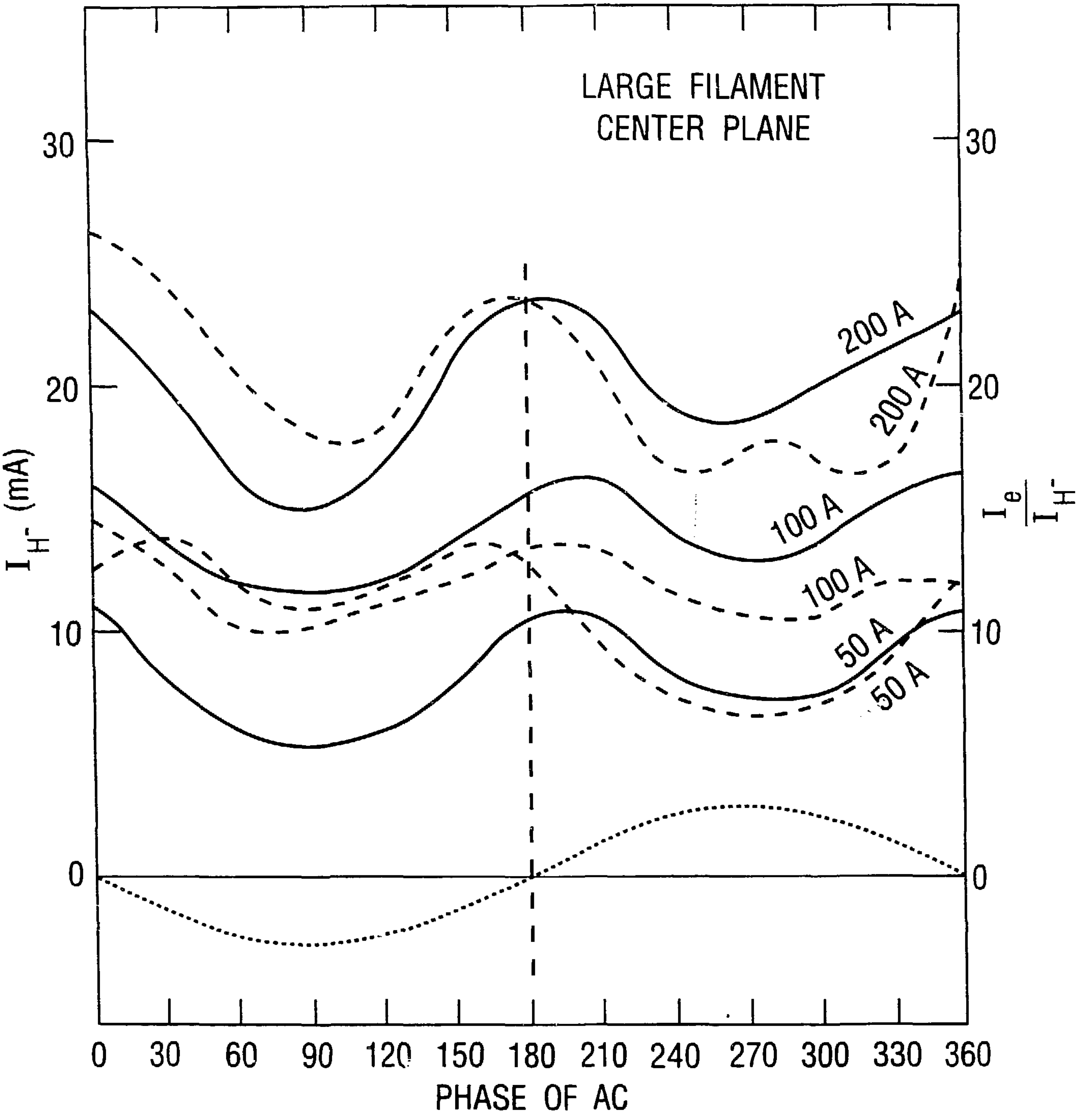

Fig. 8 H^- yield (full lines) and the ratio I_e/I_{H^-} as function of the phase of the ac filament current; filament: 16 cm diameter.

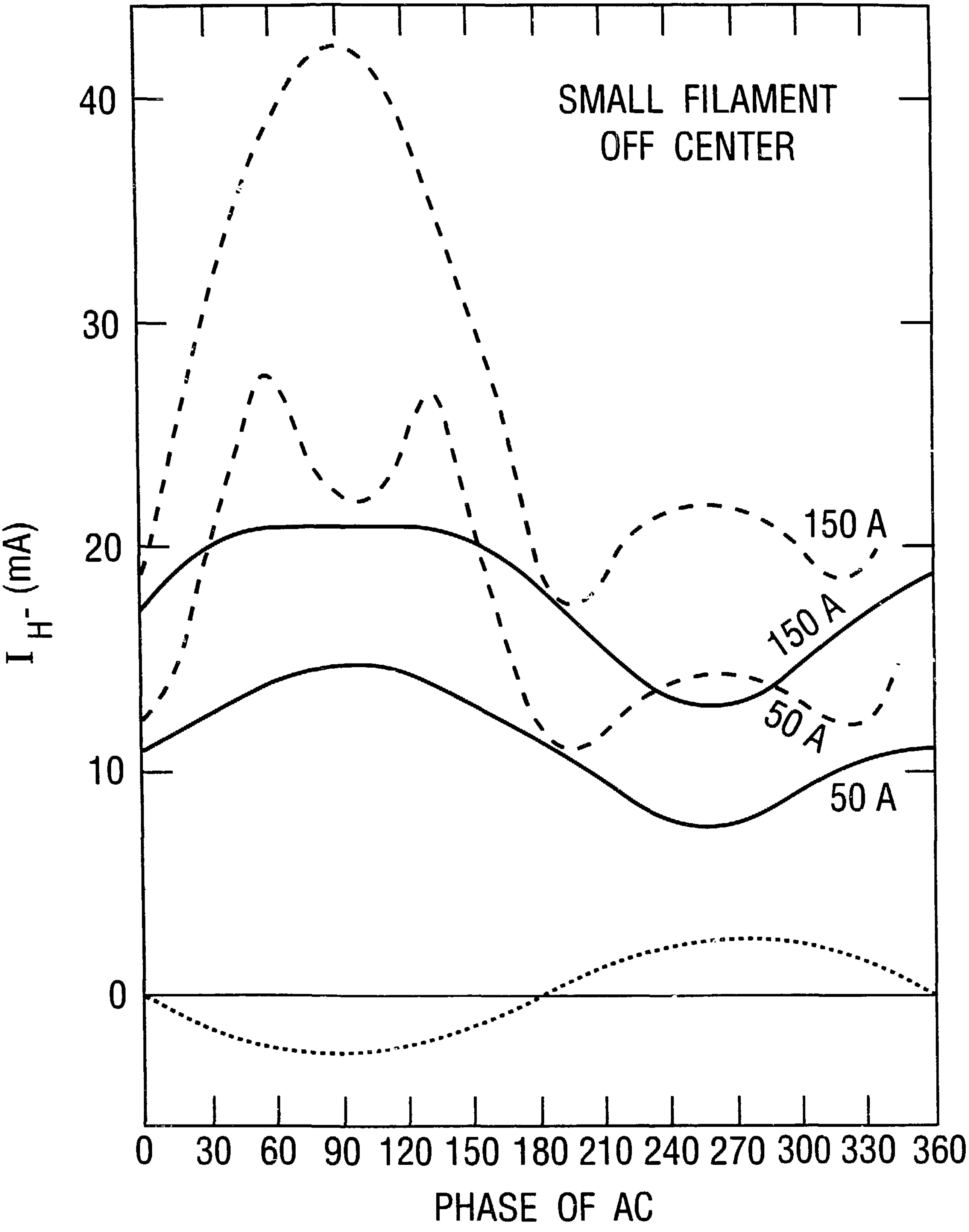

Fig. 9 H$^-$ yield (full lines) and the ratio I_e/I_{H^-} as function of the phase of the ac filament current; filament: 9 cm diameter.

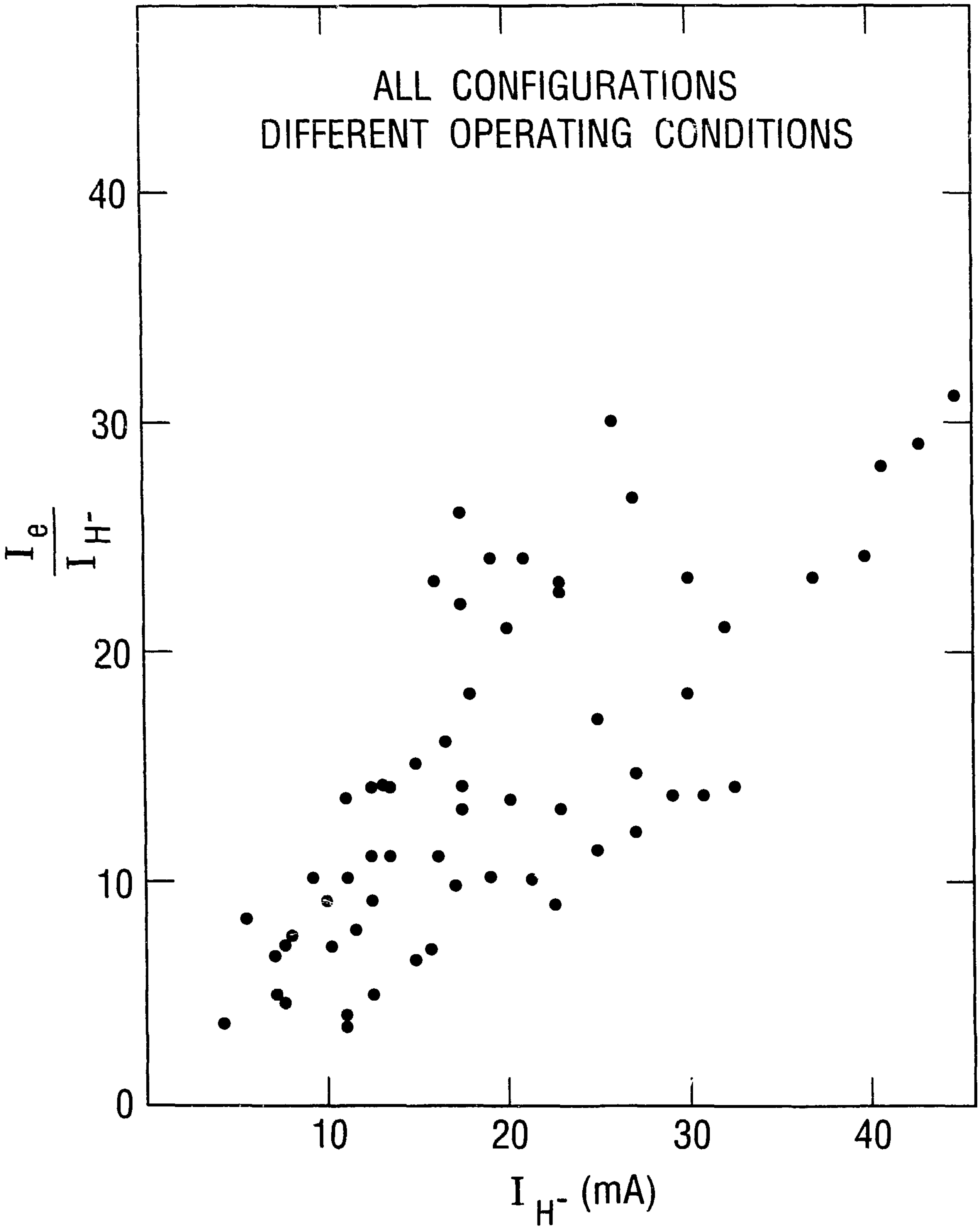

Fig. 10 Ratio I_e/I_{H^-} vs I_{H^-} for different configurations and operating conditions.