OVERVIEW ON STUDIES OF MARTIAN LIKE CO2-N2 MIXTURE BY INDUCTIVELY COUPLED PLASMA TORCH

Damien Vacher, Pascal André, Michel Dudeck

OVERVIEW ON STUDIES OF MARTIAN LIKE CO_2-N_2 MIXTURE BY INDUCTIVELY COUPLED PLASMA TORCH

Vacher D.[(1)] , André P.[(1)], Dudeck M.[(2)]

[(1)]*LAEPT, CNRS, Clermont-Ferrand, France, Damien.VACHER@laept.univ-bpclermont.fr*
[(2)]*Institut Jean Le Rond d'Alembert,University of Paris 6, France*

ABSTRACT

The purpose of the work is to make an overview on the results obtained through the studies on martian plasmas created by inductively coupled plasma torches (ICP). As the main advantage of the ICP torch is the absence of electrode compared to the others various test facilities, the radiative properties of this kind of plasmas are of interest to propose test cases in order to validate radiation models. ICP torches can work under various operating conditions in terms of pressure, enthalpy or flow. As a consequence, the studied plasma can be either at thermodynamical equilibrium or out of equilibrium, without problems of stability in time. The presentation concerns only the plasmas formed with a martian like CO_2-N_2 mixture and all the parameters of test facilities will be precised.

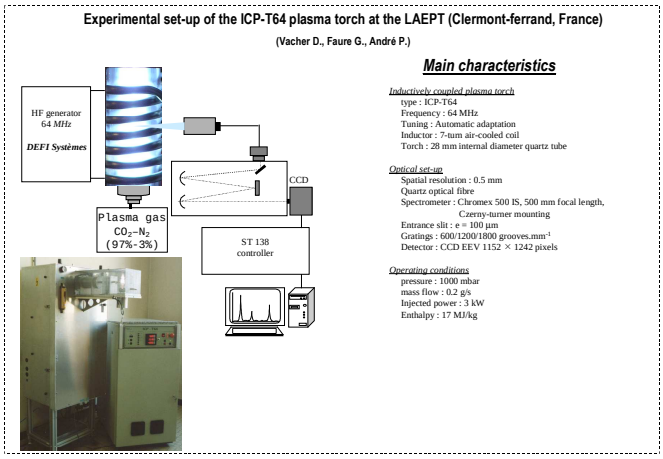
The following paper corresponds to the first step of a global paper which will be proposed later and it reports only the oral presentation which has been done during the third International Workshop of RHTG.

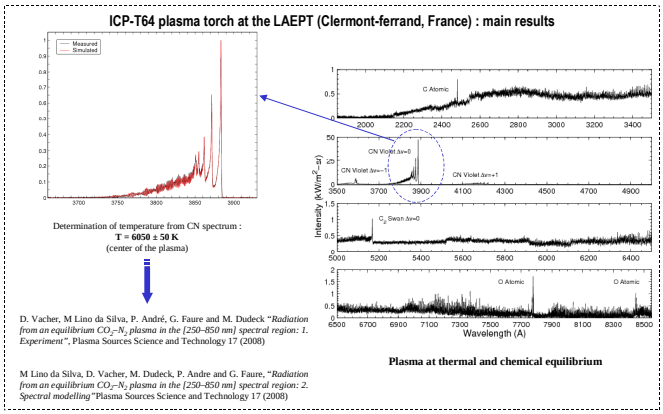
1. INTRODUCTION

Five laboratories have been found concerning the study of CO_2 or CO_2-N_2 plasmas by inductively coupled plasma torch. The laboratories which are about to start this kind of study do not appear in this presentation.

The laboratories which have obtained results are the following :
-L.A.E.P.T. (Laboratory of Electrical Arc and Thermal Plasmas) located in Clermont-Ferrand, France;
-C.O.R.I.A. (Complexe de Recherche Interprofessionnel en Aérothermochimie) located at Rouen, France;
-I.R.S. (Institut für RaumfahrtSysteme) located at Stuttgart, Germany;
-V.K.I. (Von Karman Institute) located at Rhode Saint Genese, Belgium;
-I.P.M. (Institute for Problems of Mechanics) located at Moscow, Russia.

2. L.A.E.P.T. (Clermont-Ferrand, France)





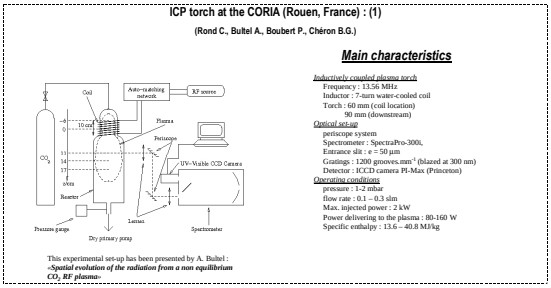
REFERENCES

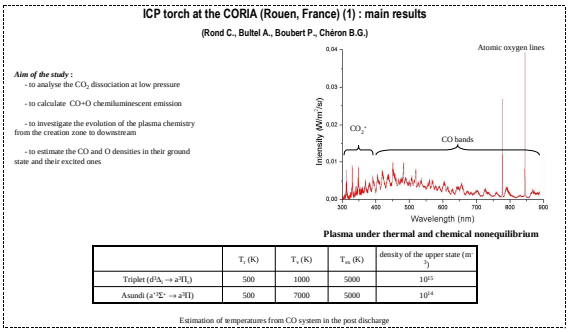
1. D.Vacher, M. Lino da Silva, P. André, G. Faure and M. Dudeck (2008) *Radiation from an equilibrium CO_2–N_2 plasma in the [250–850 nm] spectral region: 1. Experiment*
Plasma Sources Science and Technology 17 (2008) 035012 (8pp)

2. M. Lino da Silva, D. Vacher, M. Dudeck, P. Andre and G. Faure (2008) *Radiation from an equilibrium CO_2–N_2 plasma in the [250–850 nm] spectral region: 2. Spectral modelling*
Plasma Sources Science and Technology 17 (2008) 035013 (9pp)

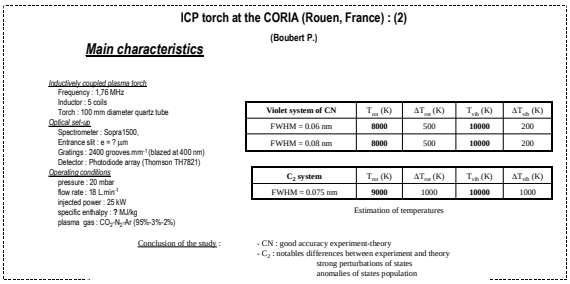
3. M. Lino de Silva, *An adaptative Line-by-Line-Statistical Model for Fast and Accurate Spectral Simulations in Low-Pressure Plasmas*
JQSRT, Vol. 108, n°1, pp. 106-125

3. C.O.R.I.A. (Rouen, France)





	T_r (K)	T_v (K)	T_{ex} (K)	density of the upper state (m^{-3})
Triplet ($d^3\Delta_i \rightarrow a^3\Pi_i$)	500	1000	5000	10^{15}
Asundi ($a'^1\Sigma^+ \rightarrow a^3\Pi$)	500	7000	5000	10^{14}



Violet system of CN	T_{rot} (K)	ΔT_{rot} (K)	T_{vib} (K)	ΔT_{vib} (K)
FWHM = 0.06 nm	**8000**	500	**10000**	200
FWHM = 0.08 nm	**8000**	500	**10000**	200

C_2 system	T_{rot} (K)	ΔT_{rot} (K)	T_{vib} (K)	ΔT_{vib} (K)
FWHM = 0.075 nm	**9000**	1000	**10000**	1000

Estimation of temperatures

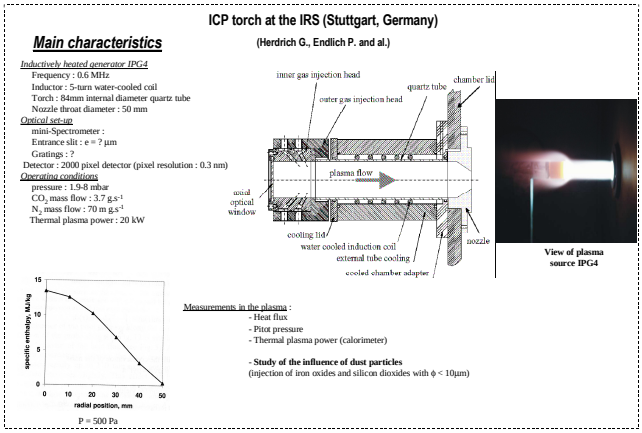
REFERENCES

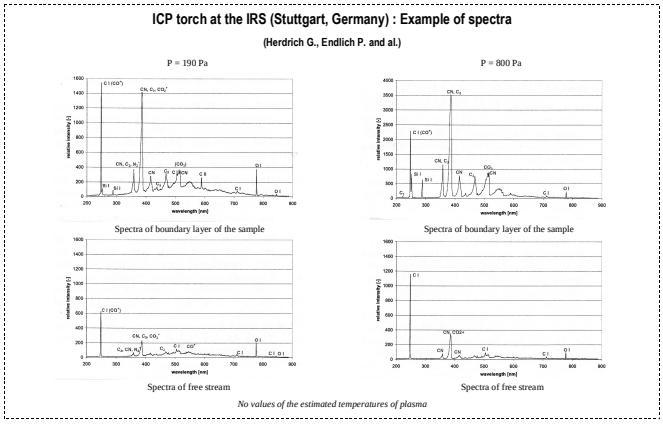
1. C. Rond, A. Bultel, P. Boubert, B.G. Chéron *Spectroscopy measurements of nonequilibrium CO_2 plasma in RF torch*, submitted to Chemical Physics (2008)

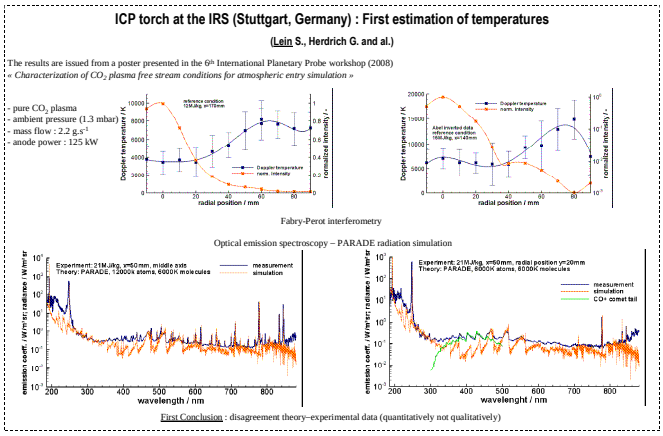
2. P. Boubert, P. Vervisch (2008) *CN spectroscopy and physico-chemistry in the boundary layer of a C/SiC tile in a low pressure nitrogen/carbon dioxide plasma flow*, Chemical Physics, Vol. 112, n°23, pp. 10482-10490

3. P. Boubert (1999) *Méthodes spectroscopiques appliqués aux plasmas et aux milieux à hautes enthalpies*, PhD Thesis, University of Rouen

4. I.R.S. (Stuttgartt, Germany)







REFERENCES

1. G. Herdrich, M. Auweter-Kurtz, H.L. Kurtz, T. Laux, M. Winter, *Operational Behavior of the Inductively Heated Plasma Source IPG3 for Re-entry Simulations*, Paper 99-3497 presented at the 33rd AIAA Thermophysics Conference, Norfolk, VA, 28 June 1999, *Journal of Thermophysics and Heat Transfer*, Vol. 16, No. 3, pp. 440-449, July-September 2002

2. G. Herdrich, M. Auweter-Kurtz, P. Endlich, *Mars Entry Simulation using the Inductively Heated Plasma Generator IPG4*, Engineering Note *Journal of Spacecrafts and Rockets* Vol. 40, No. 5, pp. 690-694, Sept.-Oct. 2003

3. P. Endlich, M. Auweter-Kurtz, G. Herdrich, *Mars Entry Simulation with Dust Using an Inductively Heated Generator*, Paper AIAA-2002-3237, 22nd AIAA Aerodynamic Measurement Technology and Ground Testing Conference, St. Louis, MI, USA, 24-26 June 2002

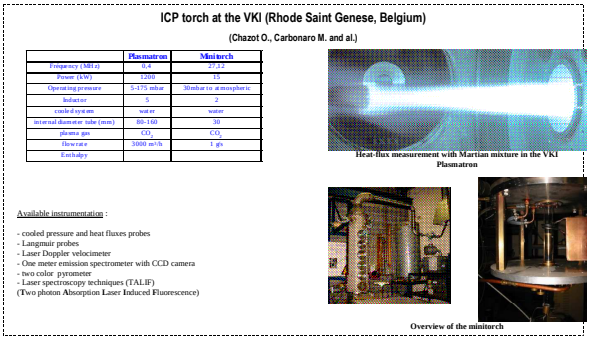
4. G. Herdrich, M. Auweter-Kurtz, P. Endlich, T. Laux, *Simulation of Atmospheric Entry Manoeuvres using the Inductively Heated Plasma Wind Tunnel PWK3*, DGLR Jahrestagung, DGLR-JT2002-254 Stuttgart, Germany, September 2002

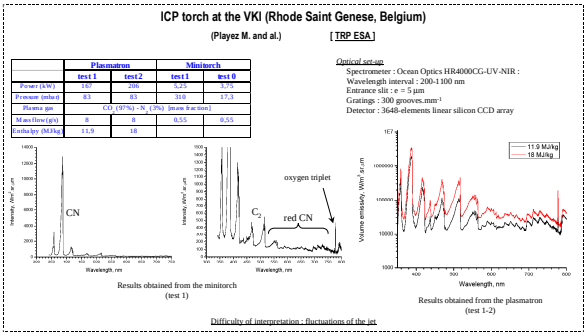
5. G. Herdrich, M. Auweter-Kurtz, P. Endlich, T. Laux, *Simulation of Atmospheric Entry Manoeuvres using the Inductively Heated Plasma Wind Tunnel PWK3*, DGLR Jahrestagung, DGLR-JT2002-254 Stuttgart, Germany, September 2002

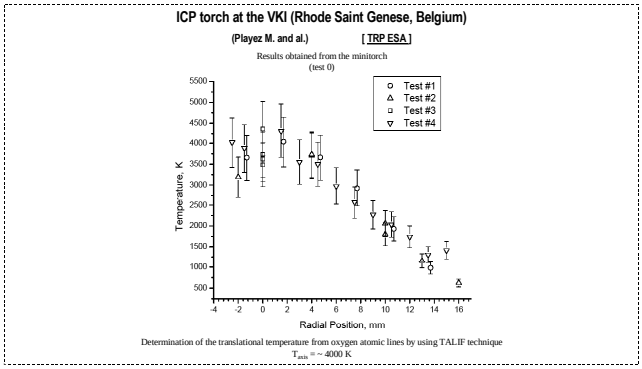
6. P. Endlich, M. Auweter-Kurtz, G. Herdrich, S. Löhle, M. Winter, *The Inductively heated Plasma Wind Tunnel PWK3 as a Means for Emission Experiments to rebuilt radiation Test Cases*, ESTEC Plasma Radiation Workshop, Portugal, Lissabon, Oct. 2003

7. G. Herdrich, S. Löhle, M. Auweter-Kurtz, P. Endlich, M. Fertig, S. Pidan, *IRS Ground-Testing Facilities: Thermal Protection System Development, Code validation and Flight Experiment Development*, Paper AIAA 2004-2596, 24th AIAA Aerodynamic Measurement Technology and ground Testing Conference, Portland, Oregon, USA, June/July 2004

5. V.K.I. (Rhode Saint Genese, Belgium)



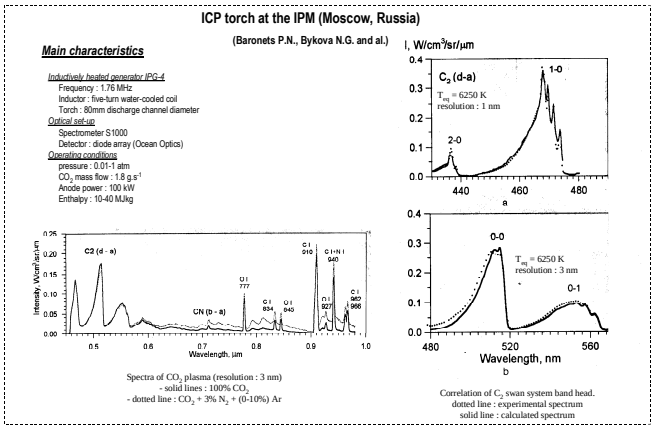


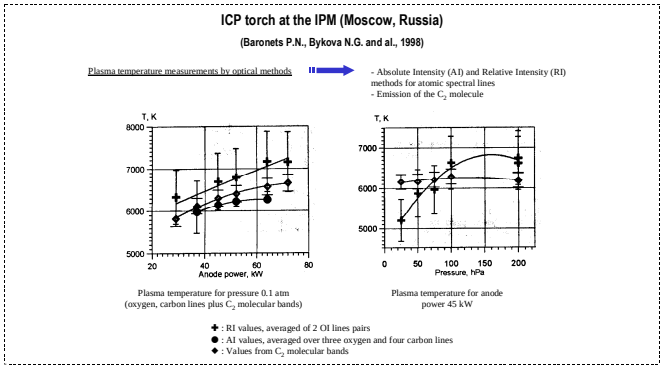


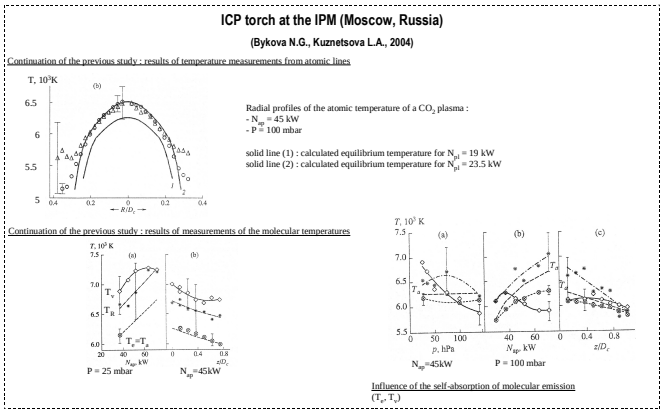
REFERENCES

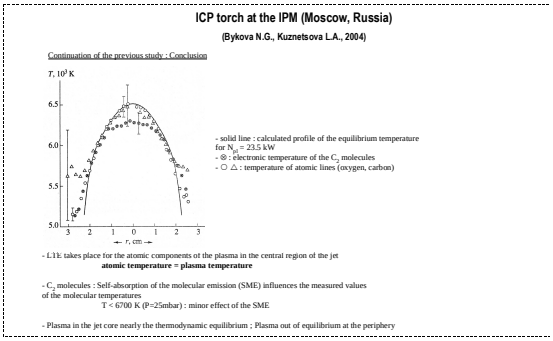
The informations are given by M. Playez.

6. I.P.M. (Moscow, Russia)









REFERENCES

1. N.G. Bykova, L.A. Kuznetsova (2004), *Measurements of the temperature of subsonic CO2 induction plasma flows by analysing their emission spectra*, Plasma Physics reports, Vol.30, n°11, pp.962-970

2. A.F. Kolesnikov, M.I. Yakushin and al. (2002), *Comparative analysis of the inductive plasmatrons capabilities for thermochemical simulation at the earth and Mars atmospheric entry conditions*

3. A.F. Kolesnikov and al. (2000), *Study of quarts surface catalycity in dissociated carbon dioxide subsonic flows*, Journal of Spacecraft and Rockets, Vol.37, n°5, pp.573-579

4. A.F. Kolesnikov, M.I. Yakushin and al. (1999), *Heat transfer simulation and surface catalycity prediction at the martian atmosphere entry conditions*, AIAA 9th International Space Plans and Hypersonic Systems and Technologies Conference, 1-5 November 1999 / Norfolk, Virginia, USA

5. P.N. Baronets, N.G. Bykova and al (1998), *Experimental characterization of induction plasmatron for simulation of entry into martian atmosphere*, Proceedings of the third European Symposium on Aerothermodynamics for Space Vehicles, 24th-26th November 1998, ESTEC, Noordwijk, The Netherlands

6. A.F. Kolesnikov, M.I. Yakushin and al. (1998), *Catalysis heat effects on quartz surfaces in high-enthalpy subsonic oxygen and carbon dioxide flows*, Proceedings of the third European Symposium on Aerothermodynamics for Space Vehicles, 24th-26th November 1998, ESTEC, Noordwijk, The Netherlands

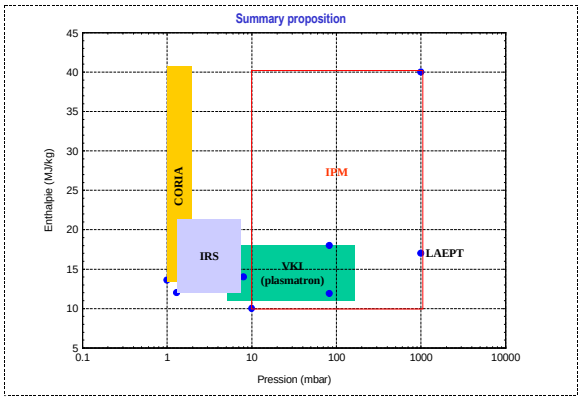
7. N.G. Bykova, S.A. Vasilevskii and al. (1997), *An induction plasmatron application for suimulation of entry into martian atmosphere*, Proceedings of the third international Symposium on Environmental Testing for Space Programmes, 24th-27th June 1997, ESTEC, Noordwijk, The Netherlands

8. N.G. Bykova, S.A. Vasilevskii and al. (1997), *Determination of the effective probabilities of catalytic reactions on the surfaces of heat shield materials in dissociated carbon dioxide flows*, Journal of Fluid Dynamics, Vol.32, n°6

7. CONCLUSION

A conclusion can not be done due to the fact that each laboratory works under different conditions in terms of flow, injected power, operating frequency and operating pressure. However, it is very interesting to gather all the data in order the domain of applications of each laboratory and also in order to create a connection between all these laboratories.

The following figure propose a regrouping of the data of each laboratory in terms of specific enthalpy and pressure. Of course, The field of investigation of each laboratories is likely to evolve.



ACKNOWLEDGMENTS

I would like to thank all the colleagues who permitted to this presentation to exist. I express all my recognition to them and thanks once again them for all the informations that they sent to me. These colleagues are : P. Boubert, A. Bultel,G. Herdrich, A.F. Kolesnikov, M. Playez and C. Rond.

I wish that the discussion will continue in order to still work together on the atmospheric entries with inductively coupled plasma torches.