Innovative artificial fog production device, a technical facility for research activities

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ABSTACT

A new innovative fog production device has been developed in close cooperation with partners of a European project called "FOG" funded by the EU. It is set up in the fog chamber of the road and bridges laboratory at Clermont-Ferrand. Most of the activities of this laboratory are dedicated to road safety but the facility is open to any other activity, such as environmental research. The recent developments consist in setting up a controllable device able to produce stable visibility levels and homogeneous fog, representative of various types of natural water droplet distribution. The fog characteristics were determined and compared to natural fog. Results are presented for a selection of conditions including stabilized visibility levels for dense fog, less than 50 metres meteorological visibility and two kinds of droplet distribution.

1. INTRODUCTION

The road and bridges laboratory had already been operating a fog chamber for about 15 years. The techniques to produce artificial fog were already used, but the installation suffered from the influence of outside weather conditions and it was not possible to stabilize the meteorological visual range of the atmosphere when required. In the fog project (André et al. 2003), two complementary developments were undertaken in parallel: the building of a reduced scale chamber with climate control, and the development of an innovative device allowing the control of the fog density in the chamber. This specific development is presented here. The objective of the development was also to increase the validity of the experimental conditions by improving the homogeneity of the atmosphere in the chamber and the control of droplet distributions. This paper will first describe the installation, the new system and the sensors to control the physical parameters. Then the results will be given, in comparison to bibliographical data obtained in natural atmosphere.

2. THE FOG CHAMBER FACILITY AT LRPC OF CLERMONT-FERRAND

Driving in poor visibility conditions, especially fog, needs to be studied in order to define strategies for the improvement of road safety. In fact, road traffic can be seriously endangered by fog. To carry out experiments on a real motorway in fog is not always easy. This is the reason why an experimentation centre has been developed at the laboratory of Clermont-Fd in charge of research on safety and visibility.

The facility, called "fog chamber" consists in an installation producing artificial fog in a laboratory that is 30 metres in length, 5.5 metres wide and 2 metres high (Colomb et al. 1999). This equipment makes it possible to study the factors that affect visibility in fog both day and night. Fog density is constantly controlled by means of a transmissiometer connected to the data acquisition system. An observation station consisting of the front of a car with headlights allows for both photometric measurements and personal observation by subjects placed in the driving position. The system for the production of fog consists of a super pressure unit, a pump, a pressure balance, a water basin as well as a system for water filtering and water de-mineralising. The injection nozzles, equipped with filters, are fixed to the water pipes. The water is brought under high pressure into the spray nozzles, which produce a thin jet of water. Figure 1 shows the installation. In the fog chamber, fog characteristics are determined by the mean of a transmissiometer measuring the transmission factor related to the extinction coefficient, K. It allows the Meteorological Visibility Range, MVR, to be determined by using the Koshmieder law as: MVR = 3/K.

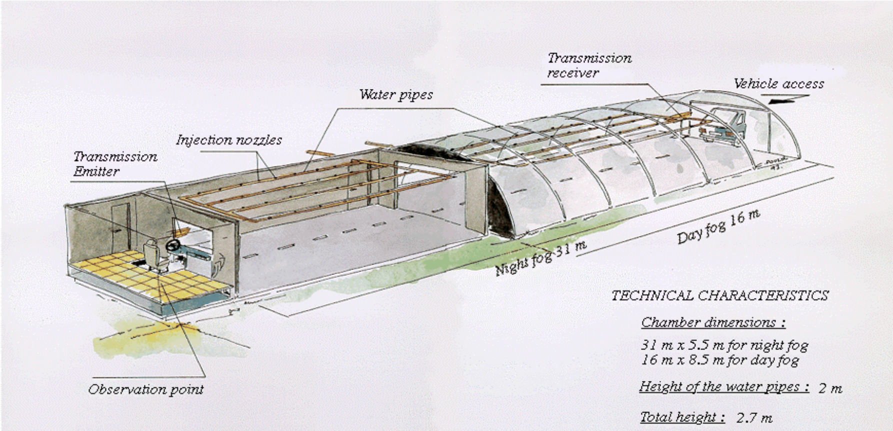


Fig. 1. Fog chamber at LRPC de Clermont-Ferrand

3. NEW FOG PRODUCTION SYSTEM

The fog chamber described above was the unique place in Europe open to any company or institute to work in fog conditions. But it had some limitations especially in terms of fog density, as it was not possible to maintain the fog density at a desired "visibility level". It was therefore decided to improve the system (Colomb et al, 2003), on the basis of specifications established by various users.

3.1 Specifications for the production system

All partners of the fog project were asked to express their requirements, and more specifically certain representatives of the safety research institutes and the automotive industry.
A stable and homogeneous fog was required in terms of visibility level and droplet distribution, representative of various natural types of fog .
- for visibility , the range concerned was between 10 and 300m, the requirement for "stable visibility level" was to maintain the visibility at +/- 20% for 10 minutes and up to one hour when necessary.
- Concerning droplet distribution, a bibliographical survey shows that the microphysical characteristics could be very different but could be split into two families:
."radiative fog" (continental or polluted areas) composed of small droplets of a few microns in diameter,
. "advection fog" (maritime or less polluted areas) composed of bigger droplets ranging from a few microns, to 10 or over 10 microns in diameter.
A detailed analysis was difficult to establish as the data depends on the sensor characteristics (value of the lowest measurement threshold, total range, type of data: droplet distribution or effective diameter….etc)
- The homogeneity of fog has to be controlled at 20%. A measuring method had to be investigated.
- The reproducibility of measurements has to be ensured for various seasons.

3.2 Development steps

The company "Dutrie" was in charge of the technical development. A new high-pressure booster allowing work between 30 and 100 bars was installed after preliminary tests. The working conditions were 40 or 70 bars. This booster is connected to new water pipes by means of magnet valves allowing short pulses of fog. Setting a «running and stopping time» on the electronic box can generate them. The nozzles are fixed on new water pipes by means of extenders that enable the water flow to be directed and a better repartition of fog production in the room. Two separate circuits enable pin nozzles or vortex nozzles to be used alternatively. Concerning the type of water, a double tank provides either ordinary water or demineralised water. An evaluation of the system's performances was carried out by LRPC and University of Nancy in the tunnel part, then the circuit was extended to the green house. Fog is dependant on the mass of water injected into the fog chamber. This parameter is related to the water pressure and to the type of nozzle.

4. PERFORMANCE OF THE NEW SYSTEM

With the old system, in order to produce fog of varying density, it was necessary to saturate the room for 15 minutes and then leave the fog to dissipate naturally. In this case the visibility increased progressively and the required value could be obtained for a short time after which the same procedure had to be repeated again and again. Therefore the main development consists in maintaining the fog at a required visibility level for a given time. The main results of the developments made by LRPC are presented below.

4.1 **Process to obtain stable "visibility levels" and reproducibility**

In order to stabilize fog at a required level, a "micro-injection" process was used. It consists in regularly supplying short water sprays, in order to compensate for the loss of water droplets, due to evaporation of sedimentation. The analysis of the visibility levels of the generated fog for various settings on the circuit, in relation to the injected water mass, enabled an "abacus" to be established in order to determine the right setting for the required level.

The figure below shows the evolution of the meteorological visual range of fog over a given period of time. The red curve corresponds to the natural dissipation of fog after saturation of the room, as obtained with the old system. The blue curve corresponds to successive stabilized visibility levels of 20 minutes, when changing the setting of the micro-injection process. For visibility less than 50 metres, the fog is stabilized with a scattering of about 10%. For less dense fog, fluctuations are more important.

Specific studies have been undertaken to evaluate the reproducibility of the method. Figure 3 shows data obtained during summer and wintertime, for visibility stabilised at very dense fog. Reproducibility is good for dense fog (less than 50m). It is the best for very dense fog (about 10 to 15 metres).

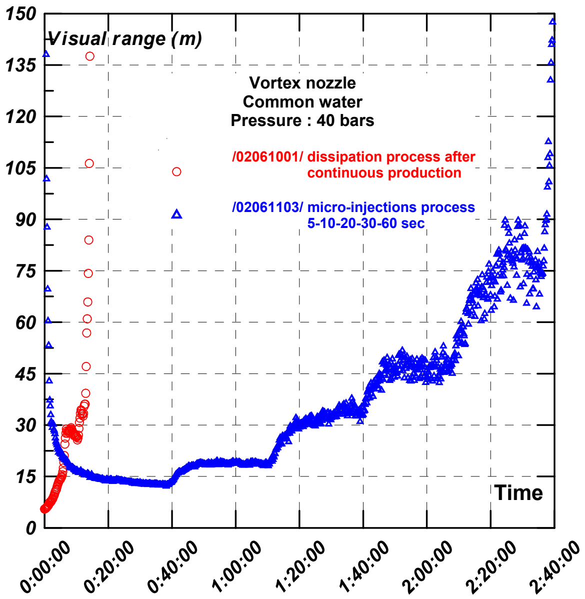


Fig. 2 : Fog production controlled by micro-injections in comparison to natural dissipation

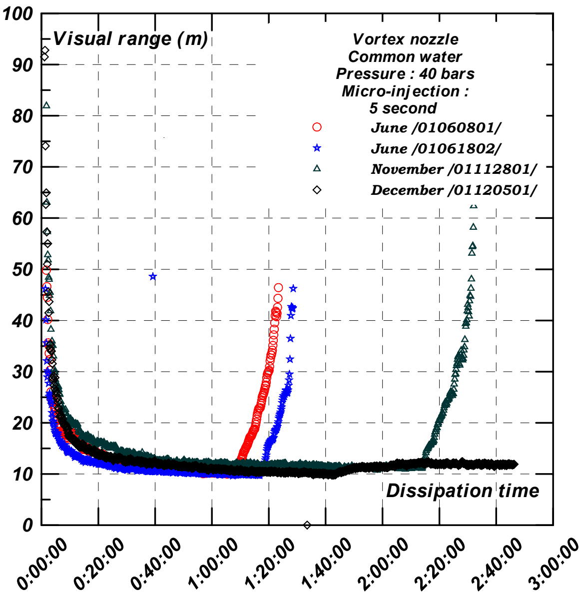


Fig. 3: Examples of reproducibility of fog stabilized at a defined level for data obtained in summer and wintertime

4.2 **Analysis of droplet distributions**

Visibility is a global parameter describing fog characteristics in relation to light transmission (C.I.E.). It is related to the extinction coefficient, which is directly connected to the fog granulometry; that is to say droplet diameter and concentration. In order to characterize these microphysical parameters, an optical granulometer was purchased during the European project. It characterizes the artificial fog droplet distribution in comparison to natural fog The sampling range in terms of diameter is 0.5 to 34 µm. Some examples of data are given in figures 5 and 6. They show the droplet distribution obtained with two types of water (ordinary and demineralised water). They are characterized by mean diameters of 2 µm and a Sauter diameter of 3.3 µm for ordinary water. A larger distribution is observed for demineralised water where the mean diameter is 6 µm and the Sauter diameter is 10 µm. Comparison with bibliographical data (Pruppacker and Klett 1978), shows that they are much more representative of radiative fog, the second distribution is nearer to advection fog. When a micro-injection process is used a good reproducibility in droplet distribution is also measured.

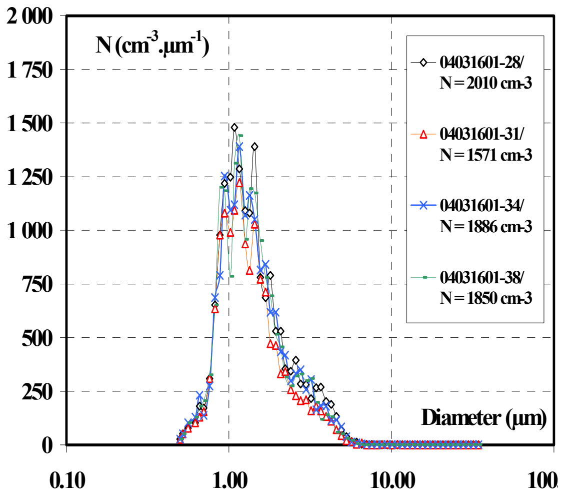
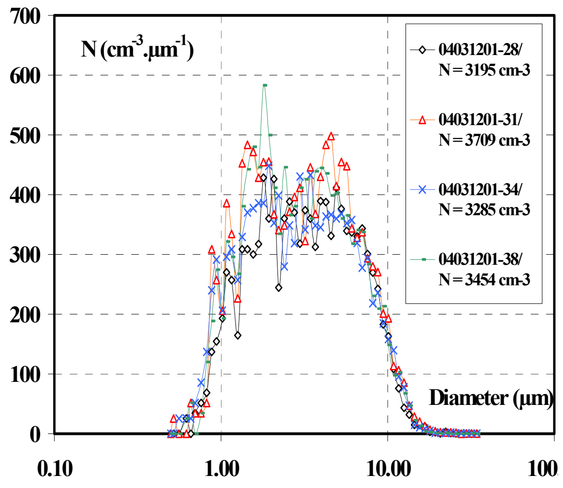


Fig. 4: droplet distribution obtained with ordinary water

Fig. 5: droplet distribution obtained with



demineralised water

4.3 **Study of fog homogeneity**

Users of the fog chamber require a good homogeneity of fog throughout the chamber. Thanks to a transmissiometer with 5 receivers, developed by the University of Liege, attempts have been made to measure spatial homogeneity. When measuring meteorological visual range during natural dissipation, a vertical variation of homogeneity is observed in the Clermont-Ferrand fog chamber. But when using successive stabilised fog visibility levels, this discrepancy is drastically reduced, due to the mixing and homogenisation of fog at each micro-injection.

5. CONCLUSION

The development of the innovative micro-injection process succeeded in reaching the goal of producing stabilized fog. The most significant results are obtained for dense fog conditions. In these conditions, reproducibility of the method has been validated, and homogeneity has been improved. Concerning fog granulometry, two types of droplet distributions could be produced. Exchanges with scientists carrying out measurements in natural conditions could be a way of making new progress. Researchers working in the field of fog as water resource are also encouraged to use this technical facility. Cooperative studies could be undertaken in order to optimise the various techniques of man-made fog collectors (Schemenauer, 2001), before field implementations.

Acknowledgements:

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