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MEASUREMENTS OF THE INFRARED OPTICAL CHARACTERISTICS OF FOG.(U)

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MEASUREMENTS OF THE INFRARED OPTICAL CHARACTERISTICS OF FOG

First Progress Report. no. 1,

by
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1.0 Introduction

There are several technology areas of interest to the Navy for which an understanding of multiple scattering of infrared radiation by fog is an important consideration. One application is in the field of electro-optics meteorology which addresses the limitations in operation of electro-optical systems due to weather. Another application is in covert communications where beam blowup by phenomena which include multiple scattering could permit transmission monitoring by the opposition. Conversely, knowledge of multiple scattering would be useful in applications where it is desired to monitor transmission by an adversary.

At present the Navy relies upon theoretical calculations for predicting multiple scattering of infrared radiation in fogs and clouds, using experimentally determined data on refractive index and particle size distribution. The multiple scattering measurement facility currently being designed at Aerodyne Research, Inc., should provide a sound experimental basis for evaluating scattering theories and calculational methods.

This facility may be instrumented for operation at various laser wavelengths and fogs may be generated with a great variety of substances. Navy interests may include studies with simulated sea fog and ocean spray. More exotic applications may include artificially seeded fogs which produce certain desired optical scattering properties. In summary, this facility may be a valuable tool for studying multiple scattering for a variety of laser wavelength/droplet composition combinations which are not presently amenable to theoretical analysis.

The current contract is directed to the achievement of fog generation on a laboratory scale. The objective is the production and measurement of fog which has a realistic droplet size distribution and which is of sufficient density to provide an optical depth at 3.8 μm of at least 10 cm. Steady state operation will be achieved in a continuously flowing system with a spatially uniform experimental volume of one cubic meter. Droplet density, size distribution, and degree of spatial uniformity will be measured with an aerosol spectrometer, Model CSAS-100, supplied by Particle Measuring Systems.

Under the current contract, Aerodyne Research, Inc. will provide suitable recommendations for a second phase of work where multiple scattering measurements of IR radiation by fog will be conducted.

2.0 Current Program Outline

The present program is directed to achievement of fog simulation on a laboratory scale, in steady state, at sufficient density to allow measurements of multiple scattering of IR radiation. Recommendations will be made for use of this fog chamber in multiple scattering studies.

Preliminary design of the full-scale fog chamber has identified all important aspects of air handling and has led to selection and sizing of mist generating nozzles. A sub-scale model of this system has been designed and fabrication is near completion. The sub-scale system contains one mist nozzle which is of the same design as those to be used in a six nozzle array in the full-scale system. Consequently, complete evaluation of performation expectations will be obtained with this sub-scale system.

Air and water pressure and flow rate measurements will provide a determination of flow velocity and fog mass loading in steady state operation of the fog chamber. The PMS aerosol spectrometer will provide absolute measurements of the droplet size distributions at various locations within the chamber. These spatial and spectral measurements of droplet particle density combine with chamber flow velocity to provide a second independent determination of water flow rate. Comparison of this determination with the water flow meter reading will provide an evaluation of overall system measurements accuracy. The accuracy of the aerosol spectrometer in identifying fog particle size distribution will be determined in tests in which the mist nozzle will operate in a single pulse mode. The droplets will fall through quiescent air at rates related to size. The spectrometer will be positioned at a fixed distance below the mist source where arrival time of droplets is related to size in a known way.

The above calibration and system performance measurements require the recording of a large volume of digital output from the aerosol spectrometer. To facilitate this data recording and subsequent data analysis, the CSAS-100 aerosol spectrometer will be interfaced with a minicomputer under this contract.

After completion of the above studies, the full-scale fog chamber will be designed. This final design will include an IR laser source and detector with appropriate mechanical drives for spatial mapping of radiation after scattering. Fabrication and testing of the full-scale chamber will be carried out under the present contract to the extent that current funding permits. Laser source and detector instrumentation will be proposed for a second phase of this work.

3.0 Current Status and Performance Schedule

A sub-scale fog chamber has been designed and construction will be completed within the next two weeks. Mist is generated by an aerosol nozzle and mixed with a downward directed air stream in a chamber of square cross section with an area of 0.56 m^2. An air speed of 20 cm/sec is sufficient to provide a uniform spectral distribution of droplets over a vertical test region of 50 cm, with a droplet mass loading as high as 1.34×10^{-4} g/cc. If the droplet spectral distribution is centered about a radius of 4 μm, this corresponds to a droplet density of 5×10^5 cc^{-1} and, for radiation at 3.8 μm, a mean free path of 2.0 cm.

Fog will be sampled with an aerosol spectrometer which was acquired under a previous contract with the Army Missile R & D Command. Apparatus for mapping the spatial uniformity of droplet spectra has been designed. Installation of sampling apparatus and particle spectrometer will be completed during January, 1978. Preliminary particle spectral measurements will be carried out during February, 1978. Digital output of the aerosol spectrometer will be interfaced with a minicomputer during February and March, 1978. Overall system calibration and evaluation will be conducted during April, May and June, 1978.

On the basis of the sub-scale system evaluation, a full-scale fog chamber will be designed which will include instrumentation for multiple scattering measurements of IR radiation. Construction of the full-scale fog chamber will be carried out to the extent that current funds permit. Instrumentation of this chamber for IR radiation scattering measurements will be recommended as a part of the future work.

Performance as described above is summarized in the schedule of Figure 1.

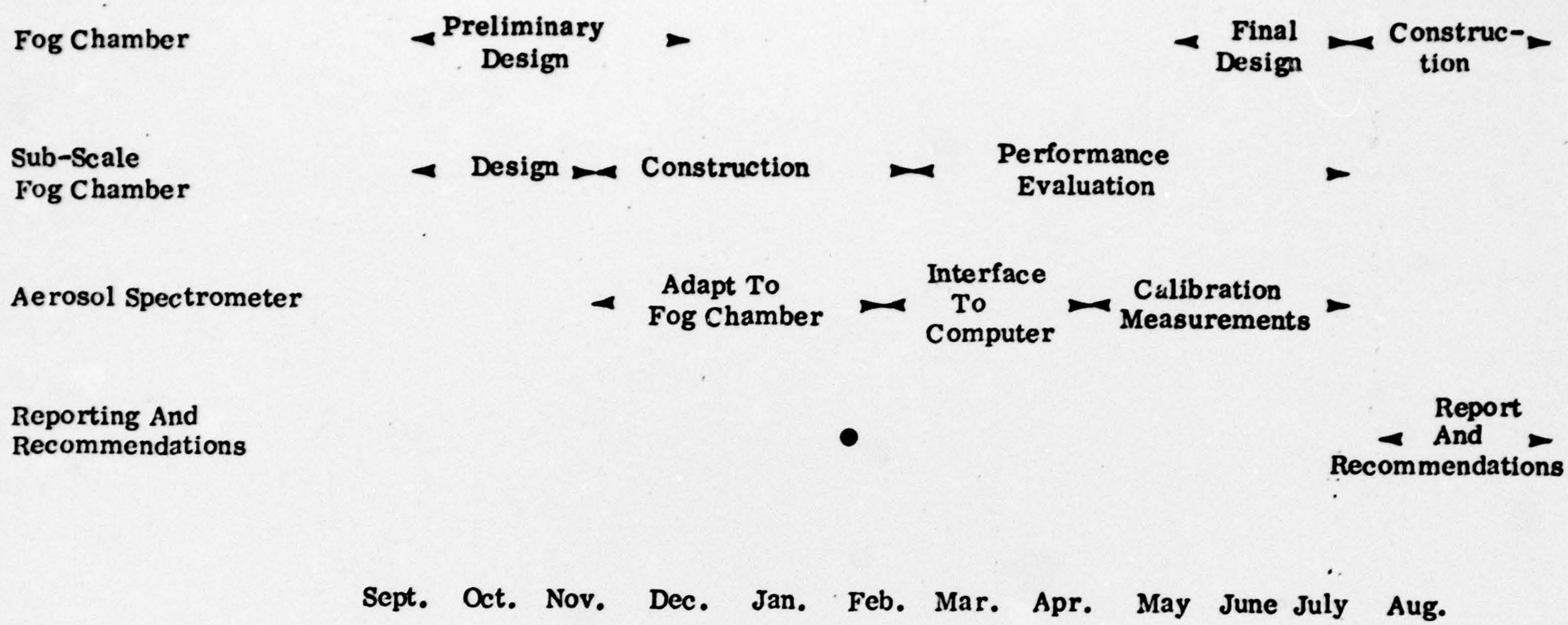

Figure 1. Performance Schedule For Measurement Of Fogs.