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Hydrochloric Acid Aerosol Formation by the Interaction of Hydrogen Chloride With Humid Air

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PREFACE

The work described in this report was performed by the Propulsion Division of the Jet Propulsion Laboratory.

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ABSTRACT

This paper describes the conditions in which hydrochloric acid aerosol is predicted by the interaction of hydrogen chloride gas with the water vapor in humid air. The liquid-gas phase equilibrium for the HCl-H_2O system is expressed in terms of relative humidity and hydrogen chloride concentration as parts per million, units commonly used in pollution studies. This paper presents the concentration (wt %) of HCl in the aerosol and the concentration of aerosol (ppm) predicted.

I. INTRODUCTION

Air pollution by hydrochloric acid has been the subject of appreciable concern in recent years (Refs. 1 and 2). This paper describes the conditions in which hydrochloric acid aerosol is predicted by the interaction of hydrogen chloride gas with the water vapor in humid air. The liquid-gas phase equilibrium for the HCl-H_2O system is expressed in terms of relative humidity and hydrogen chloride concentration as parts per million, units commonly used in pollution studies. This paper presents the concentration (wt %) of HCl in the aerosol and the concentration of aerosol (ppm) predicted.

There is an excellent paper in German (Ref. 3) describing graphically the phase equilibria of the HCl-H_2O system, where partial pressures of HCl and H_2O are expressed in mm Hg. (The data are tabulated in Ref. 4.) Enthalpy and heat of dilution data are also available (Ref. 5).

II. RESULTS

The HCl concentrations considered here ranged from 1 to 1000 ppm, and temperatures considered ranged from 263°K (-10°C) to 313°K. Figure 1 is a phase diagram showing the regions where aerosol is expected, as a function of HCl concentration (ppm) and relative humidity, for the various temperatures. The regions in Fig. 1 to the right of each isotherm represent the two-phase regions. Figures 2 - 7 present the expected HCl concentration (wt %) in the aerosol (solid lines) and the weight fraction (ppm) of liquid phase (aerosol) to gas phase (dashed lines).

III. DISCUSSION

An example of the application of these figures to a typical problem might be to determine what happens when 15 ppm HCl interacts with air at 293°K (20°C) and 84% relative humidity. Figure 1 indicates that aerosol is predicted; Fig. 5 indicates an aerosol of 10% HCl at a quantity of 100 ppm. The HCl in the gas phase can be determined from the interaction of the 10% (solid) line and the boundary line of the single- and two-phase regions; it is seen to be 6 ppm. Likewise, if the RH were 75%, no aerosol is expected.

Likewise, 100 ppm HCl interacting with air at 303°K (30°C) and 90% RH would result in 1200 ppm of an 8 wt % HCl aerosol, leaving 7.2 ppm HCl in the gas phase.

The curves in Figs. 1 - 7 were plotted from data computed from that available in the literature in tabulated form relating phase equilibrium to partial pressures of HCl and H_2O in mm Hg (Ref. 4) and for water vapor pressure (mm Hg) vs temperature (Ref. 6).

Although these curves show the predicted formation of HCl aerosol, whether or not aerosol is actually formed depends upon the presence of nucleation sites. Experiments on the formation of HCl aerosol (Ref. 7) indicated a minimum of 78% RH at ambient temperature for aerosol formation and that aqueous nuclei were required; however, further study of HCl aerosol nucleation is indicated.

IV. CONCLUSIONS

By the use of Figs. 1 - 7, one can determine predicted HCl aerosol formation, including the concentration of HCl in the aerosol, the weight fraction of aerosol, and the gas-phase concentration of HCl. This information should be useful in various aspects of the problem of hydrochloric acid air pollution.

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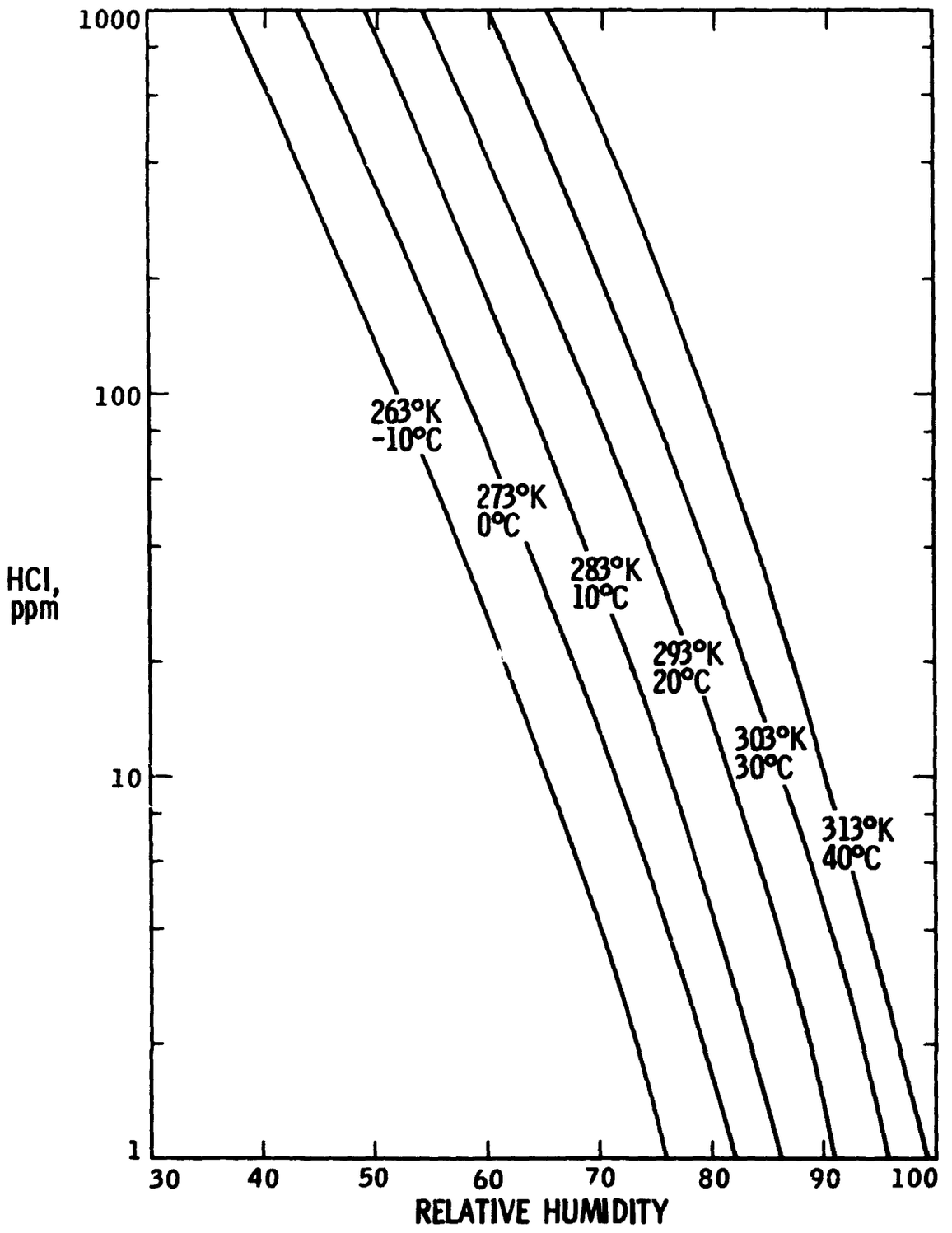

Fig. 1. HCl aerosol formation vs HCl concentration, relative humidity, and ambient temperature

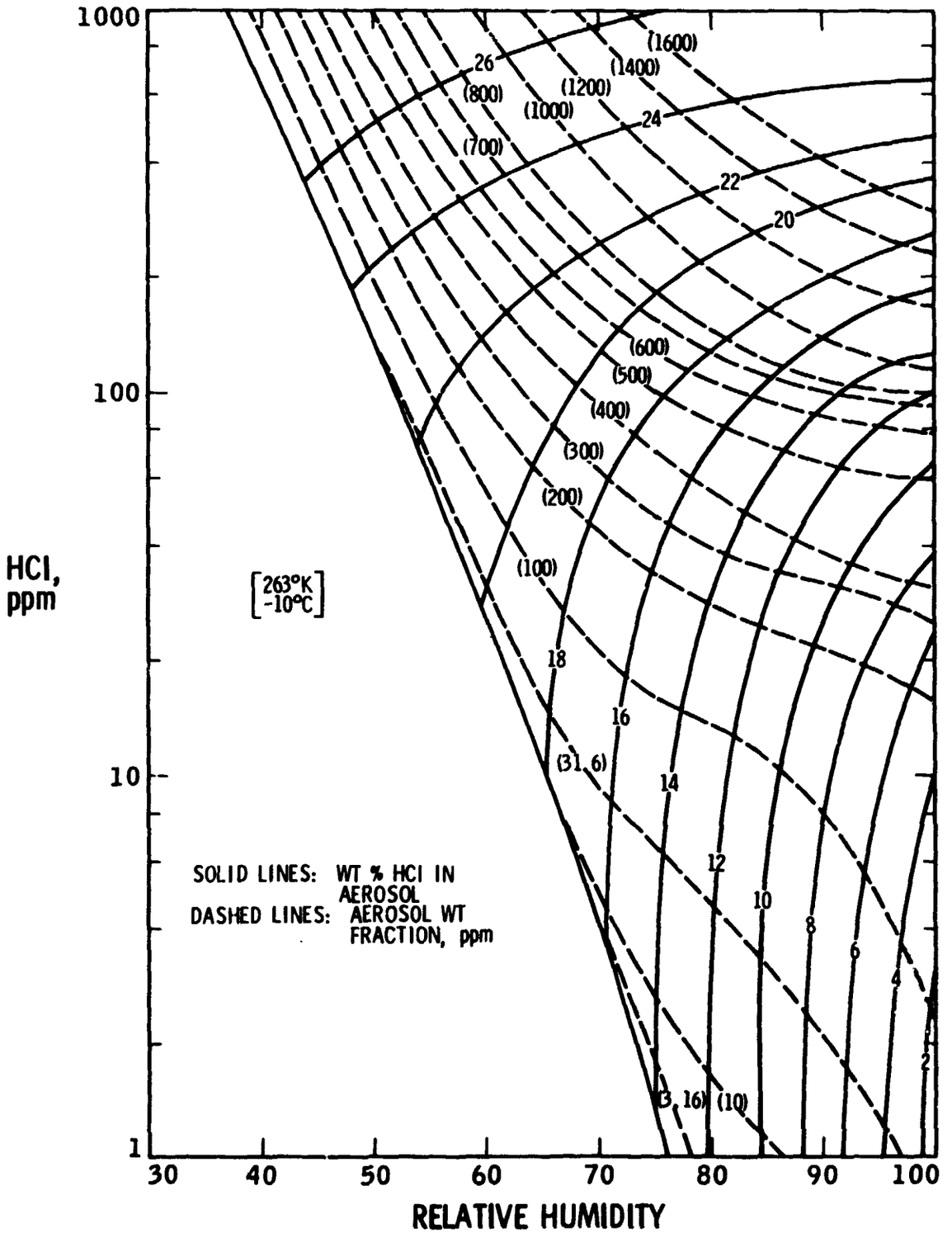

Fig. 2. Formation and properties of HCl aerosol at 263°K vs HCl concentration and relative humidity

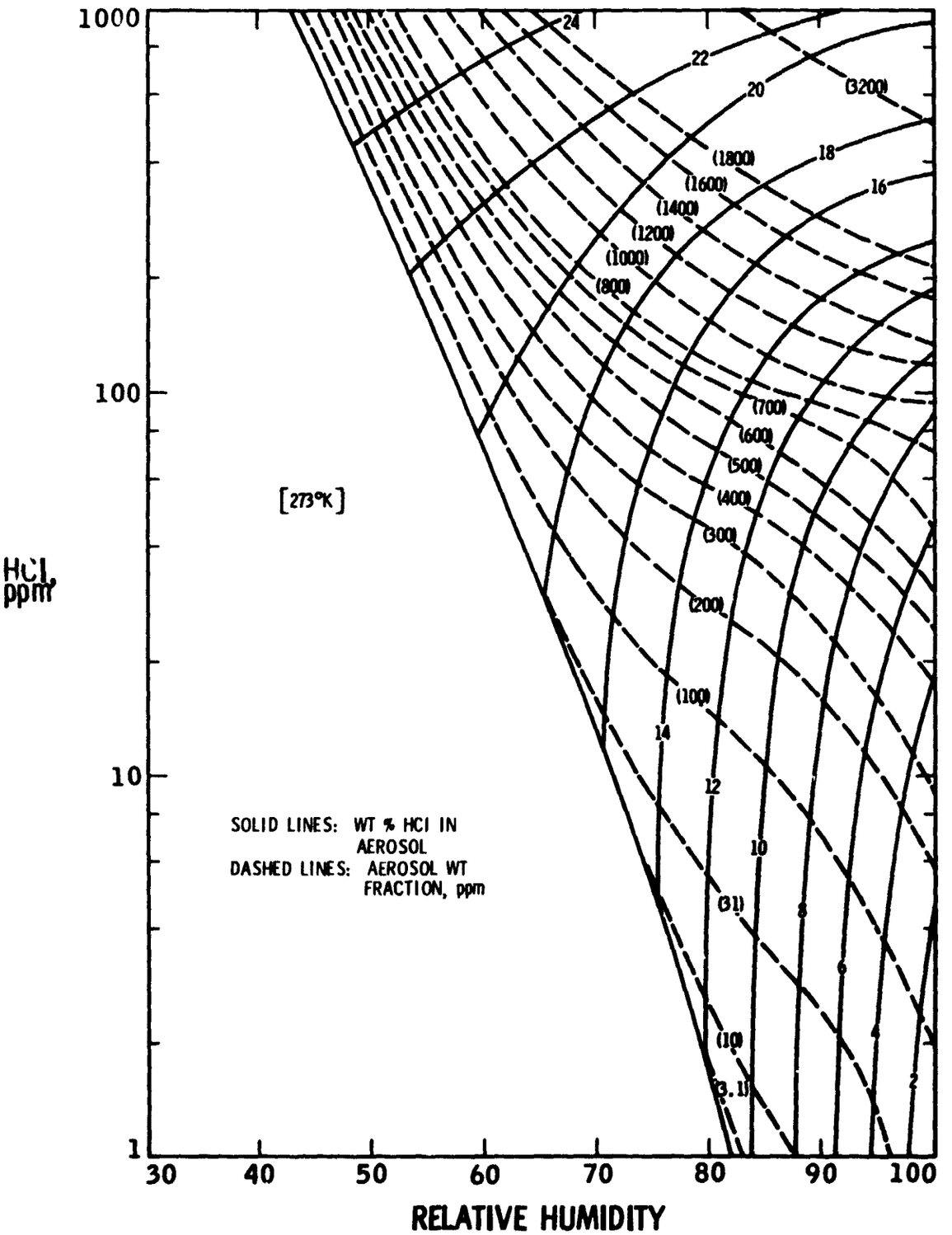

Fig. 3. Formation and properties of HCl aerosol at 273°K vs HCl concentration and relative humidity

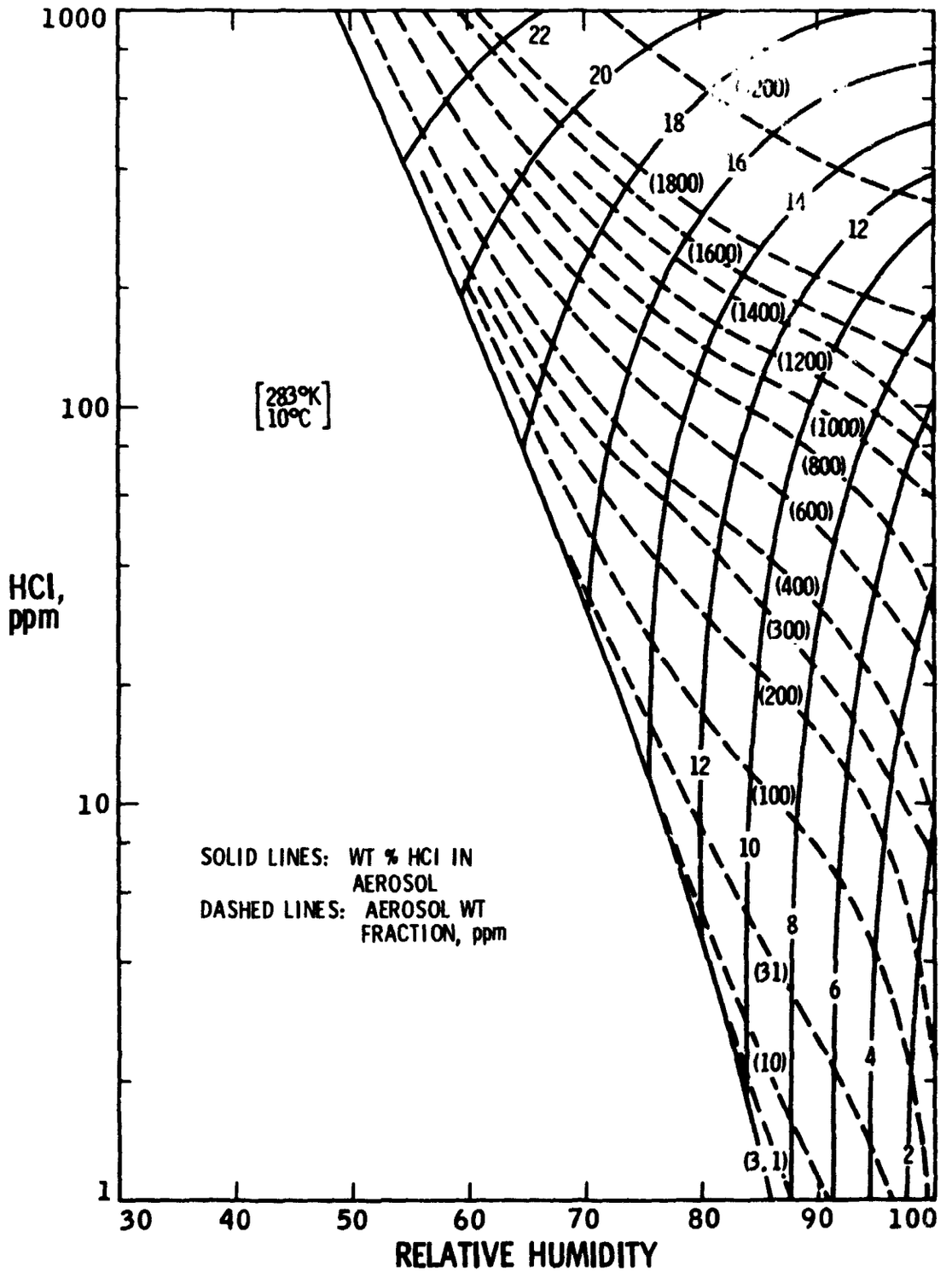

Fig. 4. Formation and properties of HCl aerosol at 283°K vs HCl concentration and relative humidity

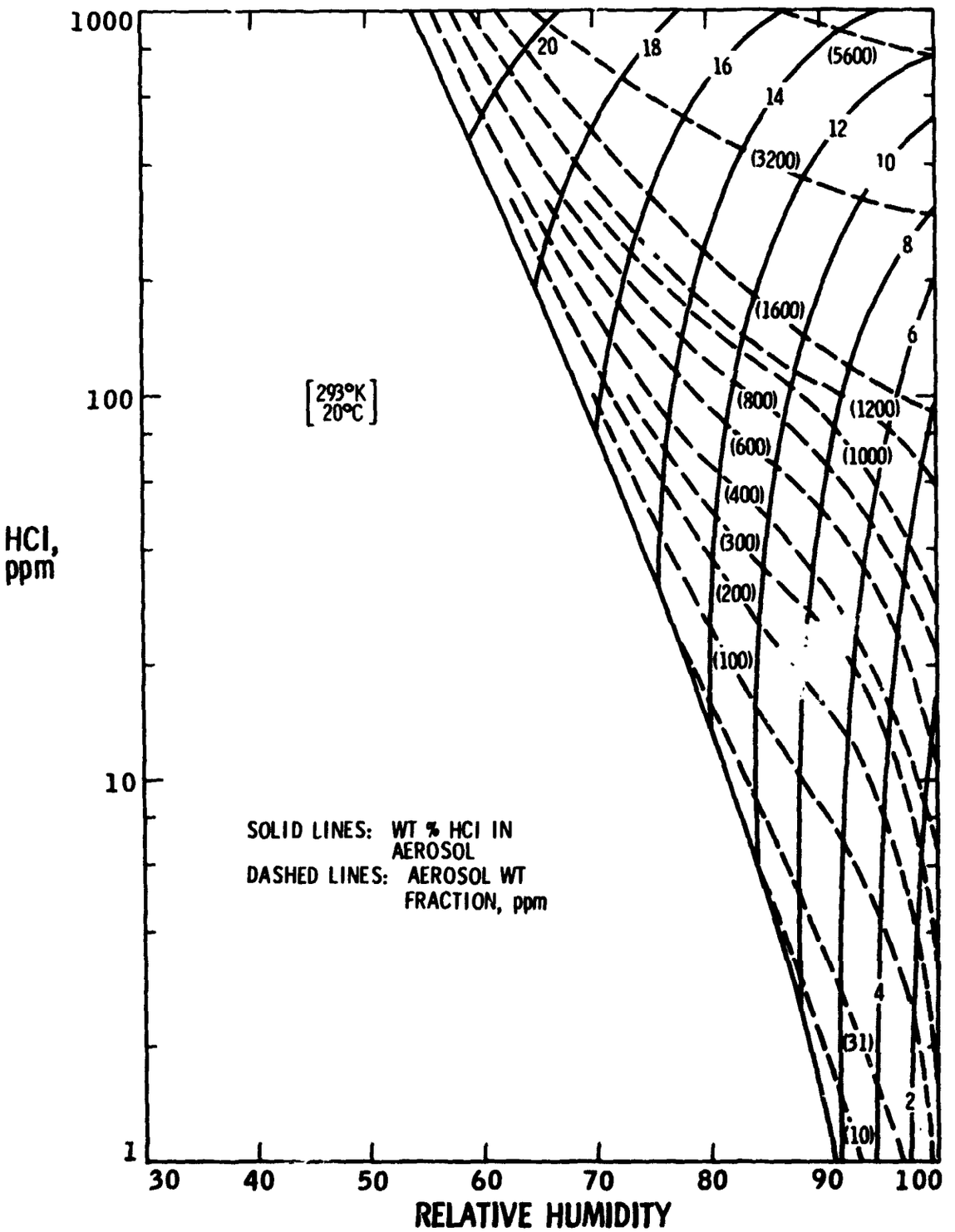

Fig. 5. Formation and properties of HCl aerosol at 293°K vs HCl concentration and relative humidity

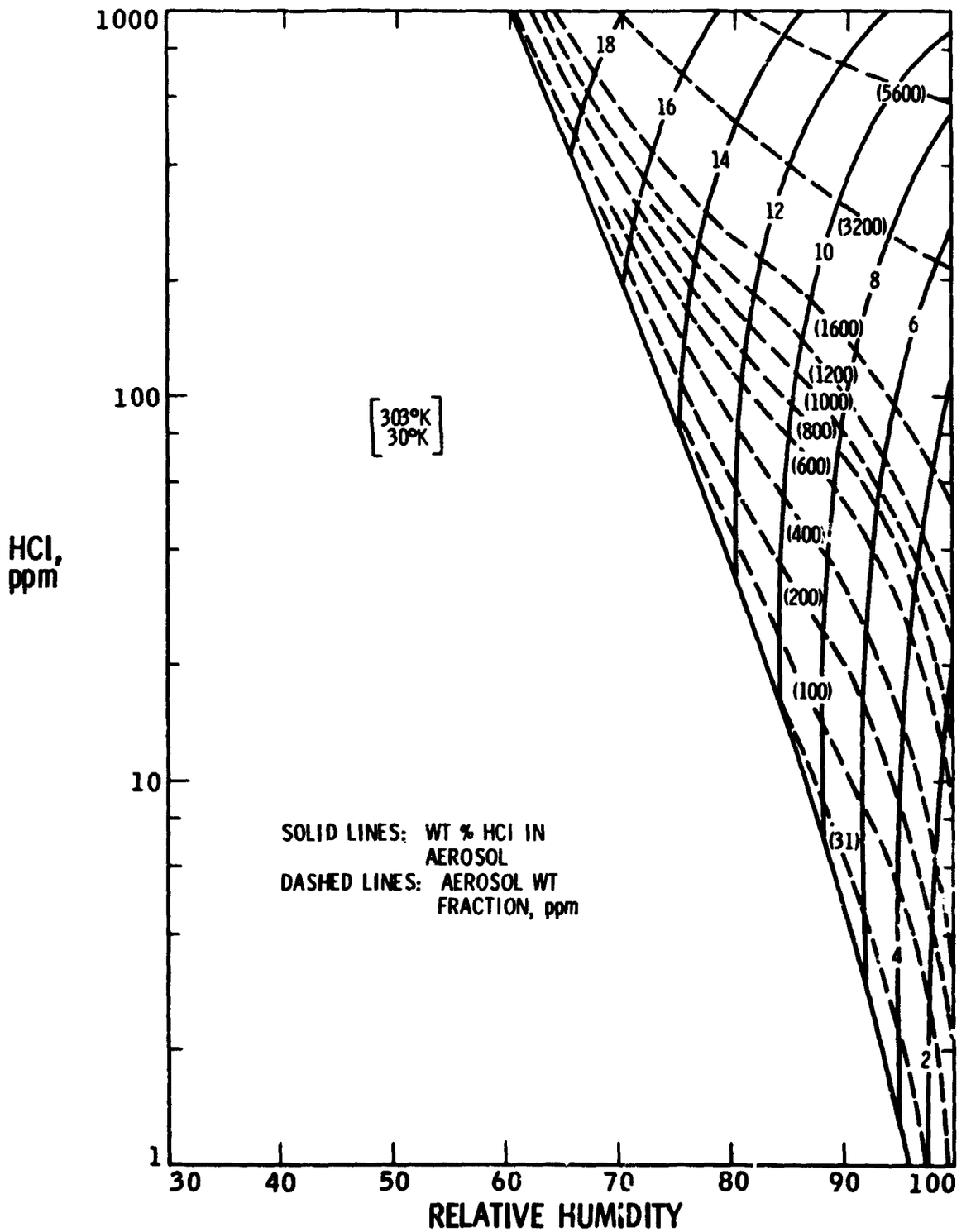

Fig. 6. Formation and properties of HCl aerosol at 303°K vs HCl concentration and relative humidity

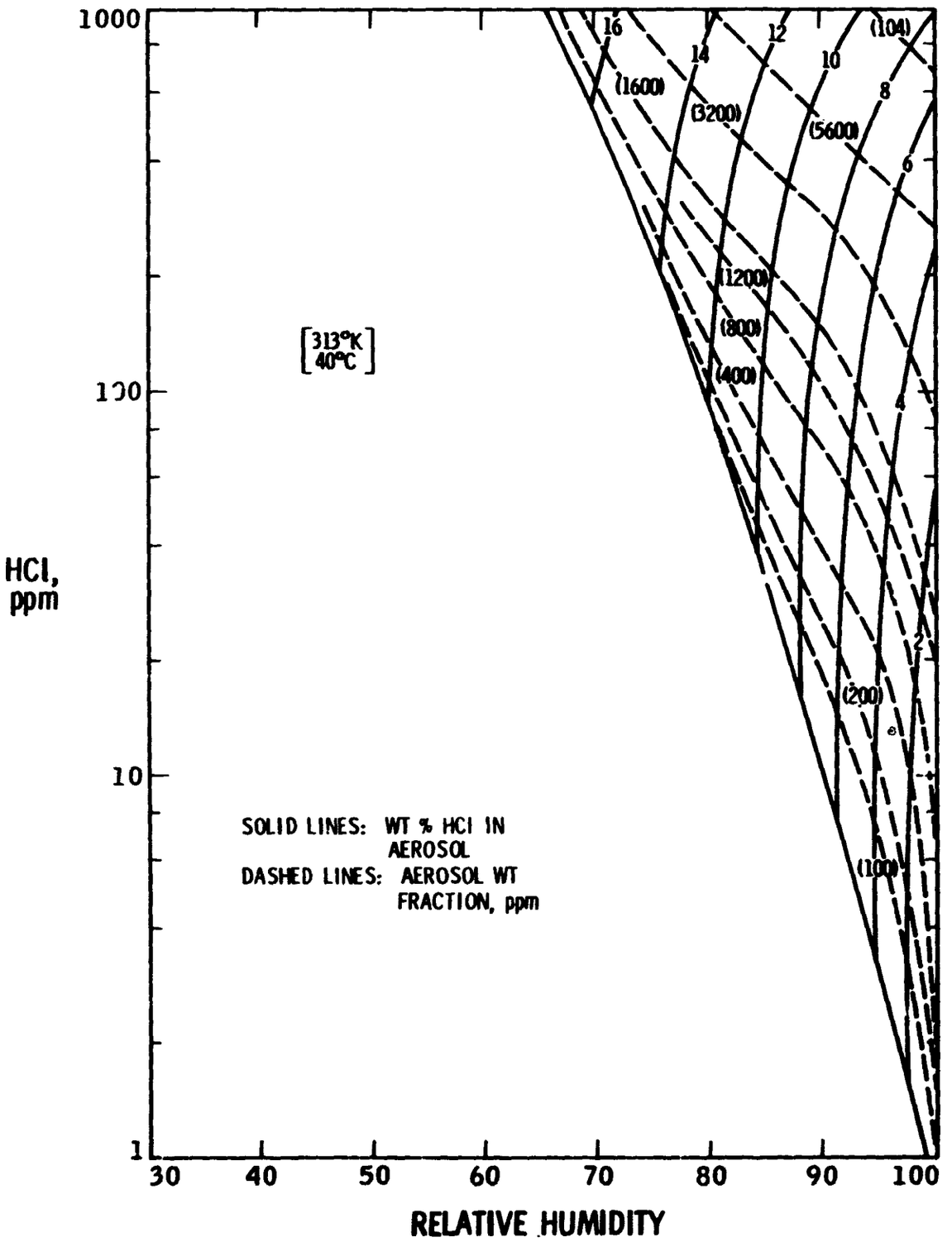

Fig. 7. Formation and properties of HCl aerosol at 313°K vs HCl concentration and relative humidity

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