# NATIONAL BUREAU OF STANDARDS REPORT

7340

## DRY POWDER DECOMPOSITION IN FLAMES

By

Ronald T. Gautreau

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

# THE NATIONAL BUREAU OF STANDARDS

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ABSTRACT

The effects of passing dry powder inhibitors past a flame in the presence of electric fields were studied. It was found that the collection of powder residues on plate electrodes is influenced by varying the structure of the electric fields. An explanation based on the action of induced dipoles in non-uniform fields is proposed.

## I. Introduction

Previous preliminary work had suggested that sodium bicarbonate, a dry powder inhibitor, acquired an electric charge when it was passed around a flame in the presence of an electric field. It was found that the powder could be collected on parallel plate electrodes placed close to the flame and that a larger amount of powder collected on the positive electrode. A sample taken from the positive electrode was analyzed and reported to be sodium hydroxide. On the basis of these results it was thought that the sodium bicarbonate had acquired a negative charge in the process of decomposition and recombination in the flame gases. Preliminary work by T. G. Lee, of this laboratory, had indicated some other, different process, probably dipole formation in the molten powder particles. The purpose of the experiments described in this paper was to investigate these phenomena more thoroughly.

## II. Experiment

The apparatus used in the experiment is shown in Fig. 1. Fuel gas was passed through the center tube of the three-tube, metal burner; the flame size was controlled by a regulating valve in the fuel line. The dry powders under observation were conducted past the outside of the flame by using a controlled vibrator to shake the powder through a screen in the hopper into the air stream which flowed through the outer tube of the burner past the flame. The rate of application of the powder was controlled by adjusting the variable vibrator. The speed at which the powder passed by the flame was controlled by adjusting a regulating valve in the air supply; the air passing through the outer tube also helped to stabilize the flame. The middle tube was not used in the experiment.

The plate electrodes were separated by four Bakelite rods whose lengths were accurate to ± 0.003 inches; the plates could therefore be assumed to be reasonably parallel. These plates were located slightly above the burner mouth and were aligned parallel to and equidistant from the burner axis. A potential greater than 600 volts was established between the two parallel plates producing an electric field transverse to the burner axis. An auxiliary wire was also available to connect the burner to either of the electrodes.

As estimated visually, an equal amount of powder was collected on each electrode when the burner was not connected to either electrode. When the burner was connected to one of the electrodes, it was observed that a greater amount of powder collected on the unconnected electrode; this effect was the same regardless of which electrode the burner was connected to--a greater amount of powder always collected on the electrode which was not connected to the burner. With the flame extinguished and the potential across the plates maintained, powder collected equally on both electrodes, but the amounts collected were much smaller than with a flame present; connecting the burner to either electrode with the flame out seemed to have no effect on the collection of powder.

To test if the observed effects were due to the heating of the powders, an electrical heater about the size of a flame (see Fig. 2) was placed in the fuel opening of the burner and powder was passed around it. The powder collected in the same manner as with a flame, showing that the observed effects were caused by the heating of the powder and not by any reaction with the flame.

It is believed that the observed effects occurred as a result of dipoles induced in the powder particles when they were decomposed by the heat from the flame in the presence of an electric field. When the burner was not connected to either of the plates, the field was symmetric about a plane through the burner axis parallel to the plate electrodes, but the field was not uniform since the metal burner and flame were close to the electrodes causing the field lines to bend downward with some of the lines going from the positive terminal to the burner and then to the negative terminal. The force on a dipole of moment $\bar{p}$ in a non-uniform electric field $\bar{E}$ is given by

$$\bar{F} = \bar{\nabla} (\bar{E} \cdot \bar{p}).$$

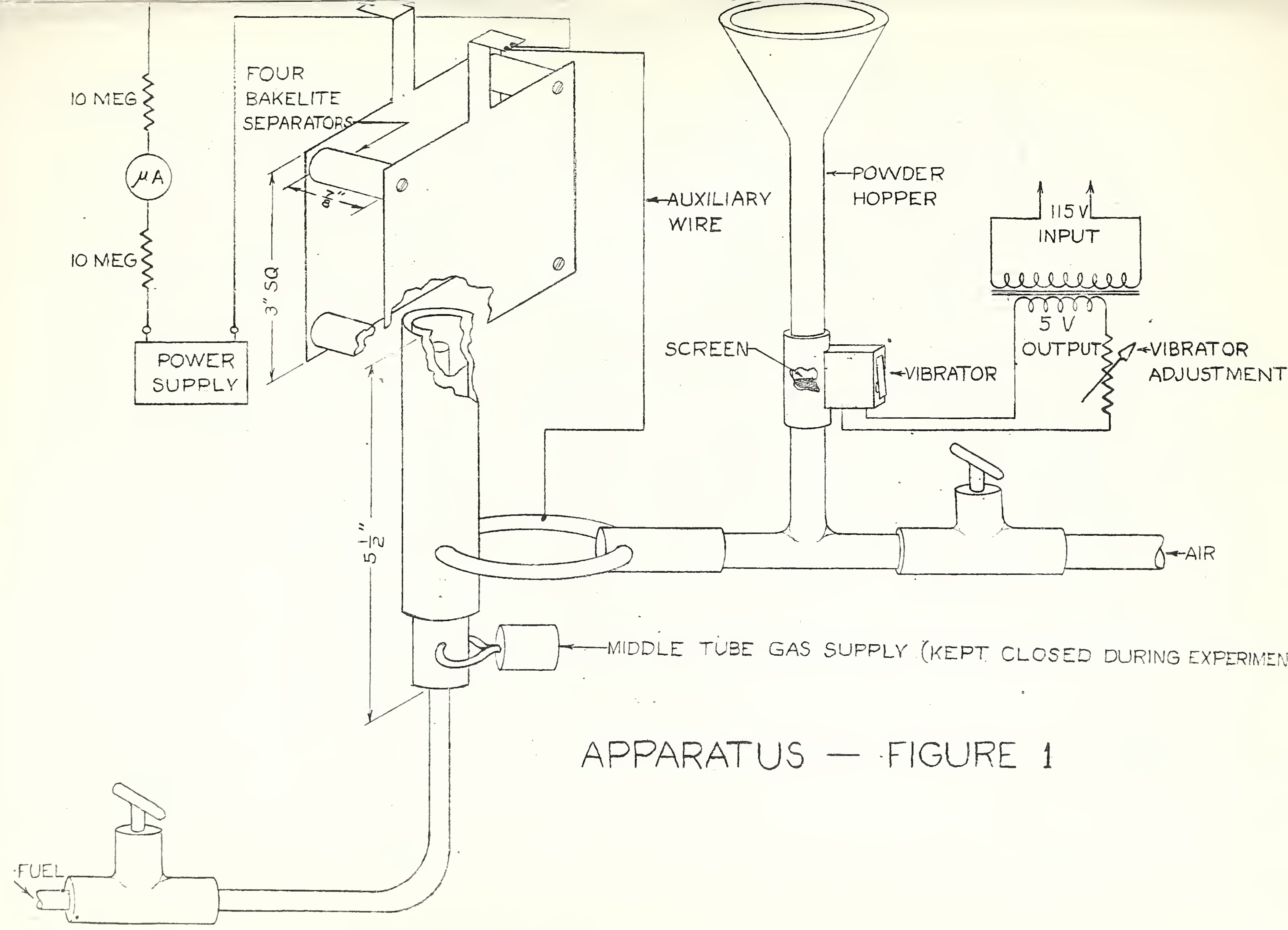
Since the electric field is symmetric about a plane through the burner axis parallel to the plate electrodes, the force field acting on the induced dipoles should also be symmetric about the same plane causing an equal amount of particles to be collected on each plate. When the burner is connected to one of the electrodes, however, the electric field is no longer symmetric about the previously described plane. If the burner is connected, for example, to the positive plate, field lines will run from the positive to the negative plate and from the burner and flame to the negative plate with no lines running from the positive plate to the burner or flame. The resulting asymmetry would tend to deflect the dipole particles toward the negative plate where the field line density is greatest.

The above effects were observed for three different powders: sodium bicarbonate ($NaHCO_3$), potassium bicarbonate ($KHCO_3$), and potassium oxalate ($K_2C_2O_4$). Samples were taken from each electrode after running the powder past the flame with the burner not connected to either electrode. A chemical analysis performed on the residue from the sodium bicarbonate and potassium bicarbonate powders showed that carbonate and bicarbonate salts were collected on both electrodes. An X-ray diffraction analysis verified this result and also indicated that no hydroxide was present. (Hydroxide cannot be detected chemically in the presence of an excess of bicarbonate since the bicarbonate neutralizes the hydroxide when the powders are put into solution.) An X-ray diffraction analysis performed on the potassium oxalate powder residue showed that the residue was mainly potassium oxalate; no other substances were identified.

## III. Summary

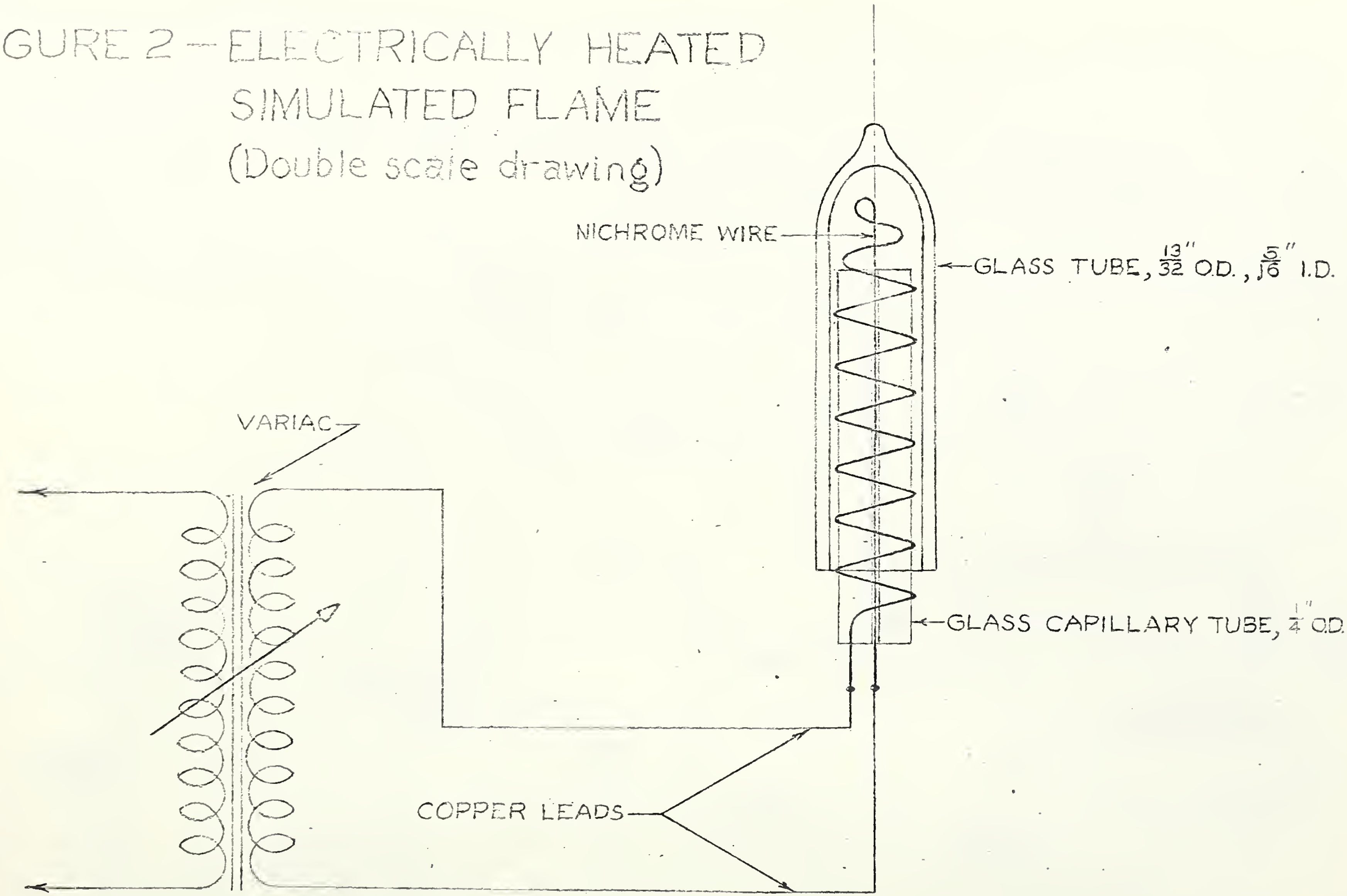
Since the collection of powder on the electrodes can be influenced by varying the shape of the electric field, the previous observation that the powder collects mainly on the positive electrode, as mentioned in the introduction, can probably be attributed to the grounding (either intentionally or unintentionally) of both the burner and the negative electrode when the preliminary experiments were performed. The collection of powder on the electrodes was apparently caused by induced dipoles rather than by the formation of negative ions. The observation that the residue collected on the positive electrode was sodium hydroxide is considered invalid. The results of the present study indicate that, the residue was composed of carbonate and bicarbonate salts with an equal amount collecting on both electrodes.

If further work is to be done along the lines described in this report, certain modifications of the apparatus would be desirable. Different material, perhaps teflon, should be used as separators for the plates. The Bakelite rods were found to conduct electricity with the conductivity increasing as the temperature of the rods increased from heat conducted along the metal plates. This caused a current (10-30 μa) to flow in the circuit resulting in a voltage drop of up to 600 volts across the resistors which protected the ammeter. For this reason the total voltage of 1300 volts from the power supply was not impressed across the plate electrodes. The plate electrodes should also be made larger in size with the burner opening in the middle of the plates instead of at the edges as was done in these experiments. It would also be advisable to use a glass burner rather than a metal one so that the field between the plates would not be disturbed to such a large extent.




APPARATUS — FIGURE 1

FIGURE 2 — ELECTRICALLY HEATED SIMULATED FLAME (Double scale drawing)



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**Metrology.** Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

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**Radiation Physics.** X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

**Analytical and Inorganic Chemistry.** Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research.

**Mechanics.** Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

**Organic and Fibrous Materials.** Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

**Metallurgy.** Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics. Electrolysis and Metal Deposition.

**Mineral Products.** Engineering Ceramics. Glass. Refractories. Enameled Metals. Crystal Growth. Physical Properties. Constitution and Microstructure.

**Building Research.** Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

**Applied Mathematics.** Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

**Data Processing Systems.** Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

**Atomic Physics.** Spectroscopy. Infrared Spectroscopy. Solid State Physics. Electron Physics. Atomic Physics.

**Instrumentation.** Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

**Physical Chemistry.** Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry.

**Office of Weights and Measures.**

## BOULDER, COLO.

**Cryogenic Engineering.** Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

**Ionosphere Research and Propagation.** Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

**Radio Propagation Engineering.** Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

**Radio Standards.** High Frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Interval Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

**Radio Systems.** High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems.

**Upper Atmosphere and Space Physics.** Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

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