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The JET Module, a tool for aerosol particle experiments in Microgravity

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Abstract

The JET Growth Motion module for sounding rockets was developed by Swedish Space Corporation. It was developed for a Jet Growth Motion in Aerosols microgravity experiment performed by Universite Libre Bruxelles, Belgium.

The JET module was able to study the JET growth motion effect for the first time. The JET growth motion is an effect due to the interaction of the particles in an aerosol and the molecules in the surrounding gas.

The system is able to inject 1000 particles from individual compartments into a reactor chamber and distribute them in the reactor chamber. A video and image analysing system keeps track of each particle individually and calculates the velocity vector for each particle in the three dimensional space.

The reactor chamber is kept at a temperature of 100°C with a maximum gradient of 0.05°C.

The JET experiment was launched successfully on the Swedish microgravity rocket MASER 8 from Esrange 15 May 1999.

1. Introduction

Swedish Space Corporation has a long experience in developing experiment facilities for microgravity and have developed facilities for manned, unmanned flights, long and short duration flights.

The unique features of the JET module are the good isothermal properties combined with a

large temperature gradient between two chambers. At the same time is a large gas molecule exchange between the chambers possible. The video and image system has the capability of tracking and calculating three-dimensional velocity vectors for all 1000 particles individually during the total experiment period. It is also able to discriminate between the active particles and the reference particles.

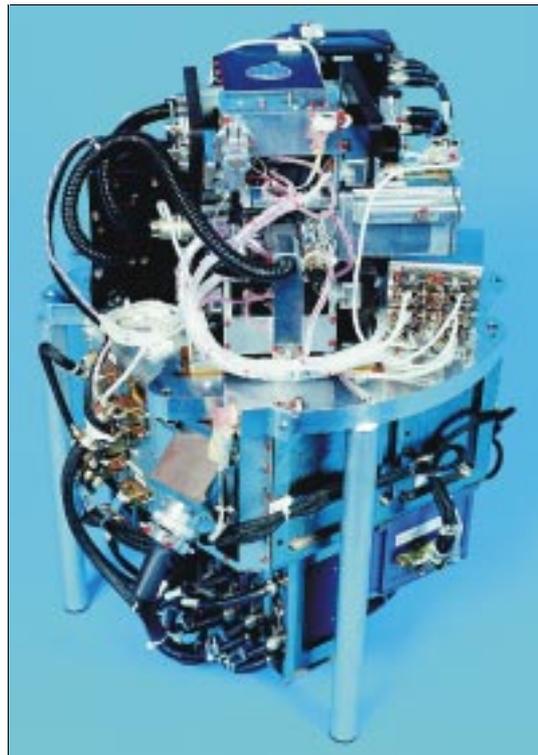


Figure 1. JET module

2. Experiment Unit

The experiment unit comprises the following parts:

Particle Bin, PB

Reactor Chamber, RC

Source of reagent gas compartment, SRG

Injection Unit, IU

2.1 Particle Bin, PB

The particles, urotropine crystals (active particles) and hollow gold plated glass spheres (reference particles) that have a diameter of approximately $40\mu\text{m}$ are kept in the particle bin before the start of the experiment. The particle bin has a grid with 32×32 (1024) conical holes covering an area of 60 mm^2 . In each hole is placed a particle and 50 % are active particles

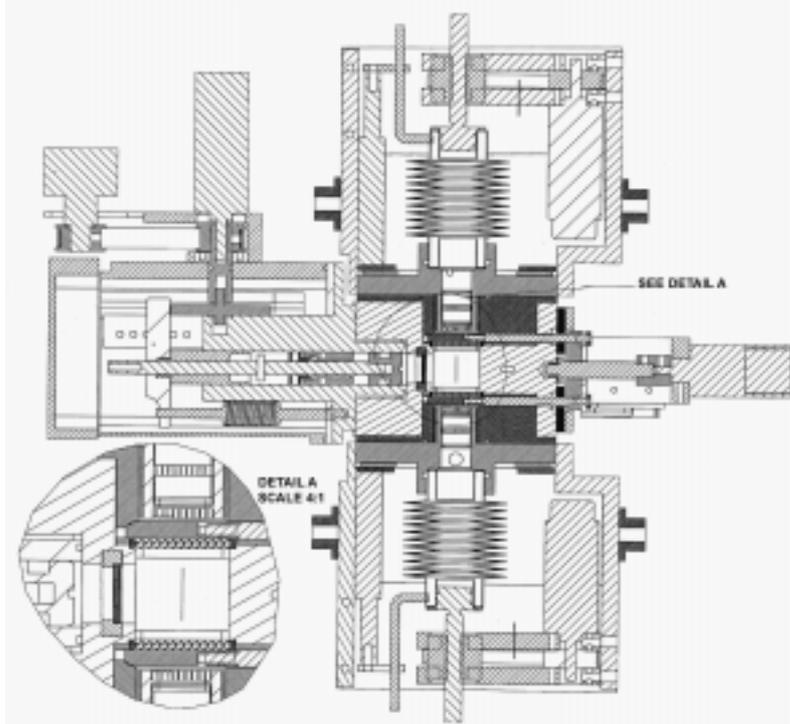


Figure 2. Drawing of experiment unit

and 50% reference particles. The grid with the particles is covered on both sides with a cover plate that is controlled with a motor. These plates protect the particles from falling out and from the surrounding atmosphere.

2.2 Reactor Chamber, RC

The reactor chamber has a volume of $1,5\text{ cm}^3$ ($10 \times 11 \times 14\text{ mm}$) and two windows. The front window is the observation window and inlet for the front illumination. A back window is used for the back illumination. The windows have double and triple glasses (interior window is sapphire) for optimal thermal properties. Along one of the sides that is open to the injection system is the particle bin placed. The bottom and top side of the reactor chamber is connected to the source of reagent gas compartments.

2.3 Source of Reagent Gas compartment, SRG

The source of reagent gas compartments are placed at the top and bottom of the reactor

chamber. The purpose of the SRGs is to supply the atmosphere in the reactor chamber with urotropine molecules during the experiment. Urotropine powder is placed in the SRGs and the gas in the SRGs is saturated with urotropine molecules. The molecules diffuse to the reactor chamber and interact with the urotropine crystals in the reactor chamber. The temperature in the SRGs is higher than in the reactor

chamber so the concentration of urotropine molecules will be higher in the SRGs. In the end

of both SRG is a motor controlled bellow placed. The bellows are used for pumping the gas between the SRGs through the RC before the experiment starts to saturate the gas with urotropine. The bellows are also used for controlling the pressure in the experiment unit during the experiment.

The interface between the reactor chamber and the SRGs functions as a thermal barrier. There is a temperature difference between the reactor chamber and the SRGs up to 10°C but both the temperature in the reactor chamber and the SRGs should be isothermal (max gradient 0,05°C). The urotropine molecules can pass the interface freely from the SRGs into the reactor chamber. The urotropine crystals and the reference particles can not pass the interface. The interface can be closed with motor controlled shutters to stop the exchange of molecules.

2.4 Injection Unit, IU

The injection unit comprises a motor/spring controlled piston placed behind the particle bin. The piston is extracted slowly with a motor and released. A spring moves the piston forward fast and the gas forced forward by the piston pushes the particle out of the particle bin and into the reactor chamber. The vortex of the gas stream contributes to a good distribution of the particles in the reactor chamber.

2.5 Temperature Control

The experiment unit is heated with four heaters placed on the reactor chamber, on heater on each SRG and two heaters placed on the outer front window. The heaters are controlled individually. The temperature in the reactor chamber is kept at 100°C. The temperature in the SRGs are kept at approximately 3°C above the RC temperature in the beginning of the experiment. The temperature in the SRGs is increased to 5°C and 10°C above the RC temperature during the later part of the experiment. This is done to increase the JET growth motion effect.

3. Video, Optical and Illumination System

The particles in the reactor chamber are monitored with an optical and video system. The videotape is the main experiment data.

3.1 Optical and Illumination System

The optical system developed by Lambda-X in Brussels comprises a system of mirrors and a single objective. The reactor chamber is monitored from four different views with the optical system. The viewing angle is 22,5° (from the axis perpendicular to the window). The observation area is approximately 10x7 mm and the depth of focus is 10 mm.

A system of colour filters is used for discriminating between the active urotropine crystals and the reference particles. The front illumination is yellow and the back illumination is blue. In the back illumination both types of particles are viewable. In the front illumination only the reference particles are viewable. Three cameras have a blue filter and can therefore see all particles. One camera has a yellow filter and can therefore only see the reference particles.

A 150 W halogen lamp with an IR-filter and optical fibres is used for the front and back illumination. The IR-filter has a very high efficiency, as it is very important that the particles are not heated during the experiment.

3.2 Video System

Four progressive scan CCD cameras are used for the registration of the particles. The progressive scan function means that the whole image is captured at the same time and not as in normal analogue video standard where even and odd lines are captured with a small time difference. The cameras are synchronised and the images are captured simultaneously in all four cameras. The images are stored in four separate image memories. The images are then multiplexed to a standard video signal. A fifth image is also multiplexed into the video signal. This image contains a binary sequence code that functions as a time code during the analysing of the images. The video sequence is stored on an S-VHS video tape with help of the onboard video recorder.

A de-multiplexer is used on ground to make it possible to observe one of the cameras in the multiplexed video sequence.

3.3 3D PTV System

A 3D particle-tracking velocimetry image analysing system developed by ETH in Zürich is used for analysing the movement of the particles after the experiment is performed. This system is capable of individually keep track of all 1000 particles during the experiment. The image analysing system calculates the 3 dimensional velocity vectors for each particles during the whole experiment.

4. On Board Computer

All functions are controlled with an on board computer that can be pre-programmed for various experiment profiles or operated in real time via telecommand. The computer also functions as a data acquisition system storing all relevant data. Except for the control and monitoring of the experiment unit and the video system the electronics also handles housekeeping signals as voltages, currents, pressures, temperatures etc.

5. Experiment

5.1 Background

In this experiment Urotropine ($C_6H_{12}N_4$) crystals was used as active particles and gold plated hollow glass spheres was used as reference particles. The diameter of the particles are around 40 μm . The particles are free floating in an argon atmosphere (1 bar) saturated with urotropine molecules. The urotropine crystals was growing in this atmosphere but the reference particles was not affected. The growth of the crystal is not uniform over the crystal surface in time. This results in that the sum of the crystal and the molecules momentum is larger than zero and the crystal starts to move. This is the Jet growth motion effect.

5.2 Experiment Procedures

The following procedures were performed on ground:

The particles (500 crystals and 500 reference) are placed in the individual conical holes in the particle bin and the particle bin is placed in the experiment unit. The experiment unit is evacuated and filled with argon, this is repeated to get a clean and dry argon atmosphere. The temperature is increased to 100°C in the whole experiment unit. The shutters in the interface between the RC and the SRGs are opened and the gas is pumped back and forth between the two SRGs through the RC by compressing and decompressing the bellows. This is performed to achieve a gas saturated with urotropine in the complete system. The shutters between the SRGs and the RC are closed and the temperature in the SRGs are increased a few degrees. This increases the concentration of urotropine molecules in the SRGs.

The following procedures were performed in microgravity:

The shutters protecting the particle in the PB are opened and the particles injected in the RC. The particles are monitored with the video system and at this stage there is no JET growth motion. This period functions as a reference period. The shutters between the RC and the SRGs are opened and the urotropine molecules can diffuse freely into the RC from the SRGs. The JET growth motion starts and is monitored with the video system. In the next period the SRG temperature is increased a few degrees and the flow of molecules increases and so does the JET growth motion.

The video sequences are analysed after the flight with the 3D particle tracking velocimetry system.

6. Results

The experiment was performed successfully and the JET module functioned nominal during the flight. Movement of the particles could be observed during the flight. A detailed analyses of the images from the flight is under progress.

7. Acknowledgements

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