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CONTAINERLESS PROCESSING IN THE EUROPEAN MICROGRAVITY PROGRAMME

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Summary

Acoustic levitation:
Acoustic levitation has been pursued for more than a decade with the prime objective of processing undercooled melts in space. Three generations of furnaces were developed and tested in sounding rocket experiments. Reasonable levitation was obtained, but some residual instabilities in times of high thermal transients need to be eliminated. The high temperature acoustic levitator is currently pending further development after a n announcement of opportunity to European scientists.

As a spinoff the capabilities of an ambient temperature acoustic levitator in crystal growth experimentation, particularly for protein crystal growth, are being evaluated in a breadboard model.

Electrostatic levitation:
electrostatic levitation has been developed in parallel with the acoustic levitator with similar applications in mind. The system tested utilised a tetrahetral electrode configuration with uncharged samples. Sounding rocket tests of this system failed due to malfunction of the image acquisition system. Due to the residual sample accelerations inherent in the positioning of uncharged samples further development of electrostatic levitators has been put on hold, pending the identification of users with specific needs for this technique.

Electromagnetic levitation
This very promising levitation technique is developed in Europe mainly under the German national programme. The ESA involvement in electromagnetic levitation is concentrated on accommodation studies for the (European) Containerless Processing Laboratory for the Space Station Freedom.

Gas Film Levitation
Gas Film Levitation is planned to form the second major element of the Containerless Processing Laboratory next to the Electromagnetic Levitator. The gas film technique is based on the processing of samples confined by porous walls. Air flow trough the walls creates air cushions which inhibit wall contact. This technique is considered particularly promising for glasses and offers unique opportunities in the processing of non-spherical samples and sample manipulation.

A series of contracts is intended to foster ground based research with this technique, advance the high temperature levitation technology, provide low temperature levitation testing in parabolic flights (under French funding), and perform advance studies for space facilities.

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ACOUSTIC LEVITATION

HISTORICALLY THE FIRST LEVITATOR DEVELOPED UNDER A EUROPEAN PROGRAMME (TECHNOLOGICAL RESEARCH PROGRAMME)

AIM:
LEVITATION OF LIQUID METALS FOR SUPERCOOLING EXPERIMENTS

1. GENERATION: RESONANT CAVITY LEVITATOR WITH ACTIVE CONTROL OF PROCESSING GAS COMPOSITION TO ADJUST THE ACOUSTIC WAVELENGTH DURING TEMPERATURE CHANGES

INITIAL TESTS UNDER MICROGRAVITY FAILED DUE TO MALFUNCTION OF PERIPHERAL EQUIPMENT. IT WAS DECIDED TO DISCONTINUE THE DEVELOPMENT TO AVOID THE COMPLEX GAS CONTROL

2. GENERATION: HALF-OPEN SINGLE-AXIS LEVITATOR WITH FIXED ACOUSTIC POWER

A SOUNDING ROCKET TEST OF THIS LEVITATOR FAILED DUE TO CATASTROPHIC ENHANCEMENT (POSITIVE FEEDBACK) OF TRANSVERSE SAMPLE OSCILLATION

3. GENERATION: HALF-OPEN SINGLE AXIS LEVITATOR WITH ACTIVE MODULATION OF ACOUSTIC POSITIONING POWER AS A FUNCTION OF THE SAMPLE VELOCITY VECTOR

A SOUNDING ROCKET TEST WAS PARTIALLY SUCCESSFUL, GIVING STABLE LEVITATION AT HIGH (NEAR-CONSTANT) TEMPERATURES, WHILE THE SAMPLE DESTABILISED DURING FAST HEAT-UP AND COOL-DOWN. THIS IS EXPLAINED BY DESTRUCTIVE INTERFERENCE BETWEEN THE STABILISING BESSEL-MODE AND INSUFFICIENTLY DAMPED LINEAR MODE WAVES. THIS PROBLEM APPEARS SOLVABLE BY PROPER ABSORBER DESIGN.

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ACOUSTIC LEVITATOR CONTINUED

STATUS:
THE TECHNOLOGY DEVELOPMENT OF THE ESTEC HIGH TEMPERATURE ACOUSTIC LEVITATOR IS CONSIDERED COMPLETE. FURTHER OPTIMISATION MAY BE PERFORMED AS PART OF SCIENTIFIC UTILISATION. AN ANNOUNCEMENT OF OPPORTUNITY HAS BEEN MADE WITHIN THE ESA SOUNDING ROCKET PROGRAMME.

THE MAIN APPLICATION OF ACOUSTIC LEVITATION IS SEEN IN FLUID SCIENCE APPLICATIONS. ESA IS CURRENTLY NOT SPONSORING HARDWARE DEVELOPMENTS IN THIS AREA IN ORDER NOT TO DUPLICATE EFFORTS BY OUR PARTNERS.

THE CURRENT ESA ACTIVITIES IN ACOUSTIC LEVITATION ARE CONCENTRATED ON CRYSTAL GROWTH FROM THE SOLUTION OF LEVITATED DROPLETS. A BREADBOARD IS UNDER CONSTRUCTION TO STUDY PROCESS KINETICS.

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ELECTROSTATIC LEVITATION

ELECTROSTATIC LEVITATION HAS BEEN DEVELOPED IN PARALLEL TO ACOUSTIC LEVITATION FOR ONE DECADE. TESTING OF THE LEVITATOR UNDER MICROGRAVITY COULD ONLY BE PERFORMED AFTER COMPLETION OF THE ACOUSTIC LEVITATOR DEVELOPMENT DUE TO RESTRICTED FUNDS AND SOUNDING ROCKET FLIGHT OPPORTUNITIES.

THE CONFIGURATION TESTED CONSISTS OF FOUR PLATINUM ELECTRODES IN A TETRAHEDRAL ARRANGEMENT. THE SAMPLE POSITION IS MONITORED BY TWO CCD'S

GROUND TESTING OF THE ELECTROSTATIC LEVITATOR WAS LIMITED TO SUSPENDED SAMPLES DUE TO THE LIMITED TIME-RESOLUTION OF CCD CAMERAS (SAMPLE OSCILLATIONS ABOVE 5 HZ COULD NOT BE RESOLVED IN REAL-TIME)

FLIGHT TESTS FAILED DUE TO MISALIGNMENT OF ONE CAMERA. UNFORTUNATELY FLIGHT DATA DID NOT ALLOW RELIABLE CALCULATIONS OF POSITIONING FORCES FROM SAMPLE ACCELERATIONS

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GENERAL PROBLEMS WITH ELECTROSTATIC LEVITATION

ELECTROSTATIC LEVITATION DOES NOT POSSESS A SAMPLE EQUILIBRIUM POSITION CONSEQUENTLY ANY PURE ELECTROSTATIC LEVITATOR WILL OPERATE BY "KICKING THE SAMPLE ABOUT" IN A SPACE THE MINIMUM DIMENSIONS OF WHICH ARE DEFINED BY ELECTRODE CONFIGURATION AND THE SENSITIVITY OF THE POSITION DETECTION.

SINCE THERE IS LITTLE OR NO DAMPING THE RESULTING SAMPLE ACCELERATIONS CAN BE QUITE SUBSTANTIAL AND CAN EXCEED THE AVERAGE MICROGRAVITY LEVEL OF THE ENVIRONMENT BY ORDERS OF MAGNITUDE

AS A RESULT ELECTROSTATIC LEVITATION SHOULD BE UTILISED PREFERABLY IN COMBINATION WITH OTHER LEVITATION TECHNIQUES

IN EUROPE'S MICROGRAVITY PROGRAMMES ELECTROSTATIC LEVITATION IS PUT ON HOLD, PENDING THE IDENTIFICATION OF SCIENTIFIC EXPERIMENTS IN NEED OF THIS SPECIFIC LEVITATION TECHNIQUE.

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ELECTROMAGNETIC LEVITATION

IN EUROPE THE DEVELOPMENT OF ELECTROMAGNETIC LEVITATION IS SPEARHEADED BY THE GERMAN NATIONAL PROGRAMMES. DETAILS OF THIS VERY POWERFUL DEVELOPMENT ARE PRESENTED ELSEWHERE IN THIS WORKSHOP AND SHALL NOT BE REPEATED HERE.

THE ESA INVOLVEMENT IN ELECTROMAGNETIC LEVITATION IS CURRENTLY LIMITED TO ACCOMMODATION STUDIES FOR THE SPACE STATION FREEDOM (CONTAINERLESS PROCESSING LABORATORY).

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GAS FILM LEVITATION

GAS FILM LEVITATION IS A FAIRLY NEW CONCEPT DEVELOPED IN GRENOBLE/FRANCE BY THE GROUP OF DR POTARD AND DR FAVIER. THE MAIN PROJECT ENGINEER IS DR GRANIER.

THE CONCEPT IS BASED ON THE BLOWING OF GAS THROUGH POROUS "CONTAINERS". CONDENSED MATERIAL APPROACHING THE CONTAINER WALLS IS REPELLED BY THE PRESSURE OF THE GAS FILM BUILDING UP BETWEEN SAMPLE AND WALL.

THE MAXIMUM AIR FLOW IS DEFINED BY THE PERMEABILITY OF THE WALL, THUS ALMOST INDEPENDENT OF SAMPLE POSITION. THE GAS FLOWS REQUIRED ARE FAIRLY LOW (A FEW STD L/MIN)

ADVANTAGES:
- NO ACTIVE CONTROL OF LEVITATION PROCESS REQUIRED
- ALL MATERIALS WITH ACCEPTABLE VAPOUR PRESSURES CAN BE LEVITATED
- REASONABLY HIGH LEVITATION FORCES
- "EASY" MANIPULATION OF LEVITATED SAMPLES
- LEVITATION OF NON-SPHERICAL SHAPES (LONG CYLINDERS) IS POSSIBLE

DISADVANTAGES:
- VERY LIMITED ACCESS FOR SAMPLE DIAGNOSTICS
- GAS COMPRESSION (CLOSED LOOP) REQUIRED FOR MANNED SPACE FLIGHT

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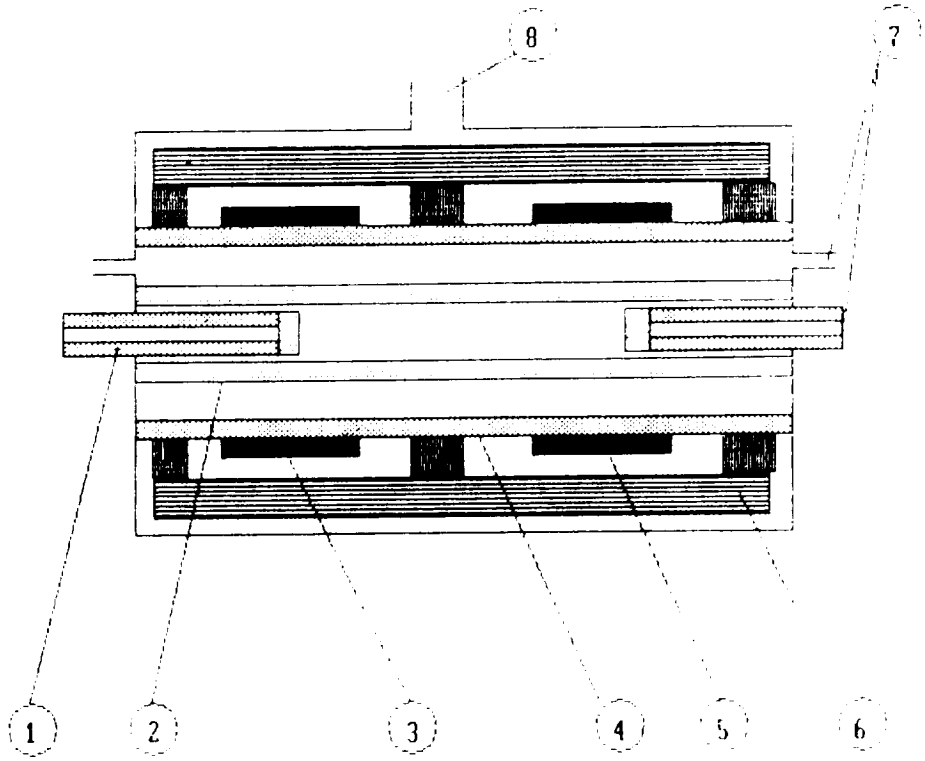
SCHEMATICS OF GAS FILM LEVITATOR



1 - Pistons
2 - Porous tube
3 - Heater : high temperature zone
4 - Leaktight tube
5 - Heater : low temperature zone
6 - Superinsulation
7 - Gas inlet
8 - Vacuum line

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CURRENT DEVELOPMENT PROGRAMME FOR GAS FILM LEVITATION

TECHNOLOGY DEVELOPMENTS:

- A LOW TEMPERATURE EXPERIMENT MODULE FOR FLUID DYNAMICS INVESTIGATIONS IN PARABOLIC FLIGHTS HAS BEEN BUILT UNDER FRENCH FUNDING.
  A FIRST FLIGHT CAMPAIGN IS SCHEDULE FOR THIS WINTER/SPRING
- A HIGH-TEMPERATURE BREADBOARD FUNDED BY ESA IS UNDER CONSTRUCTION FOR THE PROCESSING OF OXIDE GLASSES MAIN AIMS ARE TO VERIFY THE THERMAL CHARACTERISTICS OF THE LEVITATOR AND SAMPLE MANIPULATION ASPECTS.

SCIENTIFIC STUDIES:

- GAS FILM LEVITATION OF "BUTTON"-SHAPED SAMPLES OF MAINLY HALIDE GLASSES ARE UNDER WAY BOTH UNDER FRENCH AND ESA FUNDING, TO PREPARE THE SCIENTIFIC BASIS FOR FUTURE SPACE EXPERIMENTS. FIRST POSITIVE RESULTS WILL BE PUBLISHED SHORTLY

MICROGRAVITY APPLICATION STUDIES:

- DEFINITION STUDIES (PRE-PHASE A AND PHASE A) FOR A CONTAINERLESS PROCESSING LABORATORY OF THE SPACE STATION FREEDOM

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THE CONTAINERLESS PROCESSING LABORATORY FOR SPACE STATION FREEDOM

FIRST STUDY:
- REVIEW OF SCIENTIFIC RESEARCH FOR FIELDS THAT COULD BENEFIT FROM CONTAINERLESS PROCESSING
- REVIEW OF LEVITATION TECHNIQUES
- SELECTION OF FOUR PRIORITY CANDIDATES OF LABORATORY ELEMENTS
- FIRST-CUT DESIGNS OF THESE ELEMENTS

SECOND STUDY:
FOR THE SECOND STUDY THE ACCOMMODATION ENVELOPE OF THE LABORATORY WAS REDUCED TO A DOUBLE-RACK. TWO ELEMENTS WERE RETAINED:
- THE ELECTROMAGNETIC LEVITATOR FOR THE PROCESSING OF METALS
- THE GAS FILM LEVITATOR FOR THE PROCESSING OF OXIDE AND FLUORIDE GLASSES

THE MAIN ELEMENTS OF THE STUDY INCLUDED:
- A DETAILED DESIGN OF EACH LEVITATOR
- A DEFINITION OF SYSTEM INTERFACES
- A BUDGET ASSESSMENT
- ASSESSMENT OF STORAGE REQUIREMENTS
- PLANNING OF SERVICING OPERATIONS

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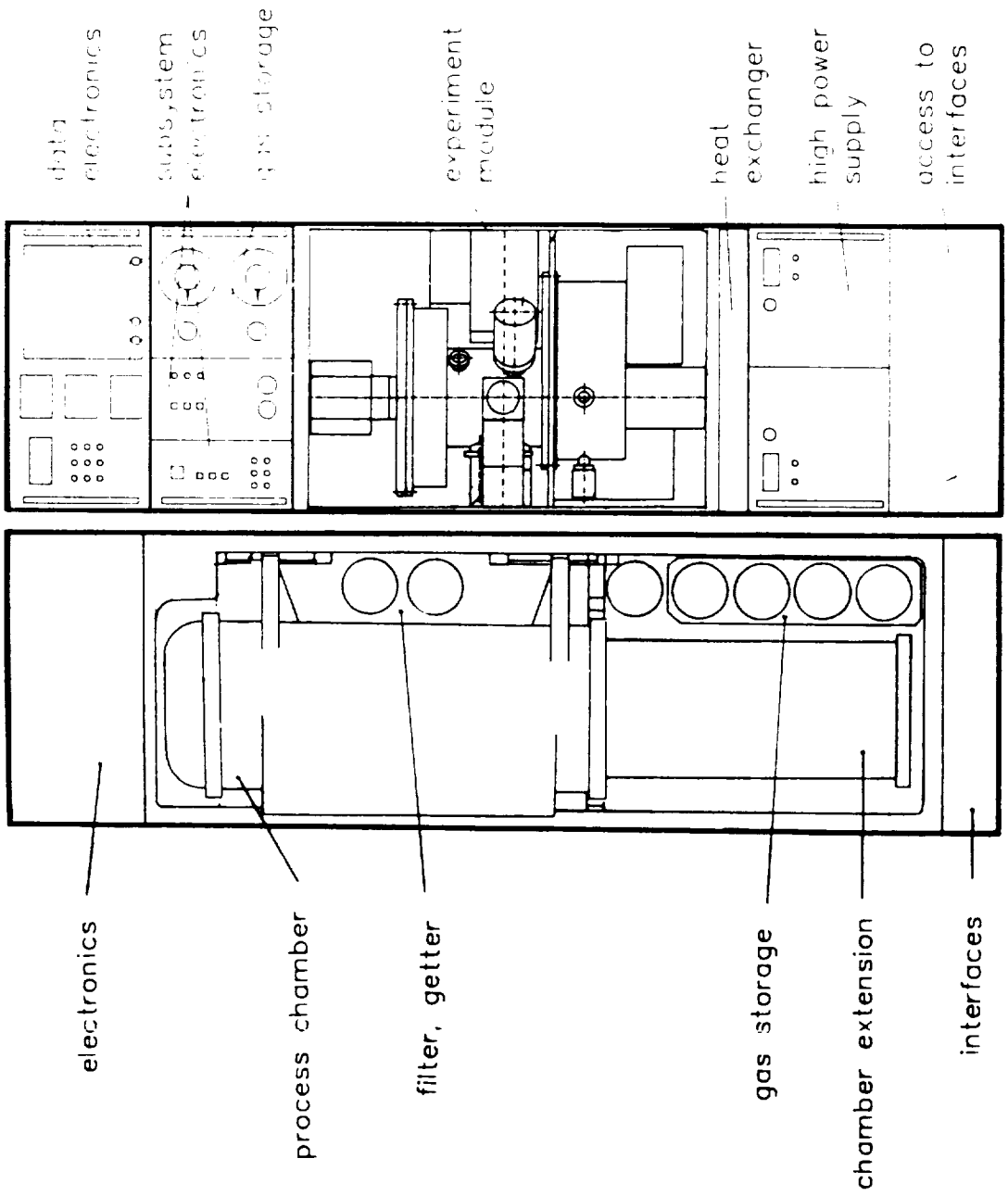

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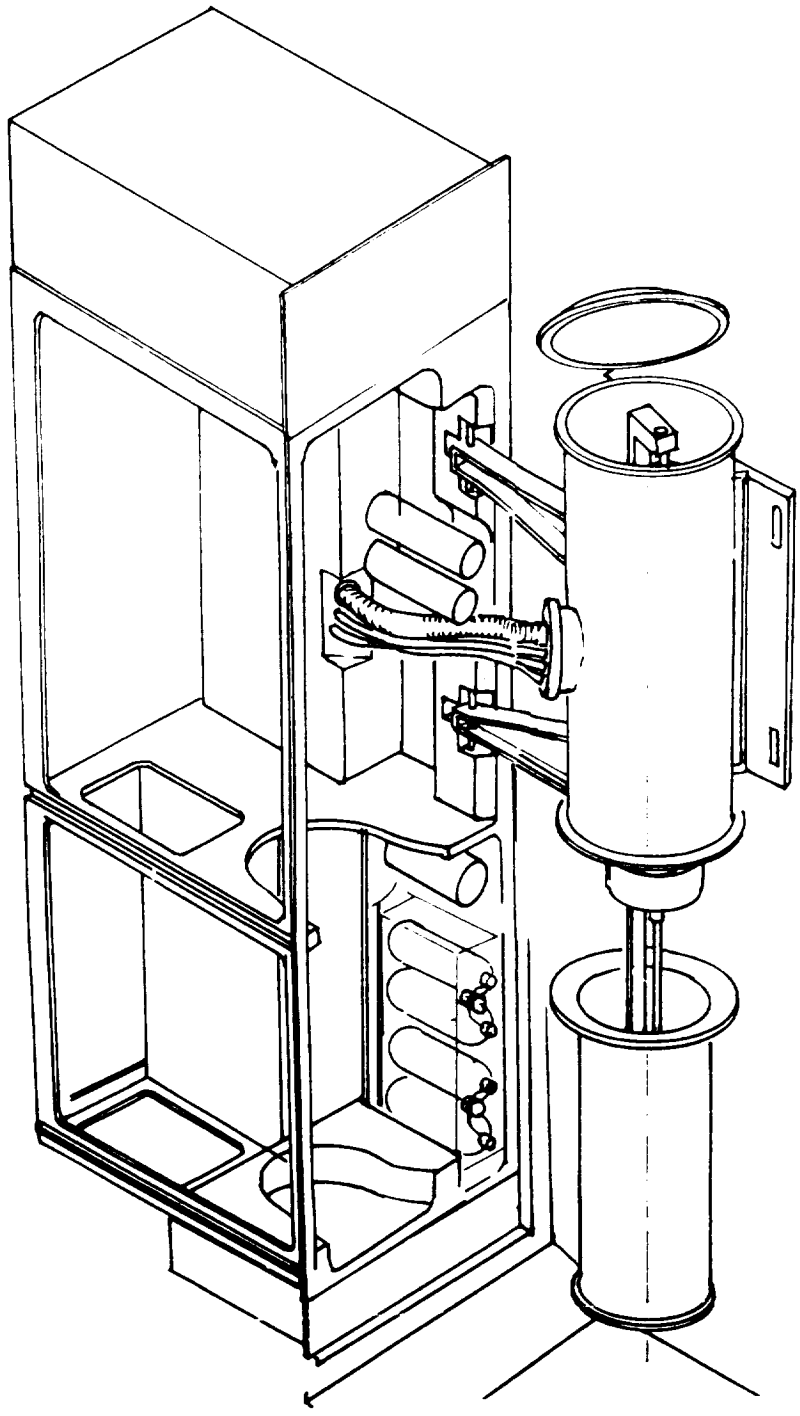

GAS FILM LEVITATOR MODULE

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