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TEMPUS - First Results

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The electromagnetic levitation facility TEMPUS developed by Dornier under the contract of BMFT is designed to operate under microgravity conditions. Compared to terrestrial levitation, μg offers the possibility to melt and undercool in ultra high vacuum thereby providing an ultra clean environment.

The technical concept of the TEMPUS facility has been tested on two KC 135 flights and in the Texus 22 mission. Preparative investigations concerning the coil system and the heating and positioning efficiencies have been carried out in the TEMPUS laboratory version. Furthermore, temperature - time profiles have been determined under various boundary conditions.

As a consequence of processing liquid metals under UHV, correct temperature measurement arises as the most critical problem. Experiences with experiments in the TEMPUS laboratory module show that due to the evaporation losses of the sample, the transmission of the CaF_2 shielding windows changes drastically during the processing time. We have started to investigate the effect of contamination on pyrometry and are developing alternative evaporation shielding methods.

During the second KC 135 flight it was possible to heat up and melt an FeNi sample under He atmosphere. Oscillations of the molten sample, which were excited by switching out the magnetic heating field, could be detected and afterwards analyzed. From the frequency of these oscillations the surface tension of the sample material could be derived. The measurement of the surface tension and viscosity of an undercooled metal is proposed for TEMPUS on IML-2.

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- PYROMETRY, EVAPORATION PROBLEM
- KC 135 RESULTS, SURFACE TENSION

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THE TEMPUS PROJECT

TEMPUS is an electromagnetic levitation facility,
designed to operate in microgravity

- two coil, two frequency concept:
  ⇒decoupling of heating and positioning
- two colour, fast (1MHz) pyrometer
- two axis visual observation by video
- processing under UHV possible

- laboratory model successfully tested in parabolic flights
- Texus version tested on a sounding rocket
- scheduled for IML-2 Spacelab mission
- under consideration for space station

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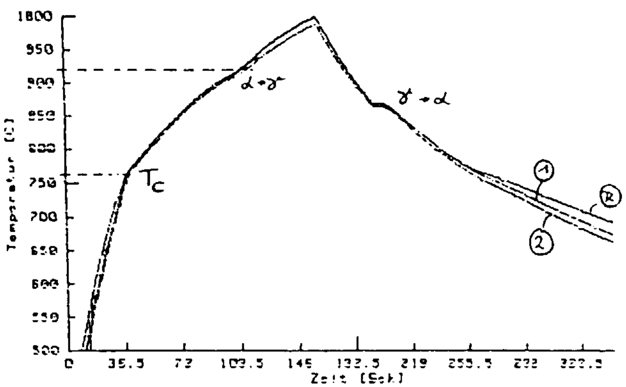
PYROMETRY

Infra-red pyrometer

- two one-colour signals, one ratio signal
- temperature range 300 °C to 2400 °C
- wavelength: 1 to 2 μm and 3 to 4 μm



temperature - time diagram of Fe

- temperature calibration at magnetic and structural phase transitions
- determination of the emissivity coefficients

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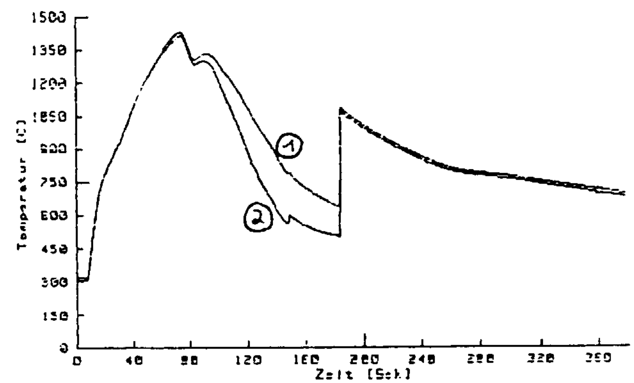
EVAPORATION PROBLEM

- evaporation losses of sample material
- contamination of the pyrometer window

⇒ decrease of the temperature signal, dependent on the wavelength



temperature - time diagram of Fe

consequence: no temperature calibration at the melting point possible
no calibration and determination of the emissivity in the liquid sample

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POSSIBLE SOLUTIONS

1. Shielding Windows
- the window in front of the pyrometer will be replaced when contamination becomes untolerable

2.Shutter or Rotor
- reduction of contamination at the expense of no continuous temperature measurement

3. Mirror Optics
- a double mirror system is placed in front of the pyrometer avoiding direct view on the sample

4. Diffraction Gratings
- putting a diffraction grating into the optical path and detecting only the diffracted light, contamination in front of the pyrometer can be avoided

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PARABOLIC FLIGHT EXPERIMENT

MAIN OBJECTIVE
- verification of technical concept could be achieved (positioning cannot be tested under 1g)

SIDE RESULTS (not planned)
- levitated FeNi sample could be melted
- oscillations of the liquid sample could be excited
- surface oscillations detectable

FREQUENCY and DAMPING of the surface oscillations are related to SURFACE TENSION and VISCOSITY.

DIFFICULTIES UNDER 1G
- shape deformation
- stirring
- magnetic damping

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EXPERIMENT ANALYSIS

Oscillations of a viscous sphere:

$R_n \sim \cos(\omega_n t)\exp(-\gamma_n t)P_n(\cos\theta)$

where

$\omega_n^2 = (n-1)n(n+2)\sigma/(\rho R_0^3)$

$\gamma_n = (n-1)(2n+1)\eta/(\rho R_0^2)$

P_n = Legendre polynomial

R_0 = unperturbed radius of sphere

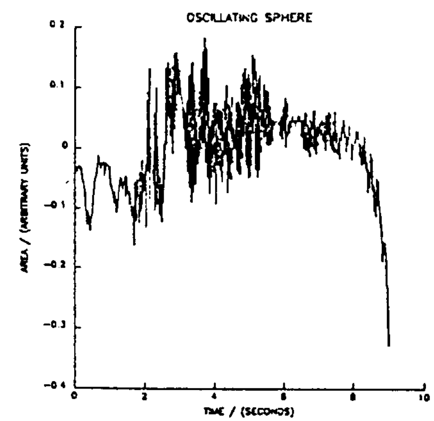
η = viscosity

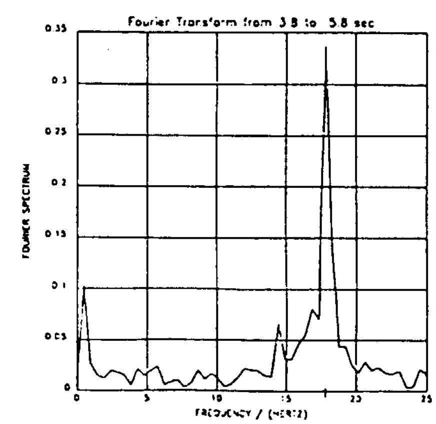
σ = surface tension

ρ = density

n = 2 fundamental mode

RESULT





ν = 17.8 Hz

m = 4.2 g

σ = 1.6 N/m

CONCLUSIONS

- EVAPORATION PROBLEM CAN BE HANDLED

- SURFACE OSCILLATIONS CAN BE EXCITED AND DETECTED

SURFACE TENSION AND (HOPEFULLY) VISCOSITY CAN BE DETERMINED

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