N91-21349

Electromagnetic Processing Onboard Spacelab

H. Lenski and R. Wilnecker
Dornier GmbH and DLR

The electromagnetic containerless processing facility TEMPUS has recently been assigned for a flight on the IML-2 mission.

In comparison to the TEMPUS facility already flown on a sounding rocket, several improvements had to be implemented. These are in particular related to:

- Safety
- resource management
- the possibility to process different samples with different requirements in one mission.

The basic design of this facility as well as the expected processing capabilities will be presented.

Two operational aspects turned out to strongly influence the facility design:

a) control of sample motion

First experimental results indicate that crew or ground interaction will be necessary to minimize residual sample motions during processing

b) exchange of RF-coils

During processing in vacuum, evaporated sample materials will condense at the cold surface and may force a coil exchange, when a critical thickness is exceeded.

TEMPUS-A FACILITY FOR CONTAINERLESS ELECTROMAGNETIC PROCESSING ONBOARD SPACELAB

H. Lenski
Dornier GmbH

R. Willnecker
DLR

The TEMPUS facility has been designed for containerless processing of metallic samples in weightlessness.

The main design driving requirements are:

- Melting and undercooling of very different sample types with the same RF system (generators, coils), for example:
    - o 6mm niobium spheres (T max > 2550°C)
    - o 10mm aluminium spheres (T min < 600 °C)
- sufficient visual accessibility to observe sample oscillations
- high symmetry of RF fields to minimize residual sample motions

The facility development started with a set of basic requirements. In due course of the development the performance range has been extended as far as possible. In particular improvements of the RF-system turned out to be necessary.

The design for the S/L-version of TEMPUS is characterized by:

- use of two independent coaxial coils (dipole, quadruple) running at two frequencies (420kHz and 140kHz)
- free oscillating circuits coupled to a low-voltage (0.20V) RF generator via a transformer

TEMPUS

A Facility for Containerless Electromagnetic Processing onboard Spacelab

January 1990

The facility has been developed under contract of DLR,
acting on behalf of the German Ministry of Research and Technology.

The design is based on experimental and theoretical work
performed by the Institute of Space Simulation (DLR).

TEMPUS Facility Characteristics:

- sample positioning and heating by high frequency electromagnetic fields
- processing in an ultraclean environment (UHV or noble gas)

Development Strategy:

Start with a set of basic requirements and try to extend the performance range as far as possible.

Flight experience:

- parabolic flights on KC-135
- sounding rocket flight (TEXUS 22)

Design Driving Requirements:

Experimental requirements:

- temperature range: melting of a 6mm Nb sphere
  undercooling of a 10mm Al sphere
- sufficient visual accessibility to observe sample oscillations
- minimized residual motion (high symmetry of RF fields)

General:

- use of the same RF system (coil, generator) for all experiment types
- limited power (two 60 A lines for S/L versions)

The development of the RF system was crucial for the success of the TEMPUS concept.

Necessary Improvements for TEMPUS on Spacelab

- Processing capability extended from 1 sample /1 cycle to 22 samples / 100 cycles
  - o sample storage magazine
  - o enlarged evaporation shielding capability
  - o more process gas
  - o turbomolecular pump
  - o data reduction for 1 MHz data/ extended intermediate memory
- More complex process control (different experiment types)
- additional diagnostics (radial IR sensor, fast video)
- improved efficiency of RF system
- increased reliability of high power electronics (derating)
- additional safety devices

TEMPUS Performance Data (Basic Design for IML-2)

sample temperature:	300°C-2500C°
sample diameter:	max.: 10mm (coils optimized for 10mm)
No. of samples (stored in vacuum):	22 (note: samples will be processed in wire cages)
vacuum quality:	ultimate pressure $< 1.10^{-9}$ mbar
gas atmosphere	He/Ar, impurities < 1ppm
RF system:	superposition of quadrupole and dipole field
combined RF power:	1980 W (quadrupole: dipole ratio about 1:1)
heating efficiency for metals:	quadrupole field 0,3% to 1,7% dipole field 5% to 37 %
power adjustment range:	0 to 100%
frequency monitoring accuracy:	0,05%
DC magnetic field damping:	inhomogeneous field adjustable, 1 to 50 mT

Sample Temperature Measurement:

pyrometer type:	Two or three colour
temperature range:	300°C to 2400°C (ε = 0,05 to 1) for at least two colours, 2600°C for one colour
accuracy:	± 5°C
resolution:	better than 0,1°C (100Hz)
max. frequency:	1 MHZ (250.000 readings internally stored)
evaporation shielding:	CaF_2 windows or double mirrors

Additional Diagnostics

video observation:	2 CCD cameras (b/w), side and top view
frequency:	up to 500 half pictures per second (side view only, reduced field of view)

radial IR sensor

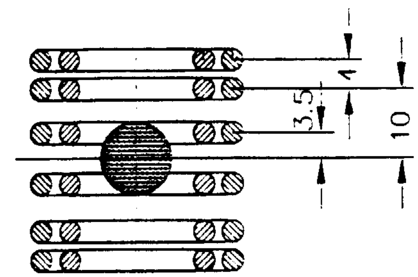
temperature range:	same as pyrometer
measuring frequency:	1MHz
internal storage:	250.000 readings

Optimization of the RF system

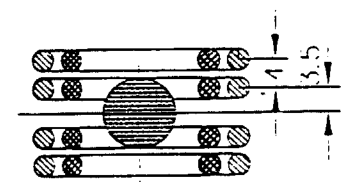
The full range of performance can only be achieved by superposing a quadrupole and a dipole field, both individually controllable.

Technical alternatives:

A) 2 independent coils,
two frequencies



B) 2 coils, identical frequency
adjustable phase shift.



Alternative B) has been calculated to be more efficient .
However, no technical solution has been found up to now.

Optimization of the RF Generators

Note: To achieve sufficient efficiency free resonant circuits have to be used

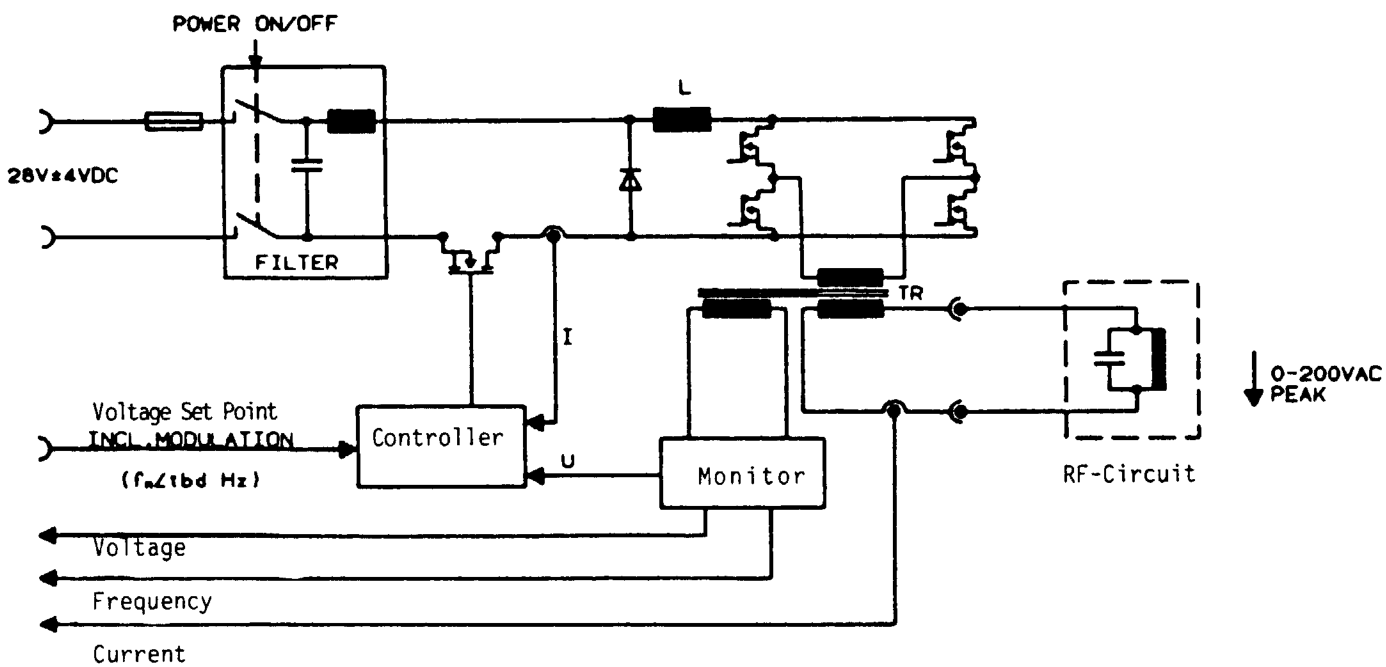
Concept for TEMPUS-TEXUS:

- RF power generated at high voltages and directly fed into the RF circuit
- input voltage 25 to 100V (by step-down converter from battery package) results in circuits voltage (peak to peak) of about 50 to 200 V

Improved concept for TEMPUS-Spacelab:

- RF generator directly powered by 28VDC bus (unregulated)
- RF output voltage 0 to 20 V, coupled to RF circuit via transformer

Advantages:
- increased efficiency (better than 80%)
- lower switching voltages, resulting in low stresses to electrical parts
- RF generator clearly separated from resonant circuit



RF CONVERTER BLOCK DIAGRAM

TEMPUS Control Concept

Facility control by dedicated processor (80386)

- data acquisition and transfer to ground (1Hz)
- interaction with flight and ground crew
- process control
- subsystem supervision including safety features
- selection of relevant 1 MHz data and transfer to ground

Fully automatic processing is possible.

Change of process parameters by flight or ground crew via serial RAU channel.

Additional manual control of some parameters to optimize dynamic positioning stability.

Control of Sample Oscillation and Rotation

sample motion is induced by

- non-symmetric fields
- rapid changes of dipole field
- low-frequency accelerations
- release from sample holder (initial energy)

passive damping foreseen by DC magnetic field

- not very efficient for low frequency oscillations

experience from TEXUS flight (FeNi sample)

- slight oscillation (rotation ?) starts immediately after sample release (± 0,25 mm)
- amplitude increased stepwise due to switching of dipole field (up to ± 0,5mm)
- no significant damping or acceleration due to other effects could be observed

Control of Sample Oscillation and Rotation (contd.)

Operational Improvements for TEMPUS on Spacelab:

- further optimization of coil system is difficult (if necessary at all)
- optimum ratio of quadrupole / dipole field has to be determined
- initial sample motion has to be avoided

As a consequence the following parameters shall be manually controllable by the flight crew:

- sample holder / cage linear motion
- quadrupole field power
- dipole field power

In Orbit Coil Exchange

Not foreseen for IML-2 but will become necessary for long duration missions because

- the coil cannot be shielded against evaporation of sample material in vacuum, thick layers will increase the coil resistance and/or flake off

- the present coil design is a compromise, optimized dedicated versions may be necessary for some experiments
  (smaller/larger samples, better observation, additional stimuli/diagnostics)

In Orbit Coil Exchange (contd.)

The present design allows exchange of the complete RF circuit including

- coils
- feed-through flange
- capacitors and transformer incl. housing

Interfaces:

- mechanical:	CF vacuum flange
- thermal	water cooling line
	(quick disconnects at capacitor housing)
- electrical	two 60 A power plugs

Open problem:

Safe containment of (toxic) metal dust/flakes during exchange