N91-21338

The Japanese Containerless Experiments

National Aerospace Laboratory
Hisao Azuma

1. Drop Dynamics Research in NAL

a) Acoustic Levitation

* FMPT related activity

Liquid drop experiment by a tri-axis acoustic levitator in the Japanese First Material Processing Test(FMPT) is to be conducted on SL-J in June 1991.

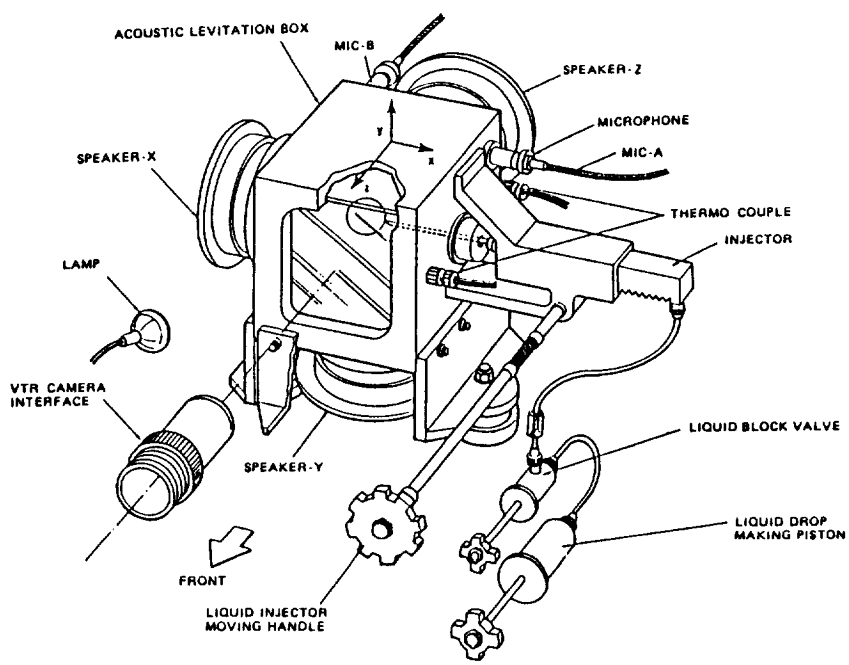
Objective of the experiment
- -Stable positioning of a liquid drop
- -Rotation of a drop
- -Deformation of a liquid drop
- -Stability of a liquid membrane

Experiments on the Earth
- -Levitation and rotation of light weight samples(styro-foam spheres)
- -Deformation of a drop and formation of a liquid film

Parabolic flight test
- -Separation of a drop from an injection needle in acoustic chamber
- -Determination of experimental parameters to position a drop in low gravity

Liquid drop experiment facility

Levitation box dimension	100W*100H*110D
Acoustic pressure	141-148 dB
Speaker input power	10 Wmax
Frequency	1400-1700 Hz
Drop size	10,19,23 mm dia.

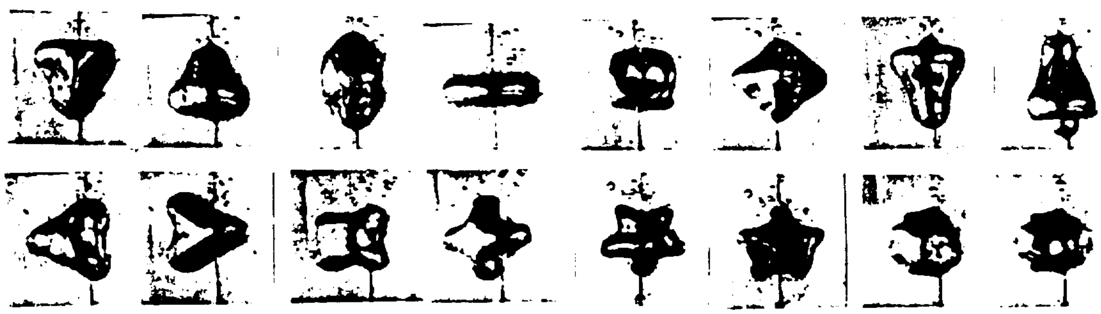


ORIGINAL PAGE IS OF POOR QUALITY

* High levitating force levitator
  - Levitation of large sized liquid drop and membrane on the earth
  - High ambient pressure

b) Large amplitude drop oscillation

Realization of three-dimensional spherical large amplitude oscillation, tetrahedron-tetrahedron, hexahedron-octahedron, dodecahedron-icosahedron by using drop tower. The oscillations were caused with surface tension variation by applying alternating current voltage.

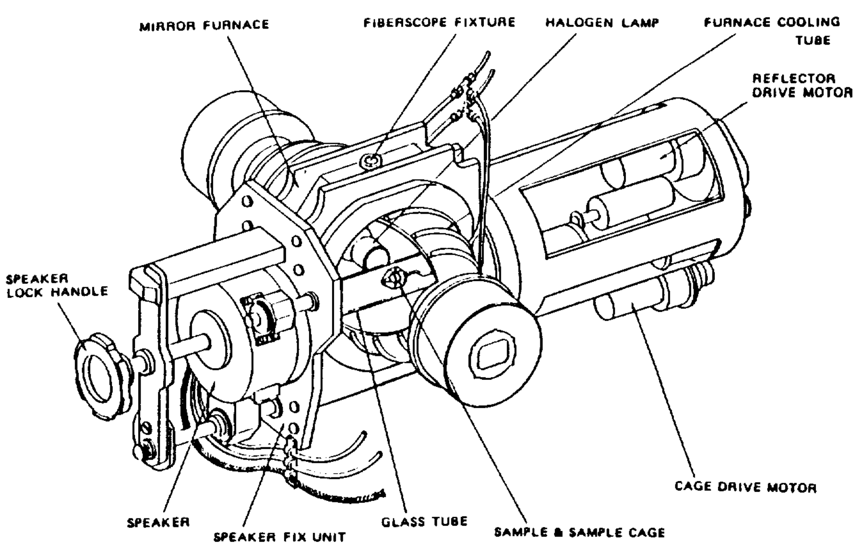


2. Optical Materials Processing in an Acoustic Levitation Furnace in Industrial Research Institute,Osaka

"Preparation of Optical Materials used in Non-visible region" to be conducted in the FMPT

- $65C_aO-25G_{a2}O_3-10G_eO_2$(near infrared transmitted oxide glass) was chosen
- 1400 °C and platinum cage for preheating is needed

Parabolic flight test
- Levitation of heated sample was made sure



3. Electrostatic Levitator Development by Melco and IHI

a) Mitubishi Electric Corporation

Development status

- Levitation and rotation of 0.1g platinum coated glass shell by a double ring type levitator
- Position data of 120Hz
- Levitation of 50g solid (metal and glass) will be tried soon by parabolic flight

Aimed performance goal

- Disturbance given to a sample should be less than 10^{-6}g
- Sample should be heated up to 2500°C (3kw AC power)
- Sample size should be larger than 20mm dia.

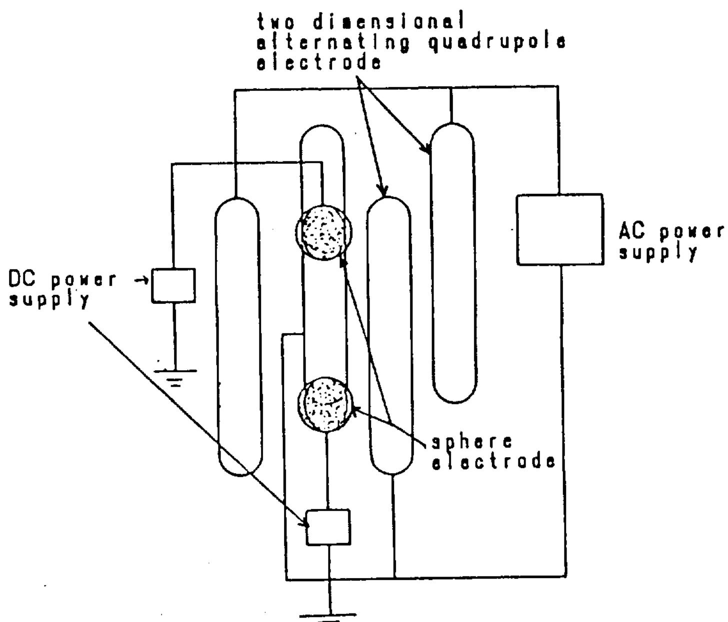
An important technology-Microwave Discharge Lamp

- High temperature in whole sphere of arbitrary size
- Choice of arbitrary gas inside the lamp to get desired wave length light

b) Ishikawajima-Harima Heavy Industries Co.,Ltd.

Development status

- Levitation of solid sample(4mm in dia. 1.5mg) by a levitator with quadrupole electrodes and a couple of spherical electrodes



Configlation of two dimensional alternating quadrupole levitation apparatus

THERMOPHYSICAL PROPERTIES OF SOLIDS AND LIQUIDS (MAINLY METALS AND ALLOYS)

JOHN L MARGRAVE
ROBERT H HAUGE
YLDIZ BAYAZITOGLU
SHANKAR KRISHNAN
NATHAN NOREM
TARIK BAYKARA

RICE UNIVERSITY AND HARC
HOUSTON, TX 77251

NASA, NSF, WELCH, GE

WHY THERMOPHYSICAL PROPERTIES ARE NEEDED

(a) ENGINEERING DESIGN PARAMETERS

- Turbine blade alloys
- Ti forgings
- Al alloys
- Composites

(b) MATERIALS PROCESSING

- On Earth: Solid state combustion synthesis:
  $Ti + C = TiC + \text{Energy}$

- In Microgravity environments:

1. On Moon

   $MO_x + F_2 \rightarrow MF_y + O_2$

   $MF_y(l) \rightarrow M + F_2$

   Breathe O_2 ; Recycle F_2

2. Space Station

3. Shuttle / Satellites

4. Wake Shield experiments

TYPES OF MATERIALS

<u>REFRACTORY METALS</u>

<u>ALLOYS-SUPERALLOYS</u> Inconel
TiAlx, NiAlx, etc...

<u>GRAPHITE</u>

<u>BINARY CARBIDES</u>

SiC, B_4C , Al_4C_3
TiC, VC_x, ...
ZrC, NbC_x , MoC_x
HfC, TaC_x, WC_x
ThC_x, UC_x, ...

<u>BINARY SILICIDES</u> $MoSi_2$, WSi_2, etc...

<u>BINARY BORIDES</u> TiB_2, ZrB_2, TaB_x, ...

<u>BINARY NITRIDES</u>

Si_3N_4, BN, AlN
TiN_x, VN_x
ZrN_x. etc...

<u>TERNARY COMPOSITIONS:</u> METAL OXYNITRIDES
METAL OXYBORIDES
METAL OXYCARBIDES, etc...

CURRENT STATE OF KNOWLEDGE

CLASS OF MATERIALS	SOLIDS	LIQUIDS	GASES
Metals	Good	Good	Excellent*
Alloys	Good	Fair	Good
Graphite	Good	Poor	Fair
Carbides	Good	Poor	Good
Silleides	Fair	Poor	Fair
Borides	Fair	Poor	Fair
Oxides	Good	Fair	Good
Nitrides	Fair	Poor	Fair

*EXCEPT FOR LASER ZAP OR EXPLODING WIRES

- TERNARY AND MORE COMPLICATED SYSTEMS ARE NOT WELL STUDIED.

- THEORIES ARE NOT EVEN ADEQUATE FOR METALS, VERY PRIMITIVE FOR LIQUID ALLOYS AND REFRACTORY COMPOUNDS.

PROPERTIES NEEDED

Cp(T)
$(H_t - H_{298})$
ΔH_{fusion}
Phase Diagram
$\varepsilon(\lambda,T)$
$\varepsilon_{total}(T)$
(Calorimetry, Pyrometry)

$\rho(T)$
CTE(T) for solids and liquids

ΔV_{fusion}
Supercooling, Nucleation, and Crystallization
(Fast Photography of weighed drops)

Surface Tension as f(T)

Viscosity as f(T)

Melting and Freezing

(Fast Photography of oscillating droplets)

Thermal Conductivity as f(T)

Thermal Diffusivity as f(T)

Resistivity as f(T)

Magnetic Properties as f(T)

*Laser flash heating

ELECTROMAGNETIC LEVITATION IS VERSATILE AND PROVIDES RAPID HEATING FOR GOOD CONDUCTORS IN VACUUM OR IN SELECTED ATMOSPHERES

- Convenient for good conductors: metals, alloys, carbides, bordies, etc.

- Heat C or SiC but not levitate

- ZrO_2, HfO_2, UO_2, etc. can be heated inductively after pre-heating

- Al_2O_3, SiO_2, NaCl, etc. neither heat nor levitate

ACOUSTIC LEVITATION

GAS JET LEVITATION

POOR ELEC. CONDUCTORS
LOW VP'S
POSSIBLE CONTAMINATION

MICROGRAVITY ENVIRONMENT - EVERYTHING LEVITATES
- RADIATIVE, LASER OR INDUCTION HEATING

LIMITATIONS OF ELECTROMAGNETIC LEVITATION

1. Must be good conductor.
2. Must have adequate surface tension.
3. Must have low VP.

UNSOLVED PROBLEMS IN DETERMINING THERMOPHYSICAL PROPERTIES OF LIQUID METALS/ALLOYS AT HIGH TEMPERATURES

- Contamination
  - Apparatus
  - Atmospheres
- Calibration Standards
  - Precision (± 0.5%)
  - Accuracy
- Reliable T(t) and Standards for T > 2000 K
- Pre-Melting/Post-Melting Phenomena
- Clusters in Liquids?
- Are There Defects in Liquids?
- Super-Cooling; Amorphous Phases; Crystallization
- Electronic Effects: Is ∂ a f(T)?
- Limits on T_{max} by VP
- Vaporization Losses as f(T, t, Metal)
- Lack of a Comprehensive Theory for Liquid Metals/Alloys: R(T); Cp(T); ε(T); Hall Effect

SPECIAL NEW TECHNIQUES

- Pulsed Laser Heating & EM Levitation
- Polarized Laser Pyrometry Yields $\varepsilon(\lambda, T, t)$ and True T as f(t)
- High-Speed Photography of Levitated and Falling Drops
- Hybrid Levitators (EM, Acoustic, Gas Jet)

GOALS OF LEVITATION STUDIES

THERMODYNAMIC PROPERTIES

$C_p^s(T)$, ΔH_{fusion}, $C_p^l(T)$

PHYSICAL PROPERTIES

Density as f(T)
Thermal expansivity
Emissivities as f(T)
Surface tension as f(T)
Viscosity as f(T)

QUESTIONS

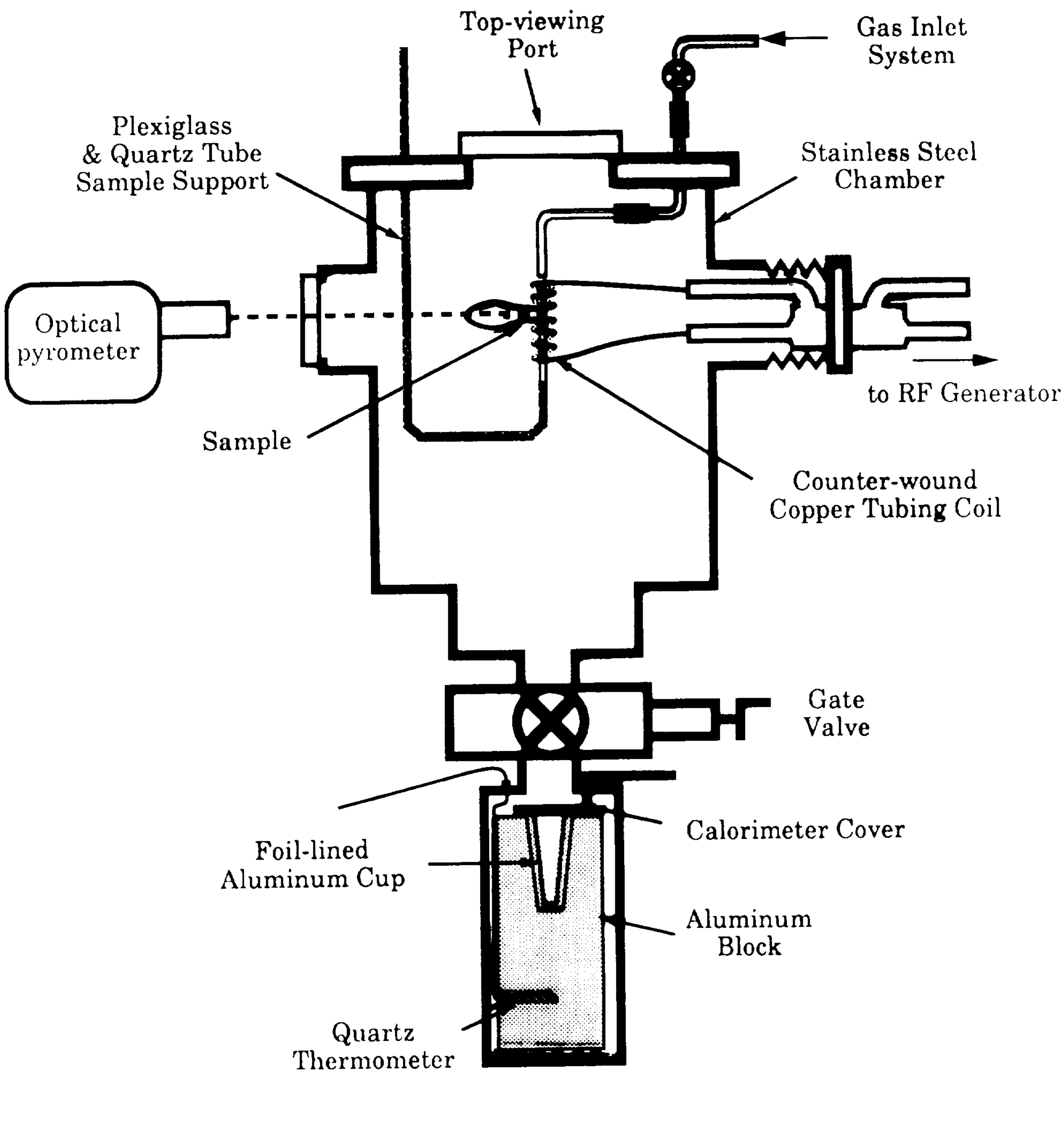
Is C_p for liquid metals:

a. Greater than, equal to, or less than C_p for the solid?

b. Increasing, constant, or decreasing with increasing T?

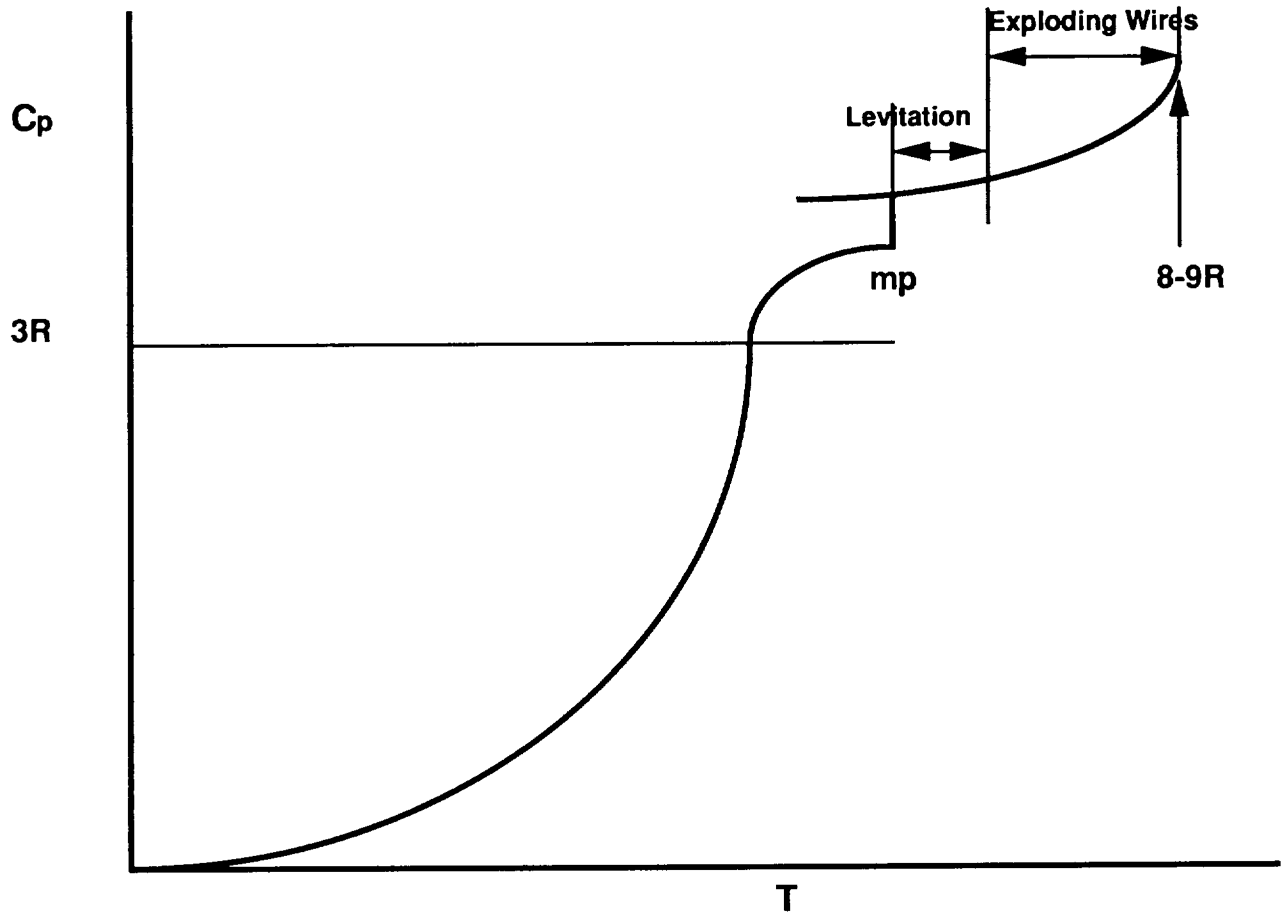
c. Appreciably higher at 5000 K than at 3000 K for liquid Mo ?

d. Approximately 3R, 5R, 6R,... for liquids at high T ?



Top-viewing Port
Gas Inlet System
Plexiglass & Quartz Tube Sample Support
Stainless Steel Chamber
Optical pyrometer
to RF Generator
Sample
Counter-wound Copper Tubing Coil
Gate Valve
Calorimeter Cover
Foil-lined Aluminum Cup
Aluminum Block
Quartz Thermometer

N. N.


Cp
3R
Exploding Wires
Levitation
mp
8-9R
T

RECENT LEVITATION STUDIES AT RICE UNIVERSITY

LIQUID SILVER (1281 K < T < 1549 K)

$(H_T - H_{298}) = 32.644\ T - 2944.9$ J/gram.atom

$C_p^l = 32.64 \pm 2.06$ J/Gram.atom K

$\Delta H_{fusion} = 10916 \pm 435$ J/Gram.atom

$\varepsilon_{650\ nm} = 0.11 \pm 0.10$

LIQUID GALLIUM (587 < T < 1630 K)

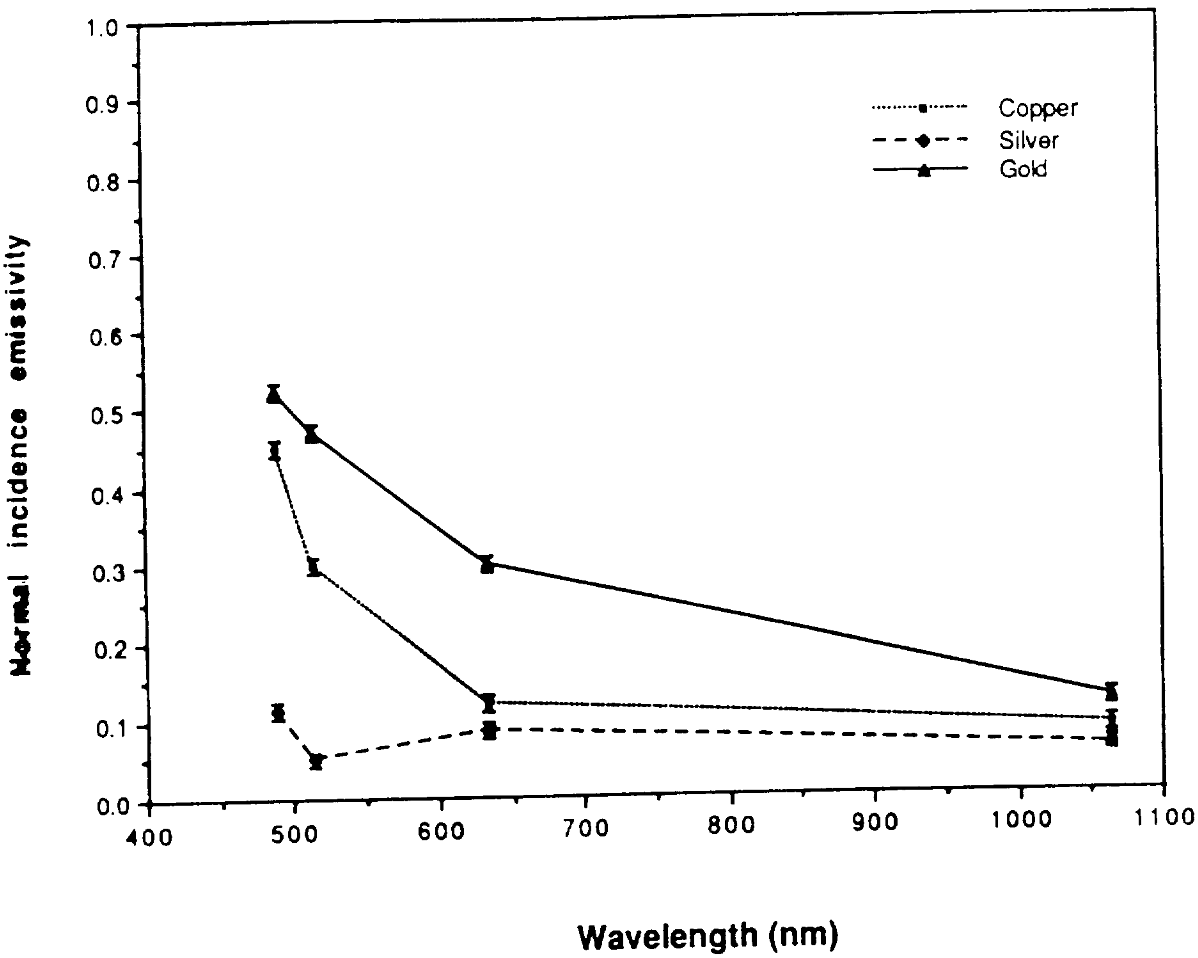
$(H_T - H_{298}) = 26.460\ T - 7677.0$ J/gram.atom

$C_p^l = 26.46 \pm 0.71$ J/Gram.atom K

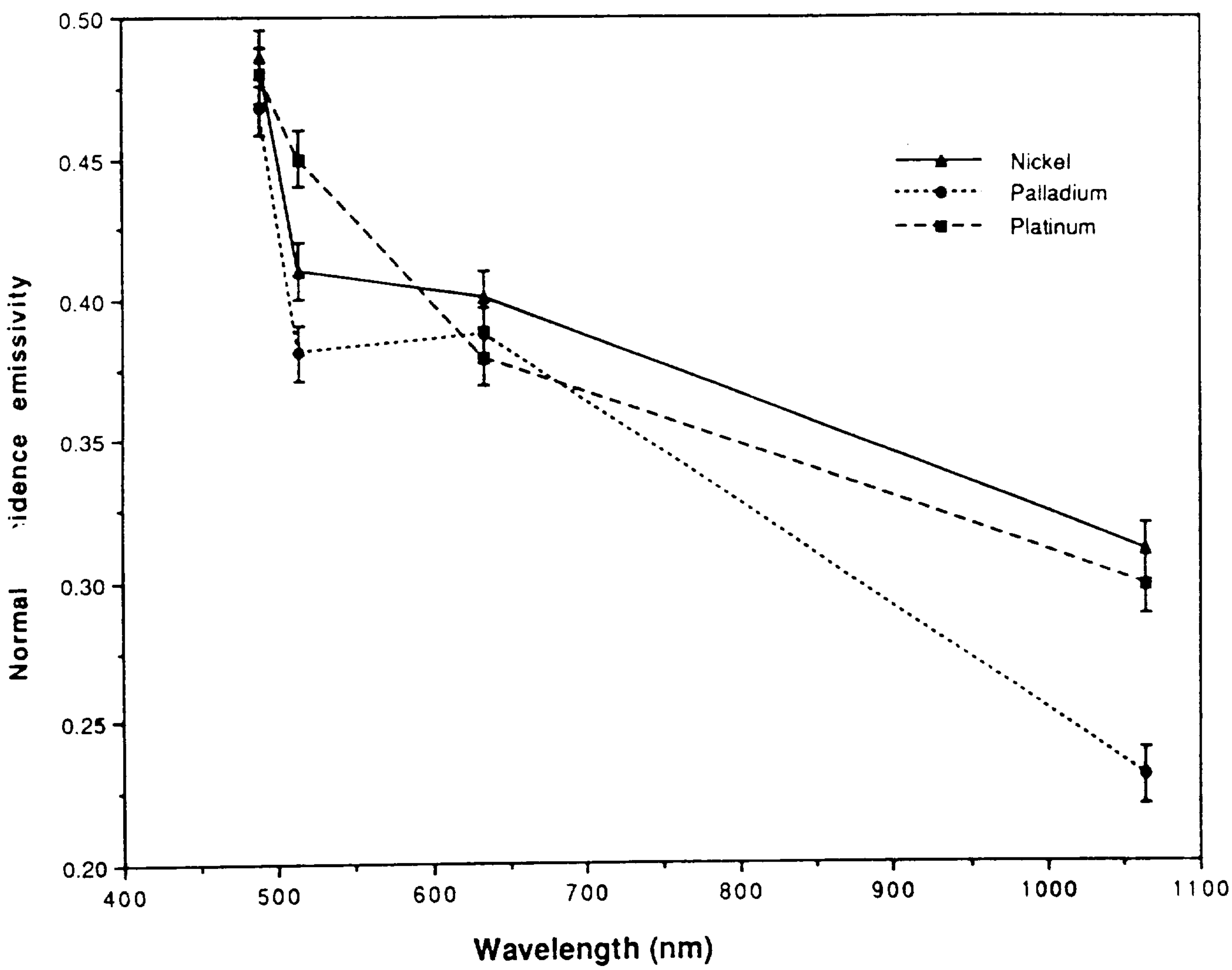
$\varepsilon_{645\ nm} = 0.14 \pm 0.10$

Also Studies of:

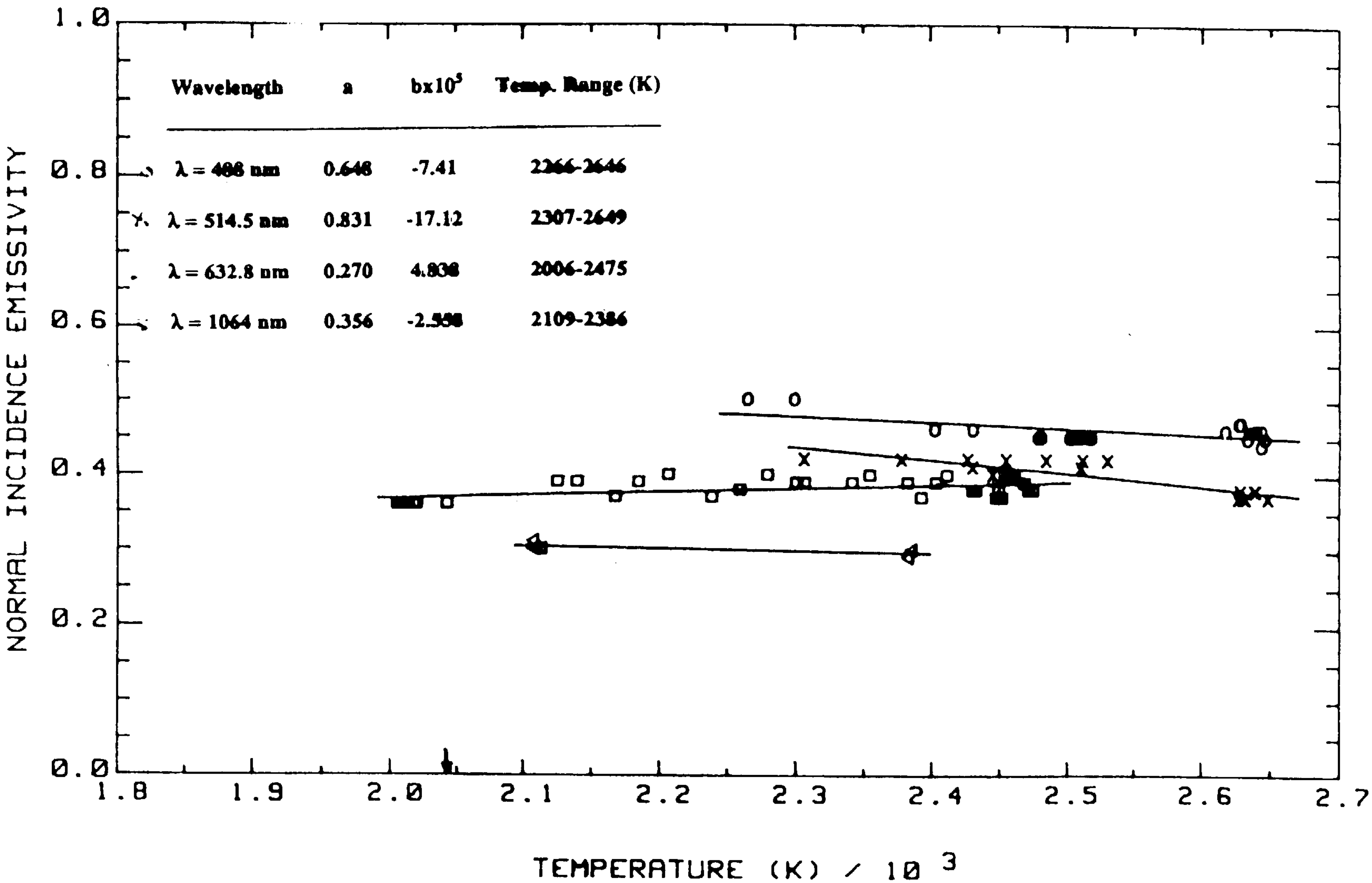
TUNGSTEN, BRASS ALLOYS, SUPERALLOYS



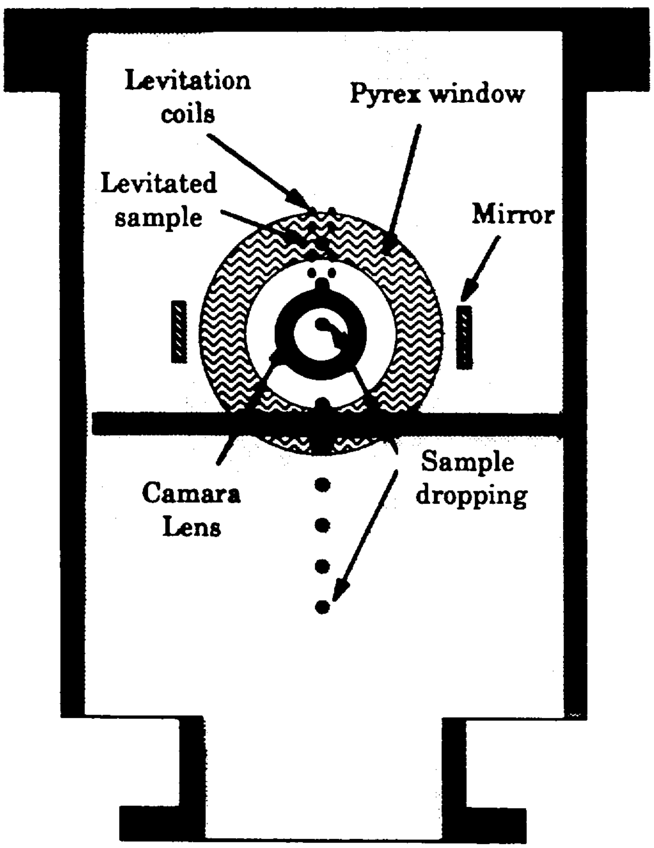
SPECTRAL EMISSIVITIES OF LIQUID METALS AS A FUNCTION OF WAVELENGTH

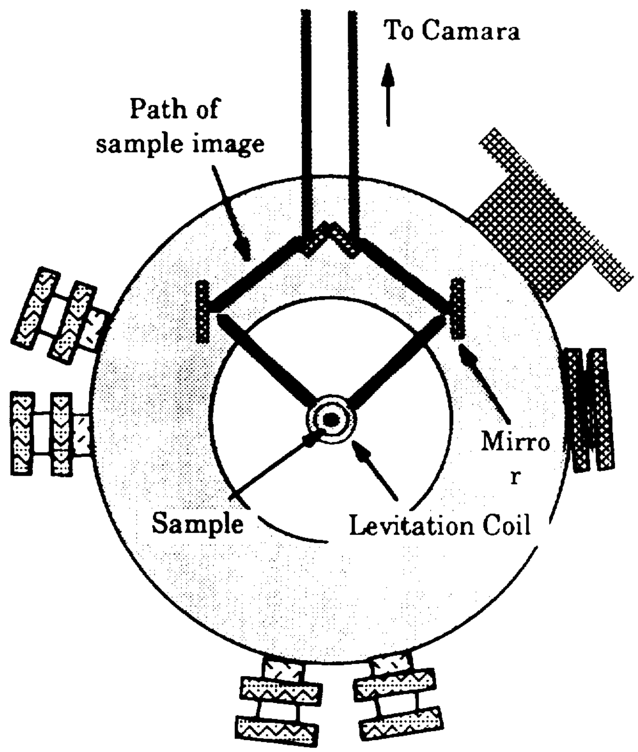


SPECTRAL EMISSIVITIES OF LIQUID METALS AS A FUNCTION OF WAVELENGTH



SPECTRAL EMISSIVITIES OF PT (liquid) AS A FUNCTION OF TEMPERATURE FOR VARIOUS WAVELENGTHS


Levitation coils
Pyrex window
Levitated sample
Mirror
Camara Lens
Sample dropping


To Camara
Path of sample image
Mirro r
Sample
Levitation Coil