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Plasma physics and high temperature chemistry

Plasma for Extraterrestrial Resources and applied Technologies

P.E.R.T project

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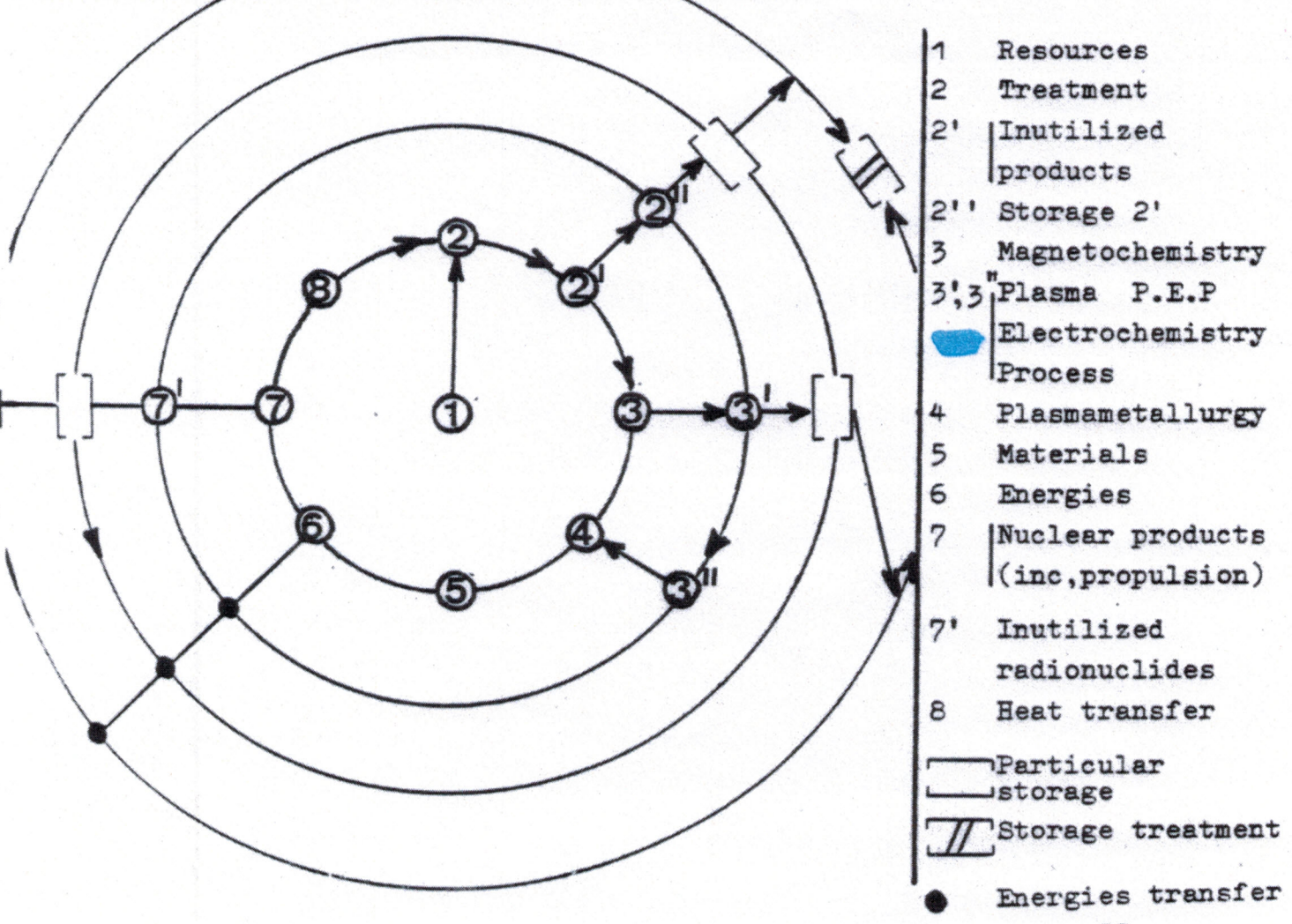
PART 3. 0

PLASMA ENGINEERING IN SPACE

As described in parts 1.0 and 2.0 plasmas proceedings will conduct echnologists to develop pertinent engineering in space, based on plasma concept, therefore apply plasmas technologies to the entire complete matter and obtain a concrete scheme of industrial production in space. We can arrange one powerfull space system to utilize everywhere resources from planets or asterofids and produce all elements or materials needed. High temperature chemistry and magnetochemistry will be strongly developped.

SPACE PLASMA ENGINEERING PROCEEDINDS.

Including survey and driving system, plasma diagnostics station.



MAGNETOCHEMISTRY

General metals selection

Diamagnetic and Paramagnetic processes.

The selection criteria utilized in the following part is based from plasma diagnostics experiments.

To take one definite scheme, we will consider one plasma as 'ionized gas' a fact but also demonstrated as 'ionized gaseous condensed matter' composed by atomic species offering diamagnetic properties.

The majority of chemical substances is made up of ions or atoms with the noble gas configuration of filled electrons shells, and it is found that $S=J=0$ and only diamagnetism is exhibited.

First the plasma is considered as optically thin to himself but also optically thick for foreign species, also waves and degenerate oscillations may cause instabilities and the plasma will be partially thick for foreign species. The plasma utilisation may be consider as one concept of radiative transfer of matter, as one special state of matter.

Plasmas are proposed as quantum observables and operators who obey to determined statistics pattern.

One L.T.E (local thermal equilibrium) plasma represents particular identifiable case described by Bose-Einstein statistics.

$$H = h^{(1)} + h^{(2)} + h^{(i)} \dots + h^{(N)}$$

with $n_1 + n_2 + n_k + \dots = N$ (N total ions)

H (Hamiltonian)=observable

One plasma defined as pure case (statistics) may be described by

if $\hat{\rho} = 1$ trace normalization with an important parameter ρ density operator often as matrix expression, therefore we can write this quantity

$$\rho = N \cdot e^{-H/kT}$$

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part 3.1

H with an Hermiticity property, and with the partition function as:

$$Z_{\mu} = \text{Tr } e^{-\mu H}$$

Free energy F, entropy S, E as energy are given by expressions:

$$\mu = (kT)^{-1}$$

$$F = -kT \ln Z$$

$$S = k \left(\ln Z - \frac{\partial \ln Z}{\partial \mu} \right)$$

$$E = \langle H \rangle = \frac{\partial}{\partial \mu} \ln Z$$

$$\text{and } S = -k \text{Tr}(\rho \ln \rho)$$

We can also express plasma definition as statistic mixture case where quantum oscillators are in L.T.E.

Each oscillator may be represent by density operator

$$\rho = \frac{e^{-H/kT}}{\text{Tr } e^{-H/kT}}$$

The partition function is given by :

$$Z(\mu) = \text{Tr } e^{-\mu H} = \sum_{n=0}^{\infty} e^{-\mu(n+\frac{1}{2})\hbar\omega} = e^{-\mu\frac{1}{2}\hbar\omega} \sum_{n=0}^{\infty} (e^{-\mu\hbar\omega})^n$$

$$Z(\mu) = \frac{e^{-\frac{1}{2}\mu\hbar\omega}}{1 - e^{-\mu\hbar\omega}}$$

with average energy $\langle E \rangle = \text{Tr} \rho H$ deduced from partition function with

$$\langle E \rangle = -\frac{\partial}{\partial \mu} \ln Z \quad \text{with } \ln Z = -\frac{1}{2} \mu \hbar \omega - \ln(1 - e^{-\mu \hbar \omega}) \quad \text{and } \langle E \rangle = \left. \frac{\partial(\ln Z)}{\partial \mu} \right|_{\mu=1/kT}$$

$$\langle E \rangle = \frac{1}{2} \hbar \omega \coth \frac{\mu \hbar \omega}{2kT} = \frac{1}{2} \hbar \omega + \frac{\hbar \omega}{e^{\mu \hbar \omega / kT} - 1}$$

to obtain the Planck formula at nearest $(\frac{1}{2} \hbar \omega)$ for the average energy of one quantum oscillator.

Part 3.1

At very low $T^{\circ}K$, $kT \ll \hbar \omega$
 the oscillator is in his fundamental state, at high temperature
 the energy tend to classical statistics as Maxwell-Boltzman.
 therefore $\langle E \rangle = kT$

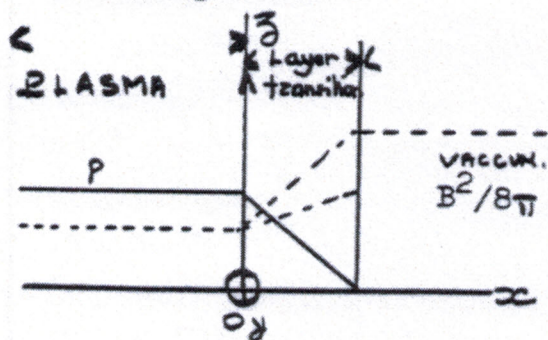
DIAMAGNETISM IN PLASMA

Plasma as species statistics scheme species gives us possibilities
 to utilize atomic selections phenomenas where internal or external
 fields are in concurrence with discernables species inside (M.B)⁺
 plasma in L.T.E.

So magnetic pressure may be express by:

$$p + \frac{B^2}{8\pi} = C^{te} ,$$

the precedent formula shows us that if p increases B decreases
 and we can see on fig 1 the interdependance with confinement
 and diamagnetism .



when p is in the same order of $B^2/8\pi$ plasma diamagnetism is
 important. Diamagnetism is one interesting physical fact because
 he is in correspondence with individual species trajectories,
 in this part we have neglected collisionals phenomenas, so we
 can get one plasma with each specie possessing one magnet moment
 as $\mu = (\frac{1}{2} m \omega^2) B^{-1}$

+ Maxwell-Boltzman Statistics.

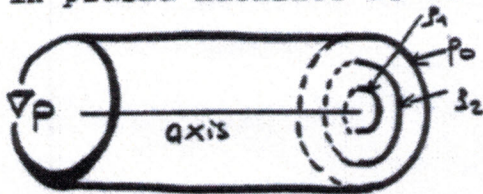
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part 3.1

we can see that this magnetic moment is directed in the inverse direction to B.

we have also to consider the function as isotropic or nonisotropic quantization, so the plasma takes one regular magnetic axis or one distort orientation in the vacuum space where the the gravitation strength is very neglectible in front of electromagnetism forces.

In plasma machines as we consider



$$\nabla p = \frac{1}{4\pi} [(\nabla \cdot \mathbf{B}) \mathbf{B}] = \frac{1}{4\pi} \mathbf{B} \nabla B - \frac{1}{8\pi} \nabla B^2$$

$$\mathbf{B} \nabla B = 0 \rightarrow p + \frac{B^2}{8\pi} = \text{cte}$$

particular for ions species in plasma we can write ::

$$\mathbf{j}_i = \mathbf{j}_{Di} + \mathbf{j}_{mi}$$

\mathbf{j}_i = current transported by ions

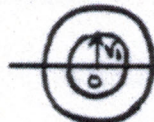
\mathbf{j}_{Di} = drift current

\mathbf{j}_{mi} = Diamagnetic current.

case 1

If magnetism field is uniform and the plasma inhomogeneous with $w_{Di} = v_i' = 0$ and $v_i' \neq 0$, the drift current is nul and the total current is confounded with diamagnetism .

We can assist to the macroscopic velocity creation in plasma on the upper region of the axis, with low plasma density (Griem condition) .



plasma magnetic axis

case 2

If the magnetic field is not uniform and the plasma homogeneous

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part 3.1

we have as contrary $w_{Di} \neq 0$ and $v_i = 0$
total current is nul because diamagnetism current cancel the drift current and ions species drift under the magnetic axis.

case 3

If the magnetic field and the plasma pressure are in agreement with $p + B^2/8 = C^{te}$ formula, diamagnetic current and the drift current takes contrary signs, and more, diamagnetic current is greater than the drift current.

So that the total current has the same sign as the diamagnetic current and with an opposite direction to the drift current.
and to resume:

$$p \ll B^2/8\pi \quad j \approx j_{Mi}, \quad j_{Di} \ll j$$

$$p \rightarrow 0 \quad \text{case 1}$$

$$p \gg B^2/8\pi \quad j_{Di} \approx -j_{Mi} \quad j \ll j_{Di}$$

case 2

As in plasma the diamagnetism is consider as one general property of the ionized condensed matter but where the species densities are lower than the classical condensed matter where the magnetic susceptibility is defined as:

$$\chi_m = -\frac{\mu_0 n Z e^2}{6 m}$$

Temperature Independent Diamagnetism (T.I.D)

the χ_m is independent from temperature.

and for diamagnetic elements(molecules) we can writtre the general formula as, $A^\alpha B^\beta$ and molecular weigh $M = \alpha A_A + \beta B_B$

χ_A and χ_B as species magnetic susceptibilities.

In this part diamagnetic susceptibily takes the minus sign:

Examples of χ :

$$H_2O = -8,6 \cdot 10^{-6}, \quad N_2 = -6 \cdot 10^{-9}, \quad Bi = -1.5 \cdot 10^{-6}$$

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part 3.1

the temperature independence of χ_m give us some possibilities of species selection in the entire plasma volume assuming or not L.T.E. More, for paramagnetic elements they will be optically thin to the plasma and the inverse for diamagnetic species, these possibilities are modified under case 1,2,3 predicted.

Temperature Independent Paramagnetism (T.I.P).

this temperature independent paramagnetism arises from a mixing into the ground state of the excited states that are not thermally populated, with $S=0$ and spin matrix will therefore zero.

$$\langle 0 | \rho_z | 0 \rangle = 0 \quad \text{where} \quad \rho_z = \frac{e}{2mc} l_z$$

$$\text{and the formula} \quad \chi_{TIP} = \frac{2}{3} N \left(\frac{e \hbar}{2mc} \right)^2 \frac{24}{\Delta_1} = 4.058 / \Delta_1$$

with Δ_1 in wave number .

Temperature independent paramagnetism has been observed in octahedral Co II complexes, which have low-lying orbital states.

Temperature dependent PARAMAGNETISM (T.D.P); the CURIE law .

Magnetic susceptibility experiments show us that χ_m increases when temperature decreases.

We can consider the atomic magnetic moment property able to give one selection possibility near the surrounded cool region of the thermal plasma, it may be consider as natural microscopic and macroscopic selection.

We can give the well known formula of the Curie law:

$$\chi = M / H_z = \frac{N g^2 \mu_B^2}{4 kT} = C/T$$

which is in the form of the Curie law where the Curie constant

$$C = N g^2 \mu_B^2 / 4 k$$

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part 3.1

the precedent formula is a special case of the more general and more familiar spin-only formula:

$$\chi = \frac{N g^2 \mu_B^2 S(S+1)}{3 kT} = \frac{N \mu_{eff}^2}{3 kT}$$

we do not discussed the Curie Law that is not found to be obeyed et low temperatures in some cases for lanthanides compounds.

Curie law can be made in the fashion: Curie-Weiss law.

$$\chi = \frac{C}{T} (1 - \Delta/T) = \frac{C}{T + \Delta}$$

MAGNETIC SUSCEPTIBILITIES OF THE LANTHANINES(the paramagnetic ions of the rare earth group).

The rare earth metals are discussed in 3.5 part(Plasma lasers selections) and in 3.6 part (Plasma lasers and excited states of rare earth worked out from asteroids resources).

we give only the following table:

TABLE 1.2 The Paramagnetic ions of the Rare Earth (f) Group (4,5).

No. of electrons in 4f shell	ion	State	L	S	J	g	Average C, in units of μ_B^2/k		Approx. energy (cm ⁻¹)
							exp	calc	
1	Ce ³⁺	² F _{5/2}	1/2	3	5/2	6/7	6	6.43	2200
2	Pr ³⁺	³ F ₄	1	5	4	4/5	12	12.8	2100
3	Nd ³⁺	⁴ F _{3/2}	3/2	6	9/2	8/11	12	13.1	1900
4	Pm ³⁺	⁵ F ₄	2	6	4	3/5		7.2	1600
5	Sm ³⁺	⁶ F _{3/2}	5/2	5	5/2	2/7	2.4	0.71(2.5)	1000
6	Eu ³⁺	⁷ F ₀	3	3	0	0	12.6	0(12)	400
7	Gd ³⁺	⁸ F _{7/2}	7/2	0	7/2	2	63	63	3000
8	Tb ³⁺	⁷ F ₆	3	3	6	3/2	92	94.5	2000
9	Dy ³⁺	⁶ H _{15/2}	5/2	5	15/2	4/3	110	113	
10	Ho ³⁺	⁵ G ₈	3	6	8	5/4	110	112	
11	Er ³⁺	⁴ I _{15/2}	3/2	6	15/2	6/5	90	92	650
12	Tm ³⁺	³ H ₆	1	5	6	7/6	57	57	
13	Yb ³⁺	² F _{7/2}	1/2	3	7/2	8/7	15	20.6	1000

part 3.1

Plasmas can be described under molecular motion scheme or quasi-continuous species motion, with determined pressure criteria. Diamagnetic and paramagnetic properties can be applied to species selection, because the temperature independent for diamagnetism, as contrary for paramagnetics ions. Therefore in plasma we can apply the Ferromagnetic selection in presence of external or internal field magnetization, for T(Co, Fe, Ni) metals, and for one complex Oxides matrix the general scheme :

\leftarrow
 (Ferro- Para - Dia) magnetism selection in plasma.
 \rightarrow

EXPERIMENTS ON (PARA AND DIA) MAGNETISM SELECTION:

In space conventional chemistries are unpracticable, because low gravity conditions and absence of atmosphere, so we have to imagine one plasma chemistry able to select species from extraterrestrial resources.

Plasmas may be used as matter or tools for technologies.

In the present report we have to consider resources as Oxides or salts (condensed matter), and modify resources by processes, temperature, velocities, densities, pressures, ions properties, magnetism internal or external, waves and appropriated volumes. In note 3 we have described the first selection for species introduced in thermal plasmas .

We can utilize one plasma in P.L.T.E (partial local thermal equilibrium) or one N.L.T.E (non local thermal equilibrium) with weak densities.

$$10^{13} \text{ cm}^{-3} < n_e < 10^{15} \text{ cm}^{-3} \quad \text{and average } T^\circ \text{K}$$

$2000 \text{ K} < T^\circ \text{K} < 3400 \text{ K}$ in the center of the plasma column.

removed from GRIEM plasma L.T.E criteria.:

$$n_e \gg 9 \cdot 10^{17} \left| \frac{E_i}{E_h} \right|^3 \left| \frac{k T_e}{E_h} \right|^{\frac{1}{2}}$$

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part 3.1

We utilize weak magnetism selection able to deplace para and ferro magnetic species from diamagnetic species under weak density plasma as defined before (P.L.T.E or N.L.T.E), but associated with M.G.D. (MagnetoGasDynamics) process. Thus, we can distinguish (macroscopic definition) in resources introduced in thermal plasmas, metals, oxides, salts and mixing materials., because in the case of diamagnetism ions who are placed in excited magnetization field, takes one magnetization directed in the inverse direction of the \vec{H} vector.

As contrary for paramagnetic species, they can be selected by their neutral properties in presence of external field, magnetization momentum directed in the direct orientation of the \vec{H} vector.

Ferro magnetic species can be selected from other paramagnetic ions by uniform or alternative homogeneous field. Waves interactions on ions are discussed in part 3.2 (Plasma Electrochemistry Process.).

In presence of thermal plasma ferromagnetic species become paramagnetic by adiabatic demagnetization.

Part 3.2

PLASMA ELECTROCHEMISTRY PROCESS:(P.E.P.) .

General purpose.

Plasma electrochemistry process is included in P.E.R.T operations as one substitution process from Earth electrochemistry needed for special or general chemistry. We have consider plasma as condensed matter from gases or metals vapours with low densities species offering "neutral" properties when L.T.E is required.

Thus, plasma as ionized gas is consider as one medium able to receive external influences or 'internal' others species. Because high temperature establishment plasma is situated in the field of the high temperature chemistry. discussed 3.3 Under L.T.E, plasma offers isotropic properties.

So P.E.P will be described by classical Maxwell. Lo.Law's or by quantum chemistry. We consider plasma species as one medium composed by ions and electrons in equilibrium caused by the recombination radiative transfer.

The situation of the plasma is assimilated as one electro-chemistry medium, as one "liquid matter" composed by cations and anions, so electrochemistry law's can be utilized to explain and investigate plasmas and introduced species . With this matter concept our technical purpose is to practize introduced metals selection.

Introduced species are evaluated by Boltzman and SAHA equations discussed part 2.0.

for NiI, NiII, NiIII densities:

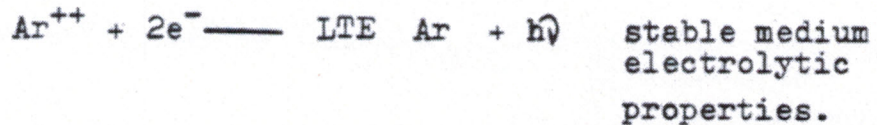
$$n_{NiIII} = \frac{1}{3(u)T} I_{NiIII} (\text{ standard})$$

$$e^{-\frac{E_k}{kT}} \cdot 8.437 \cdot 10^{-17} \sum_i f_{ik}$$

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Int[†]NiIII is easily determined by plasma diagnostic.

thus with temperature information and ionization state of introduced species we can evaluate each concentration or species density.,for one thermal distribution,so at L.T.E plasma recombination for ions we can write:



	Fe	Co	Ni
Atomic radii Å	1.165	1.157	1.149
Ionic radii(½ empiric)	0.830	0.820	0.780
	+2	+2	+2
	0.670	0.650	0.650
	+3	+3	+3

ions dimensions are 10^{-8} cm, Electric field \vec{E} between the two charges ,positive and negative(electric image) is $\approx 4.8 \cdot 10^{-10} \cdot 10^{16}$ UES or $14,4 \cdot 10^8$ V/cm.The important field may extract at 300°K,electrons from cathode,thus Ni⁺⁺ can be converted in Ni atom.

As one electrolytic medium plasma conductivity can change(0,1Ω to 100Ω cm⁻¹).

We can consider the plasma medium, as one special liquid matter associated with plasma oscillations changing it in one quasi viscous medium.

the viscosity of the assimilated electrolytic medium may be evaluated by Smoluchowski formula where Diffusion coefficient D is included.

+ line intensity.

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Electrochemistry plasma may be quite define by spectroscopic experiments and their interpretations.

Many quantities are calculated or given by tables.

Considering in our plasma model with one unperturbated Hamiltonian H and one statistic distribution function for ions velocities species as:

$$f_v = A_i e^{-(w_i)} \quad \text{and} \quad w_i = \int_0^{v_i} \frac{mv \, dv}{kT + \frac{2 e^2 E^2}{3 m_i}} \Bigg|_{ie}$$

$$\bar{v}_{ie} = \bar{v} - \bar{v}_{ae}$$

with \bar{v}_{ie} average collisional ions-electrons frequency

$$\bar{v}_{ie} = \frac{u (2\pi)^{1/2}}{3} Ne \left| \frac{z e^2}{4\pi\epsilon_0 \cdot kT} \right|^2 \cdot \left| \frac{kT}{m} \right|^{1/2} \cdot \text{Iog } \Lambda$$

as Λ fraction DEYBE radii on minimum important parameter-

$$\Lambda = 1.5 \frac{(4\pi\epsilon_0 kT)^{1/2}}{e^3 (\pi Ne)^{1/2}}$$

we have supposed that collisions in plasma are elastic.

$$\xi = \left(\sum \frac{2m \bar{v}_{ae}^M}{M - m} \right) \left(\sum \bar{v}_{ae}^M \right)^{-1}$$

with \bar{v}_{ae}^M as average frequency electronic collisions with atoms of weight M .

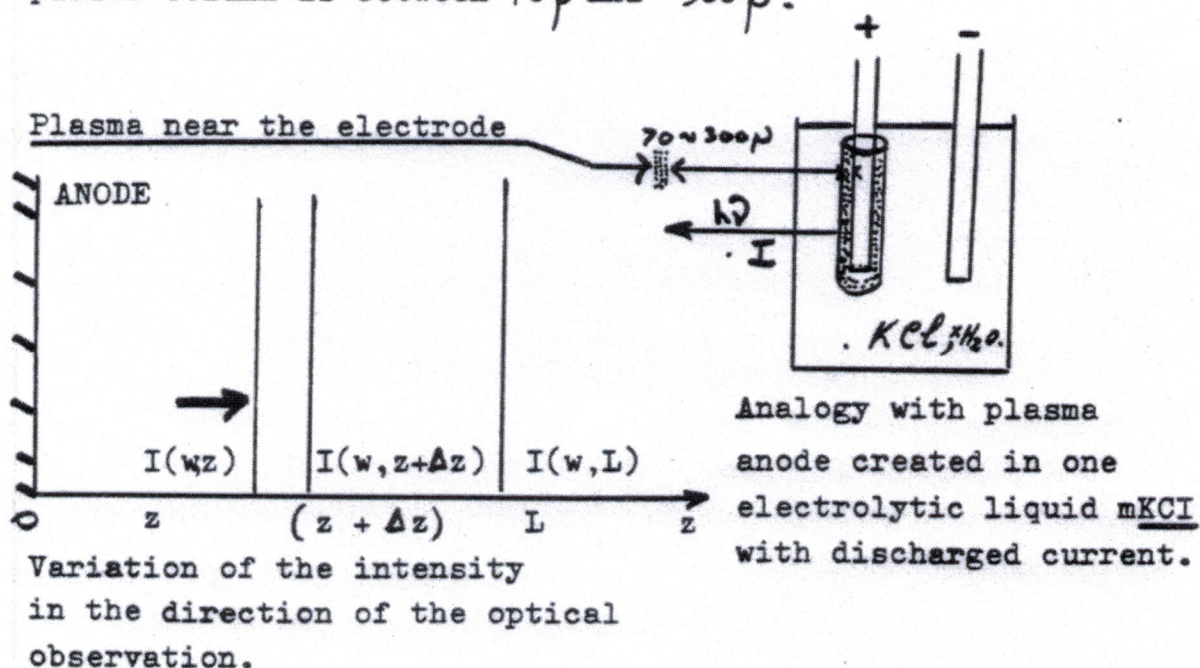
and T , Ne , $\Lambda = 24$

$$\lambda_D \cdot 2\pi \sqrt{2} \cdot \lambda_D = 0,17\rho \quad \text{and} \quad \rho \approx 8 \text{ \AA}$$

ρ as minimum impact paramater.

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We give one simple description of the experimentation, in the classical liquid as electrolytic medium, we create current discharge between the two electrodes of the medium, we can optically observe around the Anode, the radiative emission of the surround layer plasma created. The thickness of the plasma column is between 70μ and 300μ .



The critical field:

$$E_c = \frac{e}{8\pi \epsilon_0} \frac{\log \Lambda}{\lambda_D^2} \approx 60 \text{ kV cm}^{-1}$$

with E.T.L conditions and with one Maxwellian distribution.

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and $w_p \sim \omega_1$ limit of the resonance. with $a \ll \frac{q_e E_+}{m_e w \sqrt{v_1}}$

a is one dimension of containing plasma in the orthogonal plan to B and $\sqrt{v_1}$ the average collisional frequency. This part can offer us one plasmic concept to realize electrochemistry in space.

The plasma frequency is therefore for \bar{e} .

$$w_{\bar{p}} = \left(\frac{4\pi n_0 e^2}{m e} \right)^{\frac{1}{2}}, \text{ numerically, we can use the}$$

$$\text{approximated form } w_{\bar{p}} / 2\pi = f_{\bar{p}} = 9 \cdot 10^3 \cdot n^{\frac{1}{2}}$$

$$\text{for ions we can generally write } w_{n+} \approx \left| \frac{4\pi n_0 e^2}{m p^+} \right|^{\frac{1}{2}}$$

$$\text{and } f_{\bar{p}} \approx w_{\bar{p}} / 2\pi$$

$$N_{\bar{e}} < |N| < N_{Ar^+}$$

$$8.13 \times 10^{16} \text{ cm}^{-3} < |N| < 4.31 \times 10^{17} \text{ cm}^{-3}$$

$$\text{with Ni } +2 \text{ density } 1.41 \cdot 10^{11} \text{ cm}^{-3}$$

$$\text{Ni } +1 \quad 4.5 \cdot 10^9 \text{ cm}^{-3}$$

$$\text{Ni } +3 \quad 4.7 \cdot 10^8 \text{ cm}^{-3}$$

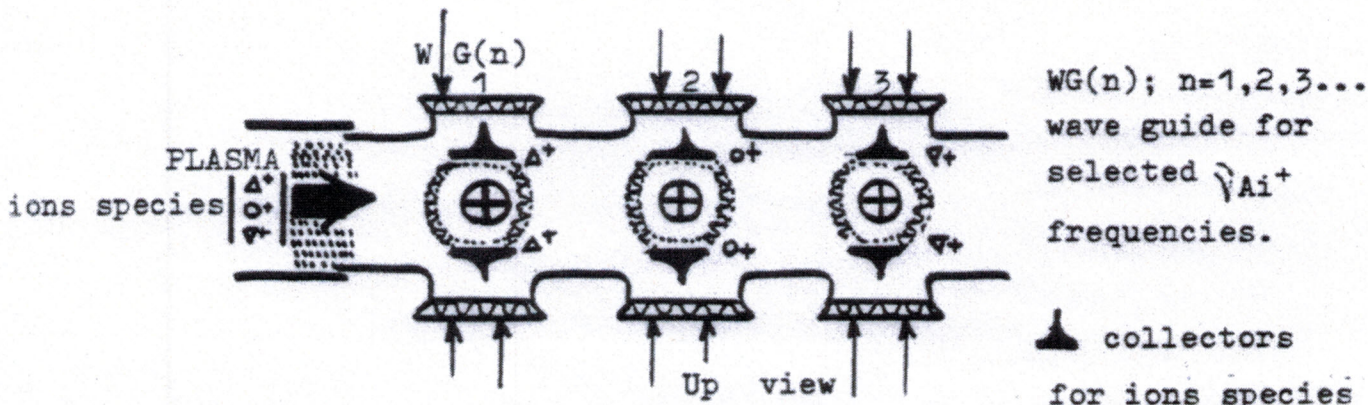
$$\text{Ar}^+ \quad 4.31 \cdot 10^{17} \text{ cm}^{-3}$$

Plasma $f_{\bar{p}}$ is normally in microwave range and it is interesting to influence the plasma by waves or by external fields to create cyclotron resonance frequency and collect species on electrodes or (special apparatus) of each considered metal, in our case Ni electrodes or Co, Fe, Si, Mg electrodes. for extraterrestrial oxides introduced in plasma.

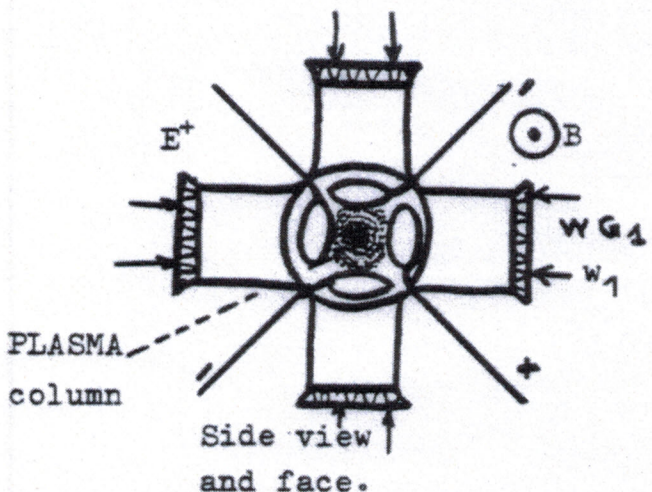
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frequency resonance for ions:	$\nu_{Ni +2}$	$\approx 7.8 \cdot 10^7$ Hertz
	$\nu_{Ni +1}$	$\approx 9.84 \cdot 10^6$ Hertz
	$\nu_{Ni +3}$	$\approx 2.62 \cdot 10^6$ Hertz

we deliver the scheme of the plasma apparatus concept (P.E.P).



Resonance for ions
Plasma electrochemistry cell



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Each foreign introduced ion is optically seen and deposited by the radiative combination on the collector worked out from the same metallic ion placed in cyclotron resonance , therefore the length column of the plasma can contain some specific electrodes.

The scheme may be considerably modify (see. 5.0) research required.

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Part 3.3

PRODUCTS AND PROCESSES FOR HIGH TEMPERATURE CHEMISTRY

High temperature chemistry is defined as the study of molecules at high temperature estimated (1800 - 12000 K), that may be considered the upper limit of the high temperature application. Experiments give us informations about the relative energies of the valence states and the electronic environments, thus transition probabilities.

Products and species from plasmas are too important to imagine the establishment of list species by species under different plasmas-genesis gases.

The more simple as natural high temperature chemistry, is the thermal dissociation of oxides in plasma into vapors as metals and collect them mixed by electrodeposition.

We can utilize also the possibility of the treatment of the oxides in reduced plasma gas(Ar+H) and metals are directly recovered by natural condensation.

The third method is based on plasmaelectrochemistry process where each metal can be deposit on electrodes of the same metal nature by ion resonance. see P.E.P part 3.2, this process also will be discussed in part 3.5 plasma lasers selections by V.U.V radiative pumping levels from atomic species in plasma and their selections.

It seems to us that P.E.P is pertinent process for space, thus the apparatus is quite simple in each recovery case.

The best adapted process will be choisen from soil relative nature of resources.

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In plasmas procedures we can imagine also to introduce other molecules (CO,CO₂,N₂,NO₂,N₂O,.....) to prepare intermediates products.

Therefore organic and ½ organic high temperature plasma chemistry can be easily proposed in space with generated plasmas with (H₂,Ar,N₂,He,CO₂,O₂.....,)

PROCEDURES

- S.F.M.O (salts,free metals,Oxides) in resources.
- ★ (Plasmas)
- M (Metals see parts 3.0,3.1,3.2)
- OMC (Organic and Metallic Chemistry)and ½ organic
- OC (Organic chemistry)

S.F.M.O

M

OMC

OC



Part 3.4

OXIDES AND SALTS TREATMENT BY PLASMAS.

Plasma technologies in space are more attractive because the human intervention is not absolutely required and one plasma station may be almost automatic.

The resources introduced in plasma machines are not dependent from sophisticated preparation or complex treatments.

The plasmas machines are not submitted to one important maintaining like motors or rotatives engines.

Rocks and materials are driven to one "explosion chamber" where materials are disaggregated by important current discharges produced by (Solar energy, Nuclear production, Lasers) in case of the more simple action the current may be alternative or continuous, and the H2O presence may offer some interest in partial conductivity for the induced current.

The rocks motion are assumed by magnetic field (continuous or alternative) the principle is proposed in note 1.

After this operation, rocks are reduced in fine powder in one rotative plasma machine described in note 2 where N.L.T.E is required for the plasmas instabilities effects needed in this process. We have mentioned in 3.1 that atomic species were separated DIA from PARA and FERRO and finally PARA from FERRO, also H2O is partially "eliminated" in dissociation phenomenas or in Diamagnetic selection, with others elements as follows:

-0.57 Li +	-0.41 Br +	+ multiply by 10 ⁻⁵	<u>Table 3</u>
-0.97 Be	-0.30 Zr		
-0.71 B	-0.95 Mo		
-0.59 Cl	-0.18 Cd		
-0.48 S	-0.10 In		
-0.90 P	-0.78 Sb		
-0.1-0.2 Si	-0.30 Te	-1 C	
-0.14 Zn	-0.32 I		
-0.14 Ge	-0.14 Au		
-0.30 As	-0.21 Tl		
-0.30 Se	-0.12 Pb		

./..

Table 3 shows us that Si and C are diamagnetic elements, the MGD or Magnetochemistry is attractive because for Dia and Para magnetic species, J is cancelled at the same time than H , with ($J = \chi_m H$) isotropic, and $\chi_m = \mu_r - 1$ with $\mu = \mu_0 \cdot \mu_r$ (magnetic permeability) and for Diamagnetic elements $\mu_r < 1$, $\chi_m < 0$, \vec{J} and \vec{H} are antiparallel.

And for Paramagnetic elements $\mu_r > 1$, $\chi_m > 0$, \vec{J} and \vec{H} are parallel, therefore the magnetization is purely induced. See part 3.1 for temperature effects. T.I.P, T.I.D.

Oxides in plasmas are dissociated at high temperature, it is attractive to introduce salts as sulphides or carbonates in plasmas to produce ions we can propose molecules dissociation:

A.X A^+, X^- X as (S, SO_x, Cl_y, CO_z, O_u)_{x,y,z,u} (integer or fractional)

For each determined (plasma diagnostic) region of the plasma, with selected dissociation reactions we can separate metals from anions. Generally oxides and salts induce in plasmas oxidation tendency, we are situated in front of 3 possibilities.

case 1:

The plasma-genesis gas is "neutral" as Ar, plasma takes oxidation tendency.

case 2:

The plasmagenesis gas support is "oxidizing" as O₂, the oxidation tendency is nul in front of the oxidizing state of the plasma.

case 3:

The plasmagenesis is H₂ gas support the oxidizing tendency is nul in front of the reducing plasma agent.

Plasmas generated by SO₂, CO₂, CO, N₂, N₂O, NO₂, Cl₂, (CO₂, H₂O) are not studies in this part., see part 5.0.

In space H₂ or Ar may be normally utilized to separate Oxides and salts by thermal dissociation and reduce them in metals.

(H₂ or other reducing agents are utilized (Ni/ AlOOH/ catalyst matrix metals).....°. see part 3.8.

./..

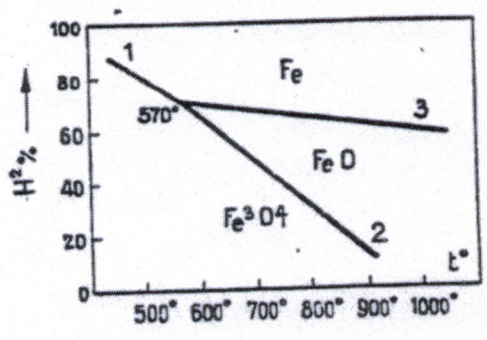
Therefore plasmas are able to become useful tools and metals to treat all salts including instable or dangerous products. Radionuclides products are discussed part 3.14 .

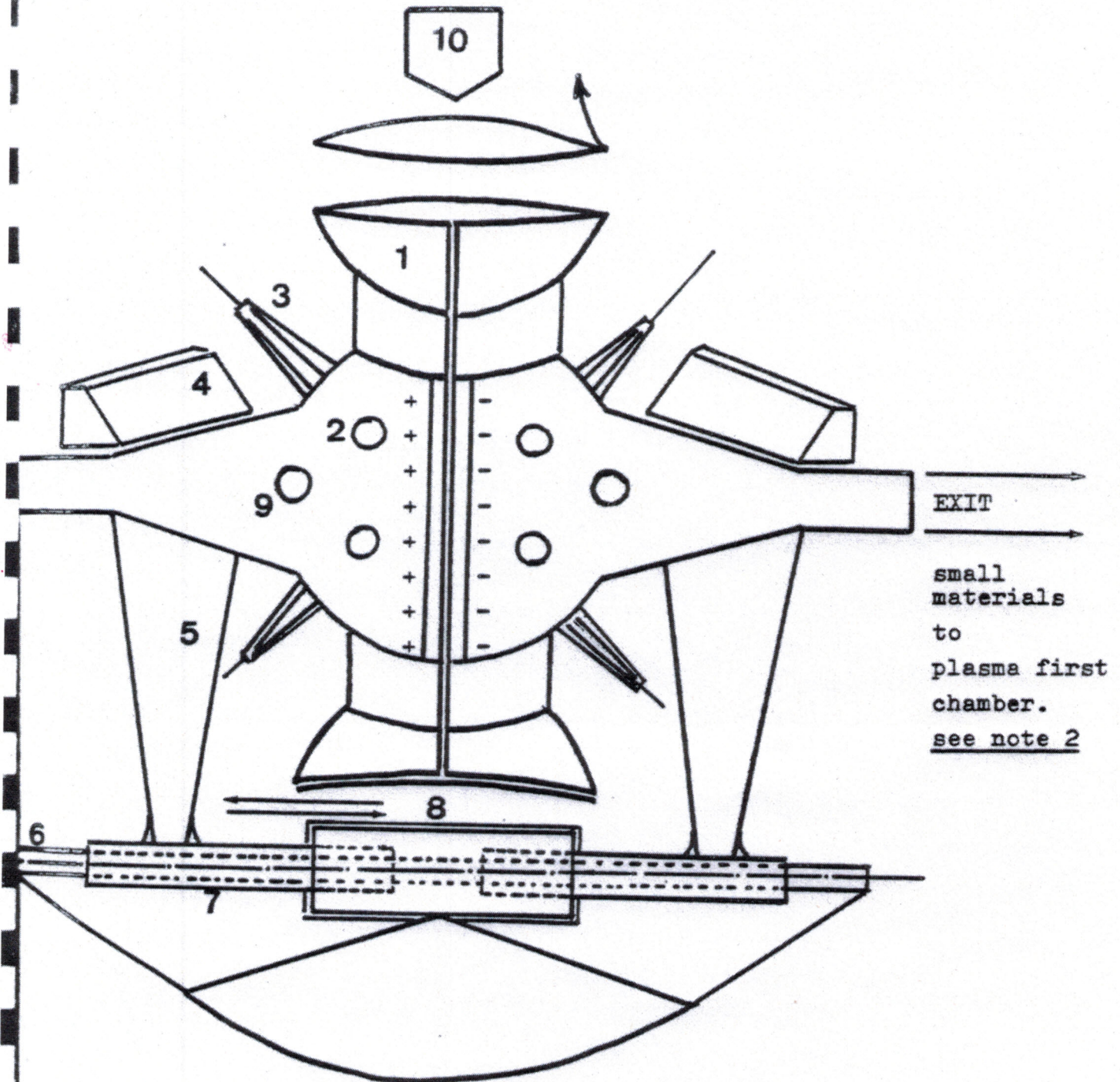
For some experiments in particular for paramagnetic ions, the color of ions may be one observable for ions metals migration in the plasma or concentration, it may consist in one experimental optical survey method of introduced ions species in plasma in one choisen procedure see part 3.0

General discussion for(H₂,H₂O) inside Ar plasma or neutral gaz, in presence of FeO or Fe₂O₃ or Fe₃O₄ may be established easily, The reducing Oxides by H₂ is endothermic, and will be completely achieved with the increasing of the temperature. In the cool regions of the plasma (500-800 K) we can utilized equilibrium constants to survey and note the reducing percentage in the cool plasma region, we deliver below the classical scheme of the eaquilibrium constants and the percentage of each phase.

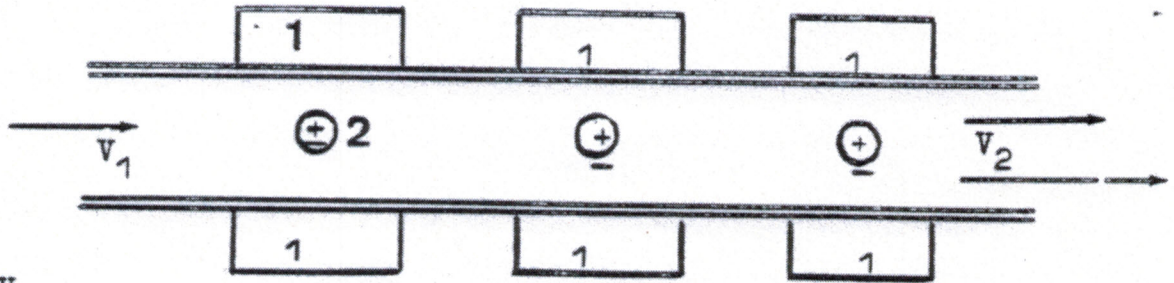
T °C	360°	440°	470°	490°	550°	570°	630°	785°	920°	615°	700°	770°	805°
h/f	8,3	5,55	5,0	4,16	2,94	2,63	2,78	1,75	1,47	1,72	1,0	0,645	0,4
phases	Fe + Fe ₃ O ₄						Fe + FeO			FeO + Fe ₃ O ₄			
	1						3			2			

h/f = H₂ pressure/ HOH pressure.



EXPLOSION CHAMBER

- 10 Rocks and materials
- 1 Introduction
- 3 Electric power
- 2 Lasers power entry (OPTION)
- 9 Survey
- 5 support
- 6 Axis support
- 7 Magnet
- 8 Magnet for 7 movement
- 4 Magnet for materials evacuation.



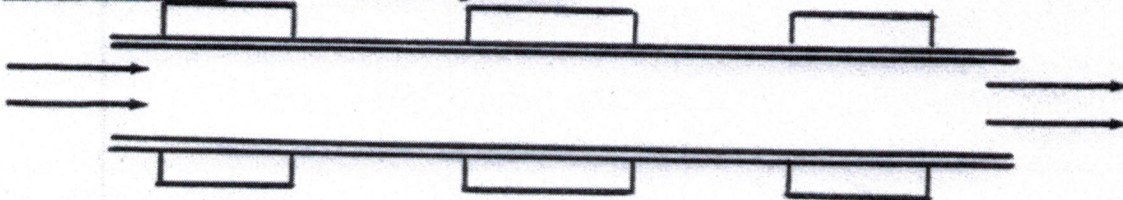
$v_1 < v_2$

3 Magnetogasdynamic (as motor for materials movement) before introduction in PLASMA CHAMBER 4 (microdivision plasma chamber).

- 1 magnet
- 2 electrodes

PLASMA CHAMBER 4 (microdivision). TWO OPTIONS:

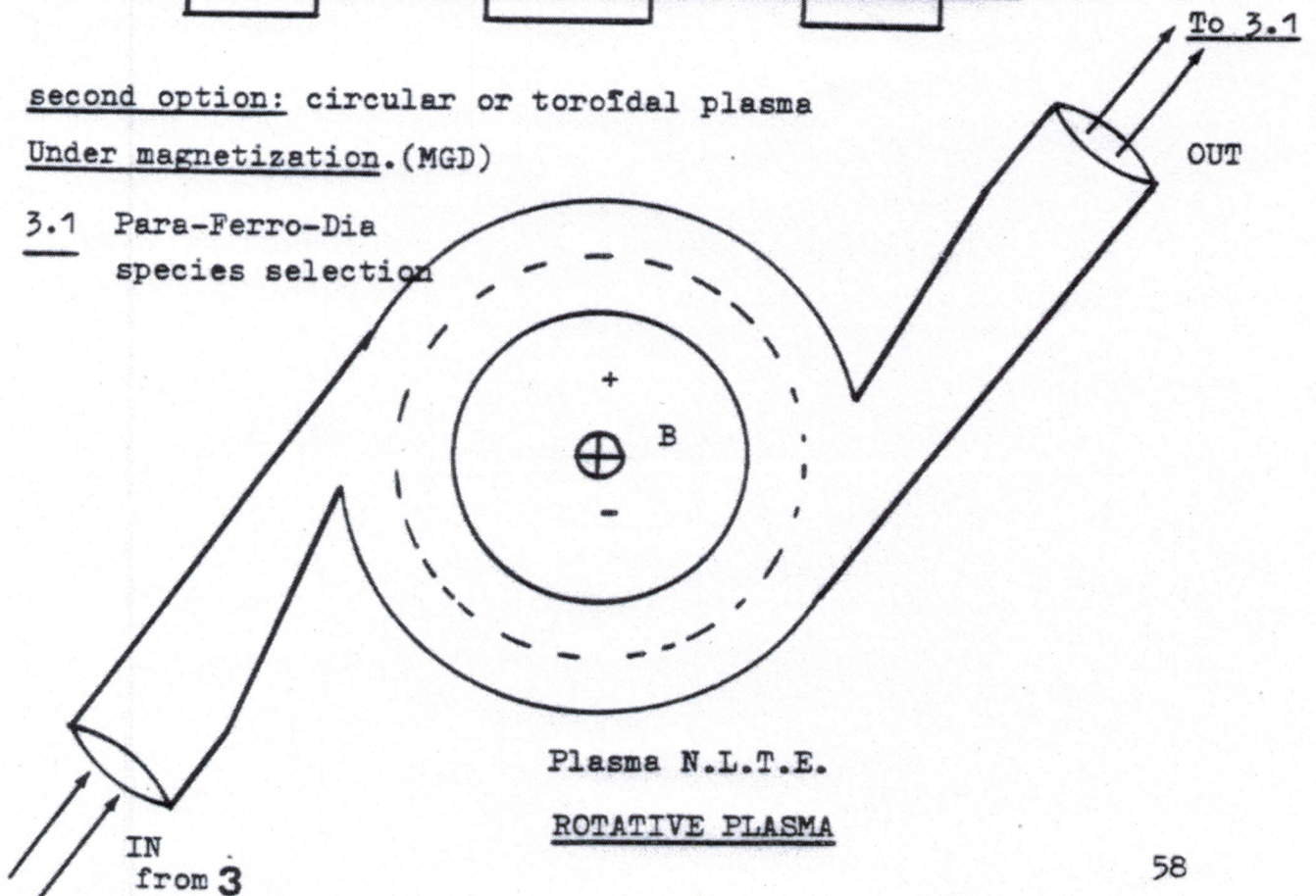
first option: linear plasma



second option: circular or toroidal plasma

Under magnetization. (MGD)

3.1 Para-Ferro-Dia
species selection



part 3.7

PLASMA THERMOCHEMISTRY DISSOCIATION.

High temperature chemistry may utilize for dissociation molecules thermal plasmas.

Between 2000 and 13000 K molecules are dissociated partially or completely to make up others molecules, reduced metals and complex species, we can observe these phenomenas in molecular or atomic spectroscopy, therefore give us precious informations on the thermochemistry disssociation process.

We have limited the development of this part at the transition Oxides and particulary $Ni_xO_y^{(+)}$, Co_xO_y , Fe_xO_y , MgOand some informations on rare earth Oxides, in the case of thermal influence oxides can be dissociated in metal vapors and Oxygen, they may be recombined on (non-stoichiometric) formulation, this process is interesting for the solid state physics, also for condensed matter research and particulary for the excited states of the rare earth vapors utilized as by-production of the Oxides metals resources (T-metals) from planets or asteroids (0.7 to 1%). discussed in part 3.6 .

The plasma dissociation under reduced atmosphere to produce T-metals is discussed in part 3.4 .

Dissociation energies of gaseous diatomic oxides is tabulated below:

TABLE VI. DISSOCIATION ENERGIES OF GASEOUS DIATOMIC OXIDES

Molecule	D_{298}° (kcal/mole)	D_0° (kcal/mole)	Uncertainty
AgO	51	30	± 20
AlO	116	115	± 5
ArO	—	<1	—
AsO	115	114	± 3
BO	192	191	± 3
BaO	131	131	± 6
BeO	98	97	± 7
BiO	87	86	± 3
BrO	56.2	55.3	± 0.6
CO	257.26	256.16	± 0.77
CaO	84	83	± 7
CdO	≤ 67	≤ 66	—
CeO	188	187	± 6
ClO	64.29	63.33	± 0.03
CoO	88	87	± 5
CrO	110	109	± 10
CsO	67	66	± 8
CuO	82	81	± 15
DyO	146	145	± 10
ErO	147	146	± 10
EuO	130	129	± 10
FO	56	55	± 10
FeO	96	95	± 5
GaO	68	67	± 15
GdO	162	161	± 6
GeO	158.2	156.9	± 3

TABLE VI (continued)

Molecule	D_{298}° (kcal/mole)	D_0° (kcal/mole)	Uncertainty
HO	102.34	101.36	± 0.3
HeO	—	0	—
HfO	185	184	± 10
HgO	—	(<65)	—
HoO	149	148	± 10
IO	47	46	± 7
InO	≤ 77	≤ 76	—
IrO	≤ 94	≤ 93	—
KO	57	56	± 8
KrO	—	≤ 1	—
LaO	188	187	± 5
LiO	78	77	± 6
LuO	159	158	± 8
MgO	79	78	± 7
MnO	96	95	± 8
MoO	115	114	± 12
NO	150.8	149.9	± 0.2
NaO	73	72	± 12
NbO	189	187	± 10
NdO	168	167	± 8
NeO	—	<1	—
NiO	89	88	± 5
O ₂	119.11	117.97	± 0.04
OsO	<142	<141	—
PbO	119.6	118.8	± 3
PdO	89.4	88.4	± 2
PdO	56	55	± 7
PrO	180	179	± 8
PtO	83	82	± 8
PuO	163	162	± 15
RbO	(61)	(60)	± 20
RhO	90	89	± 15
RuO	115	114	± 15
SO	124.69	123.58	± 0.03
SbO	89	88	± 20
ScO	155	154	± 5
SeO	101	100	± 15
SiO	192.3	190.9	± 2
SmO	134	133	± 8
SnO	127	126	± 2
SrO	93	92	± 6
TaO	183	182	± 15
TbO	165	164	± 8
TeO	81	80	+10, -1
ThO	192	191	± 10
TiO	158	157	± 8
TlO	≤ 75	≤ 75	—
TmO	122	121	± 15
UO	182	181	± 8
VO	154	153	± 5
WO	156	155	± 6
XeO	9	8	± 5
YO	162	161	± 5
Yb	98	97	± 15
ZnO	≤ 66	≤ 65	—
ZrO	181	180	± 10

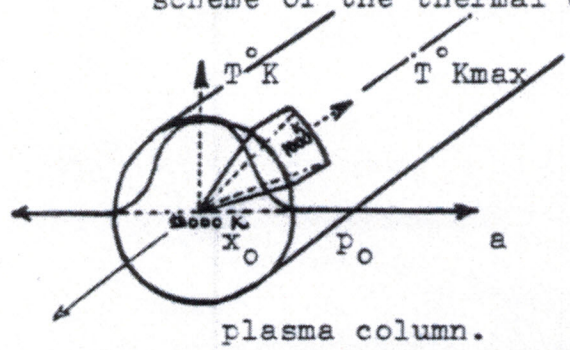
part 3.8

PROCESSES FOR TRANSITION T-METALS (Fe,Co,Ni).

3.1,3.2,3.4,3.7, parts developed can deliver to the High temperature chemistry different processes to extract foreign metals species.

One can prepare T-metals directly by H2 reducing agent on Oxides vapours molecules.

scheme of the thermal distribution in the plasma at L.T.E.



the mantle of the plasma at 1000° K
the center of the plasma at 13000° K
for 1 atm Argon.

The magnetochemistry process:

The external field can be used to confine all foreign species along the strength lines generated by the field.

3.1 discussion give us the Curie Temperature selection on the layer distribution of the plasma.

Above the Curie point temperature Ferro species properties decrease to become paramagnetic oriented on the line strength of the field, during the magnetization and the crossing of thermal region.

χ_{II} suceptibilities:

<u>300 K</u>	<u>350 K</u>	<u>1033 K</u>
NiO = +6.6 10^{-4}	CoO = +4.9 $\cdot 10^{-3}$	Fe2O3 = +3.5 10^{-3}
	Co2O3 = + 4.56 $\cdot 10^{-3}$	FeO = +7.2 10^{-3}
	Co3O4 = +7.38 $\cdot 10^{-3}$	

In the plasma chemistry the extraction orientation is as Fe,Co,Ni,

./..

It is interesting to note that Ni vapor in presence of H₂ is naturally one strong reducer, in particular as case of asteroids resources recovery, we have the simple presence of Fe_xO_y and NiO, and the metal extraction will be more simple by the reducing natural Ni process.

For all transition metals (Ti, V, Cr, Mn, Fe, Co, Ni, ... Cu.) we can utilize H₂, also CO can reduce FeO.

For more 3 metals it seems pertinent to us to utilize (plasma, electrochemistry process) , (P.E.P).

IRON ²⁶Fe⁵⁵⁻⁸⁴⁷

Melting Point	(°C)	1536
Boiling Point	(°C)	3000
Density	(g/cm ³)	7.87
Thermal Conductance	[cal/(sec)(cm ²)(°C/cm)]	0.19
Specific Heat	@ 100°C (cal/g)	0.12
Heat of Fusion	(k-cal/g-atom)	3.67
Heat of Vaporization	(k-cal/g-atom)	84.6
Atomic Volume	W/D	7.1
First Ionization Energy	(K-cal/g-mole)	182
Electronegativity	(Pauling's)	1.8
Covalent Radius	Angstroms	1.17
Brinell Hardness		82-100
Linear Coefficient of Expansion		12.6X10 ⁻⁶
Electrical Resistivity	(microhm-cm)	9.71
Crystal Structure		Cubic, body centered
Tensile Strength	(psi)	35,000-40,000
Lattice Constant	(cm)	11.7X10 ⁻⁸
Compressibility	(cm ² /kg)	0.6X10 ⁻⁶
Modulus of Elasticity	(dyres/cm ²)	21X10 ⁻¹¹

NICKEL $_{28}\text{Ni}^{58-71}$

Melting Point	(°C)	1453
Boiling Point	(°C)	2730
Density	(g/cm ³)	8.908
Thermal Conductance	[cal/(sec)(cm ²)(°C/cm)] @ 100°C	0.198
Specific Heat	@ 200°C (cal/g)	0.1225
Latent Heat of Fusion	(cal/g)	73.8
Heat of Vaporization	(k-cal/g-atom)	91.0
Atomic Volume	W/D	6.6
First Ionization Energy	(K-cal/g-mole)	176
Electronegativity	(Pauling's)	1.8
Covalent Radius	Angstroms	1.15
Coef. of Ther. Expansion		13.3 × 10 ⁻⁶
Electrical Resistivity	@ 20°C (microhm-cm)	6.844
Crystal Structure		Cubic, face centered
Lattice Constant		3.5168
Modulus of Elasticity	(psi × 10 ⁶)	30
Thermal Neutron X Section	(barns/atom)	17.5
Mag. Transformation Temp.	(°C)	357 *
Tensile Strength	(psi)	120,000
Compressibility	(cm ² /kg)	0.531 × 10 ⁻⁶
Brinell Hardness (annealed)		75

COBALT $_{27}\text{Co}^{58-933}$

Melting Point	(°C)	1495
Boiling Point	(°C)	2900
Density	(g/cm ³)	8.92
Thermal Conductance	[cal/(sec)(cm ²)(°C/cm)]	0.1653
Specific Heat	@ 25°C (cal/g)	0.1056
Heat of Fusion	(cal/g)	62.0
Heat of Vaporization	(cal/g)	1500
Atomic Volume	W/D	6.7
First Ionization Energy	(K-cal/g-mole)	181
Electronegativity	(Pauling's)	1.8
Covalent Radius	Angstroms	1.16
Vickers Hardness	@ 20°C	253
Coef. of Ther. Exp.		12.5 × 10 ⁻⁶
Electrical Resistivity	(microhm-cm)	6.24
Crystal Structure		Hexagonal
Curie Temperature	(°C)	1121 *
Thermal Neutron X Section	(barns/atom)	34.8
Poisson Ratio		0.32
Young's Modulus	(psi × 10 ⁶)	30.6
Tensile Strength	(psi × 10 ³) annealed	37.0
Compressibility	(cm ² /kg)	0.50 × 10 ⁻⁶
Brinell Hardness		125

part 5.0

RESEARCH AND EXPERIMENTS REQUIRED FOR 1.0 TO 3.8 .

Immediate experiments.

Plasmas are generated by H.F or resistive⁺ electrodes

1: Experiments under Ar with one T-Matrix

Fe,Co,Ni---X Mg-Al-Si---X

2: Experiments under Ar+H2 with T-Matrix (case L.T.E,P.L.T.E,NLTE).

T-Matrix is one restored metal oxides configuration.

X may be O or S (voluntary limited).

T1 may be FeX first metal

T2 - - Fe-X

T3 - - Fe-X-Mg-X

T4 - - Fe-X-Mg-Si-X

T11 - - FeCo-X-Mg-X

T12 - - FeCo-X-Mg-Al-X

T13 - - FeCo-X-Mg-Al-Si-X

T21 - - FeCoNi-X-Mg-X

T22 - - FeCoNi-X-Mg-Al-X

T23 - - FeCoNi-X-Mg-Al-Si-X.

Many arrangements can be computed for T-Matrix ,CoX as first metal and,NiX as first metal.

Experiments under (N2,O2,CO2,CO,CO2,SO2,...)X.,X may be nul or HOH % .,with T-Matrix.

Plasmas diagnostics

Magnetochemistry on T-Matrix

Realization of one M.G.D pump to practize the cycling of species(Plasma automatism for Station in space).

Experiments on (Plasma Electrochemistry Process). (P.E.P).

BOARDING of T-Matrix plasma experiments on SHUTTLE(for space conditions).

BOARDING for geostationary orbit(Plasma station:preliminary to Space metallurgy.).

Development of the predicted tools

Linear or rotatives plasmas

Explosion chamber

Experiments with T-Matrix (Real resources.)...

+ The two electrodes are in contact with plasmagenesis gas.

We apologize for the following paper in french.

Programme de travail à entreprendre en physique des plasmas et leur utilisation en Magnéto-Hydro-Dynamique (M.H.D).

Spécialité: Ensemencement des plasmas (Hautes Températures)

Les plasmas hautes températures représentent un support physique qui autorise des expérimentations concrètes et, envisager leur extension à des domaines complexes.

Rappel technologique;

Avant 1979 il n'existait pas de méthode générale d'ensemencement des plasmas à l'Equilibre Thermique Local (E.T.L), ou à l'état de partiel équilibre (P.E.T.L) , ou en l'état de non équilibre (N.E.T.I)

Les seules impuretés introduites dans les plasmas consistaient en les métaux associés à des molécules gazeuses, ces dernières étant mélangées à des gaz plasmagènes.

Quelques métaux ont été étudiés à l'aide de cet artifice limité des probabilités de transition ont pu être expérimentalement déduites avec des reproductibilités discutables. Le nombreux alcalins, alcalino-terreux, et groupe des TERRES RARES ainsi que des métaux lourds n'ont pu faire l'objet d'études expérimentales tant utiles aux astrophysiciens utilisant les valeurs déduites des expériences de laboratoire (forces d'oscillateur) pour la détermination des abondances stellaires . Par ailleurs ces études demeurent obligatoires pour les physico-chimistes leur permettant de mieux connaître les transferts radiatifs dans les structures solides ou liquides chargés ou dopés en impuretés métalliques, toutes ces informations sont importantes pour la meilleure connaissance des domaines de la chimie des hautes températures et leurs applications possibles et en particulier la réalisation de matériaux Ultra-réfractaires, dont le développement est tributaire et ainsi associé au progrès de la physique des plasmas hautes températures dans leurs applications proposées dans le rapport.

./..

Le développement des technologies plasmas a été limité par deux causes interdépendantes à savoir ;
d'un part l'impossibilité de maîtriser dans l'espace et dans le temps des techniques d'ensemencement des plasmas à la pression de milieu (pouvant être la pression atmosphérique), et d'autre part de trouver des matériaux ultra-réfractaires dont la résistance thermique aux températures de service soit correcte.

Par ailleurs la poursuite de travaux à la pression atmosphérique ou de milieu plasmagène nous apparaît plus prometteuse que des expérimentations au très faible pressions ou les densités électroniques et ioniques sont trop inférieures aux valeurs souhaitées.

En 1979 les travaux de doctorat de Christian.Daniel.ASSOUN. PARIS 7 délivrent une méthode générale d'ensemencement des plasmas par tous métaux ou oxydes d'éléments dans des gaz plasmagènes à l'équilibre Thermique local (12300°K).

Cette nouvelle technologie permet d'espérer une poursuite de travaux dans les domaines des plasmas à forte conductivité, associés à des dynamiques géométriques modélisées.
Ces études devaient améliorer considérablement voire relancer les applications M.H.D qui étaient limitées par les deux facteurs précités.

MACHINES A PLASMAS: à pression de milieu.

PROGRAMME DES TRAVAUX;

- 1) Ensemencement des plasmas définis dans leur enceinte géométrique.
Ensemencement par les alcalins, les alcalinoterreux, et les métaux de transition et paramagnétiques dans des atmosphères plasmagènes, (A, H, He) .
- 2) Détermination de la concentration et de la répartition spatiale des émetteurs dans le plasma ensencé méthode spectroscopique (side-on) en émission.
- 3) détermination des quantités expérimentales utiles à l'établissement des caractéristiques inhérentes au plasma créé: (forces d'oscillateur atomique des atomes introduits, densités des composants du plasma, températures et détermination des durées de vie, sections efficaces et enseignements de certains états collisionnels.
- 4) détermination de tous les paramètres utiles à la caractérisation d'un plasma en E.T.L ou N.ETL dans un volume de révolution en vue des applications M.H.D (cylindre, sphère, tore.....).

./..

5) Détermination des concentrations maximum des métaux dans les plasmas à créer, détermination de la variation de la température en fonction des concentrations.

6) détermination expérimentale de tous les paramètres régissant la dynamique plasmagène.

7) détermination d'une technologie d'ensemencement pariétal permettant de générer des zones préférentielles à forte conductivité.

8) Etudes des transitions radiatives dans un plasma contenu dans une forme géométrique de type ovoïdal, calcul expérimental de la température radiale des émetteurs d'un tel plasma.

9) ASSOCIATION DU CHAMP MAGNETIQUE (études M.H.D).
Conditions expérimentales à fort paramètre de Hall, détermination des forces d'oscillateur des atomes pendant la dynamique à proximité des électrodes (ou zones de sudation) et des zones d'application du champ magnétique, détection des instabilités possibles dans les zones pariétales, et menée des expériences visant à annuler ces instabilités.

10) Etudes d'obtention de très hautes densités de courant dans les régions pariétales, influence des facteurs champs et courants limites, détermination expérimentale de la température.

II) Détermination des paramètres permettant de comprendre l'usure des matériaux et des pollutions internes.

12) Etudes de l'ensemencement pariétal à fort paramètre de Hall comportement des atomes para et diamagnétiques dans un plasma soumis à un champ magnétique croissant se comportant comme une machine à plasmas créant des miroirs magnétiques dans les zones pariétales, étude de la variation des densités et des processus collisionnels d'atomes paramagnétiques ou diamagnétiques dans un plasma à Haute température dont l'équation d'état commence à l'assimiler à un corps pur diamagnétique (calcul des équations limites, opérateurs et oscillateurs quantiques).
Calcul des dérivées magnétiques et de la compression.

Aux conditions limites il est prévu une résonance cyclotronique des ions des atomes introduits dans le plasma au cours de l'échauffement de la zone pariétale, détermination des champs magnétiques et caractérisation de leur nature (oscillant, croissant, constant; ; ;) à appliquer dans les zones pariétales en vue de la création d'un autoconfinement magnétique du plasma dans ces régions, il sera utile d'établir les équations d'état dans les régions de l'espace plasmique séparant les zones pariétales, possibilité d'entrer en oscillation temporaire avec émission d'une onde de choc ayant tendance à se concentrer au centre de la forme géométrique contenant le plasma (centre de gravité du système).

./..

Aux conditions limites précitées il est possible d'associer l'effet laser à plasma induit par le rayonnement synchrotron des ions métalliques du plasma pour provoquer simultanément, avec l'onde de choc en provenance des zones pariétales, des élévations très importantes de la température du plasma des zones de moindre densité de courant.

les élévations de températures malgré le phénomène de détente thermique naturelle devraient avoir un bilan énergétique positif par rapport aux puissances mises en jeu et ainsi retransmettre par oscillation radiative de l'énergie aux zones pariétales, qui dans le temps seraient assimilable à des zones relativistes, la densité des milieux extérieurs aux zones pariétales étant différentes l'on pourrait constater aux conditions limites un rayonnement Cerenkov. multipolarisé et peut-être cohérent.

I3) Discussion des conditions énergétiques établies.

I4) Modélisation mathématique des zones pariétales soumises aux champs.

I5) Etudes de prototypes de machines à plasmas basées sur l'acquisition des résultats des expérimentations établies.

I6) Budget et définition des postes (à l'état d'études).

fin du rapport technique.

Discussion on J.P.L Studied processes.(see page 72-84)

We have tried to propose one objective analysis and comments on the studied processes, but we apologize for the subjective developments which may be found inside the report.

Discussion on the process 1: Vaporization/Fractional distillation.

As taken as basic concepts the process 1 seems to us useful for the soil treatment and particularly in presence of important or terrestrial gravity, or installed on planets, also at the first sight the maintaining appears important, but installed on space station it cause to us some technicals remarks.:

The thermodynamic must be carefully discussed because, the losses may be important and the output of the fractional distillation must be the more higher possible, in this present concept.

The O2 recombination may be important near the coolant system because O2+ very active by the gases velocity and may installed FexOy in layers and the metal recovery would be not so pure than estimated, this natural problem seems to us more dangerous for the Mg recovered.

The studied concept seems to be limited to two metal species and with $\Delta [F1 - F2] > \left[\frac{F1+F2}{2} \right]$ F= fusion.

improvement possibles:

in case of low gravity the residue receptacle will be not useful, because untreated materials or others will be driven by the natural gases dynamic.

The proposed δ seems to us too low because at 2100°C we can said that the oxides are dissociated and O2 is considered in short time as ionized gaz, therefore one plasma, and the molecular working at medium temperature is not favorable because the L.T.E is not assumed.

One recycling by pump or by M.G.D therefore, losses would be limited, and the CRYO system perhaps may be cancelled, and also O2 will served as plasmagenesis gas.

δ pressure.

Discussion on the process 2: IONIZED VAPOUR DEPOSITION:

At the first sight we are favorable to this basic concept because the proposed process utilize atomic properties inside ionized gas, but the ionized vapor apparatus, including Electron Beam Source, "turntable, motor", and raw material charge container seems to us not adapted to the process.

remarks:

the same for the pressure as process 1 discussion.

the motor seems to us dangerous for the procedure maintaining, the turn table, also, because, thermic damage including chemicals O^+2 active by beam action, or must be made in refractory material near the impact area electron treatment.

The material tamping may appear.

If the electron beam source is utilized the dissociation, and ionization of all species must be immediatly recovered, on charged plates and very near the beam action area (small)⁺, or must be carried by one ionized gas, to drive metal species. The life time of induced ionization is short to hope to drive atoms on plates because the recombination is almost immediate, for gf- values $Ni+2$, life time for $Ni+2$ are 10^{-6} s to 10^{-9} s see part 2.01 page 20.

We estimate that electron beam source is not technically adapted to the ionized vapour deposition, in this case, the maintaining pressure at 10^{-14} torr seems difficult, for one industrial apparatus in space.

The metal ion deposition appears as interesting basic concept, but one needed to get one ionized gas before deposition, and the time life of ionized species recombination is too short, again one important natural pollution is possible near the pressure baffles, decreasing the output of the electron beam source.

+ some cm^2 .

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improvement possible:

Increase pressure, to approach the P.L.T.E, and the temperature, therefore the densities, to obtain the ionized gas useful and able to be treated by the metal ion deposition procedure.

Therefore to introduce one ionized gas from one chosen plasma. The oxygen ion recombination causes no problems, because if one chooses one reducing gas (Ar + H₂ p %) see part 5.0.

Also as in process I one can utilize one M.G.D recycling to avoid losses, and increase the homogeneity of the species inside the ionized gas.

Discussion on the process 3: IONIZATION/ELECTROMAGNETIC RECOVERY.

We agree in the almost totality with this basic concept, because he takes place in the near realm of plasma procedure, proposed in this report, but the ionized gas from electron beam source proposed before electro-magnet entry is discussed as in the process II, plasma generated must be more pertinent and competitive method.

The same discussion for the O+2 recovery, with one reducing plasma gas.

The same discussion as in process II for the recycling.

The energy cost may be considerably reduced if the O+2 recovery is partially avoided.

Conclusion:

The proposed processes seem to us interesting basic concepts but the tendency expressed in the studied approach strongly the plasma engineering as we have discussed.

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