

ENEA-RT/COMB/84/3

R. Nannicini (ENEA - Dipartimento Ciclo del Combustibile, Ispra), *R. Ramadori* (CNR - IRSA), *F. Fenoglio* (AGN), *L. Pozzi* (ENEA - Dipartimento Ciclo del Combustibile, Saluggia)

TREATMENT OF LOW ALFA—ACTIVITY LIQUID WASTES: PRELIMINARY RESULTS RELATING TO BIOLOGICAL DENITRIFICATION

Riassunto — L'industria nucleare pone problemi di sicurezza ambientale di tale rilevanza che il trattamento depurativo degli scarichi deve prevedere, ove possibile, il riciclo completo delle correnti liquide provenienti dal processo di produzione.

Al riguardo l'"ENEA-COMB-IFEC" di Saluggia, impegnato già da tempo nella verifica e messa a punto del processo "SOL-GEL" per il recupero di soluzioni di uranio e plutonio provenienti dal ritrattamento del combustibile irraggiato, ha avviato una sperimentazione, in collaborazione con il "CNR-IRSA" di Roma, al fine di verificare l'applicabilità del trattamento biologico alla depurazione degli scarichi liquidi originatisi dal processo stesso. La presente memoria riporta, oltre ad una breve descrizione del processo "SOL-GEL", i primi risultati ottenuti, relativi al solo stadio biologico dell'intero trattamento depurativo proposto, compresi quelli ottenuti alla fine della sperimentazione oggetto di un contratto tra "ENEA-IFEC" e "SNAM-PROGETTI" di Fano.

ENEA-RT/COMB/84/3

R. Nannicini (ENEA - Dipartimento Ciclo del Combustibile, Ispra) *R. Ramadori* (CNR - IRSA) *F. Fenoglio* (AGN) *L. Pozzi* (ENEA - Dipartimento Ciclo del Combustibile, Saluggia)

TREATMENT OF LOW ALFA—ACTIVITY LIQUID WASTES: PRELIMINARY RESULTS RELATING TO BIOLOGICAL DENITRIFICATION

Summary — The nuclear industry considers sobig safety problems that the purifying treatment of liquid wastes must always provide for a complete recycle of the liquid streams from the production process as regards this problem, "ENEA-Comb-IFEC" people from Saluggia, already previously engages with verifying and setting-up "SOL-GEL" process for the recover of uranium-plutonium solutions coming from irradiated fuel reprocessing, started an experimental work, with the assistance of "CNR-IRSA" from Rome, on the applicability of the biological treatment to the purification of liquid wastes coming from the production process itself.

The present technical report gives, besides a short description of the "SOL-GEL" process, the first results, only relating to the biological stage of the whole proposed purifying treatment, included the final results of the experimental work, object of a final results of the experimental work, object of a contract between "ENEA-IFEC" and "SNAM PROGETTI" from Fano.



COMITATO NAZIONALE PER LA RICERCA E PER LO SVILUPPO
DELL'ENERGIA NUCLEARE E DELLE ENERGIE ALTERNATIVE

R. NANNICINI, R. RAMADORI, F. FENOGLIO, L. POZZI

**TREATMENT OF LOW ALFA-ACTIVITY LIQUID WASTES:
PRELIMINARY RESULTS
RELATING TO BIOLOGICAL DENITRIFICATION**

RT/COMB/84/3

Testo pervenuto in aprile 1984

I contenuti tecnico-scientifici dei rapporti tecnici dell'Enea
rispecchiano l'opinione degli autori e non necessariamente quella dell'ente

C O N T E N T S

- 1) INTRODUCTION
- 2) THE SOL-GEL PROCESS
- 3) CHARACTERISTICS OF SOL-GEL EFFLUENTS
- 4) CURRENT WASTE TREATMENT PROCESSES
- 5) PROPOSED TREATMENT PROCESS
- 6) EXPERIMENTAL PART
- 7) CONCLUSIONS
- 8) ACKNOWLEDGEMENTS
- 9) REFERENCES

"TREATMENT OF LOW ALFA-ACTIVITY LIQUID WASTES:
PRELIMINARY RESULTS RELATING TO BIOLOGICAL
DENITRIFICATION" - R. NANNICINI (ENEA-IFEC^(*)) - R. RAMA-
DORI (CNR-IRSA) - F. FENOGLIO (AGN) - L. POZZI (ENEA-IFEC).

1) INTRODUCTION

The following report deals with some of the problems connected with the treatment of low **alfa**-activity liquid wastes in uranium and plutonium precipitation process water.

It covers the following aspects:

- 1) Short description of the SOL-GEL conversion to mixed oxide process $(U-Pu)O_2$, elsewhere indicated as G.S.P. (GEL-SUPPORTED PRECIPITATION).
- 2) Characteristics of process liquid effluents.
- 3) Quality prerequisites for process water to be recycled.
- 4) Short description of treatment processes already being tested in the laboratory.
- 5) Proposed treatment with the biological process.
- 6) Description of pilot plants to test the validity of the biologic process and preliminary results from Saluggia and Fano laboratories.

(*) NOW transferred to COMB/NEPIB

2) THE SOL-GEL PROCESS

Compared to conventional conversion processes, the SOL-GEL process offers significant safety advantages during 'pelletization' of UO_2 , uranium and especially of mixed plutonium oxides. Health hazards are reduced, because the SOL-GEL process produces microspheres or granules, which are normally larger than dust-size particles, do not remain suspended in air or stick to glove-box walls, are freeflowing, and hence easily transportable during pelletization. (See Fig. 1 for process diagram).

Precisely for these reasons, the SOL-GEL process is used in the reprocessing of irradiated fuel, which contains uranyl and plutonium nitrates.

Basically, the process consists of treating waste solutions by adding an organic resin (0.2 - 0.7% p/V), such as Methocel, and a polyvalent alcohol (tetrahydrofurfuryl alcohol, i.e., Tif 18 - 40%).

A 'SOL' (or 'Broth') is thus obtained, which can, if necessary, be thermostatted to reach a required viscosity. The SOL is dripped and/or atomized into a solution of concentrated ammonia, where the droplets solidify or gel as microspheres.

The microspheres are aged by washing in a solution of concentrated ammonia, and then in ammoniacal water. At this stage, and according to standard procedure, the washed microspheres are dried by azeotropic di-

stillation with CCl_4 or tetrachloroethylene in a Marcusson device.

A "Marcusson" consists of a boiler, condenser and separator of the condensed aqueous and organic liquid phases. The aqueous phase is drained off continuously while the organic phase is recycled back to the boiler. Results obtained with the Marcusson distiller are not always satisfactory. Therefore the Chemical Processes Laboratory at IFEC designed and successfully tested an 80-100°C oven drying process. This method foresees an upstream washing of the microspheres with non-flammable organic liquids (°).

Once dried, the microspheres are calcined in air at 400 to 600°C, reduced in a controlled H_2/Ar atmosphere and pelletized, i.e. pressed and sintered in H_2 or H_2/Ar at 1550/1700°C. The dimensions of the final reduced microspheres range from 60 to 1200 μ . (microns).

3) CHARACTERISTICS OF SOL-GEL EFFLUENTS

Process effluents (~ 50 l/kg of U and Pu produced) originate from the ammonia solutions used to wash the microspheres in NH_4OH (ageing phase) and then in ammo

(°) At present this drying method, which will be an ENEA-PATENT, is still tested for liquid recovery. Results shall be reported at a later stage.

nia water. Both solutions, being enriched by increasing amounts of NH_4NO_3 , Tif and Metocel, must be cleaned and continuously made up.

The foreseen effluent composition is reported in Table 1. These effluents cannot be discharged directly into the environment, because they contain radioactive elements (such as Pu), which have high specific activities and are very toxic.

Thus, it is important to assess alternatives which enable such effluents to be recycled and/or safely stored as reduced-volume, low-hydrosoluble solids.

The possibility, that effluents might be fed back into the SOL-GEL process, absolutely rules out the presence of any ions extraneous to the process.

The only ion recyclable is NH_4^+ IN THE FORM OF NH_4OH . Only limited quantities of NO_3^- and/or organic substances, possibly present, are allowed.

4) CURRENT WASTE TREATMENT PROCESS

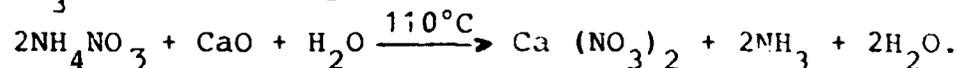
Sol-GEL process effluents may be chemically treated by the following methods:

- 1) - thermochemically with lime.
- 2) - direct thermodecomposition (Spray - Calcination Process). Both methods have already undergone preliminary tests.

The first method, flow charted in Fig. 2, comprises of the following steps:

a) STRIPPING and RECOVERY of ammonia (recyclable) and possible concentration of the NH_4NO_3 solution.

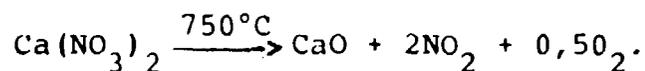
b) CHEMICAL CONVERSION of NH_4NO_3 into $\text{Ca}(\text{NO}_3)_2$ by adding lime and further STRIPPING and RECOVERY of NH_3 released (recyclable).



c) Decantation and filtration to separate possible radioactive precipitates.

d) CONCENTRATION AND DRYING of $\text{Ca}(\text{NO}_3)_2$ solution.

e) Decomposition of $\text{Ca}(\text{NO}_3)_2$ into CaO and NO_x by calcination in air:

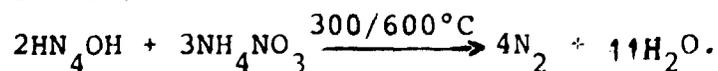


f) CaO feed back to treatment process (See Sect. b) and column absorption of NO_x as HNO_3 (recyclable).

THE DIRECT THERMODECOMPOSITION METHOD, flow charted in Fig. 3, consists of the following stages:

a) TOTAL OR PARTIAL STRIPPING and recovery of (recyclable) ammonia and concentration of the solution up to 40/60% in NH_4NO_3 .

b) THERMODECOMPOSITION of NH_4NO_3 (and of NH_4OH) IN N_2 AND H_2O by spraying into an inert fluid bed reactor at 300/600°C:



c) COLUMN ABSORPTION OF NH_3 and possible NO_x which are

formed during decomposition.

The thermochemical method, considered to be the most suitable for treating large amounts of liquid waste, has the advantage of using conventional technology already being exploited in the industrial treatment of phosphatic rocks.

Its main drawback, however, lies in the fact that evaporation of the $\text{Ca}(\text{NO}_3)_2$ solution produces a concentrate with a high quantity of unwieldy sludge containing uranium, plutonium and decomposed organic substances.

Furthermore, nitrogen oxides (NO_x) are produced during calcination, a necessary phase owing to the impossibility of stocking such an extremely soluble salt such as $\text{Ca}(\text{NO}_3)_2$. These gases are toxic and cannot be fully recovered by absorption in water.

Despite its effectiveness, its simple functioning, and its suitability to low-volume discharges (as envisaged for the SOL-GEL process), direct thermodecomposition is hazardous due to the contemporary presence of NH_4NO_3 , NH_3 , Pu, U and organic substances (Tif, etc.) at high temperatures.

The fact that only small amounts of NH_4NO_3 are present in the fluid bed reactor under working conditions at any moment, does little to mitigate the hazard involved.

Moreover, the Tif in the reactor may crack partially,

leading to carbon formation in the fluid bed and also in the condensate.

In any case, the SOL-GEL effluents resulting from both methods, must be subjected to further experimental tests, particularly to understand the behaviour of transported organic substances (e.g. Tif, Methocel and any surfactant) which might be present.

5) PROPOSED TREATMENT PROCESS

The drawbacks of the processes mentioned above induced the CNEN-IFEC 'Laboratorio Processi Chimici' (Chemical Processes Laboratory) at Saluggia to study and propose a new treatment process for SOL-GEL effluents. Such a process, has to envisage recycling and enable the

formation of precipitate of one or more insoluble salts; moreover, it has to reduce the organic substance contents in the solution treated to a minimum.

All this was to be performed under maximum plant working safety conditions. For these reasons, the biological process of denitrification (subsequent to the stripping of waste solution and prior to final thermochemical treatment with lime) seemed to be the best suited for the mentioned requirements (4).

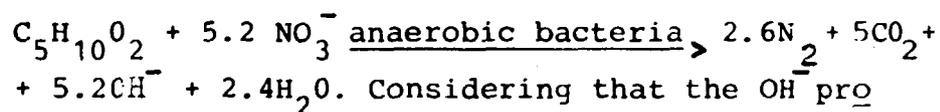
The possibility of using a biological treatment to nuclear industry discharges has been widely confirmed by tests conducted by other researchers, such as those of O.R.N.L.. They showed (5) that denitrifying bac

teria are capable of withstanding doses of up to 10^5 Rads without losing any of their activity (see Table 2). The IFEC process envisages the following phases:

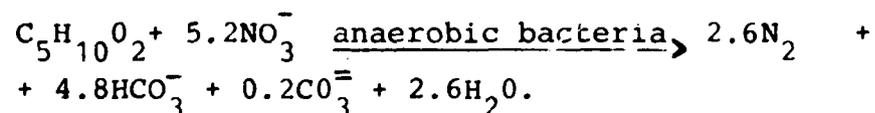
a) NH_3 STRIPPING

b) BIOLOGICAL PROCESS with, sequentially;

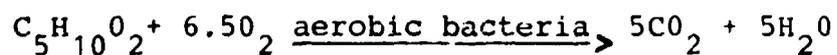
--) an anoxic DENITRIFICATION stage, during which the following reaction takes place, Tif ($\text{C}_5\text{H}_{10}\text{O}_2$) being the organic substance:



Considering that the OH^- produced reacts with CO_2 to form bicarbonate, the final reaction of BIOLOGICAL DENITRIFICATION may be rewritten as follows:



--) an aerobic stage which, in addition to the stripping of the N_2 formed in the previous stage, is also, and primarily, necessary for the biooxidation of the remaining organic carbon:



PH control is provided by a continuous dosing of one of the following acids: phosphoric, acetic, carbonic or sulphuric.

If sulphuric acid is chosen, final SOL-GEL process recycling will not be possible, because



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-
1963-A
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

the sulphates (such as CaSO_4) are only slightly soluble, whereas phosphates and carbonates (such as $\text{Ca}_3(\text{PO}_4)_2$ and CaCO_3) have a negligible solubility. The excess sludge undergoes STABILIZATION, after the liquid part, being fed back into the biological reactor, has been separated. Lastly, the sludge is dried and stored as such, incinerated or mixed into concrete or other suitable materials.

- c) CLARIFICATION by filtration or centrifugation of effluent from the sedimentation tank.
- d) CONVERSION (by LIME), of the soluble ammonium salts into corresponding insoluble calcium salts (CaCO_3 and $\text{Ca}_3(\text{PO}_4)_2$) and NH_4OH .
Addition of lime should be 'stoichiometric' or slightly "substoichiometric" so as to prevent any Ca^{++} ions from remaining in solution.
- e) FILTRATION.
- f) CONVEYANCE of filtered liquid into make up tank, so that the liquid can be sampled for a strict analytical control before being returned to the original SOL-GEL process.
Basically, the filtered liquid in question is an ammoniacal solution which can be reconcentrated, if necessary.
If sulphuric acid is used as a neutralizer in the

biological stage and recycling is ruled out for safety reasons, the filtrate may be treated thermally (strip-recovering the NH_3), concentrated, dried and stored.

Alternatively, the filtrate may be calcined with reformation of lime.

- g) DRYING of solid obtained in (e) and related STORAGE or CALCINATION with reformation of lime.

The treatment process envisaged is summarized in Fig. 4.

Understandably, it shall be susceptible to variations and/or addition depending on requirements imposed by the good working of the BIOLOGICAL DENITRIFICATION stage.

This may include partial or total replacement of the ammonium ion with Ca^{++} either before or during the biological reaction rather than after it by adding calcium acetate.

Thus, the introduction of the biological process offers the great advantage of enabling (at room temperature and hence under maximum safety conditions), not only the demolition of organic substances, but also the replacement of nitrate ions with other anions capable of forming insoluble salts with calcium, while at the same time demolishing the NH_4NO_3 and thereby neutralizing it as a hazard.

6) EXPERIMENTAL PART

In the light of the above discussion, the IFEC "Laboratorio di Processi Chimici" decided to conduct continuous lab-scale tests to obtain information on how high nitrate concentrations effected biological denitrification process kinetics. It was during this phase that IFEC reversed to CNR-IRSA (°) of Rome for scientific assistance.

It was necessary to carry out such tests due to contradictory data in the literature (Table 3).

From this table, which gives the values of denitrification kinetics constant (K_D) for high $N-NO_3$ concentration discharges, it also appears that:

- According to Francis and Mankin, the value of K_D is of the same order as found for low nitrate concentration discharges ($0.38 \text{ Kg } NO_3\text{-N} / \text{Kg VSS}\cdot\text{day}$) (°°). They also report that a significant inhibiting effect on the biomass occurs at $NO_3\text{-N}$ concentrations greater than 1350 mg/l.
- According to other researchers, K_D values are remarkably higher than those for low $NO_3\text{-N}$ concentration

(°) Italy' National Research Council Water Research Institute.

(°°) $NO_3\text{-N}$ is nitrate-nitrogen, while VSS are suspended volatile solids.

discharges; there by suggesting that various aspects of the process must be reconsidered (e.g. the recirculating stage of biological denitrification).

Tests were started using a lab-scale biological plant, (Fig. 5) comprising of an 8-liter fully mixing reactor with pH-control, a degasifier and a settling tank. Plant feed, consisting of two non-active solutions, one containing sodium nitrate, the other methanol, was fed into the plant at an overall rate of approximately 0.7 l/h.

The ratio of $\text{CH}_3\text{OH}/\text{N}-\text{NO}_3$ at reactor input was approximately 3.5:1 (g/g).

The concentrations of nitrogen were periodically determined in both influent and effluent (13).

Suspended solids concentration in the reactor was also ascertained.

Acetic acid was used to buffer denitrification reaction basicity.

Table 4 reports the most significant test results from which the following may be deduced:

- a) No inhibiting effects were found up to the highest concentration tested ($1950 \frac{\text{mg NO}_3\text{-N}}{\text{l}}$).
- b) The absence of nitrate in the effluent prevents calculation of denitrification kinetics constant ' K_D ', which must, in any case, be higher than the maximum load ($0.3 \frac{\text{Kg NO}_3\text{-N}}{\text{kg VSS}\cdot\text{day}}$) tested.

This last observation once more suggests that the possibility of various process kinetics, occurring at different $\text{NO}_3\text{-N}$ loads, must be studied further.

Consequently, we deem it important to perform continuous tests at some later stage to obtain information on:

- the exact value of K_D .
- N-NO_3 (as NH_4NO_3) concentration at inlet where possibly the inhibiting effects start.
- N-NO_3 (as $\text{Ca}(\text{NO}_3)_2$) concentration at inlet where possible inhibiting effects start.
- Capacity of the organic substances (Tif, Methocel) to be metabolised by the denitrifying bacteria.
- Radiation and toxicity effects (especially of plutonium) on the bacteria mass.

With these objectives in mind, IFEC contracted SNAM PROGETTI at Fano in September 1981 to collaborate in the study and preliminary design of a biological treatment plant.

SNAM with the advisory support of the Milan Politecnico ran experiments on two pilot plants at the Bologna University Marine Biology Laboratory at Fano. One of the plants treated synthetic SOL-GEL effluents; the other processed a feed containing calcium nitrate instead of ammonium nitrate.

Encouraging results were obtained, They

prove that denitrifying bacteria are able to utilize the organic component in the SOL-GEL effluents as a carbon substrate. In fact, it has been shown that approximately 4.5 parts of Tif are reduced for 1 part $\text{NO}_3\text{-N}$ during the nitrification stage, while remaining Tif is reduced during the biooxidation stage. The highest loads tested without detection of any inhibiting effects on the process are:

-) 0.4 kg $\text{NO}_3\text{-N}$ / kg VSS · day for $\text{Ca}(\text{NO}_3)_2$ and
-) 0.15 kg $\text{NO}_3\text{-N}$ / kg VSS · day for NH_4NO_3 .

In the case of $\text{Ca}(\text{NO}_3)_2$, solutions with N-NO_3 concentrations up to 5000 ppm (corresponding to a 1:1 dilution in the envisaged discharge) were tested and found not to inhibit processing.

In the case of NH_4NO_3 , at input concentrations over 2000 N-NO_3 ppm (1:5 dilution), denitrifying bacteria were seen to undergo inhibition, very likely because of the excessively high concentrations of the ammonium ion (NH_4^+).

The brief test-runs at μ_{max} definitely show that a conservative estimate for the value of the kinetic constant, K_D , may be safely taken as, approximately, $\frac{0.2 \text{ kg } \text{NO}_3\text{-N}}{\text{kg VSS} \cdot \text{day}}$, upon which an "ad hoc" treatment plant may be designed.

7) CONCLUSIONS

All tests carried out so far indicate that biological denitrification may be used for SOL-GEL effluents, which must only be diluted slightly, i.e. 1:5, for NH_4NO_3 , and 1:1, for $\text{Ca}(\text{NO}_3)_2$.

Current research is aimed at optimizing the main process parameters so that a preliminary design may be drawn for the plant to be adopted.

Initial results suggest that extending research for at least 6 more months would probably enable less conservative and consequently more convenient parameters to be defined.

Said activity shall be discussed in the forthcoming final report.

8) ACKNOWLEDGEMENTS

Our thanks are due to Dr. C. Cesarano and Dr. M. Gabbaglio for their valuable suggestions on the draft of this work and to Dr. N. Sparacino et al. for their contribution to the analytical controls of the process tested.

Thanks also to Mr. Vassallo for his helpful assistance during the preparation of english text.

9) REFERENCES

- 1) "Biological Treatment of Concentrated Nitrate Wa-

ste" F.E. Clark - J.M. Napier (Union Carbide Corporation Nuclear Division).

R.B. Bustmante (Tennessee Technological University) 1976.

- 2) "Biological Denitrification Disposal Technique"
H.G. Francke - F.E. Clark - J.M. Strohecker - April
le 1974.
- Second AEC. Environmental Protection Conference
Albuquerque, New Mexico.
- 3) "Biological Denitrification and Its Application in
the Treatment of High Nitrate Waste Water".
Journal of Environmental Quality, Vol. 2-1975.
- 4) "Rapporto sul Trattamento Biologico degli effluenti
liquidi del Processo G.S.P.".
R. Nannicini (CNEN-IFEC) - RTI - COMB - TECN (80) (4)
1980.
- 5) "Biological Denitrification of High Nitrate Wastes
Generated in the Nuclear Industry".
G.W. Francis - April 1980 - Manchester Conference
on Biological Fluidised Bed Treatment of water and
Wastewater.
- 6) "Resoconto della missione compiuta al KFA di Julich
(W.G.) nei giorni 25-26 Agosto 1980, per discutere
il condizionamento degli Wastes G.S.P.".
Morselli - Brambilla AGN - Medicina (DILAB/CHIM)
8/2/1980.

- 7) "Situazione G.S.P. Ibrido per Combustibile (U,Pu) O_2 al 27/10/81.
Riunione AGIP Nucleare - CNEN, Milano 18/10/81.
- 8) "Stato di Avanzamento dei Lavori relativi al Contratto CNEN - ISTITUTO Transuranici".
P. Gerontopoulos - K. Richter, EURATOM 186-87 PIPG/
/K' - 1° Ottobre 1978 - 31 Ottobre 1979.
- 9) "Contenuto in elementi Transuranici di effluenti liquidi G.S.P."
G. Arcangeli - R. Fava - P. Gerontopoulos - S. Valliers - B. Camiscioni (1981).
- 10) "Atti del Seminario sulla rimozione dell'Azoto e del Fosforo dalle acque di scarico".
Quaderno IRSA n. 38 - Roma 7/5/79.
- 11) "La rimozione Biologica dell'Azoto dalle acque di scarico".
Quaderno IRSA n. 53 - Roma 1980 - M. Beccari, A.C. Di Pinto, R. Passino, R. Ramadori.
- 12) "Prove preliminari sul trattamento degli effluenti acquosi del processo G.S.P. - Nota sull'attività svolta dal 1/10/80 al 31/3/81".
L. Beaulardi - G. Morselli - E. Quercioli - AGN.MEDICINA (BO) - 9/11/81.
- 13) "La determinazione dell'Azoto Nitrico col metodo di Griess in ambiente alcalino".
F. Adamoli - N. Sparacino (CNEN-IFEC)

(RTI) COMB-TECN (81) 1980.

- 14) "Determinazione dell'Ammoniaca e dell'Azoto totale con i metodi di Nessler o di titolazione e con l'elettrodo a ioni specifici - (RIPRO/007/79) SNAM PROGETTI - S. Ippolito, Febbraio 1979.
- 15) "Determination of Ammonia Levels in Water and Waste Water with an Ammonia Probe".
W.H. Evans and B.F. Partridge - "Analyst" June, 1974, Vol. 99, pp. 367-375.
- 16) "An Evaluation of the Ion-Selective Electrode Method for Determination of Nitrates in Highly Mineralized Drinking Water" Hana Shechter and Nahmon Gruener - Journal Oct. Dec. 1975.
- 17) Fano : Relazione finale - S.I.A.P. PROGETTI

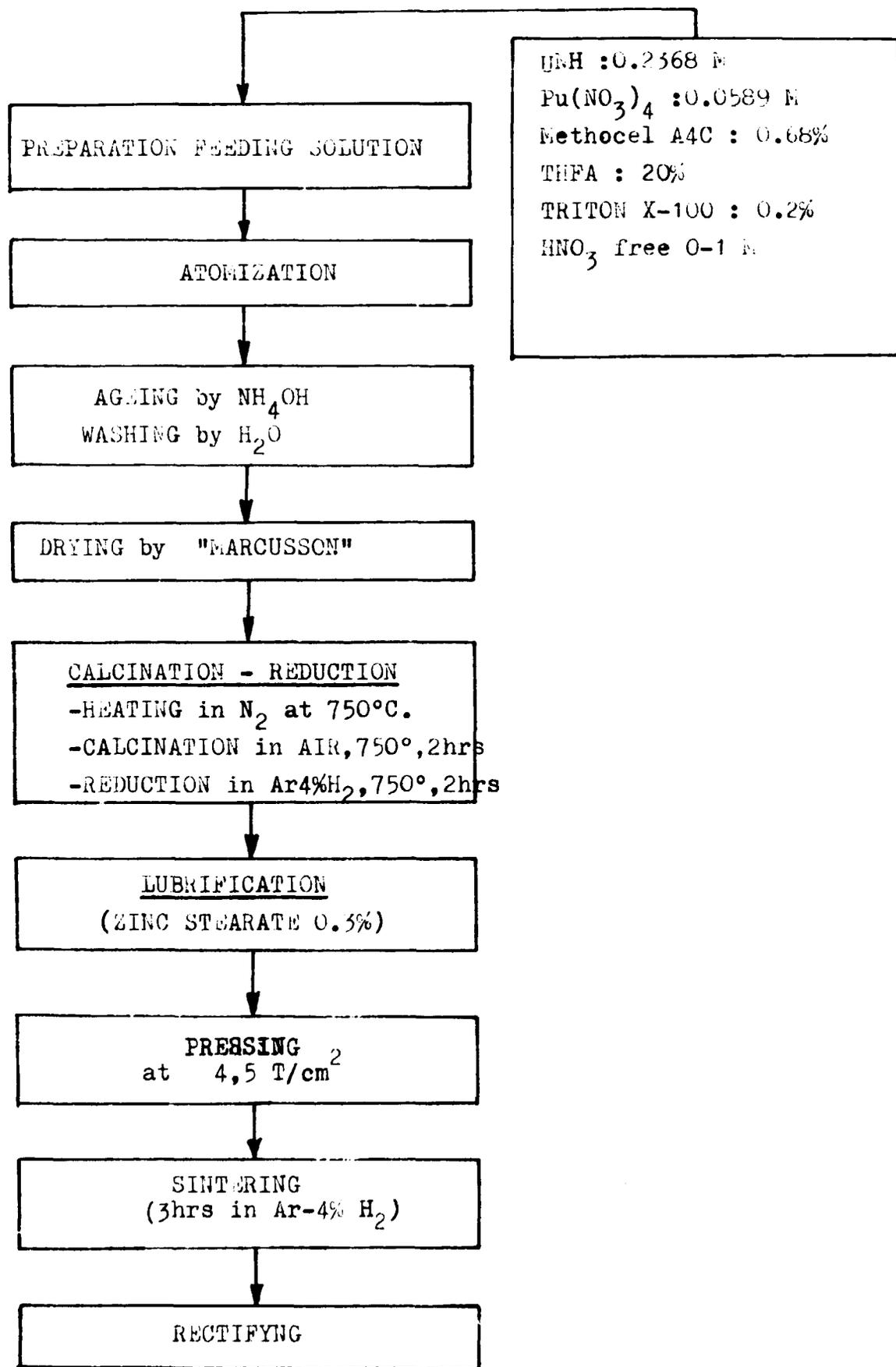


Fig.1 - Block diagram of Pellets (U,Pu)O₂ preparation by SOL-GEL or G.S.F. process

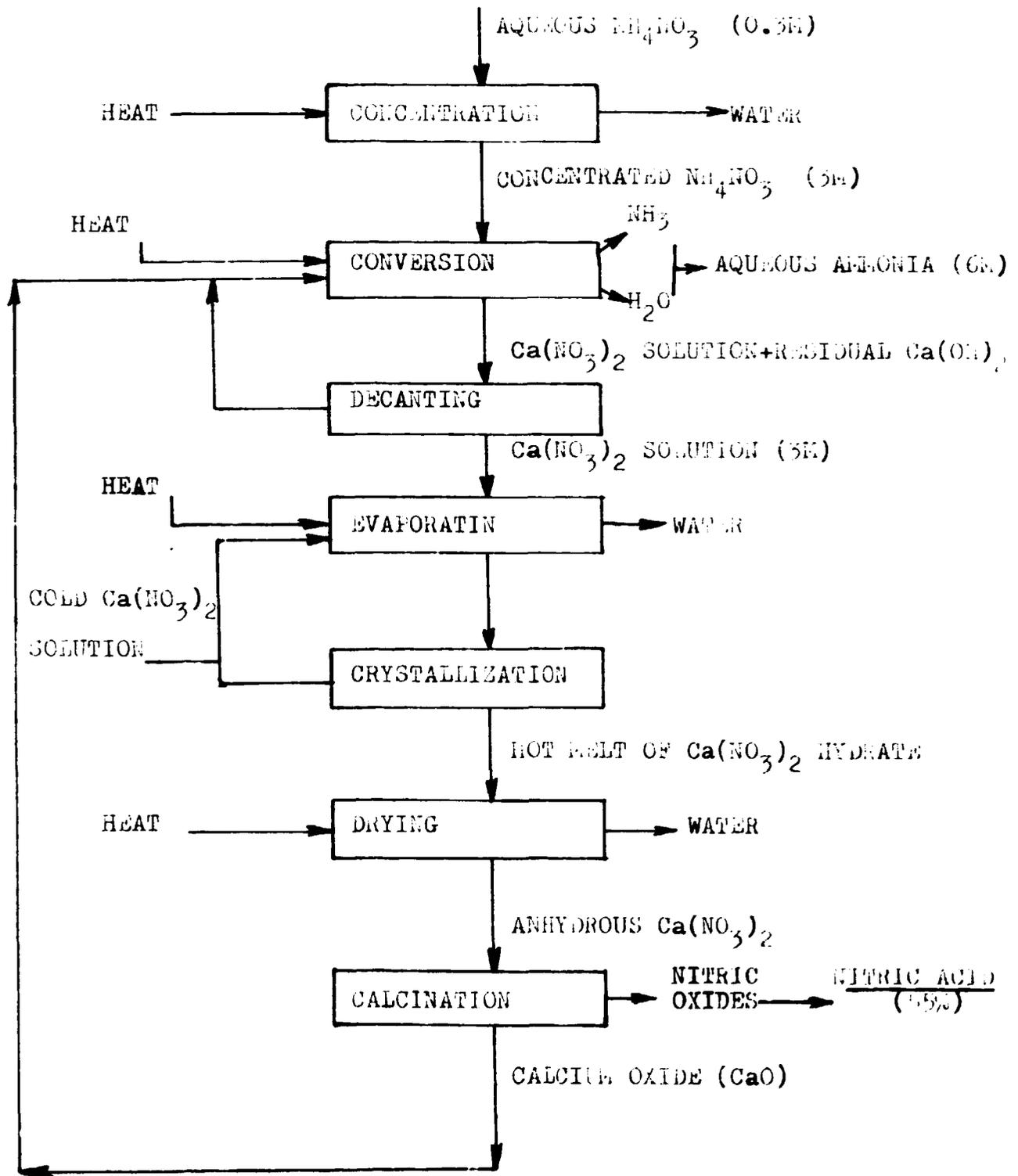


Fig.2 -Block diagram of thermochemical process

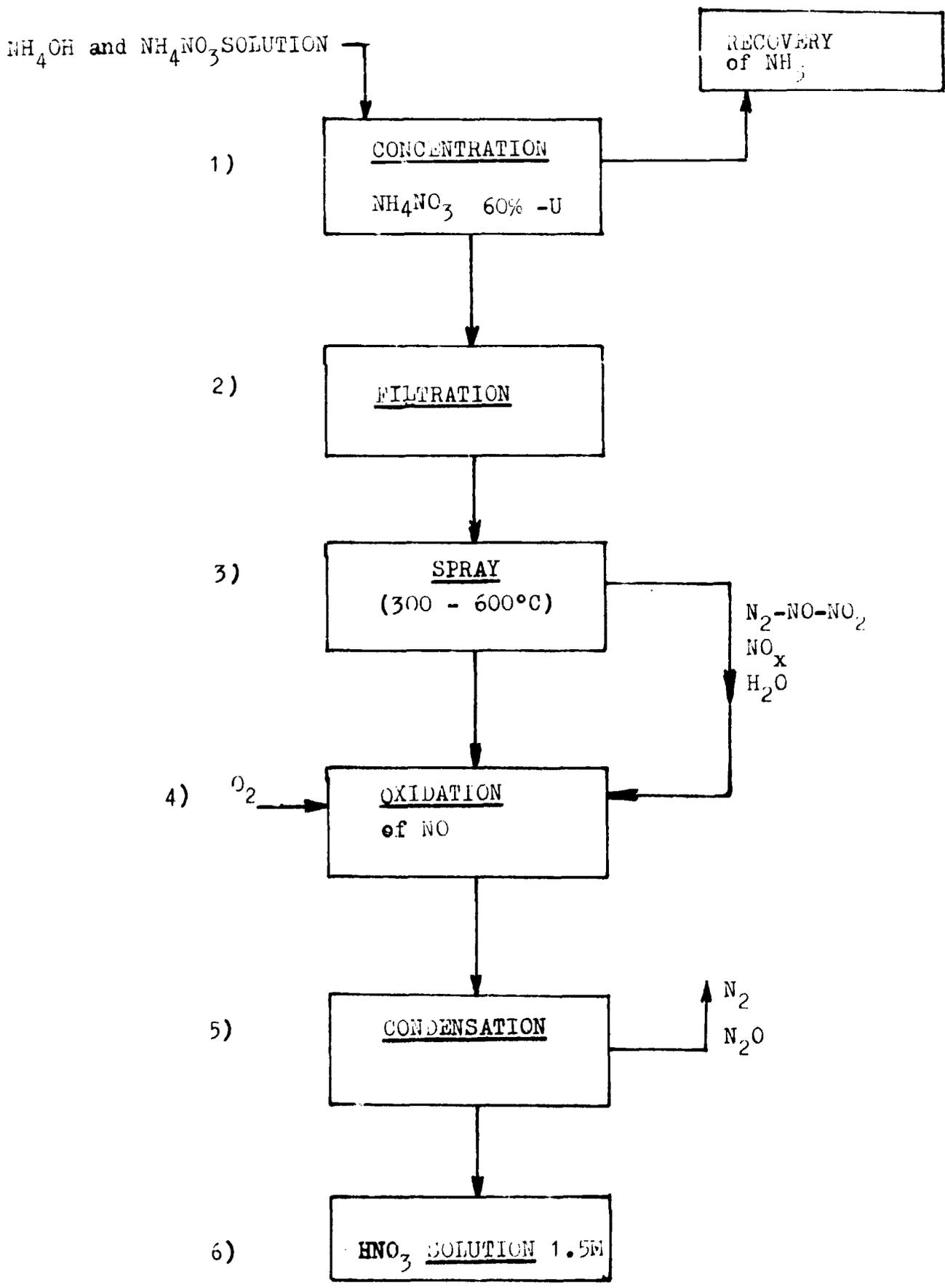


Fig.3- Block diagram of direct thermodecomposition process

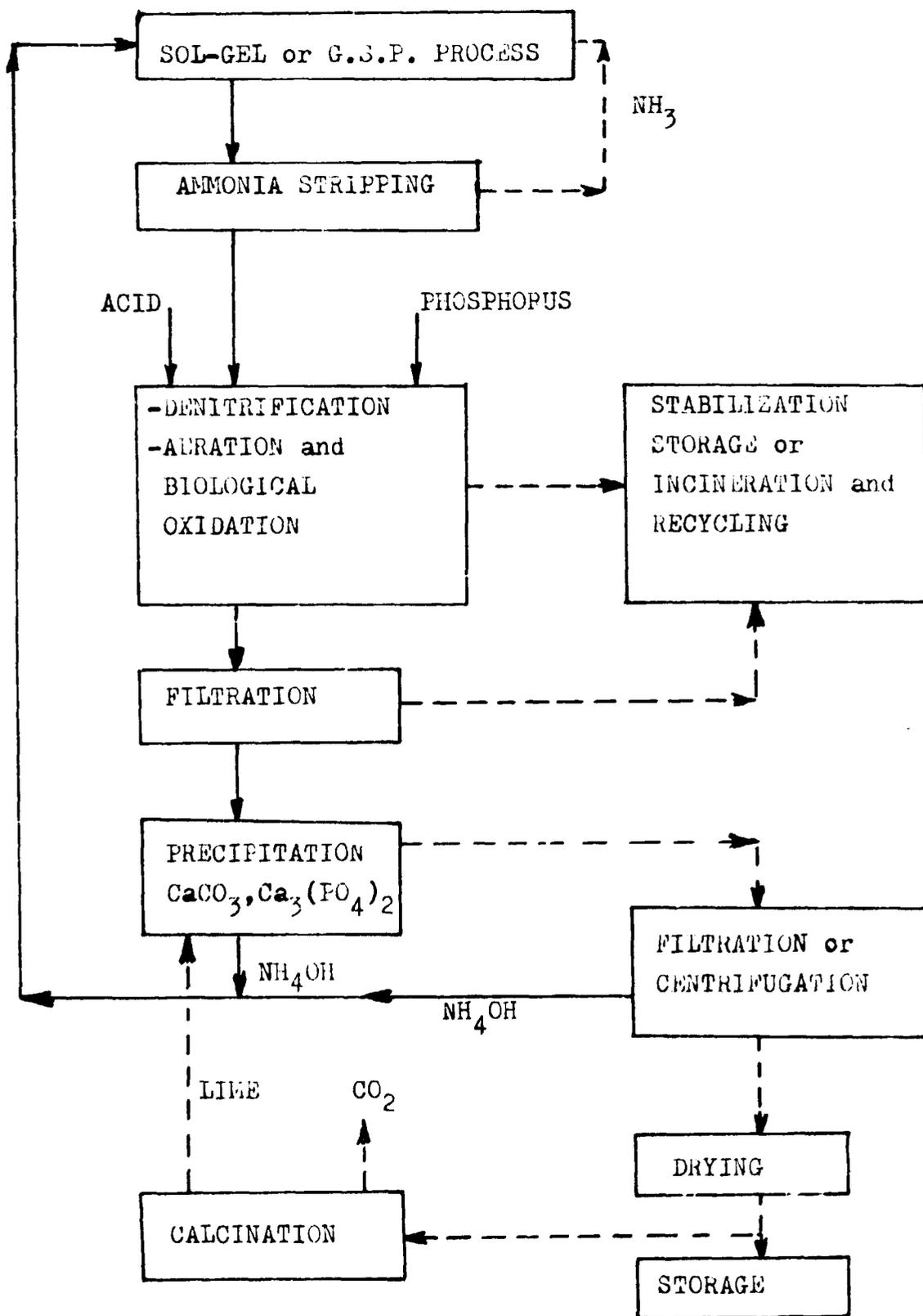


Fig.4- Block diagram of the proposed purifying treatment.

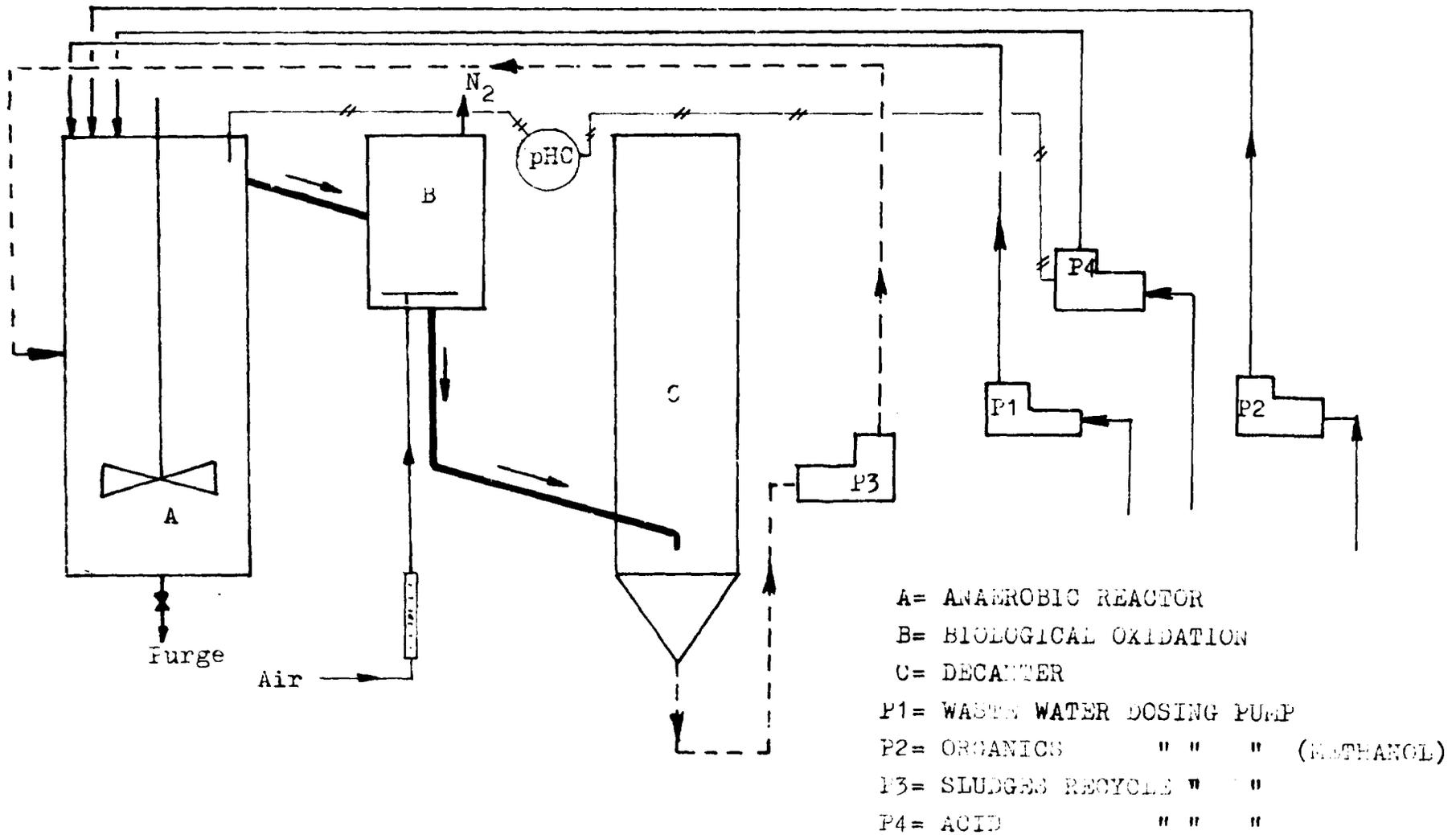


Fig.5-Scheme of the biological denitrification

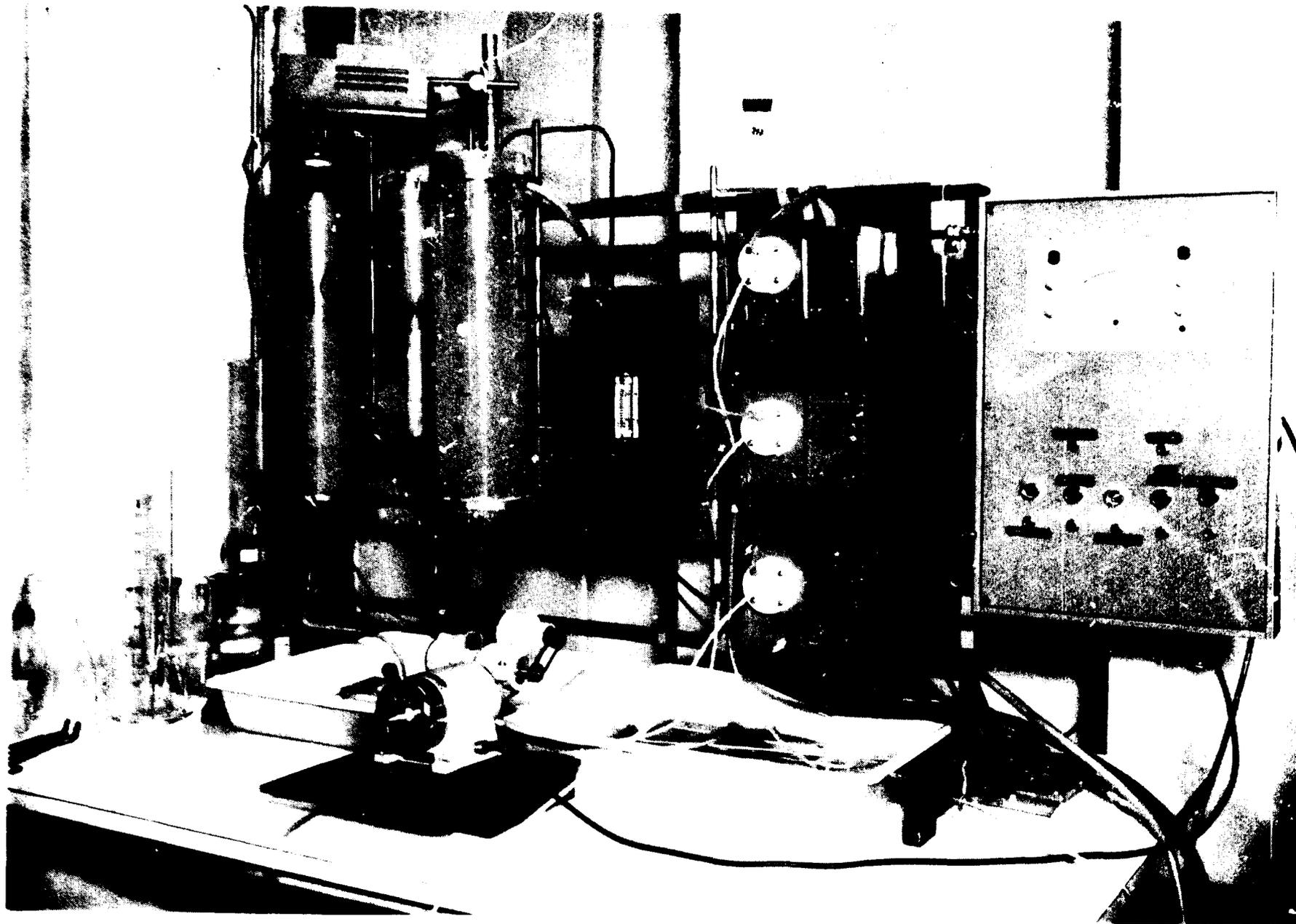


Fig. 6 - General view of laboratory plant.

TABLE 1

COMPOSITION OF THE WASTE WATER FROM THE G.S.F.	
NH_4OH	200g NH_3 /l
NH_4NO_3	40-60 g/l
TIF	~ 50 g/l
METHOCEL	~ 15mg/l
TRITON X 100	1-2 g/l
U, Pu	$\leq 1\text{mg/l}$ (°)

(°) After centrifugation

TABLE 2

INFLUENCE OF ACUTE RADIATION ON BIOLOGICAL DENITRIFICATION RATES

Radiation	Time (Days) ¹							Denitrification		
	Rads	0	1	3	4	6	7	10	Rates ²	R ²
		-----g/m ³ of NO ₃ -N -----							days ⁻¹	
0	166	141 ^a	---	22 ^a	---	15 ^a	----	0.38	0.92	
10 ³	166	142 ^a	---	28 ^a	---	20 ^a	----	0.33	0.92	
10 ⁴	166	155 ^a	---	18 ^a	---	10 ^a	----	0.44	0.93	
10 ⁵	166	146 ^a	---	53 ^b	---	12 ^a	----	0.38	0.98	
10 ⁶	166	---	161	--	100	--	20	0.21	0.48	
Control ³	230			232	235					

¹Numbers in the same column with similar superscripts are not significantly different at the 5% probability level. All treatments except the 10 Rad dose were replicated three times.

² $\hat{y} = ae^{-\lambda t}$, where \hat{y} is estimated NO₃-N in g/m³, a is initial NO₃-N concentration, λ is first order rate constant in days⁻¹ and t is time in days.

R² = Coefficient of determination of least squares fit.

³ Nitrate solutions similar to other treatments except that no denitrifying microorganisms were added.

TABLE 3

Experimental values of the kinetic constant of the denitrification process with the biological mass in dispersed phase.

N-NO ₃ Concentration in the waste water (mg/l)	Kinetic constant of denitrification $\left(\frac{\text{Kg l-NO}_3}{\text{Kg Vss.d}}\right)$	Carbon source	Temperature °C	References
1,350	0.58	Methanol	20	FRANZIS & HANKER 1977
1,150	0.70	Methanol	29	GARRASI & Others 1978
1,070	1.70	Glucose and Leptone	21	TECHNICO 1977

IMPORTANT: Authors consider concentration over 1,350 mg/l to have inhibiting effect on the process.

TABLE 4

Analytical average data and performance obtained from a preliminary laboratory-scale experience-(Operative conditions: $T=20^{\circ}\text{C}$; pH 7.1 - 7.4; hydraulic residence time of waste water =16hrs; medium age of active sludges >20 days; D.O. (Dissolved Oxygen) ≤ 0.2 mg/l; biomass concentration: 3,850 - 2,510 - 10,250 mg/l in the three series of tests respectively)

($\text{CH}_3\text{OH} / \text{N-NO}_3 \approx 3.5$; pH Control by continuous addition of an Acetic Acid solution)

PARAMETER	1 st Series of tests	2 nd Series of tests	3 rd Series of tests
N-NO ₃ concentration in the inlet flow (mg/l)	237	513	1942
N-NO ₃ Removal efficiency (%)	97	~100	~100
Denitrification rate constant $\frac{\text{kg N-NO}_3}{\text{kg VSS}\cdot\text{d}}$	0.09	0.31	0.29

Riprodotta in offset presso il Laboratorio Tecnografico della Direzione Centrale
Servizi e Affari Generali dell'ENEA - Viale Regina Margherita 125 - Roma