

FINAL REPORT ON DECONTAMINATION OF HOT CELL LABORATORY AT C.R.E. CASACCIA (ENEA)

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1. INTRODUCTION

From 1962 until 1987 in the Hot Cell Laboratory of the ENEA, called OPEC-1, situated at the C.R.E. Casaccia (Rome), research was performed on several types of irradiated nuclear fuel (mainly metallic U, its alloys and UO₂) (see Fig. 1).

After the Chernobyl accident in 1986 and a subsequent referendum, the Italian authorities decided a moratorium stopping both nuclear power plants, either in operation and under construction, and all the related research. Therefore, the facilities supporting research for nuclear power plants no longer had any reason to continue their activities.

In this framework, ENEA has developed some programs in order to decontaminate and to dismantle the Hot Cell Laboratory, amongst other facilities, conceived to support research in post-irradiation examinations on irradiated nuclear fuel.

The steps of this program are:

- achievement of the maximum safety condition in order to reduce the infrastructures necessary for its operation;
- declassing;
- change of destination of the facility (e.g. waste disposal, etc.) or final decommissioning;
- storage of nuclear materials and radioactive wastes.

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2. CELL CHARACTERISTICS AND HISTORY

Not considering all the services necessary for the hot cell operation (workshop for maintenance of manipulators, storage, etc.), the Lab has a total of three barytic concrete cells in line, two lead shielded cells for radiochemical analyses and a cell for microscopic examinations (see Fig. 2).

The dimensions of the barytic cells are as following:

CELL No.	LENGTH (m)	WIDTH (m)	HEIGHT (m)	VOLUME (m ³)	WINDOWS No.	MANIPULATORS No.
1	4,60	2,10	4,50	44	2	4
2	4,60	2,10	4,50	44	2	4
3	2,30	2,10	4,50	22	1	2

The partitions, initially 3,20 meters high, were elevated up to 4,5 m, using barytic concrete bricks.

The inside walls are covered by a steel plate 3,20 m high.

An overhead crane of 1 ton is also installed to serve the three cells.

A Master Slave power manipulator is installed in Cell 3.

During the operation of the facility the following routine analyses were performed:

- CELL 1:
- cutting of the nuclear fuel pins to withdraw specimens
 - embedding in resins
 - ceramographic and autoradiographic tests
 - grinding and polishing of metallographic specimens
 - chemical attack for metallographic examinations.
- CELL 2:
- non-destructive tests (metallurgy, X-radiography, γ -scanning, etc.)
 - sampling and analyses of fission gases
 - microcracking analyses
- CELL 3:
- testing of unit operation for reprocessing plant
 - dismantling of nuclear fuel rigs
 - Na or NaK extraction from rigs
 - waste classification and preconditioning.

Besides the standard analyses on experimental rigs, the cells have been also used to control and to analyze defective components coming from nuclear power plants.

3. CELLS SITUATION BEFORE THEIR DECONTAMINATION

During the last years of operation a remarkable quantity of wastes was accumulated, including combustible or non-combustible equipment or materials. Moreover there were a certain number slugs of irradiated nuclear fuel of enriched UO_2 (>20% in U-235).

The initial conditions of cells are shown in figures 3a, 3b, 4, 5.

In synthesis we summarize the materials accumulated in the cells at the beginning of the operations of dismantling and decontamination:

- mobile or fixed equipment for cutting highly radioactive materials and instruments for metallurgy, destructive and non-destructive testing;
- 50 pins of irradiated fuel, specimens, containing UO_2 at different enrichments and one element containing PuO_2 at 20%;
- a few hundred of small specimens withdrawn from fuel elements;
- some activated structural elements (capsules, jackets, etc.);
- solid wastes, from past activity, conditioned in metallic cans;
- a few cubic meters of solid waste.

4. PROGRAM FOR THE CELL DECONTAMINATION

The program for the decontamination of the three barytic cells foresaw the following principal phases of operation:

- extraction from cells of all the irradiated nuclear fuel, as entire bars or specimens;
- extraction of all the wastes;

- dismantling of small and large equipment and of fixed or mobile structures of services;
- decontamination of items to be removed in order to lower their exposure rates and to extract them as wastes without distinctive shielding;
- gross decontamination of the cells by a vacuum cleaner;
- isolation of the cells to realize a leaktight circuit to prevent leakage of freon (trichlorotrifluoroethane, CFC-R113), used as decontaminant, into the external environment;
- decontamination by freon;
- painting with epoxy paint.

5. METHODS AND PROCEDURES FOR INTERVENTION

The cells decontamination program has two qualifying aspects, new for us, and precisely:

- a) the utilization of the ventilated clothing (Scalhene system, two places) to minimize the risk of contamination for the operators and to reduce the volume of the radioactive wastes caused from contaminated protective garments (see Fig. 6);
- b) the utilization of freon in a leaktight circuit in order to reduce substantially also the volume of the wastes produced during the decontamination [1][2].

The operational unit shown in Fig. 7 includes:

- a protective tent, the principal purpose of which is to create an intermediate area among cells and load area to contain possible contamination;
- the Scalhene system with an emergency exit system;
- a door designed to provide maximum isolation;
- an isolation room, steel framed, the principal purpose of which is to ensure a highly isolated environment;

- the DECOFREON system, including a refrigeration system, the recovery unit and the pumps.

Moreover, the design provides for a leaktight device (box in stainless steel) for the decontamination of equipments presenting elevated contamination levels and, consequently, high exposure rates (see Fig.8).

The extraction of former equipment, should be possible only after an appropriate shielding, increasing considerably the volume of wastes.

Additionally, it was necessary the characterization and sealing of all the possible points of leakage of freon from the cells and suitably modifying the ventilation system of the cells to minimize the dispersion of freon into atmosphere (see figures 9A, 9B).

The final decontamination of the cells, after the removal of all the materials contained in them and a first gross decontamination by a vacuum cleaner to eliminate all the dust accumulated over time, was made by pressurized freon associated with the mechanical action of metal brushes. The maximum freon pressure was 120 bar, sometimes reduced to 50 bar.

In Fig.10 is shown the equipment used.

Two decontamination operations were performed for all the surfaces and 20 cleaning cycles were performed, employing about 1000 liters of freon and recycling it many times.

6. RESULTS

As already pointed (see Section 3) in the cells there were present about 2 m³ of various materials, excluding nuclear fuel.

The irradiated nuclear fuel extracted from the cells, was constituted by 150 pieces (pins, specimens, etc.) with a total weight of 43 kg of uranium.

At the moment the irradiated fuel is situated in lead-shielded containers for an interim disposal waiting for dispatching it to the reprocessing plant.

All the radioactive waste, that is, tools, components and dismantled structures, selected on the basis of type and residual activity, were extracted from the cells and conditioned in bags, oil drums unshielded or shielded with concrete and/or lead, according to their exposure rates, where the exposure required special protection. Special components, the sizes of which were not compatible with those of the drums, were removed and conditioned separately.

Table 1 shows the type and the quantity of the materials extracted before the decontamination by freon.

Table 1

TYPE AND QUANTITY OF WASTE PRODUCED

TYPE	CONTAINER		VOLUME (l)
	Type	No.	
Combustible	Bag	-	-
Non-combustible	Bag	57	4274
Combustible	Drum	29	5800
Non-combustible	Drum	38	7600

NUMBER OF MACHINES AND/OR EQUIPMENTS
REMOVED FROM THE CELLS

CELL 1	CELL 2	CELL 3
22	10	12 + 1 Power manipulator

TYPE AND AMOUNT OF CONTAINERS AND CANS

Type	CONTAINERS		No.	CANS No.
	Shielding			
	concrete (cm)	lead (cm)		
N	12	-	10	60
M	21	2	10	20
P	-	-	3	24
OPb1	9	1	3	19
Opb3	9	3	1	7
N8	9	-	1	5
TSR	-	10	5	10

Table 2 shows the contamination levels of the barytic cells after the extraction of all the materials and a gross decontamination by vacuum cleaner (June 1993) and after washing of the walls, of the ceiling and of the floor of the individual cells (December 1993).

The maximum dose rates inside the cells were reduced to:

28 $\mu\text{Sv/h}$	in	CELL 1
13 $\mu\text{Sv/h}$	in	CELL 2
17 $\mu\text{Sv/h}$	in	CELL 3

The average dose rate was, however, sufficiently low to permit the access of the personnel for the decontamination operations.

7. CONSIDERATIONS ON THE TECHNIQUES AND METHODOLOGIES

The following considerations can be made on the techniques and methodologies used, mainly on Scalhene system and use of freon.

7.1. Scalhene System

It has offered the following advantages and disadvantages:

- minimization of the risk of contamination to the operators outside the box of containment;
- during more than two years operations with ventilated-pressurized clothing, no external contamination was ever detected;
- the operators, once accustomed to the utilization of the ventilated-pressurized clothing, prefer it in respect to the other protective equipments, as it is comfortable and sure;
- a few ruptures (6) have occurred. Some of them put in evidence a defect during the fabrication, already reported to the manufacturer, for the proper measures to be taken;
- the costs of management have been 70 million Liras. In respect the cost of the protective garments of conventional type (like masks and overcoats) should be 150 million Liras;

CONTAMINATION LEVELS IN CELLS

CELL	POSITION	CONTAMINATION LEVELS (June 1993)		CONTAMINATION LEVELS (December 1993)	
		kBq/m ²	µCi/cm ²	kBq/m ²	µCi/cm ²
1	Floor	97 ± 920	10 ⁻⁴ + 3·10 ⁻³	0.5 ± 2.6	10 ⁻⁶ + 7·10 ⁻⁶
	Window wall	900 ± 2900	2·10 ⁻³ + 8·10 ⁻³	0.1 ± 2.6	2·10 ⁻⁷ + 7·10 ⁻⁶
	Door wall	80 ± 700	2·10 ⁻⁴ + 2·10 ⁻³	0.2 ± 1.5	5·10 ⁻⁷ + 4·10 ⁻⁶
	Inter-cell wall 1/2	120 ± 160	3·10 ⁻⁴ + 4·10 ⁻⁴	0.5 ± 2.2	10 ⁻⁶ + 6·10 ⁻⁶
	Inter-cell wall 1/Pb	70 ± 460	2·10 ⁻⁴ + 10 ⁻³	0.1 ± 0.8	2·10 ⁻⁷ + 2·10 ⁻⁶
	Zone over the crane Ceiling	70 ± 800 30 ± 150	2·10 ⁻⁴ + 2·10 ⁻³ 8·10 ⁻⁵ + 4·10 ⁻⁴	0.7 ± 0.8 0.03 ± 0.8	4·10 ⁻⁷ + 2·10 ⁻⁶ 8·10 ⁻⁸ + 2·10 ⁻⁶
2	Floor	30 ± 110	8·10 ⁻⁵ + 3·10 ⁻⁴	0.1 ± 0.4	3·10 ⁻⁷ + 10 ⁻⁶
	Window wall	20 ± 370	5·10 ⁻⁵ + 10 ⁻³	0.05 ± 0.6	10 ⁻⁷ + 2·10 ⁻⁶
	Door wall	15 ± 75	4·10 ⁻⁵ + 2·10 ⁻⁴	0.06 ± 0.6	1.5·10 ⁻⁷ + 2·10 ⁻⁶
	Inter-cell wall 2/1	average 25	average 7·10 ⁻⁶	0.06 ± 1.5	2·10 ⁻⁷ + 4·10 ⁻⁶
	Inter-cell wall 2/3	15 ± 110	4·10 ⁻⁵ + 3·10 ⁻⁴	0.2 ± 0.4	6·10 ⁻⁷ + 10 ⁻⁶
	Zone over the crane Ceiling	50 ± 660 20 ± 120	10 ⁻⁴ + 2·10 ⁻³ 5·10 ⁻⁵ + 3·10 ⁻⁴	0.08 ± 0.8 0.05 ± 0.8	2·10 ⁻⁷ + 10 ⁻⁶ 2·10 ⁻⁷ + 9·10 ⁻⁷
3	Floor	4000 ± 40000	2·10 ⁻² + 10 ⁻¹	0.6 ± 7	2·10 ⁻⁶ + 2·10 ⁻⁵
	Window wall	17000 ± 38000	5·10 ⁻² + 10 ⁻¹	0.3 ± 0.4	9·10 ⁻⁷ + 10 ⁻⁶
	Door wall	13000 ± 17000	4·10 ⁻² + 5·10 ⁻²	0.3 ± 0.4	9·10 ⁻⁷ + 10 ⁻⁶
	Inter-cell wall 3.2	2000 ± 12000	5·10 ⁻³ + 3·10 ⁻²	0.1 ± 0.6	2·10 ⁻⁷ + 2·10 ⁻⁶
	Inter-cell wall 3/Dec	5000 ± 9000	10 ⁻² + 3·10 ⁻²	0.2 ± 0.4	5·10 ⁻⁷ + 10 ⁻⁶
	Zone over the crane Ceiling	80 ± 700 25 ± 150	2·10 ⁻⁴ + 2·10 ⁻³ 7·10 ⁻⁵ + 4·10 ⁻⁴	0.2 ± 0.4 0.1 ± 0.6	5·10 ⁻⁷ + 10 ⁻⁶ 2·10 ⁻⁷ + 2·10 ⁻⁶

- the wastes deriving from contaminated protective garments are negligible (all contained in a oil drum l) if compared to those derived (20 m^3) from the utilization of masks and overcoats;

- the initial cost of the equipment is remarkable. We believe, however, that after 200÷250 interventions the cost will be covered considering the consumption like masks, overcoats, gloves, overshoes and other protective garments, if the protective garments of conventional type had been used.

However the economic benefit in the reduction of the wastes has not been considered.

Not all personnel is suitable for wearing the suit. In some cases it was not possible to employ personnel accustomed to the mask, for fear and/or claustrophobia.

X Young people, generally speaking, have no problems.

Specific ventilated-pressurized clothing and specific spare parts are required to overcome difficulties deriving from any to interruption of the activities

7.2. Use of the freon

It is well known that freon compounds and their derivatives are considered to be responsible for damage to the earth's atmosphere. In some countries, these compounds have been declared illegal, and the same will occur in Italy. This factor will limit their use, and, in any case, a recovery procedure is required.

Recently other compounds with similar physical characteristics are being studied with the aim of replacing chlorofluorocarbons in the future.

The advantages of the use of freon have been observed with regard to waste production. Contaminated liquids as well as other contaminated articles typical of routine decontamination technology have been eliminated.

With regard to leakages in the atmosphere, these have been reduced and limited only to the development stage of the procedure, and were extremely low during the actual decontamination procedures.

These leakages, estimated at 5% of the total volume available, are due to the cell isolation which is not alpha-tight, and to the need to maintain a lower pressure level in the cells (this may also be minimum: 12 mm of H_2O).

8. RADIOPROTECTION

From the point of view of radioprotection, the procedures which have been implemented have virtually eliminated any risk of internal contamination, and no cases occurred.

The exposure doses, due to external radiation only, for the 16 operators who worked inside the cells and, for that, receiving the highest doses, range from a few μSv to 5 mSv (average $\approx 1,4$ mSv).

Recalling that the work described in this report was performed over a period of about 2,5 years, it is obvious that thanks to the appropriate planning of the operations the individual and collective exposure doses were reduced to levels well under the ones set for professionally exposed workers (5 mrem/year, 50 mSv/year).

The data on radioprotection are shown in Table 3.

Concerning the radiological situation inside the cells the operations are still under way for fixing the residual surface contamination with paint. This operation will reduce the transferable contamination to a negligible level, and entry into the cells will not require any particular radioprotection precautions.

Table 3

DATA ON RADIOPROTECTION

Campaign	Interven- tions. No.	Workers No.	WORKERS			Workers No.	OPERATORS			Maximum dose in a single intervention (μ Sv)
			D collective (man- μ Sv)	O average (μ Sv)	S maximum (μ Sv)		D collective (man- μ Sv)	O average (μ Sv)	S maximum (μ Sv)	
Extraction of radioactive wastes (13.06.91-22.07.91)	41	23	1125	50	255	14	1065	75	255	45
CELL 2 - Extraction of equipments and working plan (07.10.91-29.11.91)	53	19	360	20	75	12	360	30	75	15
Extraction of barytic bricks (05.12.91-20.01.92)	21	18	170	10	45	10	170	15	45	15
Extra maintenance of overhead-crane (24.01.92-26.05.92)	51	18	3510	195	530	11	3130	285	515	125
CELL 1 - Extraction of equipments and working plan (02.06.92-24.02.93)	58	21	11400	545	2455	11	8710	790	2400	355
CELL 3 - Extraction of equipments and working plan (25.02.93-24.06.93)	64	20	6830	340	920	12	4610	385	820	185
Decontamination -preliminary tests (25-06.93-11.10.93)	31	21	2285	110	340	11	1710	155	335	80
CELL 3 Decontamination (12.10.93-15.11.93)	29	18	1460	80	270	11	915	85	125	40
CELL 1 Decontamination (16.11.93-02.12.93)	30	18	1180	65	200	10	770	70	110	30
CELL 2 Decontamination (03.12.93-21.12.93)	25	17	550	30	95	11	340	30	50	25
COMPREHENSIVE DATA (13.06.91-21.12.93)	403	29	28870	995	2455	16	21780	1360	2400	355

9. CONCLUSIONS

The following conclusions can be drawn on the basis of the activity carried out thus far.

After a total of 403 interventions in contaminated areas, the ventilated-pressurized suit, and in particular the Scalhene system chosen by us and connected to an emergency system, has proved to be an effective tool with a number of advantages with respect to other protective systems. These include:

- the reduction by a factor of 50 of the volume of waste resulting from traditional protective measures (overcoats, masks, filters, gloves, etc.);
- the reduction of the risk of contamination for people (up to now no cases of contamination have occurred);
- the preference of the operators, who once they have been trained to use the suit definitely prefer this protection system to other more traditional ones.

The only disadvantage of the system is the initial cost; it is believed that this cost can be covered after an estimated 200+250 interventions. In our case, 6 suits have been replaced up to now.

The leaktight circuit DECOFREON system used for the equipments (where contamination was especially difficult to remove) not only enabled us to reduce the contamination, but also to lower the radiation dose rate, thus enabling the waste products to be conditioned in simple oil drums without shielding; the amount of waste was also reduced to little more than the net volume of the equipment.

Finally we can affirm that experience has enabled us to acquire considerable practice in the field of the dismantling and decontamination of the nuclear plants.

Even if the contamination level of the cells of the CRE CASACCIA of the ENEA was not high and significant contamination deriving from transuranic elements (Pu, Am) was not present, the work had a remarkable propedeutical role for the the dismantling and decommissioning foreseen in the next years on other ENEA plants, particularly on the Plutonium Plant.

ACKNOWLEDGEMENTS

We would like to thank the staff of OPEC ed Soc. NUCLECO, whose work enables to us to complete the program within the required time.

REFERENCES

[1] G. Caporossi, et al. - "Essai de decontamination d'une cellule chaude avec des solvants organiques circulant en circuit fermé", (Berkeley, 25-26 Juin 1991)

[2] G. Caporossi et al. - "Decontamination des cellules chaudes du C.R.E. Casaccia (ENEA)", (Chinon, 15-16 Juin 1993)

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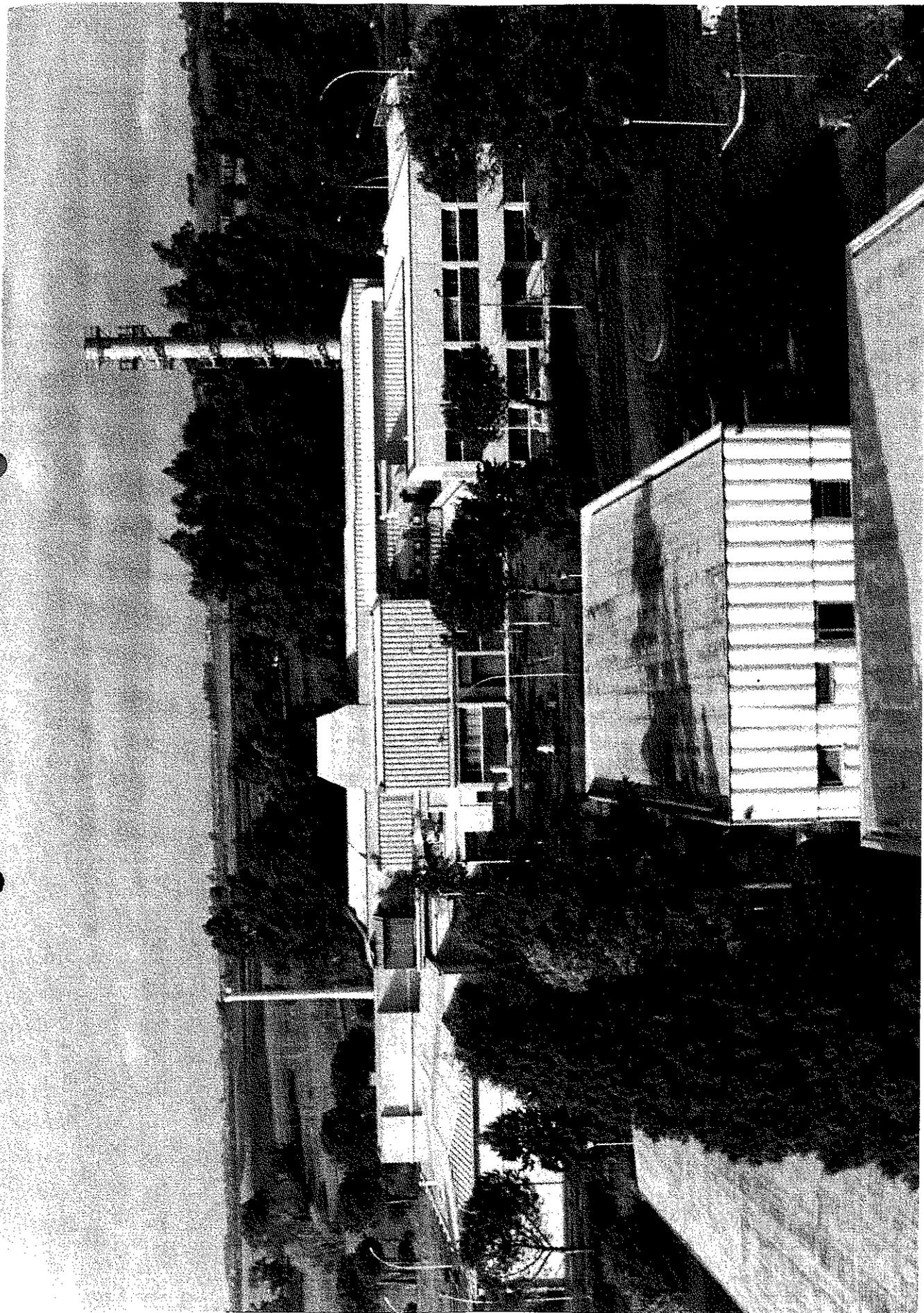


Figure 1 - VIEW OF HOT CELL LABORATORY (OPEC - 1 & OPEC - 2) AT C.R.E. CASACCIA

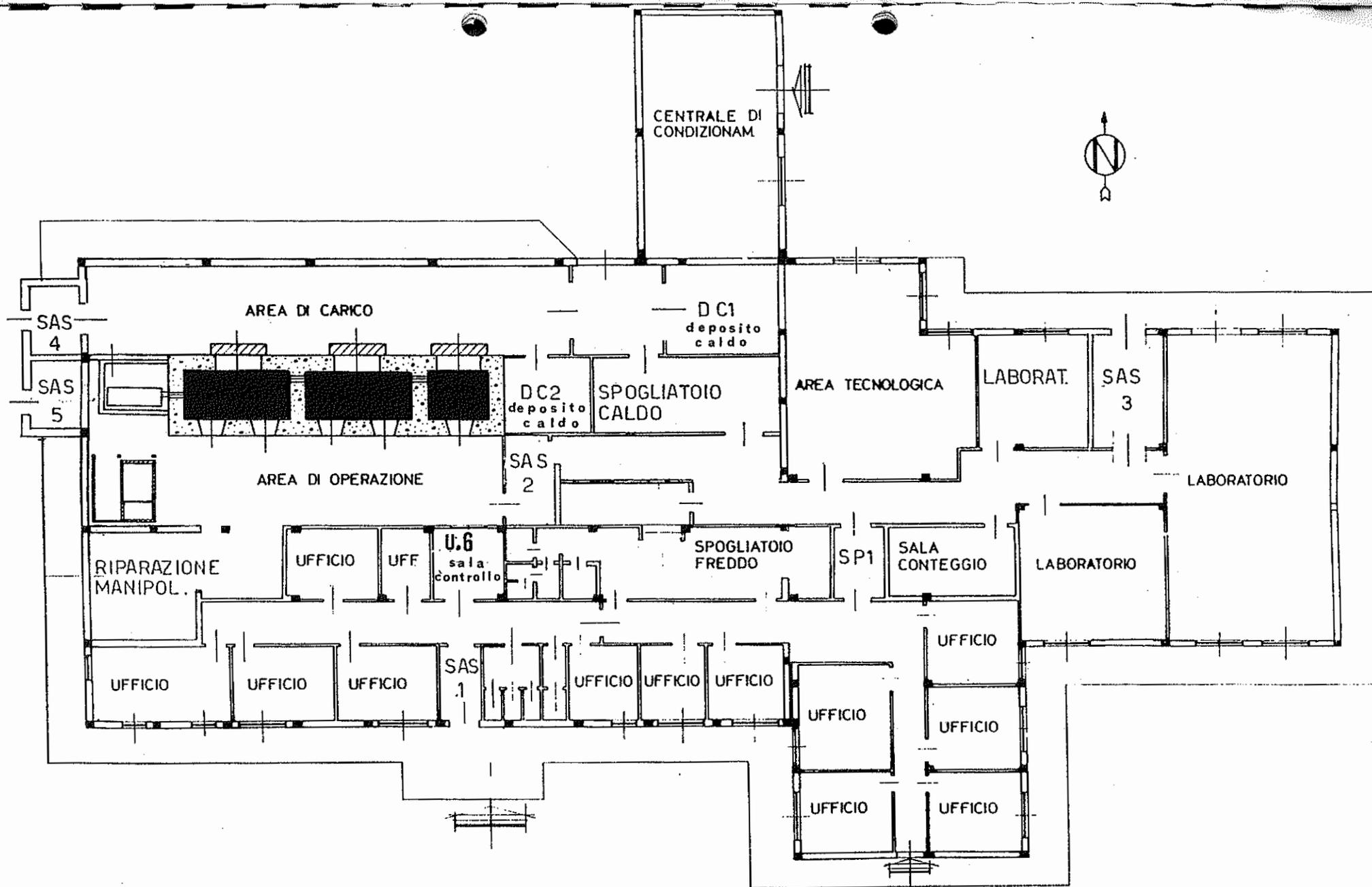


Figure 2 - LAYOUT OF HOT CELL LABORATORY OPEC - 1 C.R.E. CASACCIA (ENEA)

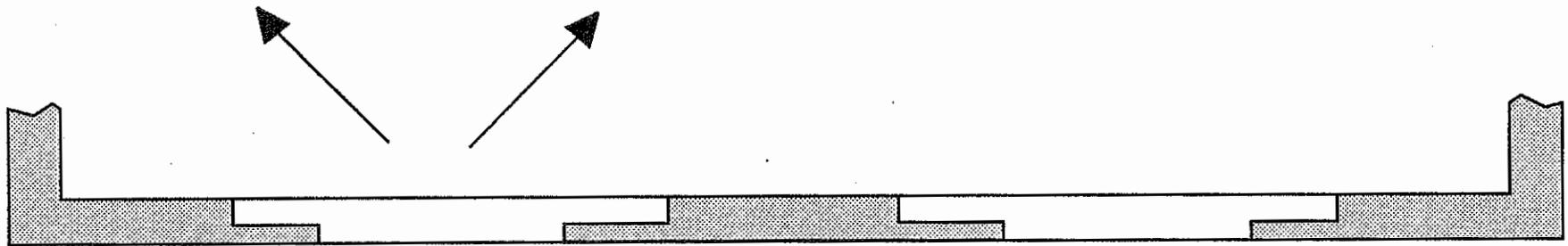
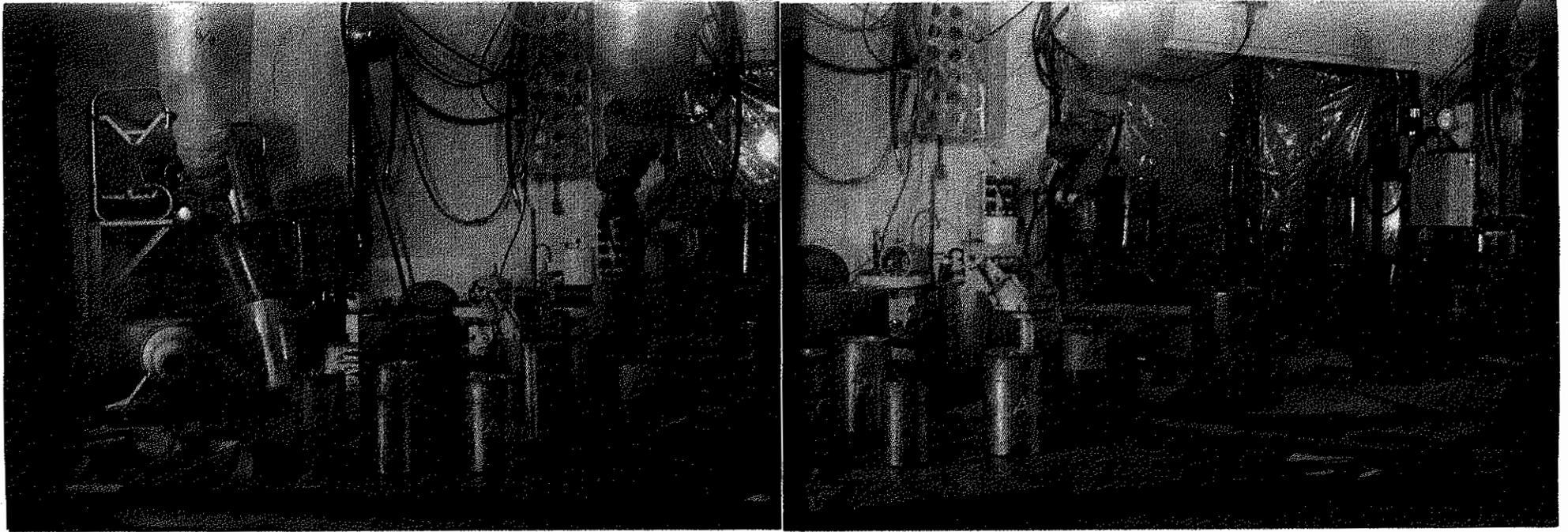


Figure 3 A - INITIAL STATUS OF CELL 1 (FROM LEFT WINDOW)

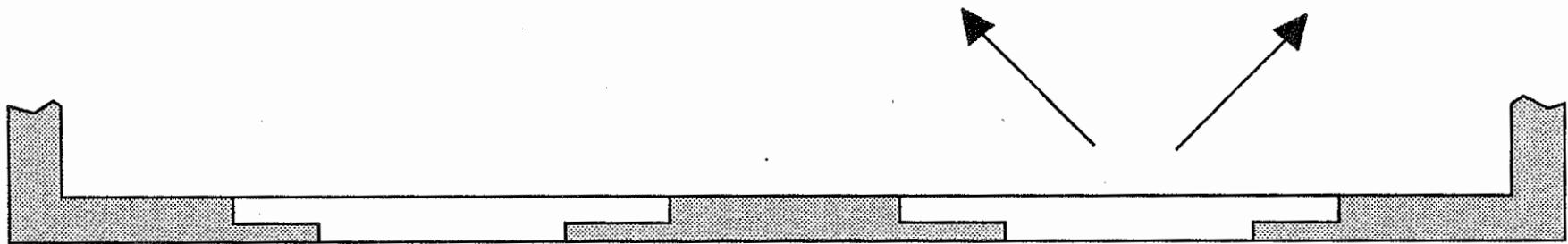


Figure 3 B - INITIAL STATUS OF CELL 1 (FROM RIGHT WINDOW)

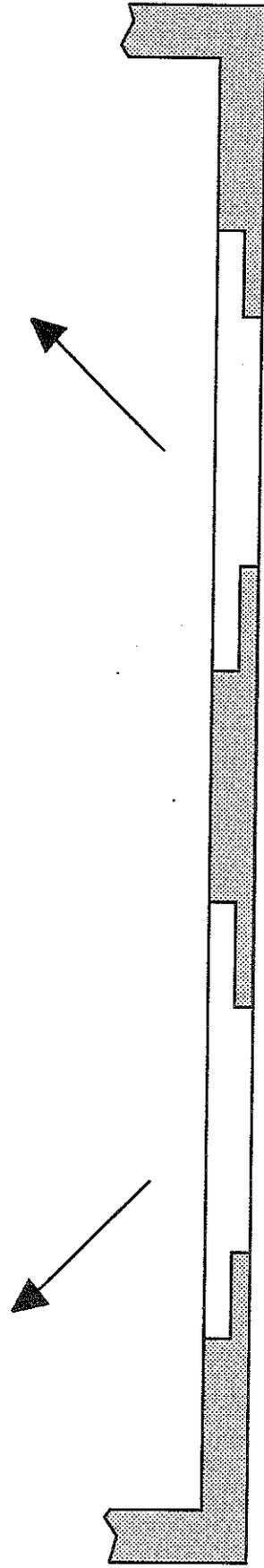
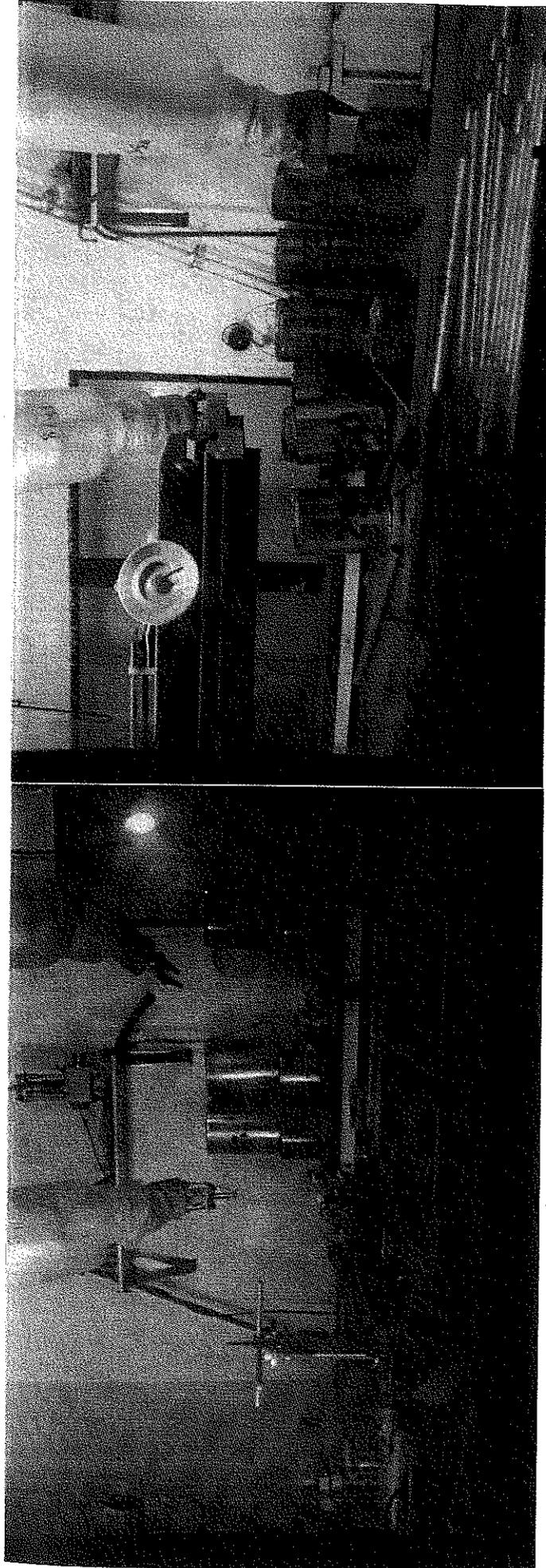


Figure 4 - INITIAL STATUS OF CELL 2

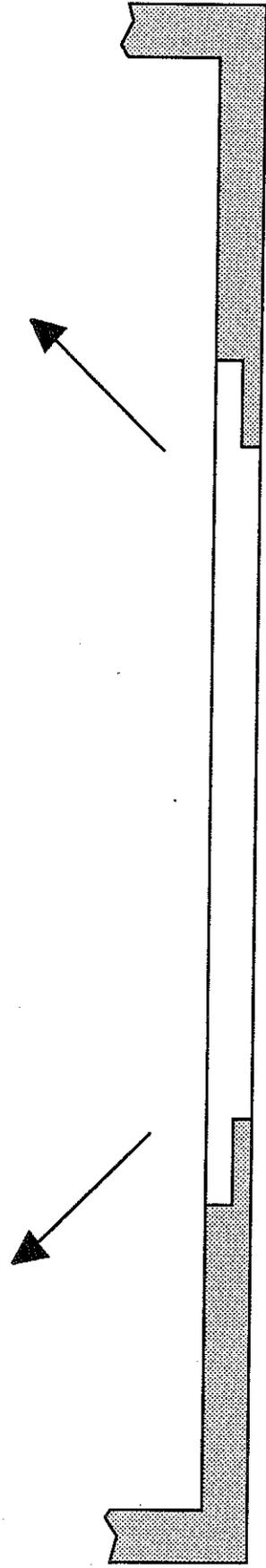
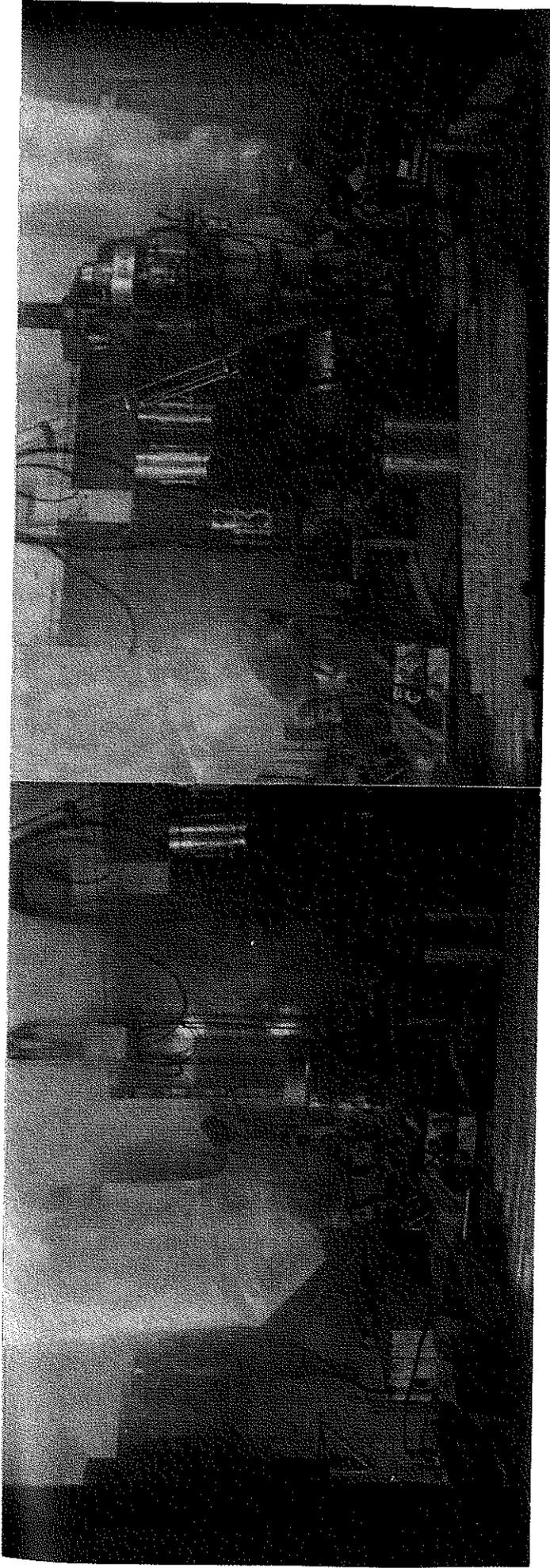


Figure 5 - INITIAL STATUS OF CELL 3

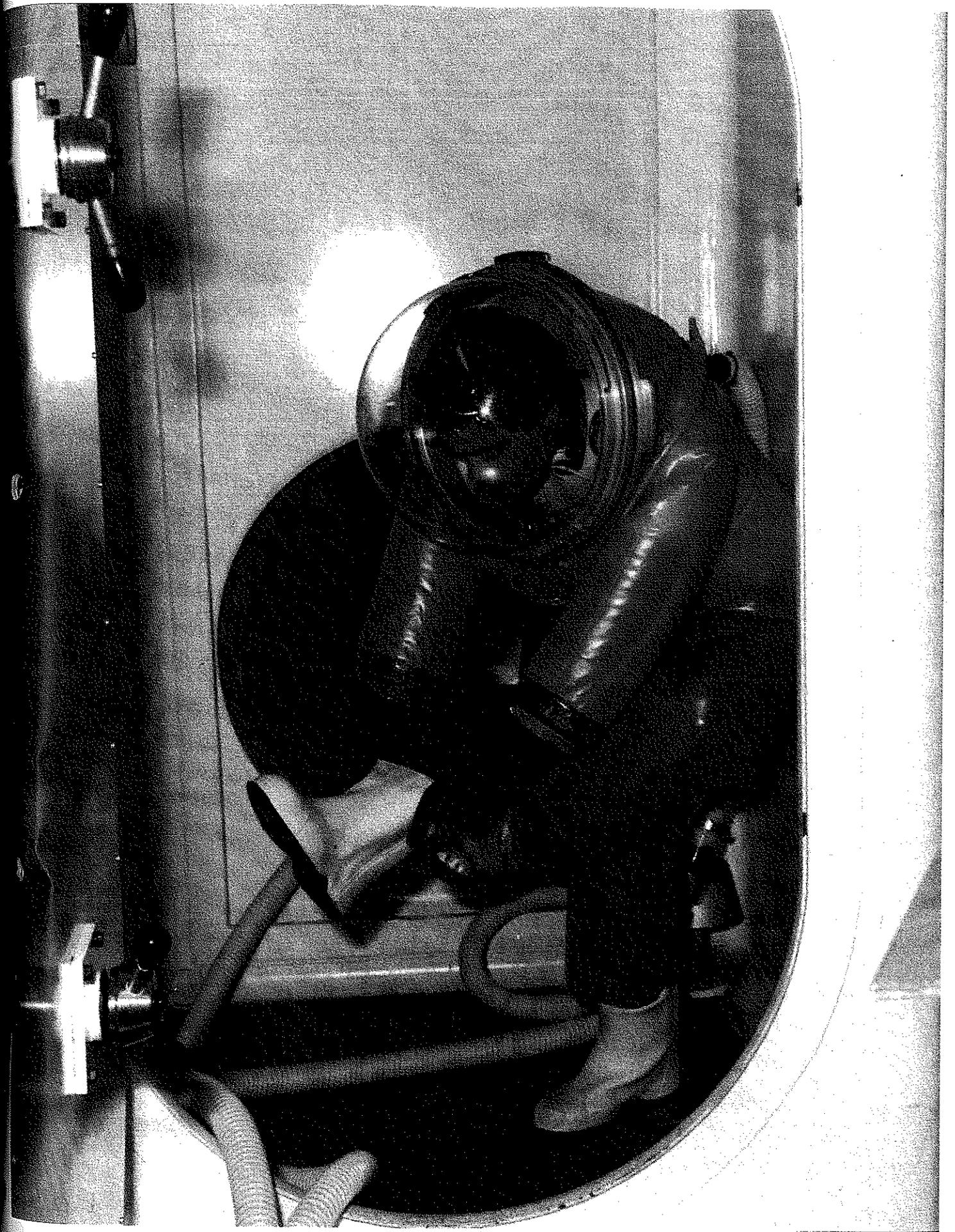


Figure 6 - OPERATOR INSIDE THE CELL

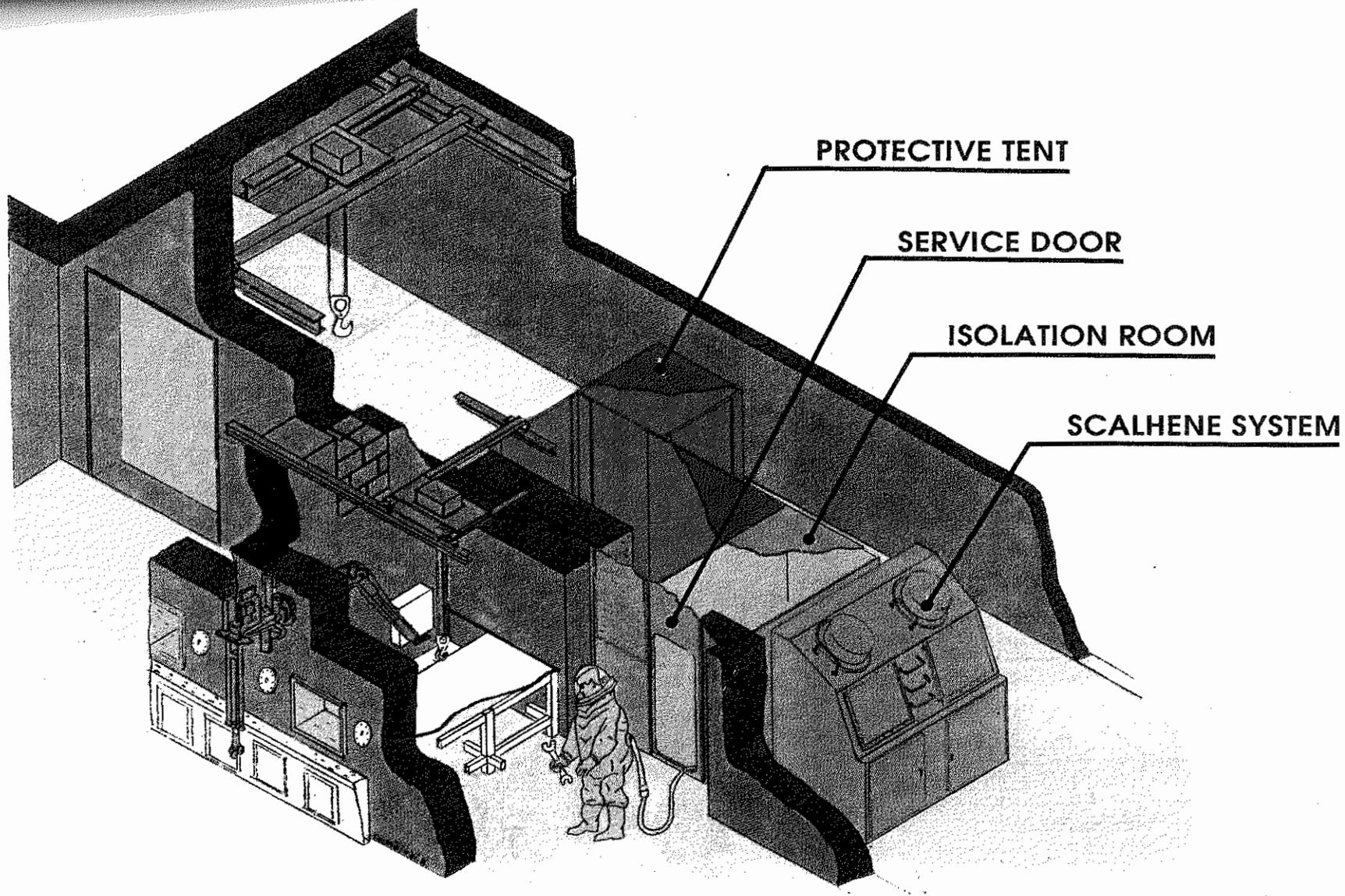


Figure 7 - DIAGRAM OF OPERATIONAL UNIT

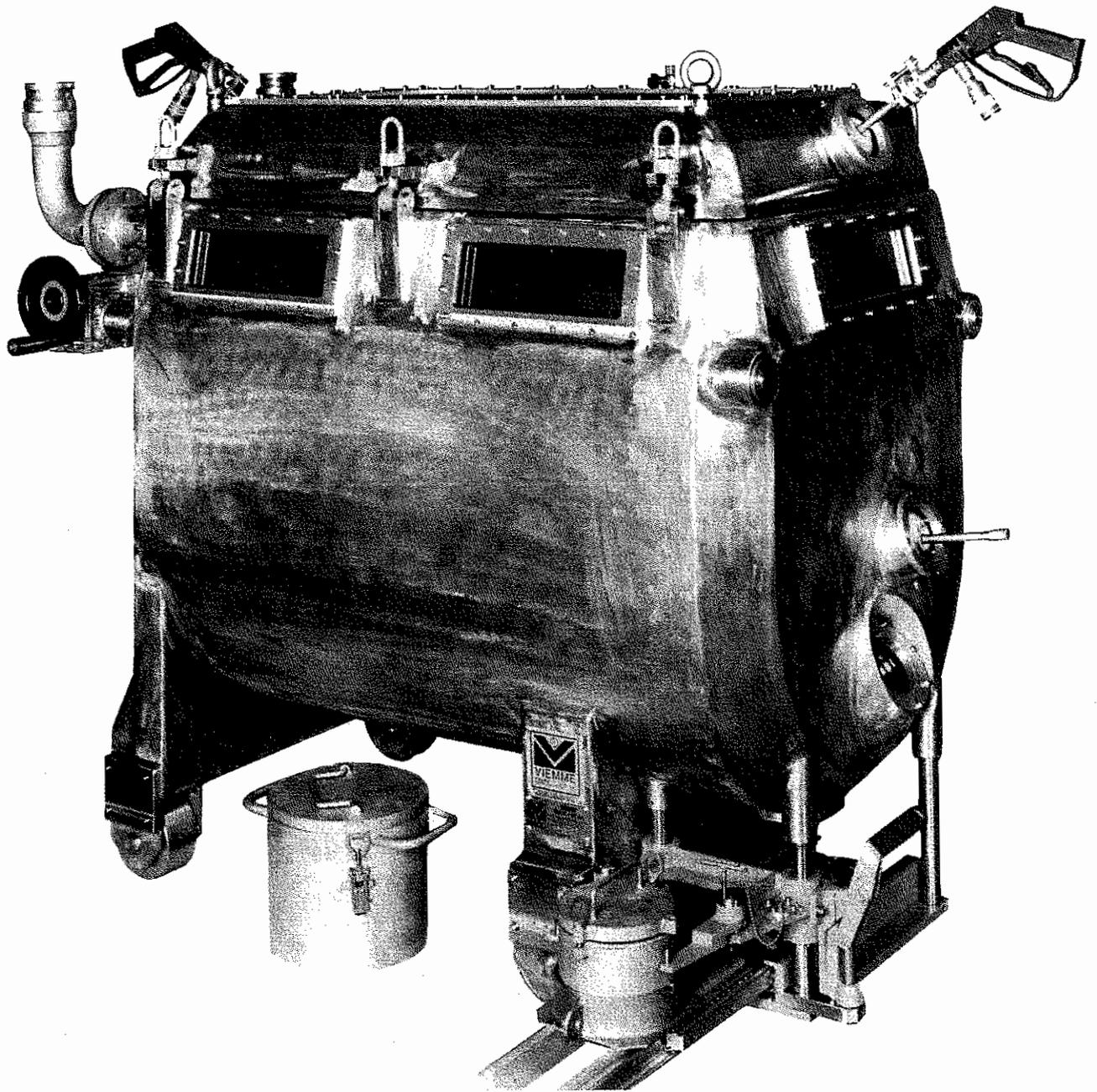


Figure 8 - BOX FOR DECONTAMINATION

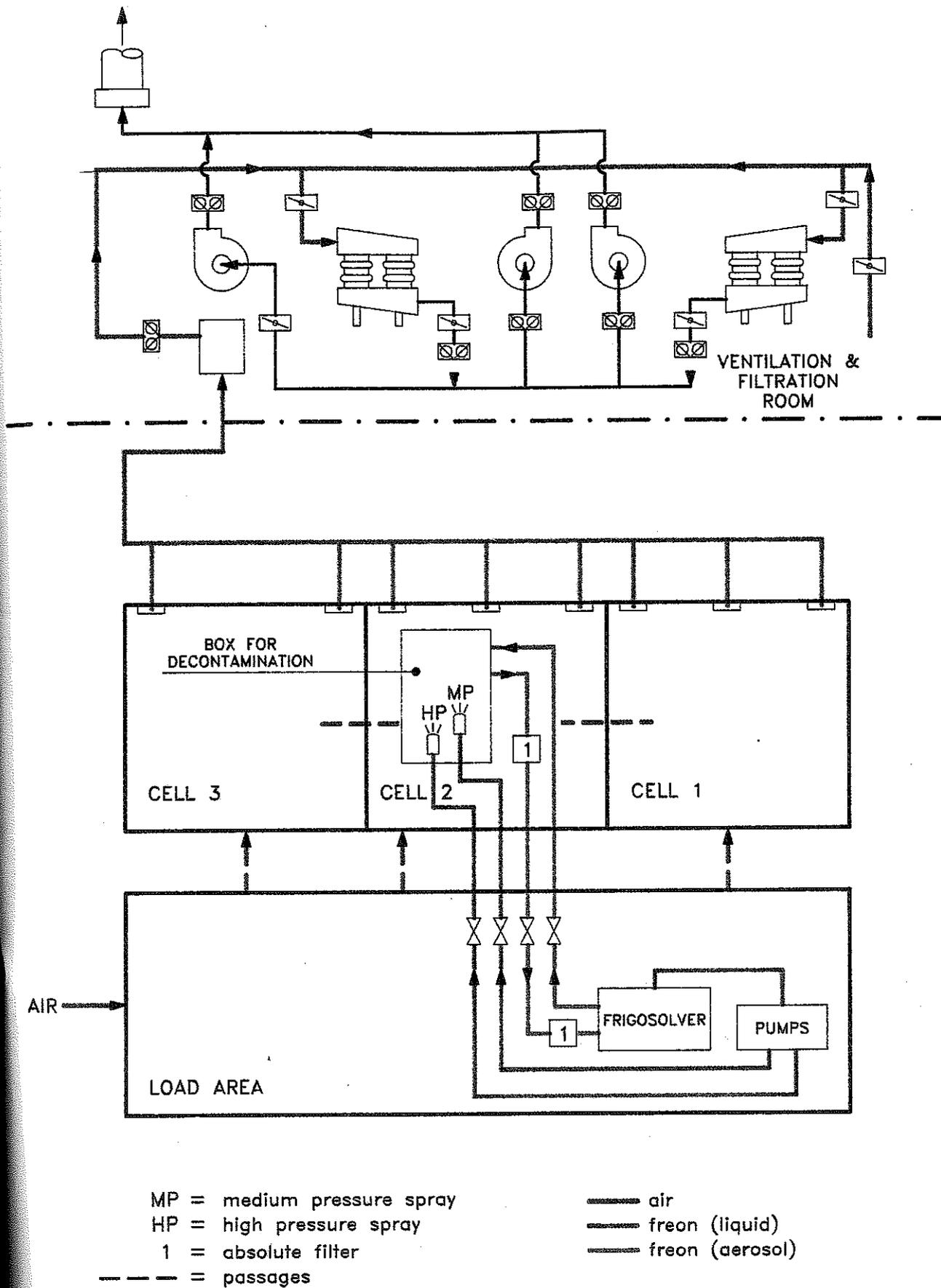
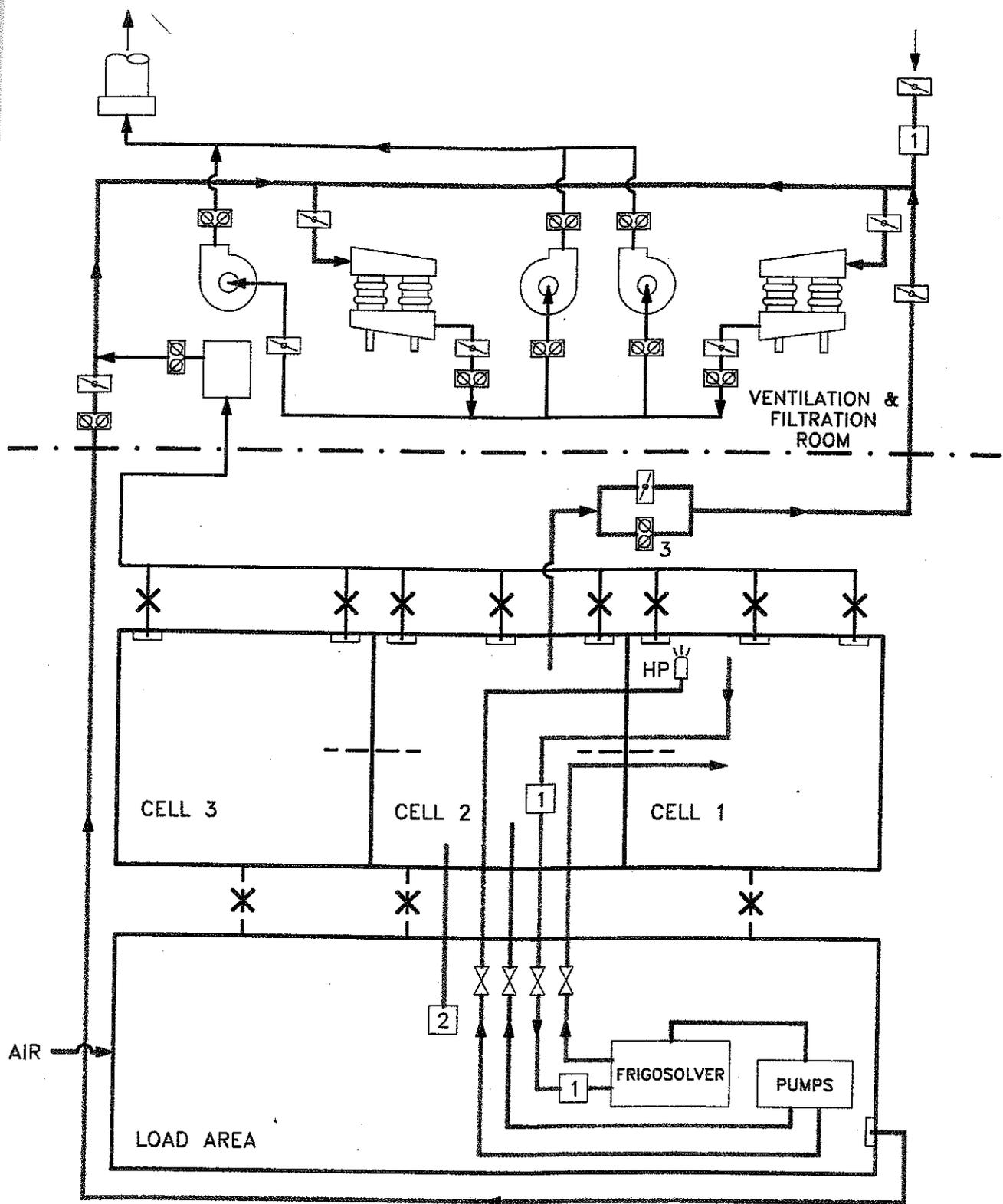


Figure 9 A - DIAGRAM OF VENTILATION & FILTRATION SYSTEM



HP = high pressure spray

1 = absolute filter

2 = pressure relief valve (rel. press. max 45 mm H₂O)

3 = relief valve (rel. press. max 12 mm H₂O)

X = sealing

- - - = passages

— air

== freon (liquid)

- - - freon (aerosol)

Figure 9 B - DIAGRAM OF VENTILATION & FILTRATION SYSTEM (MODIFIED)



Figure 10 - DEVICE WITH METALLIC BRUSHES