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DELL' ENERGIA NUCLEARE E DELLE ENERGIE ALTERNATIVE

VOLUME REDUCTION AND CONDITIONING OF ILW LLW AT ENEA CENTERS

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ABSTRACT

At the ENEA CASACCIA Center, intermediate and low level solid waste produced by ENEA research activities, by universities, hospitals and small producers are collected and treated in the new ICS-42 plant, commissioned in 1991. The plant, owned by ENEA, is operated by NUCLECO, a joint ENEA-AGIP stock company.
Volume reduction of solid active wastes is achieved by supercompaction, using a 15,000 kN press. The ICS-42 plant also includes a facility for dismantling large contaminated equipment prior to conditioning.
Drums containing dry active wastes are supercompacted and placed in an overpack 380 liter drum, which is filled with cement grout for final conditioning.
The final package meets the standard criteria for land disposal issued by the Italian Regulatory Commission ENEA-DISP.
The plant is operated through a computerized process control system, which allows fully automated and remote handling of the drums.
The first results achieved during cold tests are given.
Furthermore, at the ENEA Trisaia Center, during a campaign carried out from January to May 1989, 1,449 standard drums were supercompacted and placed in 380 liter drums, filled with cement grout for final conditioning. A transportable supercompaction unit with a 20,000 kN press was used.
The final package meets the standard criteria for land disposal as well.
A short description of the treatment and conditioning system and the results of the supercompaction campaign are given.

1. INTRODUCTION

At present a final disposal site for intermediate and low level wastes is not yet available in Italy. Wastes are currently stored at the production sites, i.e. power stations and fuel cycle facilities, except those arising from medical activities, research institutes, industries and small producers (about 2000 m^3/y), which are mostly collected at the NUCLECO Center, located inside the ENEA Research Casaccia Center, 25 kilometers from Rome. NUCLECO is a joint stock company, set up by ENEA (40%) and AGIP (60%) in 1981, owing to a decision of the Italian Government, for managing low and intermediate radwastes, under ENEA supervision and control.

At the Casaccia Center several thousands drums of non conditioned solid wastes are stored, which have arisen from the research activities carried out by ENEA over the past twenty-five years and from medical and non-nuclear activities. Due to the limited storing capacity at Casaccia, volume reduction is a must for NUCLECO. As incineration of radioactive wastes is not being permitted on the site, a decision was made in 1986 to provide volume reduction facility by supercompaction technology. Following that, a facility was installed at Casaccia, equipped with a 15,000 kN press supplied by the Joint Venture Fontijne (NL) - Snia Techint (I).

A mobile supercompaction unit is also operated for ENEA by NUCLECO. This unit is equipped with a 20,000 kN press, for providing compaction services at power reactor sites and at the other ENEA research Centers.

Both facilities can process 220 liter drums. Compacted drums are placed in 380 liter overpack drums, which in turn can be filled with cement grout depending on the level of activity.

* The high force compaction systems can handle combustible as well as non-combustible dry active wastes.

This paper describes the plant at the Casaccia Center (ICS-42 plant), which was completed in April 1989. The plant is scheduled to start active operations by summer 1991.

The paper also provides some informations and data on the treatment and conditioning campaign carried out in 1989 at the ENEA Trisaia Center, by the Hansa Project mobile supercompaction unit.

2. TREATED WASTES AT ICS-42 PLANT

Dry active wastes, classified as Second Category radioactive wastes in the Technical Guide 26, issued by the Italian regulatory body ENEA-DISP, can be treated in the ICS-42 plant.

Radioactive wastes are classified into the Second Category when, in time periods varying from a few decades to a few centuries, decay to radioactivity concentrations in the order of a few hundred Bq/g (around 10 nCi/g); the presence of very long lived radioisotopes is permitted in these wastes, provided their initial concentration is of this order of magnitude.

Typical wastes treated at ICS-42 include:

- paper, rags, clothes, rubber, plastics;
- ventilation filters;
- metallic material and small components coming from the dismantling section of the plant itself.

Wastes are mainly from ENEA research plants and laboratories and from institutional facilities (universities, hospitals, laboratories, etc.).

Tables 2.1 and 2.2 show typical radionuclide content of 220 liter drums from nuclear research laboratories and medical activities.

Radionuclide	Half-life (years)	Activity (MBq)
Fe^{55}	2.7	2.5
Co^{60}	5.3	25
Ni^{59}	$7.5 \cdot 10^{4}$	0.003
Ni^{63}	100	0.5
Sr^{90}	28.8	1.2
Zr^{93}	$1.5 \cdot 10^{6}$	$2.5 \cdot 10^{-5}$
Nb^{94}	$2.0 \cdot 10^{4}$	$2.5 \cdot 10^{-4}$
Sb^{125}	2.7	2.5
Cs^{134}	2.1	1.0
Cs^{135}	$3.0 \cdot 10^{6}$	$1.0 \cdot 10^{-5}$
Cs^{137}	30.2	2.5
Pm^{147}	2.6	2.5
Sm^{151}	90.0	0.003
$U_{nat}+U^{235}+U^{232}$		$3.0 \cdot 10^{-5}$

Table 2.1 Inventory of a typical content of nuclear research labs drum

Radionuclide	Half-life		Activity (MBq) (parent + daughter)
H^{3}	12.3	y	105
C^{14}	5730	y	15
P^{32}	14.3	d	20
S^{35}	87.9	d	7
Cr^{51}	27.9	d	6
Tc^{99}	$2.1 \cdot 10^{5}$	y	0.15
I^{125}	60.2	d	100
I^{126}	12.8	d	15
I^{129}	$1.7 \cdot 10^{7}$	y	0.2
I^{131}	8.05	d	25
Xe^{131m}	11.8	d	45

Table 2.2 Inventory of a typical content of medical activities labs drum

Plant design allows handling of drums with the following contact dose rate:

a) for continuous routine operation:
- average value 0.1 mSv/h (10 mrem/h)
- max value 1 mSv/h (100 mrem/h)

b) for single drum treatment:
- max value 2 mSv/h (200 mrem/h)

Drums with higher contact dose rates, up to 10 mSv/h (1 R/h), will be sorted in the dismantling section.

3. FINAL PACKAGING AT ICS-42 PLANT

Compacted drums are placed inside an overpack drum, with the following dimensions:

- diameter 700 mm
- height 1100 mm
- net volume 380 liters

The outside drum is made of carbon steel. The overpack drum is then filled with cement grout, having compression strength greater than 2.1 kN/cm^2.

The standard (calculated) characteristics of the final package are as follows:

a) average value:

- activity (Co^{60} eq.)	185	MBq	(5	mCi)
- total activity	2.4	GBq	(65	mCi)
- density	2.1	kg/dm^3		
- contact dose rate	0.1	mSv/h	(10	mrem/h)
- dose rate at 1 m	5.5	µSv/h	(0.55	mrem/h)
- weight	800	kg		

b) maximum value:

- activity (Co^{60} eq.)	925	MBq	(25	mCi)
- total activity	12	GBq	(325	mCi)
- contact dose rate	0.5	mSv/h	(50	mrem/h)
- weight	850	kg		

The final package meets the requirements of the Technical Guide 26 for Second Category classification, which allows final disposal of such wastes in surface repositories. Table 3.1 shows the concentration limits of radionuclides for Second Category conditioned wastes.

The final package also complies with the IAEA requirements for transportation of the IP2 type industrial package.

Class of radionuclides	Concentration			
α-emitters $t_{1/2} > 5$ years	* 370	Bq/g	(10	nCi/g)
β/γ-emitters $t_{1/2} > 100$ years	* 370	Bq/g	(10	nCi/g)
β/γ-emitters $t_{1/2} > 100$ years in activated metals	3.7	kBq/g	(100	nCi/g)
β/γ-emitters $5 < t_{1/2} \leq 100$ years	37	kBq/g	(1	µCi/g)
Cs^{137} and Sr^{90}	3.7	MBq/g	(100	µCi/g)
Co^{60}	37	MBq/g	(1	mCi/g)
H^3	1.85	MBq/g	(50	µCi/g)
Pu^{241}	13	kBq/g	(350	nCi/g)
Cm^{242}	74	kBq/g	(2	µCi/g)
Radionuclides $t_{1/2} \leq 5$ years	37	MBq/g	(1	mCi/g)

* Values must be intended as average values referred to the whole of the wastes contained in the disposal repository, taking into account that the limit value for each package cannot exceed 3.7 kBq/g (100 nCi/g).

Table 3.1 Concentration limits for Second Category conditioned wastes

4. DESCRIPTION OF THE ICS-42 PLANT

The plant has two main sections :

- dismantling and pretreatment;
- supercompaction and conditioning.

Plant lay-out is shown in Fig. 4.1; Figs. 4.2 and 4.3 show the flow diagrams of the two sections.

In the dismantling section, metallic equipment or materials can be handled having maximum dimensions of 4.5 x 3 x 2.5 m. The maximum allowed weight is 3000 kg. The supercompaction unit is designed to process 66 drums per day, on one shift. Annual expected production is 10,000 drums.

4.1 Dismantling and pretreatment

The following basic operations are carried out in this section (Fig.4.2):

- dismantling;
- precompaction;
- sorting.

For the above operations the following main equipment is used:

- 2,000 kN hydraulic press;
- container turnover system;
- shielded sorting table;
- telemanipulators;
- unshielded sorting table;
- mobile shielding;
- power master-slave manipulator;
- robotic plasma cutting torch;
- motor-driven handling table;
- motor-driven raisable table.

All equipment is housed in a 10 x 5 x 5 m stainless steel cell, equipped with systems for decontamination and for liquid effluent collection and evacuation. Air from the cell is exhausted through an HEPA filter.

Dismantling of large equipment is essentially performed by cutting, using a plasma torch operated by a fully computer-directed robot, shown in Fig. 4.4. A 3000°C torch can process a maximum steel thickness of 75 mm.

The cutting system also includes:

- capability to memorize the most used cutting lines and parameters;
- device for fumes and off-gas collection and treatment;
- closed circuit TV control system.

Cutting takes place with the aid of the raisable table and the power manipulator. All the operations are fully remote controlled. Moreover, the cell has windows and a monitoring system.

4.2 Supercompaction

In this unit the following systems are included:

- drum storage;
- drum conveyor system;
- supercompactor;

- drum selection and control system;
- liquid collection and treatment;
- turntables;
- cementation unit.

The drums to be daily pressed are stored in a shielded structure of 66 positions (Fig. 4.5), designed in such way as to give an equal distribution of the dose rate. Drum positioning and selection is performed in a fully automated and computerized mode. Transportation is carried out by a motor-driven conveyor.

Compaction takes place in a stainless steel lined cell by a double effect hydraulic press, delivering a compaction force of 15,000 kN to the waste drum. Pressed drums (pellets) are transferred to a six place staging turntable. Drum loading and resulting pellet unloading is fully automatic.

The supercompactor (Fig. 4.6), is equipped with a self-centering device for the drums. Containment is provided by a "mold", which is lowered during pressing.

The selected press has been largely tested in radioactive operations, being installed and operated in several volume reduction facilities in Europe and the US.

The pellets are transferred to one of six overpack containers, placed on an adjacent turntable. Filling of the overpack container is optimized, by ultrasonic measurement of the pellet height, through an operating software which may select any of the six pellets to load into any of the six available overpacks, in order to assure the maximum filling of the overpack complying with pre-fixed maximum weight and dose rate.

The compaction unit is also equipped with a system for liquid collection and transfer to a phase separator, where the aqueous phase is separated from the organic before cementation.

Final conditioning of the pellets in the overpack is performed in the cementation cell. Cement grout is automatically fed by a pump to the cell from a makeup station located outside the building.

4.3 Plant operation and control system

The ICS-42 plant is provided with a fully computerized system to direct the operation of the plant as well as the safety related functions.

All the process and safety parameters are operated and controlled by a "distributed intelligence" system realized through a PLC network governing each plant component performance. The network is in turn operated by a supervisor PLC which, by transferring all data to a PC, allows the whole facility to be operated by the control room (Fig. 4.7). Real time elaboration of meaningful and statistical production data is also provided.

The P&I of plant equipment can be displayed on a monitor through a Siemens videographic system. Operating data can be stored and printed every 100 seconds.

The warning system operational data are also fully stored in real time and the configuration of warned section can be displayed in the control room.

5. COLD TEST RESULTS ON ICS-42

Cold tests of the supercompaction unit began in May 1989. Over 500 drums of simulated wastes were processed during the first month.

The supercompactor system has performed satisfactorily, providing quite a high volume reduction factor (VRF). The specially designed press plate and piercing unit, along with the selected pressing cycle, allowed the springback effect to be minimized and the production of fully flat pellets. This is necessary for providing a good final volume reduction factor (FVRF).

The achieved pellet VRF strongly depends on the waste type, on how full the waste container is loaded and on how the drum is physically packaged with waste material. For the same waste type, a linear function between pellet VRF and drum weight can be established, being increasingly accurate for more homogeneous and isotropic materials.

The value of FVRF is primarily established by the need for further conditioning by cementation of the compressed drums in the overpack container. This conditioning allows the fulfillment of the requirements for final disposal in surface repository issued by the Italian Regulatory Commission.

Due to cementation, the working volume of the final overpack for pellet accommodation is about 75% of the total overpack volume.

Table 5.1 shows the values of VRF and FVRF for 3 typical simulated wastes.

For the same material, in Figs. 5.1, 5.2 and 5.3 pellet density and height are plotted versus drum density and weight. Pellet density is quite an important parameter for cementation operation, due to the possibility of pellet floating during overpack filling with cement grout. In order to prevent floating and also for correct positioning of the pellets, a metallic structure is installed inside the overpack container. This device worked satisfactorily, allowing a proper embedding of the pellets.

Active start up of the plant is scheduled in summer 1991.

Type of waste	Average waste weight (kg/drum)	Average waste density (kg/dm^3)	Average pellet density (kg/dm^3)	VRF*	FVRF**
All types	62	0.281	2.334	9.97	5.8
Papers, plastic and pvc (Type 1)	46	0.210	1.514	7.49	4.7
Precompacted metallic material (Type 4)	109	0.496	3.592	7.95	4.7
Absolute filter with frame (Type 9)	32	0.147	1.868	13.3	8.7

Note:

(*) $\text{VRF} = \dfrac{\text{Drum initial volume}}{\text{Pellet volume}}$ (**) $\text{FVRF} = \dfrac{\text{Drum initial volume}}{\text{Overpack volume}}$

Table 5.1 Results of supercompaction at the ICS-42 plant for three typical simulated wastes

6. SUPERCOMPACTION CAMPAIGN AT THE ENEA TRISAIA CENTER

At the ENEA Trisaia Research Center (Southern Italy), due to operation of the ITREC pilot reprocessing plant in the seventies, about 2,000 drums of low level solid waste were produced. In order to improve the capacity, the wastes were in-drum pressed, by a 12 kN press, with a volume reduction factor from 4 to 5.

For the purpose of incapsulate the waste for final disposal, a supercompaction campaign was carried out from January to May 1989, during which 1,449 drums, containing Second Category radioactive waste, were compacted and cemented in 326 overpacks.

A transportable supercompaction unit, Hansa Project Superpack TM 2000, equipped with a 20,000 kN press and a cementation unit were used.

6.1 Facility description

The process lay-out of the facility is shown in Fig. 6.1.

The facility was installed in an operational area, close to the ITREC plant building, delimited by a cover tent on a steel profile framework. The working area was ventilated to the absolute filtration system of the ITREC ventilation.

A short description of the main equipment is given below.

6.1.1 Supercompaction unit

The mobile supercompaction unit consists of the following components:

- semitrailer;
- supercompactor;
- hydraulic assembly;
- control station;
- air purification system;
- conveyor system;
- overpack filling equipment;
- liquid handling system.

Semitrailer

The mobility of the compacting press is obtained by the integration of a special three axle semitrailer. The trailer is additionally equipped with winch type leg supports which act as load-bearers and stabilize the compaction unit during operation.

Supercompactor

The supercompactor is basically divided in two important sections: the superstructure holding the vertical cylinder and the compacting mould. The cylinder is mounted to the press counterplate, joined to the baseplate by large diameter support columns.

The waste volume reduction takes place within the dies of the mould, designed as "clamshells", encircling the drum in order to eliminate the hangup and distortion of the compacted drum, while at same time helping to reduce doses to operators.

During high pressure compaction, the dies of the mould are held firmly together by a latch block, raised or lowered by means of hydraulic actuators.

The press is hosted in a steel profile and aluminum sheet chamber hood.

The press is designed to deliver a force of 2,000 metric tons, about 20,000 kN, with a full power rating of 110 kW.

The design throughput is from 15 to 20 compacted drums per hour.

Conveyor system

The system, including loader and unloader conveyor equipment, provides the transfer of the waste drum to the compactor baseplate by a sliding carriage and the unloading of the compacted pellet.

Liquid handling system

The compactor is designed to process dry waste or containing up to 5% of liquid volume. During the compaction of wet waste, fluid released is collected by a trough in the baseplate of the mould and directed, by nozzles and channels, to a stainless steel tank equipped with a pump to transfer the liquid.

Air purification system

The air purification system is placed in the press compartment. It consists of a three-section filter unit and of a ventilator fan. The fan exhausts the released aerosols through the filtering unit.

Control Module

This module includes two sections:

- the computer-assisted control station;
- the hydraulic pumping room.

The front wall of the module is fitted with plexiglass viewing windows, which enable the operator to monitor the compacting process from his position.

The control section contains the main switch cabinet, providing the power connections, monitoring equipment and control devices for press operation, and the control console.

The rear larger section of the module contains the hydraulic equipment, the twin motor power pack, the hydraulic cooling system. The oil tank has a capacity of 2,500 liters. The pumping system is required for the piston movements and consists of two pump sets, the rating of each pump motor being 55 kW. The operation hydraulic pressure varies from the starting value of 6.5 MPa (65 bar) to the maximum value of 25 MPa (250 bar).

Overpack filling system

This system provides handling and transfer of the pellets into the 380 liter overpack. It includes three individual bridge type stands and an electrically operated crane with mechanical grapple to pick the pellets at the conveyor end, lift and transfer them to the overpack.

6.1.2 Cementation unit

The conditioning of the pellets with cement grout into overpack is carried out with a cementation unit.

Main items are the following:

- balance for weighing and metering the dry mixture components;
- water flow rate meter;
- 500 liter capacity turbo-mixer;
- cement grout feeding system to overpack;
- vibrating table;
- roller way with storing function to assure the setting and hardening of the cement grout into overpacks.

The cement grout is prepared in a makeup station, outside the tent, and fed with a flexible hose into overpack filled with pellets. During filling, the overpack is placed on a vibrating table.

After 24 hours setting time the overpack is weighed, checked for contamination, inspected and moved to the storage.

6.2 Supercompaction campaign results

From January to May 1989, 1,449 220 liter drums with low level solid waste were treated at the Trisaia Center. This period included: the facility installation, the treatment and conditioning campaign, the final disassembly and decontamination.

The treated wastes were: metallic material, small contaminated equipment, paper, rags, protective clothes, plastic, glass, wood and ventilation filters.

The average characteristics of the treated wastes can be summarized as follows:

- Average activity per drum	20	MBq	(0.54	mCi)
- Average contact dose rate	7	μSv/h	(0.7	mrem/h)
- Average drum weight	80	kg		

The production was about 8÷10 compacted and conditioned drums per hour.

Compacted drums were placed in an overpack drum, with the following dimensions:

- diameter	700	mm
- height	1100	mm
- net volume	380	liters

The outside drum is made of carbon steel. The overpack drum is filled with cement grout, having the following characteristics:

- components (weight %):
  - Portland cement 425 62 %
  - sand 25 %
  - water 13 %
- compression strength (after 28 days setting time) equal to 3.2 kN/cm^2;
- density equal to 2.1 kg/dm^3.

The total number of overpacks produced was 326.

The final volume reduction factor (FVRF) was:

FVRF = 1,449 * 0.22 / (326 * 0.38)

FVRF = 2.6

This low value is due to the previous compaction to improve the drum filling and consequently to the high density of the waste. Considering that the precompaction volume reduction factor was about from 4 to 5, the total FVRF is:

4 * 2.6 = 10.4

The main characteristics of the final package can be summarized as follows (average values):

- Average activity per overpack 93 MBq (2.5 mCi)

- Average contact dose rate	5	μSv/h	(0.5	mrem/h)	(top)
	10	μSv/h	(1	mrem/h)	(lateral surface)
	3	μSv/h	(0.3	mrem/h)	(bottom)
- Average overpack weight	713	kg			

The secondary wastes produced were:

- Solid waste: 2 m^3 in 10 standard drums
  average contact dose = 1 μSv/h (0.1 mrem/h);
- Liquid waste: 6 m^3
  specific activity = 400 ÷ 4000 Bq/dm^3 (~ 0.01 ÷ 0.1 μCi/dm^3).

ACKNOWLEDGEMENTS

The authors would like to thank the following people of the ENEA Trisaia Center for their help in preparing this report: Dr T. Candelieri and Mr A. Gerardi.

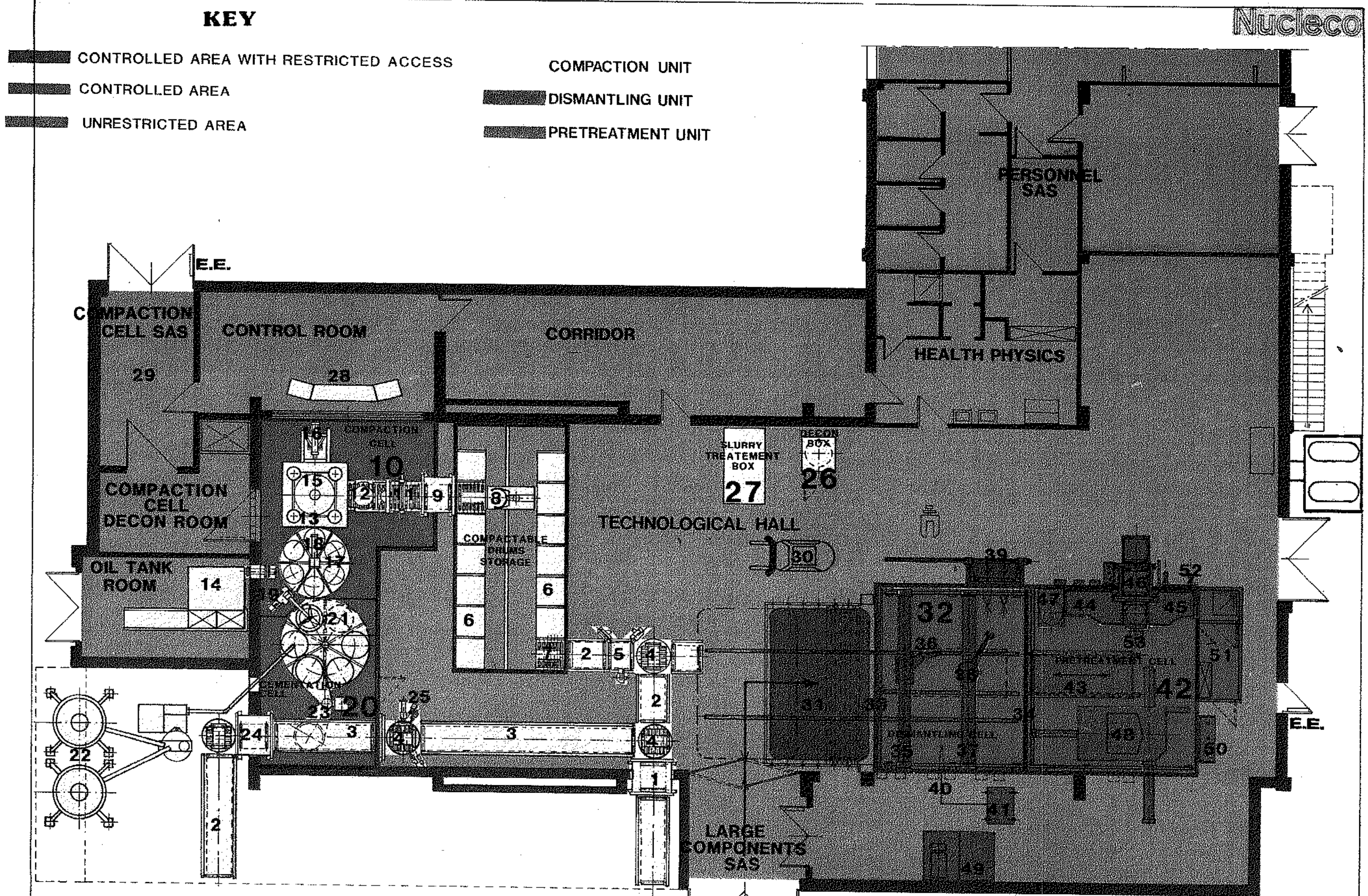


Fig.4.1 LAY-OUT OF COMPACTION AND DISMANTLING PLANT FOR LOW/MEDIUM LEVEL SOLID RADWASTES

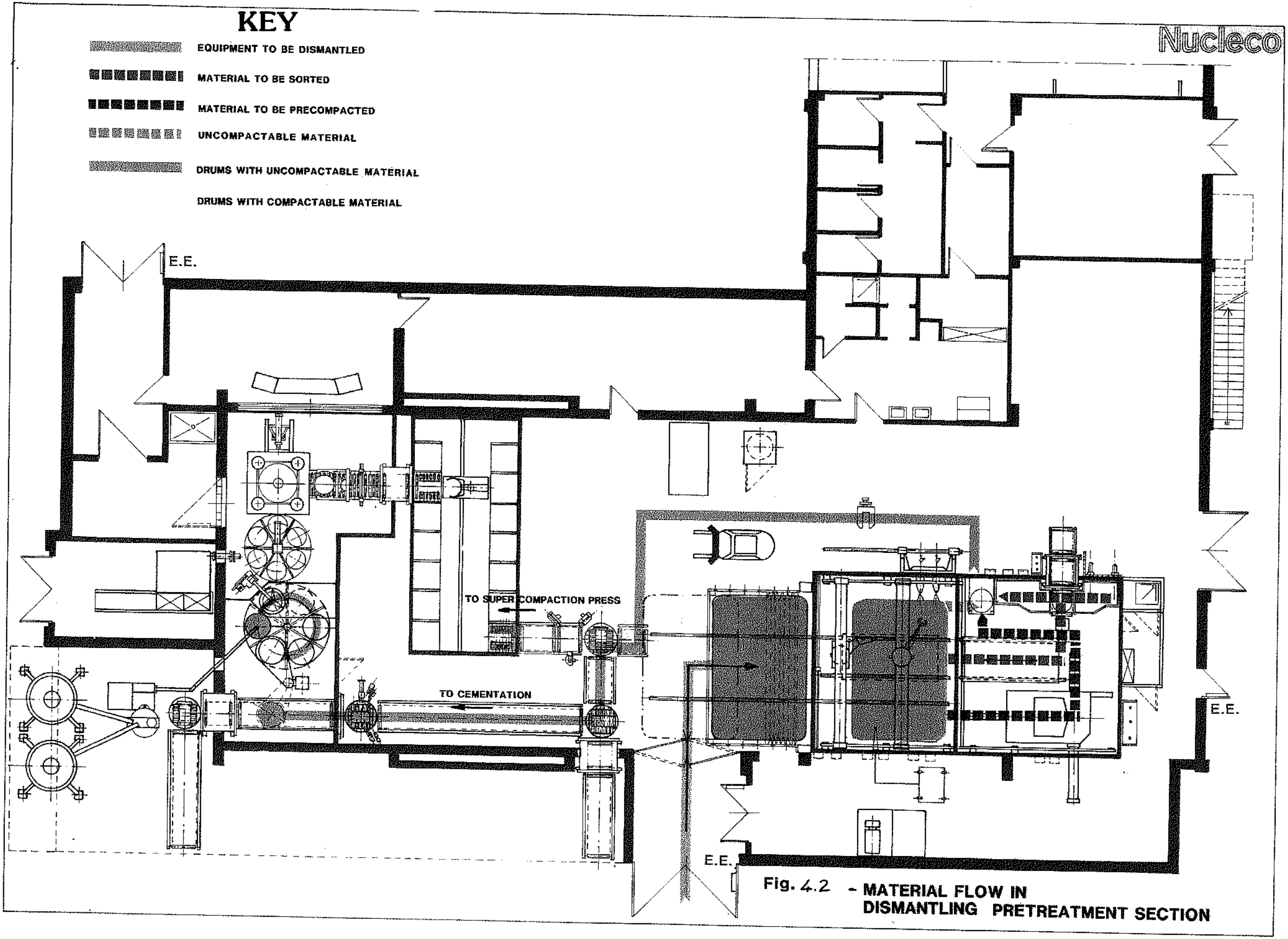


Fig. 4.2 - MATERIAL FLOW IN DISMANTLING PRETREATMENT SECTION

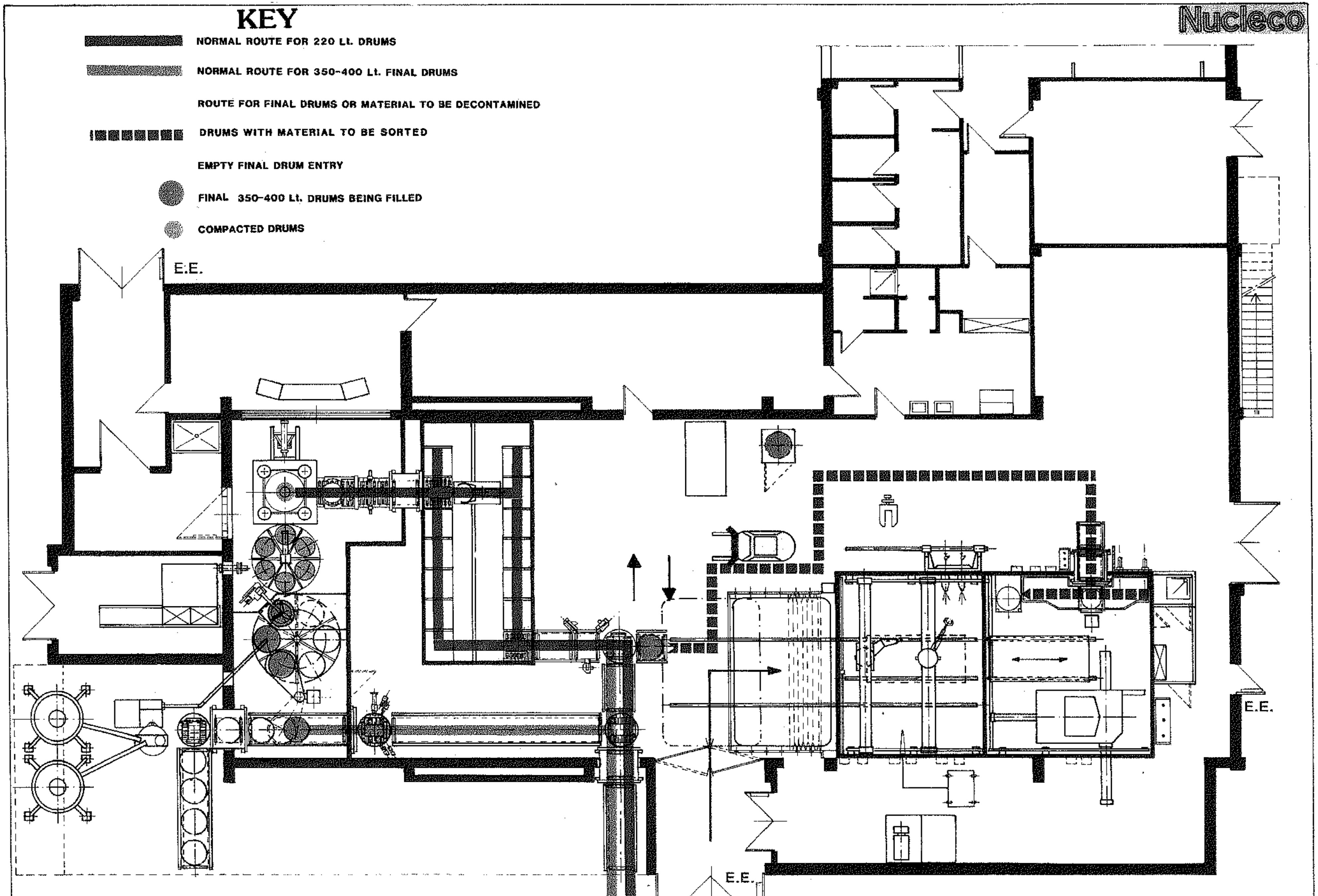


Fig. 4.3 - COMPACTION PLANT MATERIAL FLOW

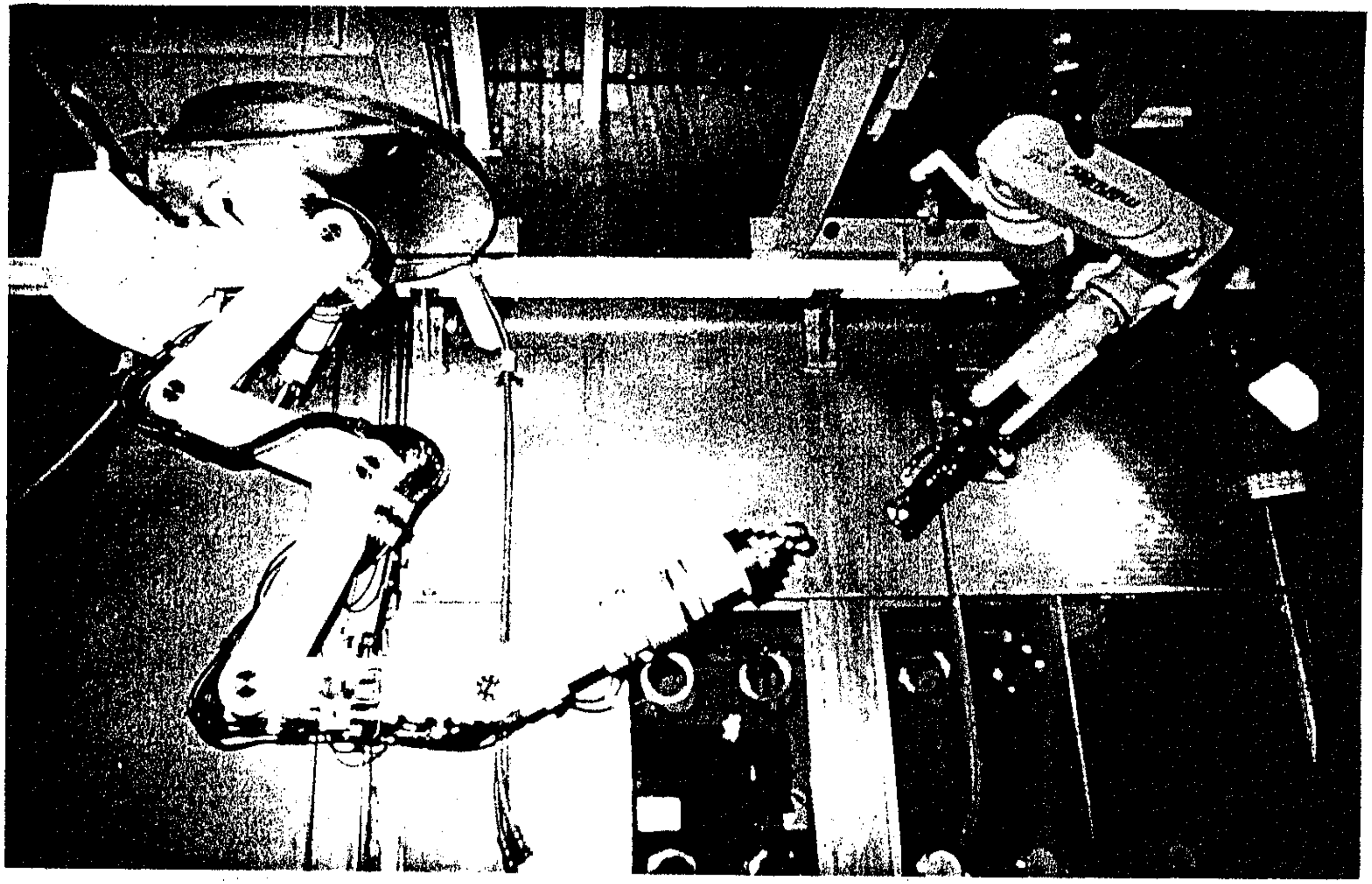


Fig. 4.4 Power master - slave manipulator and plasma - torch at the ICS - 42 dismantling section

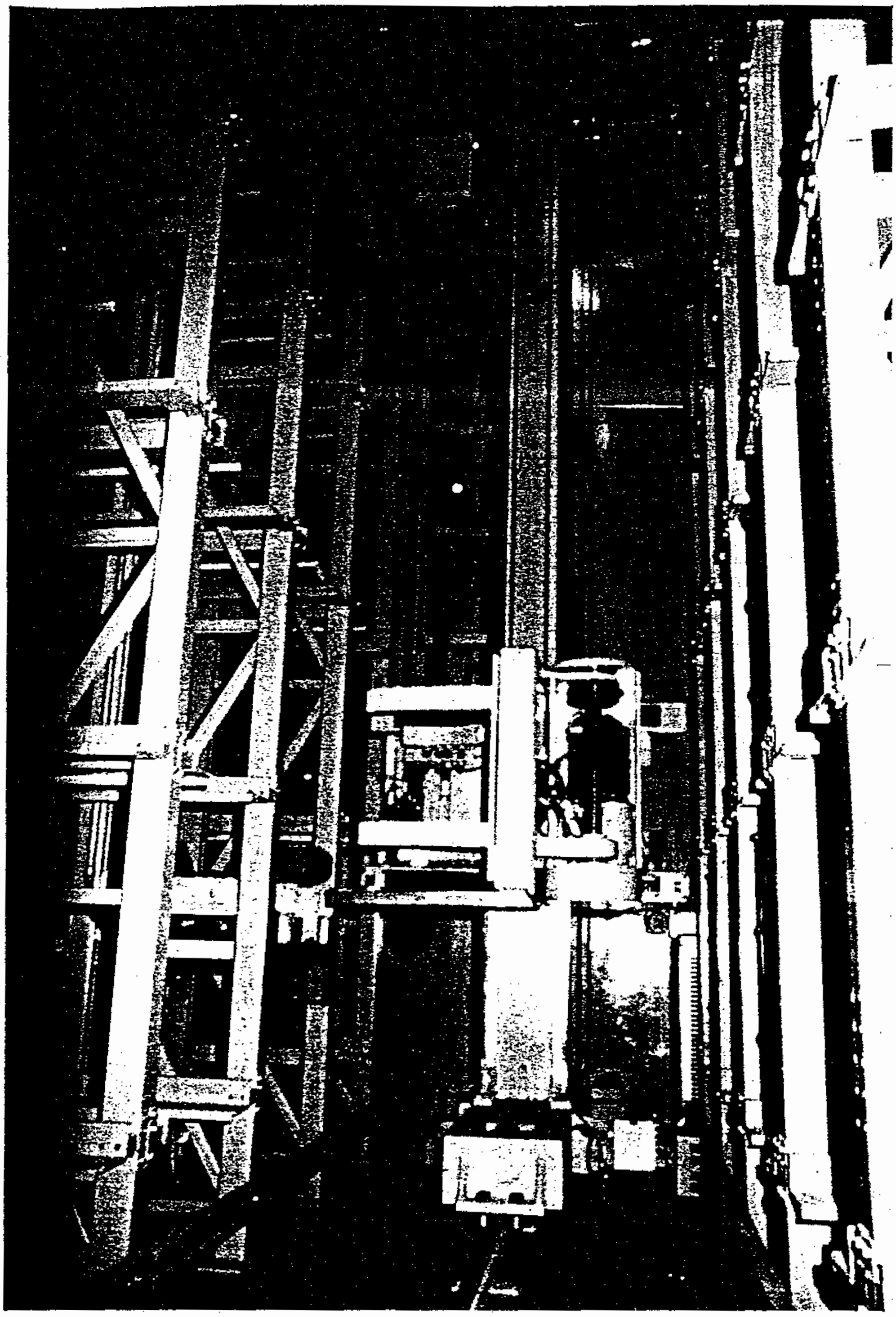


Fig. 4.5 Drums storage system of ICS - 42 plant

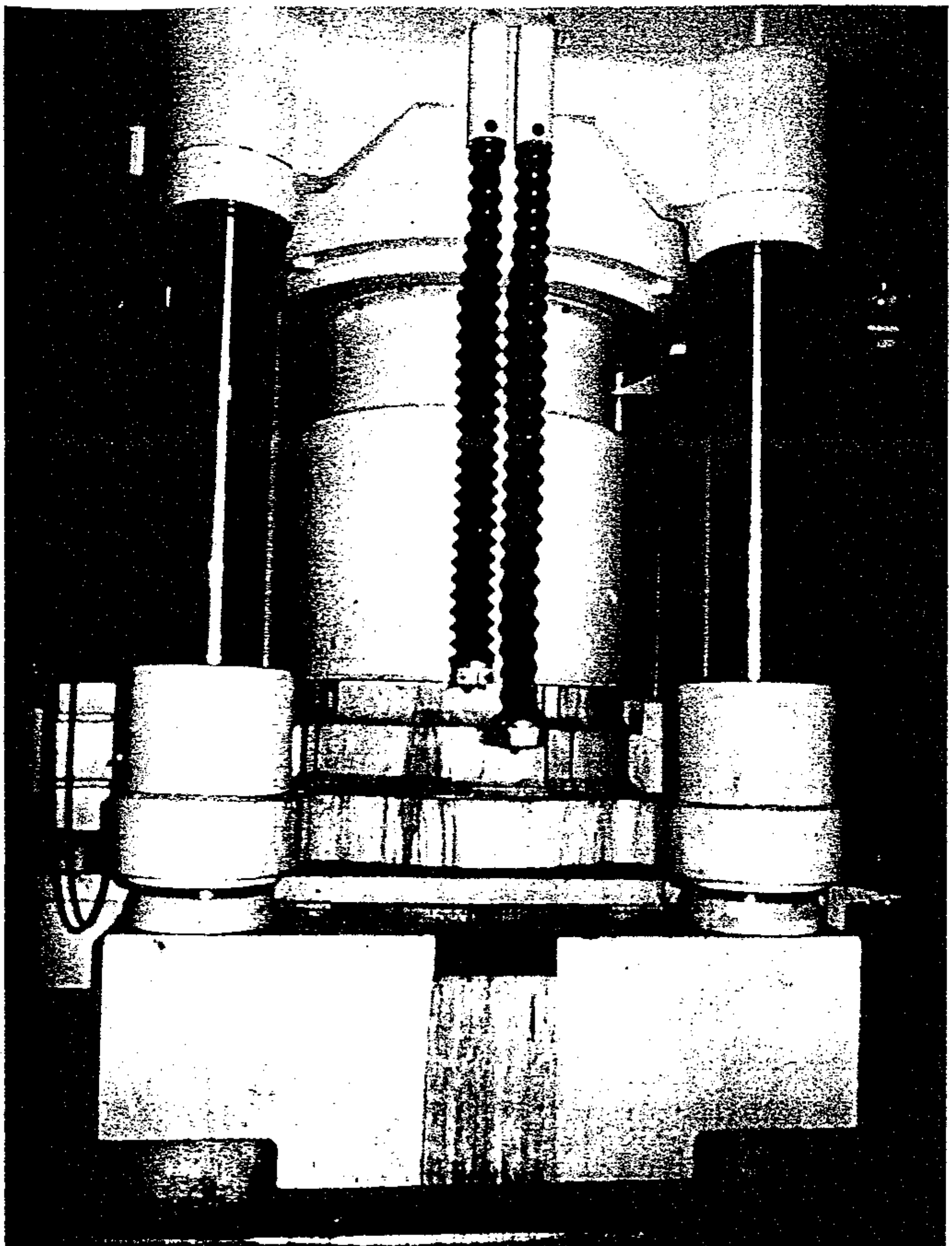


Fig. 4.6 Supercompaction head (15,000 kN)

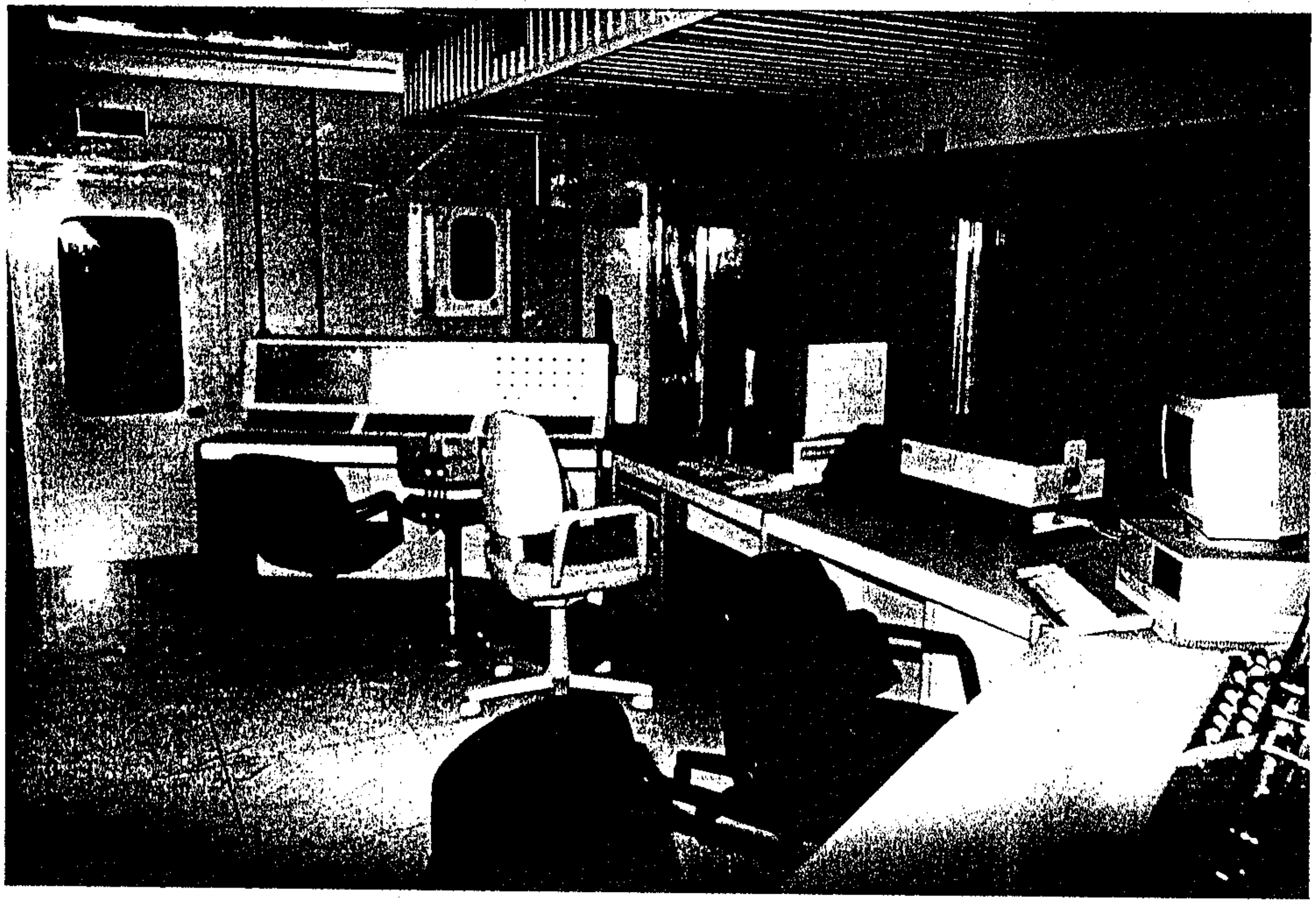
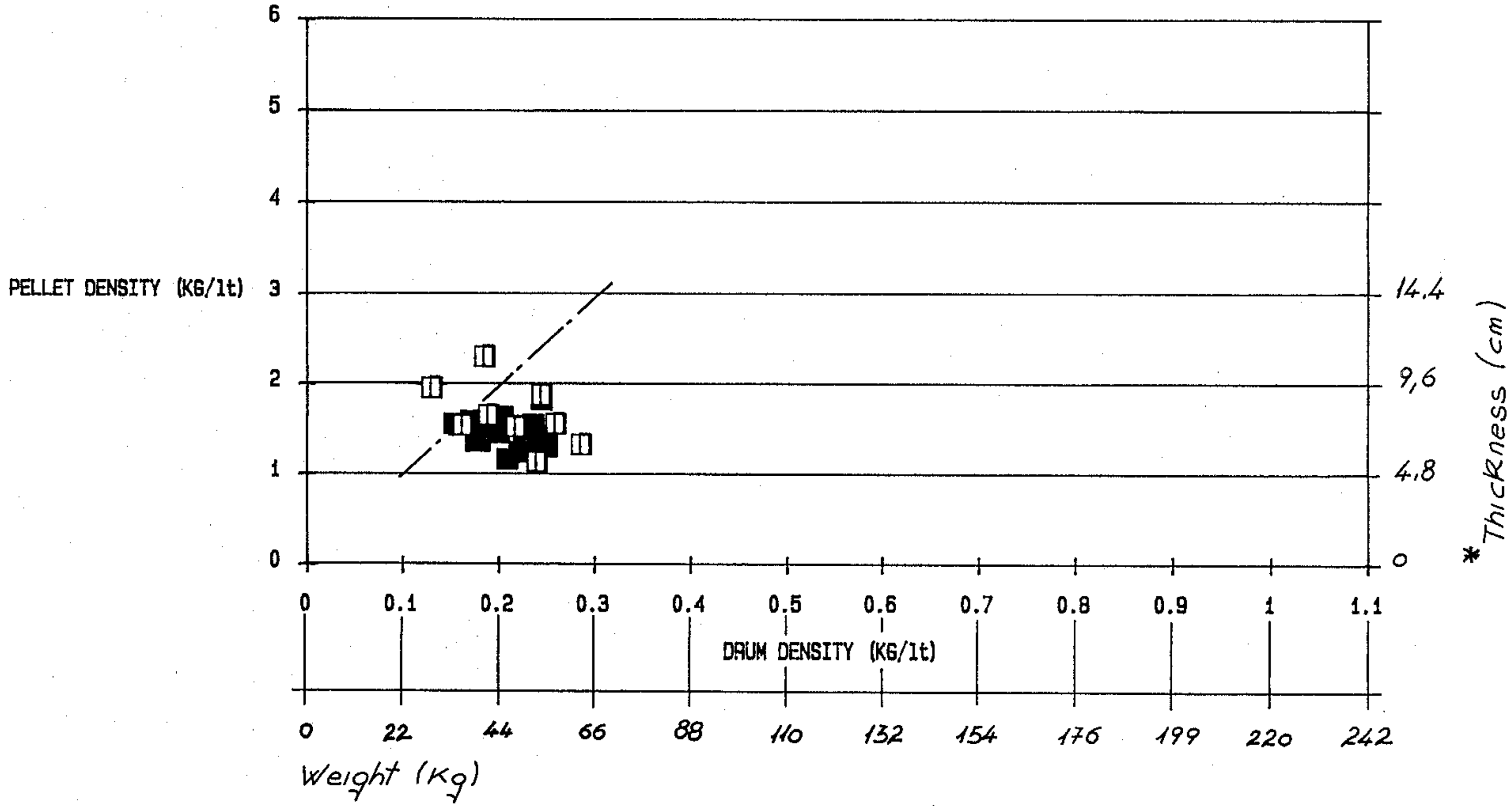


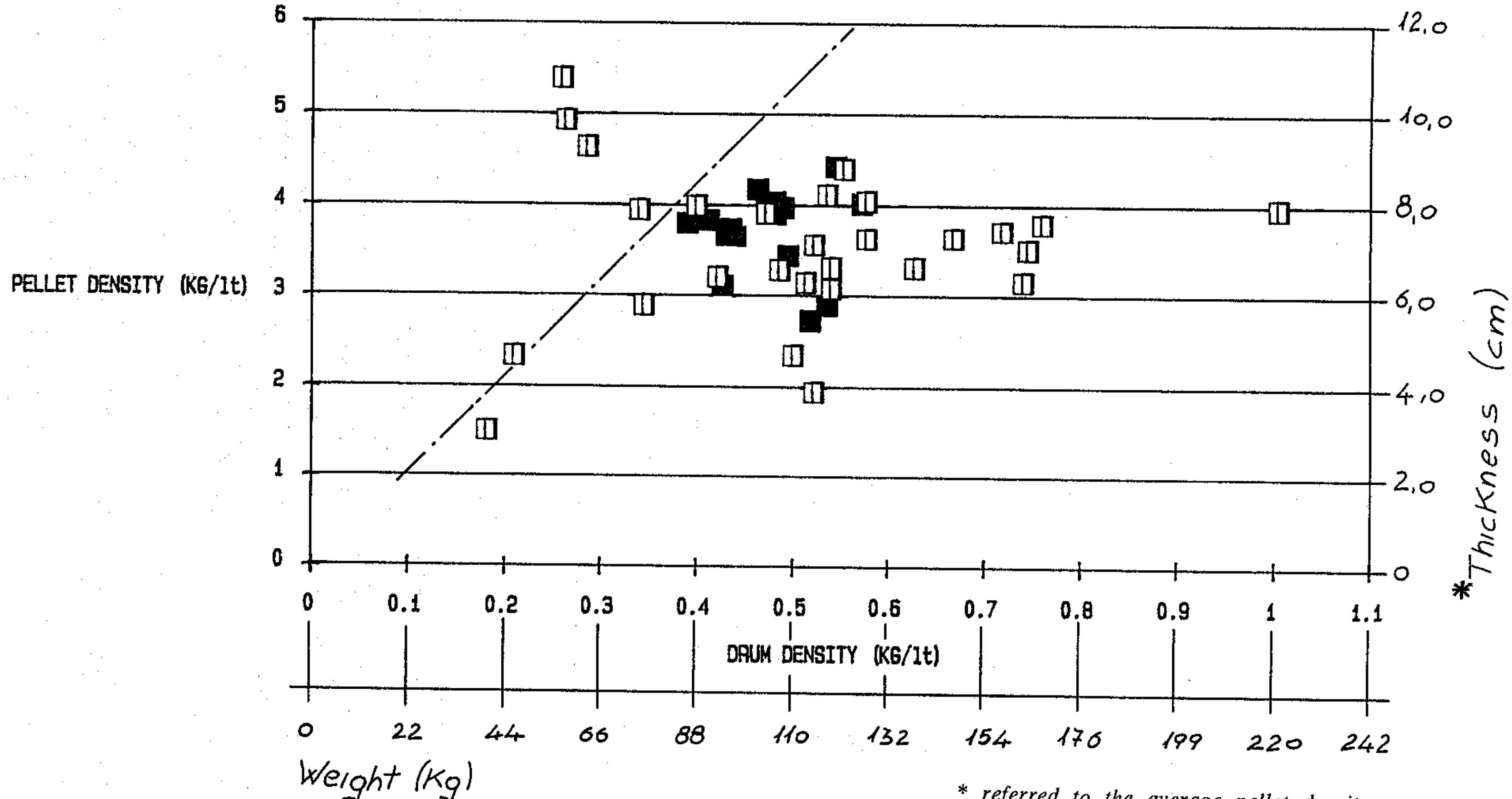
Fig. 4.7 ICS - 42 plant: control room

Fig. 5.1. I C S 42 COLD TEST - Pellet density versus drum density - Type 1 (papers , plastics , pvc , etc .)



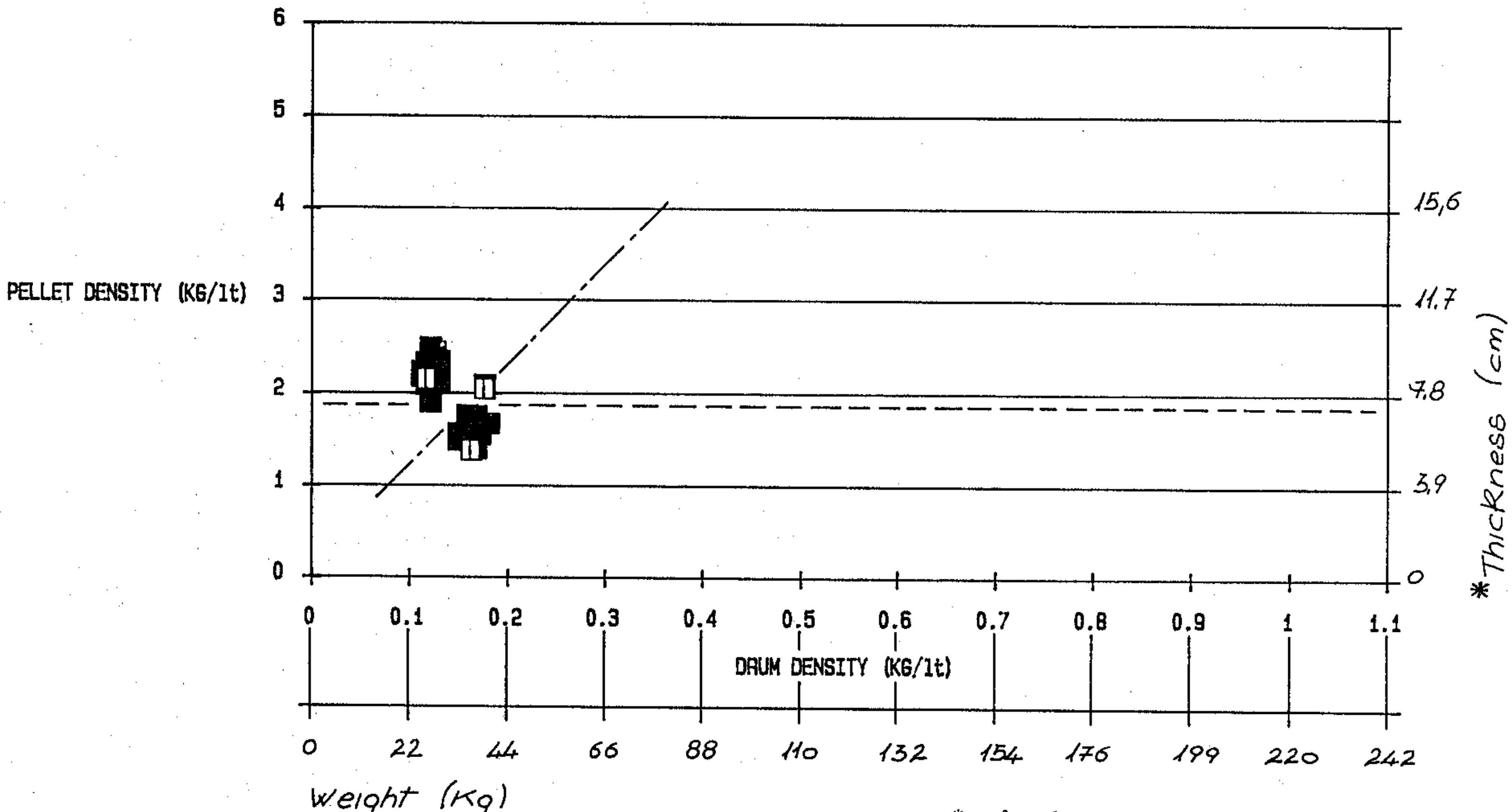
* referred to the average pellet density

Fig. 5.2. I C S 42 COLD TEST - Pellet density versus drum density - Type 4 (steel drum dismantled and precompacted at 200 t



* referred to the average pellet density

Fig. 5.3. ICS 42 COLD TEST - Pellet density versus drum density - Type 9 (absolute filter with wood and metallic frame)



* referred to the average pellet density

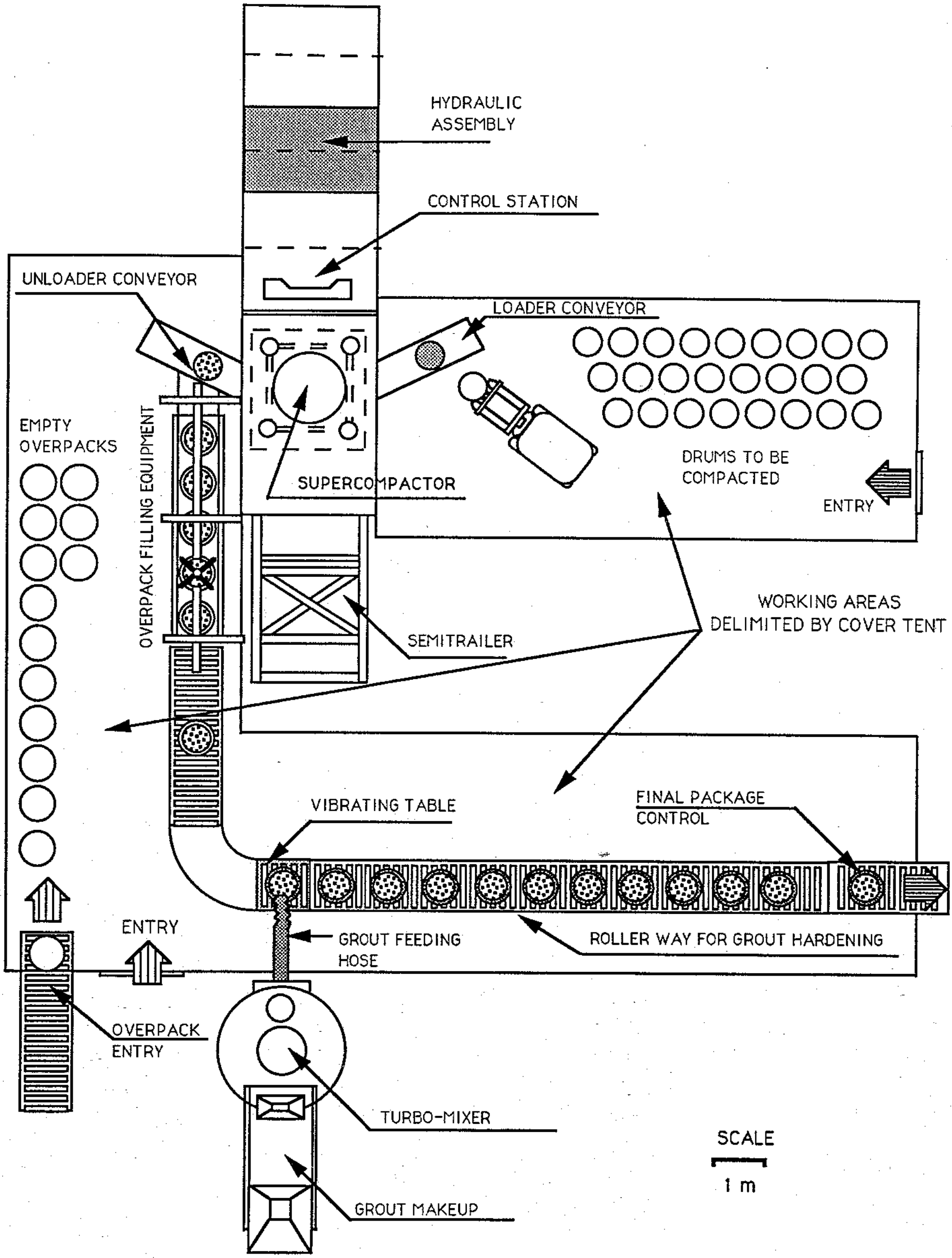


Fig. 6.1 Process lay-out of the supercompaction and conditioning facility at the ENEA Trisaia Center