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**GLOSSARY OF ACRONYMS**

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## I DATE GENERALE

**Denumirea obiectivului de investiții:**

**Centrala Nucleară Cernavodă Unitățile 3 și 4**

**Amplasamentul Obiectivului și adresa:**

Centrala Nuclearoelectrică Cernavodă este situată la 160 Km est de București și este amplasată în județul Constanța, la cca. 2 Km sud-est de limita orașului Cernavodă, la cca.3 Km nord-est de prima ecluză a Canalului Dunăre-Marea Neagră (CDMN) și a fost proiectată să funcționeze cu 5 Unități CANDU de câte 700 MWe.

**Proiectantul lucrărilor:** Consorțiu de management de proiectare și inginerie (participanți tradiționali: AECL-Canada, Ansaldo - Italia, SITON - România).

**Titularul proiectului:** PCO (Project Company)  
Compania de proiect creată de S.N  
Nuclearoelectrica S.A împreună cu investitori privati  
din tara si strainatate.

**Valoarea estimativă  
a lucrărilor:**

8 miliarde lei ( 2, 2 miliarde € la cursul din  
31.03.2006)

**din care pentru protecția mediului, inclusiv refacerea cadrului natural după  
terminarea lucrărilor: 4.826.722 lei (1.391.650 € la cursul din 31.03.2006)**

**Perioada de execuție estimată :** 64 luni/unitate

**Data punerii în funcțiune planificată:** mijlocul anului 2013 pentru U3 și  
prima jumătate a anului 2014  
pentru U4

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## II. DATE SPECIFICE PROIECTULUI

### II.1 Oportunitatea Investiției

#### II.1.1 Strategia energetică a României

Documentul "Strategia de Dezvoltare Economică a României" stabilește ca direcție principală asigurarea creșterii economice pe baza creșterii investițiilor, cu participarea semnificativă a capitalului național și atragerea capitalului străin, în special sub forma unor investiții directe astfel încât ritmul mediu anual de creștere a produsului intern brut (PIB) să se situeze între 4 și 6%.

Dezvoltarea economică prevăzută impune dezvoltarea corespunzătoare a sectorului energetic.

Astfel, pornind de la evoluția prevăzută a PIB, de la evoluția populației și de la necesitatea reducerii intensității energetice cu 30-50% a rezultat pentru perioada până în anul 2015 o producție necesară de energie electrică de 64,9 TWh în anul 2010 și de 72,9 TWh în anul 2015.

În privința strategiei energetice a României în documentul "Strategia de Dezvoltare Economică a României" sunt cuprinse recomandările din Cartea Verde a Uniunii Europene "Spre o Strategie Europeană bazată pe Securitatea Alimentării cu Energie". De asemenea strategia energetică are în vedere atât concluziile Summitului European din primăvara acestui an referitoare la necesitatea unei politici europene comune în domeniul energetic cât și politicile și strategiile de dezvoltare durabilă a sectorului energetic în Europa Centrală și de Est, zonă în care sectorul energetic este caracterizat de:

- existența de rezerve scăzute;
- dependența în mare măsură de combustibilul importat, în special petrol și gaze naturale;
- necesitatea asigurării securității energetice;
- necesitatea menținerii deschise a tuturor opțiunilor energetice pentru a asigura securitatea furnizării și pentru a acoperi cererea din ce în ce mai mare;
- maximizarea producției indigene de energie prin utilizarea resurselor disponibile inclusiv din surse regenerabile și asigurarea mixului optim energetic, strategie aprobată la Lisabona de Consiliul Europei;
- necesitatea creșterii eficienței folosirii energiei și reducerea substanțială a intensității energetice;
- necesitatea reducerii substanțiale a impactului negativ asupra mediului determinat de sectorul energetic în special în contextul Protocolului de la Kyoto prin exploatarea tehnologiilor curate (energia nucleară, energiile regenerabile, cogenerarea );

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Pe lângă particularitățile sectorului energetic din Europa Centrală și de Est menționate, strategia energetică a României are în vedere structura acuală a capacităților existente și a posibilităților de reabilitare sau scoatere din funcțiune, procesul de privatizare și consolidarea unei piețe libere și transparente de electricitate integrate regional precum și realizarea viitoarei piețe integrate de electricitate din Europa.

Pornind de la elementele strategiei energetice menționate mai sus în tabelul II.1-1 este prezentată structura producției de energie electrică în perioada 2005-2015 pe diferite tipuri de centrale iar în tabelul II.1-2 sunt prezentate puterile prevăzute a fi instalate în aceeași perioadă.

**TABEL II.1-1 STRUCTURA PRODUCȚIEI TOTALE DE ENERGIE ELECTRICĂ ÎN PERIOADA 2005-2015 PE DIFERITE TIPURI DE CENTRALE (TWh)**

Tipul de centrală	Anul		
	2005	2010	2015
Centrale termoelectrice pe hidrocarburi	14,43	13,09	14,95
Centrale termoelectrice pe cărbune (hulă și lignit)	23,83	23,93	18,59
Centrale hidroelectrice	17,0	17,2	18
Centrala nuclearelectrice	5,34	10,68	21,36
<b>TOTAL</b>	<b>60,1</b>	<b>64,9</b>	<b>72,9</b>

**TABEL II.1-2 PUTEREA ELECTRICĂ CE URMEAZĂ A SE INSTALA ÎN PERIOADA 2006-2015 (MW)**

Tipul de centrală	Perioada		
	2006-2010	2011-2015	Total
1. Capacități reabilite			
1.1 Termică	2060	210	2270
2. Capacități noi			
2.1 Termică	1445	500	1945
2.2 Hidro	200	200	400
2.3 Nucleară	707	1414	2121

### **II.1.2 Politica României privind energia nucleară**

Ca viitor stat membru al Uniunii Europene politica României privind energia nucleară trebuie privită în strânsă corelare cu politica Uniunii Europene

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Din acest punct de vedere vom menționa principalele concluzii și mesaje ale ENA ( European Nuclear Assambly) desfășurată la Bruxelles în luna martie a acestui an:

- energia nucleară reprezintă o alternativă viabilă și necesară pentru o dezvoltare durabilă a Uniunii Europene acoperind în prezent 33% din necesarul de energie electrică al acesteia;
- energia nucleară poate contribui decisiv la securitatea furnizării de energie electrică în Europa;
- energia nucleară corespunde în totalitate cerințelor privind impactul asupra mediului și are o contribuție semnificativă la combaterea schimbărilor climatice ;
- pe termen scurt și mediu sunt disponibile soluții tehnologice moderne și sigure pentru realizarea de centrale nucleare;
- energia nucleară este competitivă în raport cu alte forme de producere a energiei iar pe perioade previzibile este caracterizată printr-o mare stabilitate a costurilor de producție comparativ cu energia produsă pe bază de combustibili fosili;
- construcția de noi unități nucleare devine un fapt real și rezonabil în tot mai multe țări;
- percepția și acceptarea publică față de energia nucleară este tot mai consistentă și pozitivă.

Vom menționa totodată că studiile de perspectivă asupra prognozelor energetice pe termen lung realizate recent de Consiliul Mondial al Energiei și de Agenția Internațională de Energie atestă necesitatea ca energetica nucleară, împreună cu alte forme de energie, să participe la asigurarea cererii mondiale de energie.

Scenariile realiste anticipează că în anul 2050, în țările care vor să rămână competitive și să aibe o alimentare sigură cu energie electrică va fi necesară o capacitate instalată în centrale nucleare electrice de cca. 1500 GWe față de 370 GWe existentă astăzi.

Având în vedere cele de mai sus și în condițiile în care s-a dovedit de-a lungul celor cca. 10 ani de exploatare comercială a Unității 1 de la Cernavodă că domeniul energiei nucleare din România este un domeniu cu o tehnologie sigură, cu rezultate excelente în securitatea nucleară, eficiența economică și protecția mediului ambiant, Guvernul României și-a asumat o serie de angajamente pe termen lung referitoare la dezvoltarea în continuare a energiei nucleare. În această ordine de idei, pe lângă punerea în exploatare a Unității 2 de la CNE Cernavodă prevăzută pentru mijlocul anului 2007, este prevăzută realizarea la CNE Cernavodă până în anul 2015 a Unităților 3 și 4.

România și-a dezvoltat infrastructura națională necesară implementării, managementului și reglementării proiectelor de energetică nucleară. Este evidențiat în același timp percepția pozitivă față de energia nucleară din partea

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populației și a autorităților locale, numeroase ONG<sup>uri</sup> fiind favorabile acestora: ROMATOM, AREN, SRR<sub>p</sub>, CNR-CME, ANCER și altele.

Totodată politica națională de securitate nucleară armonizată cu cerințele europene este o garanție a unui program viabil de energetică nucleară al țării.

### **II.1.2.1 Centrala de la Cernavodă**

România și-a dezvoltat sectorul energetic nuclear, ca pe o alternativă viabilă la celelalte tehnologii. Centrala Nuclearo-Electrică a fost concepută initial să cuprindă 5 unități nucleare CANDU de 700 MW fiecare. Alegerea tehnologiei CANDU a avut în vedere posibilitățile industriei românești, pentru asimilarea producerii combustibilului nuclear, a D<sub>2</sub>O și a echipamentelor necesare. Reactorul CANDU este caracterizat printr-un înalt grad de securitate nucleară, așa cum s-a dovedit de-a lungul anilor, asigurând un nivel de producție corespunzător, în deplină concordanță cu standardele internaționale.

#### *Unitatea 1*

Unitatea 1 a CNE Cernavodă este singura unitate în exploatare comercială, din cele cinci unități aflate în diverse stadii de execuție care alcătuiesc CNE Cernavoda. Funcționarea comercială a Unității 1 a început în luna octombrie 1996. Puterea de proiect nominală instalată a acestei unități este de 706,5 MW, iar puterea netă este de 655 MW. Din momentul începerii funcționării comerciale, Unitatea 1 a produs aproximativ 37 TWh de electricitate, atingând un factor de capacitate mediu de peste 87%.

#### *Unitatea 2*

Punerea în funcțiune a Unității 2 de la CNE Cernavodă, reprezentând o prioritate națională, este prevăzută pentru mijlocul anului 2007. Finalizarea lucrărilor și punerea în funcțiune are la bază un contract de management de 4 ani încheiat de S.N Nuclearoelectrica S.A cu companiile AECL-Canada și Ansaldo - Italia, intrat în vigoare în martie 2003.

Cu darea în exploatare comercială a Unității 2, cele două unități de la CNE Cernavodă vor furniza împreună circa 20% din necesarul de energie electrică actual al României.

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### **II.1.3 Realizarea Unităților 3 și 4 de la CNE Cernavodă**

Proiectul CNE Cernaoda Unitatea 3 a fost inregistrat in Foaia de parcurs in domeniul energetic din Romania, aprobata prin Hotararea Guvernului nr. 890/2003.

Evolutiile contradictorii de pe piata energiei, inregistrate la sfarsitul anului 2005, au determinat Guvernul Romaniei sa recomande Ministerului Economiei si Comertului cresterea ponderii energeticii nucleare in mixul energetic prin promovarea concomitenta a Unitatilor 3 si 4 de la CNE Cernavoda.

Studiul de fezabilitate realizat de SN Nuclearelectrica SA impreuna cu consultantul sau financiar Deloitte – Romania a analizat viabilitatea tehnica si economica a proiectului finalizarii concomitente a unitatilor 3 si 4 de la CNE Cernavoda si a concluzionat ca proiectul poate fi realizat de o companie de proiect formata prin asocierea SNN cu investitori privati.

In prezent sub conducerea Ministerului Economiei și Comerțului se desfășoară negocieri cu potențialii investitori in vederea structurarii unei companii de proiect care sa finalizeze si sa opereze Unitatile 3 si 4 de la CNE Cernavoda. Inceperea lucrărilor este prevazuta pentru anul 2008. Exploatarea comercială a Unității 3 este preconizată pentru jumătatea anului 2013 iar a Unității 4 în prima jumătate a anului 2014.

#### **II.1.3.1 Evaluarea strategică a finalizării Unităților 3 și 4**

Principalele avantaje ale României, obținute din folosirea energiei nucleare sunt următoarele:

- Prin caracteristicile sale, sunt oferite soluții optime pentru o dezvoltare susținută, pe termen mediu și lung, în special prin creșterea siguranței alimentării cu energie și independența, aproape totală, conferită prin stabilitatea costurilor de producere;
- Energia electrică, produsă fără emisii gazoase nocive, contribuie la păstrarea unui mediu curat, și la respectarea cerințelor Protocolului de la Kyoto la care România a aderat;
- Această energie electrică permite utilizarea instalațiilor românești din domeniul fabricării combustibilului nuclear și a apei grele;

Prețul combustibilului nuclear de pe piața internațională a rămas constant în ultimii 20 de ani și se preconizează să rămână constant în continuare. Dacă prețul combustibilului crește chiar cu 50%, efectul asupra prețului energiei electrice de origine nucleara este sub 5%.

Functionarea CNE Cernavoda cu 4 unități de același tip, are beneficii economice majore din punctul de vedere al funcționării și întreținerii

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România a ales tehnologia CANDU, punând accent pe producerea în țară a combustibilului nuclear, D<sub>2</sub>O și a unor echipamente și materiale. Astfel, industria nucleară ofera un mare număr de locuri de muncă și utilizează capacitățile locale, deja implicate în programul nuclear. Domeniile cu experiență în aplicarea tehnologiei CANDU din România sunt următoarele:

(a) Producerea combustibilului

SNN filiala FCN Pitești a fost autorizată de ZPI din Canada cu care ocazie și-a îmbunătățit tehnologia de fabricare a combustibilului de tip CANDU din uraniu natural. În mod obișnuit, aceasta furnizează combustibil Unității 1, care se află în funcțiune și își va spori producția pentru a face față cerințelor celorlalte unități. Adăugarea unui număr mai mare de unități CANDU va spori eficiența acestei fabrici, conducând la costuri de combustibil mai scăzute.

(b) Producerea apei grele

Fabrica de apă grea de la Drobeta Turnu Severin poate produce anual aproximativ 170 tone de apă grea, oferind cantitatea de apă grea necesară unei unități de tip CANDU 6, la fiecare doi ani și jumătate. Alte unități CANDU vor mări eficiența tehnico-economică a acestei unități.

(c) Industria românească de execuție a componentelor nucleare

Prin implicarea în Unitățile 1 și 2 fabricanții români și personalul de execuție au dobândit experiența, care să le permită fabricarea de componente pentru proiectul CANDU 6. Acest program va permite companiilor să-și mobilizeze resursele pentru continuarea și dezvoltarea execuției componentelor nucleare în România.

(d) Unitatile de proiectare

Institutede românești, cum ar fi CITON, ICIM și ISPE, au dobândit o experiență importantă în proiectarea și evaluarea diferitelor aspecte ale centralelor de tip CANDU, jucând un rol important în aceste activități. Proiectul de detaliu pentru Unitatea 2 (C2) a fost realizat pe baza unui raport complet de mediu pentru C2, care a fost folosit pentru demonstrarea satisfacerii cerințelor internaționale referitoare la acest proiect. Capacitatea sporită a acestor institute, precum și lucrările lor pentru C2 le va permite să dețină un rol important pentru execuția Unităților 3 și 4 de tip CANDU din România.

(e) Operarea și întreținerea

Datorită experienței obținute în timpul execuției și punerii în funcțiune a Unităților 1 și 2, personalul român, cu înaltă calificare în domeniul tehnic de conducere a proiectului, va putea executa aceleași lucrări la Unitățile 3 și 4.

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(f) Stadiul actual al Unităților 3 și 4

Amplasamentul Cernavoda a fost, inițial, autorizat pentru cinci unități de tip CANDU 6. Au fost deja edificate clădirile celor cinci reactoare, iar utilitățile vor fi asigurate de la frontul fix (apă demineralizată, apă de incendiu, apă potabilă, aer comprimat, abur, apă caldă, gaze).

Utilizarea acestei infrastructuri existente va avea drept rezultat reducerea costurilor legate de finalizarea proiectului.

Se estimează că pentru Unitatea 3 lucrările hidrotehnice executate, alimentarea cu apă și canalizarea sunt realizate în proporție de 49%, în timp ce construcțiile civile atât pentru partea nucleară cât și pentru partea clasică sunt realizate într-un procent de cca. 52%. La Unitatea 4 partea de construcții civile este realizată în proporție de aproximativ 15%.

(g) Avantajele suprapunerii parțiale a perioadelor de construcție a două unități la Cernavodă

Finalizarea Unității 2 de la Cernavodă poate oferi avantaje importante pentru reluarea și finalizarea lucrărilor la Unitățile 3 și 4 în cazul în care personalul de la unitățile de construcții-montaj ar putea fi transferat de la Unitatea 2 la Unitățile 3 și 4 prin reducerea costurilor cu demobilizarea-mobilizarea și limitând pierderile de personal calificat .

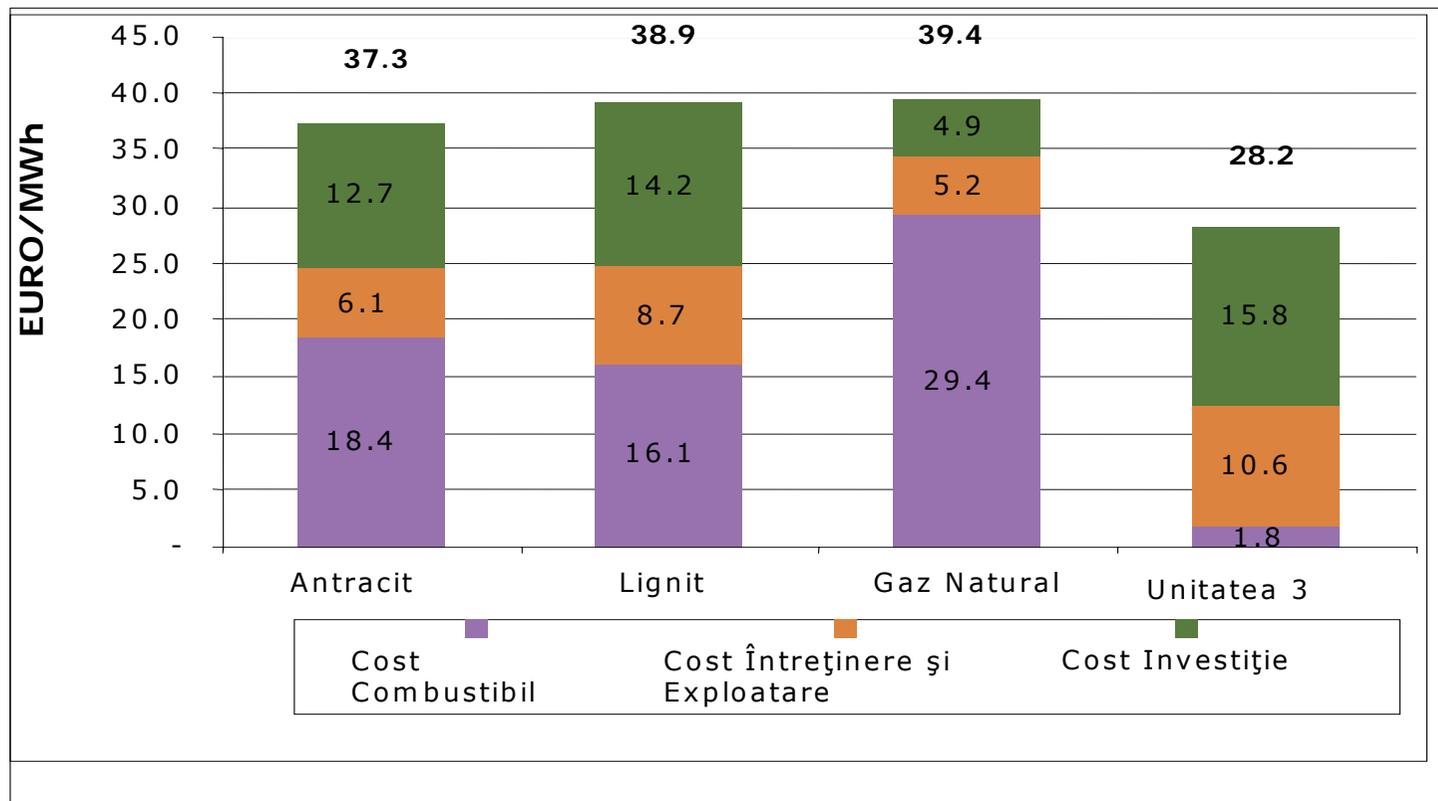
Graficul Unității 2 arată că duratele activităților legate de lucrările la partea mecanică și la cea electrică pot fi reduse la 15 luni și respectiv la 24 de la data efectivă a încheierii contractului. Dacă graficul Unităților 3 și 4 și procurarea reperelor cu durată mare de fabricație sunt coroborate astfel încât lucrările de execuție la Unitățile 3 și 4 să poată începe la aceleași termene, ar fi posibilă mutarea personalului Subcontractorului de la U2 la U3 și U4 reducând astfel, costurile cu demobilizarea/mobilizarea, limitând pierderile de personal calificat și cu experiență deja în șantierul Cernavodă.

(h) Evaluarea alternativelor

A fost efectuată o analiză în condițiile specifice din România pentru o centrală ipotetică de cca. 706 MW putere instalată considerând diferite scenarii privind tehnologia utilizată de producere a energiei electrice ca alternative la soluția nucleară.

Figura II.1-1 prezintă costurile actualizate cu o rată de scont de 5%.

Figura II.1-1 Costurile de producție actualizate cu o rată de scont de 5%\*



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\* Aceste costuri nu includ costurile externe (cum ar fi costurile de mediu) pentru toate opțiunile cu excepția opțiunii nucleare care include costurile de management a deșeurilor și de dezafectare precum și costurile de depozitare ca și costuri interne.

Aceste rezultate arată că costurile de producere a energiei electrice într-o centrală utilizând gaz natural pot fi mai mari decât costurile de producere a energiei electrice în centrale utilizând lignit sau antracit.

Explicația acestui fapt o constituie evoluția prețului gazului natural din ultima perioadă care are un impact mare în structura prețului de cost de producere (83% din costul de producere într-o centrală utilizând gaz natural este reprezentat de costul combustibilului; comparativ, pentru o centrală utilizând antracit costul combustibilului reprezintă cca. 58% din costul de producere).

Costul actualizat al unității de energie electrică într-o centrală utilizând gaz natural este similar cu cel dintr-o centrală utilizând antracit. Explicația rezidă în investiția mai mică într-o centrală utilizând gaz natural în comparație cu investiția într-o centrală utilizând antracit.

Costul actualizat al unității de energie electrică pentru acest Proiect este mai scăzut decât cel al altor forme de producere a energiei electrice ilustrând faptul că tehnologia nucleară ar putea avea avantaj din punctul de vedere al costului (în aceleși condiții ale pieței) comparativ cu celelalte tehnologii.

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## I. GENERAL DATA

### Project Name:

**Cernavoda Nuclear Power Plant Units 3 and 4**

### Site Location:

Cernavoda Nuclear Power Plant is located at 160 km East from Bucharest in Constantza County, at about 2 km South-East from Cernavoda Town boundary and about 3 km North-East from the first airlock of the Danube-Black Sea Channel (CDMN). The Plant was designed to operate with 5 X CANDU 700 MWe units.

**Project Designer:** Design and Engineering Management Consortium – AECL (Canada), Ansaldo (Italy), SITON (Romania).

### Project Owner: PCO (Project Company)

Project Company created by SN SA together with the private investors from country and abroad.

**Estimated Works Value:** 8 billion. lei (2.2 million Euros at the rate on March, 31,2006)

**Out of which :** 4,826,722.00 lei ( 1,391,650.00 Euros at the rate on March, 31,2006) for environment protection, including landscaping works after finalizing the works.

**Estimated construction time-period:** 64 months/unit

**Planned commissioning date :** Unit 3 - middle of 2013;  
Unit 4 – first half of 2014.

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## **II. DESIGN SPECIFIC DATA**

### **II.1 Opportunity of the Investment**

#### **II.1.1 Romania's Energy Strategy**

The document titled : Romania's Economic Development Strategy" is stating the economic growth of the country as the main direction , relied on the increase of investments within which the major contribution is represented by the national investments and attraction of foreign investments, specially in the form of direct investments so that the annual gross domestic product ( GDP) average rate fall in 4 to 6%.

The predicted economic growth is imposing the proper development of the energy domain.

So, starting from the predicted evolution of GDP , from the population growth and from the necessity to reduce the power intensity by 30-50%, for the period until 2015, an electric energy production of 64.9 TWe in the year 2010 and 72.9 TWe in the year 2015 need to be provided.

As regards the energy strategy of Romania, the above mentioned document is including the recommendations from the EU Green Chart - " To an European Strategy Based on Energy Supply Safety". Also, the energy strategy is considering both the conclusions of the European Summit ( held this spring) on the necessity to have a common European policy in the energy field and the policies and strategies for the sustainable development of the energy field in Central and Eastern European countries, an area in which the energy domain is characterized by :

- the existence of low energy resources;
- the dependence, to a great extent, on the imported fuel, specially oil and natural gas;
- the necessity to provide the energy safety;
- the necessity to maintain open all the energy options for to make safe the supply of energy and for to cover the ever growing demand;
- the maximization of the domestic energy production by the use of the available resources, including the renewable ones, and the provision of an optimum energy mix, a strategy approved by the European Council in Lisbon (Portugal);
- the necessity to enhance the efficiency in using the energy and the substantial reduction of the energy intensity;
- the necessity to drastically reduce the energy domain negative impact on the environment, specially considering the Kyoto Protocol, by the employment of clean technologies ( such as: nuclear, renewable, co-generation).

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Besides the above mentioned particularities of the energy domain in Central and East European countries, the national energy strategy of Romania is considering the current structure of the existing capacities and the possibilities of rehabilitation or decommissioning, the privatizing process and the strengthening of a free and transparent electricity market , regionally integrated, and the accomplishment of the future European integrated electricity market.

Starting from the elements of the above mentioned strategy, Table II 1-1 shows the structure of the electric power production in the period 2005 – 2015, broken down on different types of power plants while Table II .1-2 shows the power capacity predicted to be installed in the 2005 – 2015 period.

Table II 1-1 Structure of the total electric power production in 2005 – 2015 broken down on various types of power plants (TWh)

Type of Plant	2005	2010	2015
Oil Burn Thermal Plants	14.43	13.09	14.95
Coal Burn Thermal Plants ( bituminous coal & lignite)	23.83	23.93	18.59
Hydro Power Plants	17.0	17.02	18.0
Nuclear Power Plants	5.34	10.68	21.36
<b>TOTAL</b>	<b>60.1</b>	<b>64.9</b>	<b>72.9</b>

Table II.1-2 Electric Power to be installed in the period 2006 –2015 (MW)

Description	2006 2010	2011 2015	TOTAL
<b>1.REHABILITATED CAPACITIES</b>			
1.1 Thermal	2.060	210	<b>2.270</b>
1.2 Hydro			
<b>2. NEW CAPACITIES</b>			
2.1 Thermal	1.445	500	<b>1.945</b>
2.2 Hydro	200	200	<b>400</b>
2.3 Nuclear	707	1414	<b>2121</b>

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## II.1.2 Romania's Policy in Nuclear Power Field

As a future UE member state, Romania's policy in the nuclear power domain need to be closely harmonized with the policy of the European Union in the field.

From this viewpoint, here is below the main conclusions and messages of the European Nuclear Assembly (ENA) held in Brussels in March 2006 :

- nuclear power represents a reliable and necessary alternative for the EU sustained development , covering now 33% of the EU electricity demand;
- nuclear power can decisively contribute to the energy supply safety in Europe;
- nuclear power satisfies all the requirements regarding the environmental impact and significantly contributes to the mitigation of climatic changes;
- on short and medium term , modern and safe technologies are available for the construction of nuclear power plants;
- nuclear power is competitive related to other forms of energy generation and for predictable periods, it is characterized by a great stability of production costs, if compared to the energy produced with fossil fuels;
- the construction of new nuclear units becomes a real and reasonable fact in more and more countries;
- the perception and acceptance of the nuclear power by the public is more consistent and positive.

It is also worth mentioning that the studies on the long-term perspectives of energy, recently developed by the World Council of Energy and the International Agency for Energy, state the necessity that nuclear power along with other forms of energy, participate in the supply of the world energy demand.

The realistic scenarios are predicting that in the year 2050, in the countries that will to stay competitive and have a safe electric energy supply, an installed capacity of 1500 GWe is required, compared to the 370 GWe capacity existing today.

Considering the above and the experience and results gained along the 10 years of commercially operating Cernavoda NPP –Unit 1 , nuclear power domain in Romania proved to be a safe technology domain with excellent results in the fields of nuclear safety, economic efficiency and environment protection and therefore the Romanian Government has got involved in some long-term arrangements regarding the further development of the nuclear power domain. In line with that, besides the commissioning of Cernavoda NPP –Unit 2 (scheduled for the middle of the year 2007), Unit 3 and Unit 4 are planned to be finalized until 2015.

Romania has developed a national infra-structure required for the implementation, management and control of the projects in the nuclear power field. It is also worth pointing out the positive perception of the nuclear on the part of population and local authorities, many Non-Governmental Organizations ( ROMATOM, AREN,SRR,CNR-CME, ANCER, etc) showing a positive attitude towards the nuclear.

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Moreover, the national policy in the domain of nuclear safety, harmonized with the European requirements, is also a guarantee for a reliable nuclear energy program in Romania.

### **II.1.2.1 Cernavoda Nuclear Power Plant**

Romania has developed its nuclear as a reliable option to the other technologies. Cernavoda NPP was initially designed to include 5 CANDU units of 700 MW each. The selection of CANDU technology considered the possibilities of the Romanian industry to assimilate the production of the nuclear fuel, the heavy water and required equipment. CANDU reactor is characterized by a high degree of nuclear safety, as proved by the many years of operation, providing a satisfying electricity output in full compliance with the international standards.

#### **UNIT 1**

Cernavoda NPP – Unit 1 is the only commercial operation unit out of the 5 units that are now in various stages of construction on Cernavoda Site. The operation of the Plant Unit 1 started in October 1996. The installed rated power of the unit is 706.5 MW and the net power output is 655 MW. From the start of the commercial operation, Unit 1 generated about 37 TWh electricity, reaching an average capacity factor of 87%.

#### **UNIT 2**

Cernavoda NPP - UNIT 2 commissioning which is a national priority, is scheduled for the middle of the year 2007. Finalization of works and commissioning are based on a 4 year management contract concluded between SN Nuclearoelectrica and AECL (Canada)-Ansaldo(Italy) that became effective in March 2003.

Once the two units are commercially operated, Cernavoda Nuclear Power Plant – Unit 1 and Unit 2, will supply about 20% of today electric power demand in Romania.

### **II.1.3 Performance of units 3 and 4 from Cernavoda NPP**

Cernavoda NPP –Unit 3 Project is specified in the Road Map for the energy field in Romania approved by the Government Decision no. 890/2003.

The contradictory evolution on the energy market recorded at the end of the year 2005, have determined the Romanian Government to recommend to the Ministry of Economy and Trade, the increase of the nuclear energy weight within the energy mix by the promotion of the simultaneous finalization of Unit 3 and Unit 4 on Cernavoda Site.

The feasibility study accomplished by SN Nuclearoelectrica SA (SNN) along with its financial consultant ( Deloitte-Romania) have analyzed the technical and economic

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feasibility of the simultaneous finalization of the Project (Unit 3 & Unit 4 ) and reached the conclusion that the Project can be finalized by a design company by association of SNN with private investors.

At present, the Ministry of Economy and Trade is supervising the negotiations developing with potential investors for structuring a design company capable to finalize and operate Cernavoda NPP –Unit 3 & Unit 4. Start of the works is scheduled for the year 2008 and the commercial operation of Unit 3 is predicted to happen at the first half of the year 2013 and at the middle of 2014 for Unit 4.

### **II 1.3.1 The Strategic Evaluation of Unit 3 & Unit 4 Finalization**

The main advantages of Romania due to the use of nuclear power are the followings:

- Due to the nuclear power characteristics, optimum solutions are offered for a medium - and long - term sustainable development , specially by enhancing the energy supply safety and the almost total independence rendered by the stability of the production costs;
- The electric power generated by nuclear, noxious-emission –free, is contributing to the maintenance of a clean environment and the satisfaction of the requirements in the Kyoto Protocol , Romania has adhered to ;
- The electric power generated by nuclear allows the use of the Romanian installations dedicated to the fabrication of the nuclear fuel and heavy water;

The price of the nuclear fuel on international market , has showed no significant fluctuations for the last 20 years and it is predicted to stay constant on. If the price of the fuel is increasing, even by 50%, such an increase on the price of the nuclear-generated electricity will represent less than 5%.

The operation of Cernavoda NPP with 4 units of the same type, shows major economic advantages in point of operation and maintenance as well.

Romania chose CANDU technology bearing in mind and been focused on the production of the nuclear fuel, heavy water and some equipment and materials in the country .So, the nuclear industry has been offering a large number of jobs and has involved the local capacities already working in the nuclear program. The scope of proficiency in the application of CANDU technology in Romania are:

#### **a) Nuclear fuel production.**

FCN Pitesti , a SNN Branch , is licensed by ZPI (Canada) and has improved the technology for CANDU type nuclear fuel production from natural uranium. Currently, FCN Pitesti is the nuclear fuel supplier for Cernavoda NPP – Unit 1 which is in-service and it is to increase its production for to meet the demand for the other units as well. The addition of more CANDU units to Cernavoda NPP, will enhance the

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efficiency of the nuclear fuel fabrication plant, enhanced efficiency which will be reflected in the lower nuclear fuel costs.

b) Heavy water production

The Heavy Water Production Plant –Drobeta Turnu Severin can yearly produce about 170 tons heavy water, the quantity required for the operation of one CANDU type unit once every two and a half years. Other CANDU units will enhance the technical –economic efficiency of the Plant.

c) Romanian nuclear component fabrication units.

Getting involved in the implementation of Unit 1 and Unit 2, the Romanian manufacturers and construction personnel has got the experience required to fabricate the nuclear components for CANDU 6. Such a program will allow the companies to focus their resources to the continuation and development of the nuclear component fabrication in Romania.

d) Design units.

Romanian institutes such as SITON, ICIM and ISPE, have gained important experience in the design and assessment of various aspects related to CANDU type NPPs, playing an important role in the development of such activities. The Detail Design for Unit 2 ( C2) was finalized on basis of a thorough environmental report employed to demonstrate that the international provisions regarding the Project were implemented. The large capacity of the institutes and their works for C2, will allow them to have an important part in the construction of CANDU type Unit 3 and Unit 4 in Romania.

e) Operation and maintenance.

Due to the experience obtained with the construction and commissioning of Unit 1 and Unit 2, the Romanian personnel, highly technically skilled in the Project management, will be capable to implement the same kind of works like with Unit 3 and Unit 4.

f) Actual status of Unit 3 and Unit 4.

Initially Cernavoda Site was licensed for 5 CANDU-6 type units. The buildings of the 5 reactors have already been built and the units are to be supplied from the existing supplies (demineralized water, fire water, domestic water, compressed air, steam, hot water, natural gas).

The use of the existing infra-structure will result in lowering the costs related to the Project finalization.

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It is estimated that for Unit 3, the hydrotechnical works ( the water supply and ducting) are 49% finalized while the civil works associated to the nuclear part and classic part are about 52% finalized. In respect of Unit 4, the finalized civil works represent only 15%.

g) The advantages of the construction sequence partial overlapping at two Cernavoda units.

The finalization of Cernavoda NPP –Unit 2 may offer advantages for resuming the finalization process with U3 and U4 in the sense that the Construction - Installation personnel could be transferred from U2 to U3 & U4, reducing thus the costs related to new employees and limiting the migration of skilled personnel.

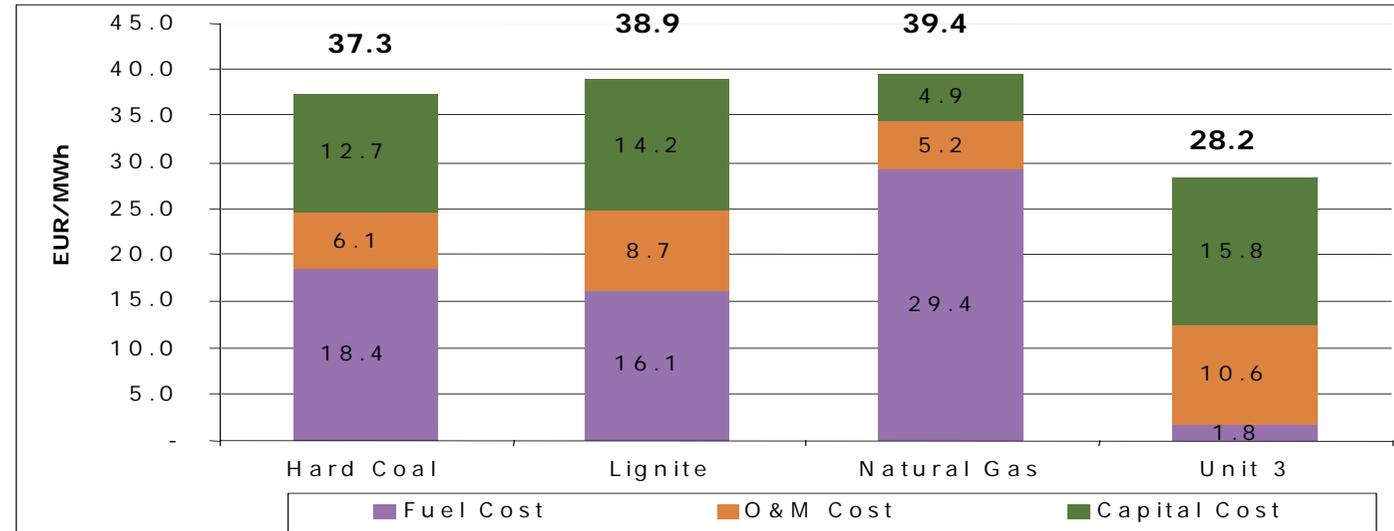
The U2 Schedule shows that the duration of activities related to mechanical and electric parts may be reduced to 15 months and 24 months, respectively, since the contract effective date. If Unit 3 & unit 4 schedules and the procurement of long-fabrication items are harmonized so that the construction works at U3 and U4 may start at the same dates, the shifting of U2 personnel to U3 and U4 will be possible and also accompanied by a cut-down of costs related to new employees and skilled personnel migration.

#### Evaluation of options

For the specific environment of Romania an analysis has been performed for an imaginary power plant of about 706 MW installed power considering various scenarios regarding the technology employed to produce the electricity as an alternative to the nuclear solution.

The figure below shows the levelised costs at a 5% discount rate.

Figure II.1-1 Levelised generation costs at 5% discount rate



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\* These costs exclude external costs (such as environmental costs) for all options except nuclear, which reflects waste management and decommissioning and disposal costs as internal costs.

These results underline the electricity generation cost for a power plant using natural gas could be higher than the electricity generation cost for a power plant using lignite or hard coal. The main reason for this is the natural gas price evolution in the last period which has a big impact in the generation cost structure (83% of the generation cost for a power plant using natural gas is represented by fuel cost; comparatively, for a power plant using hard coal the fuel cost accounts for 58% of the generation cost);

The levelized unit electricity cost for a power plant using natural gas is similar to a power plant using hard coal. The main reason for this is the small investment for a power plant using natural gas in comparison with the investment for a power plant using hard coal.

The levelized unit electricity cost for this Project basis is lower than the other forms of electricity generation, illustrating that nuclear generation technology should have a cost advantage (under the same market conditions) as compared to other technologies.

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## II. 2 Design Description

### II. 2.1 Overview

The nuclear power unit that makes the subject of herein Technical Documentation is the third and the four unit of Cernavoda NPP. The first unit was commissioned in December 1996 and the second one will be commissioned in year 2007. The commissioning of Units 3 and 4 is anticipated to be in year 2013, respective in year 2014.

The project of units 3 and 4 will take as reference design, the project of Unit 2 with modifications and improvements. The reviewed versions of design codes and standards, quality assurance and nuclear safety will be assumed.

Regarding the design solutions, along the preparation of the contracting works, both the modifications and improvements of the proposed design, will be analyzed by the designer of both AECL, NSP and ANSALDO BOP, as well as the possibility of implementing some modifications to WOLSUNG design 3 and 4, which will lead to the increase of performance and implicitly of power production supplied system.

The nuclear power plant, designed to operate at the base of load curve, has a turbo-generator that provides gross electrical power of 720 MWe, using the steam produced by the nuclear energy of a nuclear reactor CANDU-PHWR-6 type (Canadian Deuterium Uranium Pressurized Heavy Water Reactor) and 90 % a load factor.

This type of reactor is using heavy water both as moderator and coolant, in two separate systems. The fuel is natural uranium in form of uranium dioxide sintered pellets in zircaloy sheath forming fuel elements (pencils), and assembled in fuel bundles which contain 37 fuel elements each. The ceramic pellets have the property to confine the fission products within themselves.

The reactor fuel loading and unloading is continuous, bi-directional and with the reactor at power. The reactor is provided with a heat transport system with two independent loops which transfer the heat generated in the fuel during the controlled fission reaction, to four steam generators which contain light water. The saturated steam from the steam generators is expanding into the turbine, developing mechanical work and afterwards, passing through the condenser, the steam is cooled with light water taken from the Danube River via an open intake duct connected to Race 1 of the Danube - Black Sea Channel (CDMN).

The Figure II.2-1 and II.2-2 show the flowsheet of a CANDU NPP and of a reactor, respectively. The Table II.2-1 presents the general characteristics of Cernavoda NPP Unit 3 and Unit 4.

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Table II.2-1 General Nominal Design Characteristics - Cernavoda NPP Unit 3 and Unit 4

Number of Nuclear Reactors	1
Electrical Power to Grid	720 MWe
Fission Power (Thermal Power)	2180 MWt
Global Efficiency	28.9%
<b>Nuclear Reactor</b>	
Type	PHWR
Moderator and Reflector	D <sub>2</sub> O
Coolant	Pressurized D <sub>2</sub> O
Fuel	Natural UO <sub>2</sub>
Refueling	On-power, Bidirectional in Adjacent Fuel Channels
Refueling Direction	Coolant Flow Direction
Fuel Cycle	Non-recycle
Number of Fuel Channels	380
<b>Fuel Channels</b>	
Fuel Channel Length (including end fittings)	10.8 m
Reactor Core Coolant Flow	7.7 Mg/s
Reactor Inlet / Outlet Header Temperature	266 / 312 °C
Reactor Inlet / Outlet Header Pressure	11.04 / 10.3 MPa
<b>Pressure Tubes</b>	
Material	Zirconium - 2.5% Niobium Alloy
Minimum Inside Diameter	103 mm
Maximum Channel Power	6.5 MWt
Reactor Outlet Header Quality	3%
<b>Calandria Assembly</b>	
Total / Core Length	7.82 / 5.94 m
Number of Calandria Tubes / Material	380 / Zr-2
Inside Diameter (minimum) / Outside Diameter (maximum)	129 / 132.3 mm
<b>Primary Heat Transport System (PHTS)</b>	
Primary Coolant Inventory	133.18 Mg
Total Reactor Core Coolant Flow / Nominal Maximum Fuel Channel Coolant Flow	7.7 Mg/s / 24 kg/s
Number of Steam Generators (SG)	4
Steam Generators Type	Vertical U-Tube with Integral Steam Drum and Pre-heater
Primary / Secondary SG Design Pressure	10.03 MPa / 5.07 MPa
Primary / Secondary SG Design Temperature	318°C / 266 °C
Pressure at SG Inlet / Outlet Nozzle	9.9 MPa(a) / 9.6 MPa(a)
Temperature at SG Inlet / Outlet Nozzle	309°C / 266°C
Quality in SG Inlet / Outlet Plenum	4.4 %
Heat Transferred to H <sub>2</sub> O of Secondary System	2064 MWt
SG Feedwater Flow	958 kg/s
SG Feedwater Inlet Temperature (at Full Power)	187°C

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SG Blowdown Minimum / Maximum Continuous Flow	1 kg/s / 3 kg/s
Primary Heat Transport Pumps	4
Primary Heat Transport Pumps Type	Vertical, Centrifugal, Single Suction, Double Discharge
<b>Main Steam System</b>	
Number of Steam Pipes	4
Design Temperature / Pressure	266°C / 5.07 MPa
Number / Type of Main Steam Safety Valves (MSSV)	16 / Spring and Air Operated Valves
Pressure Setpoint for MSSV	5.0 ÷ 5.14 MPa
MSSV full Capacity	4,334,400 kg/h
Discharge	Atmosphere
Discharged Fluid	Saturated Steam
<b>Nuclear Fuel</b>	
Material	Sintered and Compacted Pallets of Natural UO <sub>2</sub>
Structure	<b>37 Fuel Pins Bundle</b>
Fuel Weight in Reactor: - UO <sub>2</sub> - U	96 Mg 84.5 Mg
Number of Fuel Pellets per Fuel Pin	36
Number of Fuel Bundles per Reactor Core	4560
Number of Fuel Bundles per Fuel Channel	12
Fuel Bundle Weight UO <sub>2</sub> / U	21.3 kg / 18.8 kg
Cold Fuel Bundle Length / Outside Diameter	495.3 mm / 102.4 mm
Fuel Bundle Nominal Power	800 kW
<b>D<sub>2</sub>O Management</b>	
System Inventory: - Moderator and Associated Systems - PHTS and Associated Systems - Fuel Handling System TOTAL	267.6 Mg 184.8 Mg 4.5 Mg 456.9 Mg
<b>Miscellaneous</b>	
Nominal Frequency	50 Hz
Frequency Variation for Nominal Operating Condition	± 1 Hz
Frequency Variation for Emergency Conditions	4% for very short term
Plant Lifetime	30 years
Plant Power Availability Factor	90%
Non-recoverable D <sub>2</sub> O	14.3 kg/day
Plant Internal Services Average Power	7 % Gross Power
Moderator Temperature at Calandria Inlet / Outlet	45°C / 69°C

## II. 2.2 General Arrangement

Characteristic for Cernavoda NPP Units is the location in a row of Unit 1 - Unit 4 reactors at 160 m center-to-center and the fact that each of the 5 units is independent.

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The center of Unit 5 reactor is located at 44.00 m misalignment from the center-to-center line that is connecting the centers of the first 4 reactors towards CDMN, aiming to locate Unit 5 on a foundation ground evidencing better siting conditions.

Each unit is a functionally independent assembly consisting of a nuclear part (NSP) with its auxiliaries and a classic part (BOP) with its auxiliaries.

Within Cernavoda NPP - Unit 5 enclosure there is an area that is technologically servicing the units and it is including items common to the 5 units (see the List of items common to the 5 units- GA Dwg, Sc 1:2000, code: U3/U4 - 08230-6024-CU/PG-6025-2-GA-0, Rew.0). The location (siting) area for these items is called: "Unit 0".

The activity of each independent unit is correlated with the activity developed in the common items positioned in "Unit 0".

The layout concept for all the units was so elaborated to functionally combine the two areas: "Unit 0" and the specific area of each unit.

All the buildings, warehouses and communication routes are arranged to form a optimum technological and architectural assembly. They are all located in safe conditions, separated from each other by minimum technological and protection distances that correspond to the technological and traffic flows in order to provide optimum construction and operation.

The Layout Drawing is arranging and planning all the buildings, installations and networks and their inter-relationships.

The location of the Plant items within the "Unit 0" Layout was solved on Unit 1 finalization.

The items specific to each unit were located so to define a "module" area that is repeated in each unit.

### **UNIT 3**

The location of Unit 3 items followed the same pattern like with Unit 1 and Unit 2.

The enclosure of Unit 3 has the following configuration:

- to the Intake Duct the enclosure is confined by Unit 3 Pump Station platform boundary;
- to Unit 2 Pump Station, the Unit 3 enclosure boundary is represented by the limit of the building segment associated to Unit 2 Pump Station;
- to Unit 4 Pump Station, the Unit 3 enclosure boundary is represented by the limit of the building segment associated to Unit 3 Pump Station;

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- to the access road in front of the reactors, the Unit 3 enclosure boundary is considered sideways to this road, towards Unit 3;
- the land area in front of Unit 4, positioned across the access road in front of the Unit 1- Unit 4 reactors up to the NPP secondary access road ;
- to Unit 2, the Unit 3 enclosure boundary follows the route of the road between U2 and U3 on the side towards U2 up to the 110 kV Station fence boundary;
- to Unit 4 , the U3 enclosure boundary follows the route of the road between U3 and U4 on the side towards U3 , up to Cismeaua Valley.

#### **UNIT 4**

Location of U 4 items is the same like for U1, U2 and U3.

Unit 4 enclosure has the following configuration:

- to the Intake Duct the enclosure is confined by U4 Pump Station platform boundary;
- to U3 Pump Station, U4 enclosure boundary is represented by the limit of the building segment associated to the Pump Station for U3;
- to U5 Pump Station, U4 enclosure boundary is represented by the limit of the building segment associated to Pump Station for U4;
- to the access road in front of the reactors, U4 enclosure boundary is considered sideways to this road, towards Unit 4;
- to Unit 3, U4 enclosure boundary follows the route of the road between U3 and U4 along the U3 side of the road up to the NPP enclosure boundary towards Cismeaua Valley;
- to U 5, U4 enclosure boundary follows the route of the road between U4 and U5 along U4 side of the road up to NPP enclosure fence boundary towards Cismeaua Valley;
- to Cismeaua Valley, U4 enclosure boundary is represented by NPP enclosure fence.

The El. +/- 0.00 of the buildings is the same for all the items positioned inside NPP enclosure and it is El. + 16.30 m dnMB.

The ground elevation within Unit 3 and Unit 4 areas is El. +16.00 m dnMB, the same with the elevation of Unit 5 platform.

The cold water supply source for the 5 units cooling water systems is the Danube River water via the Danube-Black Sea Channel (CDMN - Race 1), towards the Derivation Channel and the Water Intake (item 140) and next to the Intake Duct (item 141) and towards the Distribution Bay (item 047).

CDMN – Race 1, the Derivation Channel, the Intake Duct, the Distribution Bay, are all common to all NPP units.

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The cooling water required to NPP units is taken from the Distribution Bay via a block building that is housing all the Screen Houses, all the Pump Stations and all the Electric Stations of the units. The block building is divided into segments – one for each NPP unit. Each segment includes items specific to each unit.

So, the segment dedicated to Unit 3 includes the screen houses (for the circulation water and raw service water - items 048, 049), the pump stations (for the circulation water and raw service water - items 050, 051) and the electric station of the screen house (item 058).

All these items are providing the cleaning and pumping of water required for the operation of the circulation water system and raw service water system for U3.

The circulation water system is distributing the filtered raw water to the Turbine Hall (item 020) for the condenser cooling.

The raw service water system is distributing the filtered raw water to the Service Building (item 002) and the Turbine Building (item 020).

The discharge of the warm water (item 054) resulted from the condenser cooling and the other chillers in the Unit, is made via the associated hydrotechnical buildings and it can be directed (item 056 – Syphonating Bay and redirectioning) to CDMN- Race II or to the Danube (see Layout Dwg. Sc. 1:5000 U3/U4-08230-6024-CU/PG-6024-1-GA-1, Rew. 0).

Both the cold water intake system and the warm water discharge system are dedicated to each unit.

The Distribution Bay is also collecting the emergency water and fire water. The Pump Station building for the Emergency Water Supply (item 004) is a building common to U3, U4 and U5. The emergency water intake (item 010) is also common to U3, U4 and U5. The water pipe lines between the building common to U3-U4-U5 end the consumers as well as the electric cable routes for EWS are ensured to each unit.

The fire water intake, its Pump Station building (item 093), the associated tanks (item 094) are all common to all the NPP units and they are positioned in “Unit 0” area. The fire water pipe routes (AI) are particular to each of the units.

Item associated to U3, i.e. NSP and BOP items, are listed in “U3 specific items” presented on U3 enclosure General Arrangement Drawing, Sc 1:2000, code: U3/U4 - 08230-6024-CU/PG-6025-2-GA-0, Rew.0.

Items associated to U4, i.e. NSP and BOP items, are listed in “U4 specific items” presented on U4 enclosure General Arrangement Drawing, Sc 1:2000, code: U3/U4 - 08230-6024-CU/PG-6025-2-GA-0, Rew.0.

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Around the nuclear area of each unit, a shield (item 011) vertically penetrating down to the marl waterproofing layer and aiming to provide the control of the underground water beneath of the plant.

The cable channels associated to the electric network systems are both underground and aboveground, around Unit 3 and Unit 4.

The General Arrangement Drawing, Sc 1:2000, code: U3/U4 - 08230-6024-CU/PG-6025-2-GA-0, Rew.0, also shows the railways. Unit 3 and Unit 4 are not directly railway – connected from the existing railway, i.e. Saligny – Cernavoda Town railway.

The railway connection from U3 and U4 Turbine Halls can be done via U1 and U2 Turbine Halls. The railway passing through U1 Turbine Hall is extended up to Unit 4, passing through all the Turbine Halls of the other units.

The Transformer area is located in front of the Turbine Hall and it includes the Self Service Transformer Block (item 030), Power Discharge Transformer Block (item 031) and the related railways (item 033) required to handle the transformers for inspection, maintenance and repair. In front of Unit 3 and Unit 4 Turbine Halls, there will be a connection between the railway entering the Turbine Hall and the runway for Unit 3 & Unit 4 transformers.

The roads and vehicle platforms inside Unit 3 and Unit 4 enclosure are so sized to provide the circulation of vehicles carrying the equipment necessary to the Plant systems and of Fire Brigade intervention teams vehicles.

The road in front of Unit 3 and Unit 4 is a segment of the access road in front of Unit 1 to Unit 4 reactors. This road is providing the safe transport of the spent fuel by trailer from the Spent Fuel Bay of each Unit to the Spent Fuel Intermediate Storage Facility (DICA). The width of the road is 8.00 m.

The road between the Units is 6.00 m wide and it is used for transport during the construction- installation work periods as well as during the operation of the Units.

The curvature radius of the roads are calculated in function of the size of vehicles travelling inside the NPP enclosure during the construction-installation works and during operation.

Each of the Unit 3 and Unit 4 enclosure shall be individually fenced by wire- mesh fences with metal pillars. The solution was adopted for fencing both Unit 1 and the Spent Fuel Intermediate Storage (DICA).

The vehicle access into Unit 3 and Unit 4 enclosure is made from Medgidia Street via the Secondary Access Road to NPP and along the road in front of Unit 1 - Unit 4 reactors.

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The surface and juridical status of the land for Unit 3 and Unit 4 are the followings:

- the land used for Unit 3 is part of Cernavoda NPP enclosure and it was expropriated along with the land associated to Cernavoda NPP – Unit 5;
- the land is owned by SNN-SA as proprietary according to the Certificate of Land Propriety Right Assignment, Series MO3, no. 5415, issued by the Ministry of Industry and Resources on April, 25, 2000.

Out of the projects presented within the above – mentioned design, the common projects for Units U1 and U4 are presented in list 1. The projects corresponding to units 3 and 4 investment are specified in list 2, while the projects included in the services provided by SNN are presented in list 3.

## List 1

### COMMON OBJECTS FOR UNITS U1 AND U4

#### IN THE ENCLOSURE

- 038** Common Services Channels and Cable Ducts
- 047** Distribution Pool
- 075** Pipe Support
- 097** Pump Stations, stage I and stage II
- 098** Sewage Water Pipe System including the Pump Station
- 130** Intermediate Storage Facility of Radioactive Wastes

#### OUT OF ENCLOSURE

- 140** Water Intake
- 141** Cooling Water Admission Canal
- 142** Hot Water Discharge Canal
- 143** Hot Water – Cold Water mixture canal
- 150** Special structures and hydrotechnical works for site protection
- 153** Secondary Acces Road
- 154** Guard House
- 157** Outer Equipment Warehouse (Seiru Area )
- 165** Guard House for NPP Security Personnel (Saligny )
- 166** Suspended Power Line for Power Supply (20kV)
- 261** Hydro Power Station (12 MW) on Cernavoda NPP  
Hot Water Dischage Duct

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**List 2**

**OBJECTS CORRESPONDING FOR UNITS 3 AND 4 INVESTMENT**

**IN THE ENCLOSURE**

- 035** High Voltage Station (110 kV) for Common Service Power Supply
- 036** Transformers for Common Service High Voltage Power Supply Station
- 037** Transformers for Common Service Power Supply
- 057** Service Water Network
- 092** Drinking Water Distribution Pipe Network
- 095** Fire Water Distribution Pipe Network

**OUT OF ENCLOSURE**

- 142** Hot Water Discharge Canal
- 145** Grid Connection
- 146** Telex, phones, weak current connections
- 155** Canteen (in Cernavoda Town)
- 263** 400 kV Transformer Block
- 266** 110kV Electric Power Station Cernavoda NPP

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**List 3**

**OBJECTS INCLUDED IN THE SERVICES PROVIDED BY SNN  
FOR UNITS 3 AND 4**

**IN THE ENCLOSURE**

- 024** Water Treatment Plant
- 025** Common Service System Transformers
- 062** Raw Water Supply System
- 063** Raw Water Supply Systems
- 065** Auxiliary Boiler Station
- 066** Liquid and Oil Fuel Discharge Ramp
- 067** Liquid and Oil Fuel Pump Station – Stage I
- 068** Liquid and Oil Fuel Pump Station – Stage II
- 069** Motor Oil and Light Fuel Warehouse
- 071** Transformer and Turbine Oil Warehouse
- 072** Lubricator Warehouse
- 073** Emergency Diesel Station for Common Services
- 076** Process Piping for Liquid and Oil Fuel
- 077** Hydrogen Production Station
- 078** Technical Gases Warehouse (H<sub>2</sub>, CO<sub>2</sub>, He, N)
- 079** Oxygen and Acetylene Warehouse
- 080** Equipment Warehouse
- 081** Equipment Storage Platform
- 082** Maintenance Workshop and Warehouse
- 084** Motor Oil Separator
- 086** Motor Oil Supply for Common Service Diesel Group (object 073 )
- 090** Drinking Water Pump Station
- 091** Drinking Water Tanks
- 093** Fire Water Pump Station
- 094** Fire Water Tanks
- 096** Fire Cabinet and Ambulance Station
- 125** Spent Fuel Interim Storage Facility

**OUT OF ENCLOSURE**

- 131** Meteorological Tower
- 132** Housing for Meteo Tower Electronic Equipment
- 133** Environmental Radiological Monitoring Laboratory
- 134** Electric Connection to Meteo Tower
- 142** Hot Water Discharge Canal

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### II.2.3 Buildings and Structures

Buildings and associated structures of Cernavoda NPP Unit 3 and Unit 4 are shown in General Arrangement Drawing, Sc 1:2000, code: U3/U4 - 08230-6024-CU/PG-6025-2-GA-0, Rew.0 .

#### Reactor Building (objective 001)

The Reactor Building (R/B) process function is to support and to protect against the natural phenomena and the external events, the nuclear systems and equipment. R/B, also, acts as a shield against radiation for the external environment, and maintains the radioactive material leakage rate below the allowable limits (0.5% of the containment atmosphere volume/ day at the 124 kPa design pressure).

The containment represents the 4<sup>th</sup> protection physical barrier against the radioactive releases to the environment. The Reactor Building structure is designed to an internal pressure of 124 kPa, a value which is higher than the value corresponding to the Design Basis Accidents, DBA, that imply radioactive release, namely, large LOCA coincident with dousing system partial unavailable. The containment still maintains its structural integrity in case of main steam line break (MSLB) inside containment coincident with partial unavailability of dousing system.

The building houses the nuclear reactor and its control and auxiliary systems, the primary heat transport system, main moderator system and part of the special safety systems.

The R/B consists of the following main pre-stressed concrete structures: base slab and containment. The containment is made up of a cylindrical perimeter wall having internal diameter of 41.46 m and thickness of 1.07 m, and a spherical dome that closes the cylinder in the top end. The containment inside separation is made by internal reinforced concrete structures.

On the upper part of the R/B there is also a tank that consists of a spherical reinforced concrete dome, parallel to the R/B dome, and surrounded by a ring beam, with the inner surface covered by a epoxy liner and reinforced by glass fibber. The tank stores the required water inventory for accident conditions, necessary for dousing system, for emergency core cooling system, as well as for the make up water of the steam generators secondary side, whether a total loss of feed water supply event occurs.

In order to minimize the radioactive releases to the environment, the R/B inside surface is covered with a seal coating based on synthetic resins.

The R/B is seismically qualified at DBE (Design Basis Earthquake).

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### **Service Building (objective 002)**

The Service Building is a multifunctional structural assembly located adjacent to the Reactor Building, irregular in shape and with a differentiated loading condition, determined by the functional and size requirements of each area.

Service Building is a cast-in-place reinforced concrete infrastructure and a seismically braced steel superstructure, closed by thermal isolation coated steel panels.

The building houses: the main control room (MCR), D<sub>2</sub>O moderator purification system, ECCS Low Pressure heat exchangers and pumps, spent fuel bay cooling system, R/B ventilation system, electric equipment and I&C associated to Cernavoda NPP-Unit 3, emergency plan coordinating room, spent fuel reception bay and spent fuel storage bays, liquid radioactive waste tanks and spent resins vaults, heavy water management structures, warehouses, workshops, change-rooms, decontamination center and labs.

S/B is seismically qualified at DBE, so that it maintains its structural integrity, it prevents the failure of the inside seismically qualified systems if a seismic event occurs and, it provides personnel access for the operation or maintenance of such seismically qualified systems.

The connection between the S/B and the R/B internals is made via the equipment and personnel airlocks.

### **Main Integrated Building (objectives 020, 021, 022)**

The Main Integrated Building, separated from S/B by an interface building, includes the Turbine Building, the Deaerator Building and the Electric Bay and it is made of a cast-in-place reinforced concrete infrastructure and a metallic superstructure.

The Turbine Building houses the turbine, the electrical generator, the condenser and their associated auxiliary systems (instrumental air, feedwater to the steam generators, etc).

The Deaerator Building and Electric Bay accommodate the deaerator, the auxiliary equipment and the electric power distribution equipment.

The interface building (K-L area), objective 007, is separating the BOP (Turbine Building) from NSP (Service Building). This building is seismically qualified to DBE so that, in case of an earthquake, it maintains its structural integrity and S/B structures or seismically qualified systems are not damaged.

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### **Cooling Water Pump House (objectives 050, 051)**

The Cooling Water Pump House accommodates the turbine condenser cooling water pumps, the raw service water pumps, the fire water pumps and their associated auxiliaries.

Cooling Water Pump House is made up of cast-in-place reinforced concrete infrastructure and metallic superstructure covered with concrete prefabricated plates. It is provided with some common systems aimed to clean the Danube raw water from dirt and prevent the floating particle intrusion into the circulating water system and the raw water system.

The building is seismically designed according to the Romanian Standard P100 - 81.

### **Solid Radioactive Waste Interim Storage Facility (objective 130)**

The Solid Radioactive Waste Interim Storage Facility (DIDR) is located in the physical protection area of Cernavoda NPP - Unit 1, on NE direction, on the left branch of Cismeaua Valley and it is common to several units. It consists of the main storage hall for general waste packages, the spent filtering cartridges storage and the quadricell.

The general waste storage hall is made of reinforced concrete panels at its lower part and light panels, at the upper part, the roof being made of metallic trusses and ROMPAN type panels.

The spent filtering cartridges storage facility is a building of reinforced concrete, with concrete slab roof, provided with 126 storage enclosures for the filtering cartridges. The quadricell is a reinforced concrete structure with concrete slab roof, provided with 8 storage enclosures. The filtering cartridges storage and the quadricell are seismically qualified to DBE, and the general radwaste storage hall is seismically designed according to Romanian standard P100 -92.

### **Building of Emergency Power Supply and Secondary Control Room (objective 005)**

The building of Emergency Power Supply and Secondary Control Room (EPS - SCR) is located in the vicinity of the Reactor Building.

The building houses the emergency power supply system consisting of two Diesel generator sets and of their auxiliary systems, as well as the equipment of SCR, which is aimed to ensure the main nuclear safety functions accomplishment, should the Main Control Room become unavailable. The two areas, EPS and SCR, are separated through a reinforced concrete wall.

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The building has a reinforced concrete infrastructure and a metallic superstructure. In the SCR area, there is a building basement. The building is seismically qualified at DBE.

### **Building of High Pressure Emergency Core Cooling System (objective 006)**

This building houses the equipment consisting of 2 vertical tanks with light water and a horizontal tank filled with gas, along with their auxiliaries.

The building of High Pressure Emergency Core Cooling System (HP-ECCS) is located near the R/B and is made up of a reinforced concrete basement infrastructure and a metallic frame superstructure; the building closures being of thermal - isolated light panels made of corrugated sheet.

The building is seismically designed and qualified at DBE.

### **D<sub>2</sub>O Upgrading Tower and Ventilation Stack (objective 003)**

D<sub>2</sub>O-Upgrading Tower includes the D<sub>2</sub>O upgrading systems, the ventilation stack and the related mechanical and electric equipment. The building is provided with a metallic superstructure and facilities for inspections and controls, as well as I & C locating devices to monitor the parameters of the gases exhausted via the stack.

The ventilation stack is provided with pipe connections for the air exhaust ducts from S/B and D<sub>2</sub>O-Tower, as well as for the radioactive gaseous effluent monitoring system. The pollutants are retained through special fillers located on the systems connected to the stack.

The releases through the stack are monitored by continuous sampling in order to measure the concentrations of radioactive iodine, noble gases and particulate.

Tritium is monitored by periodic sampling and laboratory analyses. When certain radioactivity limits in the air exhausted via the stack are exceeded, an alarm system signals this to the control room.

### **Emergency Water Supply Building (objective 004)**

This building houses EWS pumps and their auxiliaries.

The Emergency Water Supply Building, common for three units (U3÷U5), includes a cast-in-place reinforced concrete infrastructure and a closed metallic superstructure.

The EWS building is seismically qualified at DBE.

EWS is provided also with an intake system that is a building allowing the handling of the travelling screens corresponding to the emergency water intake duct. The intake duct is anchored to the Main EWS Station of the Plant.

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EWS bay and intake are seismically qualified at DBE.

### **Standby Diesel Generators Building, of Class III (objective 023)**

In this building, two Standby Diesel Generators of class III are placed. The building has a reinforced concrete infrastructure up to the general elevation of the plant platform and a metallic structure made of braced columns and beams up to the roof.

The building is seismically qualified according to the Romanian Standard P100 - 92.

### **Fire Water Pump House Building (objective 093)**

In this building, the pumps and auxiliary installations of Fire Water Supply System are located.

The building has a concrete infrastructure and bearing walling. The building is seismically designed according to the Romanian Standard P100 - 81.

### **Chillers Building (objective 026)**

The building is located adjacent to the Main Integrated Building. It is a ground floor hall with concrete infrastructure and metallic superstructure, that houses the compressors, pumps and other equipment necessary during the process of chilled water required by various users.

The building is seismically designed according to the Romanian Standard P100 - 92.

### **Hydrogen Storage Area Structure (objective 012)**

This building is located between Reactor Building, D<sub>2</sub>O Up-grading Tower and HP-ECCS Building. The building houses bottles with H<sub>2</sub> at a pressure of 241 bar.

The structure is a bunker type with reinforced concrete walls having ventilation holes provided with metallic gride. The building is seismically designed according to the Romanian Standard P100 - 92.

### **Intake duct and water discharge channels**

The open intake duct is aimed to take water from CDMN derivation channel and supply the required water flow to the Screen House and Pump House, for the condenser cooling water, raw service water, fire and emergency water.

The intake duct was so sized that with low Danube water levels corresponding to 97% installed flow, the maximum cooling water flow be 269 m<sup>3</sup>/s required for the 5 units of Cernavoda NPP, at 1,12 m/sec velocity, a velocity that is not generating erosion of the channel bed because the hydraulic slope is 0.00054.

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The 370 m long intake duct has a trapeze cross-section with 1 : 4.5 slopes and 34 m slope base width and the duct bottom located at El. – 1.00 m dMB. The crown of the dykes on the contour is located at El. + 13.50 m dMB for to protect the lower areas against flooding, with an installed flow of 1%, like the derivation channel.

The Distribution Bay is aimed to make the connection between the open intake duct and the Screen House and to provide the water uniform access to the Pump House.

The Distribution Bay is bordered by slopes identical with the slopes of the intake duct and the distribution bay bottom is located at El. –1.00 m dMB.

The distribution bay is also supplying water to the Emergency Water System and therefore the slopes had to be checked for a DBE event.

The Institute for Hydrotechnical Researches (ICH) is considering that the maximum possible displacements of the slopes in case of an earthquake, may be about 2.00 to 3.00 m. Such a displacement is not plugging the flowing section and is not impeding the storage of a 17000 m<sup>3</sup> volume of water in the bay, a water volume required for a 90 day-period after a DBE.

The EWS water intake level is at El. + 0.50 m dMB i.e the elevation of the intake duct axis.

The cooling water flow required for the operation of one nuclear unit is 53.8 m<sup>3</sup>/sec.

Cooling up of each unit will be performed by their supply with cooling process water systems in open circuit.

The cooling water source for the NPP service water systems (circulation water and process service water) is the Danube River water. Water is taken from the Danube, from the CDMN intake and passing through CDMN –Race 1 and the derivation channel, along the intake duct and through the distribution channel where it is overtaken via the screen house and the pump house, to the users in the NPP.

The required installed flow rate for the NPP cooling water intake flow to the turbine-generator condensers (circulation water) and to the other technological consumers located in the NSP and BOB (process service water) is 97%.

Works associated to the water intake, intake duct and distribution bay are common for the circulation water system and the process service water system.

The Screen House (for the circulation water system and process service water system) is aimed to provide the mechanical purification of the water.

The Pump House (for the circulation water system and for the process service water system) is aimed to pump the water required for Unit 3 and Unit 4 operation.

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The filtered raw water (circulation water) is distributed to the Turbine Hall where it provides the condenser cooling.

Sizing of the circulation water system was based on the following data:

- number of pumps : 4;
- circulation water flow: 46 m<sup>3</sup>/sec;
- cooling water nominal temperature at circuit intake : 15° C;
- water heating in the condenser:  $\Delta t_{med} = 7,05^{\circ} C$ ;
- maximum allowable water heating in the condenser:  $\Delta t_{max} = 10,3^{\circ} C$ ;
- maximum water level (elevation ) in the condenser : + 20.45 mdMB.

The filtered raw water ( process service water) is distributed to the Service Building and Turbine Building where it provide cooling of the following equipment :

- ECC heat exchanger ;
- Spent Fuel Bay heat exchangers for cooling the water in the bay;
- Turbine oil chillers ;
- Intermediate cooling water chillers;
- chilled water production installation;
- auxiliary steam condensers;
- cooling water tanks for the Stand-by Diesel unit.

The process service water system sizing was based on the following data:

- number of pumps : 4
- process water flow : 7.813 m<sup>3</sup>/sec
- number of in-service pumps ( under normal operation): 3
- unitary flow rate /pump : 2.61 m<sup>3</sup>/sec;
- minimum temperature for the sampled raw water : 2 ° C.

The hydrotechnical part for the discharge of the warm water resulted from the condenser cooling and from the chiller associated to the raw service water, consists in hydrotechnical buildings which make possible the discharge of the warm water either to CDMN or to the Danube.

The discharge of the cooling water from NPP to CDMN –Race 2 is accomplished via a circuit made-up of the following items:

- channels and ducts for the discharge of the circulation warm water;
- channels and ducts for the discharge of process warm water;
- siphonating bays and special manholes;
- warm water discharge channel to CDMN –Race 2.
- warm-chilled water mixture channel for the “recirculation” operation mode.

The warm water channels were sized to discharge a 54 m<sup>3</sup>/sec flow per each unit.

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Through the siphonating bays and the valve houses, such channels make possible the discharge of the warm water either to CDMN – Race 2 or to the Danube.

The discharge of the cooling water from Cernavoda NPP to the Danube is made via a circuit consisting in the following items:

- boxes;
- tunnels;
- open concrete duct;
- earth-dug channel;

The circuit starts in the siphonating bay no.2, under-crosses Cismeaua Valley, the hill between Cismeaua Valley and Seimeni Valley and continues along the base of Seimeni Valley left wing.

After crossing Cernvoda – Hirsova Haighway, the channel is passing through the Danube Meadow and discharges to the Danube River at km. 296.

The hydrotechnical works associated to the water intake, the open intake duct, the distribution bay and warm water discharge are common for all Cernavoda NPP Units (Unit 1 to Unit 4).

## **II.2.4 Project Installations and Systems**

### **II.2.4.1 Reactor**

The reactor consists of a cylindrical horizontal vessel (calandria) provided with 380 horizontal fuel channels arranged in a square lattice, and of reactivity control units. The reactor vessel is filled in with heavy water as moderator and reflector for the neutrons resulted from the nuclear fission reaction.

Except for the pressure tubes from the fuel channel assembly, all the reactor assembly components, including the reactivity mechanisms, operate at low pressure and temperature conditions. The fuel channels consist of pressure tubes concentrically arranged with calandria tubes that are rolled-join into the reactor vessel inside tube plates. Between the pressure tubes and calandria tubes an adequate separation is maintained, using helicoidal spacers rings. The inner space between one pressure tube and the corresponding calandria tube is called annulus gas space and it is filled in with dry carbon dioxide aimed to provide thermal isolation, and it allows the pressure tube leakage detection. The nuclear fuel is inserted into pressure tubes by the fuelling machine.

Calandria is designed to withstand the pressure resulted from simultaneous breaks of the pressure tube and calandria tube. To limit such a pressure effect, four

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pressure relief ducts located in the upper part of calandria and provided with rupture disks, were provided.

Calandria vessel is provided with end shields (biological protections) which decrease the level of the radiation to allow the access of personnel to the pressure tube area (fuelling machine maintenance rooms) after the reactor shutdown. The end shields are parts of the reactor vessel and they also are supporting the calandria tubes passing through them.

Calandria vessel is located in a steel plated concrete enclosure, filled with light water (calandria vault). The light water ensures an additional shielding and an external proper cooling of calandria vessel.

Calandria assembly is seismically qualified to DBE.

The reactor core reactivity is controlled using some liquid and solid neutron absorbers. During normal reactor operation, the reactivity control is performed by the Reactor Regulating System that includes:

- a) Mechanical Control Absorbers Units – a control system having absorbing rods, mechanically driven;
- b) Adjuster Assembly Units, A (Adjuster Rod), AA (Adjuster Assembly) – a control system having adjuster rods;
- c) Liquid Zone Control System;
- d) Moderator Liquid Poison Injection System, which allows the insertion of boron and gadolinium as neutron absorbers into moderator;
- e) Moderator D<sub>2</sub>O Purification System, which allows the extraction of the absorbers from moderator;
- f) Neutron flux monitoring devices - flux detectors and ion chambers.

Platinum and vanadium flux detectors are located in the reactor core and ensure the neutron flux measurement. These detectors are supplemented with ion chambers installed on the outer sheath of calandria vessel.

The neutron flux measurements, performed by the platinum and vanadium flux detectors, are used to adjust the local and total power distribution. The local values are adjusted through the light water level change from liquid zone control compartments. The variation of the light water level, into these liquid zone control assemblies, modifies the local neutron absorption in 14 sub-zones of the reactor core, providing thus the bulk control of the neutron local flux level.

In case that the liquid zone control compartments cannot ensure the proper control of the neutron flux level and of the reactivity change rate, the reactor is provided with 4 solid absorber rods, vertically inserted in the reactor core and aiming to control the neutron flux level and reactivity change rate. Normally, the absorber rods are kept out of the reactor core.

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The bulk long-term or slow variation of the reactivity is controlled through addition in moderator of some neutron absorbing chemical substances, "poison" (gadolinium or boron solutions). The reactivity control is obtained by varying the "poison" concentration in moderator.

For example, to compensate for the excess of reactivity in the core, when the reactor is initially start up and the reactor core is loaded with fresh fuel, the concentration of the poison in the moderator is varied.

In order to ensure an optimum shape and smoothing of the neutron flux, 21 adjusting rods (stainless steel tubes) are provided. These rods are normally inserted in the core.

Nuclear reactor is provided with two shutdown systems, that stop safely and quickly the nuclear fission reaction, each of them being able to stop independently the chain nuclear reaction, for any postulated accident, as a response to neutron and process signals or upon the operator's request, maintaining the reactor in a sub-critical state for an indefinite period. These two shutdown systems are physically and operationally independent, both to each other, and against the reactor regulating system.

The Shutdown System No. 1 (SDS # 1) contains 28 vertical shut-off rods (tubes of Cd, stainless steel clad). SDS # 1 is provided in order to terminate the nuclear fission reaction, by gravitational insertion of shut-off rods system into the core.

The Shutdown System No. 2 (SDS # 2) is provided with 6 tanks filled with "poison" (gadolinium solution in heavy water), that can be injected into moderator, using the pressurized Helium, through 6 horizontal units for the purpose of quickly terminate the nuclear fission reaction.

#### **II.2.4.2 Process Systems of Reactor**

The main process systems of the reactor are Primary Heat Transport System (PHTS) and Main Moderator System (MMS).

##### **Primary Heat Transport System (PHTS)**

PHT system (see Figure II.2-3) is designed to provide the pressurized heavy water circulation through the reactor fuel channels to take over the heat generated by the nuclear fuel during the nuclear reaction. The heat transported by the coolant is transferred to light water in the steam generators. By vaporization, saturated steam required for the turbine-generator set operation is produced.

The pressure boundary of PHTS is the third protective barrier against the potential radioactive releases to the environment, besides the fuel matrix and the fuel element

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sheath. PHTS is designed to maintain its integrity both under normal operation and anticipated operational occurrences.

PHTS is seismically qualified to DBE in order to provide the pressure boundary integrity. During and following an earthquake, the system pump rotors shall rotate freely to maintain the coolant circulation. PHTS can be isolated after an earthquake in order to keep the D<sub>2</sub>O inventory required for thermal-siphoning process. A D<sub>2</sub>O make-up circuit is also provided to compensate for the small coolant leakage which might occur after a seismic event.

The main design objective with respect to PHTS nuclear safety is the adequate cooling of the fuel, for any operation regime, during the plant lifetime, with a minimum maintenance. Thereby, the heat is transferred to the condenser or to the atmosphere via the steam generators, or is carried out to the cooling water intermediate system via the shutdown cooling system. When the PHTS pressure boundary is intact, the system is able to remove the decay heat in order to prevent the fuel damage. In case the PHTS pressure boundary integrity is lost, the system is designed so that, along with the protective systems initiation (e.g., emergency core cooling system), it may limit the fuel failure. PHTS is a safety related system.

PHTS is mainly consisting of: 4 circulating pumps, 4 inlet headers, 4 outlet headers, 380 fuel channels, feeders connecting headers to fuel channels and 4 steam generators (U tubes primary circuit).

PHTS is divided in two separate loops. If a loss of coolant accident (LOCA) occurs, the intact loop is automatically isolated against the defective loop and against auxiliary systems, reducing thus both the loss of coolant inventory and the nuclear fuel failure rate.

The design and fabrication requirements are contained in CSA-N285.1-81-Requirements for Class 1, 2 and 3 Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants, and design and fabrication code is ASME – Boiler and Pressure Vessel Code – Section III, Division 1, Sub-sections NB and NF.

The primary coolant inventory and pressure control system is aimed to control the PHT pressure to a corresponding value required by operating regime and to add/discharge the coolant when a loss/excess of PHTS coolant inventory occurs. With the reactor at power, the pressure is controlled by a pressurizer, and the feed and bleed circuits are adjusting the PHT inventory. During shutdown state, the pressurizer can be isolated from PHT circuit, and the pressure will be controlled by the feed and bleed system.

PHT D<sub>2</sub>O purification system controls the coolant chemistry in primary circuit and prevents the buildup of radiation fields around the equipment, by minimizing the presence of activated corrosion products and fission products in reactor coolant.

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The minimizing the PHTS coolant leakage and the collecting the liquid D<sub>2</sub>O (by D<sub>2</sub>O collection system) or D<sub>2</sub>O vapors (by D<sub>2</sub>O vapor recovery system) are of major importance.

The shutdown cooling system (SDCS) ensures the nuclear fuel cooling during reactor shutdown periods or for certain accident sequences.

### **Main Moderator System**

The fast neutrons produced by nuclear fission are “thermallized” in D<sub>2</sub>O from calandria vessel. The moderator heavy water in the main moderator system (MMS) is circulated by pumps and cooled down by its heat exchangers. The system operates at low values of temperature and pressure. The heat exchangers remove the heat produced following the slowing down of neutrons in the moderator, as well as the heat transferred by radiation to the moderator from the fuel channels (see Figure II.2-4). The coverage gas for D<sub>2</sub>O is Helium, controlled in a closed circuit. The moderator purification circuit maintains the control of moderator water chemistry within the specified limits.

The Main Moderator System is able to remove the residual heat from the fuel immediately after reactor shutdown, due to the total loss of electric power supply (LOCLIV) or to the loss of coolant, LOCA, including also a LOCA event coincident with LOCLIV and ECCS unavailability. For these events, a corresponding additional cooling of moderator ("crash-cooling"), as well as an adequate suction level corresponding to normal pumps operation, are required.

Calandria vessel containing the moderator is seismically qualified to DBE, and its re-circulating system is seismically qualified to Category A of DBE. In addition, the part of this system that penetrates the containment wall is also seismically qualified to DBE.

The Main Moderator System is environmentally qualified so that it fulfils the nuclear safety function (residual heat removal) under harsh environmental conditions, as a result of a LOCA. The environmental qualification of the system is not required for the conditions which occur following a main steam line break (MSLB), as there is no requirement of residual heat removal by means of the moderator, in case of such an accident. The depressurization of PHTS using steam boilers and overpressure protection valves provides the cooling of this system and prevents the boiling of moderator in this case.

The Main Moderator System is designed as system of Group 1 because, besides the achievement of a nuclear safety function in accident conditions, fulfils the functions of fast neutrons moderation and heat removal during normal operation of NPP.

The system design is according to CAN-Standard N285.01-M81. The Main Moderator System, except for containment extensions (Class 2), is a system of Class 3.

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## Auxiliary Systems

There are some auxiliary systems associated to the heat transport system, to the moderator system and to the reactor control system, which accomplish both process and nuclear safety functions. The most important auxiliary systems are the followings:

- End Shield Cooling System;
- Spent Fuel Bay Cooling and Purification System;
- Liquid Zone Control System;
- Annulus Gas System;
- Moderator Liquid Poison System;
- Shutdown Cooling System;
- Resins Transfer System;
- D<sub>2</sub>O Coolant and Moderator Purification Systems;
- PHTS Pressure and Inventory Control System;
- D<sub>2</sub>O Coolant and Moderator Deuteration and De-deuteration Systems;
- D<sub>2</sub>O Coolant and Moderator Collection System;
- Heavy Water Management System;
- D<sub>2</sub>O Coolant and Moderator Sampling Systems.

Details regarding these systems are in Appendix 7 of document U3-08230-6013-SF/SS, Feasibility Study for U3 Cernavoda NPP Unit 3.

### II.2.4.3 Fuel and Fuel Handling

#### Fuel

The fuel used in the nuclear reactor of Cernavoda NPP Unit 3 and Unit 4 is natural uranium processed as ceramics pellets of UO<sub>2</sub> which, assembled in Zircalloy-4 claddings, constitutes fuel elements.

A fuel bundle is constituted of 37 fuel elements assembled together. Each of the 380 channels contains 12 fuel bundles resulting thus a total of 4560 bundles in the reactor core.

The nuclear fuel matrix together with its cladding, constitute the first two protective barriers against radioactive material releases to the environment.

The fuel is designed to withstand the transients and the anticipated operational occurrences during operation. It is considered that the cladding remains undamaged, whether the following criteria are met:

- there are no melting points in the fuel;

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- there is no excessive sheath deformation (less than 5% of uniform deformation for temperature of cladding lower than 1000°C);
- there are no significant cracks in the oxide layer on the sheath surface;
- sheath embrittlement due to the oxygen is not occurring.

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## **Fuel handling**

For fresh fuel handling and storage, for reactor loading and unloading, as well as for spent fuel handling and storage, special equipment will be used (Figure II.2-5).

The reactor is reloaded during operation with fresh fuel by means of two fuelling machines (F/M), one at each end of the reactor. The fuel machines operate at the opposite ends of the same fuel channel, one of them introducing fresh fuel and the other one extracting the spent fuel from that channel.

During normal plant operation, the fuelling system removes the decay heat from the fuel located in F/M head whenever the F/M is attached to the reactor, and during the fuel transfer through the fuel transfer port to the spent fuel bay.

The spent fuel is unloaded from F/M through the fuel discharge ports, in fuel reception bay, and then it is transferred under water to the spent fuel bay (SFB) that is located in the Service Building. The spent fuel bay is provided with a sufficient storage capacity in order to cool down the fuel accumulated during at least 6 years, and a backup capacity sufficient until the transfer to the other storage facilities is feasible. The spent fuel bay is provided with spent fuel hoisting and submerged transporting devices and a cooling and cleaning water system, in order to remove the spent fuel decay heat from the water bay, and to maintain the water chemistry and radioactivity to allowable levels.

### **II.2.4.4 Electric Power Production System**

The electric power production system is made up of the turbine-generator set. The turbine-generator set contains two basic components, namely the turbine and the generator.

#### **Turbine**

The turbine provided for Cernavoda NPP - U3 and U4 project is of action/reaction with condensation type, using saturated steam, being warranted to produce an active power at the shaft corresponding to a rated gross nominal output of 720 MWe, at a speed of 1500 rot/min, and the condenser cooling water temperature of 15°C. Constructively, the turbine comprises one double flow high pressure cylinder and three double flow low pressure cylinder.

The turbine is provided with five fixed steam extraction connections from different stages of expansion, in order to heat up the steam generators feed water by means of regenerative re-heaters chain.

The turbine condenser is made up of three independent shells, each of them being connected to a turbine low pressure cylinder. The condensate from the turbine

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condenser is pumped by 3 main condensate pumps (3 X 60%) through the regenerative circuit, which is constituted of three low-pressure heating stages, transferring the condensate to the de-aerator. By means of three main feed water pumps (3 X 60%), the condensate is overtaken from the de-aerator and heated in two high pressure re-heaters, in parallel configuration, and then being transported through 4 pipes to a regulating valve station for the supply of steam generators.

Both the main condensate system and steam generators feed water system, are provided with auxiliary pumps, namely: auxiliary feed water pump and auxiliary condensate pump.

### **Generator**

The turbine mechanical power is converted into electric power by means of the electrical generator directly coupled to the turbine.

The generator is of synchronous type, with stator in star connection. Its apparent power is of 800 MVA, at 1500 rot/min and frequency of 50 Hz at a voltage of 24 KV and a power factor  $\cos \phi = 0.9$ .

The generator is supplied with a static system of excitation, EX2000, and with auxiliaries cooling systems – with water, for stator windings and with hydrogen for rotor. The shaft jacking system uses oil.

#### **II.2.4.5 Electrical System**

The electrical power supplied by the generator is transferred via a 800MVA transformer to the 400 kV switchyard coupled with the national grid by 5 separate interconnection lines, located on different routes. The internal power distribution system supply is provided by two independent supply sources, one internal and the other from the national power system and is achieved by 4 transformers (of 60 MVA each), two from the generator and two from the 110 kV local switchyard.

The U3 internal services power supply is designed to provide supplying power to consumers according to their importance from the nuclear safety point of view.

In this respect, the electrical power supplying to U3 consumers is carried out by systems divided in classes, as follows:

**Class IV** power system is an AC distribution system normally supplied from the off-site grid and/or unit generator. Class IV system supplies power to all loads which can tolerate long-term interruptions of power supply without jeopardizing the plant safety, equipment or personnel. Thus, the Class IV system feeds at 10 kV the PHTS pumps and the SG water feed main pump, as well as 6 kV the circulating water pumps and condensate lift pump.

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The partial loss of Class IV supply (ODD/EVEN subsystem) imposes reactor shutdown.

**Class III** power system is an AC system normally supplied from unit turbogenerator or the off-site grid.

In case of the loss of the normal supply, the feed of Class III is made from the stand-by Diesel generators, with automatic start-up, adequately sized to supply power to essential loads, necessary for safe reactor shutdown and residual heat removal. In this way, the Class III system feeds the moderator main pumps, raw water and cooled water pumps, intermediate cooling water pumps, primary coolant make-up pumps, ECCS pumps, shutdown cooling pumps, instrumental air compressors and the auxiliary pump of SG feed water. The general class III 0,4kV panels are also fed from 6 kV class III, by the 6/0,4 kV transformers. From these panels, the uninterruptable electrical system d.c battery rectifies are also supplied, mian condensate auxiliary pump.

The loads fed from Class III system can tolerate short interruptions of power supply (maximum 180 s), required for starting-up and sequentially loading the stand-by generators.

In order to enhance the supply reliability of the Class III and IV, an automatic source transfer system at the bars level of 6 and 10 kV was provided. The total loss of Class IV supply occurs in case of the failure of both supply sources ODD and EVEN.

**Class II** power system is an AC distribution system at 400 V and 230 V supplying the instrumentation and equipment for unit control and the emergency lighting. The loads connected to Class II system do not allow interruption of power supplying longer than 5 ms.

The system consists in:

- a subsystem of two three-phases bars, at low voltage, supplying the motors of the systems required to emergency reactor shutdown. Each of these bars is fed by an inverter from a battery supplied on its turn from the Class III system;
- a subsystem of three mono-phase AC bars, at low voltage, supplying the AC instrumentation and the plant computers. These bars are fed by an inverter from the Class I bars.

In case of the inverter failure, the power is directly supplied to the low-voltage bars, and via a voltage regulator, the instrumentation bars are fed.

If a Class III interruption or loss is occurred, the batteries from the corresponding circuit will provide the uninterrupted supply by invertors for about 1 h.

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**Class I** power system is a DC system which supplies power at 48 V and 220 V to essential groups of loads: control, protection and special safety system equipment. The system consists in:

- three independent 48 V DC bars corresponding to instrumentation, each of them supplying the control logic circuits and a channel associated to the three-plicate circuits for safe reactor shutdown. Each of these bars is fed from a battery continuously charged on its turn from the Class III system by the rectifiers;
- three 220V DC bars supplying the motors, commutator and bars of AC Class II, via rectifiers. These DC bars are fed from the plant battery system, supplied on its turn from the Class III system by the rectifiers.

Applying the separation principle, in order to ensure a DC and AC power source completely independent from the sources presented above, the plant is provided with the **Emergency Power Supply System (EPS)** consisting in two Diesel generator sets, functionally independent and physically separated, being initiated by the operator.

The system is qualified to remain operable after the common-mode events (for example earthquake).

The EPS system is designed and realized so that each of the two Diesel generator sets be able to supply the important loads for fulfilling the main safety functions. The principal role of EPS system is to provide a back-up power supply, independent and seismically qualified, electrically isolated from all other power sources of the plant, to safe reactor shutdown, to remove the residual heat from reactor, containment and control of these functions in case of unavailability of all other power supply sources (including Class I and II). The system must also ensure the lighting in the secondary control room when MCR becomes unavailable.

These 2 Diesel generator sets are seismically qualified to DBE, so that the EPS system can operate in case of a high magnitude earthquake.

**Internal Service System** of the plant was designed based on the following safety and reliability criteria:

- a) The unit must remain functional and feed the internal services even if a failure resulting in the unit separation from the off-site grid occurs;
- b) Redundancy in power supply is provided;
- c) The system is designed to be stable and to isolate the failures;
- d) The system permits harmonization of the requirements of all power supply classes and the automatic transfer in accident conditions.

The electrical systems have been assigned to the two groups of special safety systems as follows:

- Group 1: Class I, II, III, IV electrical systems;

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- Group 2: Emergency power supply system.

The independence and redundancy of the internal power supply system are ensured based on the electrical system design according to ODD/EVEN separation concept, which assumes following:

- The Class III and IV electrical systems are separated in bars ODD and EVEN at all voltage levels, so that the bar duplication increases the reliability. The two channellings are completely separated, without the possibility to be interconnected;
- The Class IV loads are connected so that part of the loads required by technological processes fulfilling the same function be fed from the ODD subsystem, and the other part, from the EVEN subsystem; the redundant Class III loads are connected so that a load is fed from an ODD bar, and the redundant load from an EVEN bar;
- The auxiliary loads fed at a lower voltage than the respective primary load, are connected to the same bar section ODD or EVEN, similar to the primary load;
- In order to reach a maximum reliability in normal and abnormal conditions, a physically separation between the ODD and EVEN circuits was maintained applying this concept to the cable trays, junction boxes, etc.

#### **II.2.4.6 General Control of the Plant**

The control of Unit 3 respective Unit 4 is provided to ensure the monitoring and control of the parameters and systems in the all variation range for normal operation, anticipated operating events as well as in accident conditions, and to maintain the values of these parameters in the admissible limits.

The central part of the control system consists of a system of two process computers coupled to the plant process systems. Each of these two computers is capable of complete unit control.

In case of the main control room unavailability, the unit control is performed from the secondary control room, so that the main safety functions be ensured.

For the systems from the classic side of Unit 3 respective Unit 4, a Distributed Control System (DCS) was provided, including all the analogue or digital control functions used for the process.

The distributed control system is an integrated system accomplishing data getting and control functions, based on the use of the programmable digital controllers, connected by data lines. The process system instrumentation and control devices will be connected to the local input/output stations of DCS.

#### **II.2.4.7 Special Safety Systems**

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Special safety systems are designed to quickly shut-down the reactor, to remove the decay heat and to confine the radioactive releases which occur in case of a failure of a process system having nuclear safety function, during normal operation of the plant.

Fulfillment of these functions can be monitored and controlled both from Main Control Room and Secondary Control Room.

Special safety systems are: Shutdown System No. 1 (SDS#1), Shutdown System No.2 (SDS#2), Emergency Core Cooling System (ECCS) and Containment System.

Some of the common requirements of the special safety systems are the followings:

- a) Seismic qualification;
- b) Environmental qualification, including qualification for dynamical stresses and jets;
- c) Unavailability lower than  $10^{-3}$  events/year;
- d) Safe operation in case of failure;
- e) Testing during operation, without affecting the nuclear safety function of the system;
- f) Possibility for manually initiating from the control rooms;
- g) Separation and independence both between these systems and between each special safety system and the corresponding process system whose function fulfils.

### **Shutdown System No.1**

Shutdown System No.1 – SDS#1 provides quickly shutting down the fission reaction in the reactor core by dropping into the moderator 28 shutoff units strongly neutron absorbers. It is so designed to quickly stop the chain reaction and to maintain reactor in subcritical state for on undefined period.

The system introduces negative reactivity so that to prevent the fuel failure in case of anticipated transients and to maintain reactor in subcritical state, for an undefined period. The reactor shutdown is initiated when some neutron or process parameters exceed the operation limits.

SDS#1 is designed according to the regulation document AECB R-8 and to the safety guide SDG-001 and NSN – 13 Order no.365/2005 CNCAN (Ref. II-2).

The system is designed to ensure the safe shutdown of the reactor in the following accident conditions:

- a) Loss of Regulation (LOR);
- b) Loss Coolant Accident (LOCA);
- c) Loss of Coolant Flow (loss of Class IV power supply);
- d) Loss of secondary heat sinks;

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e) Loss of moderator cooling.

Excepting of the major loss of coolant accidents or events on a single channel, SDS#1 must prevent fuel failure in reactor channels (in case that there are no previous fuel defects), for any events above-mentioned.

Measuring each of these parameters is made by three channels. SDS#1 is initiated when a trip signal occurs on two of three channels, in whatever combination.

### **Shutdown System No.2**

Shutdown System No. 2 (SDS#2) represents a second independent quick stop of the chain fission reaction. The system injects a strong neutron absorbent solution into the moderator in case of trip signal on two from three measurement channels, whatever their combination.

The trip set-points for the two shutdown systems are different and so selected to start up first SDS#1 and, in case of its unavailability, SDS#2.

### **Emergency Core Cooling System**

The Emergency Core Cooling System (ECCS) is designed to re-establish and maintain the heavy water inventory in primary circuit, in order to ensure the nuclear fuel cooling.

The ECCS initiates in case of LOCA signal, which ensures also the isolation of the two loops of the PHTS (Primary Heat Transport System) and quick depressurization of the steam generators, on cooling purpose, in case of the design basis event LOCA-type and must respected NSN-11 Order CNCAN no. 136/2006 Ref. II-3)

The system operates in three distinct stages:

a) The high pressure stage: consists of two water tanks, a gas tank maintained in a pressurized state by a compressor, a re-circulating and chemical make-up pump and an electrical heater.

In case of the coolant pressure decreasing in PHTS headers, coincident with another conditioning parameter (high pressure in Reactor Building, high level of moderator or low pressure in primary circuit for more than 5 minutes), water from the two tanks from HPECC is injected, using the pressurized gas from the gas tank, in PHTS headers, to ensure the fuel cooling.

The heater maintains the water temperature between 18°C and 33°C, in order to ensure the system efficiency.

The water reserve is sufficient for at least 2.5 minutes in case of a maximum rupture (100% header from PHTS).

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- b) The medium pressure stage: the water source consists of the reserve attached to this purpose in the dousing tank. The system has two pumps which direct the water through one of the two heat exchangers, to the primary circuit. For a maximum rupture in the primary circuit, water from the dousing tank can ensure the injection for 12.5 minutes.
- c) The low pressure stage: uses the water collected on the Reactor Building floor (mixture of D<sub>2</sub>O and H<sub>2</sub>O), passing it through mechanical filters, cools down it by heat exchangers and re-circulates it using the pumps, ensuring in this way the fuel long-term cooling.

### **Containment System**

The containment system represents a physical protection barrier of the environment, against the radioactive material releases. The system is designed so that the release rate of the radioactive materials to the environment in case of LOCA be lower than the maximum admissible release rate (0.5% per day from the Reactor Building volume, at a design pressure of 124 kPa).

In case of LOCA simultaneous with the complete loss of the dousing system, the system will maintain the containment tightness, and in case of the events of the main steam line rupture, the system will maintain the structural integrity of the containment.

The main components of the containment system are: the containment itself, the dousing system, the Reactor Building atmosphere ventilation and cooling system, the access locks as well as the containment isolation system (automatically and manually). Containment system is respected Order CNCAN no 364/2005 Norms NSN-12 (Ref. II-4).

#### **II.2.4.8 Safety Support Systems**

The safety support systems offer necessary services, like feed water and power supply, in order to support the operation of the special safety systems.

The safety support systems are as following:

##### **a) Emergency Water Supply System (EWS)**

The emergency water supply system is designed as a safety support system, according to SDG-001.

The system ensures the fuel cooling or a long-term heat sink after events determining the loss of the systems with normal operation. Thus, it ensures the cooling water to the ECC heat exchangers to remove the heat from the primary circuit in case of LOCA followed by the Site Design Earthquake (SDE). Also, the

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system ensures the water inventory from PHTS, to compensate the leakage following DBE (Design Basis Earthquake). EWS ensures a stand-by feed water to steam generators for a long-term cooling in case of total loss of the SG feed water. EWS is seismically qualified according to SDG-002 so that it operates as a safety support system during and after an earthquake. The system components located in the Reactor Building are environmentally qualified according to SDG-003. EWS belongs to the Group 2 of safety systems and is separated from the systems of Group 1 (service water systems-see point c).

#### **b) Emergency Power Supply System (EPS)**

The emergency power supply system is designed as a safety support system, according to SDG-001. EPS ensures the power supply of the safety systems from Group 2 to remove the decay heat on long-term, and to monitor and control the plant after accident. EPS is a system belonging to Group 2 and meets the separation requirements of the two groups, as SDG-004 specifies. The system ensures the alternate power supply after the loss of Class IV and III in case of LOCA followed at 24h by SDE, or after a Design Basis Earthquake (DBE), as EPS is designed to withstand to DBE, according to SDG-002.

#### **c) Service Water Systems**

The Service water systems are designed to remove the heat from the nuclear and classic side consumers, during normal plant operation, as well as abnormal conditions, in order to avoid the possibility that these operation regimes lead to accident situations. The systems belong to Group 1, having a process function associated to normal operation of the reactor.

#### **d) Instrument Air System**

The system supplies compressed air by a distribution network, to valves and devices pneumatically acted in installations of nuclear and classic sides. The system belongs to Group 1, having a process function associated to normal operation of the reactor.

### **II.2.4.9 Process and Common Service Systems**

The process and common service systems include:

- condenser cooling water system;
- fire protection system;
- drinking water system;
- demineralized water distribution system;
- radioactive and non-radioactive leakage collection system;
- air heating, ventilation and conditioning system;
- technical gas systems;
- equipment for material handling;

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- diverse equipment (laundry);
- heavy water upgrading tower.

Details about these systems are presented in Appendix 7 from document U3-08230-6013-SF/SS.

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#### **II.2.4.10 Radioactive Waste Management System**

The radioactive waste management system ensures the collection, handling, packaging, temporary storage and controlled release of the radioactive wastes.

The radioactive wastes are classified in: liquid wastes, gaseous wastes and solid wastes; these are managed by the following systems:

- Liquid radioactive waste management system;
- Gaseous radioactive waste management system;
- Solid radioactive waste management system.

These systems are presented in Chapters III.1, III.2 and III.8.

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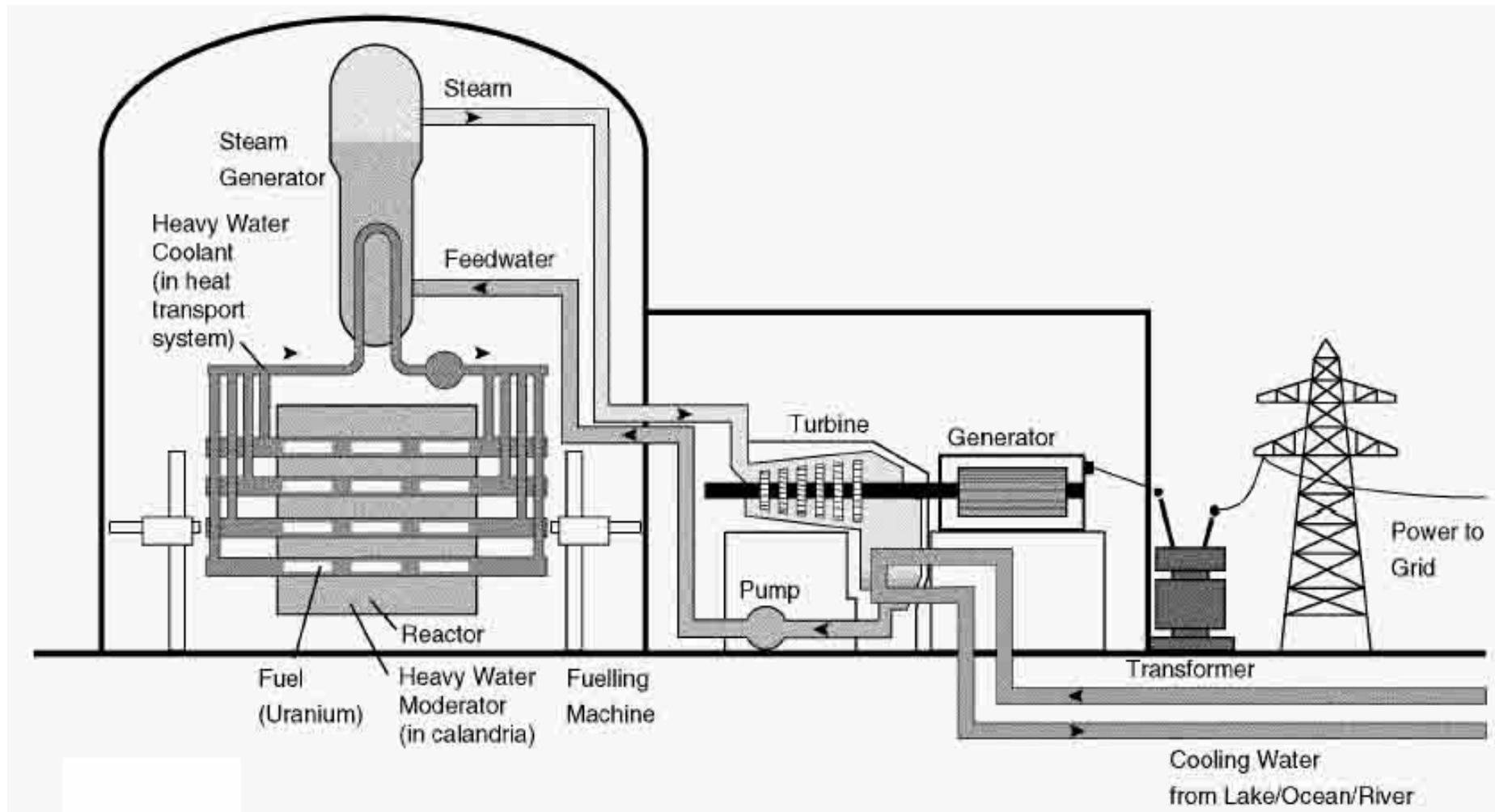


Figure II.2-1 General flowsheet of NPP CANDU 6

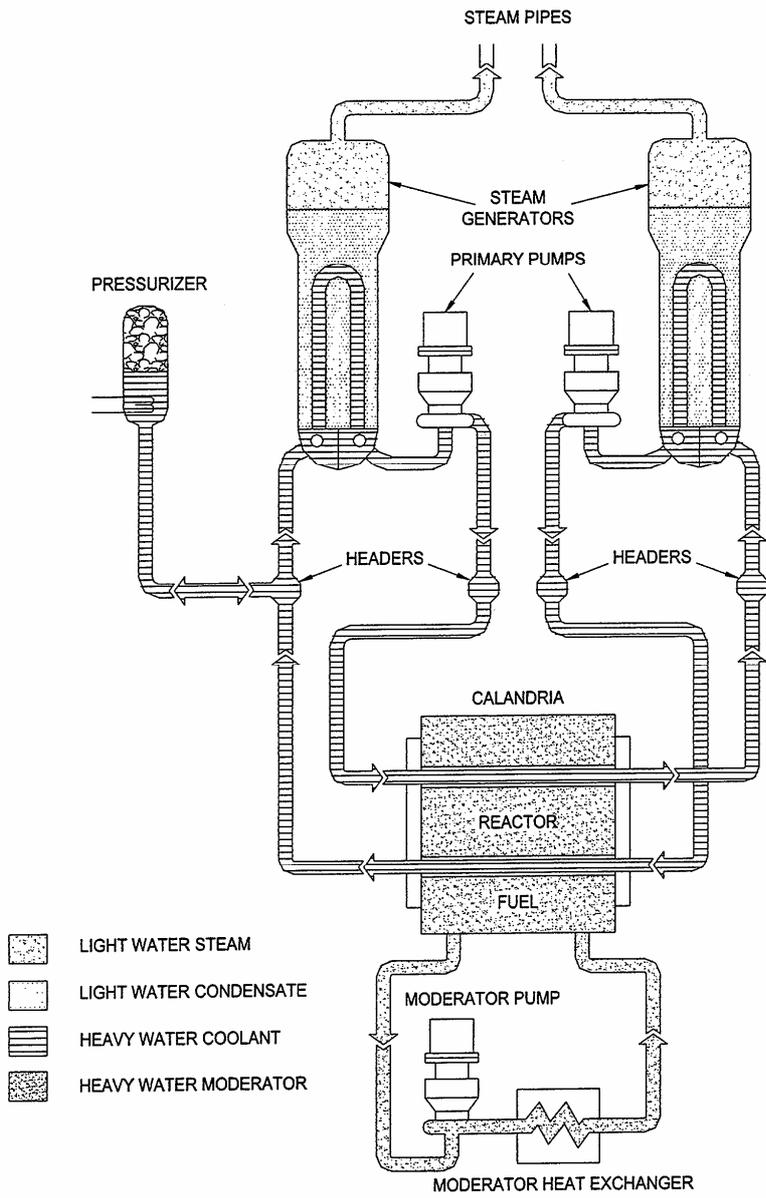


Figure II.2-2 Simplified flowsheet of Cernavoda NPP reactor (CANDU 6 type)

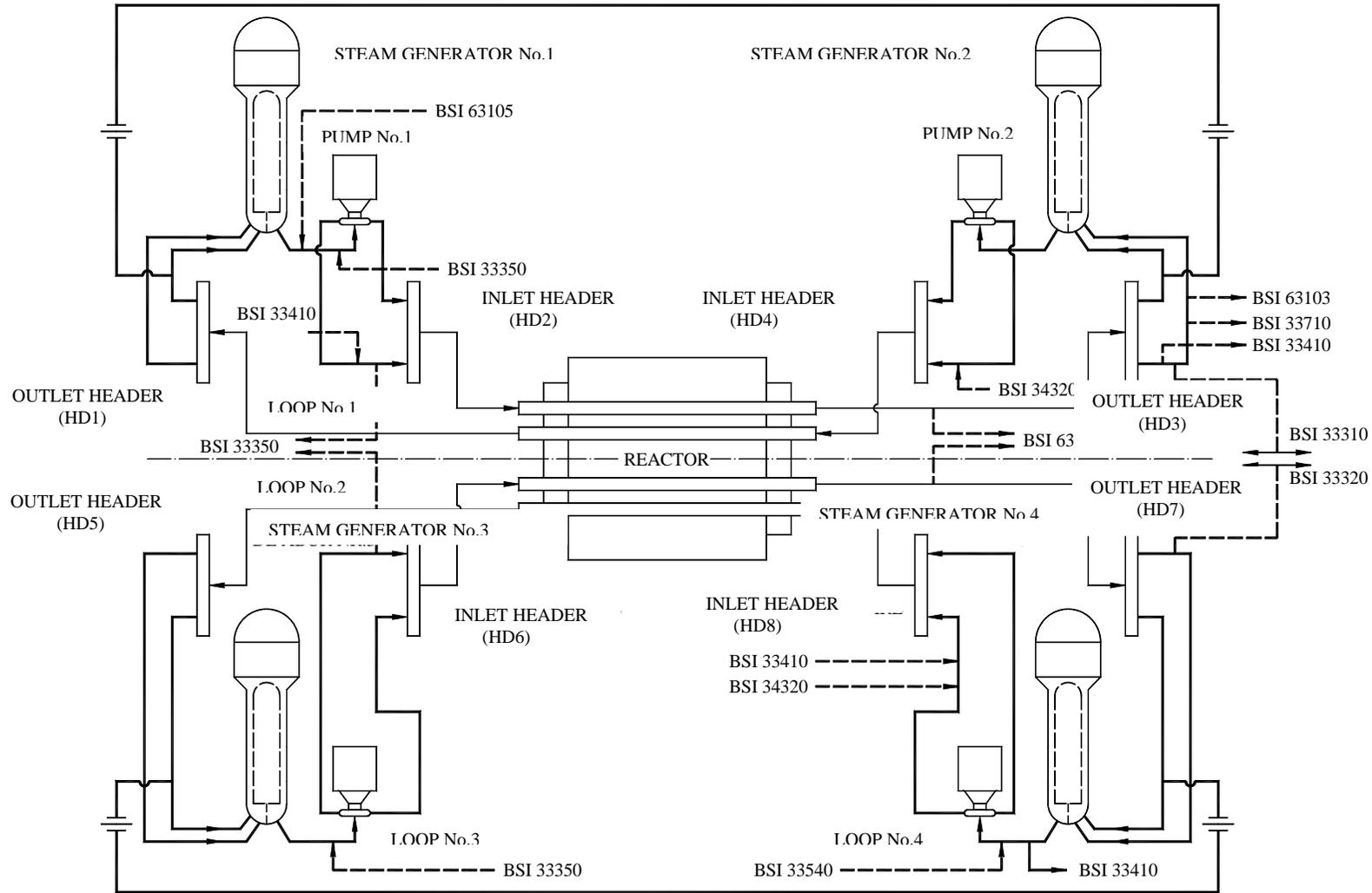


Figure II.2-3 Simplified flowsheet of Primary Heat Transport System, BSI 33100

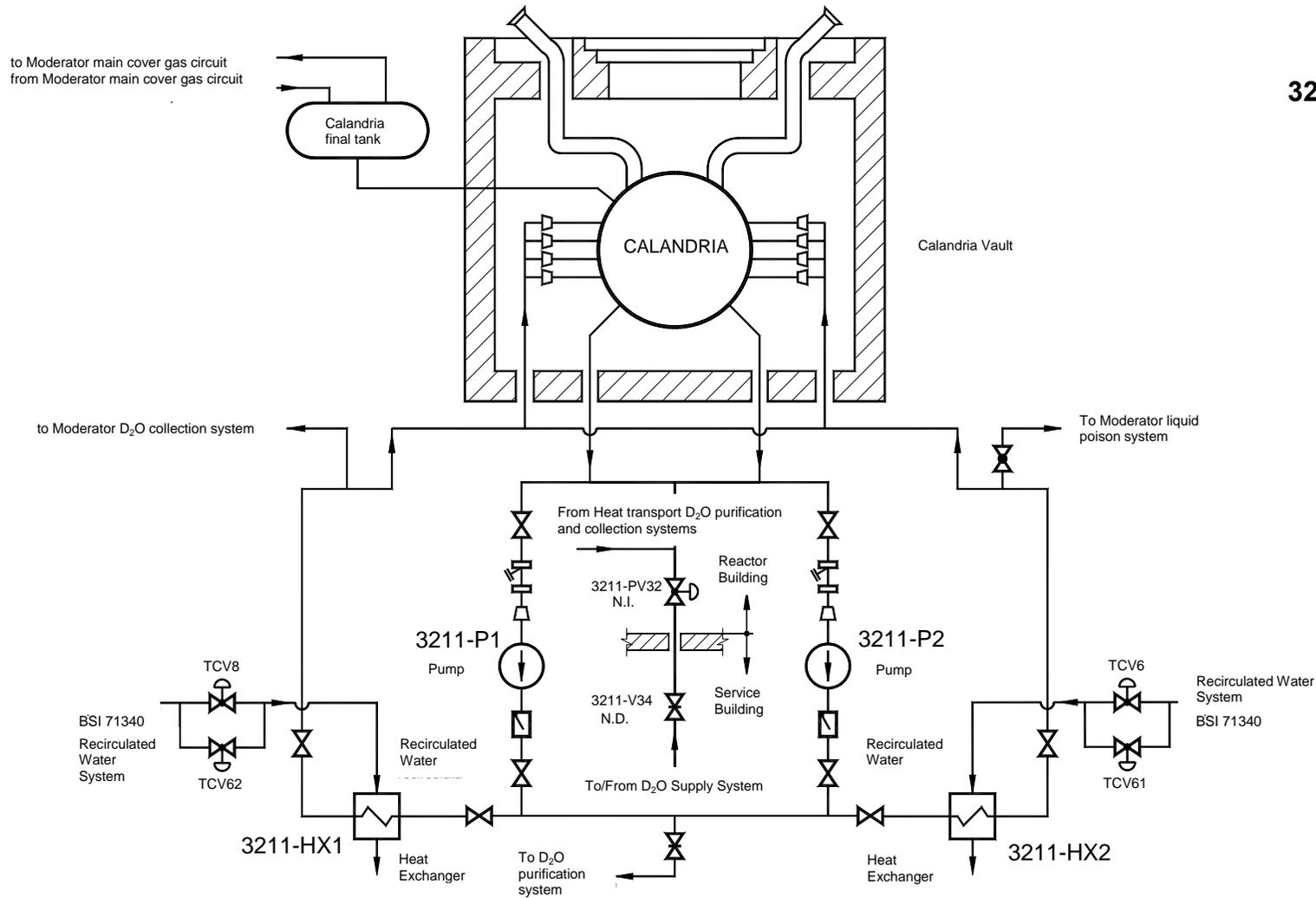


Figure II.2-4 Simplified flowsheet of Main Moderator System, BSI 32110

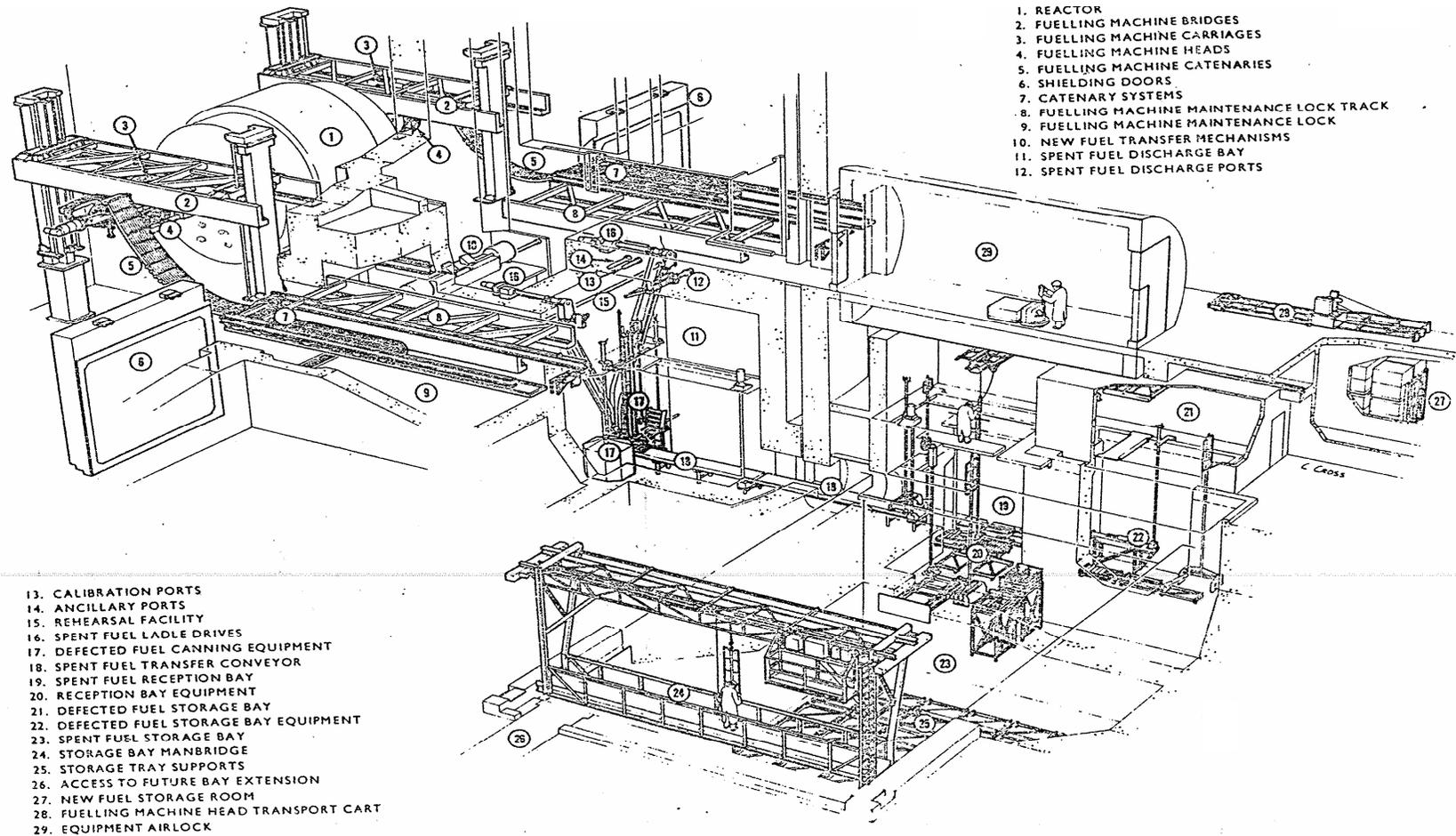


Figure II.2-5 Fuel handling system of CANDU 600 plant

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### **II.3 Activities During Construction Phase**

Cernavoda NPP enclosure is located on the platform of a former limestone quarry (Ilie Barza Quarry ) situated at about 3 km South-East from Cernavoda Town and at 1,5 km away from the first lock of the Danube -Black Sea Channel.

Initially, the quarry had elevations ranging between + 9.00 m above BSL and +10.00 m above BSL and it was North–West bordered by a limestone massif covered by loess and having the elevations +35.00 m above BSL and +45.00 m above BSL.

The arrangement of Cernavoda NPP platform implied a large volume of excavations in limestone and surface ground works in loess.

The excavated limestone was used both for the arrangement works on NPP platform and the arrangement of the temporary buildings and facilities site.

The excess of limestone was stored on the right bank of Cismeaua Valley. The loess resulted from the platform arrangement was used for the reclamation of some agricultural land (i.e. Ramadan area), an area equivalent to the land occupied by Cernavoda NPP.

The Units 3 and 4 enclosures are located at the elevation + 16.00 m above BSL, the same as Unit 1.

The above described land arrangement was made for the 5 units planned to be built between 1979-1985. Works developed with the construction of the main buildings (i. e. Reactor Building, Service Building, Turbine Hall and Hydro Pump House).

Until 1989, the common systems (water, sewage management, firewater, underground cable ducts, hydro ducts) for Units 1, 2, 3 and 4 had been constructed to various completion stages.

Works required for Unit 3 and Unit 4 finalization consist of:

a) Civil Works:

- excavations within the Unit 3 enclosure;
- floor, masonry, building internal structure and equipment foundation repairing works;
- concrete pouring for new building elements;
- steel structure installation works;
- paintings, coatings, epoxy liner application at various building elements;
- architectural works.

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#### b) Equipment & Pipe Installation Works

- equipment anchoring to foundations (for equipment not yet anchored);
- pipe support installation by welding to the embedded plates in the structures or by anchoring ;
- installation of various pipe supporting metal structures inside;
- installation of pipes and check and adjusting valves by welding ;
- finalization of pipe installation and pipe connections to outer networks.

#### c) Electrical and I & C Works

- installation of cable trays and routes;
- local I & C installation and connection for remote control;
- installation of electrical distribution and control panels ;
- installation of process computers, main and secondary control works;
- connection to the grid from the electric generator bus bars to the 400 kV transformer station.

#### d) Clearing & Flushing of the Process Systems and their Hydraulic Testing.

## II.4 Site Temporary Buildings and Facilities

Cernavoda NPP constructors have developed their own temporary buildings and facilities function of the volume of typical works and technologies available at that time so that in 1989, the area was large, including pre-assembling spaces, machining and repair workshops, warehouses and storage, all of them oversized. Note that, at that time, Cernavoda NPP platform was the place where construction works for all the 5 units developed. That is the main reason for which the temporary buildings and facilities had large spaces.

The area is encompassed between the NPP enclosure, the intake duct, Medgidia Street and the rainfall discharge duct on Cismeaua Valley.

After 1990, works have been gradually ceased for the other NPP units, so that the volume of works is represented by one unit only, so, it is very small.

For example, the concrete mixing plant is covering a very large area on the left bank of Cismeaua Valley and it is outfitted with a sorting station, underground bunkers and aggregate warehouses. This concrete mixing plant was initially sized to fabricate and deliver about 400-500 m<sup>3</sup>/day concrete and it is still operational. The needs of the site, in case that U3 works go on, can be provided by a smaller sized concrete mixing plant.

Another general characteristic of these oversized temporary buildings and facilities is that most of the units (i.e. warehouses, workshops, storage, etc ) were built long time

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ago and a large part of them were demolished. Note that they had been generally designed for about 10 year life-span.

The temporary buildings and facilities built after 1990 are generally belonging to some new private enterprises or companies established on basis of the previous existing companies.

These constructors, generally private companies occurred while a small volume of works were developing on the site, have developed their own temporary buildings and facilities corresponding to this volume of works.

These temporary buildings and facilities have the following general characteristics:

- they cover a small piece of land and have a high degree of occupancy;
- the units associated to these temporary buildings and facilities are
- generally including only the actually necessary things, namely:
  - offices;
  - penthouses for tools and construction personnel;
  - halls and workshops specially sized for low volume of works;
- trimmed aspect if compared to the large site arrangement and the
- buildings and facilities are well maintained;
- careful storage of materials, tools and equipment within the temporary
- buildings and facilities area;
- satisfactory cleanness inside the site arrangement.

Another category of units associated to the temporary buildings and facilities, designed for a good development of the construction-installation works on Cernavoda NPP, is represented by the Owner's storage.

In order to fulfill Cernavoda NPP Project, ever since the beginning, a central main warehouse belonging to the Owner, capable to provide the storage of materials and equipment to be purchased, has been designed and constructed.

In the warehouses and storage associated to the constructor's temporary buildings and facilities, only the materials directly purchased by the constructor and the equipment that require pre-assembling or verifications, are stored.

The central main warehouse belonging to "Nuclearelectrica S.A ", located in SEIRU area, covers about 5 ha land surface and is still housing equipment and materials purchased for all 5 units of Cernavoda NPP.

The warehouse includes outer storage areas and roofed sheds for keeping the materials and equipment that need not be subject to bad weather conditions.

Materials and equipment inside the warehouse are permanently maintained.

The physical condition of the warehouses is satisfactory and there are spaces, platforms and adequate access roads.

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The warehouse is outfield with a road connection and a railroad connection to the local railway, as well as capacities for on-ramp unloading.

Besides this central warehouse, after 1995, storage areas have been arranged in the Turbine Hall and Service Building associated to Unit 3, such as extended platforms for pipe storage.

These spaces are mainly housing the materials and components associated to U2 and some materials for U1 maintenance works. In the completion of construction of Unit 3 phase, the materials must be removed from these spaces.

All the platforms and temporary buildings and facilities are provided with access roads, now in a satisfactory condition.

The main temporary buildings and facilities are provided with local railway connection.

## **II. 5 Construction Installation Services**

For all the Site Temporary Facilities, **the thermal energy supply** shall be centralized by an extended distribution pipe network having as source the thermal station located in Unit 3 - Turbine Building and heat supplied from Unit 1. Resuming the works for Unit 3 will require the relocation of the thermal station, for the satisfy the Unit 4 thermal power demand.

Under certain circumstances when the thermal pipe networks is unavailable (i.e. it is plugged, broken, etc.) or when the Site Temporary Facilities are far away and the thermal pipe connection is not within the reach, heating of confined areas shall be provided by electric heaters.

**Electric Power Supply** to all Site Temporary Facilities shall be provided by a centralized system, outfitted with 4 transformer stations located in various areas, so to provide the electricity required for the proper development of the activities.

**Drinking Water Supply** to all Site Temporary Facilities is provided by S.C.N.M.S.A from the City network. Therefrom, via a very old pipe distribution network with routes which no longer can be identified, the drinking water demand is delivered to each site facility.

**Sewage Water Systems** of the Site Temporary Facilities are mainly developed in the areas in which personnel offices are located, and their connection is made via the platform sewage water discharge system which, in its turn, is connected to the City network (Valea Cismeiei Pump Station).

**Rainfall Drainage** from the Site Temporary Facilities area are performed through a system of surface trenches and discharged to Cernavoda NPP platform rainfall drainage system.

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## II.6 Raw Materials, Auxiliary and Fuels used for operation of one Cernavoda NPP unit

The required raw materials, auxiliaries and fuels for operation of one Cernavoda NPP unit, are presented in Table II.6-1.

Table II.6-1 The required raw materials, auxiliaries and fuels for operation of one Cernavoda NPP unit

<b>Name</b>	<b>Annual quantity</b>
UO <sub>2</sub> / U	108 t / 96 t
D <sub>2</sub> O	System inventory: 456,9 t Annual losses: about 5 t
Hydrogen	108 flasks
Helium (He)	500 flasks
CO <sub>2</sub>	54 flasks
Nitrogen	54 flasks
Oxygen	36 flasks
Acetylene	36 flasks
Carbide	10 tanks
Morpholyne	7450 kg
Hydrazine	1900 kg
Cyclohexylamine	505 kg
Flomate 537	42 kg
Lithium Hydroxide	16 kg
Sodium Hydroxide	111500 kg
Hydrochloric Acid	101500 kg
Ferrous Chloride	33500 kg
Limestone	220000 kg
Biocid MB-25	5950 kg
Motor oil	400 t
Turbine oil	70 m <sup>3</sup>
Transformer oil	100 m <sup>3</sup>
Lubricators	2000 l

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## References

- II-1 Cernavoda NPP Unit 2, Final Safety Report, 2005
- II-2 CNCAN Order no. 365/2005 on the approval of standards regarding CANDU type NPP shut-off systems (NSN-13) published in MO 1084/2005
- II-3 CNCAN Order no. 136/2006 on the approval on standards regarding CANDU type NPP Emergency Core Cooling Systems (NSN-11), published in MO 444/2006
- II-4 CNCAN Order no.364/2005 for the approval of standards regarding Candu type NPP Containment System (NSN-12), published in MO 1097/2005

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### **III POLLUTANT SOURCES AND ENVIRONMENTAL COMPONENTS PROTECTION**

#### **III.1 Water Quality Protection**

##### **III.1.1 Liquid Radioactive Emissions**

###### **III.1.1.1 Sources of Liquid Radioactive Effluents**

The liquid radwastes are represented by the waste waters collected in the NSP and resulted from the operation of Unit 3 or Unit 4 NSP systems as well as a result of maintenance, inspection, repair and decontamination activities. Such liquid radwastes consist of:

- domestic water used for decontamination of humans, cloths, that mostly contains detergents and soap. The large volume of clear water used for such washings, impose a substantial initial dilution;
- demineralized water radiochemically impurified and resulted from the drainages from the spent fuel tanks or from the spent ion-exchange resin collection tanks;
- chemically and radiochemically impurified demi water and sewage water resulted from decontamination operations of equipment, from the chemical lab and from the dosimetric lab;
- demiwater, slightly impurified with tritium and/or chemical substances, resulted from de-deuteration operations of spent ion-resins in the heavy water purification systems;
- floor drainage;
- waters collected in the inactive drainage pits in NSP;
- demiwater used in the process circuits in the NSP in which chemical additives were added to control corrosion.

###### **III.1.1.2 Collection, Treatment and Evacuation of Liquid Radioactive Effluents**

Collection, storage, sampling, decontamination (if necessary) and controlled discharge of the liquid radioactive wastes resulted from both the plant process system operation and from the maintenance, repair and decontamination operations are performed by the Liquid Radioactive Waste System (LRWS). The simplified diagram of the Liquid Radioactive Waste Management System (LRWMS) is presented in figure III.1-1.

The radioactive liquids are either directly transferred from some of the Plant systems to LRWS (Liquid Radioactive Waste System), or are collected by the Plant drainage systems and then transferred to LRWS.

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The liquid waste transfer to LRWS is made via the plant drainage systems (active, non-active) and the corresponding ducts, the radioactive water being separately directed to two groups of storage vaults as follows:

#### **a) active drainage systems**

a1) The active drainage system in the Reactor Building has the function to identify and collect the radioactive leakages from different areas of the Reactor Building. Light and heavy water leakages are identified by beetle-type transmitters.

The collected drainages are transferred according to the quantity, the liquid type (heavy water or light water) and the radioactivity level of the leakages (determined from the sample analysis), as follows:

- to low radioactivity floor pit in the Service Building, if the liquid volume is large 20 l, the heavy water content is maximum 2% and the beta/gamma radioactivity is below 0.37 Bq/ml ( $10^{-5} \mu\text{Ci}/\text{m}^3$ );
- in drums, in order to be transferred to the D<sub>2</sub>O clean-up system, if the leakage volume is greater than 20 l and the heavy water content exceeds the value of 2 % or the beta/gamma activity is greater than 0.37 Bq/ml ( $10^{-5} \mu\text{Ci}/\text{m}^3$ ).

a2) The active drainage system in the Service Building ensures the continuous collection of all normally active or low active drainages from building, including water for fire protection system. The system takes up also the liquids transferred from the active drainage of the Reactor Building .

The leakages from the heavy water areas in Service Building (D<sub>2</sub>O primary coolant and moderator deuteration and dedeuteration system area, D<sub>2</sub>O tower) are collected and contained in a special tank, by this system, too. The system has the possibility of sampling.

The collected liquids will be selectively transferred to the LRWS or D<sub>2</sub>O clean-up system, if the heavy water content of the liquid is below or over 2 %.

**b) non-active drainage systems** which operate in nuclear area, ensure the collection of the underground waters from outside Reactor Building, outside Service Building and outside Spent Fuel Bays areas.

The waters collected from the SFB area are directly discharged to the LRWS, while the others will be transferred to LRWS or to rainfall water drainage system, depending on their radioactivity (after a previous sampling).

The liquids from the following plant systems are directly transferred to the Liquid Radioactive Waste System:

- Spent Fuel Bay cooling and purification system (after analysis of samples taken from the water after purification through the ion exchangers of the system, this is

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- either transferred to the LRWS or is recycled by bay the cooling and purification system, depending on the result of the sample analysis);
- primary coolant deuteration/dedeuteration system (after the samples analysis taken from the deuteration/dedeuteration tanks).

Liquid wastes collected by the Liquid Radioactive Waste Management System are classified as follows:

- **Category 1** resulted from the laundry, showers, labs and floor drainage in Service Building. These wastes are called **low level active wastes**; their activity ranges between  $3.7 \times 10^{-1}$  Bq/l and  $3.7 \times 10^2$  Bq/l and the average weighted activity is  $1.85 \times 10^2$  Bq/l;
- **Category 2** resulted from the depleted D<sub>2</sub>O upgrading system, the equipment decontamination system, rubber washing room, labs and floor drainage from the Service Building. These wastes are called **active wastes**; their activity ranges between  $3.7 \times 10^2$  Bq/l and  $3.7 \times 10^4$  Bq/l;
- **Category 3** resulted from the drainage in Reactor Building, Spent Fuel Bay, Spent Resin Storage Bays, Spent Fuel Bay underground drainage pits, Reactor Building and Service Building underground drainage pits and the D<sub>2</sub>O systems area. These wastes are **coming** from special sources; their activity ranges between  $3.7 \times 10^4$  Bq/l and  $3.7 \times 10^6$  Bq/l. Category 3 wastes can be sent directly to the decontamination system before being discharged into the Liquid Radioactive Waste Management System – storage bays. Usually, they are collected together with the category 2 wastes. The resulting mixture has an activity ranging between  $3.7 \times 10$  Bq/l and  $3.7 \times 10^5$  Bq/l (the average weighted activity is  $1.85 \times 10^3$  Bq/l).

The collection and storage of the radioactive liquid effluents are carried out in 5 concrete tanks lined with epoxy resin, located in the basement of the Service Building. Two of the tanks are used to collect the radioactive wastes of level 2 and 3; the other 3 tanks are used to collect the wastes of level 1 (low-active).

The tanks are so sized to ensure for each tank a volume ( $50 \text{ m}^3$ ) corresponding to a double daily-averaged quantity of radioactive liquid wastes produced in the plant, as well as the storage of the additional waste quantities resulted from a potential failure or abnormal situation in the plant operation.

The number of tanks should ensure the normal operation or in accident conditions, without treatment, during a week-end period of 3 days. The content of one tank can be treated during 24 hours. Normally, the liquid waste radioactivity is low enough to be permitted their discharge without previous decontamination. In special cases, when decontamination is necessary, an assembly filter/ion exchanger with the auxiliary equipment is provided.

All values and C & I of the system, used in normal operation, are located in the Service Building basement, reducing thus the risk that the potential failures in the system determine radioactive releases to the environment.

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After a tank is filled half of its volume and the content is homogenized, sampling is carried out to establish if the content can be discharged directly to the cooling water canal from the condenser or decontamination is necessary. A trench for sampling is provided on this purpose.

Radioactivity of the discharged wastes is measured continuously by a monitor (MEL), which automatically closes the releasing circuit when the limit of  $5 \times 10^3$  Bq/l is reached, and the wastes are returned to the tank, for analyses and decontamination.

A subsystem for continuous sampling from the discharge duct of the cooling water from condensers is also provided, after mixing with the radioactive wastes dispersed in the duct.

The samples must be analyzed weekly, to determine their content regarding beta/gamma activity and tritium.

The sampling subsystem ensures an additional control of the radioactivity released from the plant.

Decontamination of the liquid wastes whose radioactivity exceeds  $5 \times 10^3$  Bq/l is carried out by the decontamination subsystem.

As the main radioactive contaminants consist of a combination of colloidal particles and ionic material in the demineralized water, decontamination is carried out by mechanical filtering and ion exchange, by means of a filter with special natural fiber to perform the colloidal filtering process and a filter with resin bed prepared previously, used for filtering with ion micro-resins. The preparation of the filtering material consists of a mixing process with demineralized water in a tank provided with a mixer. The operation capacity of the tank is 233 l. The filter supply is provided by a centrifugal pump of 4.55 l/s flow.

The subsystem is capable to reduce the beta-gamma activity of the liquid wastes in a tank down to allowable limits throughout a day also considering the time necessary to prepare the installation for flushing at the end of the decontamination operation. Considering an average flow rate of 3.8 l/sec and a decontamination factor ranging from 10 (at the beginning of the cycle) to 2 (at the end of the cycle); in 8 hours, by recirculation via a filter the contents of a tank can be treated. At these average values of the flow rate and the decontamination factor, the radioactivity in a tank containing about  $35 \text{ m}^3$  liquid wastes, reduces with a factor of 2 each 1 and 1.5 hours.

In case that the radioactivity of the liquid wastes is entirely ionic, the decontamination capacity depends on the total concentration of the solids dissolved. If the concentration of dissolved solid is high, the filter cannot retain but a part of the dissolved solids and consequently only part of the radioactivity. In such cases, it is mandatory to repeatedly use the ion-exchange filter until an allowable concentration is obtained.

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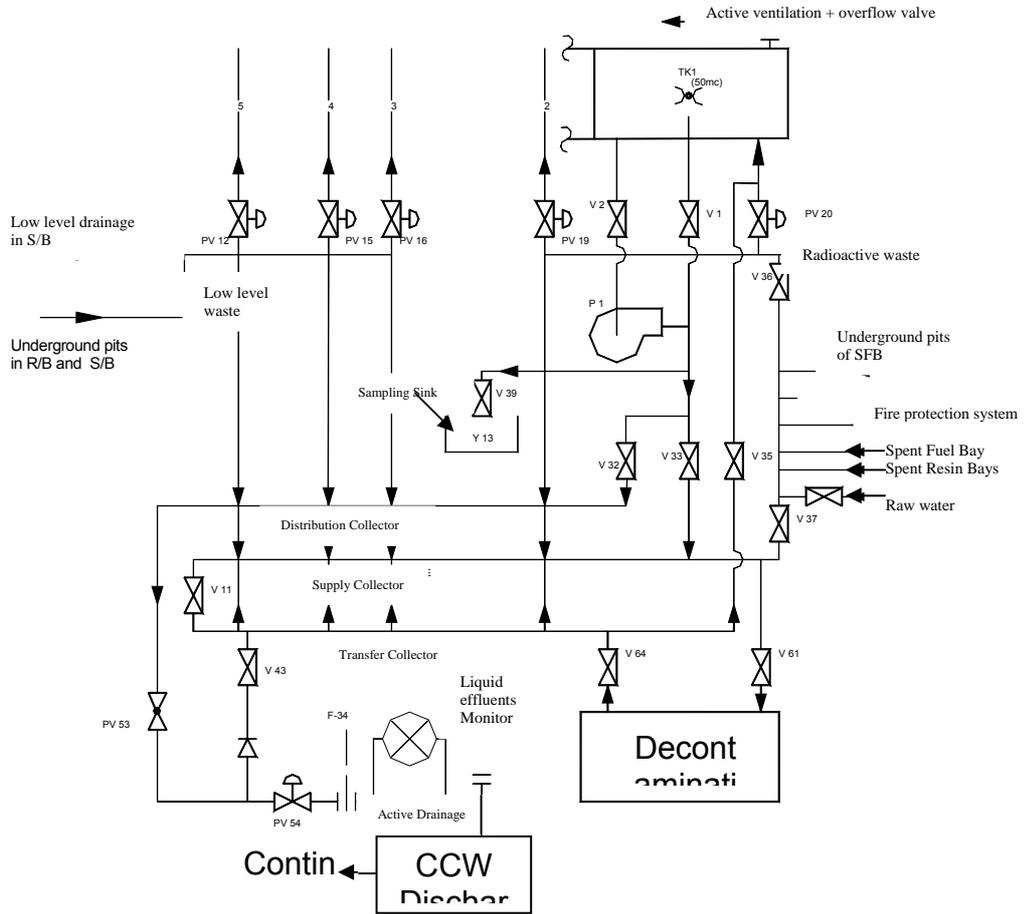
The discharge of the spent filtering material is made by filter flushing in counter flow of the demineralized water. The filtering mass shall be transferred as slurry to the spent ion resin management system collecting bays. The flushing water is returned to the liquid radioactive waste system (LRWS) via the overflow nozzles of the bays.

The wastes collected by this system are discharged into the Raw Service Water System (RSW), through the warm water discharge pipe. Finally the mixture of liquid wastes and raw water is discharged, for dilution, into the common discharge duct of the Raw Service Water System (RSW) and Condenser Circulating Cooling Water System (CCW), taking all necessary measures, so as when they are discharged into the emissary (Danube), the concentration of radioactive isotopes in the effluents is lower than the Derived Emission Limits (DEL), and the effluent monitoring program requirements are met.

### **III.1.1.3 Liquid Radioactive Waste Quantity and Radioactivity**

The annual average volume of the liquid radioactive effluents is 18,000m<sup>3</sup>, estimated value based on CANDU 6 NPPs releases during a 7 years operation period.

The radioactivity present in liquid radioactive effluents was estimated to 172 TBq for tritium and to 2.1GBq for gross beta/gamma activity. This estimation is based on the results from CANDU 6 NPPs during a 7 years operation period (Ref.III.1-1).



**Figure III.1-1 Simplified diagram of Liquid Radioactive Waste Management System**

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### III.1.2 Liquid Non-Radioactive Emissions

#### III.1.2.1 Sources of Non-Radioactive Effluents

Liquid non-radioactive effluents are generated by the following sources:

- Inactive drainage system Max. pump flow rate: 5.7 l / s
- Steam generator blowdown Flow rate: 3.2 l / s
- Hot water from condensers Flow rate: 46 m<sup>3</sup> / s
- Hot service water from condenser cooling systems Max. flow rate: 7.8 m<sup>3</sup> / s
- Sewage system Max. flow rate: 10 l / s
- Rainfall drainage system Flow rate: 3.2 m<sup>3</sup> / s (from all 5 units)
  - Rainfall drainage inside the Unit enclosure
  - Rainfalls from the roofs via the inside systems
  - Cable ducts (by accident)
  - Roads, platforms, vegetation areas
  - From the motor oil platform after having been purified in the motor oil separator
- Underground water drainage system Max. flow rate: 20l / s
- Water Treatment Plant (WTP)
  - Slime from contact beds Max. flow rate: 7l / s
  - Neutralized waters from the neutralization tanks Volume of spent waters: 330 m<sup>3</sup> / cycle
  - Flushing water from the mechanical filters Flow rate: 120-240 m<sup>3</sup> / h, max. time period 40 minutes, 3 times a day

#### III.1.2.2 Non-Radioactive Liquid Effluent Collection & Discharge

- **Inactive Drainage System** is collecting and discharging to the rainfall drainage system in the enclosure, the discontinuous drainage from equipment (waste waters containing chemicals used for the secondary circuit chemical conditioning) and the drainage (with traces of hydrazine, ammonium hydroxide and morpholine) which occur during normal & abnormal operation of process systems in the Turbine Hall, the connection building to the Turbine Hall and Service Building and Chillers Building.

- **Steam Generator Blowdown Effluents** have a very small flow if compared to the total flow of the cooling water and they include hydrazine (0.1- 0.5 mg/l) and solids in suspension in low quantities. Such waters are collected in a tank and analyzed before being discharged to the condenser cooling water.

- The entire flow of **hot service water** is discharged to the Hot Water Discharged Duct associated to the Condenser Cooling System.

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**Water discharged to the sewage system** is collected from the sanitary objects located in the buildings inside the plant and they come only from clean areas (noncontaminated areas). They are gravitationally transported through the outer network associated to Pump Station.

At the outlet from each pump station there is a manhole for sampling and a manhole for the discharge valve through which the control of the waste waters is provided. Sewage waters are pumped to Cismelei Valley pump station in Cernavoda.

**- Rainfall waters inside Unit 3** are collected and transported via the concrete ducts, which discharge the waters to the NPP collection channel.

The discharge of the waters collected in the collection channel is via a 1600 mm nominal diameter metal pipe to the Cernavoda NPP distribution pool.

Before being discharged to the suction pool, the rainfall waters are passed through a sand removal sieve.

**- Drainage system waters for the control of the water table inside the enclosure** are monitored and discharged to the rainfall water discharge system.

- Waste waters discharged from the **Water Treatment Plant** are the waters resulted from decantations (slime), from ion filter regeneration and mechanical filter flushing waters.

Waters in the WTP neutralization pools are discharged only after the pH control was performed both on the neutralization pump relief header and the chemical lab.

Neutralized waters coming from the ion filter regeneration are diluted in a ratio of 1:12000 and next, the concentrations of the calcium, magnesium, natrium, chloride and sulphide ions in the effluent as well as the pH value, fall in the allowable limits in the standards.

Flushing waters from the mechanical filters (conventionally considered "clean") are discharged via the rainfall water discharge system to the distribution pool.

**- Discharge of the heated water from all the consumers** (SFB exchangers, ECCS exchangers, auxiliary steam supply system coolers, chillers, intermediate cooling water system exchangers, turbine lubrication coolers) shall be to the heated water discharge ducts from the condensers and next, via the siphonating pool to the Danube or the Danube – Black Sea Channel –Race 2.

### **III.1.2.3 Concentrations of the Pollutants Discharged to the Environment**

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Table III.1.2-1 presents the results of the chemical analysis of the service water from Cernavoda NPP Unit 1 and the results demonstrate that the authorized limits are satisfied (Ref.III.1-2).

The quality indices for the waste sewage waters from Cernavoda NPP Unit 1 are presented in table III.1.2-2 (Ref. III.1-3).

In the already tables presented (III.1.2-1÷III.1.2-2) it is stated that at the Cernavoda NPP Unit 1 the authorized limits are satisfied. The project improvements for Unit 3 and Unit 4 will lead to pollutant concentrations smaller than those from Unit 1.

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Table III.1.2-1 Results of Chemical Analyses of the Non-radioactive Effluents at Cernavoda NPP U1

No.	Parameter	Allowable limits within authorization (mg/l)	Max. allowable limits NTPA 001 (mg/l)	1997 (mg/l)	1998 (mg/l)	1999 (mg/l)	2000 (mg/l)	2001 (mg/l)	2002 (mg/l)	2003 (mg/l)
1	PH (dimensionless)	6.5-9	6.5-9	8.19	8.17	8.1	8.12	8.11	8,12	8.07
2	Suspended solids	25	60	9.9	11.6	12.18	11.48	9.74	10.6	12.1
3	Ionic iron	1.5	5	0.11	0.163	0.23	0.14	0.18	0.245	0.19
4	Chloride	250	500	21	16.6	16.62	17.41	17.94	15.9	20.95
5	Sulphates	200	600	34.9	35.8	32.91	33.14	29.82	27.8	35.1
6	Ammonium	3	3	0.08	-	-	-	-	-	-
7	Biochemical oxygen demand (CBO5)	7	20 - 25	-	1.80	2.26	1.55	1.26	2.17	1.92
8	Sodium	100	-	18.0	16.5	15.22	17.93	14.36	11.2	16.6
9	Calcium	150	300	38.2	45.3	44.72	39.25	39.54	36.9	38.77
10	Magnesium	50	100	12.0	10.2	13.02	12.15	11.29	10.7	13..25
11	Hydrazine	0.1	-	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
12	Morpholine	0.4	-	< 0.100	< 0.100	0.100	< 0.100	< 0.100	< 0.100	< 0.100
13	Cyclohexylamine	0.1	-	-	interfere with morpholine					
14	Lithium hydroxide	0.025	-	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	0.005	0.005
15	Nitrate	1	2	< 2	< 2	< 2	< 2	< 1.0	< 1.0	< 1.0
16	Petroleum products	-	5	absent	absent	absent	absent	absent	absent	absent

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Table III.1.2-2 The quality indices for the waste sewage waters from Cernavoda NPP Unit 1 (2001-2002)

Quality indices	MU	Max. allowable limits NTPA 002/2002 (mg/l)	Allowable limits within authorization (mg/l)	2001 SP-1 Pumping Station	2001 SP-CPPON Pumping Station	2002 SP-1 Pumping Station	2002 SP-CPPON Pumping Station
PH		6,5-8,5	6,5-8,5	7,5	7,5	7,04-8,71	7,47-8,57
NH <sup>+</sup> <sub>4</sub>	(mg/l)	30	30	4	4	2,76-17,03	1,85-47,5
CCOCr	(mgO <sub>2</sub> /l)	500	500	250,25	267,75	29,05-73,5	58,9-136,1
CBO <sub>5</sub>	(mgO <sub>2</sub> /l)	300	150	109	117	7,52-16,2	6,24-27,8
Suspended solids	(mg/l)	350	300	120	134	12,0-30,0	10,0-70,0

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## References

- III.1-1 Cernavoda NPP Unit 2, Final Safety rEPORT, 2005
- III.1-2 Cernavoda NPP, Environmental Progress Report , 2004
- III.1-3 Fax CNE-PROD nr.4660/05.05.2001

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## III. 2 Air Quality Protection

### III.2.1 Air Radioactive Effluents

#### III.2.1.1 Sources of Air Radioactive Effluents

The gaseous radioactive effluents in the plant come from:

- fuel fission products;
- stable elements of process fluid activation products.

The gaseous effluents resulted from plant operation contain noble gases, particulates, iodine, tritium and C-14 (Ref.III.2-1).

The potential areas where gaseous radioactive wastes can result are:

- A. Reactor Building
- B. Spent Fuel Storage Bays
- C. Decontamination Center
- D. Heavy Water Management

#### A. Sources of gaseous wastes in the Reactor Building

A1 *Emissions from Primary Heat Transport (PHT) Circuit* (Ref. III.2-3):

- Continuous escape of D<sub>2</sub>O from the PHT circuit into the Reactor Building atmosphere; the contained noble gases remain in the air and circulate with it until the Reactor Building atmosphere is purged; this is not one of the significant pathways for noble gas releases;
- D<sub>2</sub>O leakage from Primary Coolant Collection System; this kind of wastes includes noble gases and tritiated water vapours which are not retained in D<sub>2</sub>O recovery system to which the vent of the collection tanks are connected;
- Cover Gas Purge from the Primary Circuit D<sub>2</sub>O Collection Tanks; these purged gases can contain a low activity of noble gases (due to the infrequent purge, the decay period of radioactive isotopes is long);
- Primary Circuit Degasser-Condenser, during degassing operation of the primary circuit (at startup or during normal operation); if the degassing is performed during a startup, the released gases are oxygen and nitrogen, with small quantities of deuterium and a low concentration of noble gases; the activity would be low, since the reactor would have been shut down for a period of time and the primary circuit would have been opened during the maintenance period; if the degassing is performed during normal operation, the released gases will be controlled by recirculation in the accessible area of the Reactor Building (F/M and boiler room areas); the contained noble gases will have about an eight hour decay period prior to their release (this period has been estimated considering

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normal ventilation and purge flows and a standard volume of the Reactor Building accessible area).

Generally, the emissions from primary circuit do not contain radioactive iodine, because the partition coefficient for the gaseous-liquid states of iodine, in the primary circuit conditions, is about  $10^{14}$  in favour of the liquid state.

*A2 Fuel Bundles with Defective Sheath* - there is the possibility of release of noble gases, iodine and particulates contained in the gap (interspace between the fuel elements and the sheath);

*A3 Annulus Gas Purge* - activation with neutrons of Ar-40 from CO<sub>2</sub> cover gas air trace leads to the Ar-41 production, which is a radioactive noble gas.

*A4 Activation with neutrons of C-13, N-14 and O-17 in process fluids or gasses* leads to the production of radioactive isotopes: C-14 (beta emitter), N-16 and respectively O-19.

#### B. Spent Fuel Storage Bays

The atmosphere of the rooms, in which the spent fuel storage bays are located, may contain noble gases and radioactive iodine.

#### C. Decontamination Center

The probability that radioactive gases or airborne may exist in the Decontamination Center rooms is low. The majority of wastes in this case are formed from vapours of liquid radioactive wastes resulted from decontamination.

#### D. Heavy Water Management

The D<sub>2</sub>O vapour recovery system is designed to retain the heavy water and tritium vapours released from the primary circuit, the moderator, the steam generators and the F/M into the atmosphere of the associated rooms. In this way, all the gas releases passing through the D<sub>2</sub>O vapour recovery system will mainly contain non-condensable radioactive gases, which will be captured and processed by the ventilation system.

### III. 2.1.2 Gaseous Radioactive Effluents Collection Systems

The collection of gaseous effluents is made by the ventilation system. The overall ventilation system is so designed that the air circulation should be carried-out from low-potential contamination areas to high-potential contamination areas, and finally, after filtering, the air is exhausted through a ventilation stack.

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### III.2.1.3 Gaseous Radioactive Effluents Control

The control of the gaseous radioactive effluents is performed both by filtering on the release ways and by automatically isolating of containment, when radioisotopes are detected.

At CANDU type plants, the control of gaseous emissions is ensured by:

- two drying steps, to control tritium and D<sub>2</sub>O vapour;
- filtering before the discharging to atmosphere, to retain the particulates and radioiodine;
- dispersion by releasing at height above the ground (ventilation exhaust stack).

#### a) Filtering of Gaseous Radioactive Effluents

*Reactor Building Ventilation System* is provided with an exhaust air filter unit located in Service Building.

Filtering is carried out in stages, as follows:

- Stage I – provides high-efficiency filtering for retaining the contaminant particles and it consists of a pre-filter (efficiency min 85% ASHRAE) and a high-efficiency filter (HEPA) (99.97%);
- Stage II – provides the retention of the radioactive iodine existing in the contaminated air as elemental iodine or methyl iodide and consists of an active cool bed with efficiency 99.99% for elemental iodine and 99.90% for methyl iodide;
- Stage III – provides the retention of the possible active coal particles driven by the air stream and consists of a high-efficiency filter (HEPA) identical with the one existing for the first filtering stage.

*Service Building Ventilation System* is provided with one filter unit on the air discharge line from the Spent Fuel Bay and an exhaust air filter unit on the air discharge line from all the contaminated areas.

The first filter unit includes the following filtering stages:

- Stage I – provides high-efficiency filtering for retaining the contaminant particles and consists of an auxiliary pre-filter, a pre-filter (efficiency 85% NBS) and a high-efficiency filter (99.97%);
- Stage II – provides the retention of the radioactive iodine existing in the contaminated air as elemental iodine or methyl iodide and consists of an active cool bed with efficiency 99.99% for elemental iodine and 99.90% for methyl iodide;
- Stage III – provides the retention of the possible active coal particles driven by the air stream and consists of a high-efficiency filter identical with the one existing for the first filtering stage.

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The second filter unit, on the air discharge line from all the contaminated areas provides high - efficiency filtering in order to retain the contaminant particles and consists of an auxiliary pre-filter, a pre-filter (efficiency 90-95% NBS) and a high – efficiency filter (99.97%, for 0.3 micron particles per DOP test).

#### b) D<sub>2</sub>O Vapor Recovery in Reactor Building

Recovery of D<sub>2</sub>O vapors from Reactor Building is carried out by the drier system which entraps the D<sub>2</sub>O vapors from the air, and the recovered water is next upgraded and used in the plant. A further advantage of this system is the reduction of the tritium concentration in air and of the emissions from the plant.

The dryers consist of desiccant beds, which retain the D<sub>2</sub>O vapors from the air and collect them in the desiccant. The desiccant beds are subsequently regenerated while the D<sub>2</sub>O, which carries radioactive materials, is transferred to D<sub>2</sub>O purification system for cleaning, upgrading and possible return to the plant D<sub>2</sub>O systems.

In this way, 95 % D<sub>2</sub>O and tritium vapors are recovered and the tritium releases are decreased by a factor of minimum 20 (data resulted from the CANDU plants operation experience).

#### c) Radioactive Gaseous Effluents Release and Dispersion in the Atmosphere

Gaseous radioactive effluents are released, in a controlled manner, to the stack after the continuous monitoring of the air by GEM (radioactive gaseous effluent monitor). Release at a certain height, provides a better dispersion of the radioactive isotopes and thus a reduction of their concentration, namely of the radiation dose for the public.

Radioactive effluents are released to the plant stack, which is 50.3 m high and 2.3 m inside diameter. The total flow released through the stack is 175140 m<sup>3</sup>/h in summer and 142520 m<sup>3</sup>/h in winter.

#### **III.2.1.4 Concentrations and Flows of Released Radioactive Gaseous Effluents to the Atmosphere**

The estimated volume of the released radioactive gases from one Unit of Cernavoda NPP is 283 m<sup>3</sup>/min. The estimation was made on basis of the average value resulted from the releases generated by 6 CANDU type NPP's for a 7 years period (Ref. III.2-3).

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The isotope contents and annual estimated activity are as following:

Tritium	$1.65 \times 10^2$ TBq
Noble gases	$4.9 \times 10^1$ TBq-MeV
Radioactive iodine	$0.2 \times 10^{-4}$ TBq
Particles	$0.3 \times 10^{-4}$ TBq
C-14	$1.05^*$ TBq

\* The predicted value for C-14 activity is based on the data made available for Point Lepreau weighted for the period 1989-1994.

### III.2.2 Air Non-Radioactive Effluents

The main chemical pollutants are accompanying the gases released from the R/B and S/B and they are taken over by the ventilation systems of the plant and properly treated and diluted via the D<sub>2</sub>O vapor recovery systems and the ventilation systems.

The air in Service Building is taken over by the non-contaminated air-released system and directly discharged to the atmosphere.

Other potential gaseous pollution sources which are not controlled by the plant ventilation systems are: the steam coming from the valves on the steam piping and from the safety valves which discharge the steam to the atmosphere only during abnormal operation conditions, as well as the vapor releases coming from the Diesel generators, from the oil storage tanks and from the Water Treatment Plant Drainage system.

All these pollutant discharges are limited to the surface of NPP Site; they are quite small and fall in the allowable limits from the standards.

Steam discharge to the atmosphere is occasionally and it does not represent negative effects because it can generate local clouds which are integrated into the water circuit in nature.

Regarding the oil storage tanks, located in open space, the main effect is the oil vapor or drops release to the atmosphere; the release is a continuous process throughout the plant operation life; it is reduced and confined. So, the unfavorable effects on the environment are insignificant.

The Diesel generators, which operate only during emergency regime (loss of class IV power supply) are started, periodically, to be tested at regular intervals; they have the unfavorable effect of gases releases to the atmosphere, during operation only, releases which have a low level and are local, without toxic effects on the environment, population and operation personnel.

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The Auxiliary Boiler Station is an important potential source of pollution with non-radioactive gases. Actually, the Station is in stand-by and is operated only upon the plant start –up. There is the possibility to start Unit 3&4 by taking over the required steam from the in-service U1 or from U2. The Auxiliary Boiler Station was constructed for all the NPP units on NPP Site and it was licensed, in point of environmental protection when U1 was commissioned.

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## References

- III.2-1 Cernavoda NPP - Unit 1, Final Safety Report, March 2001
- III.2-2 Environmental Impact Study for Cernavoda NPP - Unit 2, ICIM, 2002
- III.2-3 Cernavoda NPP - Unit 2, Final Safety Report, April 2003

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### **III.3 Protection Against Noise and Vibrations**

#### **III.3.1 Sources of Noise and Vibrations, Equipment and Facilities for Protection against Noises and Vibrations**

Many systems of the plant have either pumps or fans associated with them, which are sources of noise or local vibrations.

During operation, this equipment has local noise levels ranging between 75 and 95 dB. All the equipment which may be sources of either noise or vibrations, is provided with noise dampers. All equipment is located in buildings which greatly reduce both noise and vibration levels outside these buildings. Consequently, such noise and vibration levels have no significant impact upon the environment.

The noise produced by steam release into the air may occur:

- at the ASDV - atmospheric steam discharge valves (where it is reduced by noise dampers which they are provided with);
- at the MSSV - main steam safety valves (which are opened only under emergency situations).

The Diesel generators will be tested only periodically, and therefore the resulting noise levels are not persistent. The Diesel groups will be used only in the case of loss of class IV power supply.

The main sources of noise and vibrations are the power transformers inside the transformers stations, which have the following functions:

- distributing electric power produced by the electric-generator to the National Power System;
- power supply for the plant own services.

The noise level of the transformers falls within the regulatory limits of the Romanian standard EN 60551 – A1: 1999 provisions, being 79 dB at 1 m away from the transformer (as per provisions specified by manufacturer in the technical manuals).

The vibrations produced by transformers are also within the regulatory limits of STAS 8393-89 provisions, having the following characteristics:

maximum amplitude: 50  $\mu$ m  
speed: 10 - 15 mm/s.

Other noises may be generated by the material handling in the existing warehouses, work-shops, concrete preparation station in operation (outfitted with a sorting-out unit), inside transport (light and heavy vehicles) and off-site traffic (all kinds of vehicles).

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### III.3.2 Noise and Vibrations Level at the NPP Site Boundary and at the Nearest Protected Receiver

The maximum allowable limits on basis of which the environment condition in point of the noise level is analyzed, are specified in STAS 10009-88, namely 65 dB (A) for industrial enclosures (Table 3 in STAS 10009-88).

As regards the location of residential buildings (chap. 2.5 in STAS 10009-88), it shall be so established to avoid the exceeding of the maximum 50 dB (A) level for the noise level outside the building, measured at 3 m distance from the building facade, as per STAS 6161/ 1-89.

Values of the measurements, developed in January 2001 (Ref. III.3-1) in some points on NPP platform and in its vicinity, are presented in Table III.3.2-1. The noise level was measured at a 30' interval, in the most western point of NPP platform, in an area with auxiliary activities and the equivalent noise level was measured at the walk-way level of the nearest off-site highway during 1h period (STAS 10009-88 specifies a noise level lower than 70 dB (A) for class II roads).

Table III.3.2-1 Noise Level Measured Values

No.	Location	Measurement time period	dB (A) level	Noise sources
1	At the site farthest point	30 min	45.9 39.7 35.9 43.0	Concrete mixer, light and heavy vehicles traveling on near-by factory roads, workshops, warehouses
2	At the level of the highway kerb	1 hour	66.8	Vehicle traffic

In August 2004, noise was measured by ICIM in 6 points (Ref. III.3-3). The results (Table III.3.2-2) were compared with the allowable limits specified by STAS 10009-88 (Urban acoustics - Admissible limits of noise level). It was found that the measured noise level was within the admissible limit.

The usual noise level in the residential areas is not influenced by the activities of Unit 1, because of the distance and the hill between the site and the Cernavoda Town.

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Table III.3.2-2 Noise level measured in 2004

No.	Location	Equivalent noise level ( $L_{eq}$ ) dB(A)	Admissible limit for $L_{eq}$ dB(A)
1	Point 1, county road border (outside the site)	62.3	65
2	Point 2, NPP site entrance (outside)	56.1	65
3	Point 3, south-east limit of the site (outside)	54.0	65
4	Point 4, east limit (outside)	51.7	65
5	Point 5, east limit (outside)	56.2	65
6	Point 6, north limit (outside)	55.2	65

It is estimated that neither in the construction period, nor in the operation period, the environment is noise polluted by Cernavoda-U 3, U4 and the noises developed on job sites will not exceed the noise level of 90 dB (A) which could generate noise exposure beyond the allowable limits.

As residential area, Cernavoda Town is the only exposed locality. Between the Town and the NPP Site there is a natural barrier (a hill). Due to the attenuation by distance, by the absorption in the air and by diffraction, the contribution of U3 and U4 to the noise level of Cernavoda Town is assessed as negligible.

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## References

- III.3-1 Environmental Impact Study for Spent Fuel Interim Storage Facility -DICA, ICIM, 2001
- III.3-2 Environmental Impact Study for Cernavoda NPP Unit 2, ICIM, 2002
- III.3-3 Environmental Impact Assessment Report for Cernavoda NPP Unit 3, ICIM, 2005

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### **III.4 Radiation Protection**

#### **III.4.1 Radiation Sources**

The main radiation sources located in different installations of Cernavoda NPP-U3, respectively U4 are: reactor core, primary heat transport system, moderator circuit, fuelling machine, spent fuel bays, active circuit purification systems, radioactive waste storage systems, etc.

The releases from the systems transporting radioactive fluids may represent air and surface contamination sources in the areas accessible for operating and maintenance personnel.

Tables III.4.1-1 and III.4.1-2 summarize the radiation sources from Reactor Building and Service Building, respectively; the tables contain information regarding the components of the systems transporting radioactive fluids, the type of radiation emitted and its origin, as well as the type of radionuclides that are present.

##### **III.4.1.1 Reactor Core**

The reactor core is a strong radiation source for alpha, beta, gamma and neutrons emitted by the radioactive nuclides produced in the fission process or capture reactions.

Most of the alpha and beta particles are absorbed in the core.

The neutrons resulted from the fission process lead to new fission processes or radiative capture.

Normally, the fission products are retained by the sheath of the fuel element, and only a small fraction can reach the coolant and can be deposited on any surface, resulting in a new radiation source.

The activation products arising in the coolant or in any other process fluid can be transported from a region with intense neutron flux (inside the core or close to the core) to a region with low neutron flux (outside the core).

The activation products could arise also in the structural components of the reactor and the reactivity control system.

Therefore, during reactor operation, the main types of radiation taken into consideration in the shielding calculations are neutrons and gamma radiation.

After reactor shutdown, the activation products are an important radiation source in the reactor and each component removed from the reactor must be considered radioactive.

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At the reactor ends, in the fuelling machine area, the following radiation sources contribute to the dose rate after shutdown:

- Radionuclides produced from the reactions of neutrons with Co-59 and Mn-55 nuclei present in steel (end shield activation);
- The radioactive fission products arising inside the fuel elements from the core;
- The fission reactions due to the delayed neutrons and photoneutrons in the core (low power source);
- The activated corrosion products and the radioactive fission products deposited in the end fittings and the feeders.

To allow the personnel to work in the proximity of the reactor core, it is necessary to provide shields around the reactor core (primary shield) in order to reduce the radiation doses to acceptable values. Even in the zones where access is allowed only after reactor shutdown, it is necessary to reduce the radiation level due to the fission products from the fuel and due to activation of the structural materials.

The biological radiation shields have also the function of protecting the public against the radiation sources from the plant and to stop the degradation of the structural materials of the plant due to nuclear radiation.

### **III.4.1.2 Primary Heat Transport System**

The activity of the fluid in the primary heat transport system is given by the fission products and activation products (including tritium).

#### **a) Fission products**

The primary heat transport circuit is the main source of radioactive materials as it contains the fuel; during fuel irradiation, fission products are formed in increasing quantities until the equilibrium state is achieved.

These fission products are retained within the fuel elements unless there is a sheath failure, in which case some of the fission products are released to the coolant.

At the end of the first year of normal reactor operation, irradiated fuel bundles are discharged from the reactor and replaced by new fuel bundles (continuous refueling).

Thus an equilibrium inventory of fission products is essentially created in the primary circuit. The value of the inventory is determined primarily by the bundle irradiation average time.

Generally, if there are no sheath failures, there are essentially no fission products in the coolant. The only fission products present result from the "trace" quantities of uranium found in the materials of the components of the system. For example there

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is an average of about 1 ppm of uranium in the zirconium alloys used for pressure and calandria tubes, in CANDU reactors.

From CANDU-6 experience, it has resulted that only about 0.1% from fuel bundle sheaths may have fabrication defects. These defects result in the escape of only a small fraction of the total inventory of the fission products from the defected element in a bundle.

The defective bundles are removed on power from the reactor core, hence normally very low fission product inventory is present in the primary circuit. The released fission products, mainly the more volatile ones, enter the primary coolant and are distributed on the surfaces of the primary circuit and purification system, or remain in the primary coolant. Thus, the majority of the escaped fission products will decay within the boundaries of the primary circuit.

The estimated fission product activity concentrations within the primary circuit of CANDU-6 reactors are presented in Table III.4.1-3. The half-life for each radionuclide is indicated in the brackets, since its presence in the radioactive waste resulted from primary circuit depends on the activity concentration as well as its half-life.

#### b) Activation products

Metals in contact with the coolant in the heat transport system corrode easily. Some of the corrosion products are dissolving or become suspended in the coolant and so may pass through the neutron flux in the reactor core. The neutron activation of some corrosion products occurs during their transit time through the reactor core. Subsequently, these activated corrosion products are likely to redeposit in other portions of the system. Since there is a continuous exchange of dissolved and suspended materials between the coolant and the surfaces of the primary heat transport system, there is a gradual build-up of radioactive material on the system surfaces outside the active zone, producing radiation fields. Some of the radioactive materials may escape from the primary circuit, becoming a secondary source of radiation. By selection of system components to the continuing PHT purification by filtration and ion exchange, to minimize the quantities of activated corrosion products in the system are minimized.

The estimated activity concentrations of the activation products within the primary circuit at CANDU-6 reactors are presented in Table III.4.1-3.

The coolant itself and any impurity in the coolant can be activated with neutrons becoming radioactive.

The main radioactivity induced in coolant during reactor operation is given by the radionuclide N-16. Others important radionuclides are O-19 and F-17. These activation products have relatively short lifetimes: 7.1s for N-16, 26.3s for O-19 and 64.5s for F-17.

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Shielding of the PHTS main equipment (feeders, headers, piping, steam generators, etc) is mainly dictated by the high gamma radiation levels from N-16 sources .

#### c) Tritium

Tritium is also produced in the coolant mainly by activation reaction of deuterium with the thermal neutron flux in reactor core.

The tritium growth rate is affected by the annual operating period of the reactor. Thus a reactor which operates at a high capacity factor will produce more tritium than a reactor which operates at a low capacity factor. Tritium activity increases with years of reactor operation.

The estimated tritium activity concentration in the primary coolant of CANDU-6 reactors is presented in Table III.4.1-3.

#### d) Carbon-14

Another radioactive isotope produced in primary coolant heavy water is Carbon-14, which is also produced by neutron activation reactions (mainly of O-17 isotope).

C-14 produced in the primary coolant is mainly in a bicarbonated form and it is easily removed by the ion-exchange resins used in the primary coolant purification system. The estimated Carbon-14 concentration activity in the primary coolant of CANDU-6 reactors is presented in Table III.4.1-3.

Generally, heavy water is an expensive fluid and conservation of heavy water has priority during the design as well as during the operation of CANDU plants. Thus primary coolant leakages are collected and/or recovered by the D<sub>2</sub>O vapour recovery and active drainage systems. Therefore, although the leakage will carry both fission and activation products, the heavy water management systems serve as a means of control within the plant and as barriers to the release of radioactivity to the environment.

### III.4.1.3 Primary Coolant Purification Circuit

For estimation of ion exchange resins activity in the primary coolant purification system, the fission and corrosion products are taken into consideration.

The estimated values of the concentration activity on primary circuit ion exchange resins, for each radionuclide, are presented in Table III.4.1-4, for CANDU-6 reactors.

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#### **III.4.1.4 Main Moderator Circuit**

The moderator system is the other major source of radioactive materials. However, the system operates at relatively low temperature and pressure and so has a much lower heavy water leakage rate than the primary circuit.

Heavy water in moderator system is in interaction with neutron fluxes inside the reactor core, and activation processes take place, which determine the intrinsic moderator activity.

On the other hand, the corrosion of the surfaces inside the core (already activated or which can be subsequently activated) and the corrosion products penetration in the moderator, lead to another component of the moderator activity.

Stainless steel and zirconium alloy are the principal materials used for the system components and thus the concentrations of corrosion products are generally lower than in the primary circuit.

The main contribution to the radioactivity induced in the moderator fluid during reactor operation is radionuclide N-16, O-19 and F-17 are also produced.

Concerning tritium activity, the following are mentioned: as the exposure period to neutron flux of the moderator heavy water is longer than the exposure of the primary coolant heavy water and, on the other hand, the thermal neutron fluxes in the moderator are higher than those in the coolant, the activation of the moderator heavy water leads to a higher concentration of tritium. In spite of this difference in tritium levels, the primary heat transport system makes a one third contribution to the emission of tritium, due to its relatively large leakage rate. Thus, the primary heat transport system has a significant contribution to the operation dose. It is essential to keep the primary system tritium concentration to a level as low as possible, and hence the requirement that the possibility of transferring moderator heavy water into the primary circuit must be minimized. To this end, there are separate heavy water collection systems, purification and separation of the moderator and coolant heavy water, being processed by the upgrading tower. There is an enclosure around the moderator pumps, valves and heat exchangers, which is maintained at a lower pressure than the rest of containment and is provided with a vapour recovery dryer.

Referring to Carbon-14, over 95% of its total activity is produced in the moderator heavy water by the activation of O-17. The most part of Carbon-14 produced in the moderator heavy water is transformed into bicarbonate, which then is removed by the purification system. More than 98% of the Carbon-14 produced in the moderator system is removed by the moderator purification ion exchangers.

The estimated radionuclide activity concentrations in the moderator system of CANDU-6 reactors are presented in Table III.4.1-5.

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### III.4.1.5 Moderator Cover Gas System

The moderator cover gas system provides an inert gas covering the surface of the moderator in the calandria and overpressure relief ducts.

High purity helium is used for transporting the D<sub>2</sub> and O<sub>2</sub> resulted from radiolysis in the moderator through a recirculation loop designed to recombine them into D<sub>2</sub>O, thus avoiding dangerous concentrations of potentially explosive D<sub>2</sub>.

The helium used in the cover gas system has a purity of 99.99% He, and an argon impurity of not more than 1ppm. This prevents corrosion of the moderator system components and minimizes argon activation to Ar-41 in the system.

The D<sub>2</sub> concentration is maintained normally at less than 2% by recombination; exceptional increases of up to 4% are tolerated but lead to automatic action to further reduce D<sub>2</sub> concentration, to eliminate any possibility of a deuterium explosion.

Air ingress into the cover gas system (for example from outages with opening of the calandria, some residual air remains after purging) would increase nitrogen, oxygen and argon concentrations in the cover gas, so it is strictly controlled by design and closely monitored. Nitrogen is responsible for radiolytic production of nitric acid which encourages higher rates of radiolysis of D<sub>2</sub>O and also consumes ion exchange resins.

In summary, the activity in the moderator cover gas system is partially due to Ar-41, the activation product of the reaction  $^{40}\text{Ar}(n, \gamma) ^{41}\text{Ar}$ ; Ar-41 emits about 1.3 MeV (99%) gamma radiation and has a half-life of 1.83 hours.

The main source of activity in this system is the tritium, whose concentration in the cover gas is the same as in the moderator itself.

Carbon-14 is also produced in the moderator heavy water, mainly by the activation reaction of O-17. In the moderator cover gas system 99% of total C-14 is present as CO<sub>2</sub> while the organic compounds (methan-CH<sub>4</sub>) is negligible. Carbon dioxide is removed by ion exchange purification resins.

### III.4.1.6 Moderator Purification Circuit

The purification system is a closed circuit, which recirculates the moderator D<sub>2</sub>O from the discharge header of the two moderator pumps through the filter and ion exchanger columns to the suction header of the moderator pumps.

The activity of the ion exchanger resins and filters in the system is due to the radionuclide N-16 and the principal corrosion products in the heavy water: Co-60, Mn-56 and Fe-59.

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### III.4.1.7 Liquid Zone Control System

The system consists of a light water subsystem and a helium subsystem.

The liquid zone control system is part of the reactor regulating system and a fraction of the system water is in the reactor during normal operation. The neutron flux activates the water and corrosion products, producing tritium and activation products.

A source of radiation is given by the radionuclides N-16 and O-19, which result as activation products in the light water passing through the reactor core.

Another source of radiation in the water subsystem is given by the steel corrosion products which lead to the production of Mn-56, Fe-59, Co-60 by activation, and the sodium impurities leading to Na-24 production. These activation products are retained on the ion exchanger resins in the circuit.

As the water subsystem contains light water, tritium concentrations are much smaller than in the primary coolant or moderator.

At the helium subsystem, the ingress of air into this subsystem can lead to Ar-41 production.

The estimated activity concentrations of the radioactive products in the liquid zone control system of CANDU-6 reactors are given in Table III.4.1-6.

This activity may escape with any system leakage and add to the activity entering the radioactive liquid waste management system; from the CANDU-6 operating experience it has resulted that the system does not contribute significantly to the total activity of liquid radioactivity wastes.

### III.4.1.8 End Shield Cooling System

The shield cooling system recirculates the light water from the calandria vault, which is irradiated by reactor residual neutron flux.

The water contains activated products and a very low amount of tritium.

The origins of the radiation sources that are present in the system water are:

- Induced radioactivity, due to neutron activation of the oxygen from the water (the main radionuclides are N-16 and O-19);
- Activated corrosion products: the water from the system corrodes the component surfaces and the corrosion products being transported are activated in the neutron flux, inside the end shields and the calandria vault;

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- Activated impurities: although the water entering the circuit is demineralized, it still contains a small fraction of impurities, which is activated; also,  $^{41}\text{Ar}$ , produced by the activation of  $^{40}\text{Ar}$  dissolved in the water, can be present.

This radioactivity may escape with leakage of shield cooling water and reaches the radioactive liquid waste management system. From CANDU reactor operating experience it has resulted that the shield cooling system does not contribute significantly to the total activity of the liquid waste system.

The estimated specific activity at equilibrium of the isotopes in the shield cooling system for CANDU-6 reactors is presented in Table III.4.1-7.

#### **III.4.1.9 D<sub>2</sub>O Supply System**

The tanks of the system are provided to store the reactor initial heavy water load. They also contain the primary coolant and moderator heavy water due to the leakages resulted during the plant operation.

For the evaluation of the source term the most unfavorable situation has been assumed, when the tanks are filled with D<sub>2</sub>O from the primary circuit.

Therefore, the source activity is the same as the activity of the D<sub>2</sub>O cleanup system supply tanks (see Table III.4.1-8).

#### **III.4.1.10 D<sub>2</sub>O Cleanup System**

Generally, the heavy water recovered from leakage, spills and deuteration-dedeuteration system ion exchange resins must be cleaned up before being upgraded.

The cleanup system is designed to remove particulate, dissolved and organic ionic impurities from recovered heavy water.

The water to be cleaned comes especially from the primary coolant and moderator collection systems, D<sub>2</sub>O vapour recovery system and moderator and primary coolant deuteration and dedeuteration systems.

The estimated values of radionuclide activity concentration in the components of the D<sub>2</sub>O cleanup system for CANDU-6 reactors are presented in Table III.4.1-8.

#### **III.4.1.11 D<sub>2</sub>O Vapour Recovery System**

The D<sub>2</sub>O vapour recovery system recovers the heavy water leaks from the equipment located in the Reactor Building. During the processing of heavy water

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vapours, the tritium and other airborne contaminants or noble gases are absorbed in the dryer desiccant beds. The heavy water escaped in the atmosphere of the dryers room is taken over by the heavy water vapour recovery system.

The presence of some radioactive substances in air (iodine, noble gases, tritium, particulates) due to leakages from process systems containing radioactive fluids is anticipated in some areas in the Reactor Building and in the Service Building.

The concentrations of radionuclides in air in the heavy water vapour recovery areas in Reactor Building are presented in Tables III.4.1-9 ÷ III.4.1-12 for the following working areas:

- accessible areas in the Reactor Building (Table III.4.1-9);
- steam generators room (Table III.4.1-10);
- F/M vault and moderator room (Table III.4.1-11);
- moderator equipment enclosure (Table III.4.1-12).

#### **III.4.1.12 Annulus Gas System**

The annulus gas acts as a thermal barrier between the pressure tube and the calandria tube. The annular space is filled with CO<sub>2</sub> which produces an inert atmosphere. CO<sub>2</sub> was selected for its low argon and nitrogen impurity levels, ensuring that there is little Ar-41 production in the annulus gas. Another radioisotope produced in the annulus gas system in a small concentration of activity, is C-14.

The estimated activity concentration of Ar-41 in the annulus gas system, based on the existing data from CANDU-6 plants with CO<sub>2</sub> as annulus gas is 25 kBq/cm<sup>3</sup>.

#### **III.4.1.13 Fuel Handling Systems**

The new fuel and spent fuel handling systems are both potential sources of radioactive materials. In the first case (new fuel handling), the source is considered negligible. New fuel contains small quantities of uranium daughter products but since the fuel is enclosed in a sheath, only very little radioactive material can escape from sheath, the total annual escape being negligible.

The spent fuel handling system discharges fuel bundles containing large inventories of fission products.

Generally, fuelling operations do not result in any significant release of radioactive material because the fuel sheath is intact.

CANDU-6 operating experience shows that about five bundles with fuel sheath defects are handled per year (0.1% failure rate); in this case, taking into account the noble gases released during a fuel handling sequence, the annual activity released

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from the defective fuel bundles is comparable with that corresponding to the intact fuel.

The activity of C-14 produced within the fuel elements is about 3.3% of the total C-14 production; considering the small rate of fuel sheath defects, the activity of C-14 produced in the fuel which could be released in the primary system is negligible compared with the coolant activity.

#### **III.4.1.14 Moderator and primary coolant deuteration- dedeuteration systems**

The moderator and primary coolant deuteration-dedeuteration systems present a risk for contamination with tritium, because the water in these systems is strongly tritiated.

The tritium activity of the water collected by the radioactive liquid waste system is approximately 10 TBq/year from the primary heat transfer deuteration-dedeuteration system and ~ 60 TBq/year from the moderator deuteration-dedeuteration system.

Tritium as well as liquid and gaseous waste releases are monitored.

As concerns the gamma radiation level, this rises in the operating zones during the transfer of the spent resin from the ion exchanger to the dedeuteration tank and from there to the spent resin storage tank.

#### **III.4.1.15 Spent Fuel Bays**

The spent fuel bays constitute external irradiation sources, as well as contamination sources. The fuel bundles extracted from the reactor and temporary stored inside the bays are gamma radiation sources, whose intensity depends of the fuel cooling time.

On the other hand, there is another potential radiation source at the bays, consisting of the fission products that can be released from failed fuel bundles in the reception bay and failed fuel bay (the presence of failed fuel bundles inside the main storage bay is not expected).

Although the purification system removes most of the solid fission products, some of them remain inside the bay water. In addition, part of the gaseous fission products are dissolved in the water and part of them are in the air above the bay (the rest is driven through the ventilation system).

The activity concentrations of the radionuclides inside the water of the main spent fuel bay estimated for CANDU-6 reactors are presented in Table III.4.1-13.

#### **III.4.1.16 Spent Fuel Bay Cooling and Purification System**

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The spent fuel bay stores the fuel bundles discharged from the core. The bay water provides both shielding and cooling of the bundles.

Fission products from the defective spent fuel bundles and radioactive corrosion products released with impurities from the fuel element surface may enter the water of the spent fuel bays.

Also, the transfer of radioactive materials in the bay water with the small quantity of heavy water carried over with the fuel bundle should be mentioned.

All these contribute to the inventory of radionuclides in the bay water (see Table III.4.1-13).

The specific activity accumulated in the ion exchange resins is due to fission products; the estimated values for CANDU-6 reactors are:

I-131	(8.05 days)	1.11 E+6 kBq/kg
Cs-134	(2.05 years)	1.58 E+6 kBq/kg
Cs-137	(30 years)	5.71 E+6 kBq/kg

CANDU-6 operating experience demonstrated that the radioactivity accumulated in the pumps and heat exchangers is negligible.

#### **III.4.1.17 Spent Resin Storage Vaults**

The ion exchange spent resins are transferred from the various process systems (e.g. primary circuit purification, D<sub>2</sub>O clean-up, spent fuel bays, end shield cooling system, liquid zone control system, etc.), via the resin transfer system, and temporarily stored into the storage concrete vaults (room S-020 from Service Building).

The spent resins activity is mainly due to radionuclides Cs-137, Cs-134 and Co-60. The activity of all resin source systems is presented in Table III.4.1-14. The values indicated in the table are estimated based on CANDU-6 operating experience.

It has been assumed that the activities in the resins from the liquid zone control system and fueling machine auxiliary system are negligible.

#### **III.4.1.18 Radioactive Liquid Waste Management System**

The radioactive liquid waste management system is designed for the collection, storage, treatment (when necessary) and removing of any radioactive liquid waste produced in the plant. The main components of the system are the liquid waste

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storage concrete tanks located in the basement of the Service Building and filter-ion exchanger assembly.

It is conservatively assumed that the tanks contain liquid wastes with activity of 370 kBq/l. This assumption is conservative because decontamination operation is performed if the liquid wastes activity is higher than 5 kBq/l.

The estimated specific activity in the tanks and the filter-ion exchanger assembly for CANDU-6 reactors is presented in Table III.4.1-15.

### III.4.1.19 Ventilation Systems

The plant ventilation systems which are sources of radioactivity are: the Reactor Building (RB) Ventilation System and the Spent Fuel Bay Ventilation System. The Service Building (SB) Ventilation System, located inside and outside of the Service Building, does not contain and release radioactivity in the environment during normal operation.

1) The Reactor Building Ventilation System located in the RB and SB transports contaminated fluid during reactor normal operation. The contamination removal is controlled through the RB Ventilation System and D<sub>2</sub>O Vapour Recovery System together with nuclear zoning procedural control, buffer zones, change rooms, protective clothing (plastic suits, etc), etc.

The Reactor Building Ventilation System maintains the sub-atmospheric pressure in the Reactor Building to prevent the radioactive releases through the airlock or the access doors. A differential pressure is also maintained to direct all air circulations from the low contamination areas to the high contamination areas.

The air is filtered to retain radioactive particles before discharging to the ventilation stack. Therefore the filters become themselves sources of radiation and contamination, and then radioactive solid wastes.

The controlled discharging into the environment of the air recovered from RB rooms is performed through the plant exhaust stack, after a proper filtration and monitoring.

Radionuclides, as particulates (e.g. Cr-51) and iodine isotopes, remain in filters and filter cartridges of the Reactor Building Ventilation System.

In order to reduce heavy water downgrading and for improvement of the D<sub>2</sub>O vapour recovery efficiency and tritium collection, additional dryers are installed on the inlet air filter in the RB Ventilation System. These will reduce the amount of light water entered in the RB and the quantity of light water collected by the existent vapour recovery dryers.

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Therefore, the isotopic content of the condensed D<sub>2</sub>O vapours is increased and the tritium released to environment decreases.

2) The Spent Fuel Bay Ventilation System is located both in the Reactor Building and in the Service Building; it transports contaminated fluid and radioactivity outside the containment during normal operation.

In order to retain the radioactive materials of the air coming from the spent fuel transfer and storage bays area, the filter unit ensures filter parameters higher than 99.99% for the radioactive elemental iodine, 99.9% for the radioactive methyl iodide and 99.97% for the radioactive airbornes.

#### **III.4.1.20 Steam Generators and Feedwater Systems**

During normal plant operation there is not primary to secondary circuit coolant leakage; the only radioactive material which is transferred to the secondary circuit is tritium.

Any steam generator tube failure results in the transfer of some of the coolant together with the associated radionuclides from the primary circuit to the steam generator secondary side. This results in the releases of radionuclides to the environment, but the permissible limits are not exceeded. The occurrences of such failures require the reactor shutdown in order to locate and repair the failed tubes.

#### **III.4.1.21 Decontamination Centre**

The decontamination centre of Cernavoda NPP U3, respectively U4 is designed for centralized routine decontamination of the reusable materials and equipment, such as fueling machine components, small metallic components (fittings), plastic protective clothing, breathing devices, D<sub>2</sub>O drums, flasks, etc.

The decontamination equipment is arranged to allow larger objects to be handled using special procedures.

The equipment allows remote handling of the components for complete decontamination of the fixed or non-fixed contamination before maintenance and/or repairs.

Fume-hoods, benches, sinks are provided for any required manual cleaning; they are located in the low radioactivity areas of the decontamination centre.

The materials and equipment entering the decontamination centre are monitored to check radioactivity levels. The cleaned (washed) articles are monitored before being in service.

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The cleaning solutions and wash water become contaminated are removed by the decontamination centre drains, connected to the radioactive liquid waste management system. The aims of each method of decontamination are:

- to minimize radiation fields by maximizing the removal of radioactive material;
- to minimize the cost of the decontamination and the consequential radiation exposure.

The decontamination methods depend on the level of equipment contamination and type of contamination, non-fixed or fixed. Should some equipment be shipped off-site, non-fixed contamination is not allowed and fixed contamination should meet the permissible limits for radioactive materials transfer.

CANDU practices used for heavy and small equipment decontamination are presented below:

#### a) Heavy Equipment

- A plastic material sorting area is set up, with controlled access;
- Depending on the level and type of contamination, the decontamination means are the use of vacuum, sandpaper, grinding, solvents and chemicals;
- Ventilation tents with a filter train to retain contaminants may need to be installed (depending on contamination level). After utilization, the spent filters become solid radioactive waste;
- The liquids from the decontamination are transferred to the radioactive liquid waste management system.

#### b) Small Equipment

Decontamination practices may include combinations of these, a vacuum cleaning, grinding, chemicals, etc.

Since the equipment brought to the centre are generally dry, there is a very small quantity of heavy water, and hence tritium, on its surface, so that the liquid and gaseous effluents from the decontamination centre will contain very little tritium.

The D<sub>2</sub>O leakage is minimized from economic reasons also; practically, the leakage higher than 1% D<sub>2</sub>O in H<sub>2</sub>O imposes liquid waste recovery to be upgraded.

Generally, the radionuclides adhering to the surface of the equipment are the long-lived fission and activation products.

During the normal operation of the plant, the high activity wastes should be separated from the low activity ones; liquid wastes activity should be measured prior to be transferred to the radioactive liquid waste management system. In this way, solutions with high activity may be segregated, treated and/or stored.

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The small volumes produced in the decontamination centre are much easier to be treated than those that are diluted into a large volume, such as the volume of one of tanks in the radioactive liquid waste management system.

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Table III.4.1-1 Radiation Sources in Reactor Building

No. crt.	Radiation source	Radiation type and origin	Radionuclide type
1	<b>Reactor core</b>	<ul style="list-style-type: none"> <li>- fission gamma radiation</li> <li>- fission neutrons</li> <li>- capture gamma radiation</li> <li>- gamma and beta radiation from fission products</li> </ul>	Fission products of $^{235}\text{U}$ $^{60}\text{Co}$ , $^{56}\text{Mn}$ , $^{59}\text{Fe}$
2	<b>Primary Heat Transport System</b> (BSI 33100) -steam generators -headers -pumps -pipes -feeders	<ul style="list-style-type: none"> <li>- gamma and beta radiation from fission products</li> <li>- gamma and beta radiation from activation products</li> <li>- intrinsic</li> <li>- corrosion</li> <li>- photoneutrons</li> </ul>	$^{85}\text{Kr}$ , $^{85\text{m}}\text{Kr}$ , $^{88}\text{Kr}$ , $^{95}\text{Zr}$ , $^{95}\text{Nb}$ , $^{99}\text{Mo}$ , $^{131}\text{I}$ , $^{133}\text{I}$ , $^{134}\text{I}$ , $^{135}\text{I}$ , $^{133\text{m}}\text{Xe}$ , $^{133}\text{Xe}$ , $^{135}\text{Xe}$ , $^{137}\text{Cs}$ , $^{140}\text{Ba}$ , $^{140}\text{La}$ , $^{141}\text{Ce}$ , $^{144}\text{Ce}$ , $^{144}\text{Cs}$  $^{16}\text{N}$ , $^{14}\text{C}$ , T $^{24}\text{Na}$ , $^{59}\text{Fe}$ , $^{60}\text{Co}$ , $^{65}\text{Zn}$ , $^{58}\text{Co}$
3	<b>Moderator Main Circuit</b> (BSI 32110 ) - heat exchangers - pipes - pump	<ul style="list-style-type: none"> <li>- gamma and beta radiation from activation products</li> <li>- intrinsic</li> <li>- impurities</li> <li>- corrosion</li> <li>- photoneutrons</li> </ul>	$^{16}\text{N}$ , $^{14}\text{C}$ , T $^{41}\text{Ar}$ , $^{14}\text{C}$ $^{24}\text{Na}$ , $^{51}\text{Cr}$ , $^{56}\text{Mn}$ , $^{59}\text{Fe}$ , $^{60}\text{Co}$ , $^{65}\text{Zn}$
4	<b>Fuelling Machine System</b> (BSI 35200)	<ul style="list-style-type: none"> <li>- gamma and beta radiation from fission products</li> </ul>	Fission products of $^{235}\text{U}$

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Table III.4.1-1 Radiation Sources in Reactor Building (continued)

No. crt.	Radiation source	Radiation type and origin	Radionuclide type
5	<p><b>Liquid Zone Control System</b> (BSI 34810)</p> <p>a) Water subsystem - H<sub>2</sub>O return lines - H<sub>2</sub>O return header - delay tank - ion exchangers - heat exchangers - H<sub>2</sub>O pumps</p> <p>b) Helium subsystem - Helium storage tank - cooler - compressors - Helium balance header - Helium bubbling header - recombination unit</p>	<p>- gamma and beta radiation from activation products</p> <p>- intrinsic</p> <p>- impurities</p> <p>- corrosion</p>	<p><sup>16</sup>N, <sup>19</sup>O, T</p> <p><sup>41</sup>Ar</p> <p><sup>24</sup>Na, <sup>51</sup>Cr, <sup>56</sup>Mn, <sup>59</sup>Fe, <sup>60</sup>Co</p>
6	<p><b>PHT Purification System</b> (BSI 33350)</p> <p>- ion exchanger - filters - cooler - heat exchanger</p>	<p>- gamma and beta radiation from fission products</p> <p>- gamma and beta radiation from activation products</p> <p>- intrinsic</p> <p>- corrosion</p>	<p><sup>131</sup>I, <sup>137</sup>Cs, <sup>140</sup>La, <sup>140</sup>Ba</p> <p><sup>99</sup>Mo, <sup>134</sup>Cs, <sup>133</sup>I</p> <p>T</p> <p><sup>59</sup>Fe, <sup>60</sup>Co, <sup>58</sup>Co</p>

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Table III.4.1-1 Radiation Sources in Reactor Building (continued)

No. crt.	Radiation source	Radiation type and origin	Radionuclide type
7	<b>D<sub>2</sub>O Feed and Bleed, Pressure and Inventory Control System</b> (BSI 33300) - pressurizer - D <sub>2</sub> O feed pumps - heat exchanger	- gamma and beta radiation from fission products  - gamma and beta radiation from activation products - intrinsic - corrosion - photoneutrons	<sup>85</sup> Kr, <sup>85m</sup> Kr, <sup>88</sup> Kr, <sup>95</sup> Zr, <sup>95</sup> Nb, <sup>99</sup> Mo, <sup>131</sup> I, <sup>133</sup> I, <sup>134</sup> I, <sup>135</sup> I, <sup>133m</sup> Xe, <sup>133</sup> Xe, <sup>135</sup> Xe, <sup>137</sup> Cs, <sup>140</sup> Ba, <sup>140</sup> La, <sup>141</sup> Ce, <sup>144</sup> Ce, <sup>144</sup> Cs  <sup>16</sup> N, <sup>19</sup> O, T <sup>24</sup> Na, <sup>58</sup> Co, <sup>59</sup> Fe, <sup>60</sup> Co, <sup>65</sup> Zn
8	<b>Coolant Storage, Transfer and Recovery System</b> (BSI 33330) - storage tank - recovery tank - pumps	- gamma and beta radiation from fission products  - gamma and beta radiation from activation products - intrinsic - corrosion	<sup>85</sup> Kr, <sup>85m</sup> Kr, <sup>88</sup> Kr, <sup>95</sup> Zr, <sup>95</sup> Nb, <sup>99</sup> Mo, <sup>131</sup> I, <sup>133</sup> I, <sup>134</sup> I, <sup>135</sup> I, <sup>133m</sup> Xe, <sup>133</sup> Xe, <sup>135</sup> Xe, <sup>137</sup> Cs, <sup>140</sup> Ba, <sup>140</sup> La, <sup>141</sup> Ce, <sup>144</sup> Ce, <sup>144</sup> Cs  T <sup>24</sup> Na, <sup>58</sup> Co, <sup>59</sup> Fe, <sup>60</sup> Co, <sup>65</sup> Zn

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Table III.4.1-1 Radiation Sources in Reactor Building (continued)

No. crt.	Radiation source	Radiation type and origin	Radionuclide type
	D <sub>2</sub> O Collection System (BSI 33810) - pumps - tank - heat exchanger - condenser	- gamma and beta radiation from fission products  - gamma and beta radiation from activation products - intrinsic - corrosion	<sup>85</sup> Kr, <sup>85m</sup> Kr, <sup>88</sup> Kr, <sup>95</sup> Zr, <sup>95</sup> Nb, <sup>99</sup> Mo, <sup>131</sup> I, <sup>133</sup> I, <sup>134</sup> I, <sup>135</sup> I, <sup>133m</sup> Xe, <sup>133</sup> Xe, <sup>135</sup> Xe, <sup>137</sup> Cs, <sup>140</sup> Ba, <sup>140</sup> La, <sup>141</sup> Ce, <sup>144</sup> Ce, <sup>144</sup> Cs  T <sup>24</sup> Na, <sup>58</sup> Co, <sup>59</sup> Fe, <sup>60</sup> Co, <sup>65</sup> Zn
10	<b>Annulus gas system</b> (BSI 34980) - CO <sub>2</sub> supply lines - CO <sub>2</sub> bottles	- gamma and beta radiation from activation products	<sup>41</sup> Ar, <sup>14</sup> C
11	<b>D<sub>2</sub>O Moderator Collection System</b> (BSI 32510) - tank - pump	- gamma and beta radiation from activation products - intrinsic - corrosion	T <sup>24</sup> Na, <sup>51</sup> Cr, <sup>56</sup> Mn, <sup>59</sup> Fe, <sup>60</sup> Co, <sup>65</sup> Zn
12	<b>Moderator Cover Gas System</b> (32310) - Helium supply lines - Helium bottles	- gamma and beta radiation from activation products	<sup>41</sup> Ar, T
13	<b>PHT Deuteration and Dedeuteration System</b> (BSI 33360) - dedeuteration tank - resin transfer pump	gamma and beta radiation from fission products gamma and beta radiation from activation products - intrinsic	<sup>131</sup> I, <sup>137</sup> Cs, <sup>140</sup> La, <sup>140</sup> Ba <sup>99</sup> Mo, <sup>134</sup> Cs, <sup>133</sup> I  T

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	- corrosion	<sup>59</sup> Fe, <sup>60</sup> Co, <sup>58</sup> Co
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Table III.4.1-1 Radiation Sources in Reactor Building (continued)

No. crt.	Radiation source	Radiation type and origin	Radionuclide type
14	<b>PHT Pump Gland Seal System</b> (BSI 33340) - filters	- gamma and beta radiation from fission products - gamma and beta radiation from activation products - intrinsic - corrosion - photoneutrons	<sup>85</sup> Kr, <sup>85m</sup> Kr, <sup>88</sup> Kr, <sup>95</sup> Zr, <sup>95</sup> Nb, <sup>99</sup> Mo, <sup>131</sup> I, <sup>133</sup> I, <sup>134</sup> I, <sup>135</sup> I, <sup>133m</sup> Xe, <sup>133</sup> Xe, <sup>135</sup> Xe, <sup>137</sup> Cs, <sup>140</sup> Ba, <sup>140</sup> La, <sup>141</sup> Ce, <sup>144</sup> Ce, <sup>144</sup> Cs  <sup>16</sup> N, <sup>14</sup> C, T <sup>24</sup> Na, <sup>59</sup> Fe, <sup>60</sup> Co, <sup>65</sup> Zn, <sup>58</sup> Co
15	<b>Shutdown Cooling System</b> (BSI 33410) -heat exchangers -pumps	- gamma and beta radiation from fission products - gamma and beta radiation from activation products - intrinsic - corrosion - photoneutrons	<sup>85</sup> Kr, <sup>85m</sup> Kr, <sup>88</sup> Kr, <sup>95</sup> Zr, <sup>95</sup> Nb, <sup>99</sup> Mo, <sup>131</sup> I, <sup>133</sup> I, <sup>134</sup> I, <sup>135</sup> I, <sup>133m</sup> Xe, <sup>133</sup> Xe, <sup>135</sup> Xe, <sup>137</sup> Cs, <sup>140</sup> Ba, <sup>140</sup> La, <sup>141</sup> Ce, <sup>144</sup> Ce, <sup>144</sup> Cs  T <sup>24</sup> Na, <sup>59</sup> Fe, <sup>60</sup> Co, <sup>65</sup> Zn, <sup>58</sup> Co

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Table III.4.1-2 Radiation Sources in Service Building

No. crt.	Radiation source	Radiation type and origin	Radionuclide type
1	<b>Moderator Purification System</b> (BSI 32210) - ion exchangers - filter - heat exchanger - pipes	- gamma and beta radiation from activation products - intrinsic - corrosion	$^{16}\text{N}$ , T $^{58}\text{Co}$ , $^{59}\text{Fe}$ , $^{60}\text{Co}$
2	<b>Moderator Deuteration and Dedeuteration System</b> (BSI 32220) - dedeuteration tank	- gamma and beta radiation from activation products - intrinsic - corrosion	$^{16}\text{N}$ , T $^{58}\text{Co}$ , $^{59}\text{Fe}$ , $^{60}\text{Co}$
3	<b>Spent Fuel Bays</b> (34400) - reception bay - main storage bay - failed fuel bay	- gamma and beta radiation from fission products - gamma and beta radiation from activation products - intrinsic - corrosion	$^{95}\text{Nb}$ , $^{95}\text{Zr}$ , $^{131}\text{I}$ , $^{133}\text{I}$ , $^{124}\text{Sb}$ , $^{134}\text{Cs}$ , $^{137}\text{Cs}$  T $^{56}\text{Mn}$ , $^{60}\text{Co}$

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Table III.4.1-2 Radiation Sources in Service Building (continued)

No. crt.	Radiation source	Radiation type and origin	Radionuclide type
4	<b>Spent Fuel Bay Cooling and Purification System</b> (BSI 34410) - ion exchanger - heat exchangers - pumps - filters	- gamma and beta radiation from fission products - gamma and beta radiation from activation products - intrinsic - corrosion	<sup>131</sup> I, <sup>134</sup> Cs, <sup>137</sup> Cs  T <sup>56</sup> Mn, <sup>60</sup> Co
5	<b>End Shield Cooling System</b> (BSI 34110) -pumps -heat exchangers -ion exchanger -delay tank (in Reactor Building, room R-111) - buffer tank	- gamma and beta radiation from activation products - intrinsic - impurities - corrosion	<sup>16</sup> N, <sup>19</sup> O, T <sup>41</sup> Ar, <sup>24</sup> Na <sup>56</sup> Mn, <sup>64</sup> Cu, <sup>59</sup> Fe, <sup>60</sup> Co, <sup>65</sup> Zn
6	<b>D<sub>2</sub>O Cleanup System</b> (BSI 38410) -supply tanks -ion exchangers -filters - downgraded D <sub>2</sub> O storage tank	- gamma and beta radiation from fission products - gamma and beta radiation from activation products - intrinsic - corrosion	<sup>99</sup> Mo, <sup>131</sup> I, <sup>133</sup> I, <sup>134</sup> Cs, <sup>137</sup> Cs, <sup>140</sup> La, <sup>140</sup> Ba  T <sup>58</sup> Co, <sup>59</sup> Fe, <sup>60</sup> Co
7	<b>D<sub>2</sub>O Supply System</b> (BSI 38110) - D <sub>2</sub> O storage tans	- gamma and beta radiation from fission products - gamma and beta radiation from activation products - intrinsic	<sup>99</sup> Mo, <sup>131</sup> I, <sup>133</sup> I, <sup>134</sup> Cs, <sup>137</sup> Cs, <sup>140</sup> La, <sup>140</sup> Ba  T

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No. crt.	Radiation source	Radiation type and origin	Radionuclide type
		- corrosion	<sup>58</sup> Co, <sup>59</sup> Fe, <sup>60</sup> Co

Table III.4.1-2 Radiation Sources in Service Building (continued)

No. crt.	Radiation source	Radiation type and origin	Radionuclide type
8	<b>Liquid Radioactive Waste Handling System</b> (BSI 79210) - tanks - filter/ion exchanger unit - pumps	- gamma and beta radiation from fission products - gamma and beta radiation from activation products - intrinsic - corrosion	<sup>99</sup> Mo, <sup>131</sup> I, <sup>134</sup> Cs, <sup>137</sup> Cs, <sup>144</sup> Ce  T <sup>51</sup> Cr, <sup>60</sup> Co
9	<b>Spent Resin Storage System</b> (BSI 79140) - storage bays	- gamma and beta radiation from fission products - gamma and beta radiation from activated corrosion products	<sup>134</sup> Cs, <sup>137</sup> Cs  <sup>60</sup> Co
10	<b>D<sub>2</sub>O Vapour Recovery System</b> (BSI 38310) - dryers - tanks - pumps	- gamma and beta radiation from fission products  - beta radiation from activation products	<sup>85</sup> Kr, <sup>85m</sup> Kr, <sup>88</sup> Kr, <sup>95</sup> Zr, <sup>95</sup> Nb, <sup>99</sup> Mo, <sup>131</sup> I, <sup>133</sup> I, <sup>134</sup> I, <sup>135</sup> I, <sup>133m</sup> Xe, <sup>133</sup> Xe, <sup>135</sup> Xe, <sup>137</sup> Cs, <sup>140</sup> Ba, <sup>140</sup> La, <sup>141</sup> Ce, <sup>144</sup> Ce, <sup>144</sup> Cs  T

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Table III.4.1-3 Radioactive Product Activity Concentrations in the Primary Heat Transport System – Estimated Values for CANDU-6 Reactors

Radioactive Product (half-life)	Activity Concentration (Bq/kg)
<b>Fission Products:</b>	
Krypton – 85 (10.76 y)	3.30 E+5
Krypton – 85 m (4.56 h)	1.32 E+5
Krypton – 88 (2.84 h)	3.36 E+5
Zirconium – 95 (64.03 d)	4.40 E+4
Niobium – 95 (34.98 d)	5.20 E+4
Molybdenum – 99 (66.7 h)	3.00 E+4
Iodine – 131 (8.05 d)	5.73 E+5
Iodine – 133 (20.05 h)	1.66 E+6
Iodine – 134 (52.6 m)	5.69 E+6
Iodine – 135 (6.61 h)	2.56 E+6
Xenon – 133 m (2.19 d)	8.70 E+4
Xenon – 133 (5.25 d)	6.89 E+4
Xenon – 135 (9.09 h)	3.25 E+6
Cesium – 137 (30y)	1.90 E+4
Barium-140 (12.8 d)/ Lantan – 140 (40.3 h)	1.10 E+4
Cerium – 141 (32.5 d)	1.50 E+3
Cerium – 144 (284.9 d)	2.20 E+3
<b>Activation Products</b>	
Sodium – 24 (15 h)	9.80 E+4
Iron – 59 (45 d)	3.51 E+5
Cobalt – 60 (5.28 y)	1.30 E+4
Zinc – 65 (244 d)	1.10 E+3
Carbon-14 (5730 y)	1.50 E+3
Nitrogen -16 (7.245 s)	2.35 E+9
<b>Tritium</b> (12.33 y)	
After 7.5 operating years	3.70 E+10
After 15 operating years	6.70 E+10
After 30 operating years	9.20 E+10

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Table III.4.1-4 Activity Concentration of Ion Exchange Resins in the Primary Coolant Purification System - Estimated Values for CANDU-6 Reactors

Radionuclide (half-life)		Activity Concentration (Bq/cm <sup>3</sup> )
Co – 60	(5.28 y)	5.86 E+4
Fe – 59	(45 d)	3.40 E+4
Co – 58	(71 d)	1.91 E+4
I – 131	(8.05 d)	3.57 E+7
Cs – 137	(30 y)	4.71 E+6
La – 140	(40.3 h)	7.60 E+4
Ba – 140	(12.8 d)	5.29 E+5
Mo – 99	(66.7 h)	8.39 E+5
Cs – 134	(2.05 y)	2.31 E+6
I – 133	(20.05 h)	9.68 E+6

Table III.4.1-5 Radioactive Product Activity Concentrations in the Moderator System - Estimated Values for CANDU-6 Reactors

Radioactive Products (half-life)	Activity Concentration (Bq/kg)
<b>Activation Products</b>	
Sodium - 24 (15 h)	2.30 E+4
Argon - 41 (1.83 h)	1.80 E+5
Chromium - 51 (27.7 d)	5.90 E+4
Manganese – 56 (2.58 h)	1.70 E+6
Iron – 59 (45 d)	3.00 E+4
Cobalt - 60 (5.28 y)	9.60 E+3
Zinc – 65 (244 d)	4.80 E+4
Nitrogen – 16 (7.245 s)	3.13 E+9
<b>Tritium</b> (12.33 y)	
After 7.5 operating years	7.40 E+11
After 15 operating years	1.40 E+12
After 30 operating years	2.00 E+12
<b>Carbon – 14</b> (5730 y)	3.70 E+4

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Table III.4.1-6 Radioactive Product Activity Concentrations for The Liquid Zone Control System – Estimated Values for CANDU-6 Reactors

Radioactive Products (half-life)	Activity Concentration (Bq/kg)
<b>Activation Products:</b>	
Sodium – 24 (15 h)	9.30 E+3
Chromium – 51 (27.7 d)	1.90 E+4
Manganese – 56 (2.58 h)	1.50 E+5
Iron – 59 (45 d)	1.90 E+3
Cobalt – 60 (5.28 y)	1.10 E+3
Argon – 41 (1.83 h)	3.55 E+3 (Bq/cm <sup>3</sup> ) 2.34 E+7 (Bq/cm <sup>3</sup> )
Nitrogen– 16 (7.245 s)	
<b>Tritium</b> (12.33 y)	
At the end of plant life	1.80 E+6

Table III.4.1-7 Radionuclide Activity Concentrations in The End Shield Cooling System – Estimated Values for CANDU-6 Reactors

Radionuclide (half-life)	Activity Concentration (Bq/kg)		
	Cooling Water	Pumps /heat exchanger	Ion Exchanger
N-16 (7.245 s)	3.54 E+5	1.30 E+5	-
O-19 (27.15 y)	1.64 E+5	1.25 E+5	-
Mn-56 (2.58 h)	3.27 E+2	3.27 E+2	1.67 E+5
Cu-64 (12.8 h)	7.29 E+3	7.29 E+3	1.86 E+7
Fe-59 (45 d)	2.21 E+0	2.21 E+0	3.60 E+5
Co-60 (5.28 y)	1.37 E+0	1.37 E+0	4.01 E+5
Zn-65 (244 d)	3.40 E+2	3.40 E+2	8.93 E+7
Ar-41 (1.83 h)	7.29 E+4	7.29 E+4	-
Na-24 (15 h)	3.16 E+3	3.16 E+3	9.38 E+6

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Table III.4.1-8 Radionuclide Activity Concentrations in the D<sub>2</sub>O Clean-up System – Estimated Values for CANDU-6 Reactors

Radionuclide (half-life)	Activity Concentration (kBq/kg)	
	Tanks	Ion Exchangers
Co-60 (5.28 y)	4.63 E-1	2.32 E-1
Fe-59 (45 d)	3.70 E-1	1.85 E-1
Co-58 (71 d)	1.85 E-1	9.30 E-2
I-131 (8.05 d)	1.11 E+3	5.50 E+2
I-133 (20.05 h)	2.78 E+3	1.39 E+3
Cs-137 (30 y)	3.70 E+1	1.85 E+1
Cs-134 (2.05 y)	1.85 E+1	9.30 E+0
La-140 (40.3 h)	1.11 E+1	5.5 E+0
Ba-140 (12.8 d)	1.11 E+1	5.50 E+0
Mo-99 (66.7 h)	7.40 E+1	3.70 E+1

Table III.4.1-9 Radionuclide Activity Concentrations in Air in Accessible Areas of the Reactor Building-Estimated Values for CANDU-6 Reactors

No crt.	Radionuclide (half-life)	Activity Concentration in Air (Bq/m <sup>3</sup> )
1	Kr-83m (1.83 h)	2.64 E+1
2	Kr-85m (4.56 h)	3.34 E+2
3	Kr-85 (10.76 y)	2.99 E+3
4	Kr-87 (1.26 h)	6.34 E+1
5	Kr-88 (2.84 h)	3.92 E+2
6	Kr-89 (3.17 m)	2.19 E-1
7	Xe-131m (12 d)	1.95 E+3
8	Xe-133m (2.19 d)	1.84 E+3
9	Xe-133 (5.25 d)	1.62 E+5
10	Xe-135m (15.7 m)	1.18 E+0
11	Xe-135 (9.09 h)	2.15 E+2
12	Xe-137 (3.83 m)	4.15 E-1
13	Xe-138 (14.13 m)	5.76 E+0
14	I-131 (8.05 d)	1.42 E+1
15	I-133 (20.05 h)	2.17 E+1
16	I-130 (12.36 h)	0
17	I-132 (2.28 h)	2.23 E+0
18	I-134 (52.6 m)	1.02 E+0
19	I-135 (6.61 h)	9.79 E+0
20	H-3 (12.33 y)	1.98 E+7

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Table III.4.1-10 Radionuclide Activity Concentrations in Air in Steam Generator Room - Estimated Values for CANDU-6 Reactors

No.	Radionuclide (half-life)	Activity Concentration in Air (Bq/m <sup>3</sup> )
1	Kr-83m (1.83 h)	7.05 E-1
2	Kr-85m (4.56 h)	9.81 E+0
3	Kr-85 (10.76 y)	2.31 E+2
4	Kr-87 (1.26 h)	1.65 E+0
5	Kr-88 (2.84 h)	1.09 E+1
6	Kr-89 (3.17 m)	5.42 E-3
7	Xe-131m (12 d)	1.36 E+2
8	Xe-133m (2.19 d)	9.81 E+1
9	Xe-133 (5.25 d)	1.03 E+4
10	Xe-135m (15.7 m)	2.96 E-2
11	Xe-135 (9.09 h)	7.17 E+0
12	Xe-137 (3.83 m)	1.03 E-2
13	Xe-138 (14.13 m)	1.44 E-1
14	I-131 (8.05 d)	9.46 E-1
15	I-133 (20.05 h)	8.95 E-1
16	I-130 (12.36 h)	0
17	I-132 (2.28 h)	6.05 E-2
18	I-134 (52.6 m)	2.61 E-2
19	I-135 (6.61 h)	3.07 E-1
20	H-3 (12.33 y)	1.52 E+7
21	Ar-41 (1.83 h)	0

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Table III.4.1-11 Radionuclide Activity Concentrations in Air in the F/M Vault and Moderator Room - Estimated Values for CANDU-6 Reactors

No.	Radionuclide (half-life)	Activity Concentration in Air (Bq/m <sup>3</sup> )
1	Kr-83m (1.83 h)	2.01 E+2
2	Kr-85m (4.56 h)	2.22 E+3
3	Kr-85 (10.76 y)	1.19 E+4
4	Kr-87 (1.26 h)	5.01 E+2
5	Kr-88 (2.84 h)	2.82 E+3
6	Kr-89 (3.17 m)	1.92 E+0
7	Xe-131m (12 d)	7.93 E+3
8	Xe-133m (2.19 d)	8.14 E+3
9	Xe-133 (5.25 d)	6.75 E+5
10	Xe-135m (15.7 m)	1.02 E+1
11	Xe-135 (9.09 h)	1.25 E+3
12	Xe-137 (3.83 m)	3.62 E+0
13	Xe-138 (14.13 m)	4.95 E+1
14	I-131 (8.05 d)	5.78 E+1
15	I-133 (20.05 h)	1.08 E+2
16	I-130 (12.36 h)	0
17	I-132 (2.28 h)	1.65 E+1
18	I-134 (52.6 m)	8.29 E+0
19	I-135 (6.61 h)	6.05 E+1
20	H-3 (12.33 y)	4.16 E+7
21	Ar-41 (1.83 h)	1.87 E+5

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Table III.4.1-12 Radionuclide Activity Concentrations in Moderator Equipment Enclosure - Estimated Values for CANDU-6 Reactors

No.	Radionuclide (half-life)	Activity Concentration in Air (Bq/m <sup>3</sup> )
1	Kr-83m (1.83 h)	2.65 E+1
2	Kr-85m (4.56 h)	6.01 E+2
3	Kr-85 (10.76 y)	1.19 E+4
4	Kr-87 (1.26 h)	4.79 E+1
5	Kr-88 (2.84 h)	5.30 E+2
6	Kr-89 (3.17 m)	8.40 E-3
7	Xe-131m (12 d)	7.59 E+3
8	Xe-133m (2.19 d)	6.65 E+3
9	Xe-133 (5.25 d)	6.16 E+5
10	Xe-135m (15.7 m)	2.15 E-1
11	Xe-135 (9.09 h)	5.35 E+2
12	Xe-137 (3.83 m)	1.91 E-2
13	Xe-138 (14.13 m)	9.53 E-1
14	I-131 (8.05 d)	5.43 E+1
15	I-133 (20.05 h)	6.86 E+1
16	I-130 (12.36 h)	0
17	I-132 (2.28 h)	2.62 E+0
18	I-134 (52.6 m)	5.61 E-1
19	I-135 (6.61 h)	2.14 E+1
20	H-3 (12.33 y)	9.07 E+7
21	Ar-41 (1.83 h)	2.47 E+4

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Table III.4.1-13 Radioactive Product Activity Concentrations in The Spent Fuel Bay Water – Estimated Values for CANDU-6 Reactors

Radioactive Product (half-life)	Activity Concentration (Bq/kg)
<b>Fission Products</b>	
Niobium – 95 (34.98 d)	3.30 E+3
Zirconium – 95 (64.03 d)	3.00 E+3
Iodine – 131 (8.05 d)	1.80 E+4
Iodine – 133 (20.05 h)	3.70 E+3
Antimony – 124 (60 d)	1.50 E+2
Cesium – 134 (2.05 y)	3.70 E+3
Cesium – 137 (30 y)	1.50 E+4
<b>Activation Products</b>	
Tritium (12.33 y)	1.90 E+6
Manganese – 56 (2.58 h)	7.40 E+2
Cobalt – 60 (5.28 y)	1.10 E+4

Table III.4.1-14 Spent Resin Activity Concentrations – Estimated Values for CANDU-6 Reactors

System	Activity Concentration (Bq/cm <sup>3</sup> )		
	Cs-137	Cs-134	Co-60
Spent Fuel Bay	5.70 E+6	1.58 E+6	-
End Shield Cooling	-	-	4.01 E+2
D <sub>2</sub> O Clean-up	7.78 E+3	3.34 E+3	9.26 E+1
Liquid Radioactive Wastes	7.62 E+4	3.54 E+4	1.51 E+4
Primary Heat Transport	4.77 E+6	2.32 E+6	5.86 E+4
Moderator	-	-	2.67 E+2

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Table III.4.1-15 Isotope Activity Concentrations in the Radioactive Liquid Waste Management System - Estimated Values for CANDU-6 Reactors

Radionuclide (half-life)	Activity Concentrations (kBq/kg)	
	Tanks	Filter-Ion Exchanger
I-131 (8.05 d)	2.05 E+3	1.51 E+5
Cs-137 (30 y)	6.14 E+2	3.54 E+4
Cs-134 (2.05 y)	2.89 E+2	7.62 E+4
Ce-144 (284.9 d)	2.07 E+2	2.53 E+4
Cr-51 (27.7d)	2.07 E+2	2.15 E+4
Mo-99 (66.7 h)	2.07 E+2	9.64 E+3
Co-60 (5.28 y)	1.22 E+2	1.51 E+4

### III.4.2 Engineered Provisions for Radiation Protection of the Personnel and the Public

The plant design for Cernavoda NPP U3, respectively U4 has in view the radiation protection of the site personnel, members of the public and environment both in normal operation and accident conditions.

The main provisions taken by design in order to protect personnel and public are presented below.

#### III.4.2.1 Provisions for Personnel Protection

##### III.4.2.1.1 Provisions for Personnel Protection in Normal Operation

During normal operation, the provisions taken by design for radiation protection of the site personnel refer to:

minimizing the radioactive sources, by the following means:

- reducing cobalt impurities in stainless steel;
- providing chemical control of primary and moderator systems to prevent extensive build-up of activated corrosion products;
- surface treatment of components and pipes;
- minimizing of D<sub>2</sub>O leakage from technological circuits;
- D<sub>2</sub>O leakage collection from primary circuit and moderator system, by using separate collection systems;
- D<sub>2</sub>O vapor recovery system, to retain the heavy water and tritium vapors released to the room atmosphere from PHTS, moderator, steam generator and fueling machine associated areas;

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- purification system for all the water systems in connection with the reactor core;
- spent fuel bay purification system.

Reduction of the amount of liquid impurities, by the following technical solutions:

- purification system, to maintain the purity of the liquid and to minimize corrosion of components;
- using demineralized water;
- cleaning up the heavy water recovered from leakages;
- managing tritiated heavy water make-up, so that D<sub>2</sub>O with the lowest tritium level is added to the primary coolant system.

Keeping activity levels in liquid and gaseous processes low, by the following means:

- provisions for coolant and moderator purification, in order to reduce their activity, by removing the activated impurities and corrosion products;
- early detection of the failed fuel followed by prompt removal of defective fuel, to reduce the fission product contamination in the primary coolant system;
- providing a D<sub>2</sub>O vapor recovery system in rooms with a probability of heavy water leakage, to collect D<sub>2</sub>O vapors by a system of dryers.

Provisions for radiation shielding, as follows:

- primary shield, which attenuates radiation from the reactor;
- secondary shield, which attenuates radiation from the primary coolant;
- auxiliary shield, which attenuates radiation from auxiliary systems, as moderator, fueling machine, etc.
- special shield, not categorized as above, located also in Reactor Building;
- shields in Service Building;
- supplementary shields, in the penetration areas;
- temporary shields, to protect the workers in some special conditions.

Classification of the areas inside the plant depending on the radiation hazard existing in those areas:

- accessible zones, during normal operation (free access or conditioned access);
- inaccessible zones; these zones become accessible only after reactor shutdown (conditioned access, depending on the time after shutdown);

Provisions for contamination protection:

- use of high capacity ventilation systems which provide purging of ventilated areas and reduce local airborne hazards;
- establishing ventilation flows from areas which are more often frequented by workers towards areas of higher potential contamination;
- reducing airborne tritium levels by using D<sub>2</sub>O vapor recovery system and passing the contaminated air through dryers;

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- use of filtration units before the contaminated air from ventilation systems is discharged into the environment through the plant exhaust stack;
- use of breathing air equipment, to minimize the internal dose uptake of workers;
- use of decontaminable surface finishes, to prevent the fixed contamination and to make easy decontamination;
- minimizing leakage from radioactive liquid systems, in order to ensure radiation protection concerning internal radiation hazard;
- provision of enclosed drain systems, to reduce the hazard levels due to leaks;
- nuclear zoning (area contamination classification), to protect workers and to keep the contamination under control.

Nuclear zoning for Cernavoda NPP-U3, respectively U4 consists in dividing the plant area in three radiological zones, depending on potential radiation level.

The definition of radiological zones is:

Zone 3 is a clean area, without radioactive sources, except as approved, with a very low probability of cross contamination from adjacent areas and with a general radiation dose rate less than 0.5  $\mu\text{Sv/h}$ .

Zone 2 is a controlled area, without radioactive sources, except as approved, normally free of contamination, but is subject to infrequent cross-contamination due to the movement of personnel and equipment. This area contains no radioactive system and has a general radiation dose rate less than 10  $\mu\text{Sv/h}$ .

Zone 1 is a controlled area and contains systems and equipment which may be significant sources of contamination or radiation exposure.

There are provisions for clear demarcation between zones.

Access to and from radiological zones is controlled in accordance with approved procedures.

Provisions for hazard warnings:

- there are provided signs to warn personnel about radiation hazard;
- providing the access control system, ensuring an adequate access control by 3 subsystems using locked doors and interlocks.

Provisions for a good maintenance:

- portable shielding, to reduce the dose rate from equipment which is being worked on or is present in the area;
- shielded cabinets for workers performing duties at reactor face;
- keeping the equipment or vessels full of water to provide shielding during maintenance activities when appropriate;
- equipment for lifting/handling permanently installed where appropriate;

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- decreasing of the time of presence in radiation field by:
- selecting high quality equipment with low failure frequency, which requires a minimum activity for maintenance and repair;
- providing facilities for equipment maintenance and repair (suitable tools, platforms or walkways for easy access to equipment);
- ensuring the station and equipment layout so that allows easy access to equipment for easy of maintenance and repair operations, free corridors as large as possible allowing easy access of personnel and quick transport of system components inside of plant to decontamination and repair workshops;
- provisions for special remote/automated inspection equipment;
- provisions for fixed and portable radiation monitoring equipment, contamination monitoring equipment, airborne activity monitoring equipment and liquid process monitoring;
- provisions for personnel facilities, as washing/showering facilities, changing rooms, protective clothing laundry, decontamination facility.

#### **III.4.2.1.2 Provisions for personnel protection in accident conditions**

Most of the engineered provisions for radiation protection of the operator in normal operation also contribute to the radiation protection in accident conditions. The special measures provided for personnel protection during accident situations refer to:

- safe evacuation routes of the operating personnel;
- ensuring that the required post-accident operator actions can be carried out safely.

As concerns the evacuation of operators from the plant, the main requirements are following:

- provisions of early warning: this is achieved via the area monitoring system, and the alarm raised by the main control room;
- provisions of ventilated access routes: this is achieved via the ventilation system provided for operator protection in normal operation with air flows from clean to potentially contaminated zones;
- provisions for shielded routes.

As concerns the post-accident actions necessary to be carried out to maintain the plant in a safe state, there is the provision for ensuring that the radiation doses received by operators remain within limits accepted by current norms.

#### **III.4.2.2 Provisions for Public Protection**

##### **III.4.2.2.1 Provisions for Public Protection in Normal Operation**

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The following elements ensure a corresponding radiation protection of population and environment:

#### Source Control

This item concerns the measures and activities necessary for radioactive material confinement. Multiple barriers are provided to prevent the radioactive material releases from sources.

#### Effluent Control

This item covers the measures and activities necessary to control the radioactivity releases into environment to comply with specified limits.

#### Effluent Monitoring

This item concerns the measures and activities necessary for measurements of effluent releases in emission points.

#### Environment Monitoring

This item covers the measures and activities necessary for measurements of environmental radioactivity levels, to assess the radiological impact over public health and environment, due to effluent releases from the plant. In case of significant or greater releases, supplementary programs are implemented for accurate dose assessment.

### **III.4.2.2.2 Provisions for public protection in accident conditions**

Many of the engineered provisions for radiation protection of the public in normal operation also contribute to the radiation protection in accident conditions. The special measures provided for public protection during accident situations refer to:

- ensuring containment isolation to terminate releases;
- reducing activity releases.

The first requirement for public protection is to ensure that releases are terminated. Containment isolation is provided by diverse means including isolation based on measurements of Reactor Building airborne activity.

The second requirement is to ensure that where releases take place, these are reduced by an appropriate filtration and by ensuring that the volatility of radionuclides (in particular iodine) is reduced.

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The Reactor Building ventilation system provides particulate and iodine filtration to reduce discharges from the Reactor Building. Given that venting to release containment pressure may only be required following a LOCA, it is essential to ensure that the iodine filters do not degrade due to moisture loading. Reactor Building depressurisation following LOCA is performed through the D<sub>2</sub>O vapour recovery system, in order to protect against the risk of degrading the iodine filters due to moisture loading.

The release of iodine from the water within the containment is reduced by ensuring an appropriate water chemistry.

### **III.4.3 Radiation Level at the NPP Site Boundary and at the Nearest Protected Receiver**

#### **III.4.3.1 Generalities**

The main objective of radiation protection design at Cernavoda NPP – U3 is to reduce doses received by personnel and population, as low as reasonably achievable below limits specified by national legislation.

The radiological safety problems concerning the activities from nuclear facilities in Romania are regulated by Romanian Republican Nuclear Safety Norms, Reactors and Nuclear Plants, 1975 (Ref. III.4-2) and Radiological Safety Fundamental Norms, 2000 (Ref. III.4-3). These norms establish the dose limits for public and the requirements that must be fulfilled to obtain the license for radioactive effluents releases in air and water from National Commission for Nuclear Activities Control (CNCAN).

According to these documents, the project complies the following requirements concerning the dose limits for personnel and population.

The occupational exposure for an operator has to be less than following limits:

- 20 mSv for annual effective dose;
- 150 mSv for annual equivalent dose on lens of the eye;
- 500 mSv per year for skin; the equivalent dose limit is averaged on 1 cm<sup>2</sup> of most irradiated skin zone;
- 500 mSv for annual equivalent dose on extremities of the body.

The average estimated doses received by critical groups of public for licensed practice have to be less than following limits:

- 1 mSv for annual effective dose;
- 15 mSv for annual equivalent dose on lens of the eye;
- 50 mSv for annual equivalent dose on skin, averaged on 1 cm<sup>2</sup>.

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The achievement of this objective in the design phase of the plant was performed by implementing some measures, which will provide the decrease of the dose rate in the workplace and of the exposure time in radiation field. These measures are in accordance with international recommendations concerning radiation protection design in Nuclear Power Plants (Ref. III.4-4) and with current practices all over the world.

The measures taken by design to reduce the dose rate in the workplace are: radiation sources control, protective barriers and equipment, and surveillance of the radiation fields. These measures have been presented in cap.III.4.2.

The Cernavoda NPP Units site is delimited by a physical protection fence, outside of this being permitted a maximum annual limit of 1 mSv (annual effective dose for public provided by Radiological Safety Fundamental Norms).

In the area surrounding the plant with radius of 1 km, meaning the exclusion zone, there are no localities and permanent residences of population.

Radionuclides released to environment may cause external and internal radiation exposure to public via a number of potential pathways.

Generally, the value of radiation dose received by persons from public due to normal radioactive emissions are too small to be directly measured, and thus demonstrating the compliance with accepted dose limits for public.

For this reasons, and according to good safety practices, the releases control is ensured by measuring the radioactivity emissions just in the release point and by comparison to maximum admitted rate and activity of radioactive material, established for each separately.

These maximum permitted limits which regulates the normal radioactive emissions at NPP Cernavoda U3 are called Derived Emission Limits (DEL), see (Ref. III.4-5).

Derived Emission Limit (DEL) is the maximum permissible concentration for a single radionuclide or a group of radionuclides, so that the annual dose limit for an individual in the most heavily exposed group (the critical group), is not exceeded.

The assessment of these concentrations takes into account the specific atmospheric conditions and all significant possible environmental pathways to the critical group.

The critical group is made up of a rather homogenous group of persons from population, regarding its exposure to certain radiation source and exposure way, receiving the highest effective dose (or equivalent dose, if required) via this exposure way and from this source.

### **III.4.3.2 Methodology for Calculation of DELs**

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The methodology used in calculating the DELs for Cernavoda NPP is as given by Canadian Standard Association CAN/CSA – N288.1-M87 (Ref. III.4-6).

The actual process of calculating the DELs is broken into 6 steps:

- Identify the critical groups and exposure pathways, preferably from site specific surveys. Exposure pathways may be different for adults and infants. Note that there may be more than one critical group and different radionuclides may be different critical groups.
- Develop appropriate expressions relating the release rates to the dose rates to an individual.
- Select appropriate values for the transfer parameters that are relevant to the critical group under consideration.
- Calculate the DELs based on the whole body dose limit. The calculations must be done separately for adults and infants.
- For those radionuclides for which organ or skin dose may be limiting, separate DEL calculations should be performed.
- For each radionuclide select the smallest of the calculated DELs.

The critical groups considered for Cernavoda NPP are the following:

a) airborne emissions

the residents (both infants and adults) of Cernavoda town

b) liquid emissions

Cernavoda town, and for drinking water, Constanta city since its population is supplied with drinking water from the Danube – Black Sea Channel. In the event that liquid effluents are released directly to the Danube River through the alternate effluent discharge tunnel, the critical group is considered to be the population of Seimenii Mici. This critical group will be adequately protected since the DEL calculated based on the critical groups described above is more restrictive.

The pathways considered for airborne releases are:

Atmosphere → Vegetated Soil → Dose (External)  
 Atmosphere → Crops → Dose (Ingestion)  
 Atmosphere → Vegetal Soil → Crops → Dose (Ingestion)  
 Atmosphere → Vegetal Soil → Forage → Animal Produce → Dose (Ingestion)  
 Atmosphere → Forage → Animal Produce → Dose (Ingestion)  
 Atmosphere → Animal Produce → Dose (Ingestion)  
 Atmosphere → Dose (Inhalation)  
 Atmosphere → Dose (Immersion)

The pathways considered for liquid releases include:

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a) The pathways for the residents of Cernavoda town

Water → Vegetated Soil → Dose (External);  
 Water → Vegetated Soil → Crops → Dose (Ingestion);  
 Water → Forage → Animal Produce → Dose (Ingestion);  
 Water → Vegetated Soil → Forage → Dose (Ingestion);  
 Water → Crops → Dose (Ingestion);  
 Water → Animal Produce → Dose (Ingestion).

b) The pathway considered for residence of Constanta city

Water → Dose (Ingestion)

The DELs calculated for Cernavoda NPP are conservative; the actual dose that would result from a specified release rate would be less than that calculated. This occur because the following assumption are made:

- The transfer parameters along each step of the food chain are generally conservative values selected from the open literature.
- The radionuclides that are ingested or inhaled are assumed to be in their most restrictive chemical form.
- Foodstuff consumed by the local population is assumed to be grown on the site boundary.

Dose limitation requirements will be met, if during operation:

$$\sum_{j=1}^N \frac{Q_j}{DEL_j} < 1.0$$

where  $Q_j$  is the annual quantity emitted of the  $j$  radionuclide in the group of  $N$  radionuclides which irradiate a given organ, and  $DEL_j$ , is the corresponding emission limit for that particular radionuclide when considering the organ in question.

In this case no individual from the population shall receive a radiation dose larger than 1 mSv/year.

The DELs for gaseous and liquid releases (established for U1) are presented in Tables III.4.3.2-1 and III.4.3.2-2 (Ref. III.4-5). The Unit 3, respectively Unit 4 being similar to Unit 1, the DEL values will be the same.

To estimate the exposure of critical groups to radioactive releases, taking into account also the contribution of other radiation sources on the Cernavoda site, a more restrictive dose limit was established (50  $\mu$ Sv/year). This administrative limit, representing 5 % from the maximum accepted dose for public, will be ensured if the radioactive effluent emissions will be controlled so that:

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$$\sum_{j=1}^N \frac{Q_j}{DEL_j} \leq 0.05$$

where  $Q_j$ ,  $N$  and  $DEL_j$  have the same definitions as above.

For a safety operation of Cernavoda NPP, the administrative limits represent a warning level; exceeding these limits represents a symptom of a bad operation and the moment of starting the process of identifying the causes. On the other hand, maintenance of emissions at a level of 5 % of DEL leads to maintenance of some doses under the limit allowed by the norms.

Conforming to the Fundamental Norms for Radiological Safety (Ref. III.4-3), during the licensing process of a nuclear facility, CNCAN shall define a dose constraint for this facility, value which must not be exceeded during normal operating conditions. CNCAN have defined, in operating license no. SNN U1-5/2003, the dose constraint for Cernavoda NPP Unit 1, namely 0.1 mSv/year.

Since the operating target at Unit 1 (administrative dose limit) represents 50% of the dose constraint recommended by CNCAN, a good margin is ensured during Cernavoda NPP operation. This option will be also respected during Unit 3 & 4 exploitation.

A comparison between the estimated emissions and the emissions reported at Cernavoda NPP Unit 1, as well as the derived emission limits are presented in Table III.4.3.2-3. From this table it is clearly stated that the emissions for CANDU 6 plants and those reported at Unit 1 are under these DEL values. More than that, at Cernavoda NPP the administrative limits, representing 5 % of DEL will be applied.

Under the operating conditions of the four units, although the quantity of radioactive effects will be four times higher, both the gaseous emissions and the liquid ones will be under the derived emission limits.

Intermediate Spent Fuel Storage (DICA) is situated on NPP site. Under DICA normal operation, there are no emissions of radioactive effluents into the air or water (Ref. III.4-7).

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Table III.4.3.2-1 Derived Emission Limits for Airborne Releases

Radionuclide /Radionuclide Group	DEL (GBq/week)	Critical Group*	Limiting Organ
H-3 (oxide)	1.01E+06	1	WB
C-14 (gaseous)	2.11E+03	2	WB
I-131 (mfp)**	6.62E+00	2	WB
Noble Gases (GBq.Mev/week)	4.15E+05	1.2	WB
Particulates***	1.33E+00	1	WB
Cr-51	2.69E+04	1	WB
Mn-54	2.96E+02	1	WB
Fe-59	1.08E+02	1	WB
Co-58	9.54E+00	1	WB
Co-60	8.84E+00	1	WB
Zn-65	3.20E+01	1	WB
Sr-89	6.01E+01	2	WB
Sr-90+****	2.77E+00	2	WB
Zr-95+	3.04E+02	1	WB
Nb-95	6.29E+01	2	WB
Ru-103	6.47E+02	1	WB
Ru-106+	4.99E+01	1	WB
Sb-124	1.75E+02	1	WB
Sb-125	1.94E+02	1	WB
Cs-134	6.65E+00	1	WB
Cs-137+	1.33E+00	1	WB
Ba-140+	5.88E+02	1	WB
Ce-141	6.90E+02	1	WB
Ce-144+	6.43E+01	1	WB
Eu-152	2.68E+01	1	WB
Eu-154	1.95E+01	1	WB
Gd-153	1.09E+03	1	WB

\* Critical group            1 – adult Cernavoda town  
   2 – infant (0-1 year) Cernavoda town

\*\* mfp indicates the fact that conservatively, it is assumed that for the receiver, I-131 is found in a balanced mixture with the other radioactive isotopes which are fission products of iodine in a ratio of I-131:I-133:I-134:I-135 = 1.00 : 1.45 : 2.00 : 2.04 : 1.81

\*\*\* for unidentified particles DEL is considered for the most restrictive radionuclide

\*\*\*\* "+" after a isotope indicates the fact that the conversion factor of the dose includes the dose from the radionuclide

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Table III.4.3.2-2 Liquid DELs for Cernavoda NPP

Radionuclide /Radionuclide Group	DEL (GBq/month)	Critical Group*	Limiting Organ
H-3 (oxide)	6.06E+06	4	WB
C-14 (soluble carbonates)	2.45E+05	4	WB
Gross Beta / Gamma Activity**	1.83E+02	2	WB
Cr-51	2.26E+06	1	WB
Mn-54	1.01E+04	1	WB
Fe-59	1.92E+04	1	WB
Co-58	2.55E+03	1	WB
Co-60	5.72E+02	1	WB
Zn-65	5.75E+03	2	WB
Sr-89	1.98E+04	2	WB
Sr-90+***	1.83E+02	2	WB
Zr-95+	1.53E+04	1	WB
Nb-95	1.27E+04	1	WB
Ru-103	9.03E+04	1	WB
Ru-106+	1.33E+04	1	WB
Sb-124	1.89E+04	1	WB
Sb-125	6.09E+03	1	WB
I-131(mfp)****	2.90E+03	4	WB
Cs-134	1.47E+03	1	WB
CS-137+	4.63E+02	1	WB
Ba-140+	5.99E+04	1	WB
Ce-141	2.08E+05	1	WB
Ce-144+	2.36E+04	1	WB
Eu-152	5.79E+02	1	WB
Eu-154	4.37E+02	1	WB
Gd-153	7.64E+04	1	WB

\* Critical group            1 – adult Cernavoda town  
                                       2 – infant (0-1 year) Cernavoda town  
                                       3 - adult Constanta town  
                                       3 – infant (0-1 year) Constanta town

\*\* For Gross Beta/Gamma the DEL for the most restrictive radionuclide is used (i.e. Sr-90+)

\*\*\* "+" after a isotope indicates the fact that the conversion factor of the dose includes the dose from the radionuclide

\*\*\*\* mfp indicates the fact that conservatively, it is assumed that for the receiver, I-131 is found in a balanced mixture with the other radioactive isotopes which are fission products of iodine in a ratio of I-131:I-133:I-134:I-135 = 1.00 : 1.45 : 2.00 : 2.04 : 1.81

Table III.4.3.2-3 Estimated and Reported Liquid and Gaseous Emissions at Cernavoda NPP Unit 1

Emission Type/ Radionuclide	Cernavoda NPP U1 ADEL <sup>1</sup> (TBq)	Cernavoda NPP U1 5% ADEL <sup>1</sup> Administrative Limit (TBq)	Emissions averaged at CANDU 6 plants (TBq)	Emissions reported at Cernavoda NPP U1 % ADEL <sup>1</sup>					
				1997	1998	1999	2000	2001	2002
Gaseous emissions									
Tritium	$5.25 \cdot 10^4$	$2.62 \cdot 10^3$	$1.65 \cdot 10^2$	$4.88 \cdot 10^{-2}$	$9.67 \cdot 10^{-2}$	$1.62 \cdot 10^{-1}$	$3.97 \cdot 10^{-1}$	$3.42 \cdot 10^{-1}$	$5.45 \cdot 10^{-1}$
Noble Gases (TBq-MeV)	$2,15 \cdot 10^4$	$1,07 \cdot 10^3$	$4,90 \cdot 10^1$	$2,86 \cdot 10^{-1}$	$8,12 \cdot 10^{-2}$	$9,89 \cdot 10^{-2}$	$3,22 \cdot 10^{-2}$	$1,26 \cdot 10^{-1}$	0,00
Radioiodine	$3.44 \cdot 10^{-1}$	$1.70 \cdot 10^{-2}$	$2.00 \cdot 10^{-5}$	$2.05 \cdot 10^{-3}$	$2.19 \cdot 10^{-4}$	0.00	0.00	$4.14 \cdot 10^{-4}$	0.00
Carbon-14	$1.09 \cdot 10^2$	5.45	1.05*	$1.63 \cdot 10^{-1}$	$2.64 \cdot 10^{-1}$	$1.55 \cdot 10^{-1}$	$2.12 \cdot 10^{-1}$	$1.50 \cdot 10^{-1}$	$1.13 \cdot 10^{-1}$
Particulate	$6.90 \cdot 10^{-2}$ **	$3.45 \cdot 10^{-3}$	$3.00 \cdot 10^{-5}$	0.00	0.00	0.00	$2.44 \cdot 10^{-6}$	0.00	0.00
Liquid emissions									
Tritium	$7.27 \cdot 10^4$	$3.64 \cdot 10^3$	$1.72 \cdot 10^2$	$1.70 \cdot 10^{-2}$	$1.13 \cdot 10^{-1}$	$2.95 \cdot 10^{-2}$	$7.89 \cdot 10^{-2}$	$1.09 \cdot 10^{-1}$	$1.72 \cdot 10^{-1}$
Beta-gamma	5.56**	$2.78 \cdot 10^{-1}$	$2.10 \cdot 10^{-3}$	$4.52 \cdot 10^{-2}$	$3.03 \cdot 10^{-3}$	$2.93 \cdot 10^{-3}$	$1.92 \cdot 10^{-3}$	$2.97 \cdot 10^{-4}$	$3.22 \cdot 10^{-4}$

1 ADEL Annual derived emission limit

\* Average value calculated based on the monitoring data in period 1989 – 1994 at Point Lepreau NPP

\*\* The value is given for the most restrictive beta-gamma radionuclide Cs-137

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### III.4.3.3 Radiation Doses for Population

Estimation of the dose for a member of the critical group from Cernavoda NPP was made using the methodology in CAN/CSA – N288.1-M87 (Ref. III.4-6).

In Table III.4.3.3-1 the estimated doses have been presented, being calculated on the basis of emissions mediated from CANDU 6 type plants; the doses reported at Cernavoda NPP Unit 1 in period 1997-2003 are also presented (Ref. III.4-1).

In table is shown that both the estimated doses and the doses reported at Unit 1 are smaller than the dose limit established by Norms, 1 mSv/year, respectively:

- total annual dose, due to the liquid radioactive effluents recorded at U1, represents a maximum of 3.5 % (in 2003) from the administrative limit of 50  $\mu$ Sv/year, which is the operating target for a nuclear power unit located on Cernavoda site; comparing with the dose constraint value recommended by CNCAN for Cernavoda NPP Unit 1, the maximum annual dose due to liquid effluents (recorded in 2003) represents only about 1.75%;
- total annual dose, due to the gaseous radioactive effluents recorded at U1, represents a maximum of 13% (in 2002) from the administrative limit of 50  $\mu$ Sv/year ; comparing with the dose constraint value recommended by CNCAN for Cernavoda NPP Unit 1, the maximum annual dose due to gaseous effluents (recorded in 2002) represents only about 6.6%. Taking into account that the internal dose due to natural background on Cernavoda site is about 1.55 mSv/y, it results that the contribution of gaseous effluent emissions from nuclear units to the total internal dose is insignificant.

As Unit 3 & 4 are similar with Unit 1 and Unit 2, the maximum dose received by a member of the critical group at operation of the four units will be of 0.2 mSv/year (4x50  $\mu$ Sv/year), a value being situated under the dose limit for population (1mSv/year).

The contribution of the Intermediate Spent Fuel Storage (DICA) to the commitment dose of an individual living in the exclusion zone of the site is insignificant considering that its value is  $6.5 \times 10^{-4}$  mSv/year (Ref. III.4-7).

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Table III.4.3.3-1 Estimated and Reported Doses for a Member of Critical Group around Cernavoda NPP ( $\mu\text{Sv}/\text{an}$ )

Emission Type	Estimated values for CANDU 6 ( $\mu\text{Sv}/\text{a}$ )	Values reported at Cernavoda NPP ( $\mu\text{Sv}/\text{an}$ )						
		1997	1998	1999	2000	2001	2002	2003
Liquid emission	0.77	0.61	1.16	0.33	0.81	1.09	1.52	1.75
Gaseous emission	19.1	5.00	4.42	4.17	6.41	6.18	6.58	4.36
Total dose	19.7	5.61	5.58	4.50	7.22	7.27	8.10	6.11

#### III.4.3.4 Effects of other Nuclear Objectives from Cernavoda NPP Platform on the Constructors at Unit 3&4

Both the design and operation of NPP Unit 1 and Unit 2 provide maintaining of radiation doses outside nuclear buildings under the limit value allowed for public by the regulations in effect.

Unit 3 is located at about 400 m from DICA platform. At this distance the gamma dose rate of  $2 \times 10^{-3} \mu\text{Sv}/\text{h}$  was estimated (Ref. III.4-7). This value is lower than the dose limit imposed by CNCAN for DICA ( $100 \mu\text{Sv}/\text{year}$ ,  $1 \times 10^{-2} \mu\text{Sv}/\text{h}$ , respectively). Thus, the constructors of Unit 3 will not be affected by DICA Cernavoda.

Unit 4 is located at about 250 m from DICA platform. At this distance the gamma dose rate of  $1 \times 10^{-2} \mu\text{Sv}/\text{h}$  was estimated (Ref. III.4-7). This value is equal with the dose limit imposed by CNCAN for DICA ( $100 \mu\text{Sv}/\text{year}$ ,  $1 \times 10^{-2} \mu\text{Sv}/\text{h}$ , respectively). Thus, the constructors of Unit 4 will not be affected by DICA Cernavoda.

It is noted that the dose evaluation for DICA has been performed under conservative assumptions, for 27 storage modules loaded with cooled fuel along 6 years. It is expected that the real values of dose rates at different distances from DICA will be lower than the estimated ones.

#### III.4.3.5 Radiation Doses for Operating Personnel

In the followings, an estimation of both individual and collective doses for plant personnel is presented, taking into consideration both the external irradiation exposure and internal contamination.

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In Table III.4.3.5-1 the values of the total individual doses are presented (the sum between the inside and outside doses) received by the operating personnel during maintenance and plant operating works, obtained further to operating experience of CANDU type stations (based upon the average value obtained from 6 plants), as well as the registered values corresponding to 1997 ÷ 2003 period at Cernavoda NPP Unit 1 (Ref. III.4-1). The individual average doses are also presented on activity groups of the personnel.

Tables III.4.3.5-2 (a, b, c, d) present the distribution of radiation doses on working groups, from Cernavoda NPP Unit 1, during 1999 – 2003 (Ref. III.4-1).

Table III.4.3.5-3 presents the collective exposure doses of the operating personnel on groups of workers, obtained on the basis of the average value from 6 plants of CANDU-type, in the years 1987 and 1998 and from Cernavoda NPP U1 in the period 1997 ÷ 2003 (Ref. III.4-1).

In the already presented tables, it is stated that the doses for the professionally exposed personnel are much smaller than the limits established by norms (Ref. III.4-3).

Table III.4.3.5-1 Individual doses of annual occupational exposure by work groups at CANDU plants (average values)

Plant	Individual dose [ mSv ]						Plant average
	I & C Personnel	Mechanicals	Operators	Maintenance personnel	Other personnel categories	Temporary personnel	
1987							
CANDU (average)	1.65	4.9	2.63	1.62	1.38	2.7	2.49
1988							
CANDU (average)	2.9	5.8	4.0	1.7	1.4	2.7	2.61
Cernavoda U1*							
1997	0.86	0.88	0.58	0.70	1.86	- **	0.976
1998	0.57	0.91	0.53	0.52	0.95		0.696
1999	0.60	1.81	0.64	1.82	1.28		1.23
2000	0.71	1.54	1.02	1.48	1.14		1.25
2001	0.61	2.35	1.10	1.05	1.36		1.26
2002	0.59	1.35	1.08	1.03	0.61		1.12
2003	0.53	1.89	1.04	1.45	0.93		1.26

\*) The values are averaged taking into consideration personnel having a reference dose only

\*\*\*) Temporary personnel was taken into consideration on each category of operators

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Table III.4.3.5-2 a. Radiations dose distribution by work group at Cernavoda NPP U1 from 27 Dec. 1999 - 31 Dec. 2000

Work Group	Number of Persons Monitored	Work Group Size on Qtr End	Number Exposed > 0.2 mSv Effective Dose (Whole Body)	External Effective Dose (Whole Body) (man-mSv)	Internal Effective Dose (Whole Body) (man-mSv)	Equivalent Dose (Skin) (man-mSv)	Total Effective Dose (Whole Body) (man-mSv)	Station Total (%)	Maximum Individual Effective Dose (Whole Body) (mSv)	Average Effective Dose (WB)/Exposed Worker (mSv)
EI & C Maintenance	174	133	34	20.80	3.36	24.76	24.16	5.2	2.85	0.71
Fuel handling	62	41	27	28.1	15.69	44.7	43.79	9.4	3.9	1.62
Mech Maint.	177	132	53	54.34	27.39	80.29	81.73	17.5	6.85	1.54
Operations	200	186	61	19.22	42.76	62.42	61.98	13.3	3.66	1.02
Service Maint.	304	220	88	121.66	8.87	128.97	130.53	28.0	5.00	1.48
Other Groups	802	643	109	111.27	12.74	121.97	124.01	26.6	6.6	1.14
Station Total	1719	1355	372	355.39	110.81	463.1	466.2	100.0	6.85	1.25

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Table III.4.3.5-2 b. Radiations dose distribution by work group at Cernavoda NPP U1 from 01 Jan. 2001 to 31 Dec. 2001

Work Group	Number of Persons Monitored	Work Group Size on Qtr End	Number Exposed > 0.2 mSv Effective Dose (Whole Body)	External Effective Dose (Whole Body) (man-mSv)	Internal Effective Dose (Whole Body) (man-mSv)	Equivalent Dose (Skin) (man-mSv)	Total Effective Dose (Whole Body) (man-mSv)	Station Total (%)	Maximum Individual Effective Dose (Whole Body) (mSv)	Average Effective Dose (WB)/Exposed Worker (mSv)
EI & C Maintenance	200	145	75	34.32	11.71	46.69	46.03	8.0	5.02	0.61
Fuel handling	53	38	34	35.78	21.56	60.02	57.34	10.0	5.14	1.67
Mech. Maint.	160	114	48	89.19	23.67	113.46	112.86	19.6	7.25	2.35
Operations	203	190	62	38.60	29.33	69.68	67.93	11.8	5.58	1.10
Service Maint.	341	229	107	87.95	24.88	122.43	112.82	19.6	6.06	1.05
Other Groups	895	689	131	147.6	30.27	181.26	177.88	31.0	7.94	1.36
Station Total	1852	1405	457	433.44	141.42	593.54	574.86	100.0	7.94	1.26

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Table III.4.3.5-2 c. Radiations dose distribution by work group at Cernavoda NPP U1 from 31 Dec. 2001 to 29 Dec. 2002

Work Group	Number of Persons Monitored	Work Group Size on Qtr End	Number Exposed > 0.2 mSv Effective Dose (Whole Body)	External Effective Dose (Whole Body) (man-mSv)	Internal Effective Dose (Whole Body) (man-mSv)	Equivalent Dose (Skin) (man-mSv)	Total Effective Dose (Whole Body) (man-mSv)	Station Total (%)	Maximum Individual Effective Dose (Whole Body) (mSv)	Average Effective Dose (WB)/Exposed Worker (mSv)
EI & C Maintenance	196	176	59	27.02	8.02	35.27	35.04	6.4	4.32	0.59
Fuel handling	65	50	43	91.31	37.84	132.87	129.16	23.5	9.23	3.00
Mech Maint	163	133	89	66.81	53.40	122.73	120.21	21.8	5.96	1.35
Operations	245	241	75	42.17	38.86	81.64	81.03	14.7	6.41	1.08
Service Maint	340	251	111	68.77	45.48	114.81	114.25	20.8	3.85	1.03
Other Groups	1069	850	116	47.96	22.83	72.54	70.79	12.8	4.51	0.61
Station Total	2078	1701	493	344.04	206.43	559.58	550.48	100.0	9.23	1.12

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Table III.4.3.5-2 d. Radiations dose distribution by work group at Cernavoda NPP U1 from 30 Dec. 2002 to 28 Dec. 2003

Work Group	Number of Persons Monitored	Work Group Size on Qtr End	Number Exposed > 0.2 mSv Effective Dose (Whole Body)	External Effective Dose (Whole Body) (man-mSv)	Internal Effective Dose (Whole Body) (man-mSv)	Equivalent Dose (Skin) (man-mSv)	Total Effective Dose (Whole Body) (man-mSv)	Station Total (%)	Maximum Individual Effective Dose (Whole Body) (mSv)	Average Effective Dose (WB)/Exposed Worker (mSv)
EI & C Maintenance	233	195	61	17.22	15.15	34.25	32.37	4.0	3.62	0.53
Fuel handling	71	59	40	56.81	28.26	89.06	85.08	10.4	9.68	2.13
Mech Maint.	189	127	99	127.04	60.53	189.99	187.57	22.9	9.66	1.89
Operations	287	278	84	43.87	43.90	91.17	87.76	10.7	5.01	1.04
Service Maint.	324	243	165	142.12	96.96	244.36	239.08	29.2	7.71	1.45
Other Groups	1125	837	200	133.21	53.22	192.74	186.42	22.8	7.68	0.93
Station Total	2229	1736	649	520.27	298.02	841.57	818.25	100.0	9.68	1.26

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Table III.4.3.5-3 Annual Occupational Radiation Exposure by Work Groups at CANDU Plants

Plant	Collective Dose [ man · mSv ]					
	Personnel I&C	Mechanical Personnel	Operators	Service Maintenance Personnel	Other Station Staff	Attached Personnel
1987 CANDU (average)	57.5 (6.5%)	294.33 (33.31%)	165.66 (18.75%)	49.4 (4.65%)	118.33 (13.4%)	206.5 (23.37%)
1988 CANDU (average)	71.5 (1.13%)	407 (6.458%)	241.16 (3.826%)	47 (0.745%)	126.66 (2%)	164.33 (2.6%)
Cernavoda U1						
1997	20.6	30.7	27.2	37.8	169.8	- *
1998	24.94	37.3	26.0	29.43	140.1	
1999	29.79	74.2	31.4	152.84	168.33	
2000	24.16	81.73	61.98	130.53	167.80	
2001	46.03	112.86	67.93	112.82	235.22	
2002	35.04	120.21	81.03	114.25	199.95	
2003	32.37	187.57	87.76	239.08	271.50	

### III.4.3.6 Transboundary Effects

In normal operation the Cernavoda NPP releases small quantities of radioactive materials to the environment. These releases are closely monitored to ensure compliance with regulatory limits. In practice, the yearly operating target is subdivided into weekly or monthly targets to better control NPP releases. These limits are well below 5% of the derived emission limit (DEL), which ties directly to the 1 mSv/year public dose limit. Conservative modeling show that the highest dose, from four units, to a member of the critical group would be 0.2 mSv/year (0.05 mSv/year each from Units 1, 2, 3 and 4). Although these limits are focused on public radiation protection, they are so low that they have been used to assure environmental protection as well.

Taking into account the reasons mentioned above and related information provided by this assessment, it results that the operation activities of Unit 1, 2, 3 and 4 NPPs should have no significant effects in the next neighborhood of the plant (the critical group are located at about 2 km distance from the Cernavoda NPP) being greatly under both the Romanian and CE norms. As much as the distance to the plant increases, these effects are diminishing, while at distances of about 30-40 km, these effects have no practical significance.

Given the distance between Cernavoda Site and other countries (the nearest country, at around 40 Km, is Bulgaria), this study have concluded that no significant adverse transboundary effects should occur.

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## References

- III.4-1 Cernavoda NPP Unit 2 –Final Safety Report, 2005
- III.4-2 Romanian Reublican Nuclear Safety Norms, Part I-Safety Criteria for Reactors and Nuclear Plants, Chap. III-General design criteria, 1975 (in Romanian)
- III.4-3 Radiological Safety Fundamental Norms, CNCAN Order No. 14/2000 (in Romanian)
- III.4-4 IAEA, Safety Series No. 50-SG-D9/1987 Design Aspects of Radiation Protection for NPPs, Vienna
- III.4-5 RD-01364-RP4, rev.2, Derived Emission Limits for Cernavoda NPP U1
- III.4-6 CAN/CSA-N.280.1-M-M-87- Guidelines for calculating derived release limits for radioactive materials in airborne and liquid effluents for normal operation of nuclear facilities, 1987
- III.4-7 79D-01364-RFS-01, Final Safety Report for Spent Fuel Interim Storage Facility

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### III.5 Soil and Subsoil Protection

The impact of Units 3 and 4 operation on soil and subsoil could be mainly generated by the substances and materials use and handling, by the waste management or by leaks and infiltrations in soil. The impact could also appear by using the receptor water for crop irrigation.

In order to avoid the soil and subsoil pollution by substances or materials used or by wastes, the followings are provided: installations, devices, correspondingly arranged spaces, detailed measures and procedures (see chap.II.2, III.1, III.2, III.8, III.9) on material types and categories, regarding their transport, handling, storage, collecting and management. Also, the impact will be reduced to minimum by the specific regulation application.

The main chemicals used are stored in the supplier's package (hydrazine, morpholyne, cyclohexylamine, flomate 537, MB 25, lithium hydroxide) or in tanks (HCl, NaCl, FeCl<sub>3</sub>). The tanks are grouped on an anti-acid plated platform that confines the chemicals accidental leaks and allows their transfer to the waste water reservoirs. The discharging platform of chemicals from the railway tanks is anti-acid plated and equipped with transfer facilities of waste water to neutralization.

The reagents used in the Chemical Laboratory are stocked in rooms with special destination, in safety conditions: freezer for potentially explosive substances, metallic locker with double walls for flammable substances, metallic locker for toxic substances, and their use is strictly regulated.

The liquid non-radioactive waste (for example: solvents, oils) will be collected in barrels for their storage, analyses (for identification and contamination degree determination), conditioning and transfer outside of the power plant. The removing procedures take into account authorized contractors or are established according to environmental protection regulations.

The leaks that appear in normal and abnormal operation regimes of some technological systems (the turbine building, the interface building between turbine building and Service Building, and the chiller building) are collected by the nonactive drainage system and discharged in the rainwater drainage. The system ensures also the possibility to collect the leakage of water-oil mixture from the turbine main bearing and to separate the oil from water.

The radioactive leakages from Reactor Building and Service Building are collected by the active drainage system and transferred to the liquid radioactive waste management system.

The groundwater circulation and level in the Units 3 and 4 main buildings area are controlled by a shielded drained enclosure. This shield is carried out around the nuclear buildings (NSP), between land surface and the impermeable marl layer. The shielded

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enclosure was carried out by cement injection in the lime layer and from concrete in the upper filling up layer. The shielding structure has the role to avoid the diffusion of eventual leaks into the groundwater during Units 3 and 4 operation. Moreover, the groundwater level in the enclosure is maintained by a drainage system at inferior levels in comparison with external groundwater.

Thus, the groundwater flowing from inside to outside through eventual breaks of the shielding structure is avoided. The drainage system consists of pits equipped with submerged pumps, collecting and discharging pipes, automation electrical installations and dosimeter control. The dosimeter controlled waters are discharged through a collector in the rainwater drainage system. In case of accidental contamination, their discharge in the receptor is stopped until the causes are detected and removed, existing the possibility of discharge in the Liquid Radioactive Waste System.

The rainwaters from the fuel-oil management surface and discharge platform are collected by the drainage system after their purification in the fuel-oil separator.

The maintenance of the liquid and gaseous emissions bellow the DELs ensures that the soil and subsurface will be protected against radiological contamination from atmospheric depositions or from discharge of liquid radioactive wastes or from the water use for irrigation.

The effects of the land irrigation by water coming from Cernavoda NPP U1, U2, U3 and U4 effluent receptors are controlled so to monitor their falling-in the provisions of the existing standards (Order MAPM No. 1146/2002 and STAS 9450-88). Among the indicators, the pH parameter has a special importance for soil. The irrigation with water having a pH under 5.5 or over 8.6 could generate soil secondary degradation processes (STAS 9450-88). It has to be noticed that the Danube water has sometimes a pH value higher than this value. The Units 3 and 4 operation does not change the quality category of the used water.

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### **III.6 Aquatic and Terrestrial Ecosystems Protection**

#### **III. 6.1 Environmental Factors Affected by the Project**

##### *Population*

Within the area in the vicinity of Cernavoda NPP, the distribution of the urban and rural settlements on unit area is not uniform since it has been influenced by the natural conditions and economic factors.

Analyzing the distribution of the population with permanent residence in the 30 km radius area (Ref. III.6-1), it is found that the most crowded sectors located along the Bucharest – Constanta main railway, are those of Medgidia, Cernavoda and Fetesti.

So the ESE sector had 57570 inhabitants today and it will have about 58945 inhabitants at the level of the year 2030. This sector is not located on the directory of dominant winds.

Another crowded sector is located on WNW direction and its population concentration reaches about 41598 inhabitants at the level of the year 2000 and it is to be about 41370 inhabitants in the year 2030.

This sector includes Fetesti Town, located at 18 km distance from the Cernavoda NPP site, with a population of 36684 inhabitants, that is to reach 36000 inhabitants at the level of the year 2030. The town is not on the dominant winds direction.

The average density of the population in the 30 Km area is 63,5 inhabitants/km<sup>2</sup>.

Cernavoda town, the greatest concentration of population in the vicinity of the site, is located at about 2 km distance on WNW, NW, NNW sectors.

The town had 20384 inhabitants at the level of the year 2000 and is to reach about 23000 inhabitants in 2030.

The tranzient population is significant in Cernavoda Town and this is an exception due to the relatively high number of commute people reaching about 800 persons.

Around Cernavoda NPP, in the 1 km radius area (exclusion zone), there is no settlement or population with permanent residence.

##### *Water Natural Resources*

In the Cernavoda NPP area there are the following water courses:

- Danube River;
- Danube - Black Sea Channel (DBSC);
- Valea Cismeiei;
- Valea Viteilor.

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From Calarasi, the Danube river is divided in two branches: Dunarea Veche (east) and Borcea (west), that join downstream of Harsova. After 25 km from this ramification, the Bala branch that connects with Borcea Branch is detached from Dunarea Veche branch. On Dunarea Veche branch, upstream of Cernavoda, it is located the Danube-Black Sea Channel water intake, that ensures the water supply of Cernavoda NPP. The drinking water intake of Cernavoda town is located upstream of the DBSC water intake. The Cernavoda sewage discharge is done in a downstream section placed at km 298.

The Danube - Black Sea Channel, has a 64432 m length and is a navigable way with complex functions, that connects Danube at Cernavoda and Black Sea at Agigea. The canal consists of three water races, separated by the Cernavoda and Agigea locks:

- the water race I, with a length of about 4.1 km, between the Danube and the Cernavoda lock (upstream head). In the Cernavoda lock area, the derivation canal was built that connects the water races I and II, by passing the lock;
- the water race II, with a length of about 58 km, between Cernavoda and Agigea locks;
- the water race III, with a length of about 1.5 km, between Agigea lock and Black Sea.

The water race II is also a water supply source for industry and population. The DBSC project provided a total consumption of 15 m<sup>3</sup>/s in 2000 year for industrial water and drinking water treatment station supply. The monthly average consumption values recorded during 1990-2000 were between 5.9-7.8 m<sup>3</sup>/s. The main users were ROMCIM-LAFARGE Medgidia, SURSAL Saligny and the water treatment station Palas.

The wastewater and rain water discharged into the DBSC come from the safety discharges of SP IACN (in Valea Cismelei), SP Parc, SP Atom (in Valea Viteilor) and SP Columbia (discharge of harbor basin) in water race I, from the waste water treatment stations of Medgidia and Poarta Alba in water race II.

Waste waters from draining works are also discharged in water race II, through Defending Stations Saligny, Faclia and Mircea Voda.

Based on the measurements performed by ICIM Bucharest in 2001, 2003 and 2004, are may appreciate that the Danube River water falls in Quality Class II as per Order no. 1146/2002 (Ref. III.6-2).

ICIM has developed sampling and measurements on DBSC and Poarta Alba Midia Navodari Channel (CPAMN) in 1999, 2001, 2004 and may 2005 . According to the results of the measurements, are may appreciate that during the year 2001 (considering the requirements in STAS 4706-88) the water in DBSC and CPAMN was generally falling-in category I of quality (Ref.III.6-2).

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### *Terrestrial Flora and Fauna*

As a general aspect in neighboring area of the Cernavoda NPP site, it is worth evidencing the dominance of agricultural crops, depleted meadows, surfaces covered by vineyards and orchards.

The agricultural land is distributed in the NE, ENE, E and SE of the territory. Wine yards are located around Cernavoda, Cochirleni, Rasova, Aliman, Medgidia, Mircea Voda, Tortomanu; the most compact orchard area are located eastwards Cernavoda, in Mircea Voda and Medgidia zones. On agricultural areas cereal crops (corn, wheat), oleaginous plants (sunflower) and fodders represent the major weight.

The natural vegetation is represented by poplar and willow tree spots, isolated patches of forest made of various oak species, in the Carasu Valley mainly, as well as by small areas of acacia.

In the low areas along the Danube River, willow (salix) tree can be met. In the areas of higher altitude, the white and black poplar represent the main presence.

As regards the fauna, the area is the habitat of about 200 bird species. These bird species do not have a well-delimited area; they spread all over the territory.

Other valuable species such as rabbit, dear, wild pig and mouflon inhabit the forested areas and the fields.

### *Aquatic Ecosystems*

The natural aqua-systems within the 30 km area are represented by the Danube, DBSC, lakes and ponds in the area. This area as also the source of fish by-products, recreation and industrial fishing for the local population.

In aquatic ecosystems, the phytoplankton and the macrophytes represent the main live organic matter in the ecosystem. Zooplankton represents a major component in the matter circulation. Most of the species included in the zooplankton contents, belong to the primary consumers (phitophagns) and to a less extent to the secondary consumers. The trophic spectrum of the zooplankton species is represented by algae, bacteria and very fine detritus.

In all the analyzed control sections by ICIM (Ref.III.6-2), about 40 phytoplanktonic taxons have been identified, belonging to the following groups: *Cyanophyta*, *Bacillariophyta*, *Euglenophyta*, *Phyrrophyta*, and *Chlorophyta*. The zooplankton was represented by the following groups: Rotatoria, Copepoda, Cladocera and Lamelibranchiata. The taxonomic structure noticed with the zooplankton in the plant warm water discharge duct is not qualitatively different from the structure in other section subject to the study. The zoobenthos in the analyzed control sections was

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poorly represented and less diversified; the communities included some oligocheta and chironomida. *Dreissena polymorpha* traced as larva in the plankton is an almost permanent presence of this kenosis.

Qualitatively, the phytoplankton structure showed (now and then) some cyanophytes, euglenophytes, chlorophytes and chrisophytes; more frequently met with were the diatomees considered to be forms characteristic to time periods with lower temperatures of the water.

Broken-down on taxonomic groups, the algae microorganisms evidenced in the Danube water at the beginning of April 2003 (Ref. III.6-2) were: *Cyanophyta* (*Lyngbia* sp., *Oscillatoria subtilissima*), *Bacillariophyta* (*Amphora ovalia*, *Asterionella formosa*, *Caloneis amphisbaena*, *Cyclotella glomerata*, *Cyclotella meneghiniana*, *Cymbella* sp., *Diatoma vulgare*, *Diatoma elongatum*, *Fragilaria capuccina*, *Fragilaria crotonensis*, *Gyrosigma kutzingii*, *Melosira granulata*, *Navicula gastrum*, *Navicula gracilis*, *Navicula* sp., *Nitzschia paradoxa*, *Nitzschia linearis*, *Nitzschia sigmoidea*, *Stephanodiscus astrea*, *Synedra acus*, *Synedra ulna*; *Tabellaria fenestrata*), *Euglenophyta* (*Euglena* sp.), *Pyrrophyta* (*Peridinium* sp.), *Chlorophyta* (*Chlorella vulgaris*, *Closterium acerosum*, *Eudorina* sp, *Scenedesmus quadricauda*, *Stigeoclonium* sp), *Chrysochyta* (*Dinobrion* sp.).

Zooplankton (very poor and low diversified) in all the control sections subject to the analysis, was represented by a small number of forms of the systematic groups: *Ciliata* (*Vorticella campanula*), *Rotatoria* (*Ascomorpha ecaudis*, *Brachionus angularis*, *Brachionus quadridentatus*, *Keratella cochlearis*, *Keratella quadrata*), *Copepoda* (*Cyclops* sp.). The bentonic fauna mainly consists of worms, mollusks, shellfish and insect larvae.

In the analyzed Danube's sector, frequently, about 28 species of fishes are met. Among these, 18 are eating benthonitic, planktonic, perifiton organisms and macrofite vegetation, the other species being rapacious. Among fitofagous species met in the Danube, the following will be mentioned: the carp (*Cyprinus carpio*), the crucian (*Carassius auratus gibelio*), *Blicca bjoerkna*, the bream (*Abramis brama*), the orfe (*Leuciscus idus*), the roach (*Rutilus rutilus*), the sterlet (*Acipenser ruthenus*), the bleak (*Alburnus alburnus*) and the sword (*Pelecus cultratus*). The rapacious species met in the Danube are: the sheat fish (*Silurus glanis*), the pike (*Esox lucius*), *Acerina cernua*, the rapacious carp (*Aspius aspius*), the perch (*Perca fluviatilis*), the grig (*Aspro straber*), the sturgeon (*Huso-Huso*) and the zander (*Lucioperca lucioperca*). Many of these fish species as adults, can eat the plankton, as the great majority of sapling. The rapacious species, as: the pike, the sheat fish can eat the spawn, the sapling, the frogs or the chicken of the aquatic birds.

The trophical structure in the DBS Channel is basically similar to the Danube ecosystem, that represents the main source of water supply for the DBS Channel and the basic location where biocenosis, plankton (zooplankton and phytoplankton) and ihtyofauna (Ref. III.6-2).

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The DBS Channel ecosystem is a young, growing ecosystem continuously influenced by the Danube River flow regime and especially by the pollution sources generated by navigation, irrigation and other human activities.

The benthonic fauna is represented by a relatively small number of species and a large number of fishes, depositing layers as a fine clay under successive layers, favoring, thus, the maximum development of Olygocheta (worms), Chironomida (insects larvae) and a Dreissena shell larvae. Dreissena develops massively, on objects existing in the waters. All these organisms become food for the pisciculture fauna of the channel.

The pisciculture fauna comprises similar characteristics with that existing in the Danube, the following species can be identified: the carp, the sheat fish, the bream, the bleak, the orfe and the rapacious carp. Between Cernavoda and Agigea locks, a less valuable component of the pisciculture fauna occurs, the bleaks and the deposits of suspensions are populated with crucian and fry. In the areas populated with Dreissena, the bream will be met and in the areas full of vegetation, the perch can be found.

### *Soil*

NPP is located in a former lime quarry area, called Ilie Barza, on the left border of Danube-Black Sea Channel.

The site preparation works resulted in an almost flat area with an upper layer consisting of limestone. After specific engineering works, most of the prepared land area was used for various constructions and inner roads (Ref. III.6-3). Some green areas have also been arranged.

The low plain, where Cernavoda area is located, takes part of relief unit known as South Dobrogea Platform; more exact, is about the confluence area from delta plain near by Danube and the western extremity of Carasu plateau (Ref.III.6-3).

The pedological, climate, geological and geo-morphological conditions result on the developing in this area of the soils typical for low seaside plains formed on loess and loess depots.

On the right Danube border, in the floodplain, there are *alluvial soils*. These soils are young, incomplete or partial developed soils. Being undeveloped soils, they have no a-differentiated profile and they are characterized as non-homogenous, like grading aspects, as well as chemical composition.

The alluvial depots have sand to clay structures, the grading is more delicate through terrace, but there can exist some structure differences in vertical draft. These soils are reach in calcium carbonate, with a moderate basic pH (around 8).

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The Danube damming limited the flooding and water retirement processes, allowing the developing of primary soil structure, as well as the humus accumulation, all these facts resulting on the favorable conditions for vegetation development. When alluvium stops, the nutritive substance contribution decreases, so that the fertility is reduced, if adequate measurements are not taken.

Towards west, the alluvial soils are replaced with *gray soils*, characteristic for dry climate areas from S-E. Gray soils are rare and they are present especially in Dobrogea, along the Danube, in north of Valea Carasu, in Medgidia-Cernavoda sector and around Razelm complex.

Soil formation rock is represented by loess or loess depots, with a lower fine particles content.

Due to the low humidity, the alteration and levigating are less intense; due to low levigating (and alkaline reaction) humic acids are formed and the colloidal complex is entirely saturated with basic ions, calcium ions especially; this is the explanation for moderate alkaline reaction (pH = 8 – 8.3). These soils present a very low differentiated profile; the superior horizon is dark brown-yellow, unstructured or with a low and very low grinding. The gray soils are poor in humus (2 - 3 %) and nutritive substances.

Although the gray soils present good physical characteristics, due to the low rain quantities and distribution during the whole year, they don't accumulate water enough, so that, a humidity deficiency is found in the soil in the most part of the year.

#### *Climate and Air Quality*

The climate at Cernavoda and in the neighboring regions (the Danube and the Romanian Plains in the west, and the Dobrogea Plateau in the east, crossed by the Danube – Black Sea Canal), is continental, being characterized by:

- high thermic amplitudes (66.8°C);
- average thermic amplitudes (23°C);
- long time sun shinning (average value = 2200 hours /year);
- low precipitation versus the rest of the country ( $\approx$  500 mm/year) – first area of aridity.

The air circulation is mainly channeled along the Danube Valley on North-South but quite frequently the air circulation also occurs on East Romanian Plains direction. At highest, the air circulation direction is mainly West-Est.

Also due the Danube vicinity, there are many foggy days and the breeze phenomenon during hot season. In point of vegetation, it is representative for half-arid zones.

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The average annual temperature is 11.2°C and the average monthly temperatures range between 23.3°C (in warm seasons) and – 0.3°C (in winter). Differences from a monthly value to the next one are between 1.7°C and 5.8 °C. Regarding the second part of the year, air temperature is decreasing from August till January, and the decrease steps from one month to the next are between 5.9 °C and 0.7 °C (Ref. III.6-4).

The average value of air temperature at the Cernavoda meteo station during 1986-2003 is 11.4°C, and the annual average amplitude is 23.6°C.

Sometimes, the first days with **maximum temperature** over 30°C can be in April, their frequency being very low, of 0.1 days average value. Most tropical days are recorded in July and August, when the average number exceeds 15 days. The tropical days number decreases rapidly to an average number of 2.7 days in September and 0.5 days in October. The annual average number of days with maximum temperature equal or higher than 30°C at the Cernavoda meteo station is about 43 days (Ref. III.6-4).

The **absolute maximum temperature** recorded at the Cernavoda station was 43 °C, on 31 July 1985, due to a very warm tropical-continental air invasion. Therefore, the maximum temperatures in winter months are (due to warm air invasion) much higher than the respective monthly average temperatures. For example, 18.6 °C were recorded in January, much higher than the average of - 0.3 °C for this month.

The **absolute minimum temperature** recorded at the same station was -24.6°C, on 5 February 1954. The absolute minimum monthly temperatures had positive values from May till September.

The occurrence probability of such extreme temperatures (maximum and minimum values) is presented in Table III.6-1 (Ref. III.6-5).

Table III.6-1 Maximum and minimum air temperatures with various probabilities of occurrence

Occurrence probability (%)	1	2	5	10	20
Re-occurrence period (years)	100	50	20	10	5
Maximum values (°C)	44.2	42.9	41.3	39.9	38.5
Minimum values (°C)	-28.7	-26.4	-23.5	-21.0	-18.4

The **multiannual average of the annual precipitations quantities** recorded at the Cernavoda meteo station during 1986-2003 was 453.9 mm. The rainiest month is June, the precipitations average quantity being 60.8 mm. The driest months are February and January with 19.3 mm and 21.4 mm.

The greatest monthly precipitations quantities are observed after 1991, and especially after 1996, when the precipitation quantities were twice or three times the multiannual

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monthly average values. An exception is August 1999, when the monthly quantity of 170.9 mm was five times greater than the August multiannual average value during 1986-2003. The greatest annual precipitations quantity fallen during 1986-2003 was 706.1 mm, in 1999.

The **maximum precipitations quantities fallen in 24 hours**, during 1986-2003, are compared with the values in the extended period 1898-2003. Note that the values from the interval 1986-2003 are generally lower than those from the extended period with up to 10 mm in May, June, September and November, with 10 up to 50 mm in January, March, August and December, and with more than 50 mm in February, July and October. The absolute maximum quantity of precipitations fallen in 24 hours was recorded after 1986 only in April (it was 51.3 mm on 12 April 1987).

Within Cernavoda area, the monthly average number of hours with precipitations exceeds 40 hours/month from November to April. The lowest monthly averages are exhibited during summer periods. The yearly average number of hours with precipitations is 450.6.

Analyzing the wind frequency on 16 directions, calculated during 1986-2002, it is noticed that for Cernavoda area, the most frequent winds are from north and west with an annual frequency of 10.9% and 8.8% respectively, followed by the east winds (7.1%), the annual frequencies for the other directions being between 1.7-5.8%.

Atmospheric calm has an annual frequency of 25.3%, monthly values between 20-30%, with a minimum value in April (19.7%) and a maximum value in August (31.6%).

The wind speed with the highest frequency throughout all the months of the year reaches the threshold of 2-5 m/s with an annual percentage of 45.8% and high monthly frequencies during the whole year, between 39.5% in February and 51.6% in June.

The **annual average wind speed** in the Cernavoda area ranges between 2.6 m/s from south-south-west and 5.1 m/s from north. In winter, wind speeds are higher due to the baric gradients values. In spring, the wind speed is generally 3-5 m/s. During summer and at the beginning of fall, the wind speeds are lower than in the rest of the year. During the whole year, the highest wind speeds are recorded from north and east .

Analyzing the yearly average frequency of the atmospheric stratification degrees within Cernavoda site area, it was found that the highest frequency of occurrence belongs to the neutral stratification categories D (50,50 %) and to the stable categories E and F (29,16 %).

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From the analyses of meteo parameters speed, wind direction and thermal stability of the atmosphere is noticed that in Cernavoda town area exists slightly pollutant dispersion conditions due to the great occurrence frequency of atmospheric calm conditions (26.03 %) (Ref. III.6-5).

The measurements carried out in 2001 (Ref. III.6-6) show the air quality in different points of the NPP site. The samples were collected from the following points:

- P1 400 kV station;
- P2 over the tunnel that discharges the warm water in Danube;
- P3 the left side of the platform (access point to Unit 5);
- P4 in front of CPPON building.

The followed parameters were: SO<sub>2</sub>, NO<sub>2</sub>, CO and suspended powders (average values at 30 minutes). The results were compared to the maximum allowed concentrations stipulated in STAS 12574-87 and they are presented in Table III.6-2. The measured concentrations are below the maximum values admitted by STAS 21574-87.

Table III.6-2 Air Quality Analyses Results

	P1	P2	P3	P4	Maximum allowed concentrations
SO <sub>2</sub> (mg/m <sup>3</sup> )	0.032	0.027	0.051	0.057	0.750
NO <sub>2</sub> (mg/m <sup>3</sup> )	0.038	0.041	0.068	0.062	0.300
CO (mg/m <sup>3</sup> )	0.72	0.83	1.75	1.32	6
Powders (mg/m <sup>3</sup> )	0.051	0.054	0.098	0.070	0.500

### III.6.2 Pollutants and Activities Which May Affect the Terrestrial and Aquatic Ecosystems

Units 3 and 4 will be built on NPP platform, on an already built surface, so there is no impact on vegetation and fauna in this perimeter.

The terrestrial and aquatic ecosystems may be affected by liquid and gaseous pollutants. The previous chapters presented the pollutant sources for the environment and the provided protection measures.

The Environmental Impact Study on Cernavoda NPP-Unit 2 operation led to the conclusion that the main environmental effects could occur as a result of cooling water discharge into old Danube arm or into DBSC. Considering that the reference design for U3 and U4 is U2 design, in this preliminary stage, it is estimated that the main aspects related to the effluent impact on the water quality are the same.

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The influence of the continuous discharge of the effluents from Unit 1, Unit 2 and Unit 3 into the Danube River or into DBSC, was studied by ICIM-Bucharest in the document titled: "Feasibility Study for Cernavoda NPP-U3 Completion. Preliminary Environmental Impact Analysis on 3 x 700 MWe Cernavoda NPP. Preliminary Assessment on the Thermal Impact generated by the warm water discharge to DBSC and the Danube River".

The commissioning of Units 3 and 4, irrespective which cooling solution should be adopted, will not have as effect, an increase of the emissary temperature compared to Unit 1 operation, or to a simultaneous operation of Units 1 and 2. Consequently, the additional effects on aquatic flora and fauna are not approached.

Thus, in case of releases into Danube:

- the cooling water quality indicators will be kept within the limits, specified by the regulations in effect;
- the ecological status should not be affected either by chemical or thermal pollution, being determined by Unit 3 and Unit 4 commissioning and operation;
- the frequency of fog occurrence should not be modified, but the area of its development downstream of releasing point will be enlarged, as compared to the case of one unit operation.

In case of warm water simultaneous release from these four units into the DBSC, it is considered that the thermal plume extends to the entire length of the channel. Both the heating effects and algae breeding in the warm season, with associated negative effects, makes this solution being no recommended.

### **III.6.3 Work, Outfitting and Measures to Protect the Terrestrial and Aquatic Fauna and Flora**

Because the administrative and design measures lead to the limitation releases in air, so that will be under the admitted values, it results that their impact on terrestrial and aquatic ecosystems will not be significant.

The buildings and installation for water intake, channeling, use, discharge and spent water treatment shall be operated according to the operation and maintenance rulings. The optimum operation condition of the installation and water intake and discharge ducts shall be surveyed and the water quality parameters shall be monitored according to the jurisdictional authority requirements.

Samplings from Unit3 and Unit4 effluents will be collected in a section of the discharge circuit where the mixture of the condenser cooling water with the water from other installations is fully completed. In case that exceeding of the water quality parameters as per the standards are found, measures shall be so taken to eliminate the risk of impurifying the receiver.

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The periodic reporting of the results following monitoring activity to the environmental and water management authorities, will enable the permanent availability of data required to know the overall status of the water resources in the area, under the influence of the existing antropic factors assembly. The data base gathered by monitoring at Cernavoda NPP and other water users in the area, will be useful to the authorities in the field in order to analyze the causes of unpredictable effects and to maintain a proper condition of the water flows.

The analyses developed on basis of data supplied by the monitoring programs will systematically evaluate the condition of the environmental factors, before and after Unit 2, Unit3 and Unit 4 commissioning, contributing to the optimization of the decisions of the 3 units operation. The activities developed at Unit 3 and Unit 4, including the activities related to the environmental protection, shall be permanently improved on basis of the experience gained with Unit 1 and Unit 2 operation and other CANDU – NPPs, and under the cooperation with IAEA and EC.

By the elaboration and implementation of Quality Assurance and Environmental Management Systems, additional instruments, to minimize the environmental impact and continuous upgrade of the conformity with the lows in the field, shall be created.

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## References

- III.6-1 Update Study of Sistematization Regarding the Industries, Population and Settlements within Cernavoda NPP Area, S.A. Constanta Design, 2000 (in Romanian);
- III.6-2 Feasibility Study for Cernavoda NPP Unit 3 Completion. Preliminary Environmental Impact Analysis on 3 x 700 MWe Cernavoda NPP. Preliminary Assessment on the Thermal Impact Generated by the Warm Water Discharge to DBSC and the Danube River (in Romanian);
- III.6-3 Environmental impact study for Cernavoda NPP Unit 2. ICIM, 2002;
- III.6-4 Meteorological and Pollutant Dispersion Study Updating Within Cernavoda NPP Area, INMH, October, 2000 (in Romanian);
- III.6-5 Meteorological and pollutant dispersion study in the Cernavoda NPP zone. ANM, 2004;
- III.6-6 ICIM-Environmental Impact Study for Spend Fuel Intermediate Storage (DICA)-2001 (in Romanian).

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### **III.7 Human Settlements and other Public Interest Objectives Protection**

#### **III.7.1 Human Settlements and other Public Interest Objectives, Natural Monuments, Traditional Interest Areas, Distances to the Objective**

The greatest concentration of population in the vicinity of the Cernavoda NPP site, is Cernavoda town located at about 2 km distance, which had in year 2000 20384 inhabitants and is to reach about 23000 inhabitants in 2030.

Around Cernavoda NPP, on 1 km radius area (exclusion zone), there are no settlements or population with permanent residence.

In WNW sector, Fetesti town is located at 18 km distance from the site with a population of 36684 inhabitants in year 2000 and that to reach 36000 inhabitants at the level of the year 2030 (Ref.III.7-1).

Medgidia town is also included, at 18 km ESE sector from the site, a town having 46457 inhabitants in year 2000 and it is to reach 47000 inhabitants in 2030 (Ref.III.7-1).

In Figure III.7-1 is an illustration of the human settlements and economic objectives located in the geographic sectors within a 30 km radius area.

The main public interest objectives of these settlements and traditional manifestations within a 30 km radius area, are shown in Tables III.7-1 and III.7-2

Around Cernavoda NPP in an area with a 10 km radius there are the nature reserves, the natural monuments and the values of cultural patrimony approved by Law no. 5/2000. These are presented in Table III.7-3.

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Table III.7-1 The Network of Cultural – Social Units within Cernavoda NPP Site Zone (r = 30 km)  
Broken Down on Administrative Territorial Units

No.	City Town Village	City Hall	Police	Fire Fighting Unit	Cultural House	Cinema	Mail Office	Children garden/ No. of children	School/ No. of pupils	High- school/ No. of pupils	Vocational School/ No. of students	Educational Staff TOTAL	Remarks
1	Medgidia	1	1	1	1	3	1	13/1178	10/5698	4/2083	2/308	539	Cultural house, library, museum
2	Cernavoda	1	1	1	1	2	1	5/452	4/3050	2/767	1/270	238	
3	Basarabi	1	1	-	1	-	1	3/305	2/1578	1/280	-	113	
4	Adamclisi	1	1	-	1	-	1	3/67	4/311	-	-	21	Archeologic museum, fortress, monument
5	Aliman	1	1	-	1	-	1	3/85	4/384	-	-	29	
6	Castelu	1	1	-	1	-	1	3/208	3/993	1/184	1/191	95	
7	Ciocarlia	1	1	-	1	-	1	2/78	4/397	-	-	32	
8	Cobadin	1	1	-	1	-	1	4/248	3/1108	1/199	1/35	84	Cultural house
9	Crucea	1	1	-	1	-	1	5/100	6/449	-	-	31	
10	Deleni	1	1	-	1	-	1	4/78	4/356	-	-	30	
11	Ion Corvin	1	1	-	1	-	1	2/51	5/245	-	-	24	
12	Mircea Voda	1	1	-	1	-	1	4/136	7/900	-	-	58	
13	N. Balcescu	1	1	-	1	-	1	4/193	3/697	-	-	43	
14	Pestera	1	1	-	1	-	1	4/95	4/449	-	-	36	
15	Poarta Alba	1	1	-	1	-	1	3/143	4/1039	1/337	1/30	82	
16	Rasova	1	1	-	1	-	1	2/82	3/556	-	-	28	
17	Seimeni	1	1	-	1	-	1	3/64	3/264	-	-	24	
18	Silistea	1	1	-	1	-	1	2/60	2/206	-	-	18	
19	Targusor	1	1	-	1	-	1	3/88	4/371	-	-	28	
20	Topalu	1	1	-	1	-	1	1/40	2/210	-	-	13	„Vintila” Art museum
21	Tortoman	1	1	-	1	-	1	1/50	1/282	-	-	20	

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No.	City Town Village	City Hall	Police	Fire Fighting Unit	Cultural House	Cinema	Mail Office	Children garden/ No. of children	School/ No. of pupils	High- school/ No. of pupils	Vocational School/ No. of students	Educational Staff TOTAL	Remarks
<b>Constanta County Total</b>		<b>21</b>	<b>21</b>	<b>2</b>	<b>21</b>	<b>5</b>	<b>21</b>	<b>74/3801</b>	<b>82/19543</b>	<b>10/3850</b>	<b>6/834</b>	<b>1.586</b>	
0	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Borcea	1	1	-	1	-	1	6/293	5/1014	-	1/88	75	
<b>Calarasi County Total</b>		<b>1</b>	<b>1</b>	<b>-</b>	<b>1</b>	<b>-</b>	<b>1</b>	<b>6/293</b>	<b>5/1014</b>	<b>-</b>	<b>1/88</b>	<b>75</b>	
1	Fetesti	1	1	1	1	2	1	10/915	9/4693	3/1771	2/598	458	museum
2	Bordusani	1	1	-	1	-	1	2/116	4/758	-	-	42	
3	Facaeni	1	1	-	1	-	1	2/82	3/687	-	-	42	
4	Stelnica	1	1	-	1	-	1	2/82	2/191	-	-	15	
<b>Ialomita County Total</b>		<b>4</b>	<b>4</b>	<b>1</b>	<b>4</b>	<b>2</b>	<b>4</b>	<b>16/1195</b>	<b>18/6329</b>	<b>3/1771</b>	<b>2/598</b>	<b>557</b>	
<b>GENERAL TOTAL</b>		<b>26</b>	<b>26</b>	<b>3</b>	<b>26</b>	<b>7</b>	<b>26</b>	<b>96/5289</b>	<b>105 / 26886</b>	<b>13/5621</b>	<b>8/1520</b>	<b>2.218</b>	

Within the area, there are 3 fire fighting units:

- Cernavoda Fire Brigade located in the temporary facilities of DBSC and the new main office under construction on Padurea Bisericii Hill (West – North – West sector, d= 3.5 km);
- Medgidia Fire Brigade (East – South – East sector, d = 18.5 km);
- Fetesti Fire Fighting Team (West – North – West sector, d = 21.0 km).

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Table III.7-2 Zones and Objectives of Traditional Interest (r = 30 km)

No.	Location	Location related to NPP		Specifications	Characteristics, Dates
		Sector	Distance (km)		
1	Medgidia	ESE	17.00	a) Days of Medgidia b) Weekly Fair ( on Saturdays)	Annual Fair on St.Dimitru 's Day (Oct.26) the spiritual leader of the settlement: cultural, sportive, art, commercial, crafts man ship, exhibitions
2	Fetesti	WNW	20.00	a) Autumn Fair – Oct 1 <sup>st</sup> -15 <sup>th</sup> b) Weekly Fair (on Saturdays)	Amusement activities, agricultural fair, producers from neighboring settlements, commercial stands
3	Miircea Voda-gara	SE	8.70	Heros'Day (40 days after Easter)	Military and religious ceremony at the Heros' Graveyard with the participation of the people around
4	Baltagesti, Crucea (Alah Bair)	NNE	22.50	Healing Spring Day (First Sunday after Easter)	Religious annual ceremony with the participation of priests in the area
5	Aliman-Dealul Serpu	SW	21.00	Healing Spring Day (First Sunday after Easter)	Spring at Serpu Hill bottom natural reservation, people from Aliman, Ion Corvin, Rasova villages
6	Capidava, Topalu	N	19.50	a) International Creation Fiction and Science Camp (Atlantykron) b) Archeological Camp	Organized since 1989 by the National Federation for Science and Fiction in July and August for 10 days
7	Medgidia, Fetesti			Epiphany (January 6 <sup>th</sup> )	Religious ceremony by which a holy cross is thrown into a river (i.e Borcea Branch) and must be recovered
8	In all the localities in the area			<b>Dedication Day of main churches in the area</b>	St.Peter & Paul – June 29 <sup>th</sup> - Medgidia St. Dumitru - Oct. 26 <sup>th</sup> - Medgidia St.Emperos - May 21 <sup>th</sup> - Cernavoda St.George - April 23 <sup>t</sup> – Satu Nou etc.

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Table III.7-3 Protected Areas Located in Cernavoda NPP Site Zone (R = 10 km)

A. As per P.A.T.N. – section III, approved by Law no. 5/2000

NO.	ITEM IN THE APPENDIX OF LAW NO.5/2000	TITLE	TOWN VILLAGE	POSITION RELATED TO NPP		REMARKS
				Sector	Distance (km)	
<b>APPENDIX I</b>						
2.0 NATURAL RESERVES AND MONUMENTS – CONSTANTA COUNTY						
1	2.354	Fossil Place Cernavoda	Cernavoda	WNW	3.6	S = 3.00 ha
2	2.355	Fossil Deposit Seimenii Mari	Seimeni	NNE	9.5	S = 0.50 ha
<b>APPENDIX III</b>						
<b>I NATIONAL INTEREST CULTURAL PATRIMONY VALUES</b>						
1. ARCHITECTURAL MONUMENTS AND BUILDING ASSEMBLIES						
I - Industrial architecture, communication route						
3	I-3	“Engineer Anghel Saligny” Bridge	Cernavoda	WNW	4.0	
g – Castrum and associated civil settlements: Roman – Byzantine fortifications						
4	g - 12	“Axiopolis” Roman stronghold	Cernavoda	WNW	3.5	
II TERRITORIAL UNITS WITH HIGH DENSITY OF NATIONAL INTEREST PATRIMONY VALUES						
5	Cernavoda town; Villages: Aliman, Mircea Voda, Rasova					

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B. According to Center of Information and Cultural Memory (CIMEC) 1992 Listing (Computer Center and Cultural Memory of DMI)

No.	Name and no. on CIMEC listing	Location	Value Category	Reference	Position related to NPP		Remarks (description, dates, etc.)
					Sector	Distance (km)	
1	3 Fortifications dated 1916 - 1918	Cernavoda km 4 north-est from the town			NE	2.5	Ruins of fortifications dated the World War I with traces of Neolithic settlements and from age in the neighboring area
2	66 The area of the old commercial and administrative center	Cernavoda		14E0009	NW	3.1	A compact front built along 380 m and 17 buildings scattered in the central area, beginning of XX century
3	67 Stone wall	Cernavoda, south		14 A0020	SSW-WSW	3.0-3.5	Traces of "visible" walls and covered walls, X - XI century, early Middle Age
4	68 " Sofia Hill " - settlement	Cernavoda- starting from 100 m west of City Hall up to Danube	A	14 A0078	NW	3.5	Traces of superpose settlements from Neolithic-bronze ages, Cernavoda I,II,III- cultural ages
5	69 Axiopolis area graveyard	Cernavoda at 4,5 km south, 70 m west from DJ 223	B	14 A0079	SW-WSW	2.5 – 3.5	Paleochristian thumb VI- VII AC
6	70 Axiopolis Stronghold	At 3 km south from town, facing Hinog island, on the right bank of Danube	A	14 A0080	SW-WSW	3.5	VI BC-.VII AC and traces from the Byzantine period
7	70 Bridge over Danube and statues of "Dorobanti" soldiers	Southwards from the Channel confluence, upstream km 300 D		14 B0095	WNW	3.9	1890 – 1895 Eng. Anghel Saligny
8	72 St. Constantin & Elena Emperors Church	Adjacent to the central area "str. Canalului"		14 B0089	NW	3.25	1882- 1885 Historical monument

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No.	Name and no. on CIMEC listing	Location	Value Category	Reference	Position related to NPP		Remarks (description, dates, etc.)
					Sector	Distance (km)	
9	73 Islamic church	Str. Crisan No.4		14 B0090	NW	2.8	End of XVIII century- Historical monument
10	82 School (G+1 = ground floor +1 floor)	Str.Mircea cel Batran No. 7		B 27 / 82	NW	2.25	End of XVIII century- begin XIX century -Historical monument
11	85 House (G+1) with shops (marking "Fr.D")				NW	2.95	End of XIX century- begin of XX century- Historical monument
12	86 House marked "Established in 1907"	Str.9 Mai / str. Dacia			NW	3.20	Historical monument
13	Ground floor house	Str. Dumbravei No.15			NW	3.15	Begin of XX century - Historical monument
14	Great earth wave	Northwards from Cochirleni village and Gheremelelor Hill			SSE-SW	5.9-6.5	IX century
15	81 "Patulului" Stronghold and small earth wave	On the bank of Danube northwards from Cochirleni village		14 A0018	SW	6.5	IV century AC - Roman aged. Place when the Great Earth Wave ends. No researched yet
16	Hero graveyard 1916-1918	Railway Station Mircea Voda			SE	9.0	

### C. Natural Reserves – Calarasi County

1	Caiafele Forest	3.0-7.0 Km upstream A. Saligny Bridge			WSW-W	4.5-8.0	348.90 ha, on the left bank of Danube (300-400 m width)
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### **III.7.2 Industrial Activities, Roads Network, Railways and other Transport Routes Within a 30 km Radius Area**

The economic activity in Cernavoda NPP influence area consists in:

- extractive industry (quarries of limestone, sands, diatomite, bentonite, clay);
- facilities concentrated in the industrial areas existing in Cernavoda, Fetesti and Medgidia towns;
- economic units (agrarian-industrial) spread in the rural places in the area.

The economic activities in Cernavoda NPP area are grouped as follows: Cernavoda - Saligny industrial zone, Cernavoda-harbour industrial zone, Medgidia North industrial zone, Medgidia East – harbour industrial zone, Fetesti North-West industrial zone, Fetesti – East harbour industrial zone.

Pipelines with their routes represented in Figure III.7-1 carried out oil and methane gas within the Cernavoda NPP influence area. The pipelines have been provided with isolating valves when crossing the main roads, the railways or sub-crossing the waterways.

The roads network developed in this area is represented in Figure III.7-1:

- A2 (Bucharest - Constanta highway), section Cernavoda - Constanta (in perspective);
- National road 22C Cernavoda - Basarabi;
- Districtual road 223, parallel with Danube river between villages of Cochirleni, Cernavoda and Seimeni;
- Village roads DC60 and DC61, in NNE and respectively NE sectors; the distances towards Cernavoda NPP are greater than 5 km.

The existing railway is represented by the railway, Bucharest – Constanta; the nearest station is Cernavoda Bridge; in the influence area there is the secondary railway Saligny – Cernavoda town; the hazardous materials carried on this railway are used only by Cernavoda NPP.

The waterways transport nearby Cernavoda NPP is represented by the shipping waterways: Danube river and the channel Danube- Black Sea.

The international airport Constanta – Mihail Kogalniceanu is located at about 35 km versus Cernavoda NPP. From airway traffic point of view, the Cernavoda NPP influence area is considered an interdiction zone (specified as “LRP2” on the airway maps), for the flights up to 4000 ft. (about 1200m) altitude, in a cylindrical zone with 5 miles (about 10 km) radius and the axis passing through the NPP axis.

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### III.7.3 Use of Land, Agriculture and Touristic Activities

According to the way the land is used, the dominant areas are the agricultural surfaces (table III.7-4) most of them prepared for irrigation, but large areas are covered by meadows, wine yards and only few are covered by orchards.

Wine yards are located around Cernavoda, Cochirleni, Rasova, Aliman, Medgidia, Mircea Voda, Tortomanu; the most compact orchard area are located eastwards Cernavoda, in Mircea Voda and Medgidia zones. On agricultural areas cereal crops, oleaginous plants and fodder represent the major weight.

Table III.7-5 presents the agricultural crops obtained in a zone around the Cernavoda NPP site, within a distance  $R = 20$  km, in 1998.

Season work is practiced in wine yards and orchards in spring (February, March) and in autumn for harvesting when the number of employees and work time period is longer (August, September, October). Cernavoda town is an exception due to the relatively high number of commute people reaching about 800 individuals.

Touristic activities do not generate long-time stay in the analyzed area (30 km area). The character of the activity is mainly touristic and in transit to the Black Sea shore.

Table III.7-4 Land use in the zone with radius  $R = 20$  km

Categories of usage	Surface (ha)	Surface percent (%)
Arable	86084	68.5
Pasturelands	10600	8.4
Vineyards	5019	4
Orchards	1347	1.1
AGRICULTURAL TOTAL	103050	82
Forests	7774	6.1
Water-reed	6084	4.8
Buildings	2296	2
Non-productive	1340	1.1
NON-AGRICULTURAL TOTAL	22550	18
GENERAL TOTAL	125600	100

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Table III.7-5 Agricultural surfaces and crops around the Cernavoda NPP site in 1998 (within a distance r = 20 km)

No	LOCALITY	Wheat/Rye		Corn		Sun Flower		Potatoes		Sugar Beet		Vegetables		Grapes		Fruits	
		Ha	t	ha	t	ha	t	ha	t	ha	t	ha	t	ha	t	ha	t
<b>I. COUNTY CONSTANTA</b>																	
1	Medgidia	1 639	4 648	667	2 075	1 050	1 510	111	2 255	45	2 317	223	2 897	1 084	6 982	377	2 763
2	Cernavoda	238	581	403	1 194	108	212	6	50	-	-	20	239	733	2 219	120	278
3	Adamclisi	730	1 168	1 286	2 579	985	605	20	250	-	-	29	360	960	726	-	132
4	Aliman	800	1 903	1 343	4 293	540	248	25	315	-	-	68	833	889	2 530	-	67
5	Castelu	2 608	7 930	2 629	8 846	1 322	2 140	219	3 908	60	1 800	194	3 239	42	195	-	27
6	Mircea Voda	1 900	5 211	1 906	5 644	1 268	1 908	48	440	25	685	111	1 381	952	4 863	521	2 385
7	Pestera	3 785	9 984	2 896	6 561	2 830	3 826	10	120	-	-	20	260	266	923	127	1 542
8	Rasova	547	1 415	1 853	4 566	435	320	16	110	-	-	37	259	1 607	3 834	77	291
9	Seimeni	900	2 250	1 747	2 627	750	638	40	400	-	-	44	475	239	1 100	3	14
10	Silistea	2 010	6 484	548	1 537	559	842	58	1 175	-	-	59	511	175	751	-	55
11	Topalu	550	1 540	1 737	3 129	750	600	10	150	-	-	50	1 035	78	83	-	33
12	Tortoman	3 484	12 954	1 282	3 787	1 212	2 175	30	340	-	-	43	352	59	232	-	34
	<b>TOTAL I</b>	<b>19 191</b>	<b>56 068</b>	<b>17 630</b>	<b>46 838</b>	<b>11 809</b>	<b>14 624</b>	<b>593</b>	<b>9 513</b>	<b>130</b>	<b>4 802</b>	<b>898</b>	<b>11 841</b>	<b>7 084</b>	<b>24 438</b>	<b>1 225</b>	<b>7 621</b>
<b>II. COUNTY CALARASI</b>																	
1	Borcea	8 062	13 796	6 359	17 169	5 926	7 980	50	280	21	320	104	405	497	820	-	162
	<b>TOTAL II</b>	<b>8 062</b>	<b>13 796</b>	<b>6 359</b>	<b>17 169</b>	<b>5 926</b>	<b>7 980</b>	<b>50</b>	<b>280</b>	<b>21</b>	<b>320</b>	<b>104</b>	<b>405</b>	<b>497</b>	<b>820</b>	<b>-</b>	<b>162</b>
<b>III. COUNTY IALOMITA</b>																	
1	Fetesti	1 773	5 064	2 336	5 883	966	1 076	30	350	196	6 407	1 519	12 066	585	1 260	367	1 841
2	Bordusani	2 091	7 391	4 162	10 146	2 992	4 680	50	210	-	-	110	766	284	285	36	265
3	Stelnica	3 902	13 543	1 767	4 646	1 898	3 152	31	365	-	-	70	752	55	138	-	22
	<b>TOTAL III</b>	<b>7 766</b>	<b>25 998</b>	<b>8 265</b>	<b>20 675</b>	<b>5 856</b>	<b>8 908</b>	<b>111</b>	<b>925</b>	<b>196</b>	<b>6 407</b>	<b>1 699</b>	<b>13 584</b>	<b>924</b>	<b>1 683</b>	<b>403</b>	<b>2 128</b>
	<b>GENERAL TOTAL</b>	<b>35 019</b>	<b>95 862</b>	<b>32 254</b>	<b>84 682</b>	<b>23 591</b>	<b>31 512</b>	<b>754</b>	<b>10 718</b>	<b>347</b>	<b>11 529</b>	<b>2 701</b>	<b>25 830</b>	<b>8 505</b>	<b>26 941</b>	<b>1 628</b>	<b>9 911</b>

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### **III.7.4 Works, Outfitting and Measures for the Protection of Human Settlements and Protected Objectives and /or of Public Interest**

The protection of the personnel, population and environment is the main objective of Cernavoda NPP.

This objective is achieved by implementing the current practices world-wide and of the international recommendation regarding the design and operation of nuclear power plants. Further on there is a brief description of such protection measures:

a) The limitation of the internal and external radiation exposure of the population and of the objectives located in the proximity of the site is represented by an assembly of facilities incorporated in the plant design, as well as, by the adopting of operation procedure and regulation sets.

The measures taken for the protection against ionizing radiation of personnel, population and environment during the plant normal operation are presented in Chapter III.4.

The gaseous and liquid radioactive releases, that could transfer a significant quantity of radioactivity into the environment, are monitored and controlled as described in Chapter V. In addition, the limitation of the releases to 5 % from the derived emission limits (DEL) is stipulated for Cernavoda NPP. The derived emission limits (DEL) for Unit 1 were calculated considering the technologic and site characteristics so that, a person from the population would not receive a radiation dose greater than the limit dose of 1mSv/year allowed by the standards in effect (see Chapter III.4).

The solid wastes are stored so that they would prevent the radioactivity releases into the environment (see Chapter III.8).

Environment monitoring program is including all necessary activities in order to determine the radioactivity levels of the environment, and to evaluate their impact both on the environment and population, in case of the plant normal operation, as well as, supplementary programs that may be implemented when the emission are greater than DEL (see Chapter V).

b) The plant activities do not produce toxic gases releases, that may negatively affect the population or the industrial or public interest objectives (see Chapter III.2).

As regards the liquid releases, the inactive chemical monitoring environment program is including the necessary activities in order to meet the regulation requirements regarding both environmental protection and supplementary programs that may be implemented in case of accidental leakage of chemical substances (see Chapter V).

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c) For accident prevention, the limitation of their consequences and the correction of their effects by post-accident actions, in case of CANDU type NPPs, the in depth protection principle is applied. This principle implies:

- high quality equipment for the plant and a quality assurance program for all the phases of the plant construction;
- independent safety systems;
- the confinement of the radioactive materials and the multiple barriers to retain and minimize the radioactive releases.

According to this principle, for operating personnel, population and environmental protection, by the plant design, five successive protection barriers have been provided which should prevent the spreading of radioactive inventory from sources to environment.

Thus, the multi levels protection corresponding to the provided barriers has been assured. The objective of the first level is prevention of abnormal operation and failure of plant systems. In case when the first level is affected, the abnormal operation is controlled or the failures are detected by the second protection level. Whether the second protection level should be affected, the third level ensures meeting of safety functions by the special safety systems. In case of failure of the third level, then the fourth level limits accident evolution, so that to prevent and limit severe accident regimes with radioactive inventory release. The objective of the last protection level is radiological consequence limitation by the off-site emergency plan. The five barriers provided for the plant are:

- fuel matrix;
- fuel sheath;
- pressure boundary of primary heat transport system;
- reactor containment;
- exclusion area.

Upon the design, the Emergency Plan is also including technical and administrative actions for limiting the effects of accidents more severe than DBA upon the personnel, population and near-by environment.

Chapter IV presents a list of accidents and their radiological consequences considered when designing the plant .

d) Cernavoda NPP platform is so designed that the normal operation of the unit will not influence the operation of the other units.

Units 3 and 4 are designed as an independent operational unit as to Unit 1 and Unit 2, and therefore any abnormal or emergency condition generated by Unit 3 or 4 is not jeopardizing the operation and safety of Unit 1 and Unit 2 and neither their operation personnel.

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Unit 3 and 4 design is so conceived that these units don't make use of installations and systems common to the other units that once failed in the unit might induce failures in other units. The effects of failures in the objectives adjacent to Units 3 or 4 are not influencing the other units operation.

e) Chapters III.1 ÷ III.6 presents the design actions considered for the protection of waters, air, soil, land and aquatic ecosystems, protection against noise and vibration.

f) Considering the distances to the NPP platform, negative effects on the historical and ethnographical objectives are not expected.

g) Effects on the activities in the area:

The summed-up effects with the effects of the industrial units in Cernavoda town are not considered because there is no common hazardous releases. The provided design measures remove the danger of explosions in the NPP that might jeopardize the structural integrity of the near-by objectives.

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### Reference

- III.7-1 Update Study of Systematization Regarding the Industries, Population and Settlements within Cernavoda NPP Area, S.A. Constanta Design, 2000 (in Romanian)
- III.7-2 Finaly Safety Report - Cernavoda NPP Unit 2, 2005 (in Romanian)

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### **III.8 Management of Waste Generated on Site**

#### **III.8.1 Solid Radioactive Waste Management**

##### **III.8.1.1 General Principles**

In compliance with the Governmental Ordinance no. 11/2003 modified, supplemented and approved by Law no. 320/2003 (Ref. III.8-1, III.8-2), the nuclear spent fuel and radioactive waste management including the final disposal, is developing upon the satisfaction of the national nuclear safety standards, the standards on ionising radiation protection of occupationally exposed personnel, population, environment and property as well as upon the agreements Romania is part of.

National policy for radioactive wastes management corresponds to the international requirements, as established by "Common convention upon safety management of spent fuel and upon safety management of radioactive wastes", elaborated by IAEA and ratified by Law No. 105/1999 (Ref. III.8-3), as well as to the radioactive wastes management policy being promoted at EU level.

The main objective of national policy for radioactive wastes management is that of providing a negative impact, being theoretically null and a minimum reasonably one, respectively, having only a practical aspect, that of wastes management activities both upon population and environment. The first step in this direction is provision of the conformity of management process with the principles recommended by IAEA by the document "Safety Series No.111-F, Fundamental principles of radioactive wastes management" (Ref. III.8-4).

At the base of the spent nuclear fuel and radioactive wastes management and of ultimate depositing inclusively, lay the following main principles:

- the principle of using only the management processes and methods of nuclear spent fuel and radioactive wastes, providing an acceptable protection level against ionized radiations for health of both population and environment including also consideration of possible transfrontalier effects;
- the principle "generator of spent nuclear fuel and of radioactive wastes" pays;
- the principle of responsibilities of the spent nuclear fuel and of radioactive wastes generator;
- the principle of the best allowable techniques, without actuation of some unjustified costs for future generations;
- the principle of maintaining the lowest level regarding both activity and volume of the spent nuclear fuel and generated radioactive wastes.

The co-ordination, at national level, of the safe management process of the nuclear spent fuel and radioactive wastes generated by the nuclear licensees as well as their final disposal are part of the National Medium and Long-Term Strategy (Ref. III.8-5).

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The National Strategy states the general procedure for organising and developing the stages of nuclear spent fuel and radioactive waste management.

The National Strategy is applicable to all the stages of radioactive waste management process including their final disposal, and to all the nuclear facilities.

In Romania, the jurisdictional authority at national co-ordination level of the safe nuclear spent fuel and radioactive waste management, including the final disposal is the National Agency for Radioactive Waste - ANDRAD. ANDRAD is responsible for final disposal of nuclear spent fuel and radioactive waste in Romania.

Financing of activities being co-ordinated by ANDRAD will be made by "Decommissioning and radioactive wastes ultimate repository fund". The financing way of radioactive wastes safety management will meet EC recommendations to the Member States, as established by EURATOM Treaty.

The nuclear and radiological unit licensees that generate or possess radioactive waste must elaborate medium and long-term strategies regarding their own activity, strategies that must harmonize with the National Strategy on radioactive waste management.

The waste management at Cernavoda NPP (to be applied in case of Units 3&4 too) includes the initial steps of waste pre-conditioning as defined in the Fundamental standards on safe nuclear radioactive waste management (Ref. III.8-6) and IAEA Safety Series No. 111F "The Principles of Radioactive Waste Management" (Ref. III.8-4).

Cernavoda NPP Design provides installations capable to ensure the safety management of radioactive waste, and the radiological protection of operators, population and the environment.

The developed activities include: collecting, sorting, compaction (if the case) and interim storage.

The low and medium active wastes are stored in the Interim Radioactive Waste Storage (DIDR) presented in section II.2 herein.

The removal of low and medium active radioactive waste is made by final disposal that is an industrially demonstrated practice both internationally and in European Union.

According to the National Strategy on Radioactive Waste Management, the low and medium radioactive waste from Cernavoda NPP will be stored in a national final surface disposal facility (DFDSMA) planned to be put into operation in the year 2014.

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The high radioactive wastes, including also the spent fuel, after minimum 50 years of intermediate storage on NPP platform will be ultimately stored in a national geologic deposit.

The Interim Spent Fuel Storage Facility (DICA) was put into operation in 2003, being provided to be enlarged, in stages, due to the fuel quantities required to be stored.

In compliance with the National Strategy, the National Repository will be put into operation in the year 2055.

Herein below is a presentation of the radioactive waste management at Cernavoda NPP Unit 3 & 4.

### **III.8.1.2 Types and Quantities of Solid Radioactive Waste for one Unit**

During plant operation the following types of radioactive wastes are produced (Ref. III.8-8):

- Spent ion resins;
- Used filter cartridges;
- Low activity solid radioactive wastes - Type 1 (gamma dose rate on contact < 2mSv/h)\*;
- Medium activity solid radioactive wastes - Type 2 (gamma dose rate on contact between 2mSv/h and 125mSv/h)\*;
- Medium activity solid radioactive wastes - Type 3 (gamma dose rate on contact between > 125mSv/h)\*.

\* The contact gamma dose rates are monitored at the outside surface of the containers used for solid radioactive waste collection, handling or transfer.

The radioactive wastes are generated by the following sources (Ref. III.8-9):

- D<sub>2</sub>O primary coolant and moderator purification systems (the resulted solid radioactive wastes are: spent resins, filters and filter cartridges);
- Spent fuel bay cooling and purification system (the resulted solid radioactive wastes are: spent resins, filters and filter cartridges);
- End shield cooling system (the resulted solid radioactive wastes are: spent resins);
- Fueling machine D<sub>2</sub>O supply system (the resulted solid radioactive wastes are: spent resins, filters and filter cartridges);
- Liquid zone control system (the resulted solid radioactive wastes are: spent resins);
- Liquid radioactive wastes system (the resulted solid radioactive wastes are: spent resins);
- Seal gasket of the primary circuit pump (the resulted solid radioactive wastes are: filters and filter cartridges);

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- Active drainage system (the resulted solid radioactive wastes are: sumps strainer);
- D<sub>2</sub>O cleanup system (the resulted solid radioactive wastes are: charcoal active filter, spent resins);
- Reactor Building and Spent fuel bay ventilation systems (the resulted solid radioactive wastes are: filters and filter cartridges);
- Reactor components, components of the primary circuit and moderator system (the resulted solid radioactive wastes are medium activity wastes: shield plugs, pipes, pressure tubes, etc.);
- Daily operations in the plant (the resulted solid radioactive wastes are low activity wastes: textile materials, metallic parts, plastic materials, glass, paper etc.).

The characteristics of the solid radioactive waste are the followings:

#### a) Spent Ionic Resins

Spent resins are obtained from the various purification circuits of the process systems. When taking the resins out of these systems, the direct contact radiation dose rate is usually higher than 10 mSv/h. Therefore, special protection and shielding measures will be taken for their transportation, handling and storage.

The characteristics of the spent resins handled within the plant systems are ranging within large limits. Both the activity and composition of the radionuclides which are retained in the ionic exchange resins depend mainly on the function which the purification system performs in the plant, by using the respective resins. The spent resins activity (values estimated on base of CANDU reactors operating experience) and the sources are indicated in Table III.8.1-1. It is notice that resin activity in the primary coolant purification system, or of the water in the spent fuel bay is due mainly to Cesium 134 and 137, which are fission products originated from the fuel elements. Resins activity in the moderator purification system is mainly due to Cobalt 60 and Chromium 51, resulted from the activation of structural materials in the neutrons flux.

Spent resin sources and annual quantities resulted from these sources are presented in Table III.8.1-2 (Ref. III.8-10).

#### b) Used Filter Cartridges

As presented above, the spent filter cartridges result from the following process systems: primary coolant purification system, moderator purification system, spent fuel bay water cooling and purification system, primary circuit pump gland seal system, fuelling machine D<sub>2</sub>O supply system, Reactor Building and Service Building ventilation systems, D<sub>2</sub>O cleanup system.

The spent filter cartridges usually have, when they are discharged from the plant, gross beta-gamma activities which determine doses on contact up to 5 mSv/h (in extreme cases up to 50 Sv/h). For example, the maximum dose measured till now at

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Cernavoda U1 NPP has been of 12 mSv/h, for a large filter cartridge from the spent fuel bay water cooling and purification system (Ref. III.8-7).

In Table III.8.1-3, the volume and activity of filtering cartridges (estimated on operation experience of Point-Lepreau station, (Ref. III.8-8) are presented.

#### c) Solid Low Level Radioactive Waste

Solid low active wastes are wastes which have a gamma dose rate on contact under 2 mSv/h (Ref. III.8-9). Solid low active wastes are produced from the day-to-day reactor operation. They consist of materials from decontamination and maintenance operations, protective clothing and metallic parts, as well as contaminated materials and equipment.

The volume and activity of the solid low active waste (compactable and non-compactable) estimated on experience of Point-Lepreau plant (Ref. III.8-8), are indicated in Table III.8.1-3.

#### d) Solid Intermediate Level Radioactive Waste

Solid medium active wastes are grouped in two categories, in function of gamma dose rate on contact, as follows (Ref. III.8-9):

- Solid medium active wastes Type 2, with gamma dose rate on contact between 2 mSv/h and 125 mSv/h;
- Solid medium active wastes Type 3, with gamma dose rate on contact > 125 mSv/h.

From the point of view of their composition, the medium active wastes consist of:

- general wastes: paper, textiles, plastics;
- special wastes: filters from the reactor purification circuits, activated components of the systems.

Until now, the producing of this type of waste is very low.

#### e) Organic Liquid Radioactive Waste, Oils, Chemical Substances

Organic liquid radioactive wastes consist of spent oils, spent solvents, liquid scintillators, flammable solids, sludge which, due to environmental impact concerns, can not be processed through the Liquid Radioactive Waste system of the plant.

The sources of liquid organic wastes are as follows (Ref. III.8-7):

- oils: lubricating oils from pumps and motors used in Zones 1 and 2 of the plant, contaminated mainly with tritium;

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- solvents: from the decontamination area and from the laboratories and maintenance activities; spent solvents consist of: white spirit, ethylene glycol, alcohol ethyl, toluene, chloroform, acetone;
- liquid scintillator contaminated mainly with tritium and segregated by tritium content; liquid scintillator from sampling of the moderator system and the primary system and their auxiliaries is segregated from liquid scintillator from sampling of the liquid effluents system;
- radioactive sludge, from maintenance activities on the active drainage, contaminated with gamma nuclides;
- flammable solids (solid-liquid mixture) from maintenance activities, contaminated with gamma nuclides.

The volume and activity of these wastes, estimated based upon the operating experience of CANDU 600 stations (Point Lepreau) are presented in Table III.8.1-3 (Ref. III.8-8).

Table III.8.1-1 Specific Activity of the Spent Resins – Estimated Values

System	Activity (Bq/cm <sup>3</sup> )		
	Cs-137	Cs-134	Co-60
Spent Fuel Bay	5.70 E+6	1.58 E+6	-
Shield Cooling System	-	-	4.01 E+2
D <sub>2</sub> O Cleanup System	7.78 E+3	3.34 E+3	9.26 E+1
Liquid Radioactive Waste Handling System	7.62 E+4	3.54 E+4	1.51 E+4
Primary Heat Transport System	4.77 E+6	2.32 E+6	5.86 E+4
Main Moderator System	-	-	2.67 E+2
Liquid Zone Control System	negligible	negligible	negligible
F/M Auxiliary System	negligible	negligible	negligible

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Table III.8.1-2 Estimated Spent Resin Volumes

Source	Annual Volume (m <sup>3</sup> )	% Volume
Primary Heat Transport System	8.5	32
Main Moderator System	8.0	31
Spent Fuel Bay Cooling and Purification System	4.5	17
Shield Cooling System	1.0	4
D <sub>2</sub> O Cleanup System	1.8	7
Liquid Zone Control System	0.6	2
Liquid Radioactive Waste Handling System	1.0	4
F/M Auxiliary System	0.8	3
TOTAL	26.2	100

Table III.8.1-3 Types and Quantities of Processed Radioactive Waste during Operation of a CANDU 6 NPP

Type	Description	Volume (m <sup>3</sup> /year)	Activity x 10 <sup>10</sup> (Bq/year)
Type 1 Gamma dose rate: < 2mSv/h	Compactable	44.30	1.54
	Non-compactable	12.60	0.06
	Filters	0.40	0.20
	Ionic resins	0.00	0.00
	Organic liquids	0.80	0.10
	Other waste	0.40	0.01
Type 2 Gamma dose rate: 2÷125 mSv/h	Compactable	0.30	0.90
	Non-compactable	0.10	0.45
	Filters	0.20	2.20
	Ionic resins	0.00	0.00
	Organic liquids	0.04	0.37
	Other waste	0.00	0.00
Type 3 Gamma dose rate: >125 mSv/h	Compactable	0.00	0.00
	Non-compactable	0.00	0.00
	Filters	0.00	0.00
	Ionic resins	0.00	0.00
	Organic liquids*	0.35	28700.00
	Other waste	0.00	0.00
	TOTAL	59.39	28705.83

\* Solid radioactive waste of type 3 accumulated in 10 years of operation.

### III.8.1.3 Management of Solid Radioactive Waste

#### a) Spent Ionic Resin Management

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Spent ionic resins management is performed by the Spent Ionic Resin Handling System. The simplified flow sheet of the system is presented in Figure III.8.1-1.

This system was designed to meet the following functions (Ref. III.8-10):

- collection of the resins, in the form of slurry, in demineralized water;
- temporary storage of the spent resins under water, for at least 10 years of plant operation (Ref. III.8-9);
- disposal of the excess slurry water to the liquid radioactive waste system;
- measurement of the slurry level in the storage vaults;
- provision of connections on the storage vaults, necessary for subsequent discharge of the spent resins to the final storage.

Spent resins are stored in three reinforced concrete vaults, lined with epoxy resin, which are located in the basement of the Service Building, in the vicinity of the Reactor Building.

The capacity of each vault is of 200 m<sup>3</sup>. This capacity has been established conservatively considering that the amount of spent resins which are removed annually from nuclear part of the plant is about 26m<sup>3</sup> and they would be temporarily stored inside the plant for at least 20 years, before being discharged and carried to the final storage. After this storage period, the main radionuclides are: Cs-134, Cs-137 and Co-60, the dominant isotope being Cs-137. CANDU reactors operating experience has shown that, though the storage vaults are sized for minimum 20 years, it is not recommended to keep the spent resins more than 10-15 years in these vaults, because they become solidified and can not be conditioned for final storage.

Due to C-14 which is accumulated, the spent ionic resins coming from the moderator will be processed separately, the decision for their final storage following to be taken later on.

The activity of the others spent resins is considerably reduced by natural decay during storage period, so that, later on, they can be transferred into special containers and eventually conditioned for final storage, without any special protection measures.

Control of the radioactive material releases into the environment is provided as follows:

- storage of the resins in the storage vault, the water for conveying the resins being transferred to the liquid radioactive waste system, so as to decrease the probability of radioactive materials releases into the environment;
- seismic qualification to DBE, category A of the storage vaults;
- location of the storage vaults in the basement of the Service Building, so that any leakage of radioactive materials will be collected by the Service Building drainage system;

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- the walls of the storage vaults are liquid-proof by using an epoxy resin and reinforced with fibre - glass, in order to avoid liquid infiltration outside the vaults;
- accidental leakages of liquid will be signaled by alarms both in a local panel and in the main control room; monitoring of the abnormal radioactivity levels of the water in the collecting pit is made by sampling and laboratory analysis in order to determine the total beta-gamma and tritium activity.

Temporary unavailability of the auxiliary systems which supply the spent resins handling system does not cause major operating disturbances because there is the possibility of discharge by overflow, by means of a gutter, into the adjacent vault and the storage capacity is big enough to cover various events (incidents or accidents).

### c) Used Filter Cartridges Management

There are five types of filter cartridges, having the following overall sizes:

	Type 1	Type 2	Type 3	Type 4	Type 5
Diameter (mm)	455	381	366	254	120
Height (mm)	1400	1173	1158	1143	1150

The spent filters resulted from both Reactor Building and Service Building ventilation systems, having low activities, are packed in plastic sheets and transferred to the Solid Radioactive Waste Intermediate Storage Facility, from where, later on, after packing and/or processing, they will be transported to the final repository.

The spent filter cartridges of type 1-4, coming from the primary coolant, moderator and spent fuel bay water purification circuits, are handled by means of a large special container (flask) for transport, which is presented in Figure 11.3-2, having a weight of 8.1 - 8.5 tons (including the cartridge) (Ref. III.8-10).

The spent filter cartridges of type 5, coming from the main pump gland seal, and the fuel handling and heavy water clean-up systems, are handled by means of a small size special container for transport (flask), which is presented in Figure 11.3-3, and has a weight of 2.7 tons (including the cartridge) (Ref. III.8-10).

The protection wall thickness of the flasks were calculated in order to provide a reduction of the radiation dose from 50 Sv/h to 0.25 mSv/h - in case of a large container, and from 50 Sv/h to 0.15 mSv/h - in case of a small container.

The spent filter cartridges are removed from the plant systems by means of these flasks and directly delivered to the Solid Radioactive Waste Intermediate Storage Facility; before they are dried.

Transportation of both types of containers inside the Reactor and Service Buildings are performed by means of a carriage, on pre-established routes, under the strict surveillance of the Health Physics Department.

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In actual use, when replacement of used filters takes place, both the flask and new filter located on the carriage will be brought to the intervention place, where the container is taken over by a monorail and positioned above the spent filter needing replacement. By acting on the handling cable, the used filter is lifted inside the container, then the filter cartridge and the container are moved together. The new filter cartridge is introduced inside the system. The container loaded with the spent filter cartridge is transferred to the Solid Radioactive Waste Intermediate Storage Facility, by means a truck, in favorable meteorological conditions (wind speed < 1.5 m/s and without rainfall), and assisted by a person from the Health Physics Department.

At the Solid Radioactive Waste Intermediate Storage Facility the spent filters are lowered into the cylindrical holes of the storage cells.

Operations for replacement and transfer of spent filter cartridges to the Intermediate Storage Facility will be performed so that the applicable requirements of station procedures for radioactive waste management and for radiation protection are met.

#### c) Solid Low Level Radioactive Waste Management

These wastes are collected on site at collection locations provided with drums which are properly labeled function of waste type. Collection points are located so that to provide collection and a first segregation of all wastes resulted in the plant.

The low active wastes are temporarily stored in the Solid Radioactive Waste Intermediate Storage Facility, in stainless-steel drums of 0.22 m<sup>3</sup> licensed by CNCAN.

The solid low active wastes are separately collected, as both compactable and non-compactable wastes.

The compactable wastes include: paper, textiles, plastics, rubber and other compactable materials.

The non-compactable wastes are grouped in two categories: general wastes, which contain: tools, metals, wood pieces, construction materials and other non-compactable materials; special wastes: glass, iodine radioactive particles and tritium filter cartridges, charcoal cartridges, C-14 contaminated wastes.

Conditioning of solid radioactive wastes is performed in Service Building and consists of inspection, monitoring, sorting, grinding, compacting (if necessary) and packing in drums. The compactable wastes are processed by pressing them directly in the drums, using a hydraulic press, and the (general) non-compactable wastes are grounded, if necessary. The C-14 contaminated wastes are not compacted and are separately packed.

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The content of tritium in each drum is checked before its sealing. If tritium is detected ( $> 5\mu\text{Sv/h}$ ), the drum is dried before its sealing.

Operations for collection, conditioning and transfer to the Solid Radioactive Waste Intermediate Storage Facility of the low active solid wastes are performed so that the applicable requirements from CNCAN norms applicable and radiation protection and maintenance procedures of the plant are met.

#### d) Intermediate Level Radioactive Waste Management

Type 2 general wastes can be packed, transferred to and stored in the Solid Radioactive Waste Intermediate Storage Facility in the same type of drums as solid low active wastes (Type 1 wastes), with outside shielding measures.

Type 2 special wastes and Type 3 wastes are handled with supplementary shielding measures.

The Solid Radioactive Waste Intermediate Storage Facility provides the features for a limited period of time storage of the solid low and medium active wastes which result from either normal or accidental operation of the plant (Ref. III.8-11). These facilities provide continuous collection and storage of the solid radioactive wastes in accordance with the requirements of applicable romanian norms. After a decay period in which the radiation dose rates are considerably reduced, these solid radioactive wastes will be transferred to the final repository.

#### e) Organic Liquid Radioactive Waste, Oils, Chemicals Management

The lubricated oils and solvents are collected from the site in 20 l metallic canisters, which are properly labeled for each type of waste. These canisters are discharged in 220 l stainless-steel drums located in the basement of the Service Building. The drums are licensed by CNCAN.

The mixture of scintillator liquids and plant system samples is collected in 20 ml bottles and stored in this way in 220 l stainless-steel drums, located in the basement of the Service Building. The drums are authorized by CNCAN.

A separate category of wastes is flammable solids (solid-organic liquid mixture). This category contains: textile and plastic materials, paper, small size filter, diverse gaskets imbued with flammable substances. These wastes are collected from the site in 20 l containers, which are properly labeled and they are stored in 220 l stainless-steel drums, in the basement of the Service Building; these drums are authorized by CNCAN. These organic substances determine the fire risk category for the areas where they are stored. The substances which are collected and kept in present at Cernavoda Unit 1 NPP determine the category A of fire risk, associated with class 14 high explosion risk.

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Generally, the organic liquid wastes are handled and stored as per the NPP's Radiation Protection Procedures.

#### g) Spent Fuel Management

After removal from reactor, the spent fuel bundles are stored in the Spent Fuel Bay (SFB) in room S-126 in the plant, for 6 years.

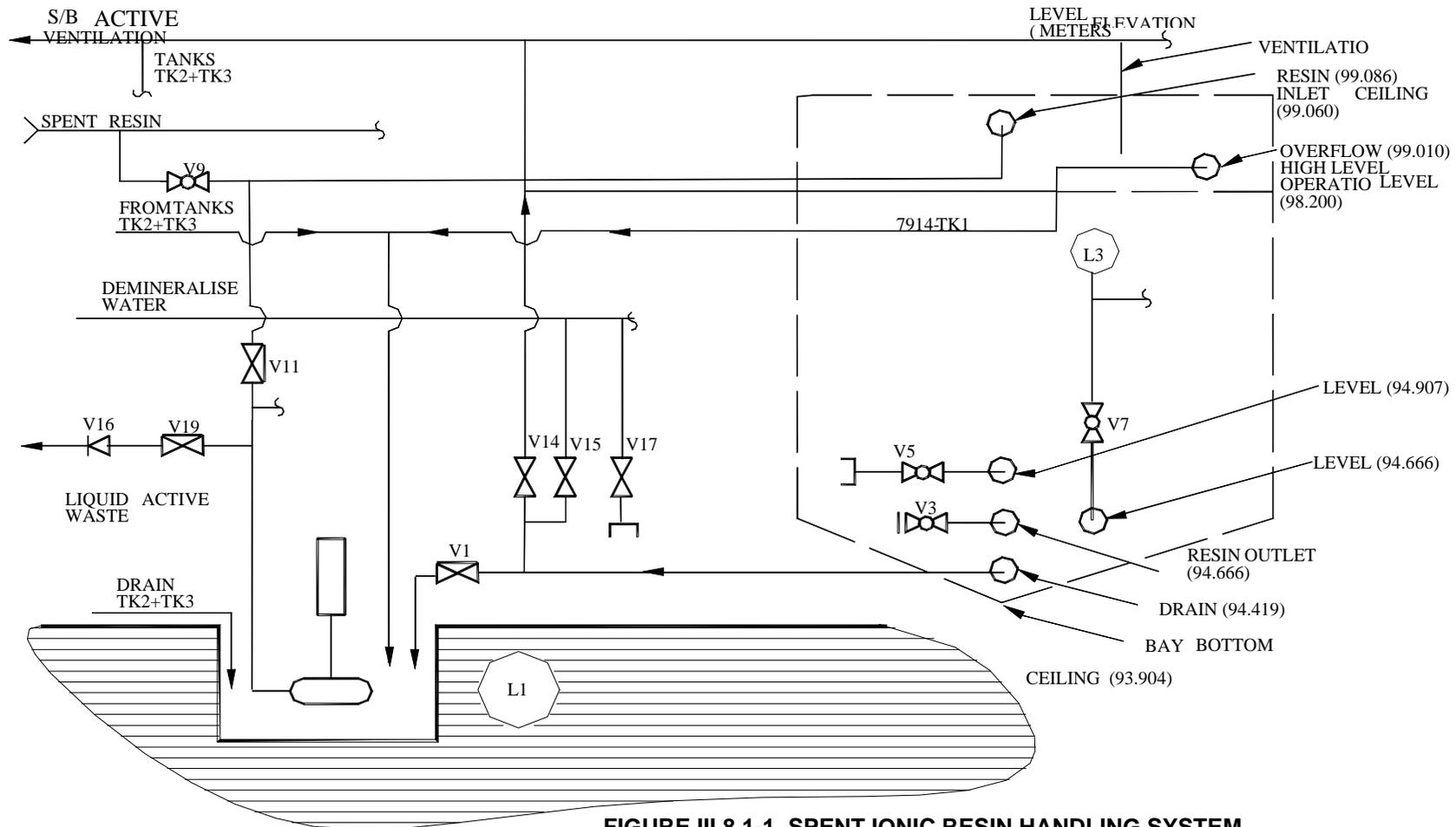
After the wet storage period when the fuel activity decays and the residual heat is reduced, the fuel is loaded in storage baskets and next transferred to the Spent Fuel Interim Storage Facility (DICA) using the same settlement as for Unit 1 and Unit 2 at Cernavoda NPP. The spent fuel preparation and loading in the storage basket and next, of the basket into transfer container, will proceed in an area of the SFB room in the plant and in the SFB – Extension Building which is to be built at each nuclear unit (Ref. III.8-12).

The dry storage for minimum 50 years shall be in concrete modules provided with cylinders for storage. The modules have a passive system of residual heat removal (inlet/outlet air openings of the module).

The storage technology requires provisions of two confinement barriers of spent fuel versus the environment, except the fuel cladding. The first barrier is represented by the storage basket (being shield by welding), and the second barrier is the storage cylinder, being also shielded by welding.

DICA has the capacity to store 150 000 spent fuel bundles (CANDU 6), previously decayed for 6 years in the SFB, representing an average spent fuel quantity from reactor 1 and reactor 2 at Cernavoda NPP in a period of 30 years.

The site is authorized and is located in front of reactor 5 (see drawing no. U3/U4-08230-6024-CU/PG-6024-1-GA-1). The storage technology is AECL.



**FIGURE III.8.1-1 SPENT IONIC RESIN HANDLING SYSTEM  
SIMPLIFIED FLOW SHEET**

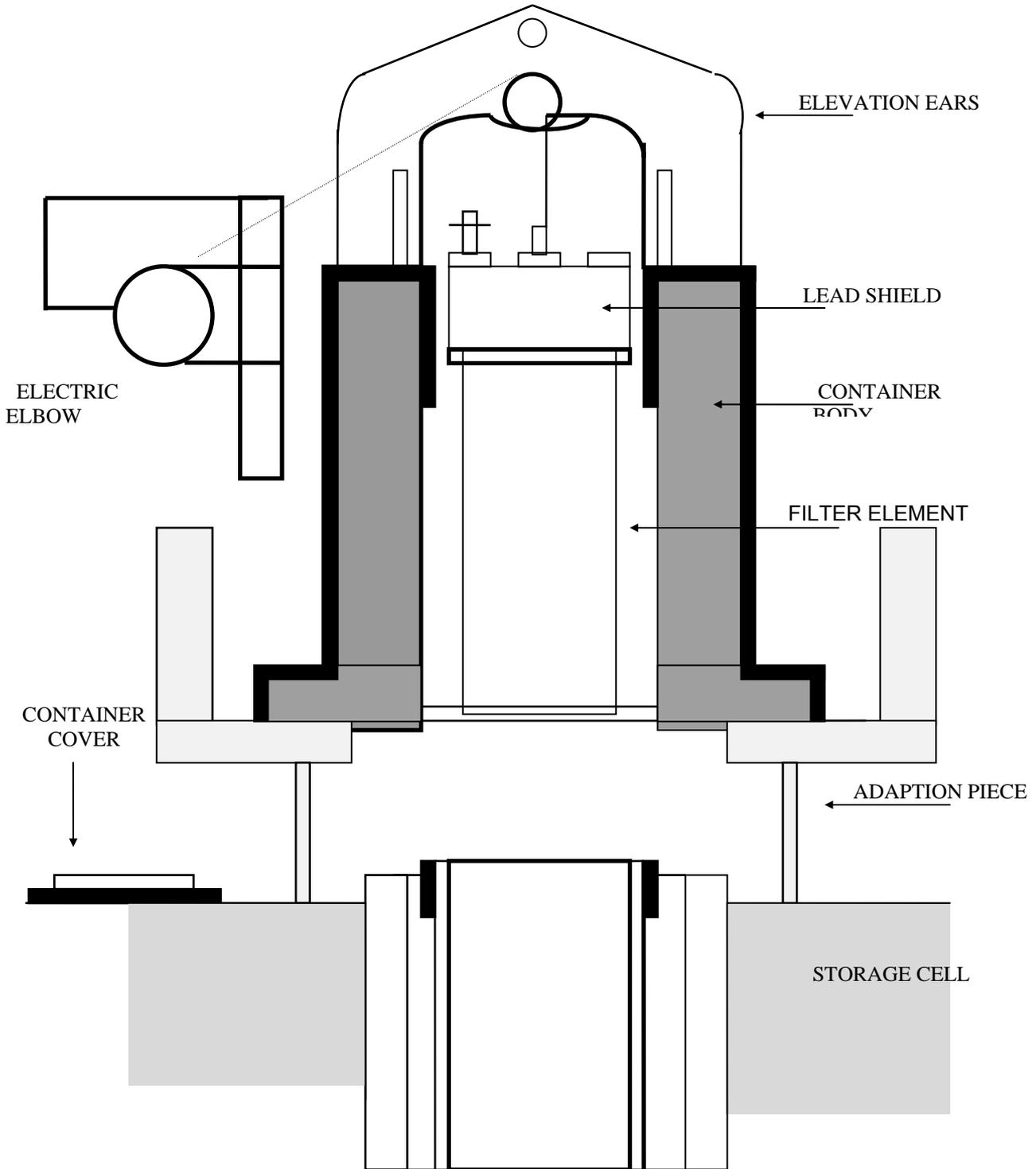


FIGURE III.8.1-2 Large Size Flask for Spent Filter Cartridge Transport

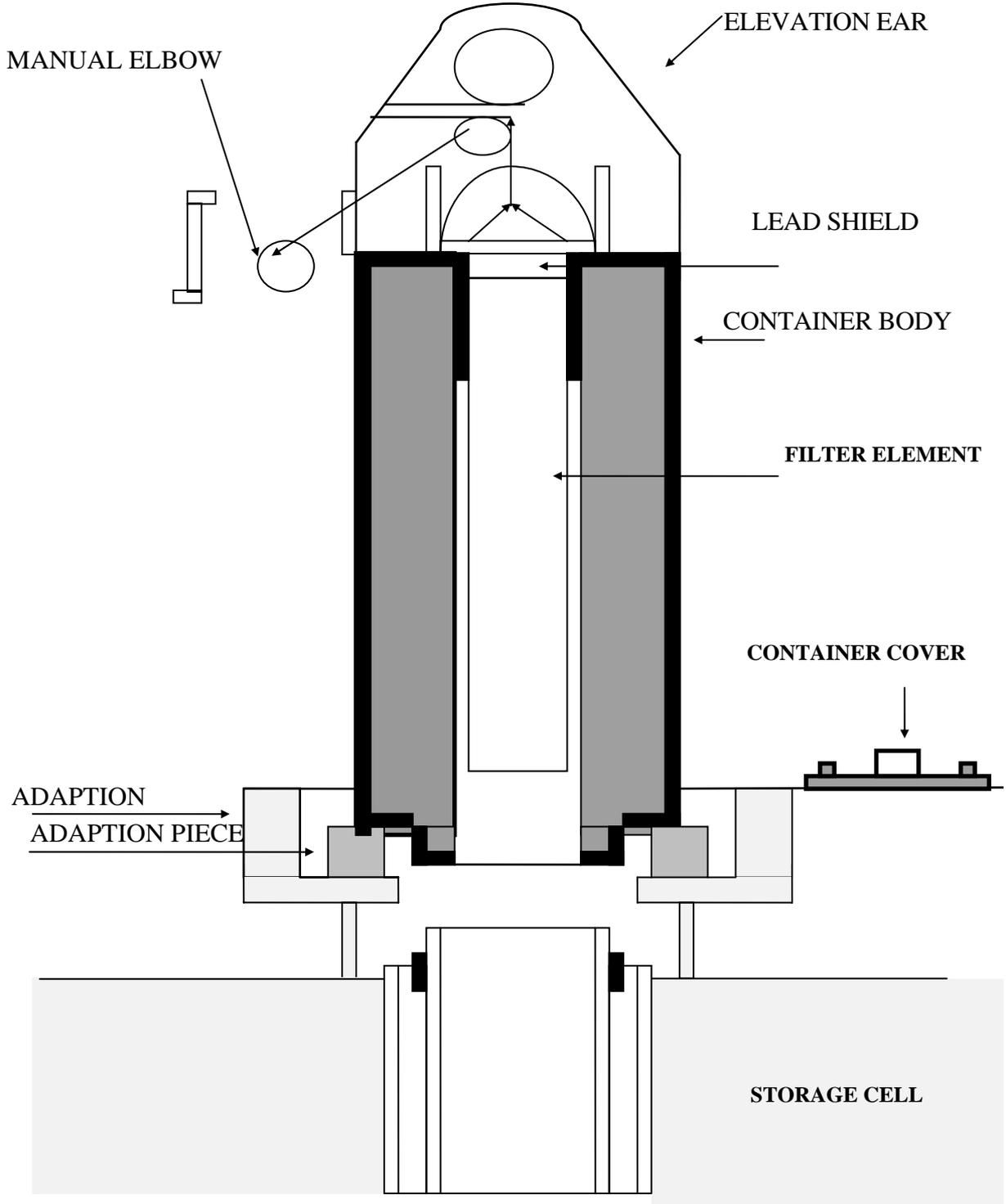


FIGURE III.8.1-3 Small Size Flask for Spent Filter Cartridge Transport

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### **III.8.2 Non - Radioactive Waste Management**

#### **III.8.2.1 Types and Quantities of Non-Radioactive Waste for one Unit**

Except the radioactive wastes in the process of electricity generation, non-radioactive (chemical/non-chemical) liquid/solid wastes will also be produced in Cernavoda NPP Units 3 & 4.

The following types of non - radioactive wastes are produced during the plant operation:

##### **A. Chemical Wastes**

The chemical wastes are liquid wastes (solvents, oils, hydraulic fluids of the turbine) or solid wastes (lavets, sand, wood spines, absorbent materials used for collecting the leaks/chemical releases or accidentally impregnated with chemical substances).

The annual quantities of chemical wastes estimated for one Unit on the basis of the Unit 1 operating experience are presented in Table III.8.2-1 (Ref. III.8-13, III.8-14).

##### **B. Conventional Non-Radioactive Wastes**

The conventional non-radioactive wastes are: paper, textile, wood, glass, construction materials, ferrous, and non-ferrous metals (cooper, bronze, and aluminum), garbage.

The annual quantities of conventional non-radioactive wastes estimated for one Unit on the basis of the Unit 1 operating experience are presented in Table III.8.2-2 (Ref. III.8-13, III.8-14).

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Table III.8.2-1 Types and Annual Quantities of Chemical Waste Produced during Operation of one Unit of Cernavoda NPP (based on Cernavoda NPP Unit 1 operating experience)

Wastename*)	Estimated quantities to be generated (t)	Waste code *)
Lubricating oil	60.5	13 02 05*
Emulsion (water+oil +sludge)	33.1	12 01 09*
Solvents	2.9	14 06 03*
Waste with organic content	8.6	16 03 06
Hydraulic fluid	2.4	13 01 11*
Battery Electrolyte	2.8	16 06 06*
Absorbant materials	3.9	15 02 03
Spent ionic resin	27.7	19 09 05
Biological sample recipients	0.8	18 01 03*
Industrial wastes (cement + lime)	23	10 13 11
Glycol (antifreeze solution)	5.8	16 01 15
Acumulators and batteries	5.2	16 06 01
Paints and varnishes	11	08 01 12
Washing solutions (H <sub>3</sub> PO <sub>4</sub> )	8	11 01 12
Used tires	1	16 01 03

Note:

\*) According to the wastes list, including dangerous wastes, noted in Annex 2 of The Government Decision no. 856/2002

\*\*) The Government Urgency Ordinance no. 78/2000 regarding the waste management regime approved with modifications and with completions by Law no. 426/2001

Table III.8.2-2 Types and Annual Quantities of Conventional Non-Radioactive Waste Produced during Operation of one Unit of Cernavoda NPP (based on Cernavoda NPP Unit 1 operating experience)

Waste name	Estimated quantities to be generated (t)
Glass	2
Wood	16.4
Ferrous waste	156.6
Cooper waste	0.74
Paper	2.3
Garbage	8000 m <sup>3</sup>

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### **III.8.2.2 Non-Radioactive Wastes Management**

#### **A. Chemical Wastes**

The non-radioactive wastes management consists in:

- the correct identification of the wastes;
- establishing the generating source of the chemical wastes;
- storage and conditioning;
- removal or treatment of non-radioactive liquid wastes using the approved procedures;
- reduction of toxic chemical product hazard for personnel;
- reduction of existing inflammable chemical product hazard for the plant.

The department which generates wastes should act carefully for their separation and collecting them at the source.

The working group for a system/component will be correspondingly trained, in order to take the necessary measures and avoid ingestion, absorption by skin and inhalation, when handling the chemical wastes.

Long exposure of the skin to liquid chemical wastes may result in skin irritation and chronic diseases. Therefore, the protection equipment is compulsory to wear in order to avoid the contact with skin.

The chemical hazardous wastes are examined and correspondingly separated. It is the responsibility of the department generating the wastes to separate the chemical wastes possibly contaminated at the source and to indicate clearly on the waste container the possibility of radioactivity existence.

Reduction of the radioactive wastes quantity must be taken into consideration. The treatment of this type of wastes is difficult and expensive.

The temporary storage facilities for non-radioactive chemical wastes will be located in the plant perimeter and will provide safety storage for wastes in order to avoid chemical danger.

The short - time storage facilities are:

- storage area for oil barrels and spent solvents;
- storage area for chemical wastes from laboratory which cannot be discharged to the drainage systems;
- neutralization tanks at the Water Treatment Plant, for wastes which have to be neutralized before release.

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The storage of liquid wastes which can be either diluted or neutralized is not allowed in the temporary storage facilities for oils and solvents.

The chemical wastes are stored in sealed and properly labeled containers, in order to avoid any spreading or air contamination.

The manufacturer's drums (or those being rugged after failure) are not used both for storage and collecting of wastes, except the situations in which approval of Chemical Department is received.

The forms and labels must be filled in with many possible details (estimated quantity, source of waste, signature, date). They enable both the classification and transfer of the wastes.

Air tests and analyses of aerosols in closed storage spaces will be periodically performed, and whenever it is necessary.

All the hoisting devices used will satisfy the Regulations of the plant approved by ISCIR.

Any quantity of chemical wastes produced and collected at a certain moment, has to be recorded in the form "Removal of non-radioactive chemical wastes".

All the chemical wastes generated further to collecting, conditioning, transfer or storage activities (as lavets, towels, pails, filters) will be put in bags or in containers and follow the procedure for solid chemical wastes.

Regarding the chemical wastes produced at Cernavoda NPP, the possibility of radioactive contamination does exist.

The operators of the Storage Area will take samples of all the wastes received from the Storage Area of Chemical Wastes, in order to have them analyzed by the Chemical Laboratory personnel. After this operation, the containers are sealed.

Visual inspections to check the sealings of the containers will be performed in order to avoid chemical leakage.

The handling procedure of the liquid and solid wastes is presented in Tables III.8.2-3 and III.8.2-4.

The main flowsheet regarding non-radioactive chemical wastes handling is presented in Figure III.8.2-1.

## B. Conventional Non-Radioactive Wastes

General Services Section of the Maintenance Department is responsible for collecting, handling, packaging, transport and storage of solid non-radioactive waste.

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The General Services Section personnel trained in this field, upon the usual tasks will perform all activities.

According to the plant procedures, the locations for collecting the non-radioactive solid wastes will be established in different areas of the plant, both in the Radiological Area (areas II and III) and outside it.

Controlled Inside Zone of Unit 3.

The strategy regarding the wastes in the Radiological Area will be established starting from the experience of Unit 1 providing a controlled collection of all the types of solid wastes.

Zone I

All solid wastes belonging to zone I are considered as radioactive ones. In these areas, yellow-colored containers will be placed, correspondingly labelled of the radioactive type of wastes, for collecting the radioactive solid wastes.

Zones II and III

Zones II and III are areas of reduced risks from contamination point of view under normal conditions, and the wastes occurring in these areas are non-radioactive.

In these areas, there are containers for non-radioactive solid wastes, having different colors from those in Area I, correspondingly identified in order to provide a first segregation of non-radioactive solid wastes.

Moreover, the non-radioactive wastes evacuation from the Radiological Area is performed after beta-gamma radioactive monitoring of each bag of wastes and after filling up the Non-conditioned Transfer card.

Further to perform all verifications, these types of wastes are transferred, in the same way, like the solid wastes outside the Radiological Area of Unit 3.

Controlled Outside Area of Unit 3

The collecting locations of non-radioactive solid wastes will be those used also for Unit 1, being situated at the Screen House / Pump House, Unit. 0, Plant 110 kV, Administrative Building, CPPON, Building 82, Mechanic Process Workshop and Electric Workshop, Fire-Extinguishing Water Pumping House, Drinking Water Pumping House, H2 Plant, Siphoning Bay, Technique Gas Deposit, Light Liquid Fuel Stage I and II.

In each collecting location, depending on the type of wastes with the highest probability of occurrence, the containers are correspondingly labelled for each type of non-radioactive solid wastes.

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Collecting and storage of non-radioactive wastes in plastic bags will be periodically performed by the General Service Section.

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Table III.8.2-3 Handling of non - radioactive liquid wastes

<b>Type of wastes</b>	<b>Oil</b>	<b>Glycol</b>	<b>Inflammable solvents</b>	<b>Others</b>	<b>FRF*</b>
Container for wastes	Grey drums labelled "Non-radioactive spent oil"	Grey drums labelled "Non-radioactive spent glycol"	Red - painted drums, labelled "Non-radioactive spent solvent: chlorinated / nonchlorinated"	The manufacturer drums correspondingly labelled for wastes	Red and white painted drums labelled "Spent FRF" or "Contaminated wastes with FRF"
Radioactivity control requirements	Gamma & Tritium	Gamma & Tritium	Gamma & Tritium	Gamma & Tritium	Gamma & Tritium
Evacuation procedure	Contractors for spent oil evacuation	Contractors for spent glycol evacuation	Contractors for spent solvents evacuation	Procedure approved by the chemist of the plant as per environmental norms in the field of waste	Contractors for spent FRF evacuation

FRF\* - Fire resistant fluid

Table III.8.2-4 Non-radioactive solid wastes handling

<b>Type of wastes</b>	<b>Oil</b>	<b>Glycol</b>	<b>Inflammable solvents</b>	<b>Others</b>	<b>FRF</b>
Container for wastes	Grey containers labelled "Non-radioactive solid oil wastes"	Grey containers labelled "Solid wastes with non-radioactive glycol"	Red - containers labelled "Solid wastes with non-radioactive solvents"	The manufacturer's drums, correspondingly labelled for wastes	Red and white painted drums, labelled "Solid FRF wastes " or "Contaminated wastes with FRF"
Radioactivity control requirements	Gamma & Tritium	Gamma & Tritium	Gamma & Tritium	Gamma & Tritium	Gamma & Tritium
Evacuation procedure	Procedure approved by the chemist of the plant as per environmental norms in the field of waste	The procedure approved by the chemist of the plant as per environmental norms in the field of	The procedure approved by the chemist of the plant as per environmental norms in the field of waste	The procedure approved by the chemist of the plant as per environmental norms in the field of waste	The procedure approved by the chemist of the plant as per environmental norms in the field of waste

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		waste			
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FRF\* - Fire resistant fluid

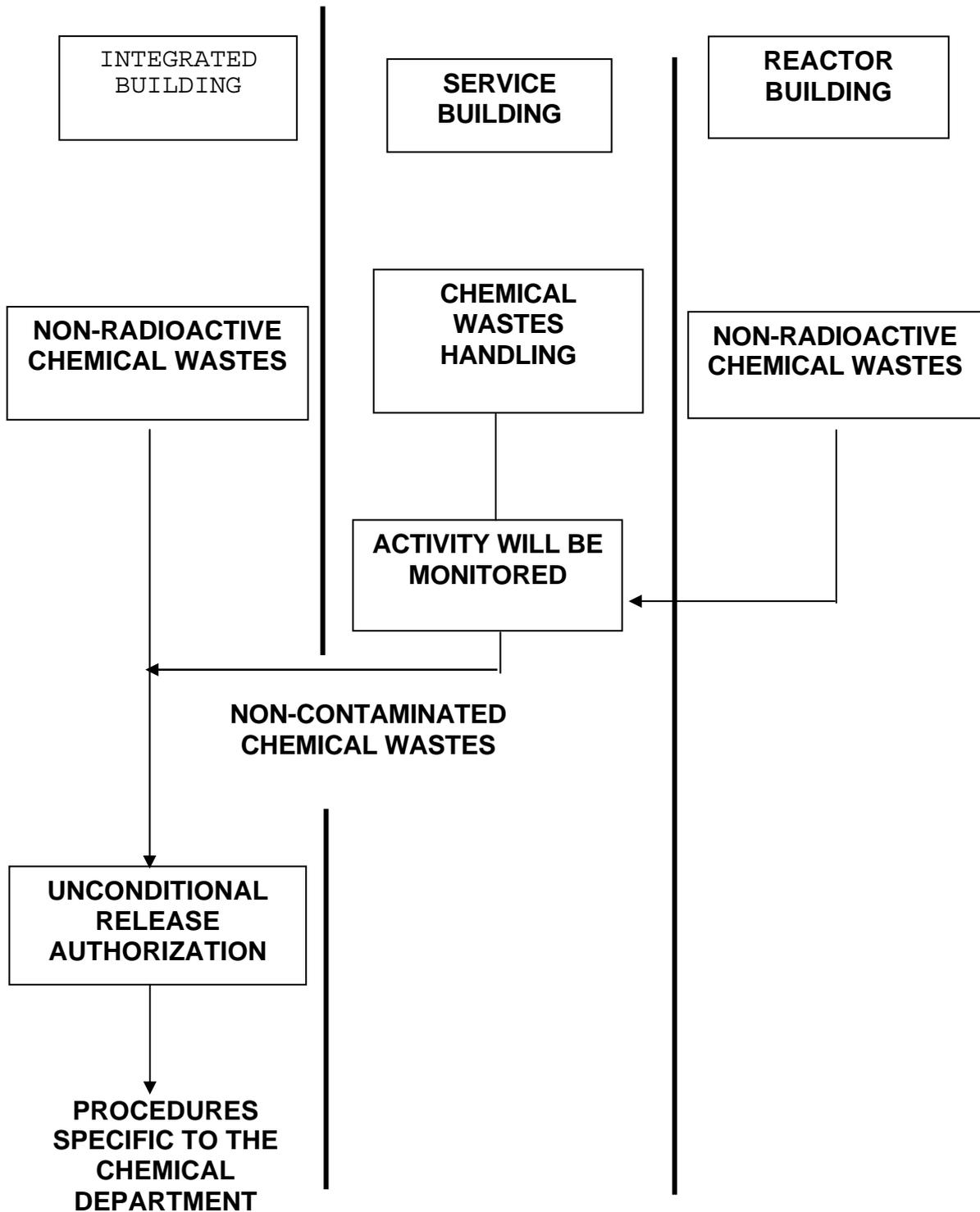


Figure III.8.2-1 Handling of non-radioactive chemical wastes

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### **III.8.2.3 Non-radioactive Wastes Elimination and Recycling**

The chemical wastes will remain in the temporary storage areas during a limited period of time until their drainage or transfer outside the plant will be possible.

The transfer and/or storage of chemical wastes will be permitted only by the Chemical Department in purposely assigned special areas, their evacuation in the environment being prohibited.

The conventional non-radioactive wastes will be transferred to the Sorting and Collecting Place.

In the Sorting and Collecting Place area, separate containers for each type of collected conventional non-radioactive wastes will be placed. Before emptying each wastes bag in the container, a sorting operation will be performed for avoiding mixture of different types of wastes.

Further to filling up these containers, wooden, ferrous and non-ferrous metallic wastes will be transported outside the plant, where are developed by the specialized units.

The other types of wastes will be transported to the garbage pit of Cernavoda Town, based upon a contract signed by the Local Council of Cernavoda Town.

The conventional non-radioactive wastes will be transported outside Unit 3 & 4, by vehicles provided by the General Services Section. The transport will be done by the Transport Section and surveyed by the department of Physical Protection.

### **III.8.2.4 Conclusions**

Development of collecting, temporary storage, depositing and transport wastes activities outside society to units authorized for storage, evaluation, elimination will be performed under efficiency and safety conditions both by the factors of population and environment, as per Government's Urgent Order 78/2000 regarding wastes regime, as approved with both modifications and completions by Law no. 426/2001.

Wastes monitoring and management produced by the activities developed at Cernavoda NPP Unit 3 & 4 will be performed as per the EC legislation, Norm 75/442/CEE respectively, transposed completely in Romanian legislation.

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## References

- III.8-1 Ordonanța Guvernului nr. 11/2003 privind gestionarea combustibilului nuclear uzat și a deșeurilor radioactive, inclusiv depozitarea finală.
- III.8-2 Legea nr. 320/2003 pentru aprobarea Ordonanței Guvernului nr. 11/2003 privind gestionarea combustibilului nuclear uzat și a deșeurilor radioactive, inclusiv depozitarea finală.
- III.8-3 Legea nr. 105 din 16 iunie 1999 pentru ratificarea Convenției comune asupra gospodăririi în siguranță a combustibilului uzat și asupra gospodăririi în siguranță a deșeurilor radioactive, adoptată la Viena la 5 septembrie 1997
- III.8-4 IAEA Safety Series No. 111 F, The Principles of Radioactive Waste Management, Viena, 1993.
- III.8-5 Ordinul Agenției Nucleare nr. 844/2004 pentru aprobarea Strategiei Naționale pe termen mediu și lung privind gestionarea combustibilului nuclear uzat și a deșeurilor radioactive inclusiv depozitarea definitivă și dezafectarea instalațiilor nucleare.
- III.8-6 Ordinul CNCAN nr. 56/2004 privind aprobarea Normelor fundamentale pentru gospodărirea în siguranță a deșeurilor radioactive.
- III.8-7 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, Romanian National Report, Second Revision, August 2005.
- III.8-8 RD-01364-RP1-Rev.3, Solid radioactive waste management concept for Cernavoda Nuclear Power Plant.
- III.8-9 CNE Cernavodă U1 – Raport Final de Securitate, martie 2001
- III.8-10 CNE Cernavodă U2 – Raport Final de Securitate, 2005
- III.8-11 Depozitul Intermediar de Deșeuri Radioactive. Raport Final de Securitate, CNE Cernavodă U1, 1994.
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### **III.9 Toxic and Dangerous Substance Management**

#### **III.9.1 Toxic and Dangerous Substance used to Cernavoda NPP**

##### *A. Chemical Substances*

Among the chemical substances approved to be used in the Plant, from the point of view of their environmental impact, the relevant chemical substances are the ones employed for the conditioning (treatment) of the water resulted from the thermal cycle. Other substances, e.g. ammonia, sodium nitrite, glycol, hydroquinone, potassium hydroxide, sodium hydroxide, citric acid, EDTA, etc., are used in small quantities and generally for laboratory purposes.

In Table III.9.1-1, the most important chemical substances used in the plant are presented, while in Table III.9.1-2, the annual used quantities for chemical conditioning of the plant systems and in the technologic process are presented.

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Table III.9.1-1 List of Chemical Substances Used in Cernavoda NPP

Item No.	Title	Description	Application remarks / recommendations
1	Cyclohexilamine	79,2% Purity	-formula: C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub> ; volatile, alkaline reactive, corrosive, toxic, inflammable liquid; -used for pH control in the secondary part of NPP
2	Hydrazine – 35%	Hydrazine hydrate 55%	- oxygen reducer and corrosion inhibitor used in the secondary part of NPP
3	Morpholine	99% Purity	- used for pH control in the secondary part of NPP
4	Biomat 5716	Biocid	- as per recommendations of Chemical Department
5	Glycol	STAS 8671-78	- for Diesel generators
6	Dowacal 10	Antifreeze-glycol mono-ethylene	-for the Glycol Water System
7	Potassium hydroxide	Flakes, 85% Purity	- as per recommendations of Chemical Department
8	Sodium hypo-chlorite	STAS 918-83	WTS- Chemical Department
9	Hydrochloric acid 36%	36%	WTS - Chemical Department
10	Adjuvant Coagulation		Chemical Department
11	Sodium hydroxide	48% Purity STAS 3068-80, type E1 or E2	Chemical Department
12	Ferrous Chloride	40% Purity STAS 8650-70	WTS - Chemical Department
13	Hexa-hydrated gadolinium nitrate	99,9% Purity	- as per Chemical Laboratory
14	Limestone	STAS 9201-80	
15	Sulphuric acid	Batteries electrolyte	

Table III.9.1-2 Chemical Substances Used for Chemical Conditioning of Plant Systems and in the Technologic Processes, Annual Consumption

No.	Chemical substance description	Measurement unit	Quantity used	Application
1	Hydrazine	kg	1900	Chemical conditioning
2	Morpholyne	kg	7450	Chemical conditioning
3	Cyclohexylamine	kg	505	Chemical conditioning
4	Lithium Hydroxide	kg	16	Chemical conditioning
5	Flomate 537	kg	42	Corrosion inhibitor
6	MB-25	kg	5950	Biocidation of cooling water
7	Sodium hydroxide	kg	111500	Anionic resins regeneration
8	Hydrochloric acid	kg	101500	Cationic resins regeneration
9	Ferrous chloride	kg	33500	Water - treatment coagulator

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10	Limestone	kg	220000	Water decarbonate treatment
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### *B) Toxic Substances*

From the list of toxic substances being located under the incidence of Decree No. 466/1979, in the Chemic Laboratory - only the reactive Arsenazo III is usually applied.

This product will be kept in the supplier's original package in a metallic, locked-up cupboard being located in a separate room of the laboratory.

The product is used to assess the Gadolinium concentration in heavy water (1 mg/measurement). The resulted solutions are not released, being collected and reprocessed by the D<sub>2</sub>O Cleanup System. The reactive is retained on the ion exchange resins.

Regarding the use of chlorinated aromatic hydrocarbons, biphenyl-poly-chloride type (PCB) at Cernavoda NPP Unit 3 & 4, the use of this type of substances, which require collecting and storage under special conditions, having a high toxicity, is not predicted.

### **III.9.2 Toxic and Dangerous Substance Management**

The following-up procedure of chemical product management will be included in the statement "Management of Chemical Products". This statement will establish both responsibilities and activities of the involved compartments, as well as the registering forms, to be issued.

The objectives will be the followings:

- maintaining of a minimum number of products by using an approved list of chemical products, for which all the information and the necessary conditions for a safety operation will be available;
- maintaining of a minimum available stock, to provide a spare for 3-6 months of operation;
- introduction and withdrawal in/from the plant of the approved substances and quantities according to working plans;
- handling, storage and using by the authorised personnel according to the approved procedures;
- reduction of the generated waste quantities.

The use of chemical substances, especially of the toxic and dangerous ones will be performed with equipments and supplies regarding labour safety as per norms in effect. The personnel handling, depositing, transporting and using chemical substances will be trained by such activities, as per legislation in effect and the specific loads, as described by the Position Flowsheet.

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All reactive used in the Chemical Laboratory will be under the direct management of the laboratory chief.

All personnel will participate at their reception, they being directly stored in the rooms with special destination in the laboratory, depending on the category (fridge for potentially explosive substances, sealed up metallic panel with double walls for inflammable substances, metallic panel for toxic substances). These substances will be used only by the laboratory personnel who will be trained as chemist - technician. Will be a specially designed person for keeping an inventory of the stock of substances, which will be weekly up-dated.

The how-to-use will be described for each substance as approved working procedures.

The working places adhering to the physico-chemical determinations will be provided with the necessary supply of risks diminishing, associated to chemical substances application (ventilating niches, emergency showers, ventilation corresponding to chemical substances preservation, panels with safety closing systems).

The chemical products will be kept in the manufacturer's packages, procedural requirements for ordering, receipt and periodic inspections being met, observing the integrity and waterproofing of packages, the correct labelling with data regarding a correct product description, plant trademark and manufacturer's denomination, manufacturing date, warranty term, strictly necessary data, in order to avoid chemical hazards, first aid residual products removal, and whenever necessary, restrictions of product application.

The storage of chemical substances will be performed as follows:

- hydrazine, morpholyne, cyclohexylamine, flomate 537 and MB25 compounds will be kept in the special deposit, as packages given by supplier, metal and plastic drums of 200 l and containers of 1000 l for biocid;
- lithium hydroxide will be stored in the chemical laboratory, in the package provided by supplier;
- the limestone will be kept in the storage sills located in Water Treatment Plant;
- hydrochloric acid, sodium hydroxide and the ferrous chloride are stored in storage cisterns located in Water Treatment Plant. The cisterns are grouped on a platform of railway type, acid-proof plated, monitoring the accidental leakage of chemical substances, allowing their transfer at the spent water tanks. Also, the launching platform of the chemicals in the railway tanks is anti-acidly plated and provided with transfer facilities of spent waters for neutralisation.

Chemical substances management will be performed, meeting the provisions of Decree No. 466/1979, of Law No. 300/2002 regarding the juridical regime of the forerunners used at drugs illicit manufacturing, modified and completed by Law No. 505/2004 and of Law No. 451/2001 for approval of the Emergency Order No.

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200/2000 regarding classification, labelling and packing of substances and dangerous chemical preparations.

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## **IV WORKS FOR SITE REHABILITATION / RESTORATION**

### **IV.1 Potential Risk Conditions**

#### **IV.1.1 Accidents Classification**

Conforming to CNCAN Fundamental Radiological Safety Norms (Ref. IV-4) and international regulation, the nuclear accidents are defined as those nuclear events which could affect the facility and produce the irradiation or contamination of the public and environment exceeding the actual permissible limits.

Taking into account the causes, the nuclear accidents postulated during a nuclear power plant design and operation are classified in:

- the events induced by natural phenomena;
- the events induced by human actions.

The events induced by human actions can be initiated by the activity external to the nuclear objective or the activities specific to this objective (human errors during facility operation or the random failures of the nuclear objective components).

The structure of this chapter is presented below.

The events produced by the natural phenomena on the Cernavoda Nuclear Power Plant (NPP) site are presented in section IV.1.2. The sitting and design features minimizing the effects of these events on the nuclear power station safety are also presented. The external events (induced by the activities performed into Cernavoda NPP enclosure and within its influence zone) and their effects on the NPP structures integrity and personnel safety working conditions are presented in section IV.1.3.

Notice that the nuclear events can have potential radiological consequences on the personnel, public and environment. Another category consists of the events without radiological consequences.

The events with radiological consequences (whose evolution and consequences will be evaluated in the safety reports) are presented in section IV.1.4. The following are presented: the list of the events classified function of evaluation objectives as well as the population dose limits function of the accident occurrence frequency. The events with the most serious radiological consequences postulated for Cernavoda NPP are also presented in this section.

The section IV.2 presents the preventive measures and the features to minimize the NPP operational risk according to CNCAN requirements; section IV.3 presents some information related to the risk evaluation for the accidents with impact on the environment and public health, during nuclear power station construction.

The conclusions of this chapter are contained in the section IV.4.

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#### **IV.1.2 Natural Risk**

The natural phenomena that could affect the NPP structures are:

- severe meteorological phenomena (storms, lightning, tornado and tornado induced missiles);
- flooding;
- earthquake;
- fires.

##### *a) Events Caused by Severe Meteorological Phenomena*

The severe meteorological phenomena frequency is so small that this type of events can be considered negligible for Cernavoda NPP (Ref. IV-3).

##### *b) Flooding*

**The Design Basis Flood** for Cernavoda site has a frequency of 1/10000 years (0.01%); the maximum water level reached (considering also the severe failure of the hydro-electrical developments situated upstream the plant) is 15,90 mBSL (meters over Baltic Sea level) (Ref. IV-1). The safety related Cernavoda NPP structures were designed to this flood by constructing the plant enclosure platform on an earth filling with the general elevation of 16.30mBSL.

##### *c) Earthquake*

The seismic design (at Design Basis Earthquake –DBE conditions) of NPP structures and systems important from the safety point of view ensures the structural integrity and operability of safety-related components in case of an earthquake. This conclusion is stipulated in Ref.IV-1.

##### *d) Fires Caused by Natural Sources*

Cernavoda NPP platform is located within a zone situated faraway from the forest or other combustible vegetal; so, their potential fires do not affect the plant.

#### **IV.1.3 Events Induced by Human Activities External to Cernavoda NPP Units 3 and 4**

##### **IV.1.3.1 Potential Hazardous Sources Existing within Cernavoda NPP Units 3 and 4 Site**

On Cernavoda NPP site there are some potential sources of explosions, fires, missiles or toxic gases releases which may affect Units 3 and 4 nuclear safety. These sources are:

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- a) missiles generated by U1, U2 , U3 and U4 turbines;
- b) explosive gas tanks (hydrogen);
- c) start-up thermal plant;
- d) toxic gases tanks.

a) The analysis made for Unit 2 (Ref. IV-1), extrapolated to Cernavoda NPP Units 3 and 4 showed that the area affected by the *rotor break or the break of a disk associated to Unit 1 and Unit 2 turbines low pressure stage* does not inflict any damage on the vital areas in Unit 3 and respective Unit 4. These areas are Reactor Building, Service Building, Main and Secondary Control Rooms, Spent Fuel Bay. These vital zones of Units 3 and 4 are protected to the missiles generated by their own turbines (see Ref. IV-1 chapter 3).

b) The Hydrogen (*produced in a plant common to the 5 units and stored in warehouses specific to each nuclear unit*) is used during Cernavoda NPP Unit 3 and respective Unit 4 operation. The maximum credible postulated events analyzed were:

- the explosion generated by violent brake or shattering bursting of some hydrogen flasks;
- the impact of the fragments ejected in case of explosion with various objects inside NPP enclosure;
- build-up of a Hydrogen-air mixture in closed or half-closed spaces and its explosion by taking fire.

The results of such analyses were considered to establish the protection distance and design protective measures (protection walls, restriction of the number of flask and their pressure) to ensure the integrity of NPP structures, components and systems (Ref.IV-1).

c) The *light liquid fuel warehouse for the thermal start-up plant* consists of 2 over-ground steel tanks (2x1000m<sup>3</sup>) containing Diesel fuel and a buffer 100m<sup>3</sup> Diesel fuel tank. The design measures to respect the protection distance and to use the adequate extinguishing systems will reduce the explosion-fire potential hazard of this fuel (Ref. IV-1).

d) The *toxic substances*, such as ammonia, sulfuric acid, hydrochloric acid, carbon dioxide are used in Cernavoda NPP. As accidental release of such gases could affect the safety of plant personnel and facilities, the measures to design and locate the toxic gas tanks for limiting the releases and ensuring the safe distance are taken.

#### **IV.1.3.2 Events Induced by Human Activities in Cernavoda NPP Unit 3 and respective Unit 4 Influence Zone**

The human activities (industry, transport routes, military activities) within the Cernavoda NPP Unit 2 influence zone are detailed presented in section 2.2 of Ref.

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IV-1. As recommended by IAEA (Ref. IV-2), the influence zone is considered to cover a 30 km radius area around the plant.

The evaluation of potential events induced by the human activities in this zone (explosions, toxic gas releases, aircraft crashes and fires) and their effects on structural integrity and personnel capacity to ensure the plant safe operation is made for Cernavoda NPP Units 1 and 2. Also the measures to prevent and/or minimize the potential risks on the plant safety were evidenced.

This analysis effectuated for Cernavoda Unit 2 (Ref. IV-1) and its conclusions are totally appropriated for Cernavoda NPP Units 3 and 4 as the design are similar and the distance between the U2 reactor and U3 and respective U4 reactors (160m and respective 360m) is small comparative with the analysed distances.

A short presentation of human activities in Cernavoda NPP Unit 3 and respective Unit 4 influence zone as well as the results of evaluation of their effects on structural integrity and plant personnel security is evidenced below.

#### **IV.1.3.2.1 Industrial Activities**

##### **IV.1.3.2.1.1 Description**

The economic activity within Cernavoda NPP influence zone consists of (Ref. IV-1):

- extraction industry (i.e. quarries of limestone, sand, diatomite, bentonite, clay);
- industrial units concentrated in the existing industrial areas in Cernavoda Town, Fetesti and Medgidia;
- agro-industrial units spread in the rural settlements in the area.

The economic activities within Cernavoda NPP U3 and U4 influence zone are grouped as per the following zones (see Section III.7, Figure III.7-1):

#### **I. 10 km radius zone**

- A. Cernavoda–Saligny industrial zone
- B. Cernavoda-Harbour industrial zone

#### **II. 10-30 km radius zone**

- C. Medgidia North industrial zone
- D. Medgidia East Harbour industrial zone
- E. Fetesti North–West industrial zone
- F. Fetesti East industrial zone

Due to the small distance between the reactors of Unit 3 and 4 (160) it is not considered necessary to represent each unit influence zone on a separate figure.

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In compliance with IAEA recommendations (Ref. IV-2), the economic objectives located at distance greater than 10 km away from Cernavoda NPP do not affect the plant safety. Therefore, all the economic objectives located on a radius of about 10 km around Cernavoda NPP were analyzed. For distances greater than 10 km within the considered influence zone, only the most important economic objectives in point of production capacity and hazardous substances involved in the production process have been selected (Ref. IV-1).

The territory of Cernavoda NPP influence zone is crossed by oil and methane gas pipelines; their trajectory is also represented in Figure III.7-1. The pipelines are provided with isolation valves when crossing the main roads and railway or sub-crossing the navigable channels.

#### **IV.1.3.2.1.2. Effects on the Cernavoda NPP Units 3 and respective 4 Safety of the Potential Events due to Industrial Activities in the Influence Zone**

The effects on Cernavoda NPP safety due to potential events (explosions, toxic gas releases, fires in natural gas and oil ducts) involved in the influence zone industrial activities were analysed (Ref. IV-1). As recommended by IAEA (Ref. IV-2) the analyses were made for dominant sources (objectives where the greatest quantities of explosives are involved located at the minimum distance from NPP).

The dominant sources within Cernavoda NPP Unit 3 and respective Unit 4 influence zone are:

**a) In the 2 km radius zone**, the greatest quantity of explosive substances is located at about 2 km SSE away from the third reactor axis (and respective 2.1 km SSE away from the fourth reactor axis) and it is concentrated at **SC Tranzit SRL and SC Liviu Star gas stations**. The result of evaluation conforming to IAEA methodology (Ref. IV-2) is a maximum of 1365 t equivalent TNT (and respective 1587 t equivalent TNT) that could explode at this distance without NPP structure integrity to be affected. This quantity exceeds the maximum quantity (considering 240% equivalent TNT) of explosive substances existing in the two economic units (i.e. 20x6m<sup>3</sup> oxygen cylinders and 1x10t gasoline tank), even in the case of their coincidental explosion.

**b) In the 2 km and 10 km radius zone around Cernavoda NPP influence zone, the explosion of a 5000t crude oil tank at SC PECO SA Oil products Storage**, located at about 4 km NW from the third reactor axis (and respective 3.9 km NW from the fourth reactor axis) is analysed. The evaluation made conforming IAEA methodology (Ref. IV-2) demonstrates that the safety distance is about 4 km; considering the evaluation conservatism one can conclude that the distance between the reactor and explosion source is enough so that the NPP safety-related structures integrity is not affected, both for Unit 3 and Unit 4.

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**c) The greatest toxic gas quantity possible to be released at the minimum distance from the plant is used in SC VIRFRUCER**, located at about 2.2 km WSW from the third reactor axis (and respective 2.35 km from the fourth reactor axis). It is sulphur dioxide that, accidentally released and taken over by the control room ventilation system, could affect the personnel capacity to ensure safe plant operation. The evaluation made according to IAEA methodology (Ref. IV-2) demonstrated that the protection by distance is sufficient even if the instantaneous release of the average consumption of the unit for 6 months is considered.

**d) Fires in natural gas and oil ducts.** The analysis demonstrated that the distance between these fire sources and Cernavoda NPP site is enough to ensure the plant structures safety and integrity.

*One may conclude that the economic objectives in the Cernavoda NPP Unit 3 and respective Unit 4 influence zone do not jeopardize either the plant structures and components integrity or plant operators capacity to ensure the NPP safe operation.*

#### **IV.1.3.2.2 Transports within the Cernavoda NPP Unit 3 and respective Unit 4 Influence Zone**

##### **IV.1.3.2.2.1 Description**

The transport routes (roads, railways, navigation and air routes) within the Cernavoda NPP Unit 2 were described and analysed in the Preliminary Safety Report (Ref.IV-1).

The transport routes (road, railway and naval) within a zone of 30 km radius around Cernavoda NPP Unit 3 and implicit Unit 4 site are presented in Figure III.7-1.

**a) Road transport network** is constituted by:

- A2 highway (Bucharest-Constantza) segment Fetesti-Cernavoda (to be finalized);
- National road 22C Cernavoda - Basarabi; minimum distance: 1.2 km from the third reactor axis and respective 1.3 km from the fourth reactor axis;
- County road 223, parallel with the Danube River, between Cochirleni, Cernavoda and Seimeni villages; minimum distance: about 400m from the third reactor axis and respective 450m from the fourth reactor axis;
- Village roads DC60 and DC61, within NNE and NE sectors, located at a distance greater than 5 km from the NPP enclosure.

The following main mixed bridges (on roads and railways) serve this roads network:

- Bridge on DN 22C, for Danube-Black Sea Channel crossing, located at about 1.5 minimum distance from the third reactor axis (respective 1.6 km from the fourth reactor axis);

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- Crossing bridge of Cernavoda NPP intake cooling channel, located in the Unit 3, respective Unit 4 exclusion zone (1km radius).

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**b) Railway transport** is represented by:

- Fetesti-Medgidia railway segment of Bucharest – Constantza main railway, served by Cernavoda Harbour station; the minimum distance from the third reactor axis is 1 km and from the fourth reactor axis is 1.2 km;
- Saligny-Cernavoda Town railway segment, located at minimum 425 m from the third reactor axis (and respective 450 m from the fourth reactor axis); Cernavoda NPP is the only beneficiary of hazardous substances traffic on this railway (Ref. IV-1).

**c) Danube River** and **Danube - Black Sea Canal** represent the naval transport; the minimum distance from the third reactor axis, estimated for the area without any physical obstacle between the NPP and Canal, is about 1.4 km; the similar distance from the Unit 4 is 1.380 km.

**d) Civil air transport**

**d1) Airports**

Considering the information from Civil Air Department, at about 35 km distance from Cernavoda NPP the international “Mihail Kogalniceanu” airport is located.

**d2) Air routes**

In point of air traffic, the Cernavoda NPP influence zone is considered a prohibited area (marked “LRP2” on the Air Passage maps) for the flights up to 4000 feet (about 1200m) encompassed in a right circular cylinder of 5 miles radius (about 10km) with its axis passing through the plant axis.

The following air routes are identified in Cernavoda NPP influence zone:

**d 2.1) Low Altitude flights (Lower Limit-L):**

- W 87/L851, passing right above the prohibited area LRP2 – minimum distance from Cernavoda NPP: 6.5 km;
- W 80/L601           -    minimum distance:                   15.0 km;
- T 100                -    minimum distance:                   24.0 km;
- W 84 / N 616

**d 2.2) High-Altitude Flights (Upper-Limit-U):**

- UL 851;
- UL 601;
- UT 100;
- UN 616.
-

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#### **IV.1.3.2.2.2. Evaluation of Effects on Cernavoda NPP Unit 3 and respective Unit 4 Safety due to Potential Events on Transport Routes**

The conservative assessments (Ref. IV-1) point out the potential danger associated to the transport carried out in the Cernavoda NPP site vicinity; case by case, the measures ensuring the plant nuclear safety were evidenced and analysed.

The evaluation results of the random explosions on the transportation routes in the NPP Cernavoda Unit 3 and respective Unit 4 influence zone are presented below.

a) For **road transport on DN 22C**, the explosion of dangerous substances carried out by a standard vehicle of 25 t solids (or 20t oil products, respectively) at the minimum distance of 1.2 km from the third reactor axis (and respective 1.3 km from the fourth reactor axis) does not impair the integrity of NPP safety related structures and components.

Regarding **the transport of dangerous substances on village road DJ 223**, due to the measures imposed to reduce the explosion risk (limit of 12 t for the maximum quantity carried out once and improvement of the transport security) one may consider acceptable Cernavoda NPP Unit 3 and respective Unit 4 protection against such kind of events.

b) For **railway transports**, the results indicate that the explosion of dangerous products transported by a railway standard wagon of 50 t solids and respectively 40t oil products **on Fetesti-Constantza railway segment**, at the minimum distance of 1 km from the third reactor axis (and respective 1.2 km from the fourth reactor axis) shall not damage the NPP safety-related structures and components.

As regards the transport of dangerous products on **Saligny-Cernavoda Town railway segment**, because Cernavoda NPP has the control upon the transport of dangerous products on this segment, the plant safety related to a potential explosion of such products is ensured by limiting the quantity carried out (to respect the protection by distance principle) or by administrative measures regarding the improvement of transport security. (Ref. IV-1)

c) For **naval transports**, the estimation developed has resulted in occurrence frequency of explosions on the Danube-Black-Sea Channel slightly greater than the limit of  $10^{-6}$  /year considered in the analysis (Ref. IV-1). Notice that this estimation has been made in conservative assumptions regarding the quantity implied in the explosion (barges tank loaded with 6000 t oil products, with 240% equivalent TNT) and the generating conditions for such explosions (the following events have to be simultaneous:

- navigation failures accompanied by fire occurrence;
- temperature of about 1100 °C on board of the barges during a fire;

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- the condition that the two events above may occur only at a time interval of 6 minutes as long as the barge is within the Danube-Black Sea Channel sector corresponding to the intake and discharge of the derivation channel -about 1.0 km long; a traveling speed of the barge convoy of maximum 10 km/h is considered).

In order to reduce the risk of channel explosions in the Cernavoda NPP influence zone additional navigation measures have been added (Ref. IV-1).

Considering the conservative degree of the analysis and the additional measures adopted to reduce the risk of an explosion occurrence on the Channel, one may consider Cernavoda NPP Unit 3 and respective Unit 4 protection as acceptable from that event.

d) Referring to the **civil air transport**, following to the developed analysis it resulted that the risk on an aircraft crash on the Cernavoda NPP due to the air traffic on the air routes and airports in the area is negligible even with the predicted future air traffic for the year 2030.

#### **IV.1.3.2.3 Military Objectives and Activities**

##### **IV.1.3.2.3.1 Description**

The military objectives and activities within Cernavoda NPP influence zone are as following (Ref. IV-1):

- objectives with potential explosion risk;
- objectives with potential noxious releases hazard (flammable, toxic, radioactive);
- objectives with potential missile generation risk;
- military airdromes / airports.

##### **IV.1.3.2.3.2. Effects on the Cernavoda NPP Unit 3 and respective unit 4 Safety of the Potential Events due to Military Activities in the Influence Zone**

The analysis of the effects on NPP safety due to military activities shows the following (Ref. IV-1):

- the potential explosions do not jeopardize the NPP structures and components integrity;
- as regards the flights of military planes in Cernavoda NPP area, the following flight restrictions are stated:
  - I. on a 20 km radius measured from the Cernavoda NPP first reactor axis to all cruising altitudes – for air crafts flying with supersonic speed;

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- II. on a 10 km radius measured from the Cernavoda NPP first reactor axis to altitude below 2000m – for air crafts flying with subsonic speed.

Considering the small distance between the reactors of Cernavoda NPP Units 1 and 3, respective 4 comparative to the analyzed distances, one may consider that the above-specified restrictions are also applicable to Cernavoda NPP Unit 3 and Unit 4.

*One may conclude that the Cernavoda NPP Unit 3 and respective Unit 4 external human activities (within the NPP site and in the influence zone) do not affect the plant structures integrity and the personnel capacity to ensure the plant safe operation.*

#### **IV.1.4 Events with Radiological Consequences Postulated for Cernavoda NPP Unit 3 and respective Unit 4**

The potential events having radiological consequences are presented in this section. These events are classified in point of their occurrence frequency and doses.

The accident analyses made for Cernavoda NPP Unit 2 are presented in Chapter 15 of Ref. IV-1. As the plant design is similar for the both nuclear units, the results of these analyses are applicable to Unit 3 and respective Unit 4 also.

The risk of events with radiological consequences is evaluated taking into account both CANDU safety philosophy, considered in CANDU 600 plant design and Romanian Regulatory Body (CANDU) safety licensing requirements.

The Canadian Regulatory Body (AECB, actual CNSC) gives the requirements for CANDU 600 NPPs, whose design is similar with Cernavoda NPP Unit 3 and Unit 4, to minimize the risk of events with radiological consequences. A list of events to be analyzed is given in the AECB Consultative Document C-6. C-6 also requires a systematic review of the plant design to identify all additional safety significant failures and combination of failures.

##### **IV.1.4.1 Classification of the Initiating Events with Radiological Consequences**

The initiating events postulated for CANDU 600 NPP are classified into four categories, depending on the evaluation objectives (Ref.IV-4):

**Category A events**, analysed to assess the performance of the special safety systems (shutdown systems No. 1-SDS1 and No.2 – SDS2; Emergency Core Cooling System – ECCS; containment systems);

**Category B events**, analysed to assess the most probable plant response in case of an initiating event, in order to identify the dependence of that response to operator

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corrective action and to demonstrate the independence between the initiating event and the mitigating system(s);

**Category C events**, analysed to evaluate the plant capability to ensure the safety functions (safe reactor shutdown, decay heat removal, radioactivity confinement and plant control) in case of common cause events (i.e. earthquake, flooding, fires, so on);

**Category D events**, to evaluate the features of the plant design or operation which reduce the probability of certain postulated events to such an extremely low level that failure consequences need not be considered.

An event can be classified in more than one category. A Loss Of Coolant Accident (LOCA), for example is analysed in categories A and B, the plant response being evaluated considering the special safety systems performance as well as the operators and other mitigating systems action to minimize the event consequences.

The evaluation methodology and acceptance criteria are different for different event categories. Briefly, the evaluation methods are:

**Category A events** are deterministically analyzed. Conservative assumptions are used for initial plant conditions and mitigating systems availability, which impose the most stringent conditions on safety system design. The category A events are called **Design Basis Events**; their analysis is the subject of Chapter 15 of a NPP Preliminary/Final Safety Report.

**Category B events** are analyzed probabilistically. Realistic assumptions are used to provide information to operators on the most probable plant response in case of the analysed event.

**Category C and D events** are qualitatively assessed.

The main events postulated in CANDU design, classified into the four categories as above, are listed in Tables IV.1.4-1 ÷ IV.1.4.-5.

**Category A events** are subdivided into subcategories A.1 (Events with Class IV Electrical Power Available, see Table IV.1.4-1) and A.2 (Events with Consequential Loss of Class IV Power, see Table IV.1.4-2). Each category A-1 event, coincident with a special safety system unavailability (SDS1 and respectively SDS2, ECCS and Containment Systems) is classified in one of the 5 frequency classes defined in Document C-6 and presented in Table IV.1.4-6.

The acceptance criteria for A and B categories (occurrence frequency and dose limits) are also presented in Table IV.1.4-6.

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The frequency limit recommended by AECB for evaluation of the events with radiological consequences is  $10^{-6}$  events/year and thus a consequence analysis is not required for event sequences occurring with less than this frequency limit.

No quantitative acceptance criteria are specified for **category C events**. The evaluation, however, shall demonstrate the existence of design provisions so that, a long-term heat sink non-affected by the considered event is ensured.

There are also no quantitative acceptance criteria for **category D events**. However, an evaluation of these events shall demonstrate that their frequency of occurrence is low ( $<10^{-6}$  events/year), based on design provisions and operating procedures.

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Table IV.1.4-1 Category A-1 events - Events with Class IV power available

Event	SDS Impairments		ECCS impairments <sup>(1)</sup>		Containment Impairments <sup>(2)</sup>					
	SDS1	SDS2	Injection	Loop Isolation	Isolation Dampers	Deflated Airlock Seals	Open Airlock Doors	Minimum Detectable Hole Size	Partial Loss of Dousing	Local Air Cooling Loss
Large Loss of Coolant	3	3	5	5	5	5	NDB	5	5	NDB
Small Loss of Coolant	2	2	5	5	5	5	NDB	5	5	NDB
Feeder Break	2	2	5	5	5	5	NDB	5	5	NDB
Pressure Tube Rupture	2	2	5	5	5	5	NDB	5	5	NDB
Channel Flow Blockage	2	2	5	5	5	5	NDB	5	5	NDB
End Fitting Failure	2	2	5	5	5	5	NDB	5	5	NDB
Steam Generator Tube Rupture	2 <sup>(6)</sup>	2 <sup>(6)</sup>	NR <sup>(5)</sup>	NR <sup>(5)</sup>	NR <sup>(4)</sup>	NR <sup>(4)</sup>	NR <sup>(4)</sup>	NR <sup>(4)</sup>	NR <sup>(4)</sup>	NR <sup>(4)</sup>
Multiple Steam Generator Tube Rupture	5 <sup>(7)</sup>	5 <sup>(7)</sup>	NDB <sup>(8)</sup>	NDB <sup>(8)</sup>	NR <sup>(4)</sup>	NR <sup>(4)</sup>	NR <sup>(4)</sup>	NR <sup>(4)</sup>	NR <sup>(4)</sup>	NR <sup>(4)</sup>
Loss of Forced Circulation (Loss of Class IV Electrical Power)	1	1	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>
Loss of Forced Circulation (Pump Seizure)	2	2	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>

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Table IV.1.4-1. Category A-1 events - Events with Class IV power available (continued)

Event	SDS Impairments		ECCS impairments <sup>(1)</sup>		Containment Impairments <sup>(2)</sup>					
	SDS1	SDS2	Injection	Loop Isolation	Isolation Dampers	Deflated Airlock Seals	Open Airlock Doors	Minimum Detectable Hole Size	Partial Loss of Dousing	Local Air Cooling Loss
Loss of Reactivity Control	1	1	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>
Loss of Pressure and Inventory Control	2	2	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>
Steam Main Break	3	3	5	5	5	5	NDB	5	5	NDB
Feedwater Loss (Loss of Flow)	1	1	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>
Feedwater Loss (Pipe Break)	3	3	5	5	5	5	NDB	5	5	NDB
Loss of Secondary Circuit Pressure Control	1	1	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>	NR <sup>(3)</sup>
Moderator System Failure	(9)	(9)	NR <sup>(5)</sup>	NR <sup>(5)</sup>	5 <sup>(10)</sup>	5 <sup>(10)</sup>	NDB <sup>(10)</sup>	5 <sup>(10)</sup>	5 <sup>(10)</sup>	NDB <sup>(10)</sup>
Shield Cooling System Failures	(9)	(9)	NR <sup>(5)</sup>	NR <sup>(5)</sup>	5 <sup>(10)</sup>	5 <sup>(10)</sup>	NDB <sup>(10)</sup>	5 <sup>(10)</sup>	5 <sup>(10)</sup>	NDB <sup>(10)</sup>

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**LEGEND:**

NR - Not Relevant; NDB - Non-Design Basis Event;

Numbers not in brackets correspond to the event classification in AECB Consultative Document C-6 (1980, presented in Table 7-6);

Numbers in brackets correspond to the following notes:

**Note**

- (1) Failure of steam generator crash cool down is not considered since the design has two independent crash cool down systems, at least one of which can be assumed to operate.
- (2) Containment systems impairments are as follows:
  - a) Isolation dampers – failure of isolation dampers in inlet and/or outlet ducting;
  - b) Dousing – Partial loss of dousing. Half of the system (either pneumatic or electro-pneumatic) unavailable;
  - c) Local air cooling – failure of all local air coolers inside the Reactor Building;
  - d) Deflated airlock seals – failure of seals in both inner and outer doors of airlock (personnel or equipment airlocks)
  - e) Open airlock doors – both inner and outer doors of airlocks (personnel or equipment airlocks) open.
- (3) Special safety systems (ECCS or containment) are not initiated or credited; therefore, these impairments need not be considered.
- (4) This event leads to loss of coolant outside containment; therefore, containment impairment is not relevant.
- (5) ECCS is not required; therefore, its impairment need not be considered.
- (6) This event is Class 1 as per AECB Consultative Document C-6 but has been reclassified in class 2 based on PSA analysis.
- (7) This event is Class 3 as per AECB Consultative Document C-6 but has been reclassified in class 5 based on PSA analysis.
- (8) This event is Class 5 as per AECB Consultative Document C-6 but has been reclassified as NDB (non-Design Basis event) based on PSA analysis.
- (9) Loss of flow and loss of cooling (service) water to heat exchangers are classified as Class 1 events (as per C-6 document). Pipe breaks are classified in Class 3 event.
- (10) NDB classification is applicable to pipe break events; NR (Non-Relevant) classification is applicable to loss of flow events

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Table IV.1.4-2. Category A-2 events  
Events with consequential Loss of Class IV Power

1. Large Loss of Coolant;
2. Small Loss of Coolant;
3. Steam Generator Tube Rupture;
4. Steam Main Break;
5. Loss of Feedwater (Loss of flow);
6. Loss of Feedwater (pipe break).

In this category there are some A.1 type events with a different plant response in case of loss of electric power due to grid disturbances following reactor shutdown (initiated by different parameters, function of the analysed events).

Table IV.1.4-3. Category B events  
(for Probabilistic Safety Assessment -PSA)

1. Failure of electric power supplies;
2. Failure of Instrument air system;
3. Failure of Service water system\*;
4. Failure of plant computer control;
5. Loss of steam generators as a heat sink\*;
6. Failures in Moderator and Shield cooling systems;
7. Large Loss of Coolant \*;
8. Small Loss of Coolant\*;
9. Failure of Fuel handling system;
10. Failures during reactor shutdown.

\* consequential flooding shall be addressed for each of these events.

The ten events listed above are not single initiating events but a grouping of key events; hence, an assessment of these events shall cover many individual-initiating events.

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Table IV.1.4-4. Category C events

- |   |
|---|
| <ol style="list-style-type: none"> <li>1. Earthquake;</li> <li>2. Site flooding from external sources;</li> <li>3. Fires;</li> <li>4. Severe winds</li> </ol> |
|---|

The events caused by the natural phenomena on Cernavoda NPP site are presented in section IV.1.2. The external man-induced events (in NPP enclosure and in the influence zone) as well as their effects on structures integrity and personnel capacity to ensure plant safe operation are presented in section IV.1.3.

Table IV.1.4-5. Category D events

- |  |
|--|
| <ol style="list-style-type: none"> <li>1. Steam generator support failure;</li> <li>2. Steam generator shell failure;</li> <li>3. Turbine break-up;</li> <li>4. Massive failure of cooling water intake tunnel;</li> <li>5. Massive failure of cooling water discharge duct;</li> <li>6. Failure of heat transport pump casing or drive shaft;</li> <li>7. Pressurizer failure;</li> <li>8. Degasser-Condenser failure.</li> </ol> |
|--|

This type of events is not considered Design Basis Events, so they are NDB types, its occurrence frequency being very small; exception is the event no. 6 that are covered by Large LOCA type events, analysed as category A or B events.

#### **IV.1.4.2. Acceptance Criteria for the Events with Radiological Consequences Postulated for Cernavoda NPP**

In point of safety analyses the risk measures the negative effects of an activity. For a nuclear power plant the potential danger consists in radiation exposure.

To quantify the radioactive risk, the International Commission for Radiation Protection (ICRP) recommends the following definition (Ref. IV-5):

Risk = radiation exposure probability × exposure consequences

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So risk is related not only to consequences but to probability also and the possibility to minimize the risk is to reduce the accident consequences as well as their occurrence probability.

Generally, the regulatory bodies for nuclear activities establish acceptance criteria for the initiating events postulated for a nuclear power plant in order to maintain the risk within the admissible limits.

Table IV.1.4-6 contains the acceptance criteria (occurrence frequency and public dose) established in C-6 Document for Category A and B events defined above.

Table IV.1.4-6 Acceptance criteria (occurrence frequency and public dose limit) for category A and B events

Event class (as per C-6 document)	Occurrence frequency (events/ reactor x year)	Public individual dose limit (mSv)	
		Whole body	Tyroid
1	$10^{-2} \leq f < 1$	0,5	5
2	$10^{-3} \leq f < 10^{-2}$	5	50
3	$10^{-4} \leq f < 10^{-3}$	30	300
4	$10^{-5} \leq f < 10^{-4}$	100	1000
5	$f < 10^{-5}$	250	2500

The inferior frequency limit considered in the Table IV.1.4-6 is  $10^{-6}$  events/year; the consequence analysis of the event sequences with lower frequency is not necessary.

No quantitative acceptance criteria are defined for Category C events; the evaluation, however shall demonstrate the design measures existence to ensure the long-term heat removal following this type of events.

Referring to Category D events, the evaluation shall demonstrate that their occurrence frequency is maintained negligible, by design measures and appropriate operating procedures.

#### **IV.1.4.3 Radiological Consequences (Radiation Doses) of the Events Postulated for Cernavoda NPP**

The chapter 15 of Preliminary Safety Report for Cernavoda NPP Unit 2 (Ref. IV-1) contains the methodology and the analysis results of Category A events (see Tables IV.1.4-1 and IV.1.4-2), defined as Design Basis Accidents. As Unit 3 and respective Unit 4 design is similar, one considers, in this phase, the same dose values for these postulated events. This assumption is a conservative one, as Unit 3 and respective Unit 4 reference design is Unit 2 design with some changes for safety improvement (Ref. IV-10, Appendix 8), resulted from operating experience of CANDU NPPs.

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Table IV.1.4-7 contains the estimated values of radiation doses due to different types of Category A events (single process failure or coincident with a safety system unavailability), selected considering the most severe radiological consequences criterion. These values, estimated at the exclusion zone boundary are extracted from chapter 15 of (Ref. IV-1).

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Table IV.1.4-7 Individual doses due to the events having the most severe radiological consequences, estimated at exclusion zone boundary

Event	Class as per C-6	Individual dose (mSv)	
		Tyroid	Effective
Large LOCA	3	1.60	0.451
Feeder break with flow stagnation	2	2.96	0.387
Fuel channel flow blockage	2	4.23	0.861
End fitting failure	2	2.10	0.393
Main steam line break outside containment	3	1.30	0.444
Steam generator single tube break followed by loss of class IV electric power	4	0.606	0.261
Large LOCA, with ECCS unavailable	5	147	17.4
Feeder break, with ECCS unavailable	5	44.2	7.10
Large LOCA, with containment isolation unavailable	5	1080	80.3
Feeder break, with containment isolation unavailable	5	1860	151
Fuel channel flow blockage, with containment isolation unavailable	5	16,5	4,08
End fitting failure, with containment isolation unavailable	5	1030	109

Notice that these estimated dose values are within the limits corresponding to the classes where the selected events are classified (see Table IV.1.4-6).

#### IV.1.4.4 Analysis on the Occurrence Possibility of the events with significant Environmental Impact

Generally, in case of Design Basis Accidents (DBA) postulated for a nuclear facility, the active and passive systems specified in the design ensure the reactor maintaining in the guaranteed shutdown state, decay heat removal and radioactivity confinement so that the consequences on public and environment are within the permissible actual limits.

In the last years, in evaluation of a NPP impact on public and the environment, an analysis of occurrence probability for severe accidents (Beyond Design Basis Events with serious core damage and great radioactive releases) has to be performed.

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Although generally the nuclear power plants are not provided with special means to withstand these events, measures to minimize or even prevent the public and environment radiation exposure are provided in emergency plans (see section IV.2).

Severe accidents at the nuclear reactors are events with extremely reduced occurrence probability implying multiple failures of essential systems, having consequences in important failures of the reactor and potential radioactive releases in the environment (Ref. IV-15).

The strong concept of CANDU reactor allows a different progression of a severe accident, in case of occurrence to such a reactor, as compared to the case of a Light Water Reactor (LWR). More precisely, the moderator presence being under low pressure in the Calandria around the pressure tubes, as well as the high volume of light water in the Calandria vessel provides an important quantity of cooling water, allowing transformation of a Design Basis Accident (DBA) in severe accident will be done in a relatively long period of time.

As compared to LWR type, CANDU reactor is provided by design with some facilities which can contribute to the reduction of the effect of a severe accident. An example is constituted by the fact that depressurizing of the heat transport main system (either following a LOCA, or by opening up of Main Steam Safety Valves -MSSV valves in the secondary circuit) happens before melting of the reactor core. Thus, any possible under pressure ejection of melted core segments, having as an effect the direct heating of the containment (followed by its failure) does not happen in case of CANDU concept.

In conformity with the international practice, application of Guide's provisions for Severe Accident Management (Severe Accident Management Guidelines –SAMG) will be performed when the core remains without a cooling possibility and started to melt. At a CANDU reactor, before SAMG provisions needed to be applied, the operating procedures are allowable to the operator under emergency conditions EOP) or operating procedures for abnormal situations (APOP) for fixing up the situation, preventing thus transformation of the event in a severe accident.

If core melting has happened and further the technical support group of the Emergency Control Center was put into operation, EOP/APOP procedure fields are abandoned, applying thus SAMG provisions.

One notice that SAMG guides does not constitute procedural requirements, but high level strategies. Therefore, SAMG will be used by the technical support group, which will train the operators in the CR (control room) about the actions they have to undertake. The detailed procedures for the operators will be elaborated based upon SAMG. The technical support group will establish direct communicating lines with ECC (Emergency Control Center) being located outside the site, for taking the proper measures, in order to reduce the consequences of such an accident.

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Drawing a conclusion of all the above, the time durations in which some DBA can evaluate as severe accidents (Calandria Vessel failure due to the concrete erosion) to a typical CANDU 6 plant are as follows:

- Total loss of electrical power supply: 133 h
- Large LOCA: 128 h

A large time duration between the two accident phases can be noticed, which will allow the plant personnel to take the proper measures for reducing the accident consequences and avoiding these DBA to develop into severe accidents.

In the above-mentioned table IV.1.4-7, the fact that the great majority of Design Basis Accidents have non-significant radiological consequences for the population located at the exclusion area boundary (1 km radius around the reactor). Even in case of accidents with extremely low frequency (under  $10^{-5}/y$ ) the radiological impact is within the limits allowed by regulating body in the nuclear field.

#### **IV.1.4.5 Transboundary Effects of Radiological Consequences Events Postulated for Cernavoda NPP Unit 3 and Unit 4**

As presented in section IV.1.4, the CANDU design ensures the Design Basis Accidents radiological consequences mitigation. Monitoring measures and actions are provided in case of extremely unlike severe accidents. CANDU type plants (Cernavoda Unit 1 included) demonstrated the design and accident analysis conservatism.

Cernavoda NPP Unit 3 and respective Unit 4 will be the beneficiary of all the CANDU plants experience referring to accident situations management to reduce as low as possible the population and environment impact (see section IV.2).

The safety analysis elaborated for Cernavoda NPP Unit 2 demonstrated that the population doses estimated at the exclusion zone boundary (1 km radius around the reactor) are within the limits, even for the accidents having the most severe radiological consequences (see Table IV.1.4-7). In these conditions there is very unlikely that Cernavoda nuclear units operation during accident conditions will jeopardize the population and environment in a 30 km radius around the Cernavoda site.

Taking into account the minimum distance between the Cernavoda site and other countries (40 km from Bulgaria) one can conclude that the transboundary effects of the Romanian nuclear units operation are insignificant even in the case of a Design Basis Accident with less than  $10^{-5}$  events/year occurrence frequency.

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## **IV.2 Measures to Reduce the Cernavoda NPP Risk**

### **IV.2.1 Technical and Administrative Preventive Measures**

Cernavoda NPP Unit 3 and respective Unit 4 design has got technical and administrative measures to maintain the nuclear facility operation risk in accordance with Romanian Regulatory Body (CNCAN) requirements. These measures have to prevent the radiological consequences events occurrence.

Technical preventive measures represent the technical features of Cernavoda NPP Units 3 and 4 design based on safety philosophy with protection in depth and system separation principles, requirements of systems failure frequency or unavailability according to Regulatory Body requirements.

These measures were developed to satisfy the basic safety functions after a nuclear accident:

- reactor shutdown and maintaining it in guaranteed shutdown state;
- fuel decay heat removal (cooling);
- radioactivity confinement;
- monitoring of the plant state during and post-accident.

The Cernavoda NPP Unit 3 and respective Unit 4 design is provided with process systems (one of them having also safety functions) and special safety systems ensuring the safety function as above in case of postulated events. To ensure protection against common cause events the physical separation between systems having the same safety function was applied.

The safety-related systems are forming two groups, each group being capable to ensure all the four safety functions. The systems that are part of the two groups and their safety functions are presented in Table IV.2-1.

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Table IV.2-1 The two groups concept of safety-related systems

Safety function	Group 1	Group 2
Reactor shutdown	Shutdown system nr.1	Shutdown system nr.2
Decay heat removal	Normal power and cooling water supply systems	Emergency power and cooling water supply systems
Post-accident monitoring	Main Control Room	Secondary Control Area
Radioactivity confinement	Manual containment isolation valves	Containment systems

Together with the technical features of U3 and U4 NPP design, a number of administrative measures were taken to ensure the safe operation of the plant. The operational documents such as: the normal and abnormal operating procedures as well as working procedures in case of radiological or chemical emergency conditions- are all developed in order to ensure that the operation of the plant is within the Regulatory Body approved limits and in accordance with the radiological and chemical national and international norms and limits.

#### IV.2.2 Protective measures to reduce the Cernavoda NPP Unit 3 and Unit 4 risk

For the design basis accidents, which set the criteria for special safety systems performance and also for radiological protective features, population protection is ensured by providing the following nuclear safety zones:

- a) 1 kilometer unpopulated zone around each reactor (**exclusion zone**), where only operational activities related to NPP are allowed.
- b) 2 km **low population zone** around each reactor, which complies with the requirement of CNCAN Romanian National Nuclear Safety Norms (NRSN), art. 18.

In the case of a severe accident (event beyond the design bases, having a very low occurrence frequency and severe radiological consequences – see section IV.1.4.4) the plant does not have special design features to withstand such a situation. An emergency plan is prepared, including measures to reduce or avoid population radioactive exposure in case of the severe accident. Within the emergency plan the Emergency Planification Zones are identified where pre-planification is necessary to ensure implementation of prompt and efficient population protection measures in case of a radiological incident. Conforming to the IAEA recommendations (Ref. IV-11), two distinctive zones were defined for Cernavoda NPP Unit 1 (Ref. IV-7):

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- 10 km zone around the reactor – on short term, for exposure to the radioactive cloud;
- 50 km zone around the reactor – on long-term, for ingestion exposure pathways.

The protective measures which should be taken in case of nuclear accident, considering the different exposure pathways of the public are presented in Table IV.2-2.

The decision to apply one of the protective measures is taken when the expected values of doses are greater than the intervention level corresponding to the specific protective measure. The levels of intervention are presented in Table IV.2-3 (Ref. IV-13). The low level significance is that the dose values are lower than that level and therefore no protective action is needed. When the doses are greater than the high level the radiological measure must be applied. In order to avoid non-stochastic effects on public health, between these levels protective measures should be applied to keep the individual doses below the level at which such effects could appear.

The technical and administrative protective measures of Cernavoda NPP Unit 3 and Unit 4 design ensure that the risk, in the case of accidents will not be greater than the maximum admissible risk which, conforming to the requirements of (Ref. IV-12), will be defined by the Regulatory Body.

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Table IV.2-2 Protective measures in case of nuclear accident

Exposure pathways	Time from exposure			Protective measure
	early	Intermediate	late	
Direct external irradiation	x x x			Sheltering Evacuation Access control
External Irradiation from radioactive cloud	x x x			Sheltering Evacuation Access control
Inhalation	x x  x x			Sheltering Stable Iodine administration Evacuation Access control
Skin & Clothes Contamination	x x x	x x x		Sheltering Evacuation Personnel decontamination
Irradiation from soil deposit material	x x x	x x x	x x x	Sheltering Evacuation Access control
Irradiation of radioactive material		x x	x x	Relocation Soil decontamination
Ingestion of contaminated food and water		x x x	x x x	Relocation Decontamination Water & food control

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Table IV.2-3 Levels of intervention and protective measures in case of a nuclear accident

Protective Measure	Dose compared with intervention level	Intervention Level (mSv)			
		Whole body effective dose		Critical organ effective dose (thyroid, lung, skin, etc.)	
		low	high	low	high
Sheltering	External dose plus dose from intake in the first 24 hours	3	30	30	300
Stable iodine administration	Ingestion dose in the first 24 hours	-	-	30	300
Evacuation	External dose plus dose from intake in the first 24 hours	30	300	300	3000

### IV.2.3 Programs

Similar with Cernavoda NPP Units 1 and 2, in order to ensure that the systems will operate according to the design, Cernavoda NPP Unit 3 and Unit 4 should and will have during operation several programs to cover different aspects so that the plant is operated with a risk lower than the maximum risk allowed by the Romanian Regulatory Body (this risk value will be established by CNCAN, as required by The Fundamental Norms of Radiological Safety, Ref. IV-12).

These programs will cover the following fields:

- environmental monitoring;
- special safety systems reliability monitoring;
- periodic inspections and maintenance;
- control of design changes and configuration;
- events analysis;
- periodic safety review;
- risk monitoring;
- operation in case of radiological emergency;
- operation in case of accident;
- severe accident management.

Developing, upgrading and updating such programs will ensure an appropriate plant response in case of an accident occurrence, so that the risk on population and the environment will be within the limits to be established by the Regulatory Body, as required in Ref. IV-12.

The Cernavoda General Emergency Plan is in place, according to the provisions of Law no. 111/1996 on safe conduct of nuclear activities with subsequent completions and modifications, the provisions of the Government Urgency Ordinance no. 21/2004

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on National System of Emergency Situation Management, endorsed by the Parliament by Law no. 15/2005, the provisions of the Law no. 48/2004 on Civil Protection and the provisions of the Radiological Safety Fundamental Norms/2000 and of Republican Nuclear Safety Norms for Planning, Preparedness and Intervention for Nuclear Accidents and Radiological Emergency/1993 (Ref. IV-16). The Cernavoda NPP General Emergency Plan is elaborated by the NPP and shall be approved by the General Inspectorate for Emergency Situations (IGSU), which is the permanent working body of the Ministerial Committee for Emergency Situations (CMSU). CMSU, which has county and local commandments is led by the Ministry of Administration and Internal Affairs. CMSU has the responsibility to approve the General Emergency Plan and to manage the intervention.

The Cernavoda NPP General Emergency Plan is presented in a set of documents ensuring the precisely planning of on-site and off-site emergency response actions in case of any events with radiological consequences likely to appear during the Cernavoda NPP operational lifetime.

The set of documents contains the following (Ref. IV-7):

- On-site Radiological Emergency Plan;
- On-site Radiological Emergency Procedures;
- General off-site Intervention Plan in case of Nuclear Accident;
- Off-site Intervention Plan in case of Nuclear Accident;
- Protection and Intervention SNN-SA Emergency Protection Plan;
- Off-site Radiological Emergency Procedures;
- Other interface documents and agreements between different organizations and authorities.

The documents of the Cernavoda General Emergency Plan are interconnected and can be individually or integrally applied function of the radiological incident nature, ensuring an appropriated protection of personnel, public and environment.

Regarding the planning for radiation emergencies in the vicinity of Romanian territory Romania is a signatory of the following international emergency response agreements (Ref. IV-16):

- Convention on Early Notification of a Nuclear Accident;
- Convention on Assistance in the case of a Nuclear Accident of Radiological Emergency;
- Convention regarding the liability for nuclear damage.

Concerning the liaison across national borders, Romania has signed the Agreements for Early Notification of Nuclear Accidents with Russian Federation, Bulgaria, Greece, Hungary, Slovakia and Ukraine.

These agreements contain provisions for:

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- taking all appropriate and effective measures to prevent, reduce and control adverse trans-boundary environmental impacts of major nuclear activities;
- ensuring that the parties are notified in case of nuclear accidents which could affect them.

The Romanian General Emergency Plan includes provisions for transboundary emergencies according to the provisions of national norms.

### **IV.3 Risk Assessment of the Accidents with Impact on Environment and Public Health during Cernavoda NPP Unit 3 and Unit 4 Completion**

During a nuclear unit completion period there is the probability of some accidents within the site due to the execution activities and/or materials and workers transport. The experience gained during Units 1 and 2 completion and operation will be used in the activities for Unit 3 and Unit 4 construction and exploitation. The management staff will have clearly defined responsibilities for approving and applying methods, practices and procedures for building, commissioning and operation, including responsibilities to develop, maintain and strengthen the specific safety objectives.

During the new construction elements completion, civil workers will take into account the chapters related to forming, reinforcing and putting in form of concrete (focused on dangers in case of working at altitude), contained in the industrial safety norms applicable to the industrial construction activities.

During construction and installation activities, both the civil work companies and the owner have to consider the design recommendations and to take into account all the mandatory measures to avoid the accident hazard. The measures have not a limiting character, the owner having the obligation to establish and meet the protection norms during completion activities.

The civil work companies have to ensure all the involved workers training in the protection norms provision so that the content of these norms will be well learn.

The measures for preventing and extinguish of potential fires, provided for the entire period of completion activities will be established by the company which elaborate the site installation documentation and also by the contractor, to respect the actual norms requirements.

The building site will be provided with all the features for fires prevention and extinguish, in respect of applicable norms. Special care has to be provided for flammable materials handling and storage.

An on-site fire station, with shovels, pick-axes and water and sand buckets have to be installed, special care being taken for welding activities.

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Strict working procedures will be established to avoid leaks of hazardous substances (toxic and/or explosive) during objective execution activities, as well as to promptly act should they occur. The experience gained in the two Cernavoda nuclear units shows that the leak amounts are small during the completion period, with limited extension and duration (due to the measures taken) and the adverse effects on population and environment will be reversible.

The toxic substances used during the execution activities are mainly paints. The explosive substances used during the same period are oxygen and acetylene. These substances will be stored in specially constructed locations, according to the norms in force.

#### **IV.4 Conclusions**

During Cernavoda NPP Unit 3 and Unit 4 completion the measures to reduce at the minimum the risk on the workers, public and environment are taken.

The technical and administrative measures of Cernavoda NPP Unit 3 and respective Unit 4 together with the programs presented in section IV.2 will ensure the plant safe operation and a risk lower than the maximum risk allowed by the Romanian Regulatory Body (to be established, as required by the Fundamental Norms of Radiological safety).

It may be stated that the accidents with radiological consequences considered in the design of Cernavoda NPP Unit 3 and Unit 4 (Design Basis Accidents) will not induce a risk greater than the maximum risk allowed by the Regulatory Body.

In the case of severe accidents (Beyond Design Bases) the risk could be close to the maximum allowed value but the use of emergency plans and accident procedures in such cases will maintain the risk in an acceptable range.

The transboundary effect of Cernavoda NPP Unit 3 and Unit 4 operation in accident conditions is insignificant similar with the case of the other two nuclear units on the same site.

The Cernavoda NPP site and design characteristics will maintain in an acceptable range the risk due to natural phenomena (i.e. severe meteorological phenomena, flooding, earthquakes). The external human activities (within the NPP site and in the influence zone) do not affect the structures integrity and the personnel capacity to ensure the Cernavoda NPP Unit 3 and respective Unit 4 safe operation.

The risk of non-radiological accidents is limited both by design measures (i.e. possibility to collect the toxic leakage, ISCIR Norms to be used in pressure equipment design, etc.) and administrative measures (i.e. well defined procedures). In case of accidental hazardous chemical leakage that may occur in the NPP, chemical emergency procedures were elaborated to include the actions that must be

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taken in order to minimize the danger to the personnel and equipment and to reduce the environmental impact.

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## **IV.5 Works Proposed for Site Rehabilitation/Restoration at the End Life of Plant**

### **IV.5.1 The decommissioning concept**

The term “decommissioning” used in the nuclear industry, means the technical and administrative actions taken at the end of a useful life of a nuclear objective in order to liberate, partial or total, from the regulatory authority (Ref. IV-17).

The actions involve, through other activities, the decontamination, dismantling and removal of the radioactive materials, components, structures and wastes.

The actions are carried out to achieve a progressive and systematic reduction in the radiological hazard; they are taken on the basis of a preplanning and assessment to ensure nuclear safety during decommissioning operations.

In some situations, in case that the nuclear objective for the decommissioning process rests a part of a functional nuclear facility, this objective will remain under the Reglementation Authority.

The time period for the decommissioning activities for a nuclear power plant depends on the radioactive inventory, the chosen decommissioning option and the used decommissioning techniques, and may range from a few years to decades.

The basic document, which regulation the decommissioning of a nuclear objective, elaborated by the Romanian regulatory body in nuclear field (CNCAN), is NSN-15 “The decommissioning norms of the nuclear objective and facilities” (Ref. IV-18). The requirements of these norms are applicated, in a special way, on the decommissioning of the research nuclear reactors, subcritical assembly, treatment facility of the radioactive wastes, spent fuel intermediate storage facility, radioactive waste intermediate storage, but these can be applicated to a nuclear power plant also.

Both the internal norms and the international standards specific to the decommissioning, (Ref. IV-18), (Ref. IV-19), (Ref. IV-20) recommend to prepare a Decommissioning Plan in three stages:

- initial plan for decommissioning, prepared during the nuclear unit design and construction phase;
- ongoing plan for decommissioning, prepared during the operation phase of the nuclear unit;
- final plan for decommissioning, prepared at the beginning of the nuclear unit decommissioning.

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The Decommissioning Plan prepared will be submitted for approval by the regulatory body, in order to obtain the license for accomplishing the decommissioning activities, according to NSN-15.

The most important technical, administrative and financial items in a decommissioning plan are considered below:

- description of Cernavoda NPP U3 and U4 and operational history;
- details of the radioactive and toxic materials;
- assessment of decommissioning alternatives;
- details of the decommissioning activities;
- project management team;
- nuclear safety;
- security and safeguards of the nuclear materials;
- safety, performance and environmental assessments;
- quality assurance requirements;
- wastes management;
- financial estimation and available funding;
- records.

The decommissioning strategy of a nuclear objective is defined on three stages. It begins with the safe shut down and ends with realization of a green field site. According with (Ref. IV-21) the three basic stages are:

- Stage 1 or “Storage with surveillance”;
- Stage 2 or “Restricted site release”;
- Stage 3 or “Unrestricted site use”.

These stages are not mandatory for the decommissioning of a nuclear objective, but it must take into account that the final goal of any decommissioning activity is the release for unrestricted use of site. This means that the remained radiological risks at the end of decommissioning process must be acceptable for the safety of workers, public and environment.

Each stage described above is defined as a physical state of the plant in conjunction with one certain mode of surveillance (Ref. IV-22). In this way, a complete nuclear objective can go through all three stages during the decommissioning activity, but a small nuclear facility can be directly decommissioned until the stage of unrestricted site use.

#### **IV.5.2 The generic options of decommissioning**

According to international practice in this field, (Ref. IV-23), (Ref. IV-24), (Ref. IV-25), three decommissioning strategies are used now:

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### *The “SAFESTORE “ option*

In first phase, this option assumes a minimum of decommissioning activities and the conversion of the plant into one safety containment, meant to prevent the uncontrolled scattering of radioactive contamination. Here, the spent nuclear fuel is removed from the nuclear unit or stored on the site. Same way, the operating waste and radioactive liquids are collected, processed and removed from the plant or temporally stored on the site. 20-50 years after these activities the decontamination and decommissioning of the facilities and liberation from authority requirements can be produced.

The advantages of this option:

- The existence of a “waiting period”, when radiation fields will be reduced due to the radioactive decay, assuring, in this way, the smaller doses for the decommissioning personal;
- Less radioactive waste;
- Less cost because short time of decommissioning funding spending.

All that contributes to reduce the impact of decommissioning activities on the personal involved, population and the environment.

Disadvantages:

- The existence of some maintenance and operation activities on long term (20-50 years) on- site;
- Unavailability of the trained personal (ex-operators) at the moment of final decommissioning activities;
- The possible raises of costs at the moment of final decommissioning activities.

In the IAEA terminology this option correspond to “Deferred dismantling” option.

### *THE “DECON” OPTION*

This option assumes the decontamination and decommissioning of the equipment and structures that are contaminated and/or activated in short time after the final shutdown of the nuclear unit. The spent fuel and radioactive waste are collected and transferred to repository. These actions ensure site availability for other activities, short time after shutdown of the operating activities.

The advantages of this option:

- The availability of the plant personal, with a good know-how of the plant, for planning and executing a part of decommissioning activities;
- Non-existence of supplementary costs for long-term monitoring of the plant;
- The site availability for other utilization, in the shortest time compared with other generic strategies.

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All that contributes to reduce the impact of decommissioning activities on the personal involved, population and the environment.

In the IAEA terminology, this option correspond to “Immediate dismantling“ option.

#### *THE “ENTOMB “ OPTION*

This option assumes the contaminated and/or activated parts of nuclear unit to be sealed in an appropriate material (for ex: concrete). The structures are monitored, until the radioactive content is reduced by decay to the level when the site is liberated from authority requirements.

The advantage of this option is that the environmental impact of the activities to prepare the “safety enclosure” is almost the same as the impact of a non-nuclear objective decommissioning.

The disadvantage is the need to rigorously evaluate the long-term environmental impact of safety enclosure at the moment of this option selection.

From this way, the option is, in principal, used for nuclear research reactors or small nuclear objectives decommissioning, but isn’t considered a possible alternative for Cernavoda NPP Unit 3 and U4.

#### **IV.5.3 Remediation/restoration activities of the site**

The goal of the remediation/restoration activities is:

- to reduce the doses to individual or groups of individuals being exposed;
- to avert doses to individuals or groups of individuals that are likely to arise in the future;
- to prevent or reduce environmental impacts from the radionuclides present in the contaminated area.

Thus, the remediation/restoration activities of the site contribute to fulfilment of the final purpose of decommissioning that is the unrestricted use of the buildings and land after the release their from any radioactive materials or contamination.

The remediation/restoration activities of a nuclear objective site consist of:

- a) the elaboration and approval of a remediation/restoration plan;
- b) the implementation of the remediatin/restoration measures;
- c) the elaboration of the site area monitoring and surveillance programmes in order to ensure the fulfilment of the proposed aim (the remediation/restoration level);
- d) the management of waste arising from the remediation/restoration activities.

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a) **The remediation/restoration plan** must show that the site remediation/restoration can be accomplished safely. This plan shall be subject to the approval of the regulatory body prior to its implementation. The approved plan shall state, as a minimum:

- the goal for the site remediation/restoration;
- the reference levels for the site remediation/restoration;
- the nature and duration of the remediation/restoration measures to be implemented;
- the waste disposal or storage site arising from the remediation/restoration activities;
- any post-remediation restrictions;
- the monitoring and surveillance programmes of the site area and arrangements for institutional control for the area to be remediated /restored.

a) During **the implementation of remedial/restoration measures**, consideration shall be given to radiation safety, transport safety and waste safety, so as to minimize hazardous impacts and to the potential for prolonged exposure after the termination of remediation/restoration.

b) During the restoration/remediation activities must elaborate a **monitoring and surveillance programmes** in order to verify the proposed remediation/restoration level and the compliance with the requirements for waste management.

The surveillance program will enable the organization responsible for the site remediation/restoration to detect any unexpected level of radiation and to modify the remediation/restoration plan accordingly. Also, the revisions to the remediation/restoration plan shall be subject to the approval of the regulatory body.

c) The fundamental principle of the protection of human health and the environment now and in the future without imposing undue burdens on future generations shall apply for **the management of radioactive waste** arising from the implementation of remedial/restoration measures. In this way, must be considered the amounts, characteristics, properties and types of radioactive waste.

The management of radioactive waste arising from the implementation of remedial/restoration measures shall be considered one component of the entire decision making process.

The cost of transport and disposal of the waste, the radiation exposure of and other risks to the workers handling it, and, subsequently, the exposure of the public associated with its disposal shall all be taken into account in the process of determining the optimum option for the site remediation/restoration.

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Also, the management of radioactive waste arising from the implementation of remedial measures shall comply with the international and national requirement for waste management.

The technologies for remediation/restoration of a nuclear objective site will be established depending of the selected decommissioning option .

Thus, the main factors to be taken into account in the selection process of the preferred remediation/restoration technologies of the Cernavoda NPP U3 and U4 site include the following:

- the performance;
- the reability and maintenance requirements for the technology;
- the associated cost of implementing the technology;
- the infrastructure available to support the techology (i.e. staff trained for operation and control of the selected technology);
- the availability from commercial point of view;
- the risk to workers and public safety;
- the environmental impacts;
- the ability of the technology to meet regulatory acceptance;
- the obtaining of community acceptance regarding the selection of remediation/restoration technology.

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## **V PROVISIONS FOR ENVIRONMENTAL MONITORING**

### **V.1 Surveillance of Activities Concerning Environment Protection**

The objectives of SNN environment policy are:

- prevention of requirement pollution;
- fulfillment of requirements from environment legislation;
- environmental objectives review;
- implementing and keeping of environment policy;
- public notifying concerning environment policy of the NPP.

For Cernavoda NPP U1, an environmental management program has been performed (01364-RD-Q10). This contains the necessary components to identify and to manage the environment items.

In 2003 year was take-out by Cernavoda NPP Unit 1 the certificate ISO 14001 for Environmental Management System.

For commissioning and operating periods of Cernavoda NPP U3 respectively U4 a similar programs to that for U1 will be introduced, which will take into account the corresponding modifications.

At Cernavoda NPP U1, in the framework of environment protection activities, the following procedures and programs have been defined:

- environmental radioactivity monitoring program;
- liquid and gaseous radioactive effluents monitoring program;
- liquid and solid radioactive waste management program;
- safety systems dealing with transport, handling and inventory of radioactive sources;
- chemical materials management program;
- procedures for industrial safety;
- non active effluents monitoring program;
- emergency plan inside and outside of the plant site.

The Radioactive Effluent Monitoring Program must satisfy the following general targets (Ref V-1):

- to prove the compliance of radioactive release levels with the emission derivate limits and with any other CNCAN requirements regarding the impact on population and environment due to the installation normal operation;
- to provide information and data required for the assesment of critical groups and population exposure or potential exposure due to the existence in the environment of radioactive materials or radioactive fields resulted from an installation normal operatioin , an emergency case or ceasing the nuclear activity;

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- to allow the inspection/checking of the operation conditions and of the radioactive effluent control opportunity and also, to allow the occurrence of unusual or unexpected conditions in the radionuclide release to the environment and, if required, to initiate an additional radioactive effluent monitoring program.

The documents which define the requirements for Radioactive Effluents Monitoring Program are RD-01364-RP4 (Ref. V-1) and SI-01365-RP6 (Ref. V-2). The first document presents the methodology and the models used to calculate the dose rates of radiological emissions; the second one, presents the requirements, the responsibilities, the control and the monitoring activities necessary to ensure the maintaining of emission limits under derived emission limits.

The Radioactivity Environment Monitoring Program must satisfy the same general targets as like the Radioactive Effluent Monitoring Program.

The typical objectives (targets) of the radioactivity environment monitoring are (Ref.V-4):

- verification of the radioactive emission monitoring program results and associated models in order to check the protections supplied by the employed models;
- supply of required data for the assessment of current or potential doses to the critical group members, resulted from the activity or authorized source;
- detection of any unexpected modification of the radioactivity concentrations and the evaluation of the long-term trends of the radioactivity levels in the environment as a result of the radionuclide releases to the environment;
- supply of information to the public.

The Radioactivity Environment Monitoring Program defined by document RD-01634-RP7 (Ref.V-5) contains all activities to assess the radiological emission concentrations into environment and their effects on population and environment.

The document presents the procedures, responsibilities, monitoring locations and environment components, which will be monitored.

The objectives of the Non-radioactive Environment Monitoring Program, defined by RD-01364-CH2 (Ref. V-6), have the purpose to reduce the chemical substance emissions into environment, and to demonstrate the concordance with applicable regulations. The document presents the responsibilities, procedures and activities for normal operation, as well as for abnormal emission.

Radioactive Waste Management for Cernavoda NPP incorporates all administrative, operational and safety-related activities related to collection, handling, conditioning, storage, transportation of all radioactive waste categories.

The Emergency Plan is described by document RP-01364-RP8 (Ref. V-7). The document defines the responsibilities, the emergency response actions and identifies

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the measures and means provided to limit the effects of accidents with radiological consequences beyond design basis accident.

The responsibilities presented in Unit 1 documents, are classified in 4 departments, each of them reporting to the plant manager:

- Radioprotection;
- Nuclear Safety;
- Chemical;
- Quality Assurance.

The Quality Assurance Department performs audits for environmental activities, for fulfillment of environment policy and applicable procedures. The results of monitoring program are reported periodically to CNCAN and to environment control authorities.

All measurements must be performed using approved procedures from the point of view of quality assurance; the equipment and calibrating sources are verified by Romanian Metrology Authority (responsible for measurement accuracy).

The procedures used for measurements are according to international standards. These procedures are periodically reviewed and approved by the plant management and competent authorities.

The Environmental Control Lab is responsible with the implementation of the Environment Radioactivity Monitoring Program.

The Environmental Control Lab is certified by IAEA.

The Health Physics Lab is responsible with the implementation of Liquid and Gaseous Radioactive Effluent Monitoring Program.

The Chemical Lab is responsible with the implementation of Environment Chemical Monitoring Program.

## **V.2 Equipment and Measures to Control the Radioactive Pollutants Emissions into Environment**

As per (Ref. V-1), in order to maintain the control on the radionuclide release to the environment, the licensor need to provide:

- prevention of any unacceptable irradiation or contamination risk on population, as a result of radioactive substance release to the environment;
- compliance with CNCAN requirements;
- reporting to CNCAN an any modification in the radioactive substance release to the environment.

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These programs have two major objectives:

- to control the radioactive releases so that the operating personnel is aware of the modifications that can result from process or procedural errors and can take actions to reduce releases;
- to measure the radioactivity releases in order to demonstrate that the Derived Emission Limits (DELs) have not been exceeded.

To satisfy these requirements, both for U3 and U4, effluent monitoring programs shall be elaborated like for U 1 programs.

### **V.2.1 Radioactive Liquid Effluent Control and Monitoring**

The control of liquid radioactive material releases to the environment is provided by:

- the collection of the entire quantity of radioactive liquid wastes generated in the plant, the treatment if necessary and their discharge, in a controlled manner, to the emissary, meeting Derived Emissions Limits (DEL) established for Cernavoda NPP; under normal operation conditions, about 26 m<sup>3</sup> of low level liquid waste and 13 m<sup>3</sup> of normal level liquid waste are collected daily in the corresponding tanks (Ref. V-7); so, the system tanks representing a storage capacity of: 3 tanks x 50 m<sup>3</sup> for low level waste and 2 x 50 m<sup>3</sup> for normal level waste, is large enough to ensure the necessary time for collection, homogenizing, analyzing, decontamination and discharge; the system is capable to store, without any discharge, the entire quantity of radioactive liquid waste resulted from 3 days of normal operation of the plant;
- the collection tanks are Design Basis Earthquake (DBE), category A qualified;
- the location of the tanks in Service Building basement, so that likely leakage of radioactive materials may be collected via the Service Building Drainage System;
- design and installation of instrumentation and control equipment so as to reduce the exposure to radiation for the personnel in wet medium;
- during normal operation, the tanks are provided with overflows to allow the discharge of radioactive liquid to the adjacent tank (when the maximum level is exceeded). In special cases, the radioactive wastes shall be discharged through the overflows from one tank to another, until all the tanks are entirely full and next, via the overflow, they shall be discharged to the active drainage pits;
- the storage tank walls are waterproofed by epoxy resins and glass fibers reinforced, to avoid the infiltration of liquid to the outside;
- the dilution of the radioactive liquid waste in the cooling water discharge duct from condensers, is accomplished with a minimum dilution rate of 1:2900; such a dilution ensures the fulfillment of DELs for liquid effluents, as established for Cernavoda NPP (Ref. V-1).

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The controlled release is ensured by laboratory analyses of samples from the tanks before the discharge, the discharge authorization and the continuous surveillance of the discharge by the Liquid Effluent Monitor (LEM).

The LEM is located in the S/B basement and consists of:

- an adequately shielded detection unit (the detectors, installed in the monitored liquid effluent area);
- a signal processor/microprocessor with specified input/output;
- a logic/sequential control unit, which will also include LEM states monitoring;
- a separated display unit which will be placed in the monitored discharge area;
- operational additional/display/indication panels.

The LEM ensures the following functions:

- display and indications about the measured parameters and monitoring of the status at any given moment;
- communication and input/output control signals to the Radioactive Liquid Waste control panel, to automatically stop the discharge when a setpoint is exceeded;
- an output signal for continuous recording of data on a recorder.

If the sample collected by LEM during the discharging reaches the alarm threshold of 5.4 kBq/ l gamma activity, the discharge circuit is automatically shut off.

The alarm threshold (set point) is established considering that all measured activity is due to the most restrictive isotopes (Cs-137, Co-60). The detector has sufficient sensitivity to activate the alarm and to stop the pump out the liquid radioactive waste before approximately 0.1% of monthly DEL has been released.

The sampling is automatically stopped when a liquid radioactive waste tank discharge is carried out. A sample taken from the discharged effluent is sent to the Health Physics Laboratory for detailed quantitative analysis using a multi-channel gamma spectrometer with Ge hyper-pure. Thus the quantity of gamma emitting radionuclides in the liquid radioactive effluent can be accurately determined. The sample is also analyzed for tritium and C-14 using the liquid scintillation counting technique.

By construction, the LEM is provided with background compensation facilities.

The LEM fulfils the following requirements (Ref. V-8):

- constant monitoring of all discharged liquid wastes, by continuous representative sampling;

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- permanent recording and display on demand of activity concentration in the discharge channel, as a function of time;
- determines the total activity released daily and monthly by integration function of time and flow rate;
- detection and measurement of the liquid effluent gamma radiation and indication of measured activity;
- permanent availability for detection and measurement of activity, whether there is pumping or not;
- detection and measurement of activity in real time;
- receives inputs and provides outputs/interlocks which will close a pumping sequence in certain cases such as for unfavorable operating conditions or monitor unavailability/failure;
- provides an output signal to another panel (Radioactive Liquid Waste System panel) to close the discharge valve in cases when the detected activity concentration or total activity are higher or equal to the preset limits;
- ensures an alarm for high activity in the Main Control Room;
- provides an analogue output signal to the recorder, which corresponds to the net activity concentration of the sample ( $\text{Ci/m}^3$ ).

A device separated from LEM takes representative samples for further laboratory analyses.

## **V.2.2 Radioactive Gaseous Effluent Control and Monitoring**

The control of the gaseous radioactive effluents is performed both by filtering of releasing ways and by automatically isolating of containment, when the radioisotopes are detected.

At CANDU type plants, the control of gaseous emissions is ensured by:

- two drying steps, to control tritium and  $\text{D}_2\text{O}$  vapour;
- filtering before the discharging to atmosphere, to retain the particulates and radioiodine;
- dispersion by releasing at high altitude (ventilation exhaust stack).

The plant is provided by design with the following gaseous effluent monitoring systems (Ref. V-9):

- monitoring of stack releases;
- monitoring of containment atmosphere.

Stack releases are monitored by the Gaseous Effluent Monitor (GEM) and the  $\text{D}_2\text{O}$  in Air Monitoring System.

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### **V.2.2.1 Gaseous Effluent Monitor**

The Gaseous Effluent Monitor (GEM) is located in the S/B and consists of:

- monitoring system: monitors for a radioactive aerosols monitor, a radioactive iodine monitor, a low range noble gases monitor, and a high range noble gases monitor,
- a tritium sampler;
- a C-14 sampler.

The GEM fulfills the following functions:

- provides alarms which annunciate the operator in the Main Control Room if there is an unexpected activity increases of aerosol, iodine and noble gas, in the gaseous effluents;
- collects for detailed analyses aerosols, iodine, water vapors (for tritium) and gases that contain carbon (for C-14) in the effluents, existent in the filters or absorbent materials;
- measures and records the activity released for each vector (aerosols, noble gases, iodine);
- sums up the effluents releases for a week and compares the results with Derived Emission Limit (DEL).

The components of the stack gaseous effluent monitoring system are presented below.

#### **V.2.2.1.1 Sampling System**

In order to obtain a representative sample from the discharge duct, an isokinetic nozzle sampler with multiple inputs is installed in the ventilation stack.

The system also includes a device for measuring the flow rate through the stack. An alarm warns the operator when there is a duct airflow velocity change of more than 1.6 m/s. The speed of the air-stream in the sampling system is automatically adjusted as a function of the flow rate through the stack.

The sampling system automatically responds to the duct permanent flow velocity changes, ignoring the transient changes of less than 5 minutes duration. The sampling nozzle is easily removable from the outside of the duct for cleaning purposes. Stainless steel tubing with maximum length is provided to run from the nozzle to the collection system. Tees, valves and a regulator are provided to isolate and purge the noble gas chamber.

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#### **V.2.2.1.2 Aerosol (Particulate) System**

The samples extracted from the air released through the ventilation stack are passed through a glass fibre particulate filter, which is measured with a beta scintillation detector to determine the activity collected in it. The detector includes a scintillating crystal, a photo-multiplier tube and an amplifier. The detected signal will be passed through a preamplifier, an amplifier and a logarithmic ratemeter and a signal conditioning circuit to produce a five decade logarithmic. The activity accumulated on the aerosol filter is proportional to the radioactive aerosol concentration from the last change of filter. The range of total particulate activity expected to be released from the ventilation exhaust is  $1 \times 10^{-4} \div 10$  GBq/day. The filter is changed weekly and a detailed analysis is performed in the Health Physics Laboratory.

#### **V.2.2.1.3 Radioactive Iodine System**

After the retaining of aerosols, the sample taken from the stack is passed through an TEDA impregnating activated charcoal cartridge. The activity accumulated on the iodine filter is proportional with I-131 concentration integrated on time, from the last change of filter, except for the decay. The activity collected in the filter cartridge is detected with a scintillation gamma detector which includes a Thallium activated sodium iodine crystal, a photomultiplier tube and an amplifier discriminator with dual window (iodine and background, background alone). The range of total iodine activity release expected from the ventilation exhaust is  $0.4 \times 10^{-4} \div 40$  GBq/day.

The filter is changed weekly and sent to the Health Physics Laboratory.

#### **V.2.2.1.4 Noble Gases System**

The noble gases system consists of a detector with scintillation whose output signal is proportional with the total detected gamma energy for low levels of activity noble gases releases expected during routine operation and a GM detector for high gamma levels anticipated in an emergency. A third, external GM counter is used to monitor the background radiation level.

The range of total activity release expected from the ventilation exhaust is for low level:  $0.45 \times 10^{-3} \div 0.45 \times 10^2$  TBq-MeV/day and for high level:  $0.45 \times 10^{-1} \div 0.45 \times 10^2$  TBq-MeV/day.

The display is daily manually reset daily.

#### **V.2.2.1.5 Tritium Sampling System**

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This system consists of a collector with molecular or silica gel strainer. The collector must not become saturated or collect chemical species that would interfere in tritium activity analysis by a liquid scintillation counter. The collector is not required to collect elemental tritium.

A sample of gas taken from the ventilation stack is passed through a desiccant (molecular strainer or silica gel), which retains the tritiated water vapors. The molecular strainer is changed twice a week and the water collected is analyzed daily by determination of tritium in the Health Physics Laboratory, using a liquid scintillation counter. The amount of tritium released through the stack is determined by measuring the volume of gas released by the stack as well as the volume of the sampled gas.

#### **V.2.2.1.6 C-14 Sampling System**

A fraction of the gas sample taken from the ventilation stack is passed through a bubbler and bubbled through a liquid solution of sodium hydroxide, which retains carbon as carbon dioxide. The sample may also be directed through a catalytic converter upstream of the collector, which oxidizes other components of carbon to CO<sub>2</sub>. The bubbling solution is changed weekly and the respective sample is analyzed in the Health Physics Laboratory to determine the content of C-14, by means of a liquid scintillation measurement system. The total amount of C-14 released can be determined, since the volume of gas released through the stack and the volume of the sampled gas are known.

In order to eliminate the interference of tritium in the C-14 collector the two collectors are serially arranged. Two complete loops for tritium and C-14 are provided for redundancy.

#### **V.2.2.2 D<sub>2</sub>O in Air Monitoring System**

The D<sub>2</sub>O in air monitoring system detects the heavy water leaks to the atmosphere through the ventilation stack (Ref. V-10).

Control pertaining to the D<sub>2</sub>O in air monitoring system is manual. Indication of the sample flow is provided locally.

The heavy water loss is measured by using a cold finger condenser connected to the ventilation duct. This cold finger condenses a sample of water vapour from the ventilation duct. The sample is then analyzed to determine the heavy water concentration. The heavy water flow rate discharged through the ventilation stack is determined by combining the heavy water concentration so obtained with the relative air humidity, the temperature determined with the dry thermometer and the air flow rate circulated in the ventilation duct.

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The air sample is extracted from the ventilation duct by the sample condenser 63864-CD 1, consisting of a glass vacuum trap placed in a thermos flask. This flask contains a small amount of liquid nitrogen, or dry ice. When an air sample enters the vacuum trap, most of the moisture will be precipitated onto the surface of the trap leaving a coating of ice. Once a day the ice is collected and this sample is taken to the laboratory. There it is melted and analyzed for of D<sub>2</sub>O in H<sub>2</sub>O concentration. On very dry winter days the sampling interval could increase, if no frozen sample can be extracted during a period of the day.

On the operator's demand, the following ventilation duct measurements will be displayed in the control room on a CRT and recorded on an hourly log:

- relative humidity;
- temperature;
- air flow;
- pressure.

Annunciation must be initiated and an alarm window should be activated in the main control room whenever Reactor Building ventilation flow is low.

### **V.2.2.3 Containment Atmosphere Monitoring**

There are two assemblies for monitoring the containment radioactivity (one on the ventilation line and one on the D<sub>2</sub>O vapour recovery line), each monitoring three control channels: N, P, Q. An independent detector for radioactivity measurement is provided for each channel. When measuring activity, if any two out of three channels indicate that the radioactivity exceeds the set points, the containment isolation is initiated by automatic closure of the pneumatic valves on the discharge lines, thus preventing radioactive releases into the atmosphere. The containment monitoring system is part of the containment system.

## **V.3 Surveillance of Environmental Factors Quality**

The information presented in this section represent a summary of environment monitoring programs from Cernavoda NPP Unit 1 (Ref.V-5, Ref.V-6).

By implementation of environmental monitoring activities for Unit 2, Unit 3 and Unit 4 into the corresponding program of Unit 1, the necessary data to assess the environment and public impacts, will be obtained, at normal operation of all four nuclear units.

### **V.3.1 Environmental Radioactivity Monitoring Program**

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The environmental radiation monitoring program includes all the activities necessary to determine environmental radioactivity levels and the impact on public health and the environment due to Cernavoda NPP normal operation (Ref.V-5).

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Monitoring program elements are the following:

- routine environmental monitoring program;
- supplementary programs.

### **V.3.1.1 Routine Monitoring Program**

The purpose of routine environmental radiation monitoring program is to provide reliable and accurate data, which comprise statistically valid data sets per radionuclide / sampled media combinations on an annual database.

The monitoring program is designed to meet the following objectives under normal nuclear power plant operating conditions:

- to measure the radionuclide concentrations in environmental media and to assess the increased radiation levels in specified environmental pathways, which might be modified as a result of Cernavoda NPP operation;
- to provide an independent assessment of the effectiveness of the source control, effluent control and monitoring based on measurements in environment;
- to validate the models and parameters used in the calculation of the derived emission limits;
- the results of the routine monitoring program may demonstrate negligible environment impact of Cernavoda NNP operation and hence contribute to public reassurance;
- to provide data to aid in the development and evaluation of models and methodologies that adequately describe the movement of the radionuclides through the environment.

The main components of the monitoring program are the followings:

- a) monitoring locations;
- b) environmental media and specific nuclides to be monitored;
- c) monitoring frequency;
- d) analytical frequency;
- e) minimum detectable specific radioactivity;
- f) assessment of adequacy of source control;
- g) individual dose assessment for population.

There are two types of monitoring locations:

- 1) indicator locations;
- 2) background locations.

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Indicator locations are outside the plant perimeter, and are established depending on emission type, critical groups and pathways considered for Derived Emission Limit (DEL) calculation.

In addition to these locations, a network of TL detector locations will be established around the plant, beyond the exclusion zone.

Since one of the objective of the routine monitoring program is to determine the radiological impact due to plant operation, it is necessary to assess the environmental background levels of radioactivity. The ambient background is primarily due to naturally occurring radioactivity (terrestrial and cosmic) and to a lower degree, from fallout from atmospheric nuclear testing or other nuclear facilities operation.

For this reason, the measurements of ambient background are made beyond the influence of station emissions.

For emissions to air and direct exposure pathway (external irradiation and inhalation) one background location is provided. For water and sediment samples, background locations are different: at Cernavoda - Danube for water and Cernavoda - Bridge for sediments.

For remaining pathways, the background contribution shall be determined by using data from governmental agencies.

The specific radionuclides, the frequency of monitoring, the frequency of analyses are established as a function of the results of the release monitoring program, of the DELs, and of the half-life of radionuclide in an identified pathway.

The frequency of monitoring or sampling is related to the mean lifetime of the nuclide in a pathway.

The minimum detectable specific activity required for each radionuclide pathway, for which DEL were established, is that specific activity or exposure rate which shall result on whole body at a dose of 50  $\mu$ Sv/year above the natural background.

The values of minimum detectable specific activity are used to select sampling equipment, analytical techniques and procedures to be used.

The analytical methods will be selected so that the minimum required detection sensitivity will be carried out.

One of the objective of the routine monitoring program is to verify the control efficiency of the radioactive emissions to the environment due to Cernavoda NPP operation.

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This objective is carried out by comparing the average measured concentrations within environmental with the predicted concentrations. The predicted concentrations are calculated using reported emission data of the plant, and applying the transport methodology, as used to derive the DELs.

The assessment of the adequacy of source control is necessary if:

- a) the concentration (exposure) is statistically different from natural background;
- b) the net concentration is assessed to result in a committed effective dose higher than 50  $\mu$  Sv/a (administrative limit).

Dose assessment for members of the general public will be performed based on the results of liquid and gaseous effluent monitoring program using the specified model in Ref. V-2 for members of the critical group.

The reporting frequency of the results to the Cernavoda NPP management and to CNCAN will be annually. The report will include a summary of the results of measurements performed and radiological impact on the environment due to Cernavoda NPP operation.

In Tables V.3-1, V.3-2 and V.3-3 the following information concerning the components of the routine monitoring program are presented (Ref. V-11):

- type of sampled medium (air, water, soil, vegetables and animal products);
- number of sampling points;
- type of used analysis (gamma spectrometry, beta and tritium analyses);
- frequencies of monitoring for each selected set of radionuclide /pathway;
- minimum detectable value of specific radioactivity.

### **V.3.1.2 Supplementary Programs**

In the event of significant effluent releases (greater than the DEL), the routine monitoring program will ensure an approximate assessment of the doses due to these releases. Meanwhile, supplementary monitoring programs will be implemented, in order to obtain additional data to ensure that dose assessment is adequate.

These programs are not required for any technical reason under normal plant operating conditions. These programs may be initiated to carry out for the following purposes:

- to provide reassurance of the public by responding to its perception of risk;
- to provide adequate dose assessment in the event of a major emission (greater than 100% DEL);
- to validate the models and parameters used in the calculation of the derived emission limits;

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- to provide data to aid in the development and evaluation of models and methodologies that describe the movement of radionuclides through the environment;
- to ensure radionuclide identification and quantitative measurements, when the emissions are greater than 5% DEL, for a certain category of emission, for the following samples types:
  - samples that are measured for global activity;
  - samples from pathways that are not measured for specific radionuclides.

Depending on the purpose, these programs may include:

- sampling from different locations than is provided in the routine environmental radioactivity monitoring program;
- sampling and laboratory analysis performed more often than is provided in the routine monitoring program;
- performing of specific analysis for positive identification of certain radionuclides.

In the case of major radioactivity releases from the plant, supplementary programs will be implemented using the resources and organization established according to the On-Site Radiological Emergency Plan (Ref. V-7).

Table V.3-1 Type of samples and number of sampling points

No.	Type of samples	Number of sampling points
1.	Particulate filters	11
2.	Activated charcoal filters	11
3.	Atmospheric water collectors	11
4.	Surface water	4
5.	Infiltration water (bore holes from DICA, DIDR)	3
6.	Underground water (bore holes with about 700 m depth)	2
7.	Water from Condenser Cooling Water duct	1
8.	Soil	3
9.	Sediment	2
10.	Wet atmospheric deposition	2
11.	Food samples (vegetables/fruits, meat, fish)	3
12.	Milk	1
13.	Ambient gamma	62

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Table V.3-2 Summary of Sampling, Analysis Frequencies and Minimum Required Detectable Specific Activity for Air Samples

Sampling medium	Type of analysis	Minimum detectable required specific activity	Monitoring frequency	Analysis frequency
Particulate in air (filters)	Gamma Spectrometry	$8.6 \times 10^{-2} \text{ Bq/m}^3$ -Cs137 $8.6 \times 10^{-3} \text{ Bq/m}^3$ -Co60 $4 \times 10^{-3} \text{ Bq/m}^3$ -Ru106 $8 \times 10^{-2} \text{ Bq/m}^3$ -Zr95 $3 \times 10^{-2} \text{ Bq/m}^3$ -Nb95 $6.2 \times 10^{-2} \text{ Bq/m}^3$ -Cs134	Continuous	monthly
	Global $\beta$	$1.4 \times 10^{-5} \text{ Bq/m}^3$		
Iodine in air (filters)	Gamma Spectrometry	$1.6 \times 10^{-3} \text{ Bq/m}^3$	Continuous	quarterly
Tritium in air (molecular sieve)	Gamma Spectrometry	$15 \text{ Bq/m}^3$	Continuous	monthly
Noble gases	TLD	44 mR/a	Continuous	quarterly

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Table V.3-3 Summary of Sampling, Analysis Frequencies and Minimum Required Detectable Specific Activity for other Types of Samples than Air

Sampling medium	Type of analysis	Minimum detectable required specific activity	Sampling frequency	Analysis frequency
Milk	Tritium (LSC)	4.1 x 10 <sup>2</sup> Bq/l	weekly	weekly
	Carbon – 14 (LSC)	30 Bq/l		
	Gamma spectrometry	1.6 Bq/l Cs137 8 x 10 <sup>-2</sup> Bq/l I131 1.5 Bq/l Ru106 6.5 x 10 <sup>-1</sup> Bq/l Co60 1.3 Bq/l Cs134 1.9 x 10 <sup>-1</sup> Bq/l Zr95 4 Bq/l Nb95		
	β global	0.1 Bq/l*		
Surface water	Tritium (LSC)	350 Bq/l	Twice a week, monthly for Valea Cismeiei samples	Monthly
	β global	0.2 Bq/l *		
	Gamma spectrometry	0.5 Bq/l Cs137 1.0 Bq/l Ru106 0.4 Bq/l Co60 0.35 Bq/l Cs134 8.0 Bq/l Zr95 0.5 Bq/l Nb95		

\* Based on Sr-90 calculation

LSC - Liquid scintillation counter

TLD - thermal luminescent detector

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Table V.3-3 Summary of Sampling, Analysis Frequencies and Minimum Required Detectable Specific Activity for other Types of Samples than Air (continued)

Sampling medium	Type of analysis	Minimum detectable required specific activity	Sampling frequency	Analysis frequency
Underground water	Tritium (LSC)	350 Bq/l	monthly	monthly
	β global	0.2 Bq/l *		
	Gamma spectrometry	0.5 Bq/l Cs137 1.0 Bq/l Ru106 0.4 Bq/l Co60 0.35 Bq/l Cs134 8.0 Bq/l Zr95 0.5 Bq/l Nb95		
Infiltration water	Tritium (LSC)	350 Bq/l	monthly	monthly
	β global	0.2 Bq/l *		
	Gamma spectrometry	0.5 Bq/l Cs137 1.0 Bq/l Ru106 0.4 Bq/l Co60 0.35 Bq/l Cs134 8.0 Bq/l Zr95 0.5 Bq/l Nb95		

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Table V.3-3 Summary of Sampling, Analysis Frequencies and Minimum Required Detectable Specific Activity for other Types of Samples than Air (continued)

Sampling medium	Type of analysis	Minimum detectable required specific activity	Sampling frequency	Analysis frequency
Fish	Gamma spectrometry	36 Bq/kg Cs137 68.4 Bq/kg Ru106 28.8 Bq/kg Co60 25.2 Bq/kg Cs134 561.6 Bq/kg Zr95 331.2 Bq/kg Nb95	annual	annual
	β global	14 Bq/kg*		
	Tritium (LSC)	2.5 x 10 <sup>4</sup> Bq/kg		
	Carbon-14(LSC)	1.1 x 10 <sup>3</sup> Bq/kg		
Vegetables-Fruits	Gamma spectrometry	1.3 Bq/kg Cs137 2.5 Bq/kg Ru106 1.0 Bq/kg Co60 0.9 Bq/kg Cs134 20 Bq/kg Zr95 12 Bq/kg Nb95	annual	annual
	β global	0.5 Bq/kg*		
	Carbon-14(LSC)	46 Bq/kg		
	Tritium (LSC)	9 x 10 <sup>2</sup> Bq/kg		

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Table V.3-3 Summary of Sampling, Analysis Frequencies and Minimum Required Detectable Specific Activity for other Types of Samples than Air (continued)

Sampling medium	Type of analysis	Minimum detectable required specific activity	Sampling frequency	Analysis frequency
Sediment	Gamma spectrometry	1 x 10 <sup>3</sup> Bq/m <sup>2</sup> Cs137 23 x 10 <sup>3</sup> Bq/m <sup>2</sup> Ru106 2.7 x 10 <sup>2</sup> Bq/m <sup>2</sup> Co60 4 x 10 <sup>2</sup> Bq/m <sup>2</sup> Cs134 2.6 x 10 <sup>2</sup> Bq/m <sup>2</sup> Zr95 8 x 10 <sup>2</sup> Bq/m <sup>2</sup> Nb95	twice a year	twice a year
	β global	89 Bq/m <sup>2*</sup>		
Depositions	Gamma spectrometry	N/A	continuous	monthly
	β global	N/A		
Soil	Gamma spectrometry	1 x 10 <sup>3</sup> Bq/m <sup>2</sup> Cs137 23 x 10 <sup>3</sup> Bq/m <sup>2</sup> Ru106 2.7 x 10 <sup>2</sup> Bq/m <sup>2</sup> Co60 4 x 10 <sup>2</sup> Bq/m <sup>2</sup> Cs134 2.6 x 10 <sup>2</sup> Bq/m <sup>2</sup> Zr95 8 x 10 <sup>2</sup> Bq/m <sup>2</sup> Nb95	twice a year	twice a year
	β global	89 Bq/m <sup>2*</sup>		

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Table V.3-3 Summary of Sampling, Analysis Frequencies and Minimum Required Detectable Specific Activity for other Types of Samples than Air (continued)

Sampling medium	Type of analysis	Minimum detectable required specific activity	Sampling frequency	Analysis frequency
Meat	Gamma spectrometry	4.1 Bq/kg Cs137 7.9 Bq/kg Ru106 3.4 Bq/kg Co60 2.8 Bq/kg Cs134 65 Bq/kg Zr95 38 Bq/kg Nb95	annual	annual
	β global	1.6 Bq/kg*		
	Tritium (LSC)	2870 Bq/kg		
	Carbon-14(LSC)	113 Bq/kg		

\* Based on Sr-90 calculation

LSC - Liquid scintillation counter

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### **V.3.2 Inactive Environmental Monitoring Program**

The inactive environmental monitoring program includes the necessary activities to accomplish the requirements of in force environmental regulations (Ref. V-4).

Monitoring program elements are the followings:

- routine monitoring program;
- supplementary program.

The main non-radiological effects on the environment may occur as a result of the cooling water discharge from the plant, into the Old Danube Branch or to the Danube Black Sea Channel.

The other consequences of units 3 and 4 operation are locally and much smaller. The discharges shall be monitored like with Units 1 and 2 or jointly.

#### **V.3.2.1 Routine Monitoring Program**

The routine monitoring program has the main components:

- a) Temperature Monitoring;
- b) Chemicals;
- c) Monitoring frequency;
- d) Sampling points;
- e) Liquid influent/effluent chemical control;
- f) Non-radiological monitoring program assessment.

By the agreement RAAR Constanta – Cernavoda NPP Unit 1, the sampling points are the followings:

- for influent - Cernavoda NPP bridge;
  - Danube (Hinog Drinking Water Station)
- for effluent - Seimeni bridge, if the discharge are made to Danube
  - NPP bridge, if the discharge is made to the Danube Black Sea Channel

The monitoring frequency and the monitoring chemicals well be established in Water Management License.

The analytical methods that will be used to analyze liquid influent/effluent samples should be chosen such as to ensure:

- procedure range must cover the approved chemical discharge limit;

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- detection limit must be lower than approved chemical discharge limit for that chemical;

The discharge limits are established by the Water Management License, on basis of the present standards and impact studies.

The assessment consists, of analyzing, usually on monthly bases, of the following aspects:

- the accomplishment of the requirements of environmental regulations and Water Management License in effect;
- the implementation of the new adequate preventive and controlling measures, if are necessary, to reduce as much as possible the negative impact with environment;
- choosing of operation mode such to ensure a decreasing of amount of chemicals discharged in the environment.

Table V.3-4 present the analyzed indicators, sections and sampling frequencies within Cernavoda NPP-U1

### **V.3.2.2 Supplementary Programs**

These programs are initiated to be implemented in case of:

- accidentally chemical spill (leakage);
- work plan involving chemical releases (for ex: maintenance, chemical conditioning, etc), in order to reduce as much as possible the negative impact on environment.

The main components of the supplementary monitoring program are the followings:

#### a) Chemicals

In case of accidentally chemical spill, the chemical identification and his quantitative analysis must be performed.

#### b) Monitoring frequency

For a effluent with a non-routine releasing, the frequency will be established by Chemical Department in a such way to ensure the release control until chemical parameters will be in specification (under approved discharge limit).

#### c) Sampling points

The sampling points must be chosen such to ensure representative samples for discharged water quality.

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d) Liquid influent/effluent chemical control

The chemical control will be performed until chemical parameters will be in specification (under approved discharge limit).

e) Measures in case of chemical spill

In case of accidentally chemical spill is necessary to proceed:

- an identification and an adequate assessment of the quantity of chemicals discharged in environment;
- the adequate measures must be taken to reduce as much as possible the negative impact on environment.

f) Chemical monitoring program assessment

The evaluation consists of analyzing of the following aspects:

- the chemical spill root-causes;
- the magnitude of impact to environment;
- the taken measures to reduce as much as possible the negative impact on environment;
- the implementation of the new adequate preventive and controlling measures to reduce as much as possible the negative impact on environment.

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Table V.3-4 Analyzed indicators, sampling sections and frequencies

No.	INDICATOR	SAMPLING SECTION	FREQUENCY
1.	Suspended solids	Danube (HINOG)	monthly
		NPP bridge	weekly
		Seimeni bridge / CPPON bridge	weekly
2.	Ph	Danube (HINOG)	monthly
		NPP bridge	weekly
		Seimeni bridge / CPPON bridge	weekly
3.	Ammonia (only when is used for the chemical conditioning with NH <sub>2</sub> OH solution)	Danube (HINOG)	monthly
		NPP bridge	weekly
		Seimeni bridge / CPPON bridge	weekly
4.	Hydrazine	Danube (HINOG)	-
		NPP bridge	-
		Seimeni bridge / CPPON bridge	weekly
5.	Morpholine	Danube (HINOG)	-
		NPP bridge	-
		Seimeni bridge / CPPON bridge	weekly
6.	Oils	Danube (HINOG)	monthly
		NPP bridge	weekly
		Seimeni bridge / CPPON bridge	weekly
7.	Petroleum products	Danube (HINOG)	-
		NPP bridge	weekly
		Seimeni bridge / CPPON bridge/ CP 26I	weekly
8.	Iron, total ionic	Danube (HINOG)	monthly
		NPP bridge	weekly
		Seimeni bridge / CPPON bridge	weekly
9.	Cyclohexylamine	Danube (HINOG)	-
		NPP bridge	-
		Seimeni bridge / CPPON bridge	weekly
10.	Lithium	Danube (HINOG)	-
		NPP bridge	-
		Seimeni bridge / CPPON bridge	weekly
11.	Sodium	Danube (HINOG)	monthly
		NPP bridge	monthly
		Seimeni bridge / CPPON bridge	monthly
12.	Chloride	Danube (HINOG)	monthly
		NPP bridge	monthly
		Seimeni bridge / CPPON bridge	monthly
13.	Calcium	Danube (HINOG)	monthly
		NPP bridge	monthly
		Seimeni bridge / CPPON bridge	monthly
14.	Nitrites	Danube (HINOG)	-
		NPP bridge	-
		Seimeni bridge / CPPON bridge	weekly
15.	Ethylene Glycol	Danube (HINOG)	-
		NPP bridge	-
		Seimeni bridge / CPPON bridge	monthly
16.	Fluorescein (only when is used)	Danube (HINOG)	-
		NPP bridge	-
		Seimeni bridge / CPPON bridge	2/monthly
		Danube (HINOG)	-

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<b>No.</b>	<b>INDICATOR</b>	<b>SAMPLING SECTION</b>	<b>FREQUENCY</b>
17.	Rhodamine (only when is used)	NPP bridge	-
		Seimeni bridge / CPPON bridge	2/monthly
18.	Biomate 5716	Danube (HINOG)	-
		NPP bridge	-
		Seimeni bridge / CPPON bridge	It is determinated only when is used (during the treatment process)
19.	Biocide MB- 25	Danube (HINOG)	-
		NPP bridge	-
		Seimeni bridge	It is determinated only when is used (during the treatment process)
20.	Sulfate	Danube (HINOG)	monthly
		NPP bridge	monthly
		Seimeni bridge / CPPON bridge	monthly
21.	Magnesium	Danube (HINOG)	monthly
		NPP bridge	monthly
		Seimeni bridge / CPPON bridge	monthly
22.	BOD <sub>5</sub>	Danube (HINOG)	monthly
		NPP bridge	monthly
		Seimeni bridge / CPPON bridge	monthly
23.	Chemical substances mixture (every component it is analyzed in accordance with the point of view mentioned above)		

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## References

- V-1 Order CNCAN No. 276 /26.09.2005 on Approval Norms Radioactive Emission Monitoring to the Nuclear and Radiological Facilities
- V-2 RD-01364-RP4, Rev.2, Derived Emissions Limits for Cernavoda NPP
- V-3 SI-01365-RP6, Rev.3, Liquid and Gaseous Effluent Monitoring Program
- V-4 Order CNCAN No. 275 /26.09.2005 on Approval Norms for the Environmental Monitoring in the Near of a Nuclear or Radiological Facilities
- V-5 RD-01364-RP7, Rev.3, Environmental Monitoring Program for Cernavoda NPP
- V-6 RD-01364-CH2, Rev.1, Environmental Non-active Chemical Monitoring Program
- V-7 RD-01364-RP8, Rev.1, Emergency Radiological Plan on Site
- V-8 82-67882-6003-TS, Rev.0, Technical Specification for Liquid Effluent Monitor
- V-9 82-67883-6002-TS, Rev.0, Technical Specification for Gaseous Effluent Monitor
- V-10 82-63864-6100-DM, Rev.0, NPP Cernavoda Unit 2, D<sub>2</sub>O in Air Monitoring System
- V-11 Cernavoda NPP Unit 2, Final Safety Report, 2005

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## GLOSSARY OF ACRONYMS

AA	Adjuster Assembly
AC	Alternative Current
AECL	Atomic Energy of Canada Limited
ALARA	As Low As Reasonable Achievable
ASDV	Atmospheric Steam Discharge Valves
ASME	The American Society of Mechanical Engineers
BAFW	Boiler Auxiliary Feedwater
BMW	Boiler Make-up Water
BOP	Balance of Plant
BSL	Baltic Sea Level
CANDU	CANadian Deuterium Uranium
CCANCOC	Central Commission for Nuclear Accident and Cosmic Objects Falling-up
CCW	Circulating Cooling Water Supply
CNCAN	National Commission for Control of Nuclear Activities
CNSC	Canadian Nuclear Safety Commission (successor to AECB)
CPPON	Training Personnel Center
CSAN	Nuclear Auxiliary Service Building
CWS	Chilled Water System
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DBSC(CDMN)	Danube Black Sea Channel
DC	Direct Current
DCS	Distributed Control System
DFDSMA	Final Disposal Facility for Low and Intermediate Level Waste
DICA	Spent Fuel Interim Storage Facility
DIDR	Solid Radioactive Waste Interim Storage Facility
DNM	Delayed Neutron Monitoring
EC	European Commission
ECCS	Emergency Core Cooling System
EDTA	Ethylene Diamine Tetra-acetic Acid
EHC	Electro-hydraulic Control
EPS	Emergency Power Supply
ESCS	End Shield Cooling System
EWS	Emergency Water Supply
F/M	Fueling Machine
FHS	Fuel Handling System
GEM	Gaseous Effluent Monitoring
GFM	Gaseous Fission Products Monitoring
HP	High Pressure
HVAC	Heating, Venting and Air Conditioning
I & C	Instrumentation and Control

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IAEA	International Atomic Energy Agency
ICRP	International Commission of Radiation Protection
ISCIR	Romanian Inspection Authority for Boilers, Pressures Vessels and Lifting Devices
	The National Institute of Research and Development for Environmental Protection
ICIM	Environmental Protection
LAC	Local Air Cooling
LOCA	Loss of Coolant Accident
LOCLIV	Loss Of Class IV
LOHS	Loss of Heat Sinks Secondary Sides
LOR	Loss of Regulation
LOSD	Loss Of Shut Down
LP	Low Pressure
LRV	Liquid Relief Valve
LZC	Liquid Zone Control
MCA	Mechanical Control Absorber
MCR	Main Control Room
MMS	Main Moderator System
MP	Medium Pressure
MSLB	Main Steam Line Break
MSSV	Main Steam Safety Valves
NDB	Non-Design Basis Event
NPP	Nuclear Power Plant
NRSN	Romanian Republican Nuclear Safety Norms
NSN	Nuclear Safety Norms
NSP	Nuclear Steam Part
PDC	Programmable Digital Controllers
PHTS	Primary Heat Transport System
PHWR	Pressurized Heavy Water Reactor
PLIAS	Post-LOCA Instrument Air Supply
PSA	Probabilistic Safety Assessment
QAV	Quick Acting Valves
R/B	Reactor Building
RCW	Recirculating Cooling Water
RRS	Reactor Regulating System
RSW	Raw Water Service
S/B	Service Building
SCA	Secondary Control Area
SDCS	Shutdown Cooling System
SDG	Standby Diesel Generator
SDS#1	Shutdown System No. 1
SDS#2	Shutdown System No. 2

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SFB	Spent Fuel Bay
SG	Steam Generators
SNN	National Company "Nuclearelectrica" Ltd
STA	Water Chemical Treatment Plant
STP	Start Up Thermal Plant
TNT	Trinitrotoluene