VISIT OF THE EDF NUCLEAR POWER PLANT OF CIVAUX

A visit of the nuclear power plant of Civaux is organized on **Friday morning October 3, 2008**.

The power station is located at 33km in the south-east of Poitiers. A transport by bus will be organized.
The number of visitors will be limited to 32. The preference will be given to the authors.

*The registration deadline for the visit is **July 16, 2008**.*

Each visitor will have to fill out an information sheet beforehand.
More precise information will be notified to the registered visitors in due course.

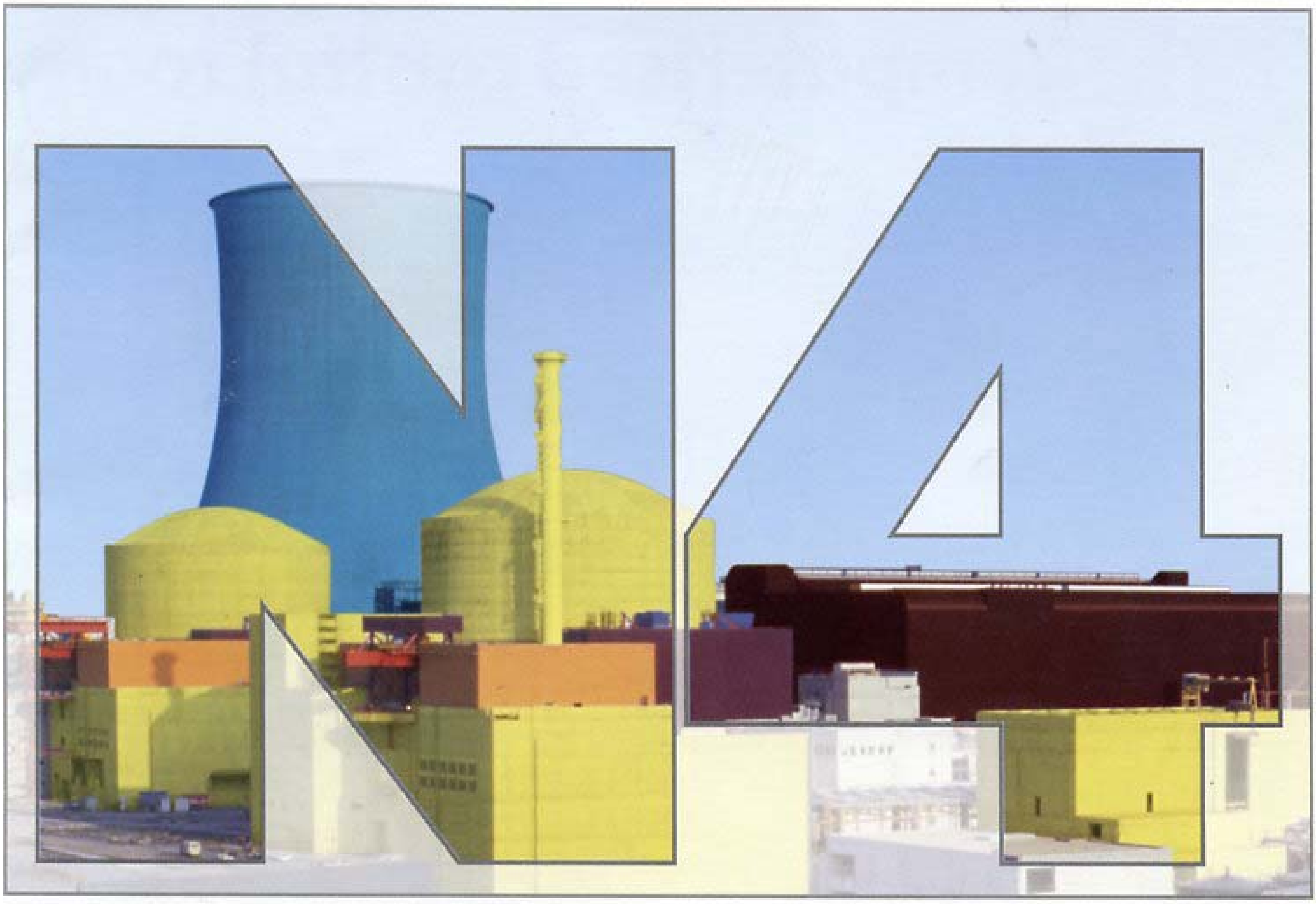
VISITE DE LA CENTRALE NUCLEAIRE EDF DE CIVAUX

Une visite de la centrale nucléaire de Civaux est organisée **le vendredi matin 3 octobre 2008.**

La centrale est situées à 33km au sud est de Poitiers. Un transport en autobus sera organisé.
Le nombre de visiteurs sera limité à 32. La préférence sera donnée aux auteurs.

*La date limite d'inscription à cette visite est le **16 juillet 2008.***

Chaque visiteur devra remplir préalablement une fiche de renseignements.
Des informations plus précises seront communiquées ultérieurement aux visiteurs inscrits.



nuclear power plants 1450 MW

The French nuclear power plant programme was launched in 1970 and subsequently stepped up in 1974 after the first oil crisis. Today, 75% of the electricity produced in France is generated by nuclear power plants. Consequently, the rate of France's energy independence has risen to over 50%, despite the lack of natural resources in the country.

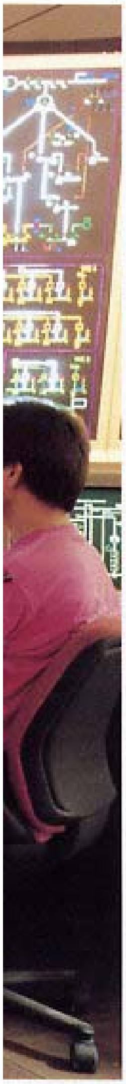
The six hundred reactor-years of experience acquired from French nuclear power plants have made it possible to upgrade safety and plant performance over the years.

Electricité de France is now commissioning the N4, a new series of 1,450 MW plants of entirely French design. This technological series takes advantage of all the experience acquired in the operation of the preceding 900 and 1,300 MW series. It is the most advanced of its generation and incorporates major technological innovations, mainly a fully computerised control room and a newly designed turbine, more efficient and compact.

EDF

The computerised control room

1. ID scanner
2. Four alarm screens
3. Alarm dialogue keyboard
4. Command dialogue keyboard
5. Three control screens
6. Track-ball
7. Touch-sensitive screens for operation, monitoring and display management
8. Alphanumeric display
9. Alphanumeric keyboard



Electricité de France's new control room concept for the N4 aims to improve safety and efficiency of control in every situation using:

- ***improved data quality, thus reducing the burden on the operator,***
- ***a very efficient alarm processing system,***
- ***reliable and relevant presentation of information,***
- ***and diagnosis assistance.***

Main features

Electricité de France and Sema Group have designed an integrated digital information and control system providing:

Sit-down operation:
all information required to monitor and operate the unit is at the operator's fingertips.

Information and operation consistency:
human/machine interface has the same features regardless of the unit's condition (normal operation, incident, or accident).

Integrated plant management:
links between operation and technical management systems improve the control of the unit.

High-level reliability:
advanced software engineering technology provides maximum system integrity.

Durability:
both software and hardware architectures are designed to allow for numerous developments.

A stuctured architecture

The unit control system is divided into four levels:

Level 3 Remote and local technical management systems
Level 2 Human/machine interface (computerised and conventional)
Level 1 Instrumentation and Control
Level 0 Actuators and sensors.

Level 2 uses the Sema Group's high-availability local area network, ARLIC.

Safety elements of levels 0, 1, and 2 are organised in two physically separate channels A and B so that either channel can run the entire unit independently.

Four identical operator workstations are in the Control Room and a basic workstation is in the Crisis Room.

The main control processors which operate the unit including in critical situations, are 32 bits machines in a redundant configuration.

The communication processors act both as data concentrators and data servers.

For diversification purposes, redundant conventional systems in a stand-by mode are also included.

A diversified control room

The control room includes:

- four identical workstations for operation,
- one active mimic wall diagram giving an overall view of the unit's status,
- one conventional auxiliary control panel to be used as backup for the computerised control system,
- conventional emergency instrumentation.

Control principles

- Choice of operating display formats
- Selection of an item using a track-ball – the operating menu appears on a touch-sensitive screen
- Selection of a command by checking the appropriate item on the screen
- Confirmation of the command by pressing a validation key
- Display of the command history on screen
- Update of the graphic presentation on screen

A newly designed turbine

In the turbine hall, where electricity is generated for transmission on the French national grid, the generator is driven by the world's most powerful steam turbine named «Arabelle». Its exceptional performance is the result of the following innovations:

Optimised architecture

The major innovation characterising this new turbine is its steam flow arrangement. Instead of the steam being subdivided into partial flows on entering the turbine, it is kept in a single flow until the pressure reaches around 3.3 bar.

This principle appears clearly in the layout of the turbine. It consists of a combined HP-IP cylinder containing two steam paths. The HP single flow steam path is opposed by the IP flow path which receives steam from the moisture separator-reheaters and expands it until it enters the LP cylinders.

By subdividing the flows only beyond the lowest practicable point in the expansion, the number of expansion states requiring more than one row of blading is minimised. Thus, the turbine is simpler and lighter.

More efficient

Various aerodynamic features such as HP and IP partial extraction diffusers, high recovery LP diffusers, supersonic profiles for the last LP blades, more single-flow states, have all contributed to the 2% overall improvement in efficiency.

To realise the true importance of this result, it should be interpreted in economic terms. By capitalising the extra energy that *Arabelle* produces over its depreciation period, the equivalent value is more than half the price of the machine.

A simpler, lighter machine

In addition to the reduction in the number of rows of blades resulting from the use of a single flow, second generation turbines also use longer LP last blading (1,450 mm / 4 ft. 9 1/16 in.). Thus, the steam passage area of the end stage is larger. This leads to the reduction in the number of exhausts of LP flows.

In comparing with the 1,300 MW units (which would have to be converted to 1,500 MW), ***Arabelle*** is 12% lighter and 7 m (22 ft. 11 9/16 in.) shorter.

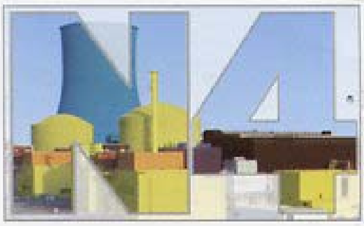
Lighter civil engineering

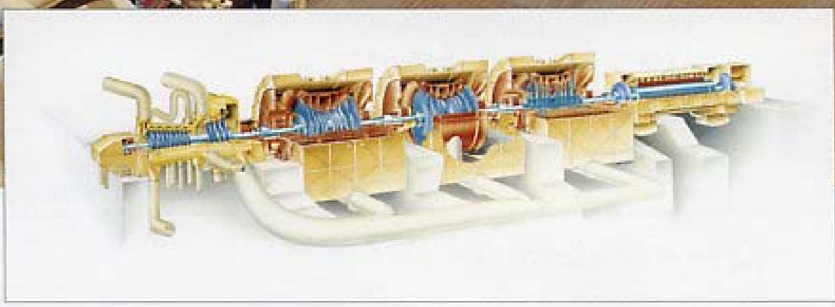
A new method of construction called «independent exhaust hood» is used for the stator part the LP cylinders. It eliminates all permanent and variable reactions of the condenser on the turbine and its foundation. As a result the overall structure is lighter and the machine is less sensitive to vacuum variations.

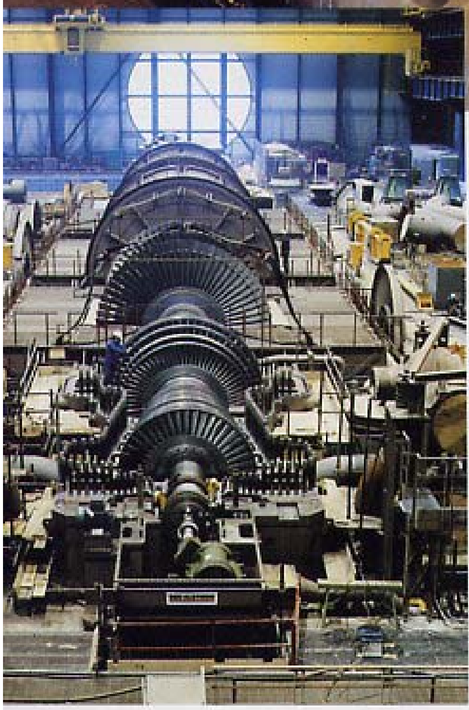
Other aspects help to simplify the civil engineering of the machine hall, such as the reduced length of the turbines and the rearrangement of the reheat steam valves around the HP-IP cylinders.

Greater reliability

Along with other improvements, a new type of control valve was developed with the benefit of full-scale experiments on a turbine of a 900 MW unit. There are also LP cylinders with an independent exhaust hood which eliminate mechanical disturbances caused by variations in vacuum, and LP last blades continuously linked by fins which decrease vibratory stresses.







The Arabelle Turbine – Specifications

1 High Pressure - Intermediate Pressure cylinder (HP - IP)
3 Low Pressure cylinders (LP)
Steam specifications:

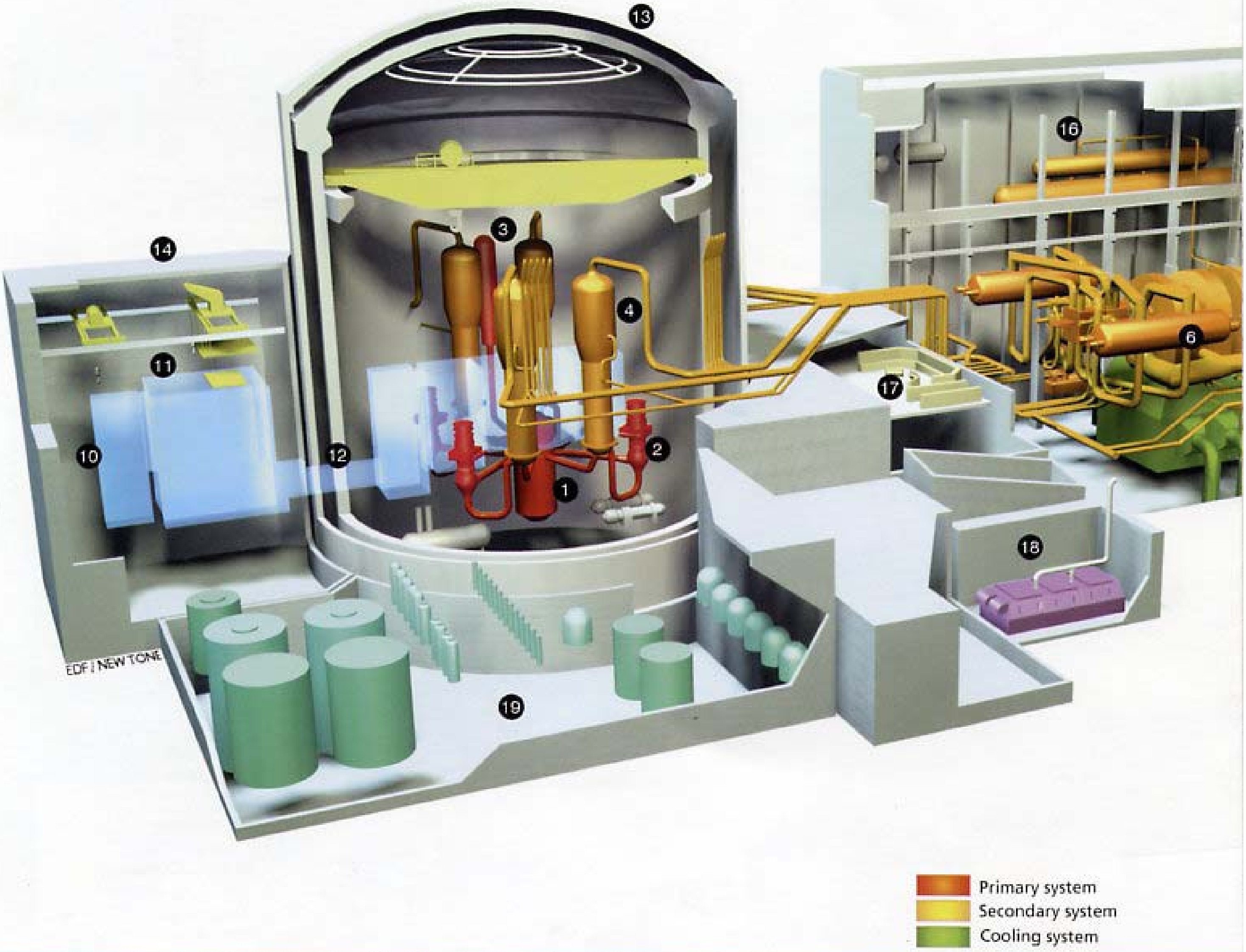
- HP cylinder inlet : 71 bar T = 286.7°C Flow = 2,176 kg/s
- IP cylinder inlet: 10.05 bar T = 268.3°C Flow = 1,482 kg/s
- LP cylinder inlet: 3.2 bar T = 151.04°C Flow = 460 kg/s

The turbine is installed on a concrete base, 16.6 meters (54 ft. 5 1/2 in.) off the floor.

- Weight of the rotational elements: 620 tonnes
- Ø last wheel IP: 4.15 meters (13 ft. 7 5/16 in.)
- Combination turbine generator: 68.77 meters (225 ft. 7 7/16 in.)
- Rotational speed: 1,500 rpm
- Electrical output: 1,520 MW

Cold start-up: 3 hours 40 minutes - Hot start-up: 1 hour 50 minutes
In a one minute time span, 50 additional MW can be supplied to meet higher demand.

THE 1450 MW NUCLEAR POWER PLANT



❶ Reactor vessel

- Height including pressure vessel head: 13.66 m (44 ft. 9 3/4 in.)
- Diameter: 4.65 m (15 ft. 3 in.)
- Thickness: 23 cm (9 1/16 in.)
- Vessel weight: 342.7 tonnes
- Vessel head weight: 84.8 tonnes
- Inlet temperature: 292°C
- Outlet temperature: 329°C
- Pressure: 155.1 bar

❷ Primary pump (X 4)

- Height: 8.50 m (27 ft. 10 9/16 in.)
- Weight: 116 tonnes
- Speed: 1,485 rpm
- Flow rate: 24,500 m^3/h
- Temperature: 292°C
- Delivery head: 106 mCE
- Electric engine power: 9,590 kW - 6.6 kV

❸ Pressuriser

- Outer diameter: 2.80 m (9 ft. 2 3/16 in.)
- Thickness: 13 cm (5 1/8 in.)
- Height: 13.536 m (44 ft. 4 13/16 in.)
- No-load weight: 117 tonnes

❹ Steam generator (X 4)

- Height: 21.90 m (71 ft. 10 3/16 in.)
- Upper diameter: 4.76 m (15 ft. 7 5/16 in.)
- Lower diameter: 3.70 m (12 ft. 1 9/16 in.)
- Weight: 421 tonnes

❺ Arabelle Turbine

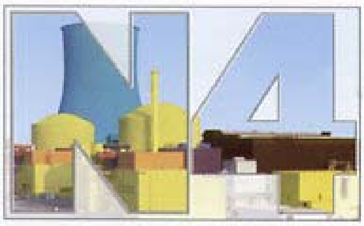
- Length: 51.205 m (167 ft. 11 15/16 in.)
- Width: 12.80 m (41 ft. 11 7/8 in.)
- Weight: 2,810 tonnes

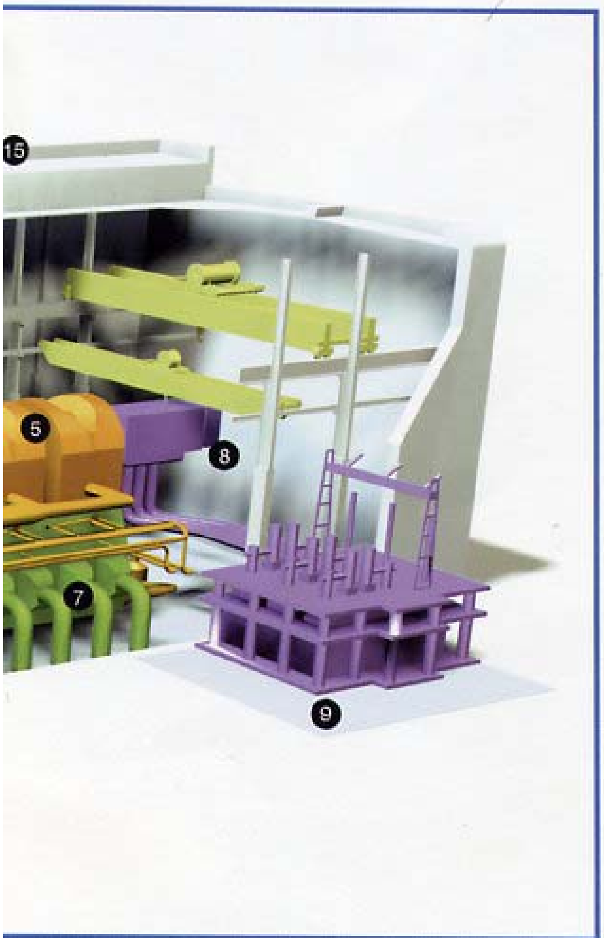
❻ Moisture separator-reheater (X 2)

- Length: 24.80 m (81 ft. 4 5/16 in.)
- Diameter: 4.70 m (15 ft. 4 15/16 in.)
- Weight: 370 tonnes
- Temperature: 180°C
- Pressure: 10 bar

❼ Condenser

- Length: 37.10 m (121 ft. 8 1/2 in.)
- Width: 21.50 m (129 ft. 1 13/16 in.)
- Height: 15.49 m (50 ft. 9 13/16 in.)
- No-load weight: 1,893 tonnes
- Number of tubes: 128,856
- Heat exchange area: 103,227 m^2
- Cooling water flow rate: 48.35 m^3/s





8 Generator

- Length: 17.57 m (57 ft. 7 11/16 in.)
- Stator diameter: 4.15 m (13 ft. 7 5/16 in.)
- Rotor diameter: 1.95 m (6 ft. 4 13/16 in.)
- Rotor weight: 230 tonnes
- Stator weight: 505 tonnes
- Generator output: 1,710 MVA
- Current: 49,363 A
- Voltage: 20,000 V
- Rotation speed: 1,500 rpm

9 Main transformer

- Weight: 840 tonnes
- Output: 1,710 MVA
- Length: 11 m (36 ft. 15/16 in.)
- Width: 6 m (19 ft. 8 3/16 in.)
- Height: 8.40 m (27 ft. 6 5/8 in.)

10 Loading pit

- Length: 4.50 m (14 ft. 9 1/8 in.)
- Width: 2.60 m (8 ft. 6 3/8 in.)
- Depth: 13 m (42 ft. 7 13/16 in.)
- Volume: 152 m^3

11 Spent fuel pit

- 612 cells
- Normal water temperature: 50°C
- Unloading water temperature: 60°C
- Cooling water flow rate: 380 m^3/h
- Length: 12.50 m (41 ft. 1/8 in.)
- Width: 7.50 m (24 ft. 7 5/16 in.)
- Depth: 14.30 m (46 ft. 10 15/16 in.)

Fuel assembly:

- Section: 214 X 214 mm (8 7/16 in. X 8 7/16 in.)
- Height: 4.793 m (15 ft. 8 11/16 in.)
- Weight: 780 Kg
- 264 fuel rods
- Fuel rod diameter: 8.17 mm (5/16 in.)

12 Fuel transfer tube

- Length: 7 m (22 ft. 11 1/2 in.)
- Inside diameter: 0.50 m (19 11/16 in.)

13 Reactor building

Containment building - outside:

- Diameter: 50.90 m (166 ft. 11 7/8 in.)
- Height: 63.18 m (207 ft. 3 3/8 in.)
- Wall thickness: 0.55 m (21 2/3 in.)

Containment building - inside :

- Diameter: 43.80 m (143 ft. 8 3/8 in.)
- Height: 59.85 m (196 ft. 4 3/16 in.)
- Wall thickness: 1.20 m (3 ft. 11 3/16 in.)

14 Fuel building

- Height: 38.25 m (125 ft. 5 7/8 in.)
- Width: 26.4 m (86 ft. 7 5/16 in.)
- Length: 28 m (91 ft. 10 5/16 in.)

15 Turbine hall

- Height: 50 m (164 ft. 1/2 in.)
- Width: 65 m (213 ft. 3 in.)
- Length: 120 m (393 ft. 8 3/8 in.)

16 Feedwater tank and deaerator

Feedwater tank:

- Length: 45.50 m (149 ft. 3 1/4 in.)
- Diameter: 4.20 m (13 ft. 9 1/4 in.)
- Weight: 235 tonnes
- Volume: 600 m^3
- Temperature: 207°C
- Pressure: 18 bar

Deaerator:

- Length: 32.60 m (106 ft. 11 3/8 in.)
- Diameter: 3 m (9 ft. 10 1/16 in.)
- Weight: 113 tonnes

17 Control room

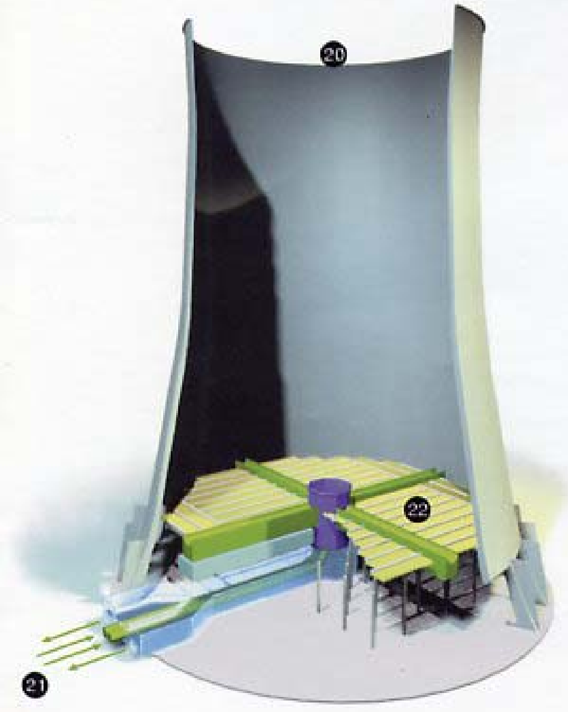
- Height: 3.20 m (10 ft. 5 7/8 in.)
- Width: 11.40 m (37 ft. 4 13/16 in.)
- Length: 15 m (49 ft. 2 1/2 in.)

18 Diesel generator building

- Length: 9.50 m (31 ft. 1 15/16 in.)
- Diesel engine weight: 104 tonnes
- Generator weight: 39 tonnes
- Electric power: 7,500 kW
- Voltage: 6.6 kV

19 Waste auxiliary building

- Primary and gaseous waste
- Boric acid storage
- Volumetric and chemical monitoring



The cooling tower

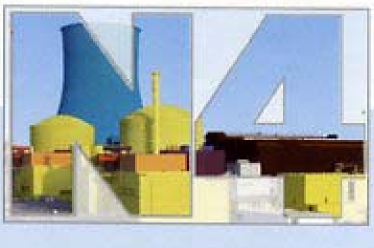
20 Cooling tower

- Shell diameter at the base: 134.45 m (441 ft. 1 3/16 in.)
- Diameter at the top: 87.83 m (288 ft. 1 13/16 in.)
- Air intake height: 14.10 m (46 ft. 3 in.)
- Total height: 172 m (564 ft. 3 5/8 in.)
- Thickness of the shell : 1.71 m (5 ft. 7 5/16 in.) at the base to 0.27m (10 5/8 in.) at the top

21 Cooling water intake / discharge

22 Water / air exchange area

- Water flow to be cooled: 174,000 m^3/h (48.35 m^3/s)
- Hot water temperature (inlet): 35°C
- Cooled water temperature: 21.5°C
- Water loss due to evaporation: 0.75 m^3/s (or 1.5%)



The most advanced plant in the world

At the cutting-edge – the newest generation of nuclear reactors

• Advanced in terms of level of safety

The N4 incorporates into its design the most far-reaching operating experience in the world. It reflects the knowledge accumulated from France's 54 standardised PWR units managed by a single operator, namely Electricité de France. It also takes into account feedback from nuclear facilities worldwide and lessons learned from the Three Mile Island accident.

• Advanced in terms of technology

The N4 implements state-of-the-art technology in the field of metallurgy, the most advanced ideas in nuclear core neutronics, and the most impressive technical innovations in the Arabelle turbine – more efficient, more compact.

• Advanced especially in terms of its Instrumentation and Control

Unique in the world, a bona fide "computer-assisted operation" system

All the conditions that can exist during power plant operation have been included and loaded into the computers. The computers give the operator diagnoses in real-time of actual situations in the power plant and relay the most appropriate procedures to be applied.

This modern control system design, whose principle is also being put into use in the aviation industry, is possible only through an in depth knowledge of power plant operations. Thus, every minute detail is taken into account for the diagnosis of the reactor's condition and the unit's operating procedures.

Technically speaking, the N4 is highly advanced compared to all the other nuclear power plants commissioned prior to Chooz B1, the first unit of this new series. The safety of the design and operation of the N4 can be advantageously compared to the advanced reactors of the new generation, while no plants in this category have yet been built and none are even under construction.

The N4 is the result of extensive experience in France where nuclear power has proven to be the safest way to produce electricity, the most cost-effective and the most environmentally friendly.

Four N4-level units will be commissioned from 1995 to 1998: two at Chooz in Northern France near Belgium, and two at Civaux in Western France.

The N4 is the result of 600 reactor-years of operating experience

Since 1977, every incident and every detail in the operation of Electricité de France's nuclear units have been recorded, resulting in the publication of a report and a thorough technical analysis. The results are used to make further improvements in the safety and operation of existing plants. But even more, they are the basis for designing the systems, equipment and operating methods for the power plants of the future. Without this operation feedback, it would have been impossible to develop the N4's Instrumentation and Control system for instance.

To date, the N4 is the most impressive result of Electricité de France's engineering and operating expertise in the field of nuclear pressurised water reactors, an experience acquired over more than thirty years.

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