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"PRACTICE FOR THE UPGRADING OF TRINO VERCELLESE NPP: TECHNICAL AND ECONOMICAL ASPECTS"

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ABSTRACT

In this report the experience gained in seismic re-evaluation of an old NPP (Trino Vercellese) is described.

This PWR plant was not seismically designed.

The main purpose of the upgrading, from the point of view of the Italian Directorate for Nuclear Safety - ENEA/DISP, was to have guaranteed the plant capability of achieving and mantaining a safe cold shutdown condition after a SSE seismic event.

The main steps of the seismic review are discussed:

- definition of the new input motion;
- selection of structures, systems and components essential for a safe cold shutdown;
- definition of Codes and evaluation methods;
- seismic qualification of systems and components.

Finally some modifications of a number of plant systems are described together with economical aspects.

INTRODUCTION

The main purpose of the TRINO VERCELLESE E. FERMI nuclear power plant re-evaluation was to demonstrate the plant capability of achieving and mantaining a safe cold shutdown condition, after a SSE seismic event was initiated while the plant was at normal 100% full power condition (1), (2).

The seismic re-evaluation was performed through two distinct phases.

The phase I was addressed chiefly to identify the structures, systems and components to be qualified and to determine criteria and methodology to be adopted.

The phase II consisted of

- detailed design of the measures to be taken;
- supplies of components and component supports;
- implementation of modifications.

In other words the phase I concerned the execution of static and dynamic analyses of systems and components and relative supports and anchorages, while the phase II was constituted by the design of measures and improvements to be taken, to assure the seismic adequacy of the reactor coolant system, auxiliary systems, electrical and instrumentation components and systems.

A seismic evaluation was performed on all the safety-related plant buildings and on all the structures, systems and components needed to bring and to keep the reactor in a safe cold shutdown condition.

The plant functions to be preserved during the SSE seismic event were identified in the following ones:

1) The reactor shutdown;
2) The pressure boundary integrity;
3) The electrical power availability;
4) The control instrumentation integrity and operability.

1. REVISION CRITERIA FOR CIVIL STRUCTURES

With reference to the international position, concerning the seismic qualification of nuclear power plants, a particular attention was given to the methodologies and criteria adopted in the United States in performing the seismic evaluation of old nuclear power plant of the same generation of TRINO VERCELLESE nuclear power plant, such as San Onofre 1 - Diablo Canyon, Robert Ginna and Yanke Rowe nuclear power plants (3), (4).

The reference seismic input to be used was defined essentially on a historical basis and in a prudential way, in order to qualify safety-related structures, systems and components in front of updated safety standards.

The historical seismic data provided to determine the maximum postulated seismic event for TRINO VERCELLESE site as an earthquake having VII degree M.C.S. (MERCALLI - CANCANI - SIEBERG) intensity and return periods much longer than 1000 years.

Moreover it was believed adequate to consider the Newmark response spectra, in conformance with NRC R.G. 1.60 (5) and corresponding to the maximum horizontal ground acceleration of 0.1 g.

The most significant aspects considered in the analyses of civil structures were the following ones:

1) MATHEMATICAL MODELING

The structures were modeled with the finite element method implemented on SAP - Structural Analysis Program Computer Code (6).

2) SOIL-STRUCTURE INTERACTION

The soil structure effect was considered and soil parameters were obtained by the formulas of LAMBE and WHITMAN with the 50% embedment reduction effect as recommended by NEWMARK.

3) DYNAMIC ANALYSIS METHOD

A modal analysis was adopted with the response spectra method. Modal dampings were obtained by the weighted average of the involved elastic energies, limiting the resulting damping to 10% of the critical damping.

Final stresses and displacements were calculated by SSRS of modal contributions (7).

4) LOAD COMBINATION

The earthquake horizontal components were considered each contemporary of the earthquake vertical component.

Moreover the 33% of the live loads were considered acting at the same time.

5) REINFORCED CONCRETE CROSS SECTION CHECK

On this item the reference document was ACI 318-71, adopting the ultimate stress design method.

It is worth noting, however, that the overall seismic review of TRINO NPP has been exclusively conducted in reference to criteria congruent with the plant age and according to procedure already applied in USA similar plants. In this context no incremental factors of allowable limits has been taken into account, although it is well known that international research programs like "Safety Margin Research Programm" (SMRP) and "NRC Systematic Evaluation Program" (SEP) claim for the existence of "Strength Reserve" originated by:

- actual damping of structures and components generally higher than the ones assumed in the analytical calculations (8);
- broadening of the applied response spectra (9);
- typical conservativism of the envelop FRS;
- stress criteria;
- actual mechanical properties of materials;
- relatively high margins exist both in definitions of seismic imput and in combinations of seismic response in each directions;
- finally, ductile behaviour of structures, supports and components is generally underexstimated.

Besides actions for systems some interventions that have been performed on buildings are (Fig. 1, Fig. 2):

Fuel Building:

1) Introduction of reinforced concrete walls in substitution of existing curtain walls.
2) Stiffening of many beams using steel sections fastened by Hilty anchors.
3) The typical thickness of walls is about 20 cm with a rebars arrangement of ϕ 16/25x25 cm T&B.

Engine Building:

1) Realization of 25 cm thick concrete wall (ϕ20/25x25 cm) connected to existing curtain wall by ϕ 30 bars.
2) Strengthening of crane beams by steel plates connected with epossidic resins.

Auxiliary Building:

Realization of two 50 cm thick concrete wall (ϕ20/25x25 cm), substituting the existing masonry walls.

Fans Hall:

1) Strengthening of the existing steel roofing by means of metallic bracings connected to existing beams and columns.
2) Fixing of simply supported principal roof beams by means of metallic ties to the existing columns.

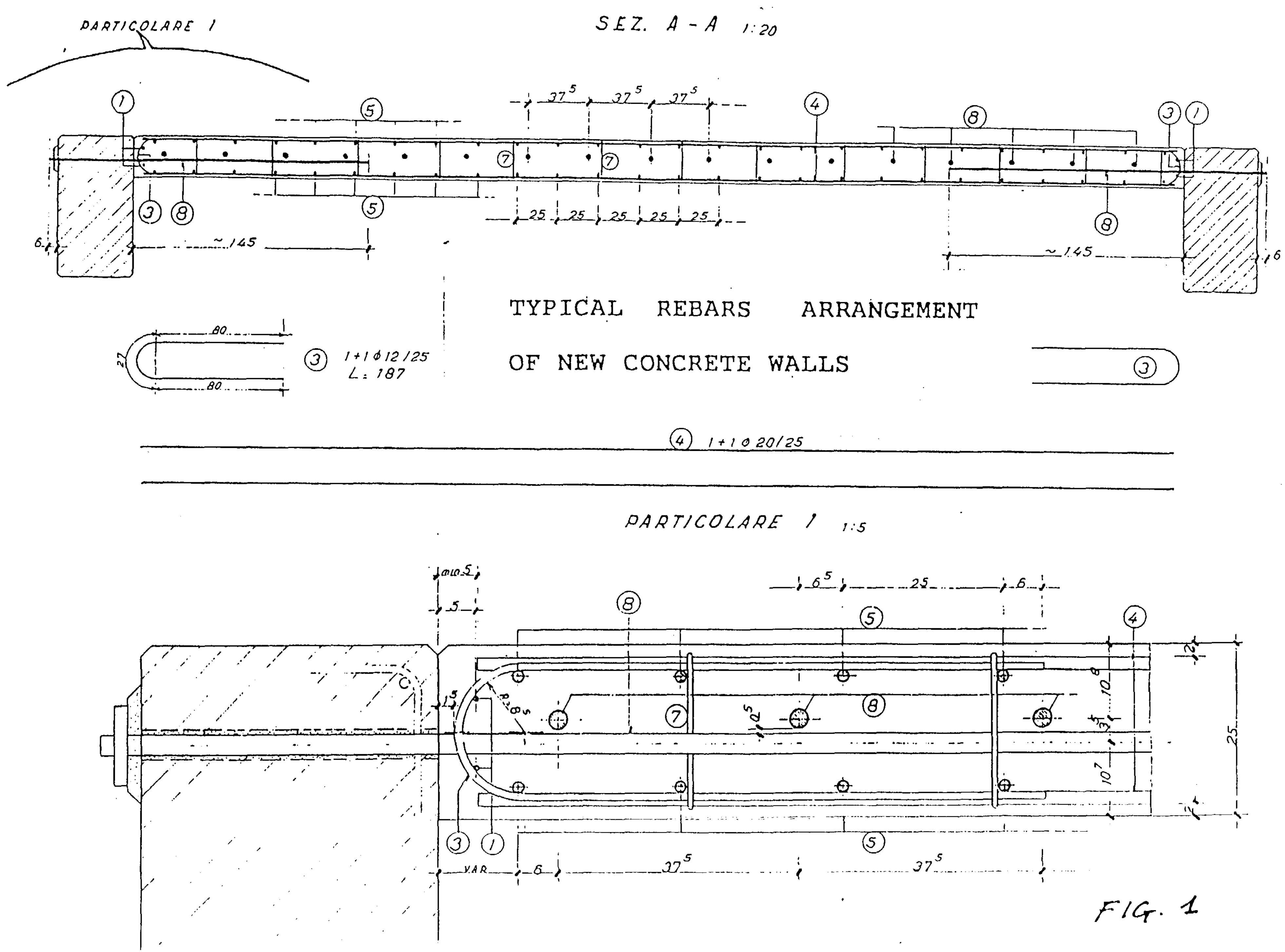
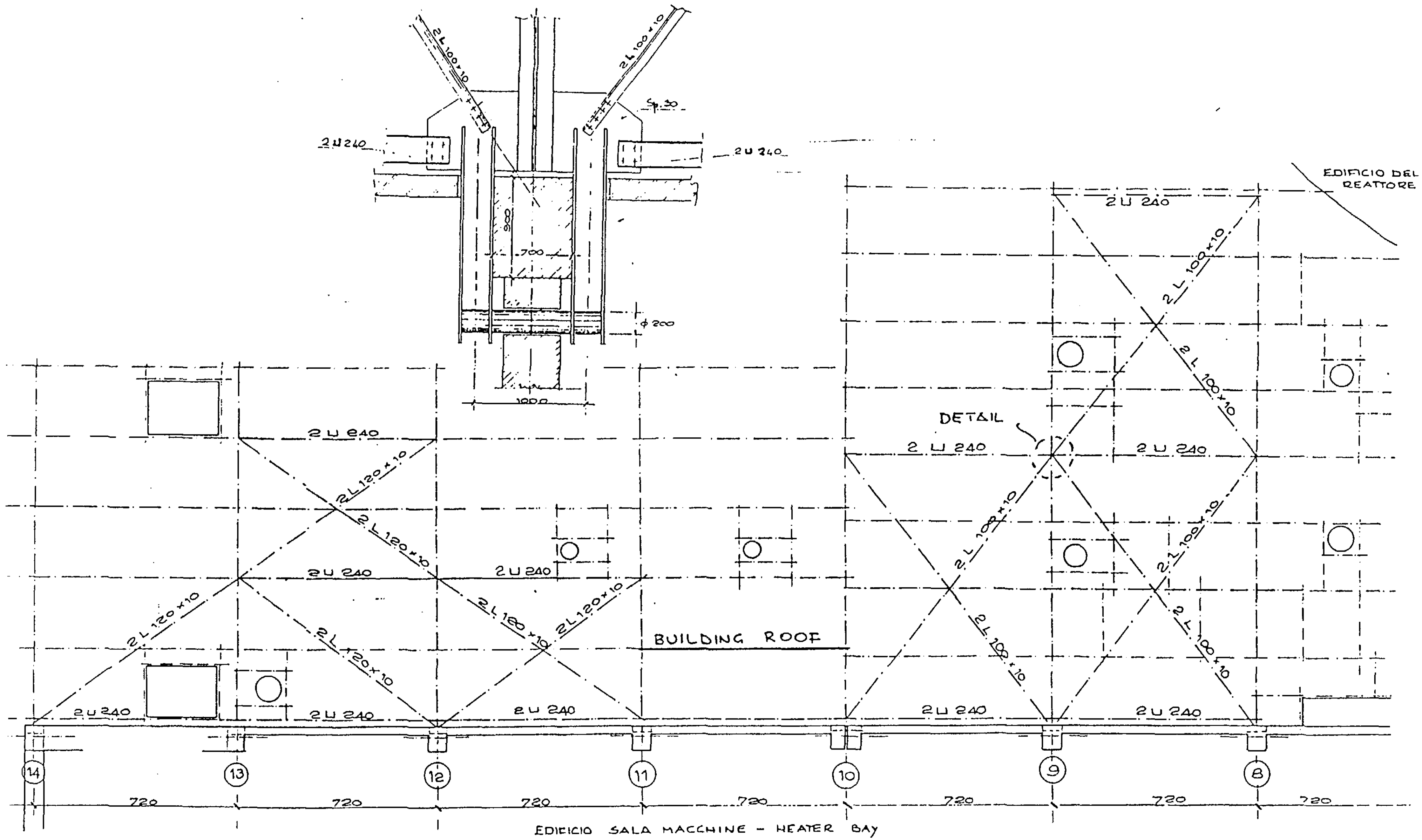

PARTICOLARE 1
SEZ. A - A 1:20
~145
TYPICAL REBARS ARRANGEMENT
OF NEW CONCRETE WALLS
1+1 ϕ 12/25
L: 187
1+1 ϕ 20/25
PARTICOLARE 1 1:5
VAR

FIG. 1



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TYPICAL BRACINGS OF FANS BUILDING.

FIG. 2

2. MECHANICAL AND ELECTRICAL SYSTEMS

The general procedure to define the acceptance criteria of the mechanical and electrical systems is as follows:

- for the Reactor Coolant System Components (Reactor Pressure Vessel, Steam Generators, Pressurizer and Primary Pumps) load conditions, the ASME III - App. F (10) is taken as a reference for the faulted conditions;
- the Reactor Coolant Loop Piping has been qualified according to "ANSI B.31.1" (11);
- the Reactor Coolant Loop supports have been qualified according to AISC Specifications (12);
- the Auxiliary Piping Systems have been qualified according to acceptance criteria of already cited ANSI and with the related Summer Addenda '73.

All the fluid systems which are considered necessary to safely withstand the postulated condition of the Safe Shutdown Earthquake while the plant is a normal 100 percent full power operating condition, were going to be qualified.

For each system which must be qualified, safety functions that the system shall ensure during a Safe Shutdown Earthquake must be pointed out in order to define systems boundaries to be seismic qualified.

Boundaries between systems/components which need to be dinamically qualified were located as follows:

- at a "normally closed" valve location;
- at "a check valve location" which closes the pressure boundary;
- at "a normally open" valve having (or will have) an automatic actuation;
- on a pipe location having no valves, but on which an isolation valve was installed.

The seismic re-qualification for the electrical equipment has been performed according to the SQUG (Seismic Qualification Utility Group) method (1982) with EPRI data base (3), (4).

The basis for the SQUG Program is to determine the realistic seismic hazard to the equipment installations of NPP, based primarily on the experience of conventional facilities with comparable installations in past earthquakes.

On this base, the seismic analysis of control panels, cable trays, motor-operated valves, distribution panels, batteries racks, etc. has been executed with the punctual purpose to verify the adequacy of Structural Support and to calculate deformations in order to avoid the possibility of interruption of power supply during and after the seismic event.

Generally the measures to be taken concerned the following points:

1) in most cases the existing support systems required reinforcement of the old supports or their replacement or the addition of new and more resisting supports. Moreover sometimes it was necessary to introduce rigid restraints and snubbers (Table 1, Fig. 3, Fig. 4);
2) support anchorages often were modified or stiffened by the adoption of concrete expansion bolts or stronger welds (Table 2, Table 3).

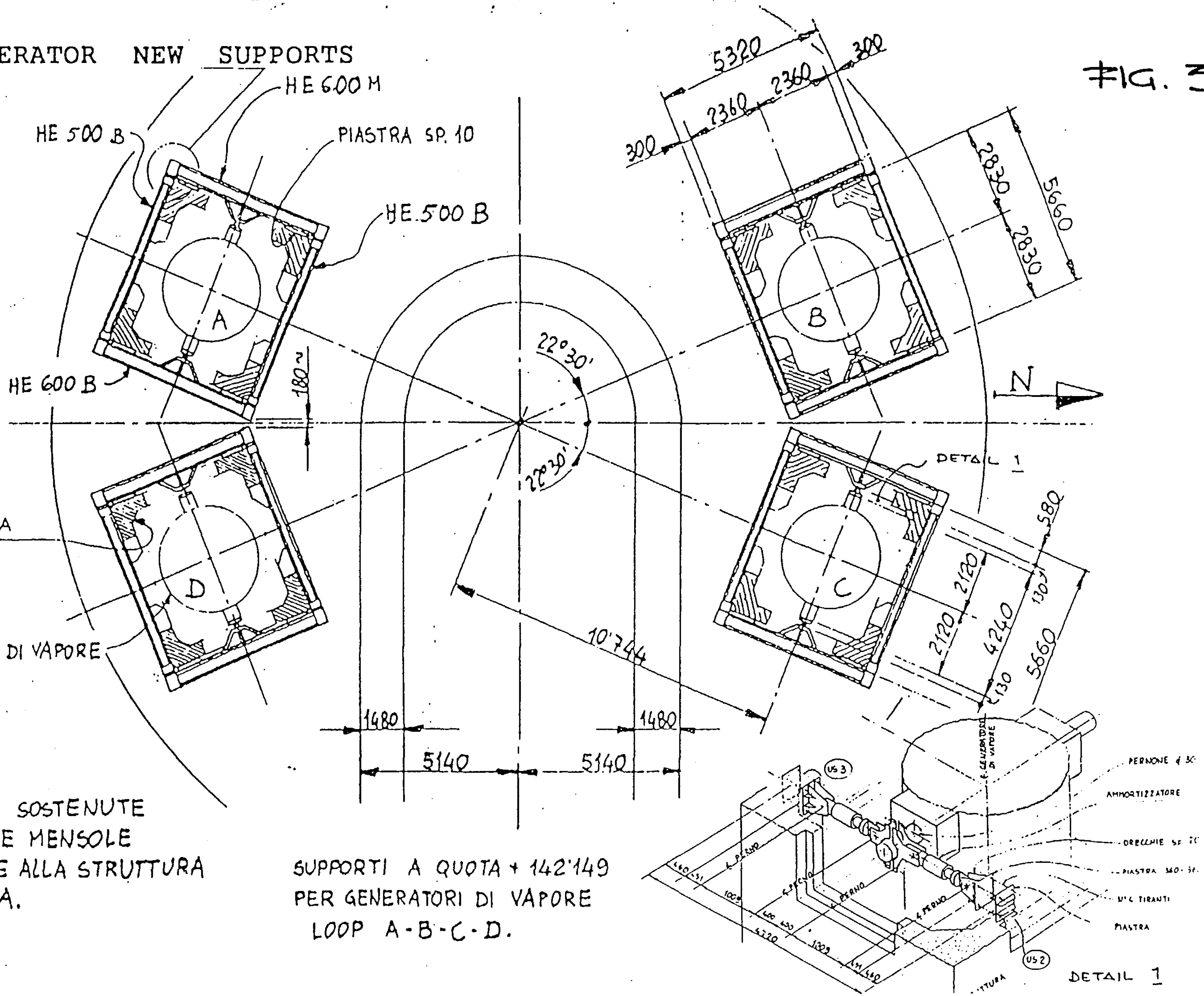
S Y S T E M S

	SUPPORTS TO BE MODIFIED	NEW SUPPORTS
Main steam System	26	8
Main Feedwater System	36	34
Emergency Feedwater System		4 (snubbers)
Emergency Core Cooling System	14	20
Decay Heat Removal System	23	13
i) Intermediate Heat Exchanger (203/A/B/C)	Reinforcement of existing anchorages	
ii) Penetrations C3 e C17	Stiffenings of plates and sleeves	
Surge Line	2	2
Pressurizer Spray System	10	16 (9 snubbers are included)
Chemical Shutdown System	11	0
i) Shutdown Tank	4 lateral supports	
ii) Service Chemical Shutdown Heater		2
Pressurizer Safety and Relief	8	12
Neutron Shield System	4	14
i) Neutron Shield Surge Tank	Modification of existing anchorages	
Component Cooling System	33	116 (3 snubbers are included)
i) Surge Tank	Replacement of anchor bolts	
ii) Intermediate Cooling Water Pump (pompe 431-9A/9B/9C)	" " " "	
Service Water System	1	9
i) Service water cooling (exchangers 1/2/3)	Reinforcement of base plinthas	
Demineralized Water System	4	8
Auxiliary Feedwater System		2
Raw Water System	9	38
i) Raw Water Heat Exchangers (204 A, B,C)	Support on the nozzles	
ii) Booster pump ventilation (N1A e N1B)	Replacement concrete anchor bolts	
iii) Raw water vertical pump (1A, 1B, 1C)	Replacement of bolts of connection to guide tube	
Spray system	10	40
Instrument Air System	Stiffening of existing support system	
i) Expansion tank (inside containment)		
Charging Volume Control System	50	14
i) Surge Tank	Reinforcement of supports	
Feed and bleed heat exchanger	Replacement of anchor bolts.	

TAB. 1

STEAM GENERATOR NEW SUPPORTS

FIG. 3



NB. TRAVI SOSTENUTE
TRAMITE MENSOLE
FISSATE ALLA STRUTTURA
IN C.A.

SUPPORTI A QUOTA + 142'149
PER GENERATORI DI VAPORE
LOOP A-B-C-D.

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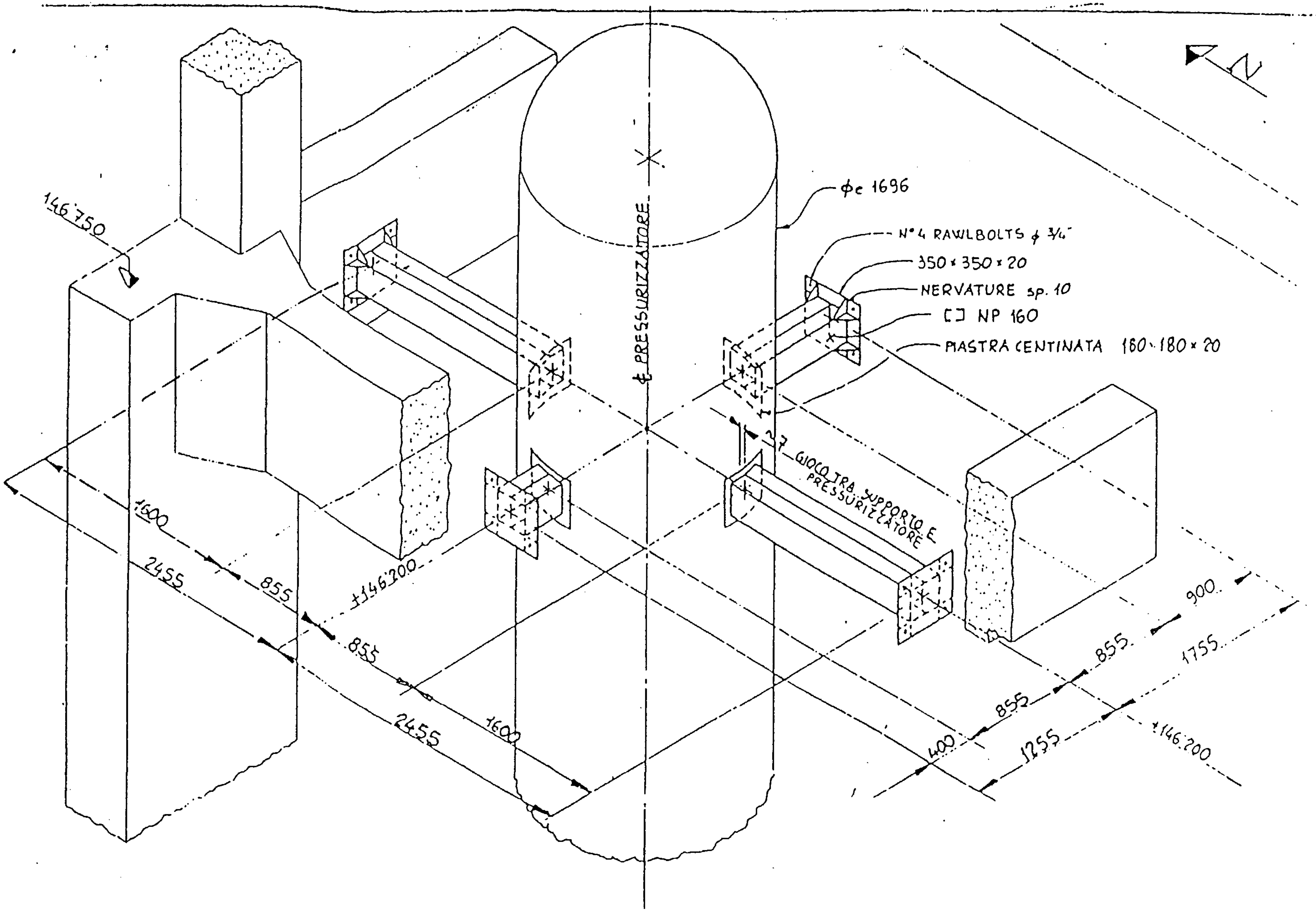

PRESSURIZER NEW SUPPORTS

SUPPORTI A QUOTA +146.200
PER PRESSURIZZATORE

FIG. 4

ELECTRICAL CABINETS, DESKS AND PANELS

COMPONENT	MODIFICATION
CABINETS P2 - P3 - P4 - P10	Anchorages to the floor
CABINETS P5 - P21 - P21A	Anchorages to the floor
CABINETS P11 - P12 - P13 - P14 - P15	Anchorages to the floor
PANEL MCC 1 B2E/1A MCC 12 B2E/1A	Anchorages to the floor and fastening drawers to the panels
PANEL INVERTER/DIVERTER	Anchorages to the floor
PANEL MCCA	Anchorage to the floor
PANEL MCC 1 B2E/1 MCC 1 B2E/2	Anchorage to the floor
BATTERY CHARGER 1A AND 1B PANEL	Anchorage to the floor
UNIMETA 12 B1E - 1B1E PANEL	Anchorage to the floor
BORON TRACER PLANT PANEL	Anchorage to the floor
RACKS P6A - P6B - P6C - P6D - P6E - P1	Anchorages to the floor and door locking device
DESKS B1 - B2 - B3 - B4 - B5	Anchorage to the floor

TAB. 2

CABLE TRAYS

SUPPORT SYSTEM	MODIFICATION
Under Control Room	
S 135 (cantilever)	To stiffen with an oblique structural member
Pump Room	
S 99 (cantilever)	To stiffen with an oblique structural member
Engine Room	
S 64	To insert a fastening structural member
S 67	To insert a structural member
S 92 - S 92 A	To insert 16 new Saddles

TAB. 3

3. ORGANIZATION OF THE ACTIVITY FOR SEISMIC QUALIFICATION OF STRUCTURES, SYSTEMS AND COMPONENTS

The seismic analysis concerns the evaluation of the capability of Nuclear Power Plant (NPP) to safely withstand the postulated condition of the Safe Shutdown Earthquake while the plant is at normal 100 percent full power operating condition.

Specifically all the activities are divided into two phases strongly connected, as illustrated in the next figures.

The seismic analysis of systems and components was performed with the Floor Response Spectra obtained by seismic analysis of corresponding buildings.

Moreover in the Phase 1 the verifications of anchor points of seismic qualified components and pipings were included (Fig. 5).

On the basis of obtained results in the Phase 1, the next step, called Phase 2, will be organized so to avoid interference with the normal service of the NPP (Fig. 6).

PHASE 1 ORGANIZATION FLOW CHART

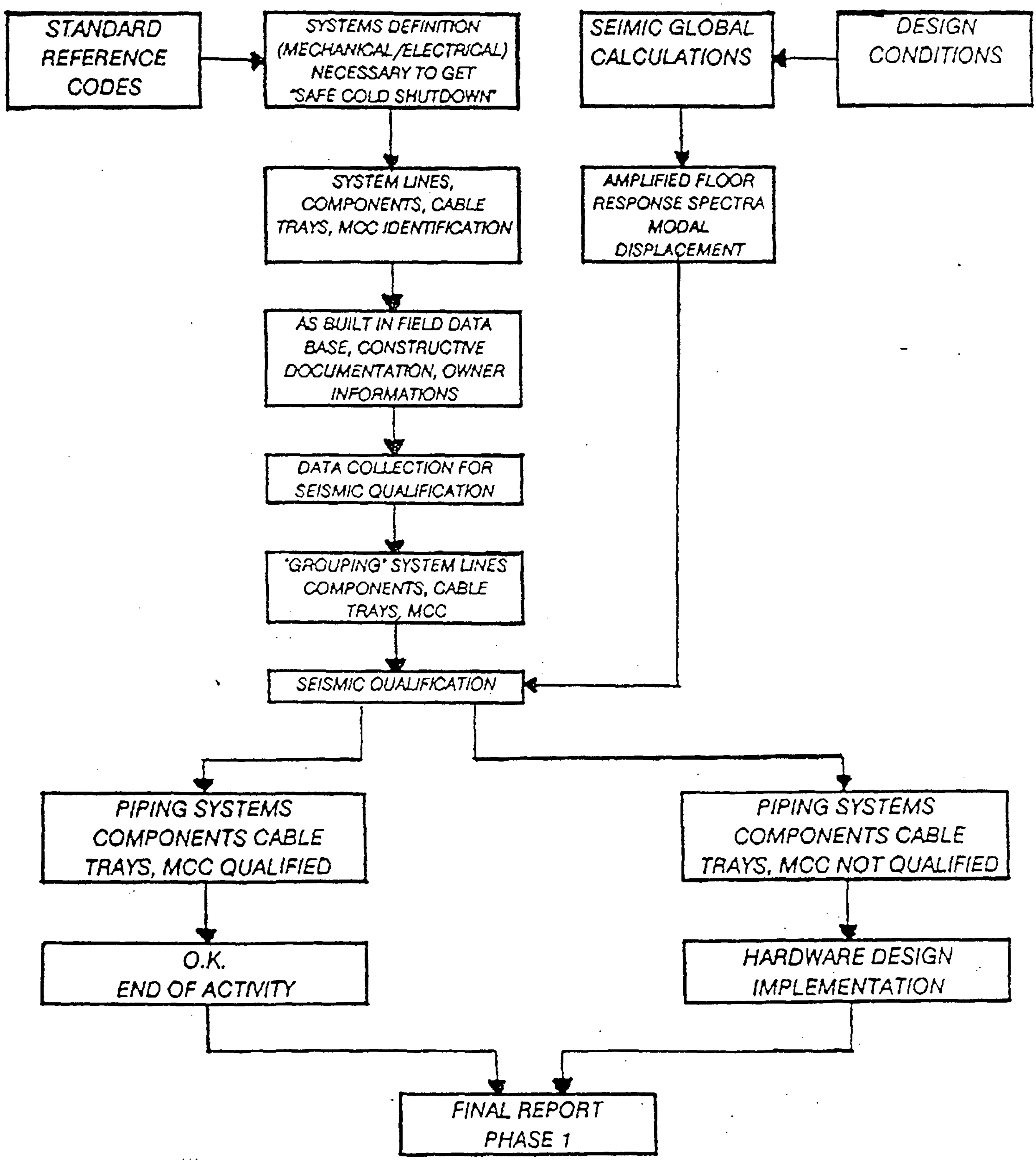

FIG. 5

PHASE 2 ORGANIZATION FLOW CHART

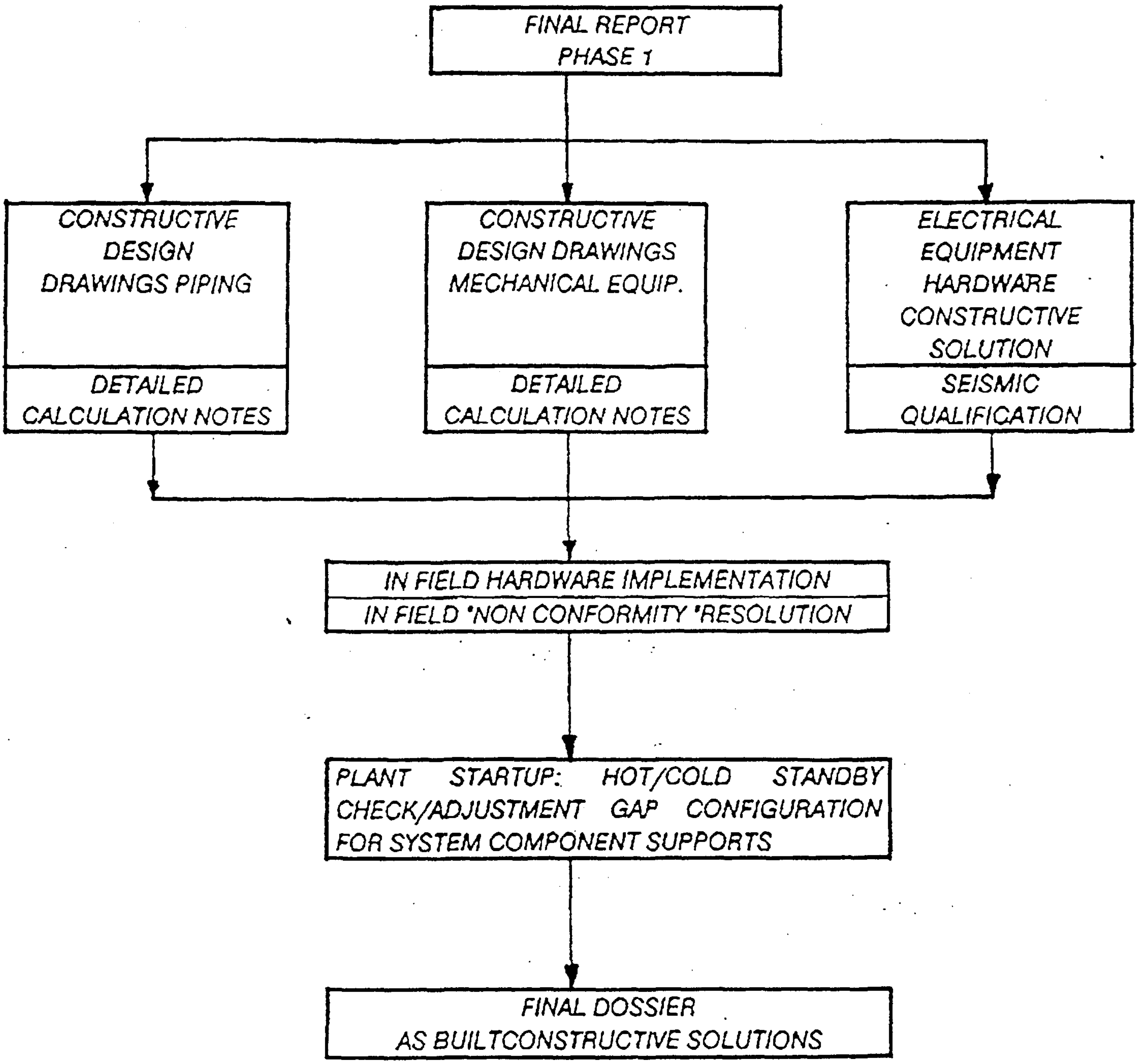

FIG. 6

4. ECONOMIC COSTS

We believe that, in this kind of intervention, the examination of economic costs should be carefully conducted.

The knowledge of relative percentage of costs of each taken measure and their typology for the Pressurized 270 MWe TRINO V. NPP can be very useful in the case of similar future works. The global costs of Main Contractor (Ansaldo SpA-Genova (Italy)) comprehensive of Engineering, Procurement, field activity and plant restart can be presumably shared as follows:

1)	Civil Works (Upgrading of Bunker Diesel, Generators, and New Constructions, Resolution of Reactor Building)	10%
2)	Primary pumps upgrading	5%
3)	Steam Generator Supports	5%
4)	Fluid systems piping and supports (Upgrading comprehensive of procurements and field activity)	5%
5)	HVAC Control Room	10%
6)	Fire protection upgrading	3%
7)	Electrical Equipment (mainly Control Room)	7%
8)	RPV engineering upgrading	5%
9)	RCL " "	5%
10)	Auxiliary Components	10%
11)	Instrumentation (SQUG Method) Upgrading	5%
12)	Revision of the snubbers and support thermal gaps after start-up	5%
13)	Pressurizer upgrading	5%
14)	Phase I Engineering cost	10%
15)	Phase II " "	5%
16)	Indirect costs (project management)	5%
		100%

The global costs referred to years 1983-1985 was estimated to be about 100 billions lire (about 50 million dollars).

5. FINAL REMARKS

Following the results of the overall analysis required for the seismic upgrading of the TRINO V. NPP it can be stated that with a reasonable number of interventions the plant is capable to achieve and maintain a safe cold shutdown condition after a SSE seismic event. The typology of the taken measures was demonstrated to be in accordance with the international operating experience on the failures and consequences occurred at nuclear stations and industrial installations.

Analyses showed that the typical interventions were as follows:

- support modifications to the Steam Generator;
- support modifications to the Primary Pumps;
- support modifications to the Pressurizer;
- strengthening of supports on some auxiliary lines;
- realization of new anchorage systems to floor for electrical equipments.

In most cases the primary reasons leading to the modification were large diplacements of not adequately restrained or completely unrestrained large components.

To give an idea of the magnitude of the taken measures it can be said that on about eight hundred existing supports on reactor coolant system piping and components and on auxiliary systems the 74% of them resulted to be adequate without any modification. The 26% of them had to be redesigned and about 350 new supports had to be added.

ENEA/DISP, the Italian regulatory body believes that the reference standards (ASME CODE Section III Subsection NF - 1980 edition) (10) used for stiffening, modifying or adding supports and anchorages are quite adequate for the importance of the measures to be taken.

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