4.1.2 - General Remarks

The different stages of construction have to be considered, as well as the different operation stages.

The erection procedures for the structure has to be carefully studied to define the appropriate erection loads.

The loads resulting from erection of components are indicated in load drawings for each particular case.

4.1.3 - Dead Loads (D)

4.1.3.1 - Structural Loads (Ds)

The loads due to all structural elements and related materials shall be taken into account, concerning all stages of erection of concrete elements, structural steel, flooring, roofing, siding, staircaises. They shall also include the temporary structural elements needed during erection of components.

4.1.3.2 - Components (Dc)

4.1.3.2.1 - Turbine Building

The load of components will be specified by amount and location in the load drawings. The turbine table will be supported on springs and so no dynamic effects have to be considered, since the spring support leads to a complete dynamical separation between turbine table and structure.

4.1.3.2.2 - Electrical Building

The load of components will be specified by amount and location in the load drawings.

4.1.3.3 - Earth pressure (De)

4.1.3.3.1 - Statical Earth Pressure

The calculation of the statical earth pressure is based on the theory of Coulomb

For the frequent case of a vertical wall and a horizontal soil surface, the following pressure coefficients are assumed:

- angle of internal friction of the soil Ø = 35
- active earth pressure
  - angle of friction between wall and soil S = +1/2 Ø
  - coefficient for active pressure $\lambda a'$=0.24
- passive earth pressure
  - angle of friction between wall and soil =-1/3 Ø
  - coefficient of passive pressure $\lambda p'$ = 5.56
- at rest pressure
  - at rest pressure coefficient λo = 0.4 (for comparison Brinch - - Hansen: 1 - sin Ø = 0.43)

4.1.3.3.2 - Seismic Earth Pressure

The dynamic increment of the earth pressure due to seismic events is calculated according to the theory of Mononobe/Okabe.

The computations will be executed using the program Monokmot, available at MC ING.

The pressure resulting from the Mononobe/Okabe computations are distributed starting from zero at the interface between the gravel and rock to a maximum value at ground surface (see fig. 4.1.3.3.2a)

pe - seismic earth pressure

pq - overload earth pressure

4.1.3.4 - Rock Pressure (Dr)

The direct rock pressure is derived by the equilibrium of displacement of rock and structure, assuming elastical behaviourof rock and structure.

4.1.3.5 - Ground Water

Concerning water pressure and watertightness both, the maximum and minimum phreatic level have to be taken into consideration:

- Maximum phreatic level   0.50 m below surface
- Minimum phreatic level   5.00 m below surface

4.1.4 - Live loads (L)

4.1.4.1 - Live LOad on Floors and Staircases (Lf)

Basically, the live loads are given in the Design Specifications for each building or structure. Where the loads are not specified the following live loads have to be considered:

a) Main operating floors   10 KN/m2

b) Intermediate service and operating platforms   5 KN/m2

c) Walk and stairways 5 KN/m2

4.1.4.2 - Live Loads on Roads (Lr)

The maximum live load on the roads, including entrance part of the turbine building, is the transport load of the generator stator.

Where no special erection or transport loads are specified, the design has to be based on the Portuguese Code RSEP, Section 24.

4.1.4.3 - Crane Loads (Lk)

4.1.4.3.1 - Turbine Building

Two cranes on the same crane rails each one with a loading capacity of 110 t are provided. The loading scheme will be provided by MAGUE.

4.1.4.3.2 - Electrical Building

In the equipment hatch , a hoist with a loading capacity of 7 ton is installed.

4.1.5 - Vibration Loads (V)

4.1.5.1 - General

All vibration loads shall be duly considered in particular those related to equipment and rotating machinery. Feed-water Pumps, Induced and Forced-draft air Fans, Air Compressors, piping strokes.

The Coal Pulverizing Mills will be supported on a block. resting on a complex of springs and viscodampers in order to isolate the surrounding structures. Whenever necessary, such as air compressors, the isolation of the foundation blocks of rotating machinery shall be performed.

4.1.5.2 - Coal Mills

The foundation mass, the type of block and its supporting will be very much depending on the mill vibration characteristics. However, the need for isolating other surrounding main structures foundations could lead to support the block on a system of springs and dampers.

The loads will be a stochastic sequence of strokes. The basic input for a dynamic analysis will be issued.

4.1.6 - Dilatation (C)

4.1.6.1 - Shrinkage (Cs)

This type of load shall be considered for concrete structures having in mind the following parameters: concrete mixture, dimensions of elements, amount of reinforcement, time after pouring and the ambient conditions.

For very simple structures the shrinkage effect shall be taken as a uniform temperature decreasing:

15°C for elements with ≥0,5% reinforcement
20°C " " " <0,5% "

If the largest dimension in plan view is less than 25 m (for protected/indoor structures) or less than 15 m (for non protected/outdoor structures) the shrinkage effects can be disregarded.

4.1.6.2 - Creep (Cc)

The parameters to define creep are the same as for shrinkage, plus the overall time interval during which the load will be acting.

For usual concrete structures the long term deformation can be obtained multiplying by 3 (three) the instantaneous deflections.

For special cases the CEB-FIP code shall be followed.

4.1.6.3 - Temperature (Ct)

Uniform and differential temperature variations shall be taken as indicated in RSEP, clauses number 58 and 59.

The pertinent operating temperatures of equipment shall be considered in the design of supporting structures.

The thermal linear expansion coefficient shall be as follows:

steel, concrete .... $10x10^{-6}$ $^{o}C^{-1}$

Masonry work .... $10x10^{-6}$ "

Wood .... $5x10^{-6}$ "

For uniform temperatures variations the young modulus will be:

steel .... $2,1x10^{6}$ kg/cm^{+2} ($2,1x10^{4}$ KNm^{-2})

concrete ....$1,4x10^{5}$ kg/cm^{+2} ($1,4x10^{3}$ KNm^{-2})

Masonry work .....$1,4x10^{5}$ kg/cm^{+2} ($1,4x10^{3}$ KNm^{-2})

4.1.6.4 - Friction

The calculation of active friction forces shall be based on the following friction coefficients:

steel on concrete 0,45

steel on steel 0, 35

Friction forces due to pipe expansion:

For individual pipes .... 0,30 x vertical load

For pipe racks .... 0,10 x vertical load

4.1.7 - Snow (S)

This load case shall not be considered.

4.1.8 - Settlements (F)

Important for the structure is basically not the absolute value of the settlement, but the relative settlement of adjacent foundations.

Generally, the relative settlement of adjacent foundations has to be smaller than 1/300 of their distance:

$$\frac{\Delta s}{l} \leq \frac{1}{300}$$

Δs = relative settlement of adjacent foundations

l = distance between adjacent foundations

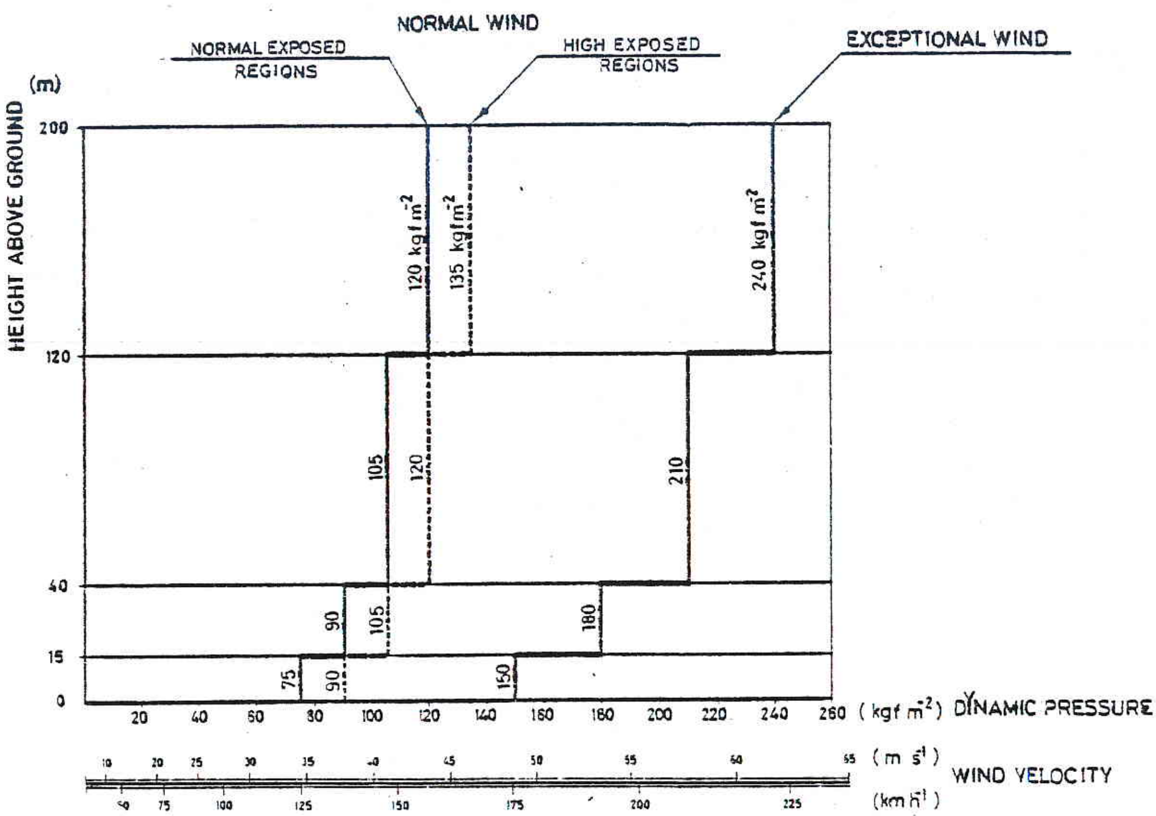
4.1.9 - Wind (W)

4.1.9.1 - General

Basically, the wind loads on structures are specified in the Portuguese Code RSEP, Section 48 to 53. These loads are quantified under the subsequent Chapter 4.1.9.2. With respect to Section 54 of RSEP, the wind load on the chimney is considered separately in the subsequent Chapter 4.1.9.3.

4.1.9.2 - Buildings excluding Chimney

The following wind pressures shall be taken into account and the relevant "form coefficients" will be taken from RSEP or any foreign code as advisable.



4.1.9.3 - <u>Chimney</u>

4.1.9.3.1 - General

Section 54 of RSEP prescribes special considerations of the wind load on chimney. This requirement is fulfilled by using well-known foreign standards that take into account the dynamic wind effects and are applied on chimneys:

- ACI - Code 307, Issue 1969 (Revision 1978)
- DIN - Code 1056, Issue 1969 and Issue 1978
- CICIND - Recommendations (Issue 1979)

(CICIND = Comité International des chiminées industrielles)

The ten-minutes mean wind speed for design purposes at Sines, estimated at 10m above ground in an open situation to be exceeded on the average of 50 years, is in the range of 28 m/s.

4.1.9.3.2 - Preliminary Design

For preliminary design purposes, the wind load specification of ACI - Code 307, Issue 1969 and the DIN - Code 1056, Issue 1969 can be used.

These codes cover the dynamic wind-load effects roughly by an increased statical load. For a more realistic check, the procedures of Chapter 4.1.9.3.3 can be already used at this stage.

Since the load specification of the ACI Code and the DIN Code are primarily related to the country of issue, the conditions of transformation to the Sines Site are defined subsequently.

ACI - Code 307

The basic wind pressure is defined according to different zones with different basic wind velocities in the UBC (Union Building Code). The applicable UBC zone for the Sines Site can be determined by the Sines mean wind speed, defined above.

DIN - Code 1056

According to the investigations of the CICIND (Comité International des chiminées industrielles), resulting in wind-speed isopleths of the entire Europe, the wind conditions in Northern Germany are similar to the ones of the Sines Site. It is, therefore, justified to use the DIN Code in connection with its most severe wind zone.

4.1.9.3.3 - Detail Design

For the detail design, more accurate considerations of the dynamic wind-load effects are necessary.

These effects are:

- The gust impact parallel to the wind direction
- The vortex shedding normal to the wind direction.

By using the following standards, the above-mentioned requirements are fulfilled:

- Proposal of CICIND recommendations for the design of chimneys (CICIND = Comité international des chiminée industrielles). This method uses a gust spectra.

- DIN - Code 1056 (draft 1978, free-standing chimneys massive-type of construction, calculation and design). The gust impact is specified in a simplified way.

4.1.10 - Earthquake (E)

4.1.10.1 - General

Basically, the earthquake loads on normal structures are specified in the Portuguese Code RSEP, Sections 63 to 66. According to this code, the earthquake load is covered by a statically equivalent load which is specified for the Sines Plant under. Chapter 4.1.10.2.

The chimney design requires accurate considerations which are specified under chapter 4.1.10.3.

The Sines Site is assigned to a zone of considerable seismic intensity.

4.1.10.2 - Buildings excluding chimney

The following static horizontal coefficients shall be applied according to RSEP:

		(1)	(2)
Overall buildings or structures	With reserve of strength due to non structural elements	0,10	0,15
	With no reserve of strength	0,15	0,20
Individual elements of buildings	Walls and similars	0,20	
	Chimneys, balconies and other attached elements	0,30	

Column (1) are figures for normal soil conditions.

Column (2) figures will be used for particular unfavourable soil conditions for seismic actions:

mud, clay, and silty soils.

All permanent masses shall be acted by these related accelerations: self weight of all structural elements, walls, platforms finishings and all permanent equipment.

For the Sines site the static horizontal coefficient 0.15 shall be taken

4.1.10.3 - Chimney

4.1.10.3.1 - General

Well-known foreign standards will be usedto take into account for a more accurate consideration of the dynamic character of the seismic load on a chimney.

The design earthquake for the Sines Site is the earthquake with a return period of 100 years and has the modified Mercalli intensity of VII.

4.1.10.3.2 - Preliminary Design

For preliminary design purposes, the simplified load specification of the:

- ACI Code 307, Issue 1969
- DIN Code 1056, Draft 1979
- CICIND Recommendation, 1979 (approximative method)

can be used. For more accurate considerations, the procedures of the subsequent Chapter 4.1.10.3.3 can be already used at this stage.

The transformation of the foreign codes to the Sines Site has to be based on the design earthquake, defined in Chapter 4.1.10.3.1 for Sines

4.1.10.3.3 - Detail Design

The earthquake load is based on the earthquake-response spectrum of U.S. Regulatory Guide 1.60, adopted for the seismic intensity of the Sines Site.

The following standards take into account this requirement:

- DIN Code 4149, Draft 1976, Buildings in German Earthquake Areas, Design Loads, Analyses and Structural Design.
- CICIND Recommendation, 1979

4.2 - Load Combinations

4.2.1 - General

- To obtain the most severe conditions, calculations shall be performed combining all loads that might occur simultaneously.
- For each main structural element the most suitable load combinations shall be performed
- For load combinations type II exceptional wind and earthquake must not be taken simultaneously.
- For all loads and design methods, appropriate load factors or safety coefficients shall be used.

4.2.2 - Load Combination Type I

Dead loads (including earth and ground water pressure) + + live loads (including crane and erection loads) + + vibration loads (if applied) + dilatation (including temperature, shrinkage and creep) + settlements (if foreseen) + + normal wind

4.2.3 - Load Combination Type II

Dead loads + live loads + vibration loads + dilatation + + settlements + exceptional wind;

or

Dead loads + live loads + vibration loads + dilatation + + settlements + earthquake.

5 - DESIGN METHODS

5.1 - Reinforced Concrete Structures

5.1.1 - General

The design of all reinforced concrete structures shall be in agreement with REBA. The safety evaluation will deal with :

- Permissible stresses or ultimate strength
- Maximum allowable deformations
- Instability effects
- Permissible crack width

5.1.2 - Design with Permissible Stresses

The design with permissible stresses shall take into account the values given in paragraphs 3.1.2 for concrete and 3.2.2 for reinforcing steel.

This type of design is not allowed for simple compressed members.

For simple supported or continuous slabs with a thickness less than 8cm and for a cantiliver slab with thickness than 12cm, the permissible stresses shall be reduced by 10%.

5.1.3 - Ultimate strength design

The ultimate strength design shall be based on the values given in 3.1.3 and 3.2.3 for concrete and reinforcing steel.

The load factors for load combination type I and II according to RSEP shall be:

For load combination type I 1,5
" " " " II 1,0

. Concerning load combination type I, the permanent loads, whenever more restrictive, shall have a load factor 1,0 .

. For slabs as indicated in 5.1.2 the load factors shall be increased by 10%.

5.1.4 - Principles for structural design

5.1.4.1 - Control of cracking

Crack width shall be calculated, according to clauses 37, 38 and 39 of REBA , for any load combination type I without any load factor.

If reinforcing bars are in agreement with the maximum bar diameters indicated in the following table, the crack width calculation is not necessary to be made for normal structures.

Maximum bar Diameter of Main Reinf.Steel(mm)

Type of exposure		Non protected elements		Protected elements	
Steel class		A40	A50	A40	A50
Rein-forcing Percen-tage (%)	$\tilde{\omega} \leq 1,0$	16	12	25	16
	$1,0 < \tilde{\omega} \leq 1,5$	20	12	**	25
	$1,5 < \tilde{\omega} \leq 2,0$	25	16	**	**
	$\tilde{\omega} > 2,0$	**	20	**	**

Permissible Crack Width

The definition of the permissible crack width follows the recommendations of CEB (Comité Européen du Beton):

a) For watertight concrete, the maximum crack width W_k will not exceed 0.2 mm.

b) For all other cases, the maximum crack width W_k is limited to 0.3 mm.

The design is performed for the characteristical crack width W_k which covers the 95 % fractile of the statistical crack-width distribution.

Computation of Crack Width:

The computation of the crack width is based on the theories of Falkner and Leonhardt.

5.1.4.2 - Deformation

Short and long term deformation for load combinations type I without any load factor shall in general not exceed the following values:

Slabs and beams : $\frac{1}{300}$ of span for permanent + acidental loads

$\frac{1}{500}$ of span for acidental loads only

Beams supporting masonry work or glazing:

$\frac{1}{500}$ of span for permanent + acidental loads

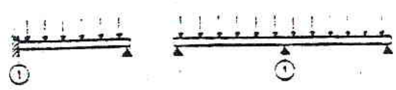
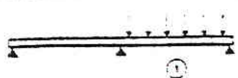
Roofing : $\frac{1}{200}$ of span for permanent loads

If there are equipments that impose more restrictive figures for deformations, a suitable structure shall be looked for.

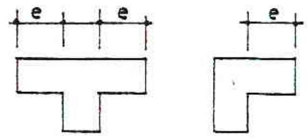
5.1.4.3 - Redistribution of forces

The following redistribution coefficients can be used for the moment diagrams, supposing an elastic behaviour. The moment diagrams shall be modified accordingly.

Redistribution Coeffs.

Type of Structures	Coeff. applying to moments on section (1)	
	Steel Class	
	A24 A40 ($\tilde{\omega}_0 \leq 1\%$)	A40 ($\tilde{\omega}_0 > 1\%$) A50 A60
	0,80	0,90
	0,90	1,00
	0,80	0,85
	0,85	0,90
	0,85	0,90

5.1.4.4 - Width of plate in T and L beams



The distance e shall be smaller than:

. $\frac{1}{2}$ of the distance between beam faces

. $\frac{1}{10}$ of the distance between sections of zero moment

. $\frac{1}{10}$ of span for simple supported beams

5.2 - Steel Structures

5.2.1 - General

The design of all steel structures shall comply with REAE. The safety evaluation will deal with:

. Permissible stresses or ultimate strength analysis

. Maximal allowable deformation

. Instability phenomena

Ultimate strength (plastic analysis) shall only be used with current mild steel structures.

5.2.2 - Ultimate Strength Analysis (Plastic Analysis)

For this type of analysis an elasto-plastic behaviour of current mild steel structures will be considered, even allowing the formation of plastic hinges according to REAE clauses 53, 54 and 55.

Safety coefficients to be used:

Loading type I 1,7
Loading type II 1,0

The yield stresses for the plastic behaviour of current mild steel sections will be :

"Comercial" .... 2 100 kg/cm^2

"Garantido" .... 2 400 kg/cm^2

5.2.3 - Design with Permissible Stresses

For members not subject to buckling the allowable stresses will be as indicated in 3.3.2. For elements with triaxial stress loading the limiting stresses shall be according to clause 50 of REAE.

Secondary effects due to eccentricities and stiffnesses different than admited will be taken into consideration when designing and checking all members.

5.2.4 - Instability Design

The instability phenomena shall be checked either for each structural member or for the whole structure itself.

All buckling effects shall be taken in consideration as per REAE clauses 61 through 64.

5.2.5 - Design of Bolts

The connections with bolts shall comply with REAE clauses 73 through 76.

For normal bolted connections the following allowable stresses will be taken:

Loading Combinations (RSEP)	Bolt Type	Permissible Stresses (kgf/mm2)		
		Shear	Tension	Crushing
Type I	normal	8,4	11,2	23,8
	adjusted	11,2	11,2	31,5
Type II	normal	12,6	16,8	35,7
	adjusted	16,8	16,8	47,2

5.2.6 Design of Welds

The connections with welds shall comply with R.E.A.E. clause 77.

The connections at low temperatures or at bad weather conditions have to be designed in a way that the concentrations of stresses are minimized and to eliminate the carving effects.

The welds under high temperatures, from 20°C to 200°C have to be calculated in order to attend to the reduced strength of the material or of the weld material.

5.2.7 Deformations

For deformations conditions see 5.1.4.2

The elastic constants for deformation design are the following:

Young Modulus $E=2,1 \times 10^6$ kgf/cm^2 $(2.1x10^8 KN/m^2)$
Poission Ratio $=0,3$
Shear Modulus $G=0,8 \times 10^6$ kgf/cm^2 $(0,8x10^8$ $KN/m^2)$

5.2.8 Composite Structures

5.2.8.1 Design Documents

The design of composite structures shall be based on the following documents:

(1) "Verbundträger im Hochbau" April 1971	Swiss Chamber of Steel Construction SZS
(2) "Verbundquerschnitte im Hochbau"	Swiss Chamber of Steel Construction SZS

In the document (1), two design philosophies for the design of composite structures are treated:

- Elastic design of component structures
- Plastic design of composite structures

It is up to the design engineer to use one of these design philosophies, but in consideration of an economical design, preference shall be given to the plastic design.

In the document (2), section properties of composite structures are listed, related to the depth of the concrete slab.

5.2.8.2 Shear Connections

Studs with leads shall be used, respecting the following rules:

- Distance between studs in longitudinal direction 6 d

- Distance between studs in transversal direction — 2.5 d

- Length of stud — hd 4 d

- Thickness of top flange of steel selection — 1/3 d

Studs shall be made of steel ST-373K in accordance with DIN 17 100, having the following mechanical properties:

- Tensile strength min. 450 N/mm2
- Yield strength min. 350 N/mm2
- Elongation 15%

5.2.8.3 Composite Decking

The design of a composite decking shall be done in accordance with Chapter 4.1 in (1).

Special attention shall be given to the reduced depth of the concrete slab, taking into account the height of the ribs of the sheet-metal decking.

5.3 Seismic Design

5.3.1 General

According R.S.E.P. seismic loadings will be of Type II.

The equivalent static coefficient analyses shall be generally used for all structures and equipment.

These static coefficients will be according to 4.1.10.2

Wherever necessary the dynamic analyses, even simplified will be performed to demonstrate the behaviour of structural elements, mainly the foundations of vibrating machinery and chimney, that will reffered in other points: 5.3.3 and 5.5

The maximum allowable stresses for each structural material will take into consideration the Type II loading case according to the relevant codes.

5.3.2 Main Building

According to R.S.E.P the necessary load combinations will be taken together with other types of loadings as indicated on chapter 4.2.3.

Generally an equivalent static coefficient at least of 0,15 shall be used, unless stated otherwise in any specification.

All loads from vibrating equipment supported by any parts of the buildings shall be investigated in order to prevent any malfunctions either of the building or of the equipments itself.

Whenever necessary a dynamic analysis shall be performed or an isolation assembly shall be envisaged.

5.3.3 Chimney

5.3.3.1 Preliminary Design

In the Portuguese Code RSEP, the dynamic behavior of a structure is not considered and complete rigidity of the structure is assumed.

Since for the chimney, its dynamic properties become of major influence on the seismic resistance, a more accurate investigation is necessary.

For preliminary design purposes, the dynamic properties of the chimney can be taken into account in a simplified way, by using the methods of the standards listed in Chapter 4.1.10.3.2.

For a more accurate check, the procedures of Chapter 5.3.3.2 can already be used at this stage.

In the case of a steel liner, the observations stated in the report, "Design and Construction of Steel Chimney Liners, by the Task Committee on Steel Chimney Liner, Fossile Power Committee, Power Division of the ASCE" should be considered.

5.3.3.2 Detail Design

For the detail design, more accurate considerations of the dynamic behavior of the chimney are necessary. In particular, a model analysis has to be performed.

The analysis must be based on either a Lumped-mass model or on a model with distributed mass, solved directly by Duhamel integration.

Descriptions of these methods are given in the following standards:

- DIN Code 4149, 1976. This Standard is based on the Lumped-mass model method.

- CICIND Recommendations, 1979. This standard is based on the distributed-mass model for chimneys.

5.4 WIND LOAD

5.4.1 General

According R.S.E.P. Wind Loading can be either of type I or of type II.

These two types shall imply in using apropriate coefficients for structural design.

Type I - 1.5 or 1.0

Type II - 1.0

When more unfavourable for type I the shorter coefficient has to be used.

The wind loads will be considered as an uniform load distributed along the building faces after increased by the form coefficients.

Whenever necessary the dynamic analyses, even simplified will be performed to demonstrate the behaviour of structural elements.

5.4.2 Buildings Excluding Chimney

According to R.S.E.P. the necessary load combinations will be taken together with other types of loadings as indicated on chapter 4.2.2.

The form coefficients to be used will be adequated to the geometry of the buildings and whenever R.S.E.P is unsufficient other standard codes can be used.

The design shall consider either the buildings as a whole or each detached building element, to ensure the necessary stability.

5.4.3 Chimney

5.4.3.1 General

In the subsequent chapters, the standards which are admitted for wind design are defined. Special attention has to be given, however, to the fact, that, these codes are consistent within themselves and that, therefore the design methods and the load specifications cannot be mixed up between different codes.

In the case of a steel liner, the observations stated in the following report should be considered:

"Design and Construction of Steel Chimney Liners, by the Task Committee on Steel Chimney Liners, Fossil Power Committee, Power Division of the ASCE".

5.4.3.2 Preliminary Design

The applicable standards are stated in Chapter 4.1.9.3.2 The methods given therein do not take into account the dynamic properties of the chimney.

For a more realistic check, the procedures of Chapter 5.4.3.2 can be used already at this stage.

5.4.3.3 Detail Design

For the detail design, the dynamic properties of the chimney have to be considered. The standards stated under Chapter 4.1.9.3.3 provide for this requirement:

- CICIND Recommendation, Issue 1979:
  Using this method, a rigorous dynamic analysis is performed based on the theories of Wyatt and Davenport.

- DIN Code 1056, Draft 1978:
  Using this method, a simplified approximation of the windstructure interaction is performed.

5.5 - MACHINE FOUNDATIONS

5.5.1 - List of Considered Foundations

- Turbine building - Feed-water pumps, Air compressors, Turbine Table
- Electrical building - No machine foundations
- Boiler House - Coal mills, Primary and Secondary Air fans, Induced draft fans before chimney

5.5.2 - Methods for Foundation Design

Well proved design methods shall be applied having in mind the specific requests of the rotating equipment.

In general the Rausch method shall be applied. Particular attention shall be paid to the type of structure used and to the dynamic soil properties.

Particular care shall also be taken when investigating the propagation of vibrations to the surrounding structures.

The maximum amplitudes as well as the frequency ranges shall be thoroughly investigated, in order to prevent all malfunctions, according to the machine manufacturer data.

See also 3.1.8.