Specific Requirements – Meteorological Events

The extreme values of meteorological variables and rare meteorological phenomena listed below shall be investigated for the site of any installation.

A- Extreme values of meteorological phenomena

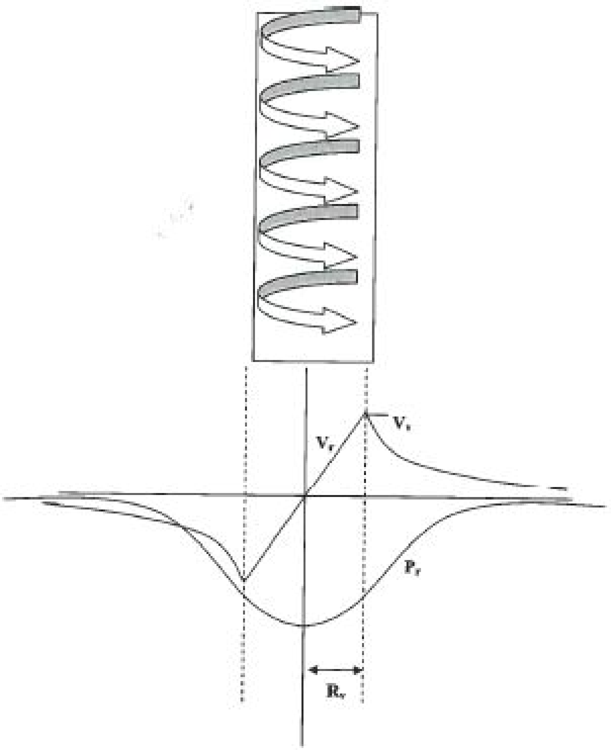
In order to evaluate their possible extreme values, the following meteorological phenomena shall be documented for an appropriate period of time: wind, precipitation, snow, temperature and storm surges.

The output of the site evaluation shall be described in a way that is suitable for design purposes for the plant, such as the probability of exceedance values relevant to design parameters. Uncertainties in the data shall be taken into account in this evaluation

Specific Requirements – Meteorological Events

<u>The tornado</u> is defined by the following paramenters:

Maximum wind speed-300 mph (135 m/s)
Maximum rotational speed-240 mph (108 m/s)
Maximum transational speed – 60 mph (27 mph)
Radius of maximum rotational wind from center of tornado – 150 ft (46 m)
Atmospheric pressure drop – 2.0 psi (0.13 atm)
Rate of pressure change – 1.2 psi/sec (0.081 atm/sec)



Velocity and Pressure-Tornado of R radius

Specific Requirements – Meteorological Events

The NI (Nuclear Island) structures shall be designed to protect safety related equipment against damage from tornado missiles. The following missiles shall be postulated:

a. **A massive high kinetic energy missile which deforms on impact, assumed 4000 lb (1800 kg) automobile impacting the structure at normal incidence with a horizontal velocity of 105 mph (47 m/s) or a vertical velocity of 74 mph (33 m/s). This missile shall be considered at all plant elevations up to 30 feet (9 m) above grade.**

b. **a rigid missile of a size sufficient to test penetration resistance, assumed to be a 275 pound (125 kg) 8’’ armor piercing artillery shell impacting the structure at normal incidence with a horizontal velocity of 105 mph or a vertical velocity of 74 mph.**

c. **A small rigid missile of a size sufficient to just pass through any openings in protective barriers, assumed to be 1’’ dia. solid steel sphere assumed to impinge upon barrier openings in the most damaging direction at a velocity of 105 mph.**

Specific Requirements – Meteorological Events - Flooding

A- Floods due to precipitation and other causes

The region shall be assessed to determine the potential for flooding due to one or more natural causes such as <u>runoff resulting from precipitation or snow melt, high tide, storm surge, seiche and wind waves that may affect the safety of the nuclear installa</u>tion. If there is a potential for flooding, then all pertinent data, including historical data, both meteorological and hydrological, shall be collected and critically examined.

A suitable meteorological and hydrological model shall be developed with account taken of the limits on the accuracy and quantity of the data, the length of the historical period over which the data were accumulated, and all known past changes in relevant characteristics of the region.

Specific Requirements – Meteorological Events - Flooding

The possible combinations of the effects of several causes shall be examined. For example, for coastal sites and sites on estuaries, the potential for flooding by a combination of high tide, wind effects on bodies of water and wave actions, such as those due to cyclones, shall be assessed and taken into account in the hazard model.

The parameters used to characterize the hazards due to flooding shall include the height of the water, the height and period of the waves (if relevant), the warning time for the flood, the duration of the flood and the flow conditions.

Specific Requirements – Meteorological Events - Flooding

B- Water waves induced by earthquakes or other geological phenomena

The region shall be evaluated to determine the potential for tsunamis or seiches that could affect the safety of a nuclear installation on the site. If there is found to be such a potential, prehistorical and historical data relating to tsunamis or seiches affecting the shore region around the site shall be collected and critically evaluated for their relevance to the evaluation of the site and their reliability.

On the basis of the available prehistorical and historical data for the region and comparison with similar regions that have been well studied with regard to these phenomena, the frequency of occurrence, magnitude and height of regional tsunamis or seiches shall be estimated and shall be used in determining the hazards associated with tsunamis or seiches, with account taken of any amplification due to the coastal configuration at the site.

Specific Requirements – Meteorological Events - Flooding

The potential for tsunamis or seiches to be generated by regional offshore seismic events shall be evaluated on the basis of known seismic records and seismotectonic characteristics.

The hazards associated with tsunamis or seiches shall be derived from known seismic records and seismotectonic characteristics as well as from physical and/or analytical modelling. These include potential draw-down and runup that may result in physical effects on the site.

Specific Requirements – Meteorological Events - Flooding

C- Floods and waves caused by failure of water control structures

Information relating to upstream water control structures shall be analyzed to determine whether the nuclear installation would be able to withstand the effects resulting from the failure of one or more of the upstream structures.

If a preliminary examination of the nuclear installation indicates that it might not be able to withstand safely all the effects of the massive failure of one or more of the upstream structures, then the hazards associated with the nuclear installation shall be assessed with the inclusion of all such effects; otherwise such upstream structures shall be analyzed by means of methods equivalent to those used in determining the hazards associated with the nuclear installation to show that the structures could survive the event concerned.

Specific Requirements – Geotechnical Hazards

A- Slope instability

Kobe, Japan 1995 (M=7.2)

Washington, 2001 (M=6.8)

B- Collapse, subsidence or uplift of the site surface

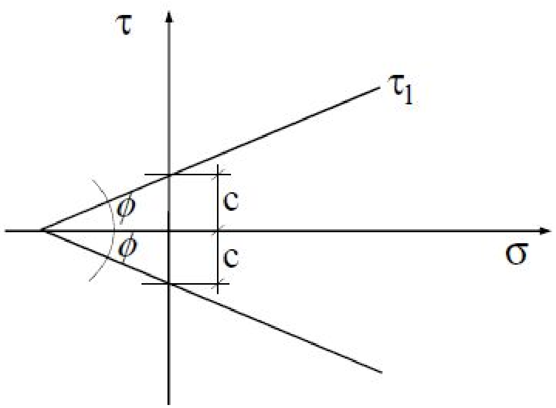
Geological maps and other appropriate information for the region shall be examined for the existence of natural features such as caverns, karstic formations and human made features such as mines, water wells and oil wells.

Specific Requirements – Geotechnical Hazards

C- Soil liquefaction

Mohr-Coulomb Criteria

$$|\tau_l| = \sigma \ \mathrm{tg}\phi + \mathrm{c}$$



c = cohesion
p = water pressure
σ = effective stress

A state of 'soil liquefaction' occurs when the effective stresses of a soil is reduced to essentially zero, which corresponds to a complete loss of shear strength.

Loma Prieta, 1989 (M=6.9)

Loma Pietra 1989 (M=6.9)

Specific Requirements – Geotechnical Hazards

C- Soil liquefaction

$$\sigma_t = \bar{\sigma} + p$$

$$|\tau_l| = (\sigma_t - p)\ \mathrm{tg}\phi + \mathrm{c}$$

τ 0 **Liquefaction**

The particles tend to a denser configuration. Water does not have the time to be expelled, it is trapped and prevents the approach of the solid particles. This causes the increase of pore pressure. The solid particles lose contact with each other and the deposit behaves like a liquid.

Niigata, Japan (M=7.5)

Specific Requirements – Geotechnical Hazards

D- Behaviour of foundation materials

The geotechnical characteristics of the subsurface materials, including the uncertainties in them, shall be investigated and a soil profile for the site in a form suitable for design purposes shall be determined.
The stability of the foundation material under static and seismic loading shall be assessed. The groundwater regime and the chemical properties of the groundwater shall be studied.

Specific Requirements – External Human Induced Events

A- Aircraft crashes

The potential for aircraft crashes on the site shall be assessed with account taken, to the extent practicable, of characteristics of future air traffic and aircraft.

The hazards associated with an aircraft crash to be considered shall include impact, fire and explosions.

B- Chemical explosions

Activities in the region that involve the handling, processing, transport and storage of chemicals having a potential for explosions or for the production of gas clouds capable of deflagration or detonation shall be identified.

Specific Requirements – External Human Induced Events

B- Chemical explosions

Hazards associated with chemical explosions shall be expressed in terms of overpressure and toxicity (if applicable), with account taken of the effect of distance.

C- Other important human induced events

The region shall be investigated for installations (including installations within the site boundary) in which flammable, explosive, asphyxiant, toxic, corrosive or radioactive materials are stored, processed, transported and otherwise dealt with that, if released under normal or accident conditions, could jeopardize the safety of the installation. This investigation shall also include installations that may give rise to missiles of any type that could affect the safety of the nuclear installation.

Specific Requirements – External Human Induced Events

OTHER CONSIDERATIONS

Historical data concerning phenomena that have the potential to give rise to adverse effects on the safety of the nuclear installation, such as volcanism, sand storms, severe precipitation, snow, ice, hail, and subsurface freezing of subcooled water (frazil), shall be collected and assessed. If the potential is confirmed, the hazard shall be assessed and design bases for these events shall be derived.

In the design of systems for long term heat removal from the core, site related parameters, such as the following, should be considered:

(a) Air temperature and humidity;
(b) Water temperatures;
(c) Available flow of water, minimum water level and the period of time for which safety related sources of cooling water are at a minimum level, with account taken of the potential for failure of water control structures.

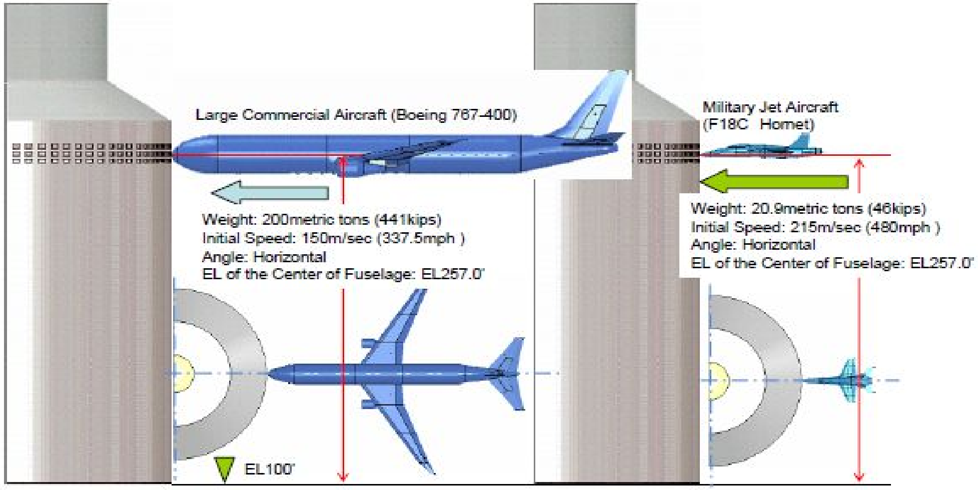
AIRPLANE CRASH IN NPP DESIGN: SHORT HISTORY

- **Until '60ies:** only small aeroclub planes (max 1 to 2 t weight) considered to impact NPP and only if airfield is in close proximity of plant (a few km); impact velocity low (up to 80 m/s)
- **From late '60ies to Sept. 11th 2001:** Phantom 4 fighter considered in some european countries (20 t, 200 m/s) due to fall of a significant number of fighters during exercise flights and afterwards to the discovery of secret terrorists plans
- **Since Sept. 11° 2001:** study of protection of **new** plants against the fall of a large jetliner (up to 350 t, about 200 m/s) required by most countries

Air Combat Command

- EUR Requirements
- Guidelines for Aircraft Crash Analysis
- ACC –Possible Protection Alternatives
- Analysis for Protection of the Buildings (Local / Global)

Protection against aircraft crash shall be based on probabilistic approach … *unless the authorities require a deterministic approach.*



ACC Event – EUR Requirement

The probabilistic approach shall assess:

- aircraft crashes in the vicinity of the plant.
- aircraft impact with buildings which house:
  - significant amounts of radioactivity
  - systems which if damaged could lead to an accident
  - systems required to bring the plant to a Safe Shutdown State.
- radiological consequences exceeding the release limits once the above equipment is damaged.
- identification of parts of the plant that have to be protected against each category of aircraft (except for very specific sites the aircraft to be assessed are either considered non-commercial or light, or military).

ACC Event – EUR Requirement

Deterministic approach includes:

- identification of the parts of the plant which have to be protected in accordance with the requirements of the national Safety Authorities.

- identification of the buildings which have to be protected.

- development of a standard design which provides aircraft crash protection by increasing the thickness of the building walls exposed to the impact and/or by physical separation of sensitive equipment.

- incorporation of thick outer walls (1.3 m is expected to be adequate) which shall prevent perforation and scabbing when the wall is hit perpendicularly by the aircraft.

- assessment of the effects of induced vibrations on equipment in the buildings impacted.

ACC Event – EUR Requirement

September 11, 2001: escalation of terrorist action
Reconsideration of aircraft crash design basis, now:

- Still consider light and military aircraft but also add large passenger aircraft
- No immediate release of significant amount of radioactive substances.
- Initiation and maintenance of key safety functions in spite of direct consequences of the event (penetration of structures by impacting parts, vibration, explosion, fire) without release of significant amount of radioactive substances to the environment/
- Microwave and biologic weapon consideration.

ACC Event – Guidelines for Aircraft Crash Analysis

- Purpose: To validate confidence that nuclear plant structures can withstand aircraft impacts, even though they were not specifically designed for such impacts.

- Aircraft Analyzed: The reference aircraft chosen for analysis was the Boeing 767-400 (maximum takeoff weight 450,000 pounds, traveling at 350 mph, which includes 23,980 gallons of fuel; with two engines weighing 9,500 pounds each). Weight of the Boeing 767-400 envelopes about 88 percent of all commercial flights in the United States.

  - Example: The plane used by terrorist to be flown into the World Trade Center was a smaller version of the plane in this study, Boeing 767-200ER (max. takeoff weight of 395,000 lbs)

ACC Event – Potential Crash Locations

- Control room – Redundant Separate Controls would allow Plant Safe Shutdown even if Control Room is destroyed.
- Spent Fuel Pools – Spray System would prevent Fire to damage fuel and cause radioactive release.
- Shield Building – Design enhancements will prevent fuel from getting inside the building.

ACC Event – Light Aircraft

- Cessna 172
  - Mass: 2420 lb (1100 kg)
  - Impact speed: 100 mph (45 m/s)
  - Crash Angle: 0 to 85 from Horizontal

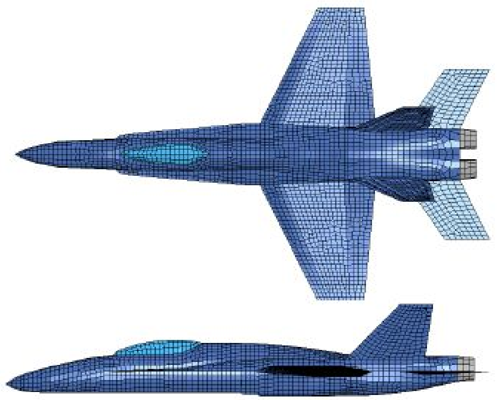
Load Forcing Function
For Simplified Analyses

- *Not Governing*.

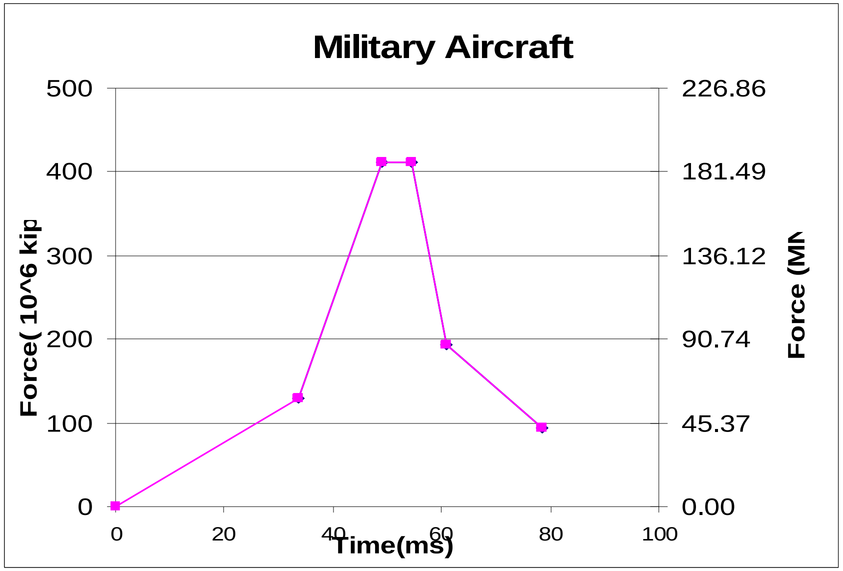
ACC Event – Military Aircraft

- F18 Hornet
  - Mass: 44,080 lb (20000 kg)
  - Impact speed: 480 mph (215 m/s)
  - Crash Angle: 0 to 85 from Horizontal

Load Forcing Function
For Simplified Analyses



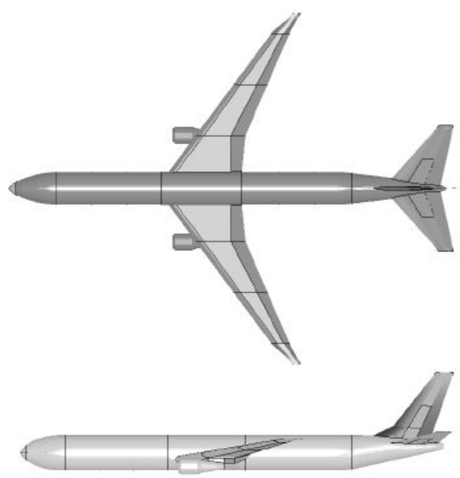
Type: F-18C Hornet
Dimensions: Length=56' (17.1 m), Wingspan=40' (12.3 m), Height=5'-4" (4.7 m, Gears included)
Weight: 46.03kips (204.76kN, 20.9metric tons)



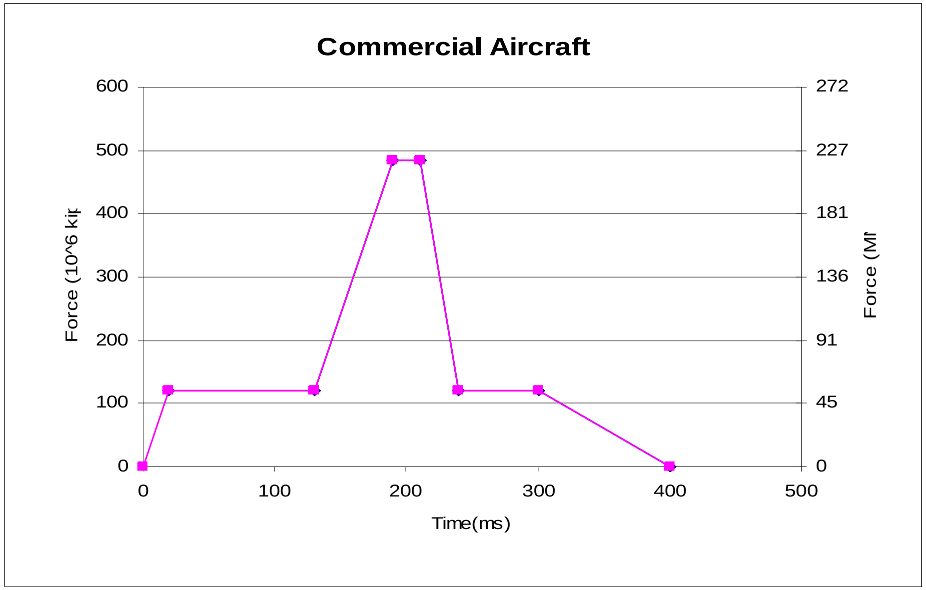
ACC Event – Commercial Aircraft

- Boeing 767-400
  - Mass: 450,000 lbs (204174 kg)
  - Impact speed: 350 mph (156 m/s)
  - Crash Angle: Horizontal

Load Forcing Function
For Simplified Analyses

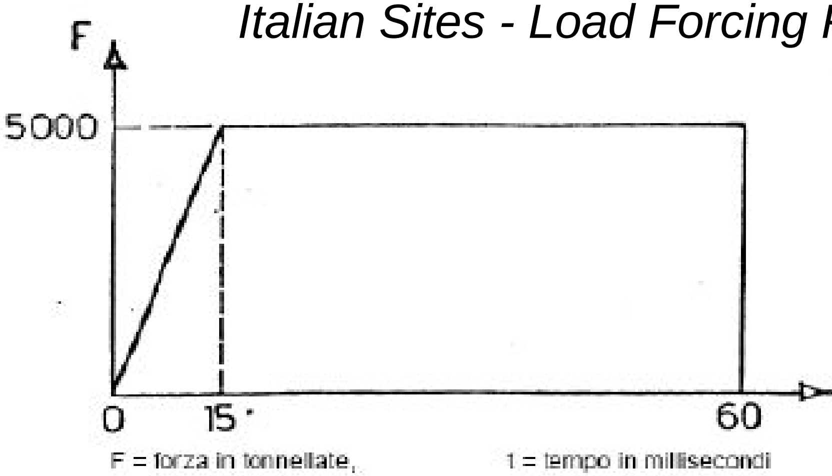


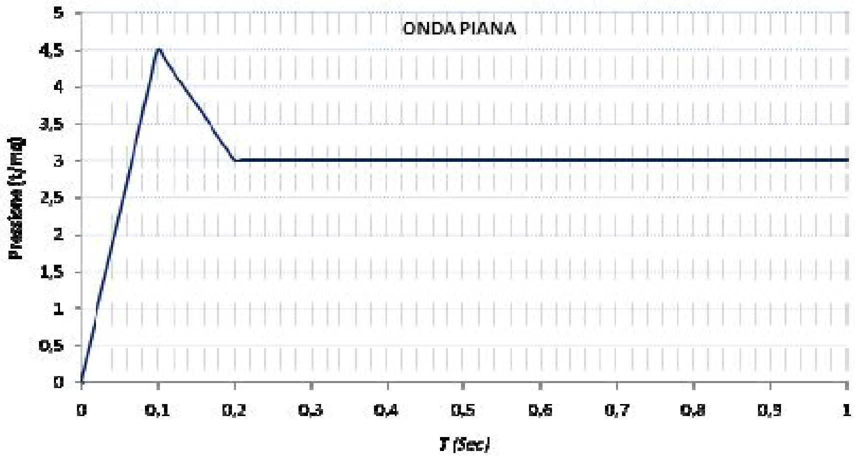
Type: Boeing 767-400ER
Dimensions: Length=201'-4" (61.3m), Wingspan =170'-4" (51.9m), Height=52'-4" (16.8m, Gears included)
Weight: 441kips (1961.3kN, 200metric tons)).



ACC Event – Italian Load Forcing Function

Italian Sites - Load Forcing Function





- Mass: 44,080 lb (20000 kg)
- Impact speed: 480 mph (215 m/s)
- Crash Angle: 45° from Horizontal
- Impact area: 7m2

ACC Event – Seismic Analysis

- Perform seismic analyses for enhanced nuclear island structures
- Compare new floor response spectra to current FRS.
- Determine new RCS seismic support loads for steam generators, pressurizer, reactor pressure vessel, etc are still under the allowable design loads.
- To avoid redesign of supports, equipment response spectra will be sufficiently close to current design spectra while still providing necessary resistance to an ACC