

ARPANSA Regulatory Assessment of the Replacement Reactor Construction Application

18 July 2001- Reactive Review Questions and Issues

Chapter 4 Buildings and Structures

Ref	Section number and name	Topic	ARPANSA Comment, Issue or Question and ANSTO's Response
4.1.	4.2 Overview of Buildings and structures Comprising the Reactor Facility.	The reactor facility is shown on Figures 4.2/1 and 4.2/2. They show the Reactor Building, the Neutron Guide Hall, Conference centre, and Auxiliary Services Buildings	The main features are covered in terms of interfaces with the LHSTC, such as landscaping, bushfire controls, stormwater and general service. There needs to be more information on these interfaces particularly in relation to essential services, such as electricity, water and waste management. The involvement with other LHSTC facilities should also be described, such as the pneumatic pipe connection to Building 23 and possible storage of spent fuel during pool inspection and maintenance.
			<p>Response:</p> <p>Details on the essential services at the LHSTC are described in Chapter 3, Section 3.2.7. The connection to Building 23 is described in Chapter 11, Section 11.4.6. Should the pool need to be emptied then spent fuel containers will be arranged and used with controlled temporary storage.</p>
4.2.	4.2 Overview of Buildings and structures Comprising the Reactor Facility.	The Reactor Building is located in the centre of the site with the Neutron guide Hall extending to the north.	The interconnection between non-Safety Class buildings such as the Guide Hall and the Reactor Building needs to be assessed for earthquakes. This is to ensure there are no damaging effects on the reactor from collapse of the Guide Hall or any other attached structures.

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			<p>Response: The Reactor Building is structurally isolated from adjacent buildings, namely Neutron Guide Hall, Auxiliary Building and Offices. The East offices at the Reactor Building access are structurally linked to the Reactor Building. At roof level of adjacent buildings the isolation will be achieved by a physical gap. At floor level sliding bearing arrangement will be used to allow sliding movements. The main issued to be considered for interaction between structures with different categories is between the Reactor and Neutron Guide buildings. In this case the gap will be greater than for the other buildings. The reactor building is structurally separated from the Neutron Guide Hall by movement joints that ensure there will be no damaging effects on the reactor from its collapse. See Section 4.6.2 last paragraph. The NGH also has reserve seismic capacity due to the ductility of its lateral framing. Nevertheless, a failure of the NGH would not have a significant overall impact on the Reactor Building because the seismic mass associated is relatively small compared with that of the Reactor Building.</p>
4.3.	4.3.2.1 Seismic Design	Three Seismic categories are defined for structures, systems and components (SSC). Seismic Category 1 shall use the SL-2 earthquake, Seismic Category 2 will use the SL-1 earthquake, and Seismic Category 3 will use the SL-0 earthquake.	A paper has been prepared for the Nuclear Safety Committee (NSC) covering seismic analysis and design and the relevant standards. The basis for the selection of the SL-1 has not been explained adequately. Its value (0.09g PGA) is not much different than the value from the Australian Seismic Risk Map for the region. The SL-1 appears to be about the 1000 year return period earthquake, but this should be confirmed.

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			<p>Response: The SL-1 earthquake was selected on the basis of international practice as identified in IAEA Safety Series 50-SG-S1 (Rev 1) "Earthquakes and Associated Topics in Relation to Nuclear Power Plant Siting". The SL-1 is described as corresponding to a "...less severe, more likely.." event than the SL-2 event. It is also stated that in some member states the SL-1 event corresponds to a level with a probability of 10^{-2} per year of being exceeded (equivalent to about 0.05g as described in the IGNS report). ANSTO selected a pga of 0.09g as the value to be used for such an event. This conservative figure would actually correspond to a return period considerably in excess of 100 years. Additionally, it should be noted that the use of a spectrum based on a scaled USREG 1.60 gives additional conservatism, as discussed in relation to the SL-2 event. The frequency content of the specified SL-1 event is significantly higher than that of the IGNS spectrum; resulting in accelerations 14% higher at a period of 0.1 second, up to >100% at 0.4 second.</p>
4.4.	4.3.2.1 Seismic Design	Seismic Category 1 and 2 buildings and structures are designed to take into account the dynamic response to earthquake loads (US RG1.60 Response Spectrum). The Floor Response spectra for the SSC are generated from Time-History accelograms. The Seismic Category 3 buildings and SSC will be built using the Equivalent Static Method.	<p>It is claimed that the failure modes of SC2 and SC3 buildings will be "fail safe" with respect to SC1 areas. It is not clear what is meant by this, and how is it achieved in practice. Please clarify.</p>
			<p>Response: SC2 & SC3 buildings are separated by movement joints from SC1 areas. Light structures such as those of the NGH and the Auxiliary Building will not damage the substantial (SC1) Reactor Building structure.</p> <p>Please refer to Section 4.6.2.</p> <p>The access areas to the Emergency Control Centre will be maintained following the SSE earthquake.</p>

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4.5.	4.3.2.1 Seismic Design	The horizontal acceleration design spectra for both the SL-2 and SL-1 are shown in Fig 4.4/10. It is noteworthy that the SL-1 uses 4% damping and the SL-2 uses 7% damping	The response spectrum in fig 4.4.10 is not the same as the AGSO (Carbon Canyon Spectra) used in the HIFAR Seismic Upgrade. The use of the RG1-60 spectrum (for Australian rock sites) underestimates the high frequency content (>6.5 Hz), and grossly overestimates the low frequency content. It is also not clear why differing percentages of critical damping have been used for the SL-1 and SL-2. Please clarify.
			<p>Response: The response spectrum adopted is a broad-band envelope spectrum based on the recommendations in USREG 1.60. Damping has been adopted in accordance to the international guidance given in US Regulatory Guide 1.61 (Damping values for Seismic design of Nuclear Power Plants).</p> <p>The same damping values are also given in ASCE 4-98 (Seismic Analysis of Safety Related Nuclear Structures).</p>
4.6.	4.3.2.2 Structural Design	The US concrete building codes ACI 318 and 349 have been used for Seismic Category 1 and 2 structures. Australian Concrete (AS3600) and Steel Standards (AS4100) are also used for Seismic Category 1, 2, and 3 structures.	This mixture of US and Australian standards and codes is potentially confusing. If they differ which gets precedent?
			<p>Response: The various codes have been used in a logical and consistent way. ACI 318 has been used for the design of Seismic Category 1 and 2 structures with the loads combinations as given in ACI 349 for OBE (SL-1) and SSE (SL-2). ACI 318 has been used in preference to AS3600 since AS3600 is not intended for high seismic loadings. For Seismic Category 3 structures the applicable Australian Standard AS 3600 is used.</p>
4.7.	4.3.2.2 Structural Design	IAEA 50-SG0D15 has requirements for a minimum number of cycles and structural ductility. For the SL-1 events stress levels are kept in the elastic range to allow for an	It is not clear what is intended for SL-2 Structures, Systems, and Components. Do the Structures, Systems, and Components that are SL1 go into a ductile range or not. The selection of a damping factor of 7% critical damping would suggest there is some ductility allowance, and this is discussed in Ch.2 of the PSAR. One benefit of using a suite of time histories for the building design (and not just for floor response spectra) is

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		unrestricted number of cycles.	that duration and number of cycles is considered. This does not happen with Response Spectra based design. The absence of consideration of duration and number of cycles for the structural design needs justification.
			<p>Response:</p> <p>Structures are analysed and designed elastically under OBE (SL-1) and SSE (SL-2) earthquakes. No reliance has been made on ductility.</p> <p>The damping value of 7% adopted for the SSE is applicable for elastic responses as indicated in ASCE 4-98.</p> <p>Time history analysis, number of cycles and duration have no influence on the response of the building structure as it has been designed elastically.</p> <p>For components, where applicable, the number of cycles will be taken into account both in analysis and testing and according to the guide IAEA 50-SG-D15; which specifies 10 peak amplitudes per seismic event.</p>
4.8.	4.3.3 Design Loads	A listing of design loads, including dead loads, live loads, thermal loads and environmental loads (earthquake and wind) is given.	<p>The key issue for the design of Structures, Systems, and Components is how these loads are combined, particularly under SL-1 and SL-2 earthquakes. Large bushfires should also be considered since they are a frequent event and the resulting thermal load on Structures, Systems, and Components should be evaluated. Secondary damage to services from bushfire should also be considered since electrical and water supplies may be threatened, and the habitability of the reactor building may be threatened.</p>
			<p>Response: Load combinations have been considered in accordance with the nominated codes. Bush fires are discussed in Chapter 16, Section 16.17.2. The fire load from the aircraft impact, in Section 4.4.3.2.4, is a bounding case for the Reactor Building.</p>
4.9.	4.3.3.4 Other Design	Fire compartmentalisation, fire detection systems, fire suppression systems meet the requirements of the	It is important that a fire hazard analysis is undertaken for the Final Safety Analysis Report. The PSA has considered that fires do not challenge reactor safety directly.

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	Features	Building Code of Australia. Consideration is also given to fire resistance of all materials, and location of corridors and exits.	
			Response: Comment noted and addressed in Chapter 10, Sections 10.2 and 10.2.4.
4.10.	4.4 Reactor Building— Design Concept	The design concept is described in paras (a) to (m). In essence the reactor building constitutes a series of physical barriers to uncontrolled release to the environment. It is designed to withstand the effects of dead load, live loads, wind, temperature and earthquake. Low probability seismic loads from beyond design basis events were considered to ensure ductile behaviour of structures. It is also designed withstand a light aircraft crash and maintain reactor integrity.	A significant design concept is the ductile behaviour of the structure beyond the SL-2 earthquake. The margins that exist for these beyond design basis events should be tabulated in terms of High Confidence Low Probability of Failure (HCLPF) at various return periods.
			Response: Information on the behaviour of the reactor building beyond the SL-2 earthquake is presented in Chapter 4, Section 4.4.3.3.2.5 (page 4.4-32), "Seismic Overload on the Structure". The margins beyond the design basis event will be addressed in the Detail Engineering Seismic Design Summary. For the safety analysis, significant capacity beyond the SL-2 event has already been demonstrated. The PSA also considers larger events.
4.11.	4.4.2 Architectural Design	The reactor basement (Level-7) contains a Refilling Pool that is used for temporary storage of pool water for maintenance purposes. This pool	When the main pool and the refilling pool are interconnected there is a potential for draining the core (and the pool). Has this been considered in the PSA and Ch.16 of the PSAR? The Safety Class of the Refilling Pool and interconnecting pipe work needs consideration.

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		can also be used to collect water in a Loss of Coolant Accident (LOCA).	
			Response: Yes, analyses are presented in Chapter 16, Section 16.11 and the PSA.
4.12.	4.4.2 Architectural Design	At Level -5 there are three Core Cooling Rooms, each of which house one set of primary cooling system pump and heat exchanger.	The main pumps have flywheels and run at high speed to maintain flow for up to 100 seconds after loss of pump power. The failure of a flywheel needs to be evaluated since it is likely to do major damage within the a Core Cooling Room, including rupturing the primary pipe work. The design and failure evaluation of the flywheels, together with associated damage estimate is required.
			Response: See Chapter 16, Section 16.11.2.1, failure evaluation, Chapter 6, Section 6.2.7.1.1, flywheel characteristics and Chapter 6, Section 6.2.8.7, early warning of pump vibration by pump instrumentation
4.13.	4.4.2 Architectural Design	The layout of rooms and equipment at the higher levels (+4, +8, +10, and +13) is described.	At these higher levels the floor seismic response spectra (see figures 4.4.15A to 15L) show quite high accelerations, around 9 Hz. The selection of the time history accelograms for design is important There should be a number of them to cover both near field and far field earthquakes. The conservatism of using RG 1.60 and associated time-histories has been questioned by the IAEA in relation to equipment with natural frequencies above 7 Hz. Please discuss.
			Response: Floor response spectra presented have been generated from a synthetic time-history that complies with the RG 1.60 based design response spectrum. Further time-history analyses using two other conforming time history accelerograms will be completed during the Detailed Engineering phase. The RG 1.60 based design response spectrum is a broad spectrum and will cover near and far field earthquakes. The generated floor response spectra have been broadened and smoothed to account for uncertainties in seismic input.
4.14.	4.4.2 Architectural	Above Level +13 is the Reactor Hall and access to the pool top. This area	The containment design features in this area may need special consideration, since it is a large volume directly exposed to the pool water. It also has many important barriers

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	1 Design	can be directly viewed from the Main Control Room.	between areas designated within the containment and areas outside the containment.
			Response: Comment noted, these issues are addressed in Chapter 7, Sections 7.8 and 7.8.3.
4.15.	4.4.2 Architectural Design	The Emergency Control Room (ECR) is located at Level +4 outside the designated containment. The Main Control Room (MCR) is at Level +13 and outside the designated containment. The meal room is at Level +8 outside the designated containment.	The ECR and MCR are Safety Class 1 systems and should be accordingly classified. (See Table in Chapter 2 PSAR.)
			Response: The ECR systems are classified as Safety Category 1. The MCR has both Safety Category 1 and Safety Category 2 systems. These are classified in Chapter 2, Table 2.5/2. Both the ECR and the MCR are inside the Reactor Building and will thus survive the SL-2 seismic event.
4.16.	4.4.2.10.3 Principal Movement Routes in Reactor Building	The circulation route for staff other than reactor operators is described.	Security and accounting for people within building may be an issue with such a complex building layout, with many floors and levels. Will people have to sign in the MCR before entry. A security, communications and safety alarm evaluation for all the rooms and levels needs to be undertaken.
			Response: People will be logged by the access controls through the main entry at the APS post for the reactor building. The entry to internal containment floors, MCR and other controlled areas are through individual access controls or alarms that log the usage, monitor the work procedures issued from the MCR and ensure that security or safety requirements operate efficiently. A comprehensive set of communication systems and procedures cover the whole facility during normal and emergency conditions. See Chapter 10, Section 10.3.

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4.17.	4.4.10.2.5 Fuel Handling	The transportation arrangements for movement of fresh fuel into the reactor building and spent fuel out are described. For spent fuel a special flask has to be lifted into the pool.	The PSAR Chapter 16 will need to consider accidents that could lead to unplanned criticality during handling and storage of fresh and spent fuel. ARPANSA would expect that criticality detection and dosimetry systems are also considered. The potential for dropping the flask and crushing fuel and damaging the pool liner should be covered in Chapter 16.
			<p>Response: Fresh and spent fuel handling and storage and criticality issues are discussed in Chapter 10, Section 10.1. Events related to criticality in the fuel storage are addressed in Chapter 16, Sections 16.13.4 and 16.8.2.</p> <p>The reactor hall crane incorporates a double breaking system and special interlocks to prevent the movement of the spent fuel flask above the reactor pool.</p> <p>The transfer flask is parked in the service pool on a specially designed device that absorbs its load.</p> <p>These safety provisions make crushed fuel and damaged liners very unlikely events. These are addressed in Chapter 16.</p>
4.18.	4.4.10.2.5 Fuel Handling	Spent fuel is transferred out of the pool by means of a special flask via the Reactor Beam Hall.	Please provide information is needed on how the containment integrity is maintained for this transfer route between the Beam Hall and the pool.
			<p>Response: This transfer will be carried out during a reactor shutdown by the 25T reactor hall crane. The floor hatch in the reactor hall level 13 will be lifted out and the flask handled through the Reactor Beam Hall. During this transfer the Reactor Beam Hall will be closed to the environment as it is provided with an airlock system in its truck access. The floor hatch will be reinstated and the operation of the multiple hatch seals confirmed by testing as detailed in containment procedures and the FSAR.</p>
4.19.	4.4.3.1.2 Load Combinations	The load combinations for SC1 and SC2 structures are taken from ACI-349-1997: Nuclear Safety Structures Code. This covers dead loads, live loads, SL-1 loads, SL-2 loads and	It is noticeable that the factors used for including dead, live and thermal loads are significantly less for Load Case 4 which involves the SL-2 (or SSE). This could mean that the actual stress could be greater in the SL-1 case. What is used for the load combinations on components and systems since ACI-349 only refers to structures?

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		wind loads.	
			Response: For design of Building Structures load factors are applied to basic design loads. This is the normal ultimate strength method using applicable codes. For components, the adopted (and usual) design method uses loads without amplification factors and compares the actions (in terms of stresses) against allowable stress limits. These allowable limits are fractions of yield and/or ultimate strength. For example, allowable stresses are given in the adopted ASME code for mechanical component design. The ASME service limit adopted for combination with seismic events is B (elastic)
4.20.	4.4.3.2 Evaluation of Loads	Information is given on self weight, dead load, live loads, plant and equipment loads, etc	The loading on items that form the containment barrier during the pressure rise following containment isolation needs to be considered. A particular case needing attention is the pressure loading in the MCR glass windows.
			Response: As indicated in Chapter 7, Section 7.8.3.2.2 the containment MCR window will be designed to withstand a pressure difference of 2.5KPa. Detailed engineering and verification associated with this window will be included in the FSAR.
4.21.	4.4.3.2.1.4 Plant and Equipment Loads	Dynamic effects where relevant are included in plant and equipment loads.	There needs to be some recognition of earthquake loads and the relevant floor response spectra for plant and equipment anchorages. All plant and components should be considered since there can be secondary damage from failure of Seismic Class 2 and 3 components.

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			<p>Response: Please see Chapter 2, Section 2.5.2 for details on components qualified as Seismic Class 1. Relevant floor spectra are considered for equipment and anchors. See Chapter 2, Section 2.6.1.7.2.1.6. The seismic classification has been carried out in accordance with IAEA 50-SG-D15. The code specifies for seismic category 1; "Items within this category shall be designed or demonstrate to withstand the consequences of ground motions associated with earthquake level SL-2". The code also specifies that if the failure of an item could jeopardize the functioning of items with higher category, the first one must be classified in the same category as the endangered ones, or the endangered item must be protected. This criteria has been incorporated into the seismic classification methodology described in Chapter 2, Section 2.5.2 and provides protection to Safety Category 1 components and systems against "secondary damage" originated by other components that are not Safety Category 1.</p> <p>As examples of protection, grids have been adopted to protect Beam Bellows and the Core. As examples of reclassification, Reactor Pool Internals without safety function were classified as Seismic Category 1 (Escape Ladder, Racks, Lighting supports, Platforms).</p>
4.22.	4.4.3.2.1.5 Crane Loadings	Crane loads applied to the building structure are calculated in accordance with AS-1418 Crane and Hoist code.	In addition to meeting AS1418, consideration should be given to any relevant nuclear crane guidance. In particular seismic loads and seismic supports to prevent collapse of the crane support structure.
			Response: Specific requirements for cranes are discussed in Chapter 2, Section 2.6.1.7.2.1.5. NUREG 0554 is used for the reactor hall crane and crane support structure, See Section 4.5.2.
4.23.	4.4.3.2.2 Wind Loads	The Reactor Building will be designed for wind loads determined in accordance with AS-1170.2-1989.	The statement of a 5% probability of wind speed exceedence in 2000 years, is interpreted as a 95% confidence level for a 2000 year return period wind speed value.
			Response: Correct.
4.24.	4.4.3.2.3 Earthquake	The Reactor building must survive the OBE without damage, and the SSE	As discussed in earlier comments the basis for the selection of the OBE is not clear. In the USA, from which much of the design guidance is taken, it is normally half the SSE

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	Loads	must not prevent shutdown of the reactor and removal of decay heat. The OBE is 0.09 PGA with a response spectrum based on 4% critical damping. The SSE is 0.3g PGA with a response spectrum based on 7% damping (see Fig 4.4/10)	(or 0.15 g PGA). The justification for using 7% damping for the SSE is also questioned. It should also be required that the containment meets its design specification in both the OBE and SSE.
			Response: Please refer to the answer given to Question 4.3. The 7% damping for reinforced concrete structures during SSE is adopted in compliance with USNRC Guide 1.61. The elastic design basis and the relevant load factors for the OBE and SSE will ensure that the containment design criteria are met.
4.25.	4.4.3.2.4 Light Aircraft Impact	Based on IAEA guidelines a small jet aircraft has been used to determine the aircraft crash impact forces. The unique external grill has been designed to absorb the impact forces without damage to the reactor and the pool. The fire threat from such an impact is also assessed, with a fire that lasts 20 minutes.	There is a need to look closely at the grillage design, to see if it can withstand a side impact and a prolonged fire without collapse. Please state the rationale for reliance on an external grill at the expense of a stronger containment building.
			Response: Side impact cases have been included. The grillage is designed for impact loads. There is no requirement for it to withstand subsequent fires. The concrete envelope can withstand the loads from the collapsing grillage in the event of fire (separately from the aircraft impact). Refer also to the response to Question 4.50. The effect of a fire with a duration of 20 min has been assessed. Such an event was found not to govern the failure load capacity of the grillage. The use of an external grillage as well as the inner concrete envelope provides a double layer of energy absorption. Thus many aircraft impact scenarios could be survived without damage to the inner concrete envelope. The grillage also serves as an architectural feature. Information on the grillage is presented in Section 4.4.3.3.3.

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4.26.	4.4.3.2.5 Temperature and Shrinkage	ACI-318-1999 is used to assess the stresses from concrete shrinking and thermal forces. Special consideration given to the reactor block in view of its massive nature.	<p>In view of its importance to the life of the reactor an independent check should be undertaken to ensure cracking of the concrete is not a life limiting factor. The thermal stresses and cracking should be evaluated for normal operation pool temperature, cyclic life over 50 years, anticipated operational transients and design basis accidents.</p> <p>Is there any need for a shield cooling system from the gamma heating effect on the concrete at the core level?</p>
			<p>Response: The detailed engineering phase is documenting work on the reactor block for finite element analysis of thermal effects, performance of the concrete and demonstration of adequate crack control. Significant issues arising from this work will be included in the FSAR.</p> <p>There is no need for a shield cooling system due to the large water volume between the reactor core and the concrete.</p>
4.27.	4.4.3.2.6.2 Maintenance and Life Cycle Costs	Floors subject to decontamination or exposure to chemicals will have an applied epoxy surface both for ease of cleaning and to ensure durability.	The behaviour of the epoxy surface in a fire should be indicated.
			Response: The supplier's material data sheets will be used to assess the performance under fire conditions and the results will be included in the Fire Hazards Analysis.
4.28.	4.4.3.2.6.4 Impermeability	The water storage tanks, the below ground perimeter walls and the internal basement slabs on ground are all designed to AS 3735-1991- Concrete Structures for Retaining Liquids. For the tanks at -7 level there is clearance between the tank and the floor to detect any leakage. There is also an extensive leak detection and leak connection system, with epoxy	The whole approach to preventing inwards or outwards water leakage and from the ground water needs further evaluation. Should there be bunds for the tanks? Should there be a metal liner on the floor levels below grade. IAEA guidance should be obtained and not reliance solely on an Australian Standard? What guidance is provided by the IAEA?

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		coated surfaces to prevent possible ingress of liquid.	
			<p>Response: Line B and C tanks at level -7 are provided with bottom trenches. This allows early detection of spillage or leaks from the tanks and early implementation of countermeasures.</p> <p>There is no IAEA guidance with respect to the use of metal liner. IAEA Safety Standard Series, Safety Requirements for Research Reactors (Draft DS272, April 2000) does not call for the use of a metal liner in the floor levels below grade.</p>
4.29.	4.4.3.3 Analysis and Design - Footings	The main body of the Reactor Building is to be founded some 9 m below the existing surface level. The footings and rock foundation are modelled and analysed using SAP 2000NL. Rock anchors are required to hold the Reactor Building base slab down under earthquake loading.	The dependence on rock anchors needs further explanation. What happens if not present, and will they age over the 50 years life. Also more information is needed on the embedment and the lack of grouting associated with the embedment.
			<p>Response: Please note that there is ample experience regarding the use of rock anchors in the civil engineering field. Buoyancy and seismic overturning require rock anchors to resist uplift. If rock anchors were not present, the building would need to be "keyed" into the rock around the perimeter of the basement by undercutting the rock.</p> <p>The rock anchors are galvanised for corrosion. In addition, the rods have been oversized to provide a sacrificial thickness for corrosion over a 50 year life, in the absence of grouting. The detail engineering will provide further analysis of this issue.</p> <p>Anchors are grouted for a specified embedment length into rock. Above the grouted length a free (ungROUTED) length of approximately 1 metre is provided to allow extensions to occur under the beyond design basis earthquake condition (i.e. beyond SSE). This free length has been adopted in determining the margin achievable beyond the SSE earthquake.</p>
4.30.	4.4.3.3.1.2 Water	To ensure adequate water tightness the design is to comply with AS3735 and	See above comments in relation to impermeability (4.4.3.2.6.4).

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	Storage Tanks at Level -7m	ACI -318.	
			Response: See response to Question 4.28. The basement will be designed and constructed as a water retaining structure. To ensure that water tightness has been achieved in the as-built condition, the tank will be tested with external water pressure during the construction phase.
4.31.	4.4.3.3.1.4 Shear Walls	The reinforced concrete shear walls of the reactor building are designed principally for the in-plane seismic loading obtained from SAP 2000NL	Have the differential pressure loads associated with sealing the containment been taken into account in the load combinations for the shear walls?
			Response: The identified containment related pressures have been taken into account. However, these do not govern the design of shear walls as the out-of-plane seismic stresses are higher than those arising from containment pressures.
4.32.	4.4.3.3.1.6 Roof	The Reactor Building roof is designed using SAP 2000NL and ACI-318 and AS3600 standards for the concrete construction.	More information is needed on the roof design to withstand seismic, differential pressure, wind loads etc. It is not clear why the aircraft grillage governs the design since this is a much less frequent event than the OBE and SSE seismic events.
			Response: Aircraft impact loads govern the roof design due to their magnitude despite their low frequency of occurrence. The situation is similar to the governing role of high magnitude and low frequency SSE loads on shear walls of the Reactor Building. Further details will be available once the Detail Engineering is completed.
4.33.	4.4.3.3.2 Seismic Modelling	Three dimensional modelling of the reactor building structure has been carried out. The period of oscillation and base shear estimates for E-W and N-S earthquakes are given as well as the period of oscillation.	The frequency of oscillation varied from 4.87 Hz to 7.46 Hz for the walls. It would appear that the estimates of base shear are based on separate estimates (E-W and N-S) and these components have not been combined. These E-W and N-S components should be combined with the vertical to obtain the worst loading case. Please comment.

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			<p>Response: During detail engineering the building analysis will be re-evaluated taking into account the combination of seismic spatial components. The 100% : 30% : 30% approach is adopted for building analysis following the criteria specified in TECDOC 348 (issue 1999 Draft). The same criteria are also specified in AS 1170.4 for irregular structures.</p> <p>For equipment analysis, the SRSS combination method is adopted.</p>
4.34.	4.4.3.3.2 Seismic Modelling —Seismic Mass	Seismic mass for the building is calculated using the recommendations of IAEA TECDOC 348. The seismic design loads used are not always the maximum permissible, and in general the uniform loads are 25% of allowable, but the concentrated loads are 100%.	The seismic mass used in the calculations should reflect the later IAEA guidance and ACI codes. A sensitivity study should be done to see what effect increasing the uniform loading would have.
			<p>Response: From inspection of the calculations it is clear that live loads represent a small proportion of the overall seismic mass. Furthermore, conservative values for live loads have been intentionally adopted so that variations in live loads will not affect the overall design. Based on these considerations, sensitivity studies regarding live loads are not required.</p>
4.35.	4.4.3.3.2 Seismic Modelling - Rock Structure interaction	The Reactor Building is modelled as being supported on the rock at foundation level without lateral support from adjacent soil or rock. The design response spectra are applied at the foundation level. A sensitivity study showed that the period of oscillation of the building and base shears are not significantly affected by the rock stiffness (range 8.85Hz (rigid support) to 5.3 Hz for	The modelling of the horizontal, vertical and torsional springs used for the rock structure needs to be more transparent. Does the presence of ground water around the embedment change the soil – structure interaction?

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		weaker rock).	
			Response: Values of rock properties were provided by Geotech consultants. Rock properties are indicated in Chapter 3, Section 3.2.5.3.3.4. The sensitivity analyses outlined in the PSAR envelope the variations in rock stiffness due to material properties including saturation and drying. This will be covered in the Design Manual. See Chapter 3, Section 3.2.5.
4.36.	4.4.3.2.2 Analytical Methods 0-Response Spectrum Analysis	Three dimensional response spectrum used for the seismic analysis of category 1 and 2 buildings under OBE and SSE. The first 20 modes of vibration of the structure are tabulated in Table 4.4/4 to ensure that not less than 90% of the building mass is participating in the direction under consideration.	The response spectra method permits the identification of the peak seismic response of the modes of vibration of the structure. It is surprising that the structural design has not been based on Time History accelerograms arising out of the HIFAR Seismic Upgrading—(AGSO recommended the Carbon Canyon Suite), or the Time History Accelerograms arising out of the 1999 IGNS report. A sensitivity study should be undertaken to identify any differences in the estimated forces and deflections for these differing methods.
			Response: See response to Question 4.37
4.37.	4.4.3.3.2.2 Analytical Methods—Time History Analysis	The response spectra method used for the Reactor Building structure does not produce floor spectra. Three statistically independent sets of ground motion time histories were developed synthetically using the OBE and SSE design spectra and appropriate duration for the OBE and SSE. Fig 4.4/15 shows a set of Floor Response Spectra for a range of damping values and floor levels.	It is a surprise that synthetic Time Histories Accelerograms are used in view of the availability of suitable time histories from actual earthquakes (see AGSO and the HIFAR Carbon Canyon suite, and the IGNS (1999) recommended time histories). Since they do not represent any real time history for an actual earthquake event, the applicability of these synthetic time histories is questioned.

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			<p>Response: The RRR design response spectra used has been selected as a bounding case from those corresponding to the accelerograms used by AGSO, HIFAR Carbon Canyon & IGNS Studies. Therefore the time history from the mentioned earthquakes would be inconsistent with this approach. So, the only logical and consistent approach is to produce synthetic time histories that match the agreed spectra. The use of USREG guide 1.60 (An internationally adopted standard) at 0.3g will be sufficiently conservative and bound both the IGNS spectrum and a smoothed averaged Carbon Canyon spectrum in the periods of interest. For time history analysis USREG1.165 recommends that synthetic time histories be constructed from the enveloped design response spectrum.</p>
4.38.	4.4.3.3.2.3 Analytical Tools	<p>The designer used the finite element computer codes ETABS7 and SAP2000NI for the building structural analyses (Response Spectrum Method), while elastic time history used for floor response spectra. Independent verification was undertaken by ANSTO using NISAI and ABACUS.</p>	<p>The results from the ETABS7 and SAP2000NI are presented in Tables 4.4/2 and 4.4/3. The check or verification results using NISAI and ABACUS should be also presented, an differences explained.</p>
			<p>Response: Checks and verification using a range of codes and input data are currently underway and no significant differences have been found to date. These will be documented and presented with a consolidated seismic report during the detailed engineering phase.</p>
4.39.	4.4.3.3.2.4 Summary of Analysis Outputs - ETABS	<p>Two load cases are presented in Tables 4.4/2 and 4.4/3 for earthquakes in the E-W and N-S directions. The deflections, total shear force, and fraction of load taken in the shear walls and reactor block are shown.</p>	<p>These tables are only for the E-W, and N-S components. They will have to be combined with each other and with the vertical component to determine the actual load and deflection cases. How have these components been combined in evaluating the loads and deflections? Should the method used for the floor response spectra be used, namely Square Root of the Sum of the Squares (SRSS)?</p>

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			<p>Response: The building analysis will be re-evaluated, documented and verified during detailed engineering to take into account the combination of seismic spatial components. The 100% : 30% : 30% approach is adopted for building analysis as detailed earlier. Chapter 4 also indicates the significant capacity of the building beyond the SL-2 event. For component analysis, the SRSS combination method is adopted.</p>
4.40.	4.4.3.3.2.4 Summary of Analysis Outputs – ETABS - Response Spectrum.	The mode shapes and effective modal masses are shown in Table 4.4/4, and the significant mode shapes are shown in Figures 4.4/13A.	<p>The results presented in Table 4.4/4 show that the modes at 5.4Hz, 6.34Hz, and 9.25Hz are the largest participation factors. This could be important since the chosen RG1.60 Response spectrum may not be conservative at these frequencies. Please discuss.</p>
			<p>Response: Comparisons were presented in Chapters 3 and 4 indicating the bounding nature of the RRR spectrum. When compared with the recently revised IGNS curve the RRR spectrum bounds all frequencies up to about 15 Hz.</p>
4.41.	4.4.3.3.2.4 Summary of Analysis Outputs - Floor Response Spectra.	SAP2000NL was used to subject the building model to the selected time histories of ground motion. The resulting floor response spectra are shown in Figs 4.4/15 A to L with generally peaks around 7Hz to 9Hz.	<p>The selected time history (1971 San Fernando) has been modified for frequency content and damping (7%). In view of the fact that neither AGSO nor IGNS selected this time history accelogram for SE Australia, what is its applicability for deriving floor response spectra. Two other time history accelograms were considered (El Centro and West Washington), but do not appear to have been used to generate the floor response spectra</p>
			<p>Response: The frequency content of the 1971 San Fernando earthquake has been altered to ensure its response spectra match the agreed design response spectra (in RG 1.60). The El Centro & West Washington earthquakes are being modified to produce two other matching time histories. The floor spectra encompassing response to these two time histories will be included in the Design Manual. The final floor spectra are however not expected to exceed those already reported.</p>
4.42.	4.4.3.3.2.5	The reactor block forms a very stiff	<p>In view of its importance in withstanding the seismic load, it is important that issues</p>

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	Design of Primary Elements Subject to Seismic Loads - Reactor Block	element in the reactor building structure and will carry up to 40% of the seismic loading on the reactor building.	raised above in relation to time histories, combination of seismic components, damping value etc are resolved.
			Response: Please refer to the responses to Questions 4.07, 4.33 & 4.38 for explanation. Also note that a detailed SAP2000 model involving brick finite elements is being used for stress analysis of the Reactor Block under OBE and SSE. Independent verification is being undertaken by ANSTO using three separate codes as described in Section 4.4.3.3.2.3.
4.43.	4.4.3.3.2.5 Design of Primary Elements Subject to Seismic Loads— Concrete Walls	The concrete walls provide the majority of the seismic bracing for the Reactor Building. The load combinations for the wall appear to only consider a single horizontal component, either parallel or perpendicular to the wall.	How have these components been combined in evaluating the concrete wall loads and deflections? Should the method used for the floor response spectra be used, namely Square Root of the Sum of the Squares (SRSS)?
			Response: See response to Question 4.39.
4.44.	4.4.3.3.2.5 Design of Primary Elements Subject to Seismic Loads -	Floor diaphragms use the same analysis as the concrete walls, but the vertical load is also considered in the load combinations.	How have these components been combined in evaluating the floor loads and deflections? Should the method used for the floor response spectra be used, namely Square Root of the Sum of the Squares (SRSS)?

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	Floor Diaphragms		
			Response: See response to Question 4.43.
4.45.	4.4.3.3.2.5 Design of Primary Elements Subject to Seismic Loads— Aircraft Steel Grillage	The peak response of the building at the support points for the grillage is obtained from the SAP2000 analysis and used in the STRAND& analysis for the grill.	There is no separate seismic treatment presented for the Reactor Building roof or the seismic strength of the Stack. These are important parts of the containment and the loads. Stresses and deflections for the OBE and SSE should be presented.
			Response: The design of the Reactor Building roof is governed by the aircraft impact, however, the seismic loads will be applied to all associated structures. Seismic analysis and design of the Stack under OBE and SSE are also being carried out as part of the Detail Engineering and will be included in the FSAR.
4.46.	4.4.3.3.2.5 Design of Primary Elements Subject to Seismic Loads— Footings	The major issue for the footings is the restraint of the uplift under the concrete walls. Lift of the base slab from the rock foundation must be prevented, and this is achieved using rock anchors. Rock anchors are not required for the reactor block in view of its monolithic nature.	The dependence on rock anchors needs justification. Would thicker floor slabs and shear walls avoid the dependence on rock anchors. Increasing the thickness of the floor slabs (above 300mm and 500mm) would also improve floor leak tightness. Could there also be a substantial benefit from grouting around the building footing (embedment)?

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			Response: Options such as use of thicker base slab, and socketing the reactor building footing in the rock by grouting or under cutting (as outlined in the response to Question 4.29) can reduce/eliminate the need for rock anchors. These options have, however, been considered unfavourable from the practical point of view and these aspects are being documented in the detailed engineering work.
4.47.	4.4.3.3.2.5 Design of Primary Elements Subject to Seismic Loads— Detailing— Elastic Behaviour	The Reactor Building is designed to provide an elastic response to the SSE. Limited inelastic behaviour is permitted, but only outside the containment and Category 1 structures.	This elastic behaviour does not fit in with the justification elsewhere for some ductility and the subsequent use of a 7% critical damping factor for the SSE (see Fig 4.4/10). There needs to be an explanation on how ductility is used and where.
			Response: As discussed earlier (response to Question 4.7) elastic response was assumed for the Reactor Building and the presence of any potential BDBA ductility was conservatively ignored in the seismic analysis. The use of 7% damping is allowed for “elastic” response (ductility of 1) under ASCE4-98 as detailed earlier.
4.48.	4.4.3.3.2.5 Design of Primary Elements Subject to Seismic Loads— Boundary Elements	The design of the Reactor Building is in accordance with ACI 318 Concrete Structure Code. The requirement of the detailing is that areas within the shear walls and floor diaphragms behave in a ductile manner.	This requirement for ductility is presumably well beyond the SSE, since it is implied that all parts of the containment and Safety Category 1 structures behave elastically up to the SSE. Please clarify.

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			Response: Floor diaphragm and shear walls with the dimensions used in the reactor building are inherently stiff members. The specified good detailing practice would however provide some level of ductility for seismic events beyond SSE. We reiterate that a ductility of 1 was assumed for events up to the level of SSE.
4.49.	4.4.3.3.2.5 Design of Primary Elements Subject to Seismic Loads— Seismic Overload on the Structure	The Reactor Building remains elastic for loadings up to the SSE, but will survive earthquakes larger than the SSE. The safety factor is expected to be two, but under this loading there would be loss of some minor shear walls, substantial deflections, concrete cracking and yielding of reinforcement.	A listing of the reserve strength of walls and components would be useful in order to establish the fragility data for the systems, components and structures important to safety. Cyclic loading and duration of the earthquake would be an important factor for any shaking of a weakened structure (see IAEA 50-SG-D15).
			Response: Reserve strength of individual walls does not necessarily reflect the overall performance of the Reactor Building under an event beyond the SSE. Issues such as overturning and level of damage induced in the walls need to be considered at the same time. The work will be carried out under the beyond design basis analysis and the associated verification work outlines these parameters.
4.50.	4.4.3.3.3.1 Aircraft Impact— Design Principles	In an aircraft crash the reactor core is protected by the Reactor Building roof and an additional layer of protection in the form of an Aircraft Impact Steel Framed Grillage (AISFG). The bulk of the aircraft kinetic energy is absorbed by deformation of the AISFG steel members, but it is anticipated that the reactor roof will have to prevent unacceptable damage	The use of the grillage is at the expense of a thicker roof structure for the reactor building. Does this limit the building's ability to withstand other external loads such as blast and missile?

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		from the engine missile.	
			Response: The composite system of the grillage and concrete roof and walls have been designed to withstand (separately) loads due to the SSE and the specified missile loads as detailed earlier. A blast pressure analysis will be undertaken for the FSAR.
4.51.	4.4.3.3.3.2 Design Methodology	<p>A US Department of Energy Standard (DOE-STD-3014-96 - Accident Analysis for Aircraft Crash onto Hazardous Facilities). Three methods have been utilised</p> <ul style="list-style-type: none"> • Equivalent Static Analysis • Transient Dynamic Analysis • Time-History analysis 	The analysis should be independently reviewed by ANSTO and the results provided to ARPANSA. [In view of its low likelihood (5×10^{-7} per year) ARPANSA is giving it less priority than seismicity (OBE and SSE).]
			Response: Comment noted. ANSTO will independently analyse the Grillage structure as part of verification of design deliverables.
4.52.	4.4.3.3.3.2 Design Methodology and Composite Roof Structure	The reactor hall roof thickness is set by the aircraft crash and estimates of the scabbing thickness and perforation thickness of the concrete on impact (DOE STD-3014-96). The minimum thickness is 310 mm. The permanent steel formwork is left in place to prevent concrete dropping into the pool	The reactor hall roof thickness is set by the scabbing and perforation calculation. The resulting thickness needs to be considered from the seismic and blast resistance capability, since it is a major part of the containment structure. In addition, the ultimate internal pressure and external pressure capability of the resulting roof structure should be determined to establish the limiting factors for the building pressure design capability.
			Response: As discussed before, roof slab design is governed by Aircraft Impact loads. For completeness, checks against other applicable loading conditions will be undertaken.
4.53.	4.4.3.3.3.2	A combination of welded and bolted	Has column failure been considered in either aircraft impact or seismic loading? If the

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	Design of Principal Elements	steel connections is used to provide the AISFG with the necessary strength and ductility. It is anchored on concrete columns at each corner of the frame, and these columns are founded at Level-5. The impact loading will impart very little additional stress to the reactor block, and seismic loading dictates the design of the building.	columns fail what happens to the reactor building?
			Response: Columns inside the Reactor Building which are supporting the grillage are designed not to fail under aircraft impact loads or seismic loads and are detailed as noted earlier.
4.54.	4.4.3.3.4 Thermal Forces	The heavyweight concrete walls of the reactor block have a thickness of 2.4 m around the lower part of the pool and about 1.5 m at the upper part. Stresses are induced by the temperature gradient due to the dissipation of heat generated in the reactor pool at the core level.	In addition to withstanding the normal range of operating temperatures, the pool is the ultimate heat sink under accident conditions. The thermal forces on the pool should be evaluated for the temperatures associated with this scenario.
			Response: The temperature loads on the Reactor Block are very low, even under accident conditions. However, a thermal Finite Element Analysis of the Reactor Block under temperature conditions is being carried out.
4.55.	4.4.3.4 Structure Description —Slabs at – 5 and-7 Levels	The slabs at -7 level and -5 level are supported directly on the rock foundation, and their principal stress is from uplift due to groundwater. They are designed to AS 3735-1991. The slab thicknesses are from 400mm to 600mm.	This slab is the only barrier between the groundwater and the contents of the reactor basements at Levels –5 and -7. Does such a design meet nuclear standards, and has a metal liner for these basement levels been considered.

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			<p>Response: There are two barriers: the epoxy covering 4mm thick that covers levels -7 and -5, and the concrete slab. In addition, all the tanks and components that normally retain liquids, either activated or containing dissolved activated particles, are located with appropriate separation from the floor slab of level -7 and -5.</p> <p>IAEA Safety Standard Series, Safety Requirements for Research Reactors (Draft DS272, April 2000) does not call for the use of a metal liner for such basement slabs.</p>
4.56.			<p>ANSTO Responses to Questions 56 to 75 (relating to Chapter 4, Section 4.5) have been addressed separately. These were sent to ARPANSA on 21/8/01 under Document transmittal number gjs/PSARcomments/ARPANSA/0297.</p>
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4.73.			
4.74.			
4.75.			
4.76.	4.5.2 Cranes— Reactor Hall Crane	The crane will be designed to AS1418 and NUREG-0554 and will withstand the OBE without losing operational capability. The crane or its supports will not collapse in the SSE	See previous comment that crane supports should be designed as Seismic Class 1. The crane chosen should meet modern standards equivalent to the upgrade of the HIFAR Polar Crane.
			Response: The crane chosen does meet modern standards (as indicated in Section 4.5.2.1.2) equivalent to those of the upgraded HIFAR Polar Crane.
4.77.	4.9.1 Cooling Towers	The Cooling Towers are part of the Secondary Cooling System (SCS) and connected to the Reactor Building with buried piping. They are classified as Safety Category 2 and designed for the OBE.	In the review of Chapter 2 PSAR the safety categorisation of the SCS was questioned. It provides a decay heat removal capability during normal operation, and could be a diverse heat sink in accidents through the use of the shutdown pumps. An upgrade to Safety Category 1 would not affect the Cooling Towers, but it would require the SCS pipework and Cooling Tower pond to be Safety Category 1. The burying of the SCS pipework is also questioned since it makes repair, inspection difficult.
			Response: The ultimate heat sink of the reactor is the reactor pool, whose coolant boundary parts are Safety Category 1. Please refer to the response to Question 2.14 and 2.39.
4.78.	4.9.2 Reactor Stack	The facility is provided with a ventilation stack that vents the air from the containment. It is classed as Safety category 2, Seismic Class 2 and Quality Level B. It is claimed to be designed with a failure mode that ensures adjacent Engineered Safety Features are not affected.	Please clarify how collapse of the stack will not damage the containment. Is it used in the containment ESF function as part of the venting or energy removal?

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			Response: The base of the stack, within the reactor building, is Safety Category 1. The rest of the stack is Safety Category 2. The containment is protected by the aircraft grillage from a collapse of the stack. It is not used in the containment ESF function.