The dome leaks — but it's safe

The futuristic copper-clad dome of the Australian Academy of Science, home to Australian scientific prestige, has been a prominent Canberra landmark since 1958. It's an architectural *tour de force*, but from an engineering view it does have problems.

The cladding leaks, and it's poorly insulated (despite chilly Canberra winters), making it sometimes feel more like an igloo than a putative flying saucer.

Recently, a big question mark was raised about the dome's structural integrity. A similar building, the Kresge Auditorium at the Massachusetts Institute of Technology, had to be extensively repaired and modified when it became unsafe.

It too had leaked, and the water had seeped into the Auditorium's concrete structure. In winter, the water had alternately frozen and melted, and this daily freeze–thaw cycle had caused the concrete to crack and disintegrate. The Academy's architectural and engineering advisers had wondered if something similar was happening in the Canberra dome, but they had been unable to provide a definite answer.

So, to assess the seriousness of the threat, scientists from the CSIRO Centre for Environmental Mechanics were called in. They brought their expertise — in understanding heat and water transport in many aspects of the natural environment, from soil strata to the lower atmosphere — to bear on this man-made layered structure.

The dome is essentially concrete 6–30 cm thick, covered with a 6-cm layer of vermiculite insulation and topped with the copper cladding. The upper half of the dome, where the concrete is thinnest, is not reinforced.

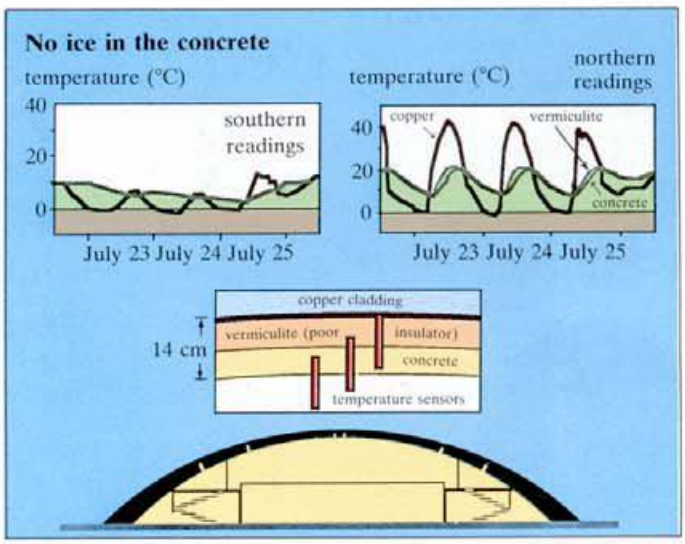
The dome of the Academy of Science — flying saucer or igloo?

The scientists, Dr Peter Coppin and Mr Steven Zegelin, monitored the temperature and water content of the layers at various points over 33 weeks during 1987/88, including a critical winter period (Canberra regularly freezes on winter nights).

Confirmation that the roof leaked came as no surprise. Whenever it rained, moisture sensors registered a rapid increase in water content below the copper. The vermiculite became wet — sometimes nearly saturated — within a few hours after a storm. It then dried out over the ensuing day or so.

The leaks probably occur through cracks in the joints of the welded copper panels caused by expansion stresses, Dr Coppin believes. He measured daily temperature variations of up to 55°C in the copper, sufficient to change the distance from one side of the roof to the other by several centimetres.

As the scientists' temperature measurements showed, the vermiculite's insulating property was surprisingly poor. (The 'R' value — a measure of thermal resistance — was gauged to be a mediocre 1 when dry and a miserable 0·1 when wet; for domestic dwellings in Canberra, an R value of 3 is recommended for ceiling insulation.)



Although the temperature of the copper cladding sometimes fell below zero, the scientists' probes showed — reassuringly — that the temperature of the concrete never did.

The worry, then, was that when outside temperatures were below zero water in the concrete may freeze too. Did that happen?

Although the duo recorded 20 nights when the temperature of the outside copper fell below zero, the temperature measured in the concrete — fortunately — never fell below freezing. Its lowest reading was 3°C, at a time when the copper reached −3°C.

Two factors account for the concrete remaining warmer than the copper, despite poor insulation in between. First, the large water loading of the wet vermiculite helped delay the penetration of the transient Canberra frost into the insulation.

More important, however, was heat emanating from inside the building and stored in the concrete shell. It was no coincidence that the lowest concrete temperature — a mere 3° away from potential damage — was recorded after the heating system in the building had been turned off for 4 days. When the heating was in use, the lowest thermometer reading was 6°C.

Dr Coppin calculates that about 18 kW pours through the roof of the dome when the insulation is dry, and something near 55 kW when it's wet. The problem in Massachusetts was brought on by much colder winters than Canberra's.

As long as the Academy can afford to heat the place, at least every few days in winter, freezing of the concrete can be avoided. Ironically, though, if it installs efficient insulation under the concrete shell, reducing heating requirements, the dome's structure may be put at risk.

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