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TEAP TH29 Test Report July 1997

**Examination of the Latent Heat Storage Material
TH29 of TEAP Pty Ltd, Perth, Western Australia**

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1. Introduction

An important point for the utilization of latent storage materials is the reversibility of the phase conversion process. Some of these products, however, have a tendency to lose their good heat-retaining characteristics as the number of phase conversions completed increases.

The material TH29 manufactured by TEAP Pty Ltd of Perth, Western Australia, which was examined in an initial study with regard to heat capacity by The Australian National University, was subjected to a cyclical thermal load by TEAP in order to determine its influence on the heat capacity, and in that way to draw conclusions as to its practical applicability.

2. Cyclical Load

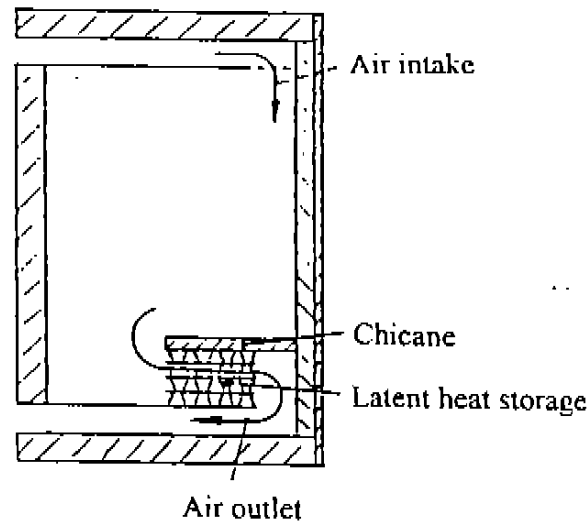
The heat capacity of 64.2 kg of TH29 material was measured in an initial study at the TEAP factory in Perth; about half of this material was subjected to a cyclical thermal stress by TEAP. The rest of the material was stored in an TEAP air-conditioned room at 20°C and 60% humidity.

In order to avoid any diffusion of water through the packaging (which would have resulted in a change in the mixture ratio and thereby of the melting point), water could not be used to act as the load, as is the case when measuring the heat capacity; instead, heated and cooled air had to be used to do this. For this purpose, a double climates chamber in the engineering department was modified in the following way:

- A cover was used to make it possible to operate one chamber at a time.
- The controls were arranged so that the cooling and heating operation could be alternated by a switch timer.

The latent storage material to be examined was built into the chamber in such a way that the air was forced to flow by the material.

Fig. 1: Construction of the latent heat storage material in the chamber



Through experimentation, the minimum heating and cooling times required for the phase conversion were determined to be 1 x 1 h. In this way an initial series of 500 cycles were run. For verification purposes, the temperatures during a cycle were recorded at intervals on a graphic recorder. Figure 2 shows such a record of 2 material temperatures (between packaging of clamped thermal elements) and the intake air temperature. The strong oscillation of one of the material temperatures can be attributed to a defective electronic component of the graphic recorder. After completion of the first series, the change in mass was measured as the first step in verification. The results are summarized in Table 1. Because of the good result and the fact that the device was available in any case, it was decided to run a second series of 3500 cycles in the same way. In this case as well, the change in mass was subsequently measured.

Fig. 2: Record of temperatures during a load cycle

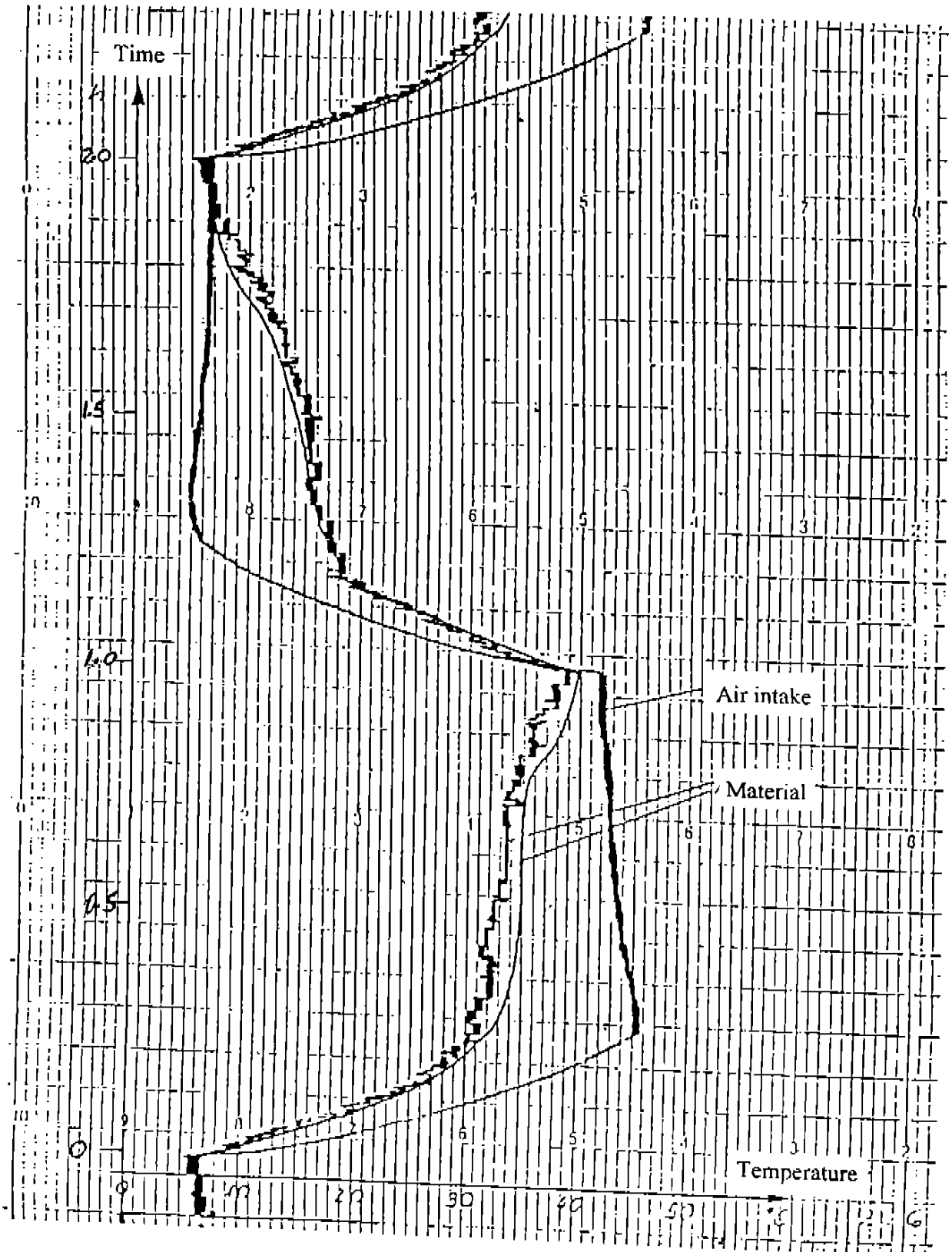


Table 1:

Mass before the 1st series:	32.076 kg		
Mass after 500 cycles:	<u>32.066 kg</u>		
Decrease in 1st series:	0.010 kg	=	0.03%
Eliminated:	<u>1.853 kg</u>		
Mass before the 2nd series:	30.213 kg		
Mass after 4000 cycles:	<u>30.243 kg</u>		
Increase in 2nd series:	0.030 kg	=	0.1%
Increase in 4000 cycles:	0.020 kg	=	0.07%

In accordance with Table 1, a portion of the material must have been eliminated, as a result of defective packaging, to be precise. The unusually high stresses compared to normal usage and in particular the incorrect piling up during the 1st series of cycles caused damage to the covering foil. In view of these defects (as a result of which some fluid material leaked out as well), the extraordinarily small changes in mass are to be viewed as 0.

3. Heat Capacity after Cyclical Load

Subsequent to the 4000 cycles, TEAP measured the heat capacity of the material in November 1996 in the same way as in the 1st examination. In this experiment, one container of the measurement apparatus was filled with 30.15 kg of the cyclically loaded material and with 30 kg of water, while the other was filled with 30.15 kg of the material stored at TEAP and with 30 kg of water as well. On the basis of the almost non-existent change in mass, an unaltered heat capacity was to be expected. However, the measurement showed two clear differences between the two charges:

- The cyclically loaded material had an approximately 6% smaller heat capacity.
- A temperature course lying about 1 - 1.5 °K higher.

This result called for a repetition of the measurement to prove its reproducibility, and this was carried out in July 1997, that is, 8 months later. In the interim, the material was stored at TEAP.

The results of all four measurements are summarized in Table 2:

Table 2:

Measurement	Measured Range °C	Q _{tot} kJ/kg	Q (ΔT)		ΔH _s kJ/kg
			24 - 36°C	kJ/kg 22 - 38°C	
1: July 95	21.9 - 38.2	188	176	188	157
2: Nov. 96 w. cycling	22.4 - 38.2	199	166	188	157
3: Nov. 96 wo. Cycling	22.0 - 38.6	195	173	191	161
4: July 97	22.8 - 37.9	186	171	188	157
Margin of Error		± 8	± 7	± 8	± 7

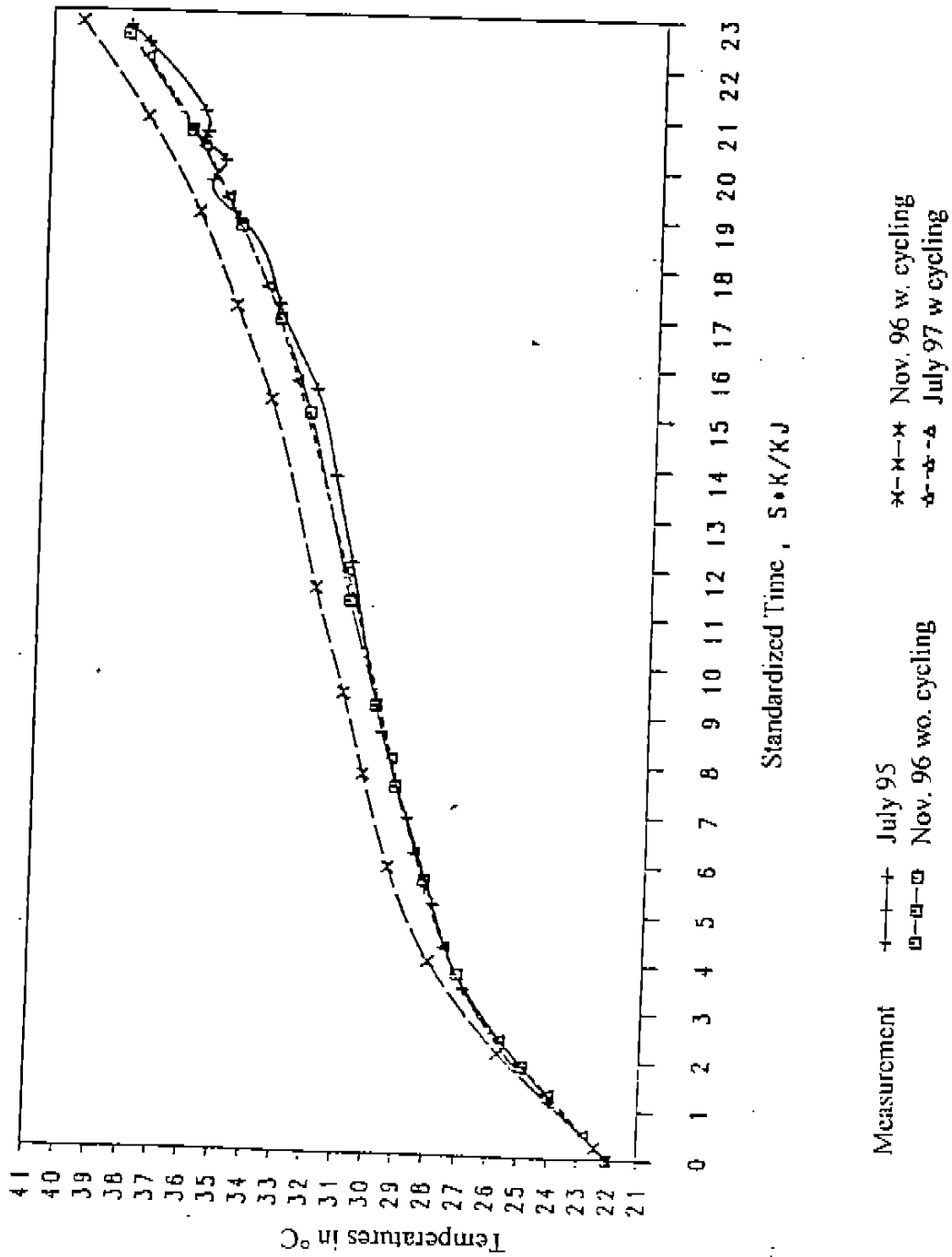
Figure 3 presents a comparison of the temperature curves of the 4 measurements. As a consequence of the different filling of the apparatus, the time axis had to be standardized by dividing the time in each case by the total heat capacity deployed (latent storage and water) (unit s °K/kJ = °K/kW). The wavy line in the upper part of the curve from the July 1995 measurement is the result of two incidents of unintended switching off of the heating for a short period of time.

The following results are evident from these two presentations:

- The increase in the heat capacity of the cyclically loaded materials in the range between 24 and 36°C was not completely confirmed in the second measurement. The 2nd measured value lies within the margin of error.

Fig. 3: Comparison of the recorded temperature lines from four measurements

TEAP Pty Ltd, Perth, Western Australia
Comparison of the recorded temperature lines



- The shift of the temperature curve upward by 1 - 1.5°K could not be reproduced either. A possible explanation may be the placement of the sensors (too close to the heating coil) in the Nov. 1996 measurement.
- The phase conversion temperature range (24 - 36°C) supposedly determined in the 1st experiment is too narrow. The theoretical heat of fusion of the (also theoretical) melting temperature of 29.2°C calculated as

$$\Delta H_s = Q - c_{lim} \cdot (29.2 - T_u) - c_{il} \cdot (T_o - 29.2)$$

increases with the increased selected differential $T_o - T_u$, i.e. the conversion process is not yet completed. The range probably depends on the heating up speed, i.e. on the filling in the case of the existing measurement equipment.

- With the larger temperature range of 22 - 38°C, no differences in heat capacity and in the theoretical heat of fusion can be determined before or after the loading.

4. Summary of Results and Closing Remarks

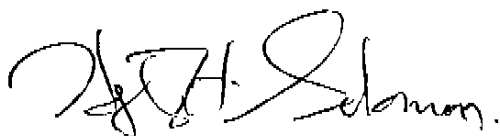
The most important results of this examination can be summarized as follows:

- After the thermal load comprised in 4000 cycles, the product shows an unaltered heat capacity. This is 188 kJ/kg in the range between 22 and 38°C, which corresponds to a factor of 2.8 compared to water at the same temperature range.
- The theoretical heat of fusion is >157 kJ/kg with a melting point of 29.2°C.

In practice, the important point is not the theoretical heat of fusion, but rather the capacity within a range, since the conversion includes such a range as a result of the transfer of heat into the interior of the material and the non-convertible portion (packaging). It should also be mentioned that the temperatures stated here are water temperatures and, as a result of the heating process, are somewhat higher than the actual material temperatures. The difference may be estimated at about 1°K, but depends on the heating performance. Analogously, the water temperature during discharge would be correspondingly lower than the material temperature. This problem is intensified if air is used as a heating medium, as Figure 2 shows, although there the work density was relatively large for the fastest possible change of phase. Such an application, however, is not exactly one of those recommended by TEAP.

The heat capacity values stated here are understood to include the packaging and not purely the content; in this case as well, the values relevant in practice are given.

Perth, 16 July 1997



General Manager



TEAP Engineering Department
Chief Engineer