An Investigation into the Monitoring of the Surface Temperature of Wall Paintings

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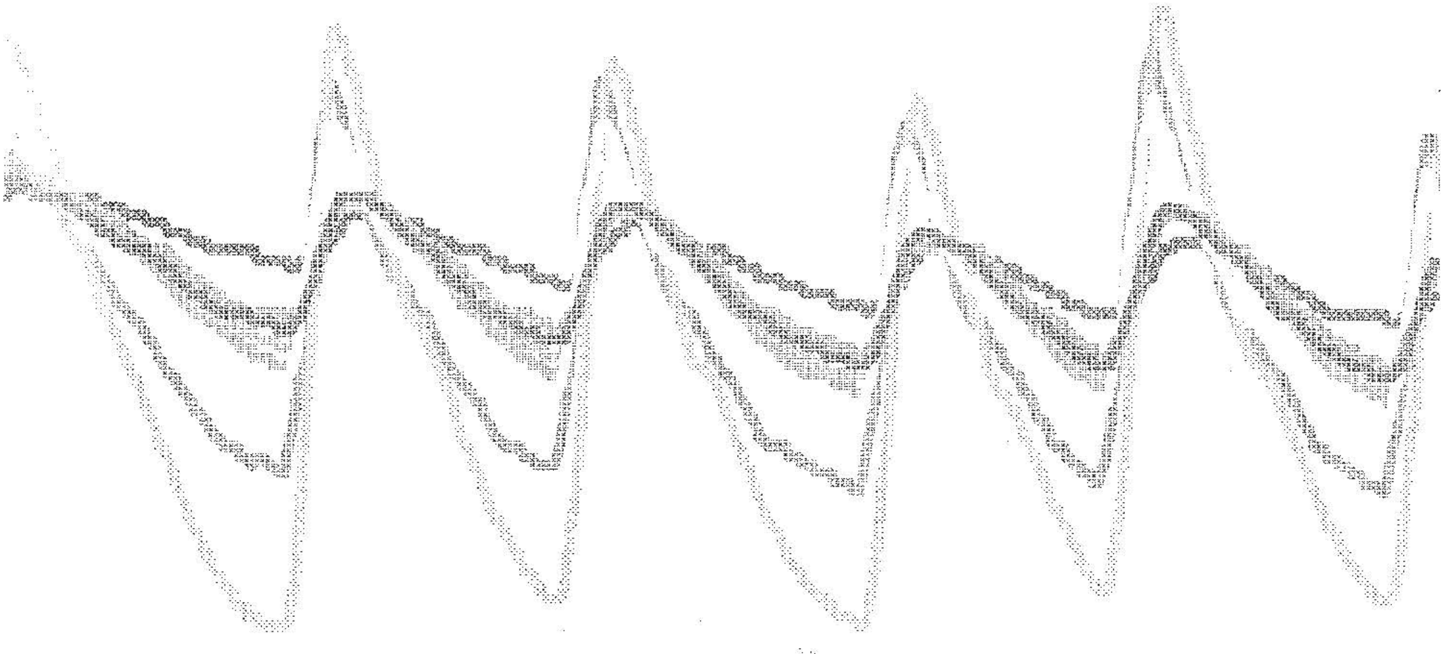

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Note: Terms marked with ^{G} *are defined in the Glossary.*

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ABSTRACT

The environmental monitoring of microclimate promises a better understanding of the decay mechanisms operating on any particular wall painting, and can be used to design strategies of preventative conservation and of treatment that are both most effective and least invasive in the long term. In designing monitoring systems and in interpreting the data from them, however, it is necessary to understand the major sources of error in the measurements taken and their minimisation.

The particular case of the measurement of surface temperature is discussed in detail here, with the problems peculiar to wall paintings – a delicate and inhomogenous surface, of low thermal conductivity and of a temperature very similar to that of the ambient air – being closely examined. The importance of measuring surface temperature is presented in terms of associated deterioration phenomena, alongside a selection of case studies of its monitoring from the recent conservation literature.

A series of experiments designed to test various methods of attachment for contact surface temperature sensors is described, and the results reported in detail. These suggest in particular that thermal insulation of the sensors is highly desirable. Non-contact surface temperature measurement using infra-red thermometers is also examined, with tests being made to determine the impact of emissivity on the readings.

In conclusion, it is argued that – since the greatest source of error comes from measurements which are insufficiently well-related to the site and to the patterns of damage and deterioration present on the painting – the final design of any system of environmental monitoring is most properly the province of the conservator rather than of specialised consultants, and to make this possible the wider discussion within the conservation field of its mechanics is highly desirable.

1. INTRODUCTION
The Environmental Monitoring of Wall Paintings

Traditionally, the history of wall painting conservation has been one of treatment to remedy the results of deterioration, but gradually a better picture has been building up of the mechanisms that have caused the paintings to degrade in the first place. Understanding the complex environmental factors affecting an individual work of art – such as microclimate and salt activity – can be the best way to ensure the work's survival: before deciding on a method of, for example, fixing an area of flaking, it is obviously desirable to understand why the flaking has occurred, whether the mechanisms causing it are still active, and whether or not these mechanisms can be controlled or at least modified:

> ...precise diagnosis takes priority over the actual interventions, because the latter, if applied erroneously, can aggravate rather than improve a situation already serious enough in itself.
>
> MASSARI 1988, *p91*

In this manner conservators hope to avoid the spectre of those increasingly frequent cycles of damaging interventions which have characterised the care of wall paintings up until now. As Arnold and Zehnder [1991, *p103*] comment

> In recent decades it has often been observed that wall paintings decay more rapidly after conservation... To preserve the paintings, it is indispensable to understand the genesis and behaviour of the salt concentrations, the chemical and physical processes damaging the paintings, and the conditions under which decay occurs.

The study of the environment of a wall painting implies a combination of careful monitoring[G] and scientific examination. Such research is by essence slow and it can be expensive, and funding bodies and clients naturally prefer the dramatic results which are achievable with treatments:

> Monitoring has never been popular with those who fund conservation. A preference for clearly visible results - for before-and-after photographs - militates against it.
>
> CATHER 1993, *p42*

However much conservators would like to shift the emphasis from dramatic results over a short period to careful and methodical examination over a long one, before this can happen methodologies for monitoring and examination must be developed, which are at least as well thought-out and rigorous as those which have come into use for treatments. With this ammunition, and aided perhaps by the recent controversies over treatment generated by James Beck and others, it may be possible to move the examination of the painting and its environment into a central position in every campaign of conservation.

That such methodologies are not self-evident is clear from the experience of the conservators working in this field. For example, the history of the current programme of conservation at Arezzo, which aims to preserve Piero della Francesca's Cycle of the True Cross in the church of S. Francesco and which has been conducted methodically in an atmosphere of unusually open debate, shows just how complex and difficult monitoring can be. An assessment of the first intensive period of examination was convened at Arezzo in 1990, bringing together conservation experts from many different countries and backgrounds to discuss the results. The environmental monitoring to date was considered in detail, but delegates felt that its results could not be regarded as conclusive. An amplified programme was recommended before treatment options could be assessed with confidence; there was felt, for example, to be too little connection between the environmental data and the condition of the painting itself. As Cather observes

> ...we are not very good at monitoring; we have little experience and few guidelines. We study systems in which there are too many variables and measurement is difficult.
>
> CATHER 1993, *p42*

1.1. Designing a Structured Approach to Environmental Monitoring

It would however be a mistake to conclude that the difficulties of environmental monitoring of wall paintings are insurmountable. To date, it has generally been undertaken by specialist consultants, but in fact the conservator – who has a thorough understanding of the paintings and their condition – may be the most appropriate person to design monitoring installations. At present a typical environmental monitoring installation would consist of a computerised datalogger[G] recording the signals of a range of electronic sensors[G] in a variety of locations around the painting, each reading various parameters such as air temperature and humidity, surface temperature, air velocity, light levels and so forth. All this equipment is quite simple, and no particular expertise is needed to obtain readings. For meaningful results, however, the choice of parameters measured and the selection of sensor positions must be determined by the pattern of deterioration visible on the painting, and it is here that expert knowledge is vital. Continual reference to the painted surface and to the building in which it is situated is the best way to ensure relevant and accurate monitoring, with results comparable both to other sites and to the same site in the future.

Although each site is different, a general approach which applies to all can still be developed which may not indeed answer every question that may arise, but which will instead provide guidelines to help the conservator decide the most important aspects of the individual situation.

A structured format is often applied to the assessing of treatments: it is an accepted approach to consider each alternative in terms of its **working properties** (that is, the ways in which the treatment is applied) and its **performance characteristics** (the ways in which the added materials will behave and interact with the wall painting over time). A flake-fixing adhesive, for example, might be assessed in terms of working properties such as solvent types, setting times and viscosity, and for performance characteristics such as glass transition temperature, colour change, and changes to its degree of solubility over time. Identical considerations can easily be used to form a framework for environmental monitoring. Sensor type and sensor position, for example, must be considered both in terms of ease of installation and access (working properties), and in terms of the type of information that the sensor is capable of capturing – is it generally applicable to the site?; will the sensor be disturbed by other factors, such as radiant energy from interior lighting, so as to give a misleading reading? (performance characteristics). In principle, just as for treatments, where there is a clash of interests the performance characteristics should be the deciding factor, since flawed results may be so misleading as to be worse than no results at all.

In order to build up an understanding of environmental monitoring in such terms it is therefore necessary to begin by examining the individual measurements which make up a programme, before looking at such programmes as a whole. This dissertation aims to make a small contribution to this process by considering in some detail a single very specific aspect of monitoring: the measurement of surface temperature. Surprisingly, the problems inherent in the measurement of the temperature of any surface, and especially of such a fragile and important one as that of a wall painting, have to date received little attention in the conservation literature.

It is to be hoped that this detailed examination of the particular problems involved in surface temperature measurement will deliver some basic information about methodologies of choice, and perhaps also provide some ideas as to how similar examinations might be tackled in the future. Collating a series of examinations of each of the many facets of measuring microclimate might provide the foundation for a more structured approach to environmental monitoring, and would certainly provide a useful tool for conservators taking environmental monitoring into their own hands.

1.2. Defining the Aims of Environmental Monitoring

The monitoring of the ambient conditions in and around historic buildings is now quite commonplace, and increasingly electronic dataloggers are taking the place of thermohygrographs[G] – familiar, but unfortunately prone to calibration error, and giving results in a rather inflexible form. In museums, where this type of environmental monitoring first came into use, the aim has often been to use systems with feedback control (whether automatic or manual) which could keep the interior ambient temperatures[G] and humidities within an optimal range and thus – it is hoped – limit the deterioration of the objects on display. Of course, for most *in situ* wall paintings it is not possible to control the microclimate to such a degree, and indeed an attempt to do so might even prove detrimental. Wall paintings are an intrinsic part of the building in which they are sited, and these buildings are *ipso facto* immersed in the uncontrollable macroclimate of their region. For this reason most environmental monitoring of wall paintings aims to compare the exterior conditions of climate around the building with those in direct contact with the painting itself, in an attempt to locate the sources of conservation problems (particularly those related to problems of humidity – condensation, capillary rise, hygroscopicity, and infiltration) [See FIGURE 1].

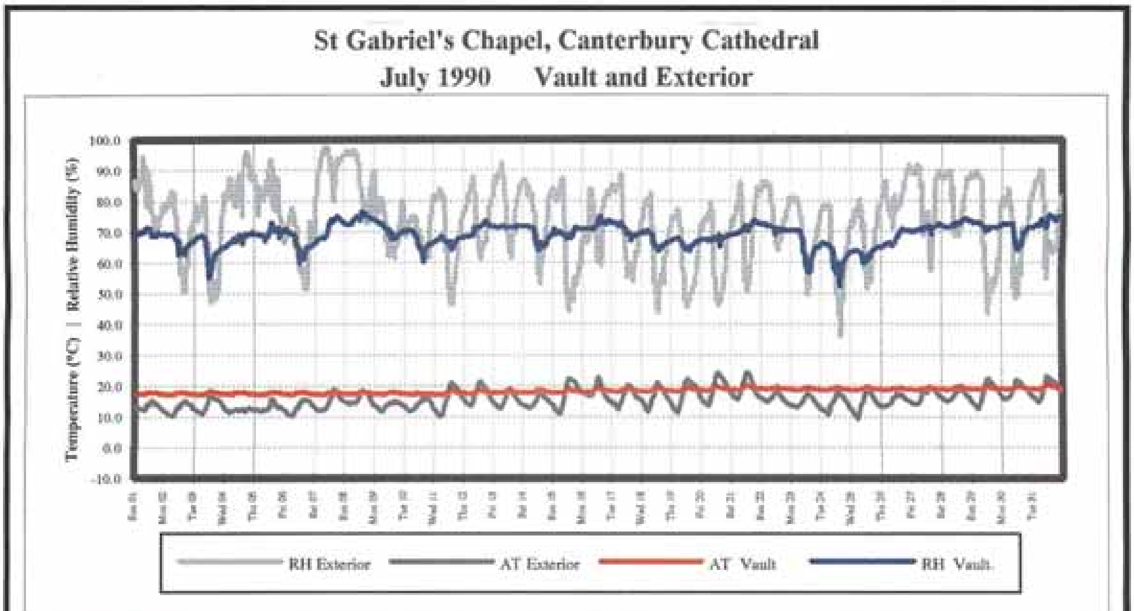

Figure 1: Data from St Gabriel's Chapel in Canterbury Cathedral shows the relationship between the exterior and interior climates over a period of a month in summer. Typically, the variations in the exterior climate are modulated in the interior. *Data from the monitoring programme of the Conservation of Wall Painting Department, Courtauld Institute of Art.*

Comparisons of interior and exterior absolute humidities, for example, reveal the degree to which the moisture levels in the church are buffered. [See FIGURE 2]

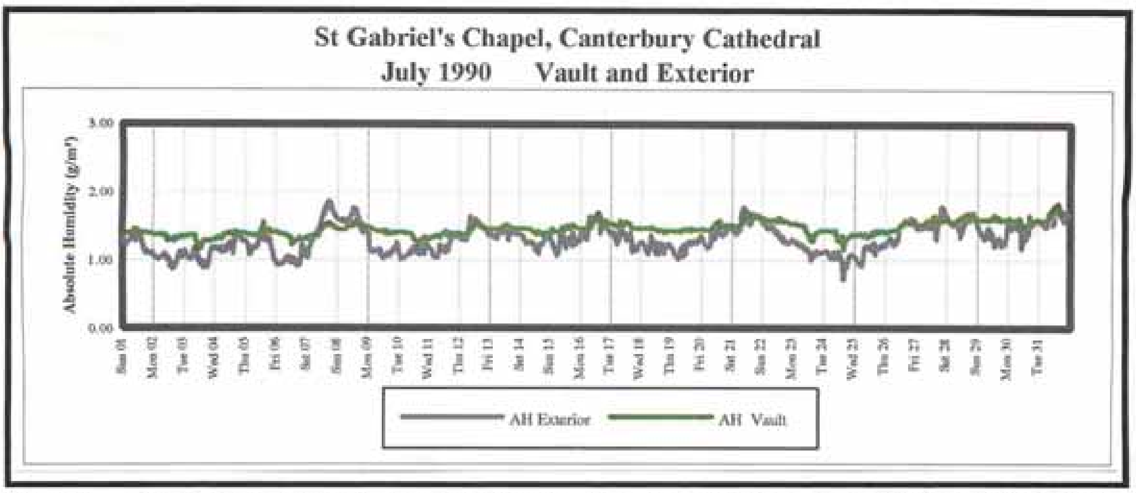

Figure 2: Comparisons of the exterior and interior absolute humidities at Canterbury (calculated from recordings of the temperature and relative humidities for the same period as the data of FIGURE 1) indicate moisture buffering within the building: although the basic direction of change is the same, the extent of moisture variation is considerably less within the chapel. *Data from the monitoring programme of the Conservation of Wall Painting Department, Courtauld Institute of Art.*

Of course, the possible environmental parameters which might be monitored are not limited to the microclimate, although this is usually of the greatest importance. Limited only by the range of sensors available, the conservator might choose to measure air movement, light levels at different wavelengths, structural movement or vibration, deposition of particulates, the chemical composition of the air, or any number of factors. The choice must depend on the conservator's informed assessment of the likely causes of deterioration of the painting and/or the structure; since data is always time-consuming to process, it is important to limit recording to those parameters suspected of being of direct importance to the condition of the work of art. The aim of environmental monitoring is to submit initial qualitative hypotheses of the environmental causes of deterioration to quantitative assessment.

1.3. Monitoring the Microclimate

There are however very few situations where the environmental parameters of temperature and humidity are not of paramount importance in assessing the condition of a wall painting and its support. At the simplest level, the aim is to compare the exterior and interior climates by installing the appropriate sensors in such a way as to make their readings as directly comparable as possible (for example, wherever possible one should install sensors at the same heights). Then from concurrent recordings of relative humidity[G] and air temperature it is possible to calculate other important parameters such as the absolute humidity[G] (the actual amount of water vapour held by the air) and dew point temperature[G] (the temperature at which the air is saturated). Where the monitoring is recorded electronically with a datalogger such calculations can be simply performed with standard software.

1.4. The Importance of Monitoring Surface Temperature

As Eshøj and Padfield [1991, *p5*] observe, data confined to the thermohygrometric conditions of the air tells us little about what is actually occurring at the surface of the wall, which is after all the actual location of the painting. Massari [1988, *p89*] lists the three most important measurements which must be taken in order to define a problem of dampness:

- Measurements of ambient temperature and relative humidity of both the interior and exterior
- Measurement of the moisture content of the masonry (by, for example, core sampling)
- Measurement of the temperature differential between the structure and the ambient.

The last step involves the measuring of the temperature of the wall surface; this can answer important questions such as whether condensation is a frequent or even a likely occurrence (atmospheric water will condense whenever the surface temperature drops down to or below the dew point temperature). FIGURE 3 shows a detail of the environmental monitoring at St Botolph's in Hardham; from this graph it is possible to say that condensation is likely to have occurred at regular intervals throughout the month.

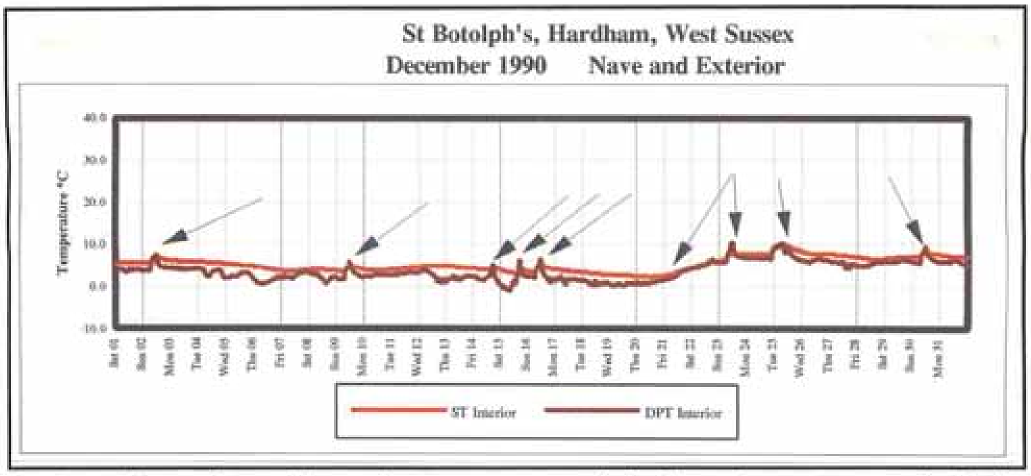

Figure 3: Comparison of the surface temperature and the dew point temperature (calculated from the ambient conditions over the same period) during December at the church of St Botolph's, Hardham, indicates that condensation probably occurred on the wall frequently during the winter. *Data from the monitoring programme of the Conservation of Wall Painting Department, Courtauld Institute of Art.*

Both the humidity and the actual temperature of the painted surface are implicated in a wide range of decay mechanisms; indeed, both are involved at least to some extent in all the problems of deterioration conservators find on wall paintings, from microbiological activity to pigment alteration. [1,2] To emphasise the importance of the measurement of surface temperature, it is worth examining some of these links between surface temperature and deterioration in a little more detail.

---

1 "Il clima degli 'ambienti confinati' rappresenta certamente uno dei fattori che concorrono a determinare la conservazione delle 'cose' ad esso assoggettate. A parti gli eventuali problemi dovuti a sollecitazione meccaniche relative alle dilatazioni termiche o a quelli derivanti dalle radiazione elettromagnetiche, la presenza di umidità e le sue variazioni nel tempo rappresentano il fattore principale di degrado di tutto ciò che è contenuto nell'ambiente. Alti valori di umidità ambiente favoriscono la proliferazione di microorganismi o attivano processi chimici latenti mentre valori molto bassi possono causare deformazioni o, nel caso delle pitture, distacchi di colore."

The climate of confined spaces certainly represents one of the factors which combine to determine the conservation of the object at hand. Apart from the possible problems due to mechanical stress, related to thermal dilation or resulting from electromagnetic radiation, the presence of moisture and its variation with time represents the principal degradation factor of everything that is contained in the ambient. High values of ambient humidity favour the proliferation of microorganisms or activate latent chemical processes, while very low values can cause deformation or, in the case of paintings, flaking of the colours.

MARCHETTI 1989, p297

1.4.1. Decay Mechanisms Associated with Surface Temperature

1.4.1.1. The Accumulation of Dirt and Pollutants

Differential temperatures produce air currents. Daws [1970, *p250*] notes that

Where a wall surface is cooler or warmer than room air, a... laminar flow develops ... against [along] the surface...

Such currents then serve to deposit dirt onto the painted surface:

The walls remain cooler than the air inside the church and so dust accumulates through the thermophoretic[G] effect: the thrusting of dust particles towards the cool surface by the greater kinetic energy of the air molecules approaching the surface than those leaving it.

ESHØJ + PADFIELD [1991, *p3*]

This effect is particularly important at sites with pollution problems, such as the Yunguang grottoes in China:

Measurements of atmospheric particle concentration and composition show that outdoor particle concentrations are dominated by a combination of soil dust and carbon particles, which are drawn into the caves at a higher rate by the natural convection flow driven by the temperature difference between the cave walls and the outdoor air.

CHRISTOFOROU *et al.* [1993, *p95*]

Torraca [1970, *p172*] notes that resilient crusts can be formed over the surface of a wall painting when deposited dirt is cemented in place by condensation. Additionally the presence of moisture (particularly from condensation), in combination with pollutants deposited on the picture surface, can result in the formation of dangerous acidic solutions [see FIGURE 4]. He observes

Condensation is an extremely dangerous source of damage in polluted atmospheres.

TORRACA [1970, *p171*]

Even if the exterior air is relatively unpolluted, sulphurous materials can be pumped directly into the air around the painting by heating systems without proper flues.

---

2 "...il comportamento termico ed igrometrico della muratura, contribuisci a determinare la variazione di umidità e di temperatura degli strati superficiali (intonaco e pittura). Queste variazioni associate all'azione degli inquinanti atmosferici sono le cause principali di degrado della pittura."

...the thermal and hygric behaviour of the walls help determine the variation of the humidity and of the temperature of the surface layers (render and painting). These variations, associated with the action of atmospheric pollutants, are the principle causes of the deterioration of the painting [at Arezzo].

FASSINA+STEVAN 1991, *p203*

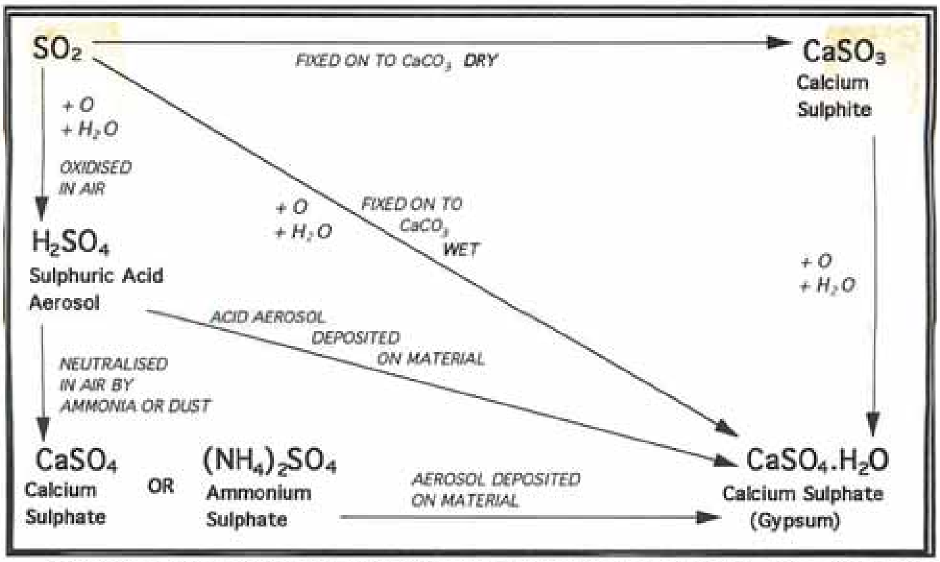

Figure 4: Possible paths of sulphur fixation on calcareous materials. *After TORRACA 1988, p41.*

1.4.1.2. The Activity of Soluble Salts

...even small variations in relative humidity can lead to cycles of wetting and drying due to solution and crystallisation of salts. Differences between surface and ambient temperature can increase this phenomenon.

HAMMER 1991, *p47*

Differences in the vapour pressure[G] between the ambient air and the air within the pores of the wall can drive the mechanism of capillary rise, aggravated by the degree of air movement across the surface (which, as noted above, can be driven by these same temperature differences).[3] Padfield *et al* [FORTHCOMING] measured surface temperatures in a mediæval church in Denmark to demonstrate that the remarkable constancy of RH in the vicinity of the wall surface could be explained by the temperature difference between the air and the surface driving an exchange of water vapour.

Whenever the relative humidity at the wall surface changes, the state of any deliquescent salts in the area will also change, with crystals forming or dissolving. Even the actual nature of such crystals depends intrinsically on the moisture level of the substrate on which they are growing, and thus on the thermohygrometric conditions pertaining in the surface pores of the painting. The damage due to salt activity is of course much discussed in the conservation literature, since it is well recognised as the most significant cause of deterioration (not only for wall paintings, but for all architectural works of art) [see PLATES 1 to 6]. The reader is referred in particular to the papers by Vos [1970] and Arnold and Zehnder [1991].

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3 For a description of the mechanisms involved in capillary rise, see VOS [1971].

1.4.1.3. Microbiological Activity

Grant and his colleagues [1989] note that moisture is regarded as the key factor in promoting the growth of mould in buildings, and cites evidence that in at least 60% of serious cases of dampness the cause is condensation. The research work undertaken by the team showed that surface temperature was also involved (aside from its implications for the relative humidity at the surface); below a certain surface temperature threshold some moulds could not propagate whatever the humidity. For example, *C. sphærospermum* would not grow on woodchip paper with a surface temperature of 12°C, even when the humidity was 100%. It could however establish itself at high humidities when the surface temperature was around 25°C. FIGURE 5 illustrates some of their results.

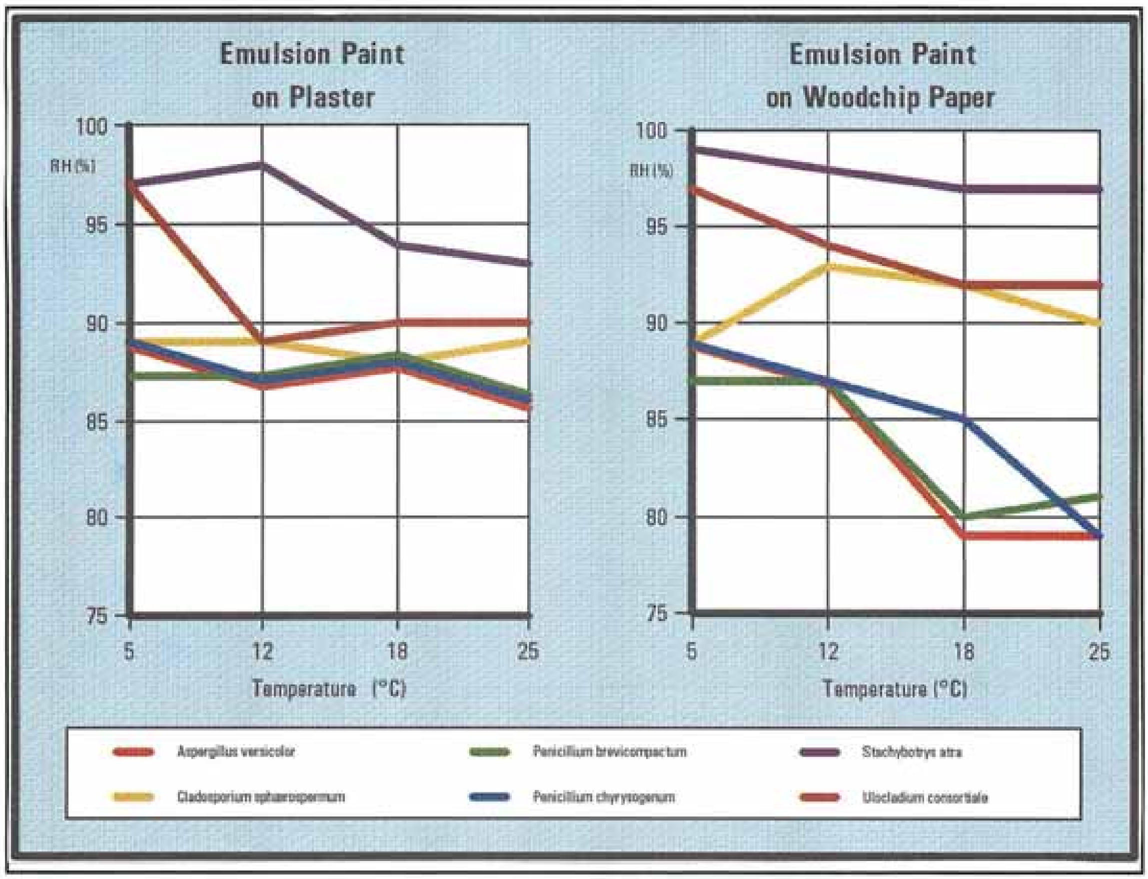

Figure 5: The effect of surface temperature on the minimum RH necessary for the growth of a selection of micro-organisms. *After GRANT et al. [1989, pp276-77].*

The view that microbiological activity is to some extent affected by surface temperature is echoed in the conservation literature. Krumbein and Petersen [1990, *p120*], observe that temperature is a major factor governing the microbiological activity; one of the strains of bacteria isolated from Krummhörn-

Eilsum, for example, is known to have optimal growth at around 20°C. Caneva and Salvadori [1988, *p189*] point out

A higher temperature generally increases biological growth because it increases the speed of chemical reactions. Most micro-organisms have an optimum between 15°C and 25°C.

This of course has particular implications for heated buildings; however in general it must be stated that the main aspect of surface temperature controlling microbiological activity is its relationship to the dew point, and the consequent likelihood of condensation providing sufficient humidity.[4] Micro-organisms are varied, and different types can flourish under a vastly different conditions of temperature and chemistry - Krumbein and Petersen even report finding halophilic (salt-loving) bacteria in Krummhörn-Eilsum[5] - but all do require a source of moisture.

PLATES 7 to 10 illustrate damage to wall paintings due to microbiological activity.

1.4.1.4. <u>Thermal Stresses</u>

As Marchetti [1989, *p297*] observes in reference to sunlight falling directly onto the painting at Arezzo, changes in surface temperature (especially if these occur rapidly) can introduce stresses into the painted surface arising from the differential expansion (or contraction) of its various elements[6]. One might expect this to be most significant where the materials are very disparate, such as for attachments or areas of gilding on painted plaster, or for later repairs. TABLE 1 gives the thermal expansion coefficients for a range of materials used in buildings:

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4 Caneva *et al.* [1991, *p15*] observe
"Indoor temperature is rarely a limiting factor for biological growth, but heating can favour development if other environmental parameters (especially humidity) are advantageous."

5 KRUMBEIN + PETERSEN 1990, *p119*

6 Vouvé *et al.* [1990, *p795*] mapped the changes in surface temperature of a painted cave on Easter Island:
"Ce chapitre est donc très important dans le sens de l'interprétation de l'equilibre mécanique présent et futur de la paroi ornée et du site souterrain."
This study is therefore very important in interpreting the present and future mechanical equilibria of the painted wall and of the subterranean site.

The Thermal Expansion Coefficients of Materials used in Buildings	
MATERIAL	COEFF OF EXPANSION microns per metre per °C
Concrete	10
Concrete with gravel	9 to 12
Concrete with expanded clay	7 to 9
Cement mortar	10 to 11
Lime Mortar	8 to 10
Limestone	7
Brick	5
Granite	8
Glass (10% alkali)	4.8
Iron	11.5
Steel	10 to 14
Copper	16.8
Aluminium	23.8
Lead	29.4
Pine, along fibres	5.4
Pine, across fibres	34.1
Oak, along fibres	3.4
Oak, across fibres	28.4
Fir, across fibres	58.4
Wood laminates	10 to 40
Polyester resins	100 to 150
Glass-polyester laminates	35 to 45
Epoxy resins	60
Epoxy with silica fibres	20
Acrylic resins	70 to 80
PVC	70 to 80
Nylon 66	70 to 100

Table 1: The coefficients of thermal expansion of a range of building materials. *From TORRACA [1988, p37].*

With regards to the conservation of wall paintings, this cause of deterioration has not yet been much investigated. However, several studies have been made into the stress induced in historic structures caused by differential heating (as caused for example by solar radiation). Bernardi *et al.* [1988] report thermal shocks to the fabric of the Ara Pacis in Rome due to the building being subjected to alternating strong solar radiation and intense shadow. They note

> The thermal cycles of the marble are very marked in comparison with the observed temperature range of the air near the surface... The thermal shocks may be great, in particular from 6.00 to 8.30 and when some zones are shadowed by the pillars of the building for some minutes, and then again hit by solar radiation causing... abrupt shock.
>
> BERNARDI *et al.* [1988, *pIII/3.10*]

Bernardi and Camuffo's study of the exterior surface temperatures of the Cathedral at Orvieto [1989] relates damage to the mosaics of the façade to the absorption of solar radiation causing mechanical stresses at the interface between the adhesive and the tesseræ.

At least two studies have attempted to relate thermal expansion directly to visible patterns of deterioration. Macías *et al.* [1992, *p1219*] relate spalling and fissuring of the stonework on the façade of the cathedral in Toledo to thermal oscillations of the order of 40°C or more:

The results of mineralogical composition of materials deduced from the experimental analytical tests show little content of soluble salts, [so] the disruptive forces due to the formation and growth of crystals could not be considered the mechanism responsible for the deterioration observed. However the different thermal expansion behaviour of the base dolomite and the rendering mortar could explain the magnitude of the damage. Thus, at 50°C the lineal expansion of the intermediate gypsum mortar is almost ten times the dolomite base stone.

Galán *et al.* [1992] evaluated the impact of daily and seasonal temperature changes on the preservation state of a selection of columns at a single site, the Court of the Lions in the Alhambra Palace, and their introduction to the study is interesting to quote at some length:

Thermal weathering essentially depends on the thermal conductivity of the rock, the expansion coefficients of the different minerals and their heat absorption capacity, and the daily temperature variation and its distribution on the rock... Under thermal variations, the low thermal conductivity of the marble may produce high temperature gradients between the exposed surface and subsurface, then shearing stresses could develop...

GALÁN *et al.* [1992, *p906*]

1.4.1.5. <u>Decohesion of the Paint Layer and the Support</u>

Brunet *et al.* [1993, *p86*] note that significant dehydration of the paint surface - especially if occurring rapidly - tends to disturb the cohesion of both paints and mortars. Torraca takes into account condensation and, using the fact that much atmospheric water contains dissolved carbon dioxide (forming carbonic acid), he pursues the idea of decohesion:

As is well known, carbonic acid solutions can dissolve calcium carbonate by converting it into water-soluble calcium bicarbonate. Calcium bicarbonate in turn reverts to calcium carbonate upon evaporation of the solution, but obviously calcium carbonate is not re-precipitated in exactly the same position it had before nor does it exert the same binding action. The paint layer can thus be affected by the process and lose its cohesive strength while an efflorescence of calcium may appear.

TORRACA [1970, *p171*]

He goes on to note that this normally slow process is vastly accelerated in badly polluted atmospheres, when the agent formed might just as easily be the strong sulphuric rather than the weak carbonic acid.

1.4.1.6. Alteration of Original and Added Materials

The normal processes of ageing, especially for organic materials such as binders and fixatives, will be accelerated by the extremes of temperature and moisture content reached by the surface and by how rapidly and frequently it attains these extremes. A number of researchers are currently investigating the impact of small temperature fluctuations on the long-term stability of conservation materials.[7] As well as affecting the performance characteristics of a treatment material, surface temperature and moisture content will also have a most significant effect on its working properties. For instance, to treat an area of decohesion successfully with a consolidant the conservator must carefully control penetration, but factors such as viscosity and miscibility could be drastically affected by the presence of water or by a very low surface temperature.[8]

Recent research on pigment alterations has also implicated both temperature and moisture as important factors [PLATES 11 to 14 illustrate the effect of such alterations]. Cather and Howard [1994], for instance, cite moisture as a major contributor (along with UV radiation and high alkalinity) in the lightening of red lead to cerussite ($PbCO_3$). The surface and ambient temperatures may affect the rate of alteration.[9] Further research may demonstrate that there are threshold moisture levels and temperatures below which alteration cannot occur.

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7 See, for example, the report by Kwasny-Echterhagen [1992], examining the long-term properties of polymers commonly used in construction.

8 See, for example, HORIE [1987, pp17].

9 Personal communication Helen Howard 1993; perhaps this contribution is analogous to the impact of UV radiation, since they both serve to increase the free energy at the surface.

2. CASE STUDIES

Surface Temperature Measurement in Conservation

As has already been discussed, in the field of conservation surface temperature measurements are generally only one aspect of a more wide-ranging monitoring of the environmental conditions pertaining to the work of art. For this reason the thermometers chosen are generally electronic sensors fixed in some way to the surface of interest, which feed information into a central datalogger alongside the readings from other sensors measuring factors such as ambient humidity and temperature and wind speed [see FIGURE 6].

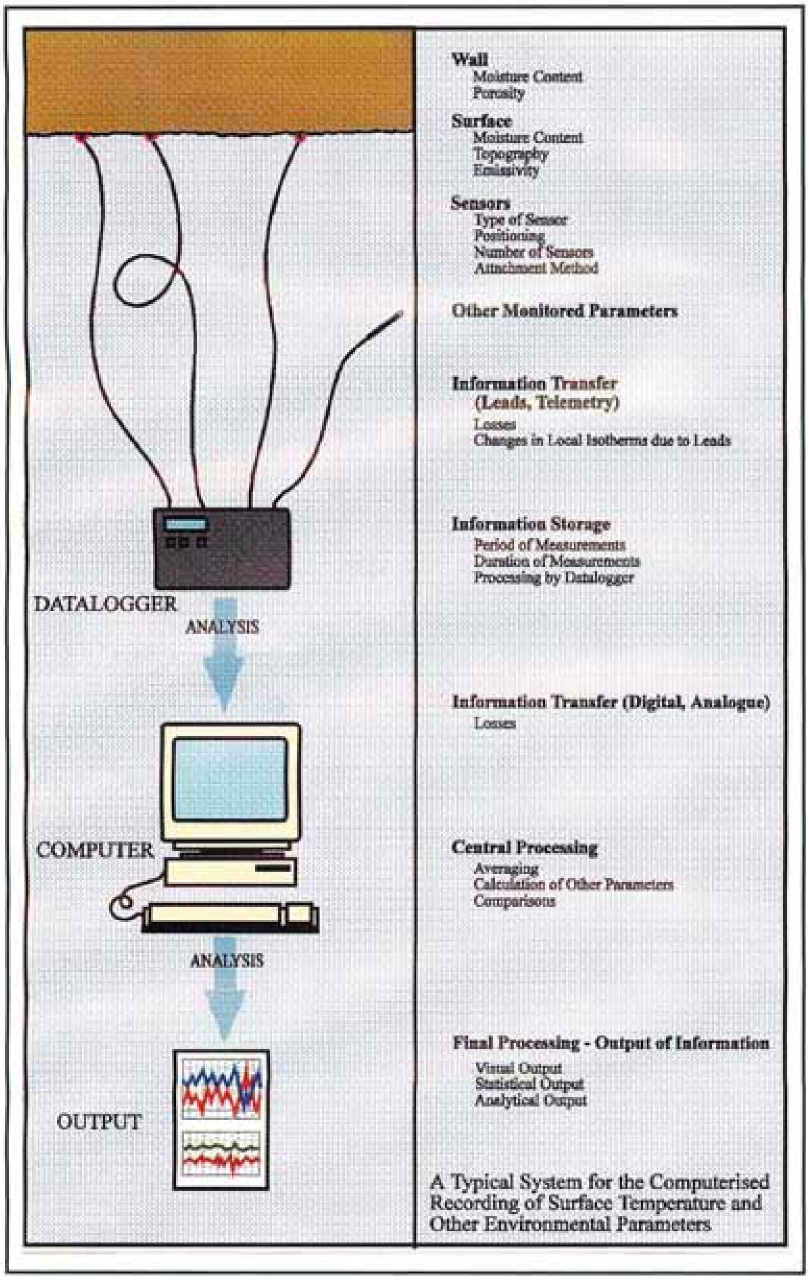

Figure 6: The configuration of a typical system for datalogging. Each component of the system can be considered as a potential source of error which will accumulate in the final measurement and its interpretation.

Of importance to the interpretation of the results, then, are the following factors:

- the choice of sensor;
- the choice of attachment method - both where and how the sensors were fixed;
- the stimulus selected for initiating a recording (an event, or a pre-set interval);
- the other parameters to which surface temperature is being compared;
- the way in which the data is processed prior to interpretation;
- the reasoning behind the interpretation (this must include the way in which the data is being presented).

When this information is clearly published alongside the results of the monitoring, readers are able to judge how much confidence they can place in the final analysis. Also, reporting not only what was done but also why allows others to apply interesting solutions to problems encountered at their own sites. The information given should be detailed enough that readers of the paper would in theory be able to reproduce the configuration quite accurately.

How, then, has the measurement of surface temperature been reported in the conservation literature? The following case studies typify the problems and approaches encountered by researchers, and include investigations into building materials as well as those directly concerned with wall paintings. The intrinsic link between a wall painting and its support makes these latter relevant, and – unfortunately – their methodology is frequently far more carefully reported.

2.1. Environmental Monitoring as Prelude to the Conservation of the Cycle of the True Cross at Arezzo

Stevan and Strada [1988]

To provide a secure foundation for the treatment of the Piero della Francesca 'Cycle of the True Cross' in the church of S. Francesco in Arezzo, the environmental conditions were carefully monitored before treatment began, and this monitoring has been continued during the current phase of intervention. Surface temperature was measured (chiefly in order to evaluate the possibilities of condensation occurring on the painted surface) with Pt100 resistance detectors attached to lacunæ and repairs with silicon putty at 30 different points in the chapel, which were determined by the patterns of damage and apparent dampness [see PLATE 16]. Infra-red thermography was used to gain a basic picture of the surface temperature distribution under different conditions. The values provided by the contact sensors were used to calibrate the results of the thermography.

The paper lists quite full details of the configuration used, giving the manufacturer's name as well as the stated accuracies for the sensors (±0.1°C over range 0 to 100°C). Although complete results are not included, the data-handling methods are described as being based on spreadsheets (Lotus 1-2-3) and then representative groups of data being transferred to 3D AutoCAD drawings of the chapel; the number of probes[G] and consequent density of data was felt to eliminate graphing as a viable method of presentation. Examples of the resulting diagrams are shown in the paper [see FIGURE 7]. Stevan and Strada also note some problems in integrating the results of previous monitoring into the present campaign.

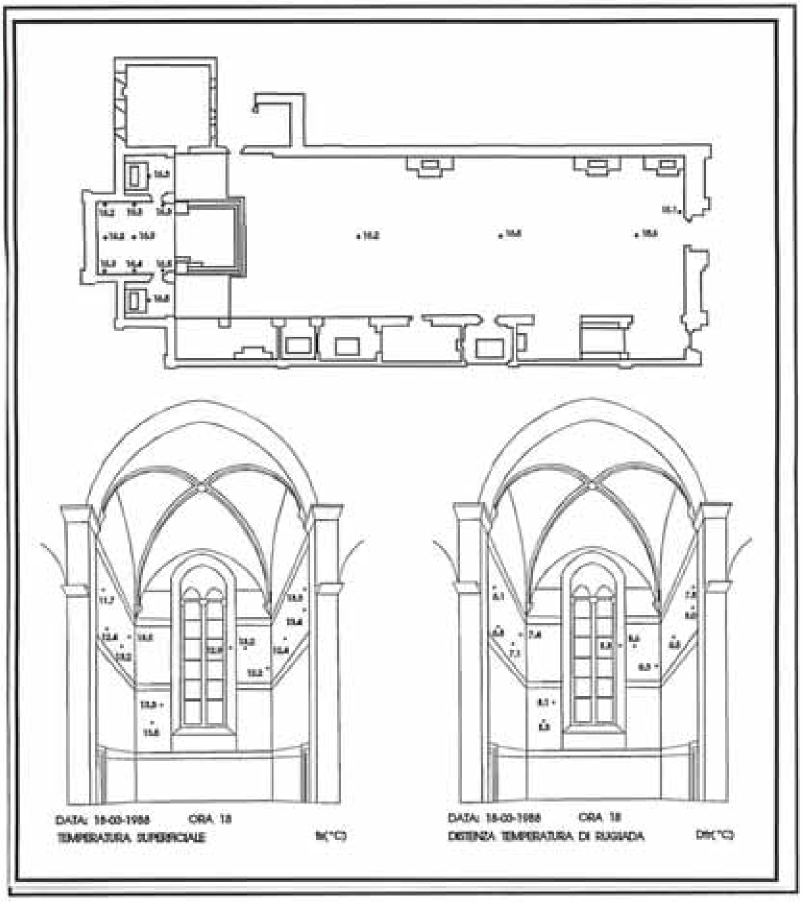

Figure 7: An example of the published surface temperature data from Arezzo, showing the use of three-dimensional plans and drawings to locate the measured temperatures around the chapel at a single time. *From STEVAN + STRADA [1988, pIII/14.313-14].*

The formal assessment of this period of monitoring at Arezzo concluded that the sensor placement was faulty, as it did not take into account the peculiar characteristics of the space – such as the vault, and the different nature of the exterior walls. There was no attempt to link sensor location to perceived problems on the painted surface, such as the degradation apparently related to the light radiating through the window. Careful assessment of the patterns of damage and simple tests prior to the placement of long-term monitoring allows more relevant data to be collected from fewer probes (also simplifying the analysis and assessment of the results).

Three-dimensional graphics can give a feeling for the spatial relationship between the data points, but in general it is a rather restrictive and time-consuming way to present the information from environmental monitoring. Simple graphs give a rather better feeling for the temporal aspect of the phenomena: the daily, weekly and seasonal events.

2.2. The Microclimate of a Church with Fragile Wall Paintings in Denmark

Eshøj and Padfield [1991], Padfield *et al.* [Forthcoming]

Monitoring of the interior and exterior climate of Gundsømagle Church in Denmark revealed the strong capacity of the wall to buffer changes in the absolute humidity. Copper-constantan (Type T) thermocouples were used to measure surface temperature, with readings taken every minute and then averaged over ten minute intervals. The configuration of the sensors, and their positions in the church, are all clearly described in words and diagrams; the sensors were positioned in lacunæ in the paintings. The accuracy of surface temperature measurement over the range -20 to +50°C is given as ±0.5°C.

The theory that the relative humidity at the surface of the wall was comparable to that in the body of the church was tested and confirmed by a simple experiment, in which a rubber cup attached to the wall and the conditions within and without the cup monitored and compared (they proved virtually identical). The wall temperature was compared to the dew point temperature in a series of graphs representing typical periods. In another interesting experiment (reported in the forthcoming paper by Padfield *et al.*) the water flux through the wall at the ambient RH was examined using an infra-red camera to monitor the surface temperature on and around areas of the wall sealed temporarily with thin plastic foil. Summaries discuss the findings of the environmental monitoring in terms of the present and future condition of the paintings.

These papers are notable for the care with which they describe the installation and positioning of the sensors, and the reasoning behind the decisions made. Tests of the way in which the measurement system was operating were made and duly reported, allowing the reader to have confidence in the interpretation placed on the results. In many ways, a model paper.

2.3. Monitoring in Order to Understand Complex Deterioration Processes at Müstair

Arnold + Zehnder [1991], Arnold *et al.* [1992], Küng [1986]

The deterioration of the important Carolingian and Romanesque paintings in the convent church at Müstair in Switzerland is largely due to the activity of complex mixtures of salts within the painted surface. In order to understand how such salts react *in situ*, the salt activity is being recorded in association with a long-term monitoring of ambient conditions and of surface temperature. The paper by Küng reports that the sensors used are Pt100 resistance thermometers, with an estimated error of ±0.3°C in the range -15 to 35°C. Two of these sensors were installed in the apse (in conjunction with RH+T sensors); their positioning was decided on the basis of thermographs taken on fine days in both summer and winter, which established in particular the location of the coldest points on the wall. The method of sensor attachment is not reported in any of these papers; however a visit to the site in February 1993 revealed the surface temperature probes to be installed over the painted surface, but not in direct contact with it [see PLATE 15]. Recordings of the environmental conditions were made every 30 minutes.

The results obtained from the monitoring suggest that the surface temperature is one of the factors modifying the behaviour of the salt mixture within the painting (as opposed to its projected behaviour from laboratory tests). In the graph of surface and ambient parameters alongside crystallisation events given by Küng it can be seen that a sharp change in RH does not necessarily mean activation of the salts, which, particularly in the case of $NaNO_3$, seem to follow the changes in surface temperature more closely. Certainly the researchers believe that the temperature measurements have enabled them to separate condensation events due to microclimate from those due to the hygroscopicity of the salts.

The behaviour of the painted surface itself – as opposed to that of fills and losses – is difficult to monitor with contact methods, as these invariably place it at some danger. It is not however clear how reliable the sensor readings can be where there is no surface contact being made.

2.4. Examining the Impact of Visitors on a Painted Cave in China

Maekawa [1993]

The microclimate of Cave 323 in the Mogao Grottoes, Dunhuang, was monitored in order to detect changes due to visitors. The air temperature and relative humidity near the surface of the painted wall, and the surface temperature of the wall, were recorded at four locations in the cave during and following such visits. In this short summary of a paper given at the International Conference on the Conservation of Grotto Sites no specific details of the monitoring methods are provided, but from conversations with the researcher it is possible to say that surface temperatures were measured with thermocouples attached directly to the painted surface with gauze 'bandages' fixed with Paraloid B72. General measurements of surface temperature were also made with infra-red pyrometers[G].[10] Maekawa reports the disturbance of surface temperatures due to the turbulent air motion generated by people moving about the cave. A particularly interesting feature of the programme was that the recording intervals were adjusted according to the likelihood of changes in the environmental conditions: an electronic eye in the doorway is used to register the arrival of visitors, sending to the datalogger a signal which causes it to speed up its rate of data acquisition.

The control of the recording interval points towards one possible way of making monitoring more efficient. A datalogger can be set to record events (rather than regular intervals), but this is rarely sufficient as it implies that what constitutes an important event is known; controlling the rate of recording is a cunning way of minimising data collection whilst retaining a good chance of recording important (but previously unsuspected) phenomena.

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10 Personal Communication S Maekawa 1993.

2.5. Research into the Causes of Recent Damage to Historic Wall Paintings

Berling [1990]

It has been proposed that the factors underlying the accelerated damage to wall paintings in the past few decades have much to do with changes to the microclimates of the buildings in which they are situated. For this reason study for the Bundesministerium für Forschung un Technologie is examining temperature, humidity, and air movement in and around the painted surfaces, comparing this to careful studies of the exterior climate. As a model for future work in this field, the environment of a church in Krummhörn-Eilsum, Lower Saxony, was monitored for a period of one year. Surface temperature measurements were made in the apse, with one sensor placed on the inside wall and another at the same height on the exterior. The variations of the exterior surface temperature were very much greater, with a daily spread of up to 25°C (as compared to average interior diurnal variations of around 1°C). The dew point was calculated from ambient conditions, and it was demonstrated that the interior wall surface did indeed fall below the DPT at times.

In this paper, Berling does not specifically relate the sensor positioning or the monitoring results to any pattern of damage on the paintings or within the structure. The sensor type and installation and the measurement errors are also not given.

2.6. An Investigation into the Possibility of Condensation at Lascaux

Brunet *et al.* [1993]

In order to compare the ambient conditions with the temperature of the cave walls, so that significant incidents of change in the moisture level of the painted surface could be detected, the surface temperature of the rock was measured at 19 specific points and the ambient conditions at 24. The general results are given in the form of isothermal[G] areas plotted on an elevation; the sensor types, attachment methods, and periods of measurement are not given. Also, since this is part of a general paper on the importance of the microclimate, the authors report no specific results.

The large number of sensors used in this programme is uncommon, but is not explained in the paper. Wherever possible sensor numbers should be kept to a minimum, to facilitate the analysis of the information collected. It is wise to collect only that data which can be clearly interpreted.

2.7. An Investigation into the Moisture Requirements of Moulds

Grant *et al.* [1989]

In order to investigate the *in situ* behaviour of a selection of common moulds, wall surface temperatures were measured at different heights on different walls (0.45m and 1.00m) with Grant type EU thermistors at half-hourly intervals, with ambient T and RH being monitored at the same intervals. Vapour pressure was calculated from the ambient measurements so as to determine the theoretical relative humidity at the surface.

The surface temperature results were reported in tabular form with a summary of the form 'the largest temperature fluctuation during a single week was 10.5°C'. Graphical information would probably have been easier for the reader to interpret. A problem with the methodology was that the surface temperatures have been monitored at different heights, possibly making direct comparison dubious.

2.8. An Investigation into Thermal Stresses on an Ancient Monument

Bernardi *et al.* [1988]

In order to examine the impact of solar radiation levels on the Ara Pacis in Rome, the surface temperatures of the external bas-reliefs were related to the light levels which reach the stone during the day. Contact thermistors were used for continuous monitoring with the floor temperature being measured as a reference, and in addition infra-red pyrometers were used to measure the east side of the building in the summer and the south side in the autumn at a height of 1m. It is not clear how often such measurements were taken.

Bernardi and colleagues do not report the manner in which the sensors were attached, nor how the difference in emissivity (and therefore in the response to radiation) between the probes and the stonework was minimised. Since the impact of radiation is intrinsically difficult to measure with contact probes, it would be helpful for other researchers if the way in which these difficulties were handled by the team was more completely described.

2.9. Relating Changing Thermal Loads to the Decay of Marble

Galán *et al.* [1992]

In the present work, a thermographic study of the columns of the Court of the Lions at the Alhambra Palace in Granada was carried out with the purpose of evaluating the impact that daily and seasonal temperature changes have on the preservation state of the columns. Although thermal weathering depends on conditions of exposure to the sun, temperature changes produce different thermal effects in relation to the structural decay pattern (obtained by ultrasound) and to the alteration forms (contour scaling, flaking, swelling, blistering ...). In general, the effects of thermal changes on altered structures seem to contribute to accelerate the process of destruction of the marble.

GALÁN *et al.* [1992, *p905*]

In this study the possible errors introduced by the differential response of sensor and material to radiation have been avoided by using infra-red temperature measurement. An infra-red camera (Instaterm 14-220), with a range of -10°C to +60°C was used to take readings of the surface temperature of the marble columns over a period of one year, measurements being made every two months. For each column, a single set of measurements was made up of a grid of 4 readings at each of 6 heights from column base to capital. Each measurement was made at the same distance from the pillar. All readings were completed within an hour, and a for each day of measurement readings were taken at sunrise, at midday, and at sunset. Thus the researchers collected a total of 432 data points for each column; these were then processed by computer to obtain isothermal maps.

Galán and colleagues observe that problems of thermal deterioration must invariably escalate, since damaged areas will show a different response to radiation, accelerating the decay still further. Their method of presenting the data as overlay maps on photographs of the columns allows for an easy visual link to be made between the measurements and the observed deterioration phenomena.

3. SURFACE TEMPERATURE MEASUREMENT

The dictionary definition of 'temperature' is one that would instinctively be recognised by most people:

The degree or intensity of heat of a body in relation to others, especially as shown by a thermometer or perceived by touch etc.

THE CONCISE OXFORD DICTIONARY

However, in order to understand the principles of temperature measurement, it is more helpful to turn to James Clerk Maxwell's definition that the temperature of a body is its thermal energy state, regarded as a measure of its ability to transfer heat to other bodies.[11] Heat may be transferred by conduction[G], convection[G], or radiation[G]: contact thermometers measure temperature via conduction and convection, whereas non-contact thermometers (also known as pyrometers) measure heat transferred by radiation.[12] All thermometers work by coming into thermal equilibrium[G] with the object they are measuring; that is, no more heat is being transferred. It is important to note that the transfer of heat can proceed in either direction: if the thermometer is hotter than the object, it will pass some of this heat to the object until they are both at the same temperature (the speed of this heat transfer depends on the nature of the objects involved). When measuring ambient temperatures, this interaction is not problematic, since the mass of the air is far greater than that of the thermometer and is also in constant motion. For surface temperature measurements, however, the situation is extremely complicated. Yong Lie *et al.* [1986, *p350*] state simply

Surface temperature is probably the most difficult common temperature measurement to make.

The basic problems are summed up by Dean Baker *et al.* [1975, *p170*]:

Any apparatus brought near to, or in contact with, the source body changes the heat transfer rates between the surface area and its environment. The rates of surface chemical reactions, evaporation, and condensation may be similarly affected. The result of this *blanketing* or *thermal damming* [*sic*] is that the temperature to be measured is altered by the means of measurement.[13]

In general, however, the problem seems to have been little discussed in the conservation literature, and perhaps has not been universally appreciated. Thus, although Eshøj and Padfield [1991, *p9*] note that

Any attempt to place a sensor close to the wall would disturb the exchange of water vapour...

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11 Quoted in MICHALSKI et al. 1991, *p1*

12 For a classification of temperature measurement methods, see HENDERSON + McGHEE 1993.

13 For other discussions in the scientific and engineering literature, see (for example) MICHALSKI *et al* [1991], PREOBRAZHENSKY [1980], BENEDICT [1977], and DUTT [1972].

elsewhere we read that the temperature of inner wall surfaces is a parameter that can be measured with certainty [BRUNET *et al.* 1993], and that

> Measurements [of the temperature differential between the structure and the air]... are no problem today, especially given the availability of simple and precise equipment on the market. Thus we will not dwell on how to conduct these measurements.
>
> MASSARI 1988, *p90*

It is true that many of the difficulties of designing environmental monitoring systems have been alleviated in recent years by the availability of excellent equipment 'off-the-shelf', but it should be clearly borne in mind that the best tool can be no more accurate than the manner in which it is used [see APPENDIX 4, ERROR ASSESSMENT]. Indeed, equipment errors are probably those of the least significance, being much smaller than the probable errors of sensor position and attachment.[14] How significant these latter are – that is, how much they are likely to effect the final interpretation of the results – is a matter of conjecture that must be resolved by controlled experiment.

The scientific literature on surface temperature measurement does provide some guidance on how significant the various errors might be, but it must be borne in mind when assessing particulars that most research in this field has been directed to industrial problems, which are in many ways quite different from those encountered by conservators. Nevertheless, the methods of approaching the problem can be considered universal.

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14 See the Commissione Normal's Raccomandazioni 5/83, concerning the measurement of temperature in general, which states

"Per ottenere una buona precisione delle misure è necessario l'impiego di particolari sensori... Va inoltre posta particolare cura nel posizionamento e nella schermatura degli elementi sensibili.... È da notare che la precisione di ±0.1 °C, con i tre tipi di sensori indicati, è ottenibile solo se si è avuta cura di ottimizzare la realizzazione della linea di mesura: schermi, contatti, taratura, ecc."

To obtain the highest precision in measurement it is necessary to use particular sensors... Also take particular care in the positioning and in the shielding of the sensor elements... It is noteworthy that the precision of ±0.1°C, which the three types of sensor give, is obtainable only if one takes care to optimise the line of measurement: shielding, contact, etc.

COMMISSIONE NORMAL 5/83 [1983, *p2-3*]

3.1. Assessing the Errors Involved in Measuring Surface Temperature

How then does one assess the errors in the measurement of surface temperature caused by the presence of the sensor? Michalski *et al.* [1991, *p317*] group the systematic error into three parts:[15]

ΔT_1 = the error caused by deformation of original temperature field

ΔT_2 = the error caused by thermal contact resistance[G] (that is, by a less than ideal contact between the sensor and the surface)

ΔT_3 = the error caused by the design of the sensitive element itself.

ΔT_1 can be minimised by choosing a thin sensor of high thermal conductivity[G] and by fixing it permanently to the surface. ΔT_2 is dependant on the smoothness and cleanliness of the surface, as well as on the force applied to the sensor (and consequently on the elasticity of the sensor materials and those of the wall); it can therefore by minimised by cleaning the surface and by increasing the contact force. ΔT_3 is reduced by selecting the type of thermometer most appropriate for the job in hand.

The main physical property of a surface affecting temperature measurement is its thermal conductivity: as this decreases, ΔT_1 increases. That is, a material with a low thermal conductivity - such as plaster - is more difficult to measure accurately than, for example, a metal, because the sensor deforms the local temperature field more. In fact, ΔT_1 is a hyperbolically decreasing function of thermal conductivity, so that as the conductivity of the surface approaches zero the error becomes, effectively, infinite.[16] The response time of the sensor is also affected; it takes longer to obtain a steady reading from a temperature probe which is measuring a surface of low thermal conductivity. Dean Baker *et al.* [1975, *p175*] emphasise that low conductivity surfaces are intrinsically difficult to measure:

> Tests... indicate that under favourable conditions surface temperatures are measured correctly to within a few percent of the elevation above ambient. However, for poorly conducting materials, errors may be much larger.

FIGURE 8 illustrates how strongly the thermal conductivity can affect accuracy.

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15 See APPENDIX 4 for a definition of systematic error.

16 For the complete derivation of this rather complex equation, see MICHALSKI et al. 1991, *p331*

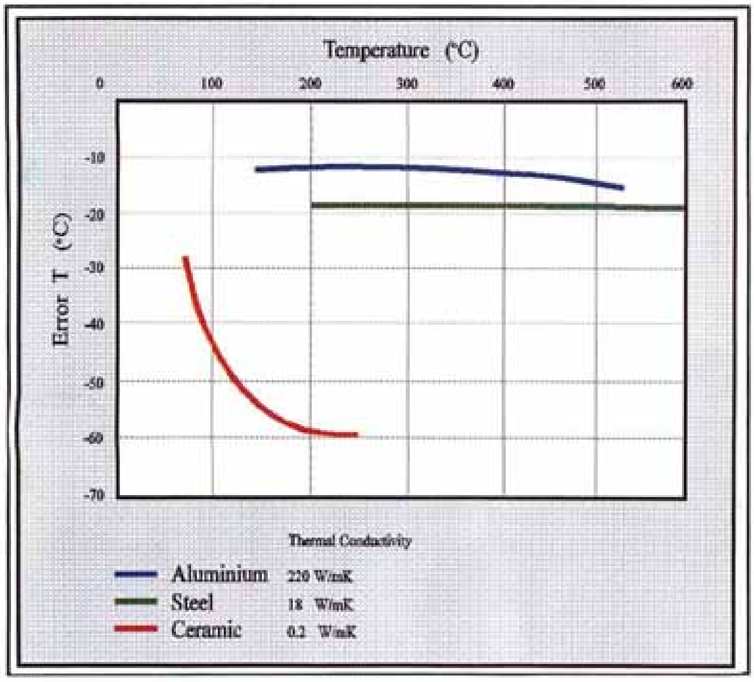

Figure 8: The error in the measurement of surface temperature (in this case, by a disk thermocouple) arising from the thermal conductivity of the surface. Although these data show a much higher range of surface temperatures than those encountered in conservation, they do serve to demonstrate how comparatively difficult it is to measure materials of low thermal conductivity. *After MICHALSKI et al. [1991,p342].*

Benedict recommends the following precautions:

- keeping the sensor installation as small as possible
- keeping sensor wires in an isothermal region for at least 20 wire diameters
- locating the sensor as close to the surface as possible
- disturbing the ambient conditions at the surface as little as possible (that is, for instance, by using sensors with a very low profile to limit air turbulence around them)
- reducing the thermal contact resistance between the sensor and the surface as much as possible.

In practice, however, the errors arising from the thermal contact resistance, ΔT_2, are usually larger than both ΔT_1 and ΔT_3 together. To quote Benedict [1977, *p259*]

The main difficulty in sensing surface temperatures usually concerns the method of attachment of the sensor to the surface. That is, the sensor must attain and yet not upset the surface temperature.

Similarly, Dean Baker *et al.* [1975,*p179*] note

The thermal contact between the surface and the sensitive element, with the element merely pressed against the surface, is disposed to be dubious; furthermore through the leads... the element is in fair thermal communication with the ambient.

In industry, dealing as it does with the surface temperatures of homogeneous and highly conductive solids, the recommended approach is to measure interior temperature at a number of points and then extrapolate these to the surface

[DEAN BAKER *et a* 1975, *p170*; MICHALSKI *et a* 1991, *p345*].[17] In the case of wall paintings, however, such invasive installation is neither possible nor desirable. Wall paintings are not homogeneous; indeed, their most important component - the very surface being measured - is a dishomogeneous layer only a fraction of a millimetre in thickness.

Is there a way of attaching the sensors so that a reading of surface temperature can be obtained to an acceptable accuracy (and how might such acceptability be determined)? It is clearly not possible to imbed sensors into the painting, and even if such damage were considered permissible the reading thus gained would still not reflect the temperature of the paint layer itself. What is the best way to ensure a good thermal contact with the surface? How much is the contact resistance affected by moisture in the air? Should the sensor be insulated (as advised by Dutt [1972, *p1016*])? The only way to answer these questions is by making a number of experiments under controlled conditions in the laboratory.

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17 Even in this case, however, it is necessary to be aware that the presence of sensors and of the holes made for them within the object will certainly alter its thermal characteristics to some degree.

4. EXPERIMENTS
The Accuracy of Surface Temperature Measurement

4.1.1 The Aim of the Project

There is obviously a need to clarify and quantify the manner in which the problems of surface temperature measurement affect the accuracy of environmental monitoring data. It is clear that the measurement is of vital importance to our understanding of the ways in which wall paintings interact with their environments, and it is therefore necessary to establish the best methods of minimising error (as well as gaining a feeling for what the size and the significance of that error might be) so that we can proceed with confidence in acting upon the data we acquire.

The dissertation project for the Postgraduate Diploma in the Conservation of Wall Painting Department at the Courtauld Institute of Art provided an opportunity to investigate some of the difficulties concerned with the measurement of the surface temperature of wall paintings. The project being of only three months' duration, it was important to limit the scope of any experiments to what was achievable on this time-scale and, accordingly, the decision was made to concentrate in two quite narrow aspects of the problem, to whit the manner in which contact sensors are attached to the wall, and the accuracy of infra-red thermography when used to measure a painted surface at close to ambient temperatures. In both cases it was felt that usable information could be gained from simple experiments.

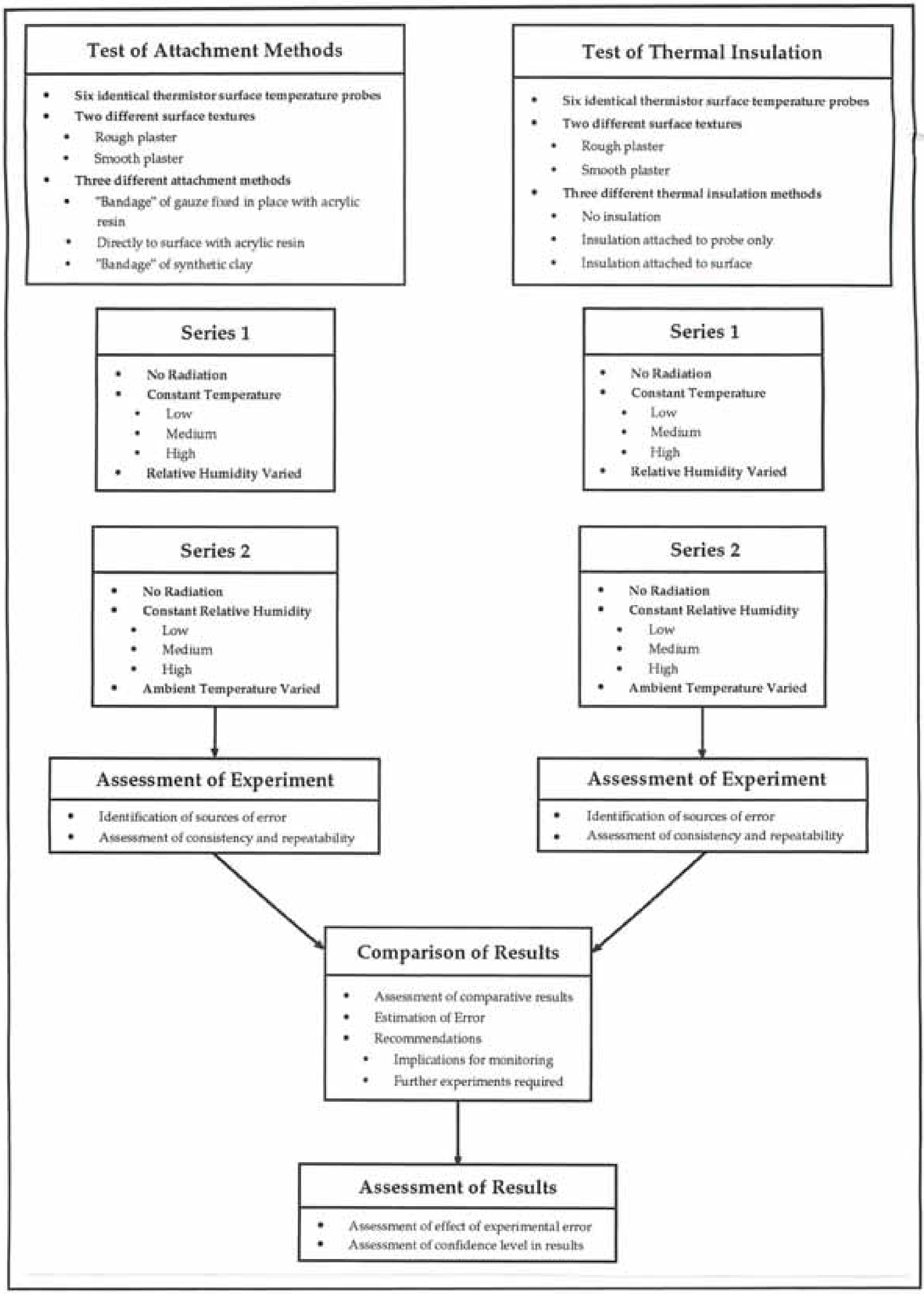
4.1.2 The Aim of the Experiments

Since the major factor affecting surface temperature measurement seems to be thermal contact resistance, a function of the manner in which the sensors are attached, an experiment was made to verify this by quantifying the levels of error arising from some of the standard methods of attachment as currently used in the field. In order for this to be achievable on the given time scale, it was necessary to limit the number of attachment methods to three generic types (that is, "bandages" of clay, direct attachment with glues, and "bandages" of light gauze). In addition, it was possible to test only one type of sensor; thermistors were selected for reasons outlined below.

It was also useful to briefly examine the possibilities for non-contact surface temperature measurement by infra-red pyrometry: what are the type of errors involved with this kind of configuration, and how badly do they distort the measurement? Does the improvement obtained by measuring the painted surface itself, justify the much increased costs of this equipment? These high equipment costs made elaborate experimentation unfeasible, and so a simple series of tests was developed which could be rapidly undertaken at a single site. The tests were designed to investigate the effect of the unusual features of wall paintings on the temperature reading: do different pigments give different results? Does a variable surface texture distort the measurement? How accurately must the emissivity be known in order to take acceptably accurate measurements? With the kind co-operation of a manufacturer of this equipment, Land Infrared, it was possible to run a state-of-the-art portable infra-red thermometer through these tests.

4.2. Experiment: the Quantification of Errors Associated with Contact Measurement

Flow Chart of Contact Surface Temperature Measurement Tests



It was important to relate any experiment as completely as possible to the peculiar case of wall paintings, which meant that the surface being used in all tests should be of aged painted plaster. In order to examine exactly what the variously attached sensors might be measuring it was necessary to have a surface which was in some manner 'controlled': but how does one control the temperature of an object with such a low thermal conductivity? On consideration, it was decided that if the model surface could be made to fit inside a climate chamber (in which ambient conditions could be varied in a controlled manner) it would suffice if the surface had a very high thermal inertia. Then, if ambient conditions were cycled rapidly, those configurations which most lagged behind the changes in the ambient would theoretically be those most closely reading the surface temperature. This assumption could be checked with a further temperature sensor imbedded in the plaster support, so as to obtain some evidence of how the internal temperature of the plaster was behaving.

Therefore in the final apparatus design, detached sections of identical aged plaster some 1*cm* thick were mounted onto a 5 *cm* thick slab of York Stone (a rock with a density on the order of $3 gcm^{-3}$), using a lime putty-sand mixture with a little hydraulic lime added to speed setting. This was then given a 1*mm* thick coat of lime-sand plaster, coarse on one side and smooth on the other, and painted with a thin ochre limewash. A hole was drilled into the centre of the plaster, parallel to the surface, so that an interstitial probe could be inserted. The exposed surfaces of the stone were then covered with insulation-grade styrofoam[18] (glued in place with a commercial spray adhesive), and the whole was mounted inside a box made of painted fibreboard, 9 *mm* thick (the paint ensured that the moisture take-up inside the climate chamber was minimal). Handles were bolted onto the case to make the equipment easier to move. The final result can be seen in PLATE 17, and in cut-away view in FIGURE 9 [for full details of the materials used, see APPENDIX 2].

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18 Expanded poly (styrene) foam, often known by the trade name Styropor™.

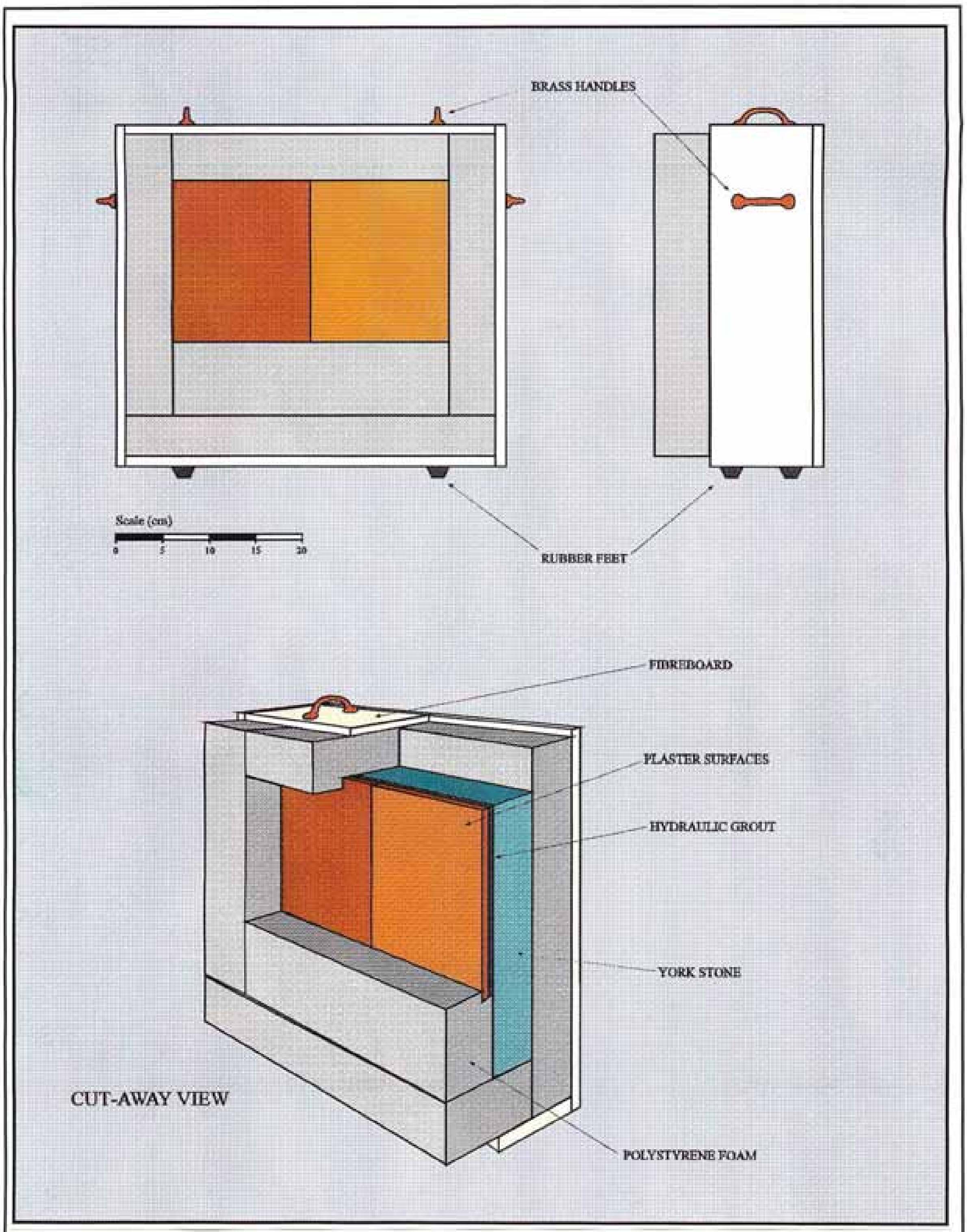

Figure 9: Construction of the model surface for surface temperature sensor attachment testing. The left (dark) half of the surface is rough, and the right (light) half smooth.

4.2.1. Attachment Methods

Since limitations in the time available for the experiment made exhaustive testing of a wide range of attachment methods difficult, the three techniques most representative of those being used in the field were selected for testing on both rough and smooth plaster. The methods selected were:

- the sensor attached with a gauze 'bandage' and acrylic resin; in this case, the probe is held in contact with the surface, but is not itself glued in place;
- the sensor itself attached with acrylic resin (to facilitate removal a double intervention layer of Japanese tissue - well doused with resin - was also added);
- the sensor attached with a 'bandage' of clay (in this case a proprietary synthetic clay, for reproducibility).

See FIGURE 10 and PLATE 18.

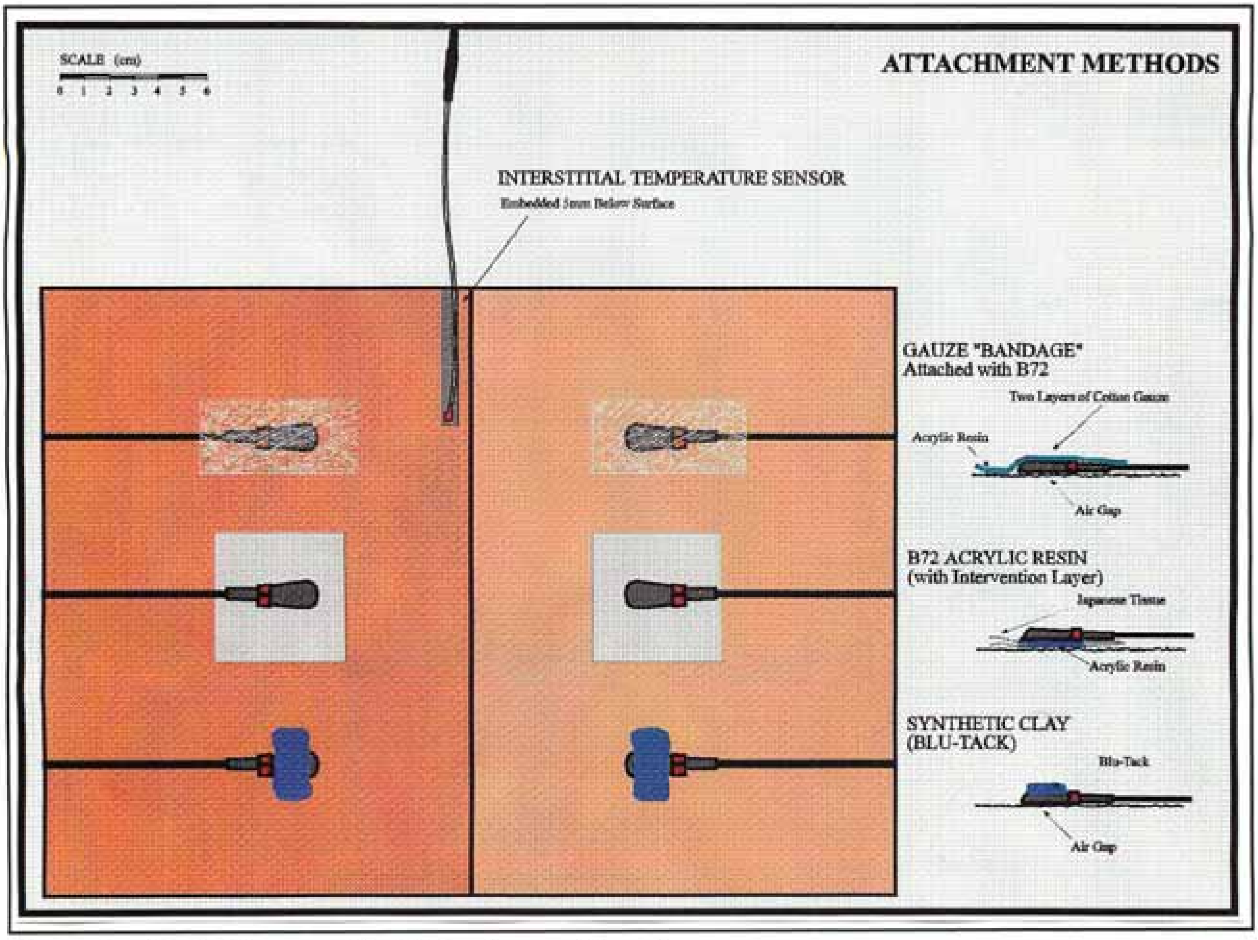

Figure 10: Scale diagram of initial testing configuration.

4.2.2. Insulation Configurations

For ease of testing during the next stage of the experiment, all the sensors were fixed with B72 and Japanese tissue as per the second attachment method. The testing was then re-run, this time using three possible approaches to insulation:

- no insulation;
- polystyrene insulation attached to the probe back only;
- polystyrene insulation attached to the painted surface around the sensor.

See FIGURE 11 and PLATE 19

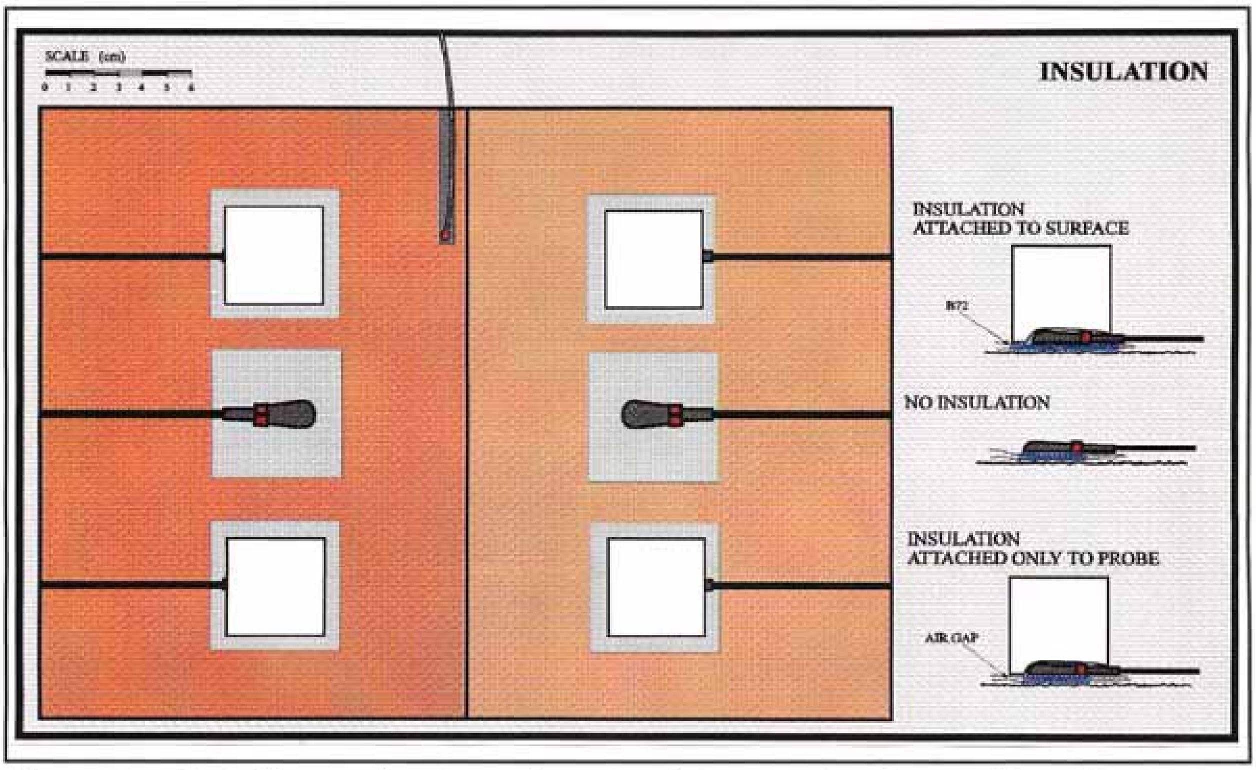

Figure 11: Scale diagram of testing configurations for investigating the use of thermal insulation.

4.2.3. The Characteristics of the Various Electrical Thermometers

For the readings of temperature to be directly comparable, it was necessary to select a single type of sensor device; for this reason the literature on the characteristics of the different types of contact thermometer suitable for datalogging was examined. It is useful to present at this point a summary of the information acquired.

A wide variety of temperature measurement devices is available, but relatively few sensors deal well with the range of temperatures of interest to conservation [see FIGURE 12].

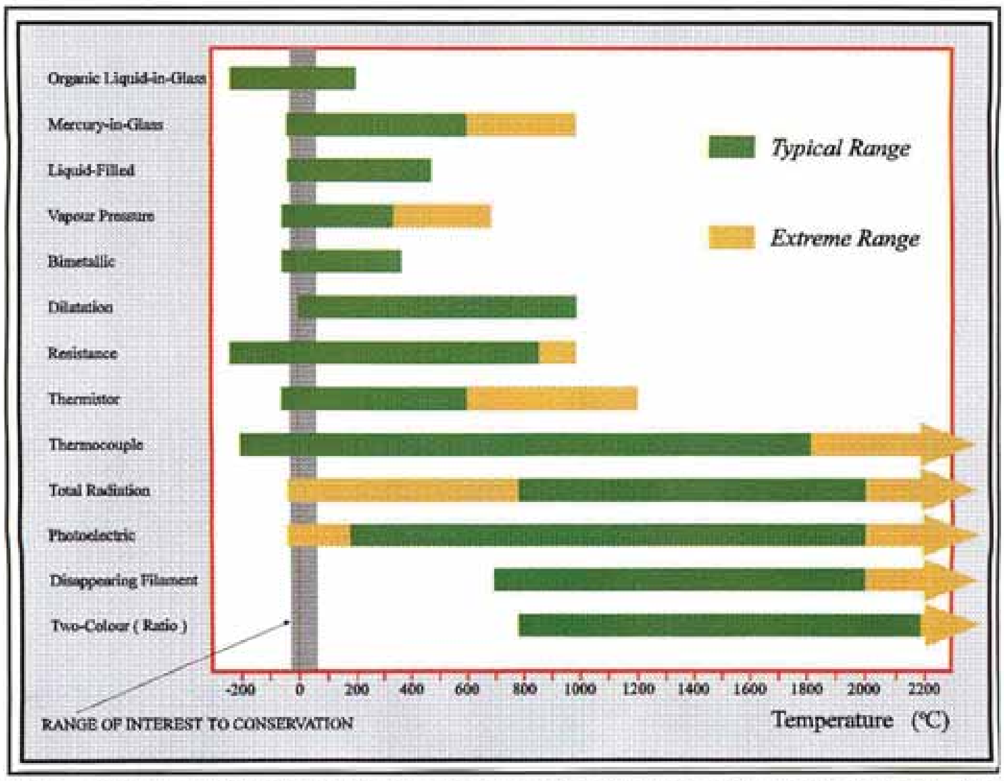

Figure 12: The operational ranges of common temperature measuring devices. Note the very small range which pertains to temperature measurement in conservation. *After Michalski et al. [1991, p15].*

For logging of surface temperature, the choice is further limited to a small range of the electronic sensors: resistance thermometers, thermistors, thermocouples, and radiation thermometers (or pyrometers). The first three of these are contact sensors, and are discussed in detail below.

4.2.3.1. Thermocouples

It was first noted in the early nineteenth century that current flows in a closed loop of two dissimilar metals when the junctions are at different temperatures, and this observation led to the development of a simple temperature-measuring device, the thermocouple. Thermocouples are composed of two wires made of dissimilar conductors, fixed together at one end with the best possible electrical contact to comprise the measuring junction; the other (open) end is known as the reference or 'cold' junction. A thermocouple sensor is the unit made up of a thermocouple, along with its associated wires, insulation, terminal head, and a suitable protective sheath.

The values for temperature for a given measured electrical current in the thermocouple are tabulated in the scientific literature - see for example KINZIE [1973] - but it should be noted that this relationship is non-linear. The tables also assume a cold junction temperature of 0°C, so in most cases it is necessary either to adjust the results in some way, or alternatively to hold the cold junction at 0°C by using (for example) an ice point apparatus. The size and clumsiness of such equipment generally limits its use to the laboratory. It is possible instead to measure the temperature of the reference junction directly with some other sensor, but in the ambient range this results in large errors (±0.8°C in the range 5 to 45°C, although this can be reduced somewhat with correcting bridge circuitry).[19] However, as Tzschach and Bartsch [1984, *p515*] observe,

Each link in the chain of devices gives rise to measurement errors.

Thermocouples are much used in industry, as they are cheap and rugged, and the means by which surface temperature errors from thermocouple measurements can be minimised are consequently much discussed in the literature (see, for example, DEAN BAKER *et al.* 1975, *p175* and PREOBRAZHENSKY 1980, *p258*).

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19 Figures from MICHALSKI et al. 1991, *p15*.

Their applicability to environmental monitoring however is rather dubious, in spite of their common use for this purpose. In industry they are generally used to measure temperatures far above the ambient, where the cold junction inaccuracy is relatively trivial. In conservation they must be used to measure lower temperatures which differ little from the ambient, and consequently they are prone to significant error. Since the leads of a thermocouple form part of the sensor itself there arise further problems when the system is measuring temperatures close to that of the ambient conditions. McGhee believes they are inappropriate instruments for measurements below about 200°C.[20] Hatfield [1993, *p30*] summarises the drawbacks:

> Thermocouples generate a very small signal which is proportional to the temperature difference between the two ends of the thermocouple. The instrument has to measure its own temperature in order to calculate the actual temperature of the sensor. For accurate measurement at ambient temperatures, thermocouples should definitely be avoided.

4.2.3.2. Resistance Temperature Detectors (RTDs)

The electrical resistance of a metal conductor depends on its temperature - specifically, the resistance increases with increasing temperature. This effect is highly linear and can be measured very accurately; platinum RTDs are the standard measuring instrument for ITS-90.[21] In addition, with recent advances in technology the sensors can be made very small indeed, so for example thin-film RTDs with dimensions of $10 \times 3 \times 1\,mm$ can be easily purchased. The major drawback in theory is the possibility of the sensor self-heating as resistance increases, but in practice this effect is avoided by using extremely small currents (on the order of milli-amps). The final accuracy of RTD sensors does depend on the circuitry used, but in general the error is around ±0.01°C for a Pt100Ω detector.

Platinum RTDs are increasingly finding favour in conservation; they were the sensor of choice for the second phase of monitoring at Arezzo (see STEVAN + STRADA 1988, *pIII/14.8*). Hatfield [1993, *p30*], however, warns

> Platinum resistance detectors have very small temperature coefficients so that special techniques are needed to eliminate lead resistance.

That is, the low electrical resistance of the sensor increases the effect of the resistance of the leads and plugs, which thus become a significant source of error.

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20 PersComm J McGhee 1993. See also MICHALSKI et al. *[1991, p15]*.

21 The International Temperature Standard, agreed in 1990: see PRESTON-THOMAS 1990.

Additionally, it is worth noting the exotic materials and delicate manufacturing processes needed to produce the smallest and most sensitive RTDs tend to make them prohibitively expensive [see TABLE 2].

4.2.3.3. Thermistors: Semi-conductor Thermometers

The most popular of the thermometers using the principle of semi-conduction is the thermistor. Thermistors are non-linear, temperature- dependent, semiconductor resistors. They are minute and very sensitive – although over a narrower temperature range than the other types of contact thermometer – and their low thermal inertia enables them to respond rapidly to temperature changes. The manufacture of thermistors is complicated, involving oxide powders or slurries being melded to platinum alloy wires and then sealed in glass or teflon or epoxy to make tiny beads or disks which can form the central component of a more elaborate sensor apparatus. Nevertheless they are relatively inexpensive.

The extremely non-linear response of thermistors means that the electrical signal from the sensor must be processed in a comparatively elaborate way before the temperature can be deduced. If used in very high temperatures, thermistors can become permanently decalibrated but they are an excellent choice for measuring temperatures around the ambient, being the most appropriate sensor for environmental monitoring according to Hatfield [1993, *p30*]

> Interchangeable thermistor sensors are simple to use and the most accurate in this field for general purpose measurements. The sensor is a resistive element with a high negative temperature coefficient (typically 100Ω/°C at 20°C). This means that the sensor can be attached to a long length of cable without introducing significant errors.

Amongst others, Bernardi *et al.* [1988, *pIII/3.4*] report using thermistors for measuring surface temperatures in the Ara Pacis in Rome, and they were also used by Grant *et al* [1989, *p264*] to monitor the walls of a domestic dwelling in England.

The benefits and drawbacks of three sensor types summarised in TABLE 2.

Type of Sensor	Benefits	Drawbacks	Approx Cost (£)
Thermocouple	Very cheap Rugged Small	Need for a cold junction Leads form part of sensor (problems at ambient temperatures)	£ 15
Platinum RTDs	Highly accurate Small	Low sensor resistance (increases problems with leads) Very expensive	£ 200
Thermistors	Cheap High sensor resistance	Non-linear response Prone to decalibration if roughly handled	£ 25

Table 2: Comparison of the three applicable types of surface temperature sensor.

On the basis of this information, it was decided to conduct the experiment with thermistors; this decision had other advantages in that the appropriate sensors were readily available in a form compatible with the datalogger used for the experiment, and, importantly, that the temperature sensitive elements in the other probes being used (namely an RH+T probe, to monitor the ambient conditions, and the interstitial temperature sensor) were also thermistors, and of exactly the same type. Consequently - at least in theory - the response of all the sensors used in the experiment should be directly comparable.

4.2.4. Data Analysis

In order to reduce the effect of random error on the results of the experiments, each combination of steady and variable ambient conditions was cycled five times. The results were then processed both graphically and statistically so as to examine the relationships between the measurements made by the various sensors with the readings of the ambient and the interstitial thermometers. Although the true surface temperature is unlikely to match exactly that either of the air or of the interstitial air cavity within the plaster, it can be assumed that its behaviour (governed as it is by the inertia of the model surface) more closely approaches that of the latter. The best sensor would be that which basically follows the interstitial temperature patterns, and resists responding to intermittent changes in those of the ambient conditions.

The level of agreement can be given a numerical value by using the mathematical technique of correlation, which quantifies the relationship between any two variables. The correlation coefficient – that is the number given by the technique – is defined to be the covariance of the variables, divided by their standard deviations (where covariance is a measure of the interdependence of the measurements: the summation of the products of their deviations from average)[22]

$$\text{Covariance} = \frac{1}{N}\sum_i (x_i - \bar{x})(y_i - \bar{y})$$

where N is the number of measurements of x (or y) .

The value of the Correlation is then given by

$$\rho = \text{correlation coefficient} = \frac{\left[\frac{1}{N}\sum_i (x_i - \bar{x})(y_i - \bar{y})\right]}{\sigma_x \sigma_y}$$

where

$$\sigma_z = \text{standard deviation} = \sqrt{\frac{1}{N}\sum_i (z_i - \bar{z})}$$

So

$$\rho = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}}$$

The figure for correlation must lie between -1 and 1, with 1 being a perfect correlation (matching data sets), 0 being no correlation (no correspondence between data sets), and -1 being a perfect negative correlation (data sets that are varying in the opposite manner to each other). In terms of data which varies over time, correlation can be seen as a measure of the phase relationship between two varying quantities: that is, whether they tend to vary in synchronisation (reacting in the same way or the opposite way to some external stimulus), or whether they show very dissimilar responses to the external stimuli.

Analysing the data in this fashion was made easy by using the spreadsheet programme Excel™, which can determine the correlation between columns of data in a single step [see APPENDIX 2 for details of this software].

22 See BARLOW [1989] for the derivation of these equations.

A useful visual assessment may also be made by examining a graph of the temperature and humidity measurements against time, also made using Excel. Plotting data gives a qualitative feeling for the patterns of behaviour of the system which complements the numerical analysis given by the correlation coefficient.

4.2.5. The Final Design of the Experiment

As shown in the flow diagram in Section 4.2, to examine the operation of the surface temperature sensors in widely varied conditions it was decided to select three humidities representative of those which might be found on most wall paintings - a low, an average, and a high relative humidity - and vary temperatures over the likely extremes. Similarly, in order to determine whether the measurements were in any way dependent on moisture, low, medium and high temperatures were chosen to be held whilst humidity was cycled through extremes as rapidly as possible. In practice, however, the operation of the climate chamber (humidity is controlled by setting dry and wet bulb temperatures) meant that maintaining a steady relative humidity whilst varying temperature proved not to be possible. The values of ambient temperature and relative humidity finally used are listed in TABLE 3.

#	EXPERIMENT	TEMPERATURE	HUMIDITY
1	Attachment: Low T	7°C	45-95%
2	Attachment: Med T	15°C	60-98%
3	Attachment: High T	27°C	35-99%
4	Attachment: Low RH	26-29°C	Average 20%
5	Attachment: Med RH	16-27°C	Average 42%
6	Attachment: HighRH	7-31°C	Average 89%
7	Insulation: Low T	6°C	70-98%
8	Insulation: Med T	18°C	65-100%
9	Insulation: High T	27°C	30-100%
10	Insulation: Low RH	25-27°C	Average 37%
11	Insulation: Med RH	15-26°C	Average 64%
12	Insulation: High RH	8-22°C	Average 84%

Table 3: Summary of the ambient conditions used to test surface temperature sensor attachments.

In view of the speed with which the chamber used operates, it was decided to log data once every fifteen seconds. All sensors were sampled concurrently, which allowed for easy correlation of the readings.

4.2.6. Results

4.2.6.1. Bench Test Indications

In order to test the operation of the experimental equipment, and develop the chosen methods of analysis, a bench test was run, with the datalogger set to record overnight in the normal ambient conditions of the Courtauld Wall Paintings studio. Under these conditions of course the variation in temperature and humidity was both small and slow [see GRAPH 1];[23] however it was possible to gain tentative information from the test. TABLE 4 lists the results of the correlations between the various surface temperature probes and the ambient and interstitial probes. It can be seen that the worst of these correlations is still better than that between the ambient and interstitial probes, which does suggest that surface temperature is indeed affecting all readings to some extent. The worst performance is that of the sensors attached with clay; these show both the closest correlation with the ambient and the least correlation with the interstitial.

Bench Test Correlations

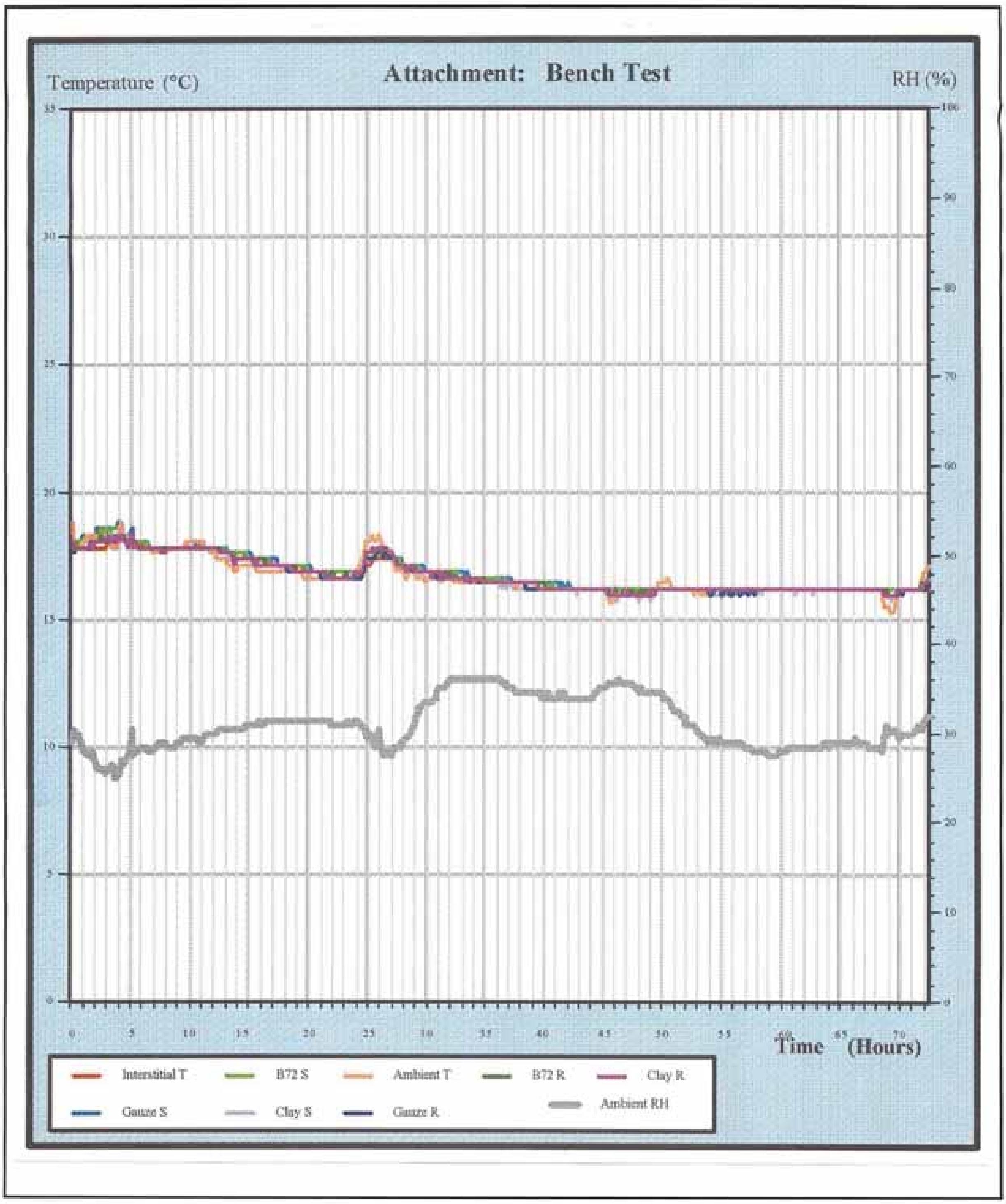
	IntT		AT
Interstitial T	1.000	Ambient T	1.000
Gauze R	0.984	Clay R	0.967
B72 R	0.984	Clay S	0.965
B72 S	0.984	B72 R	0.961
Gauze S	0.982	Gauze R	0.953
Clay R	0.979	B72 S	0.953
Clay S	0.974	Gauze S	0.948
Ambient T	0.927	Interstitial T	0.927

Table 4: Correlations between the surface temperature sensors and the interstitial and ambient temperature during the bench test.

4.2.6.2. Results of Experiment

The analyses of the individual experiments are given on the following pages [see APPENDIX 3 for a tabulation of the actual results obtained]. The information given by plotting the measured data against time is confirmed by comparison with the values of the correlations between the surface temperature measurements and the ambient and interstitial values; as discussed above, the best result is taken to be that which most closely follows the interstitial temperature.

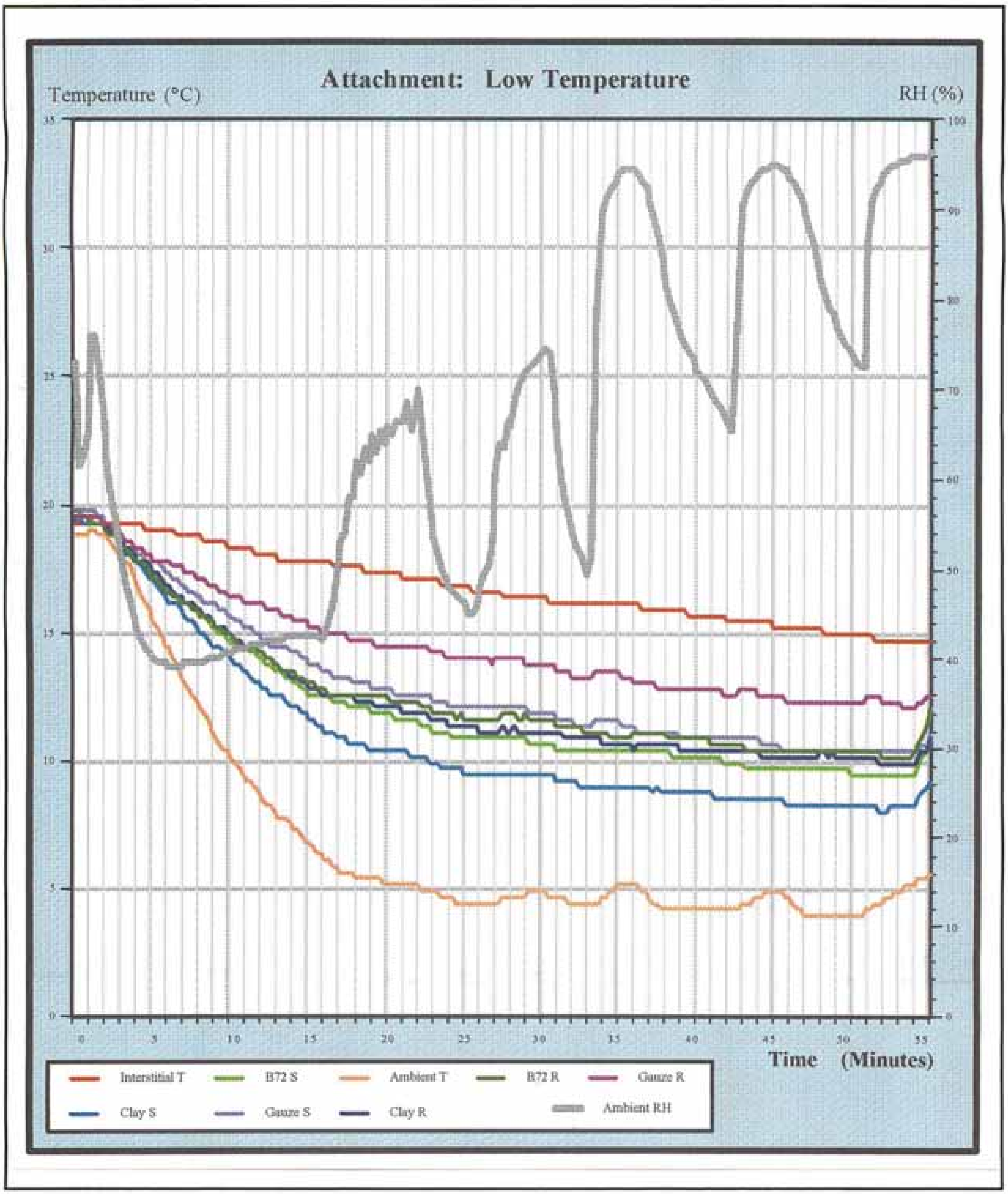
23 Note that, even with the vertical scale vastly expanded, the graphed temperatures are virtually undifferentiable.



Graph 1: Graph of temperature and relative humidity against time for the bench test.

Experiment 1 ATTACHMENT: Low Temperature

For this experiment a low temperature was held steady and the ambient humidity was varied by adjusting the wet-bulb temperature of the climate chamber. In this way it was hoped that any patterns of behaviour governing the operation of the attachment systems under cold conditions with widely fluctuating humidities would be revealed.



Graph 2: Graph of temperature and relative humidity against time for Experiment 1.

The responses of the surface temperature sensors are spread out between the interstitial temperature (which gradually declines in response to the lowering of ambient temperature from 20° to 15°C) and the ambient temperature (which reaches a fairly steady 5.0°C after 20 minutes). At such a low ambient temperature, it proved difficult to cycle the relative humidity accurately; however, a reasonable range of around 50% was achieved.

The best response was that of the gauze bandage on the rough plaster; the worst was that of the clay on the smooth plaster. The other probes have much more similar responses, all falling into a band of some ±1°C. In descending order of accuracy

- Gauze on Rough differs from interstitial by 2-3°C
- Gauze on Smooth differs from interstitial by ~5°C
- B72 on Rough differs from interstitial by ~5°C
- Clay on Rough differs from interstitial by ~5°C
- B72 on Smooth differs from interstitial by ~5°C
- Clay on Smooth differs from interstitial by ~7°C

Attachment; Low T

	IntT	Clay S	B72 S	Gauze S	AT	Clay R	B72 R	Gauze R	RH
Interstitial T	*1.000*	0.916	0.927	0.947	0.830	0.923	0.922	0.964	-0.776
Clay S	0.916	*1.000*	0.998	0.995	0.981	0.999	0.997	0.985	-0.590
B72 S	0.927	0.998	*1.000*	0.997	0.975	0.999	0.998	0.988	-0.600
Gauze S	0.947	0.995	0.997	*1.000*	0.961	0.996	0.995	0.996	-0.636
Ambient T	0.830	0.981	0.975	0.961	*1.000*	0.977	0.974	0.939	-0.457
Clay R	0.923	0.999	0.999	0.996	0.977	*1.000*	0.998	0.987	-0.601
B72 R	0.922	0.997	0.998	0.995	0.974	0.998	*1.000*	0.987	-0.594
Gauze R	0.964	0.985	0.988	0.996	0.939	0.987	0.987	*1.000*	-0.666
Ambient RH	-0.776	-0.590	-0.600	-0.636	-0.457	-0.601	-0.594	-0.666	*1.000*

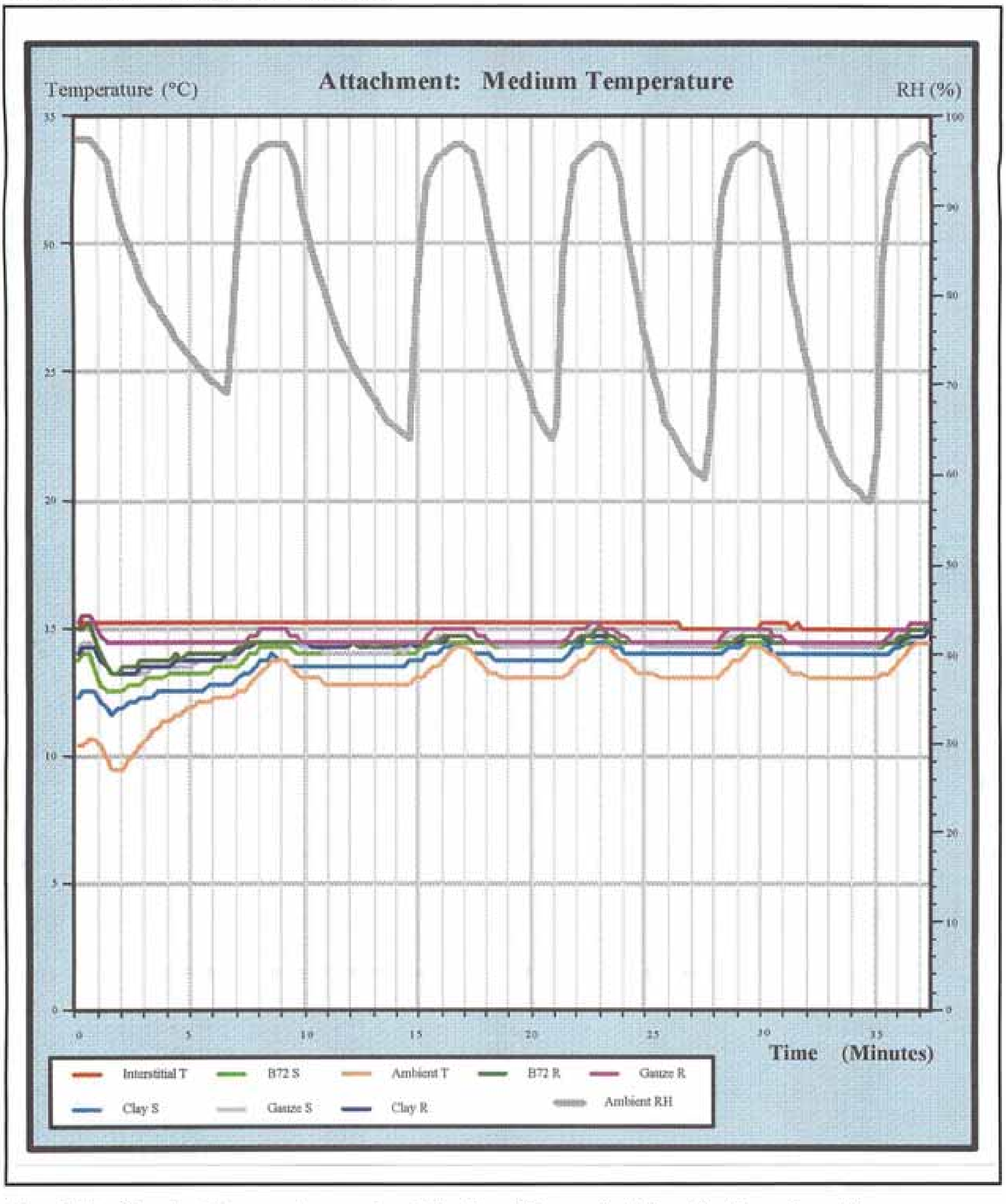
Int T		AT	
Gauze R	0.964	Clay S	0.981
Gauze S	0.947	Clay R	0.977
B72 S	0.927	B72 S	0.975
Clay R	0.923	B72 R	0.974
B72 R	0.922	Gauze S	0.961
Clay S	0.916	Gauze R	0.939
AT	0.830	Int T	0.830

Table 5: Correlations for Experiment 1; at right the values for the relationship between the ambient and the interstitial are given in descending order.

An analogous picture is given by the values for the correlation coefficient; in particular the correlation between the sensors attached with gauze bandages and the interstitial and ambient temperatures confirms that this attachment method performed particularly well, especially on a rough surface. Note however that the other two methods of attachment showed more consistency between the two surfaces (as indicated by, for example, the correlation of 0.999 between the probes attached with clay to the rough and to the smooth plaster).

Experiment 2 ATTACHMENT: Medium Temperature

For this experiment a medium temperature was held steady and the ambient humidity was varied by adjusting the wet-bulb temperature of the climate chamber. In this way it was hoped that any patterns of behaviour governing the operation of the attachment systems under average temperatures but with widely fluctuating humidities would be revealed.



Graph 3: Graph of temperature and relative humidity against time for Experiment 2.

The results of this experiment are so close as to make interpretation difficult: the proximity of the ambient temperature (an average 13.3°C after 7 minutes) to that of the surface (the interstitial temperature is an average 15.1°C) means that there is little spread in the data. RH is varied over a range from about 60% to 98%; note the peaks in ambient temperature which correspond to the high humidities. Similar peaks may be seen with all probes except the interstitial, but it is not possible to say whether the sensors are responding to AT or RH (or a combination of both).

As far as it can be ascertained, the accuracy in descending order is

- Gauze on Rough differs from interstitial by ~1°C
- Gauze on Smooth differs from interstitial by 1-2°C
- B72 on Rough differs from interstitial by 1-2°C
- B72 on Smooth differs from interstitial by 1-2°C
- Clay on Rough differs from interstitial by 1-2°C
- Clay on Smooth differs from interstitial by 1-2°C

Attachment; Medium T

	IntT	Clay S	B72 S	Gauze S	AT	Clay R	B72 R	Gauze R	RH
Interstitial T	*1.000*	-0.378	-0.315	-0.305	-0.233	-0.317	-0.297	-0.105	0.172
Clay S	-0.378	*1.000*	0.955	0.866	0.946	0.940	0.789	0.320	0.094
B72 S	-0.315	0.955	*1.000*	0.902	0.916	0.959	0.879	0.408	0.153
Gauze S	-0.305	0.866	0.902	*1.000*	0.840	0.906	0.886	0.660	0.463
Ambient T	-0.233	0.946	0.916	0.840	*1.000*	0.896	0.743	0.323	0.166
Clay R	-0.317	0.940	0.959	0.906	0.896	*1.000*	0.891	0.396	0.137
B72 R	-0.297	0.789	0.879	0.886	0.743	0.891	*1.000*	0.596	0.252
Gauze R	-0.105	0.320	0.408	0.660	0.323	0.396	0.596	*1.000*	0.762
Ambient RH	0.172	0.094	0.153	0.463	0.166	0.137	0.252	0.762	*1.000*

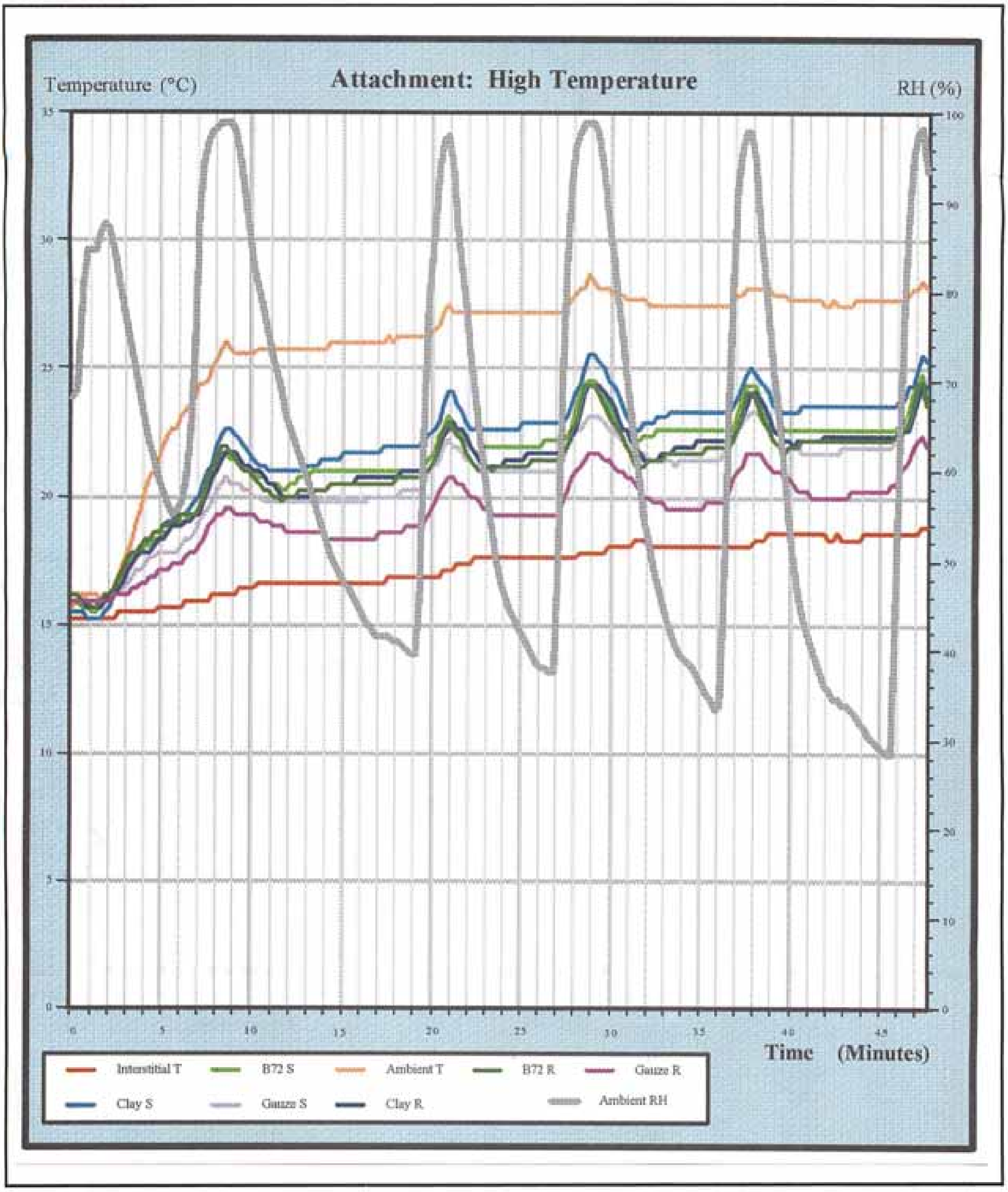
Int T		AT	
Gauze R	-0.105	Clay S	0.946
AT	-0.233	B72 S	0.916
B72 R	-0.297	Clay R	0.896
Gauze S	-0.305	Gauze S	0.840
B72 S	-0.315	B72 R	0.743
Clay R	-0.317	Gauze R	0.323
Clay S	-0.378	Int T	-0.233

Table 6: Correlations for Experiment 2; at right the values for the relationship between the ambient and the interstitial are given in descending order.

Probably for much the same reasons – that by retaining conditions so very near the ambient no conclusive results are obtained – in this case the correlation coefficient proves to be of little help. No sensor shows what might be termed a good correlation with the interstitial temperature.

Experiment 3 ATTACHMENT: High Temperature

For this experiment a high temperature was held steady and the ambient humidity was varied by adjusting the wet-bulb temperature of the climate chamber. In this way it was hoped that any patterns of behaviour governing the operation of the attachment systems under hot conditions with widely fluctuating humidities would be revealed.



Graph 4: Graph of temperature and relative humidity against time for Experiment 3.

Here again the response of the sensors is clearly spread out between the ambient temperature and the interstitial temperature (which gradually increases from around 15° to 19°C). The humidity is strongly cycled over around 64%, producing a response that is interestingly sharper for the contact probes than for the ambient temperature sensor. It seems that the attachment materials take up atmospheric moisture to a degree that significantly affects the sensor readings at high humidities; under normal room conditions, one would expect that RH and AT would vary inversely rather than directly (as here), so it seems likely that the pattern revealed is a product of the way in which the chamber operates. For example, to drop the humidity it is necessary to heat the air inside the chamber, so peaks of temperature and humidity may occur in conjunction during rapid cycling.

The gauze bandage on the rough surface both shows the most moderate response to the changes in RH and also is closer to the interstitial temperature by a considerable margin. The other probes are more alike, but again clay on the smooth surface shows much the worst response.

In descending order of accuracy, then,

- Gauze on Rough — differs from interstitial by 2-5°C
- Gauze on Smooth — differs from interstitial by 5-7°C
- B72 on Rough — differs from interstitial by 5-8°C
- Clay on Rough — differs from interstitial by 5-8°C
- B72 on Smooth — differs from interstitial by 6-8°C
- Clay on Smooth — differs from interstitial by 7-9°C

Attachment; High T

	IntT	Clay S	B72 S	Gauze S	AT	Clay R	B72 R	Gauze R	RH
Interstitial T	*1.000*	0.880	0.888	0.913	0.842	0.867	0.843	0.876	-0.295
Clay S	0.880	*1.000*	0.995	0.982	0.967	0.991	0.985	0.950	-0.097
B72 S	0.888	0.995	*1.000*	0.985	0.957	0.989	0.987	0.958	-0.072
Gauze S	0.913	0.982	0.985	*1.000*	0.932	0.984	0.978	0.985	-0.016
Ambient T	0.842	0.967	0.957	0.932	*1.000*	0.943	0.927	0.884	-0.210
Clay R	0.867	0.991	0.989	0.984	0.943	*1.000*	0.991	0.969	-0.019
B72 R	0.843	0.985	0.987	0.978	0.927	0.991	*1.000*	0.966	0.026
Gauze R	0.876	0.950	0.958	0.985	0.884	0.969	0.966	*1.000*	0.118
Ambient RH	-0.295	-0.097	-0.072	-0.016	-0.210	-0.019	0.026	0.118	*1.000*

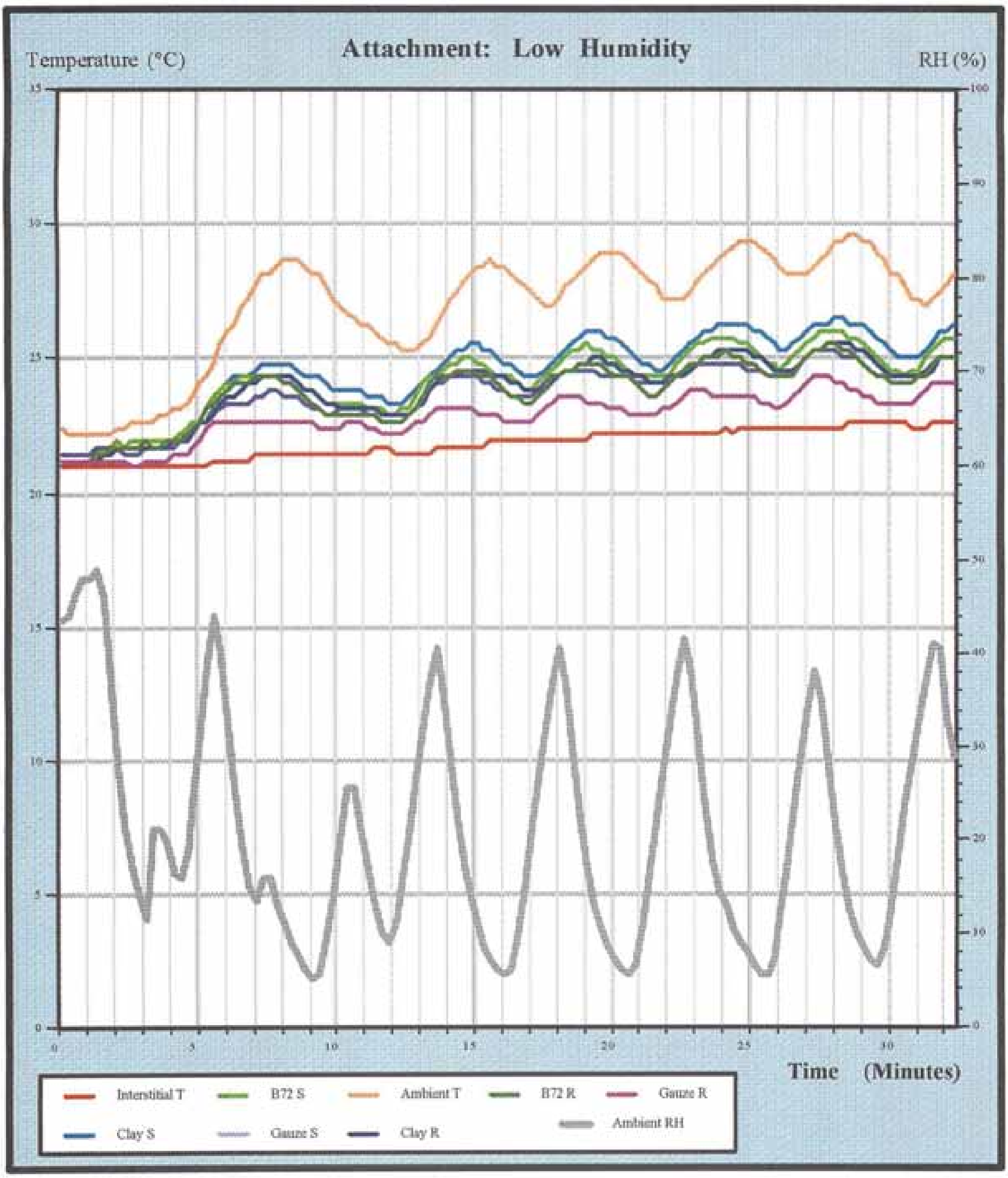
Int T		AT	
Gauze S	0.913	Clay S	0.967
B72 S	0.888	B72 S	0.957
Clay S	0.880	Clay R	0.943
Gauze R	0.876	Gauze S	0.932
Clay R	0.867	B72 R	0.927
B72 R	0.843	Gauze R	0.884
AT	0.842	Int T	0.842

Table 7: Correlations for Experiment 3; at right the values for the relationship between the ambient and the interstitial are given in descending order.

Examining the correlation coefficients however suggests a rather more complex picture: since the interstitial temperature is hardly varying, no probe is very much in phase with it, the best being the gauze bandage on the smooth surface. The correspondence to the varying of the ambient appears to be much closer.

Experiment 4 ATTACHMENT: Low Humidity

The intention of this experiment was to hold a low relative humidity steady whilst varying the ambient temperature; this would have revealed any patterns of behaviour governing the operation of the attachment systems under dry conditions with widely fluctuating temperatures. In practice, however, the operation of the climate chamber is such that humidity varies as well.



Graph 5: Graph of temperature and relative humidity against time for Experiment 4.

As the ambient temperature is varied (over around 3°C) all the surface temperature sensors show cycling; the fact that these peaks slightly precede those of the ambient temperature suggests that the concurrent cycling of humidity (over a range of about 35%) is of itself having a strong effect. The interstitial temperature remained steady at an average 21.8°C.

As for the temperature tests, the gauze bandage on the rough surface produces by far the most accurate response. The other sensors respond in more or less the same way, but it is interesting to note that the pattern is repeated in each cycle, giving confidence in the experimental method.

In descending order of accuracy, then,

- Gauze on Rough — differs from interstitial by 1-2°C
- Gauze on Smooth — differs from interstitial by 2-3°C
- B72 on Rough — differs from interstitial by 2-3°C
- Clay on Rough — differs from interstitial by 2-3°C
- B72 on Smooth — differs from interstitial by 2-3°C
- Clay on Smooth — differs from interstitial by 3-4°C

Attachment; Low RH

	IntT	Clay S	B72 S	Gauze S	AT	Clay R	B72 R	Gauze R	RH
Interstitial T	*1.000*	0.870	0.849	0.892	0.804	0.859	0.814	0.884	-0.222
Clay S	0.870	*1.000*	0.988	0.979	0.951	0.994	0.977	0.954	-0.328
B72 S	0.849	0.988	*1.000*	0.985	0.910	0.986	0.990	0.967	-0.227
Gauze S	0.892	0.979	0.985	*1.000*	0.901	0.976	0.976	0.980	-0.169
Ambient T	0.804	0.951	0.910	0.901	*1.000*	0.956	0.900	0.856	-0.504
Clay R	0.859	0.994	0.986	0.976	0.956	*1.000*	0.981	0.945	-0.335
B72 R	0.814	0.977	0.990	0.976	0.900	0.981	*1.000*	0.954	-0.218
Gauze R	0.884	0.954	0.967	0.980	0.856	0.945	0.954	*1.000*	-0.076
Ambient RH	-0.222	-0.328	-0.227	-0.169	-0.504	-0.335	-0.218	-0.076	*1.000*

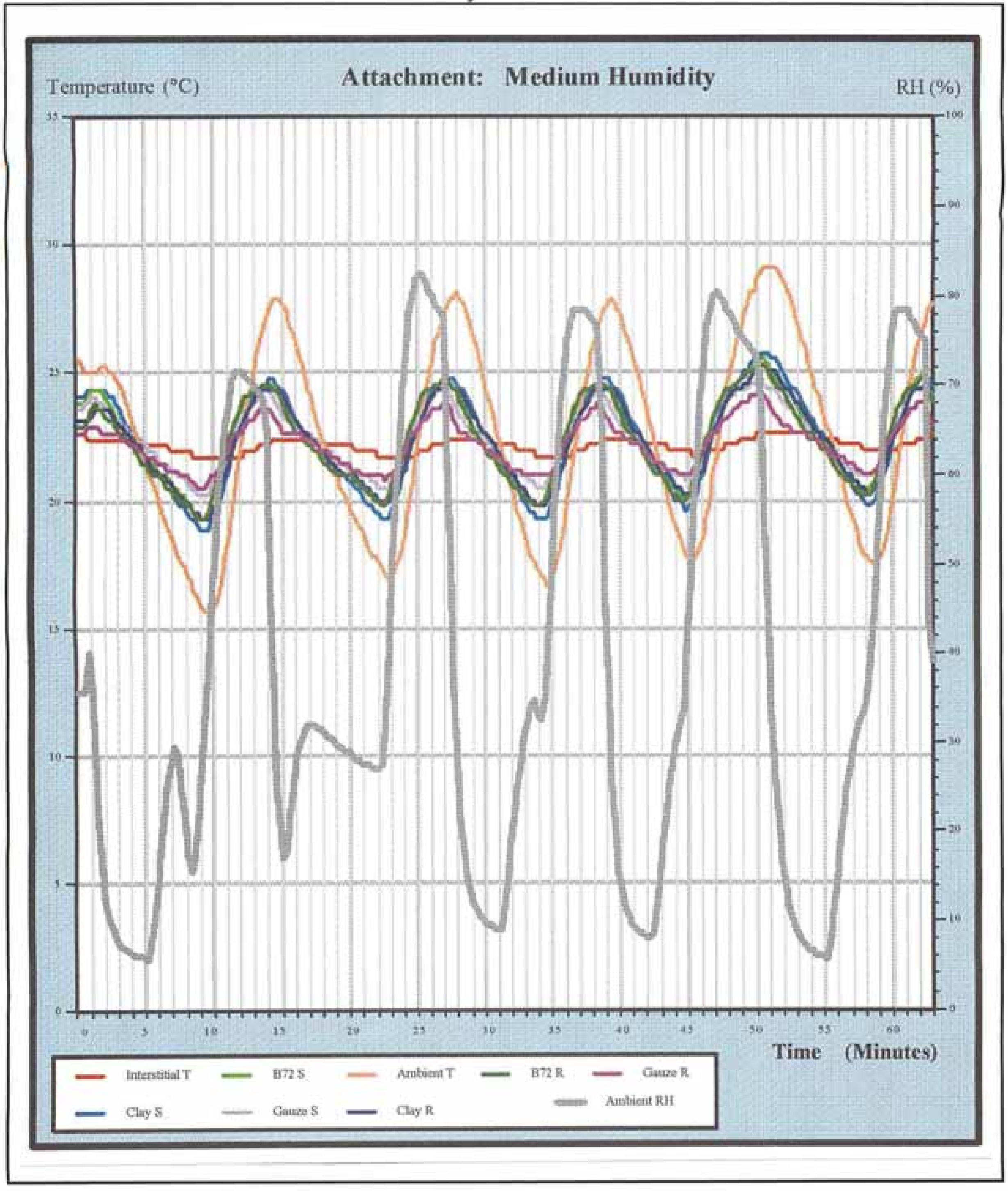
Int T		AT	
Gauze S	0.892	Clay R	0.956
Gauze R	0.884	Clay S	0.951
Clay S	0.870	B72 S	0.910
Clay R	0.859	Gauze S	0.901
B72 S	0.849	B72 R	0.900
B72 R	0.814	Gauze R	0.856
AT	0.804	Int T	0.804

Table 8: Correlations for Experiment 4; at right the values for the relationship between the ambient and the interstitial are given in descending order.

Again, the picture given by the correlation coefficients is rather different: as in Experiment 3, the probes show a closer correlation to the ambient than to the interstitial temperature. The relationships between the same probe configurations on different surfaces are in this case rather closer, however.

Experiment 5 ATTACHMENT: Medium Humidity

The intention of this experiment was to hold a medium relative humidity steady whilst varying the ambient temperature; this would have revealed any patterns of behaviour governing the operation of the attachment systems under dry conditions with widely fluctuating temperatures. In practice, however, the operation of the climate chamber is such that humidity varies as well.



Graph 6: Graph of temperature and relative humidity against time for Experiment 5.

Experiment 5, with the ambient temperature cycled over some 11°C and the relative humidity ranging over 73%, gives a very similar picture to that of Experiment 4, with the sensors appearing to respond mostly to the periods of high humidity. The interstitial sensor also displays a slight response (on the order of ±1°C), but apparently to the variation in ambient temperature rather than water vapour content.

All probes show a very similar response, but again their order repeats every cycle. In descending order of accuracy

- Gauze on Rough — differs from interstitial by ~2°C
- Gauze on Smooth — differs from interstitial by ~2.5°C
- B72 on Rough — differs from interstitial by ~2.5°C
- B72 on Smooth — differs from interstitial by ~2.5°C
- Clay on Rough — differs from interstitial by ~2.5-3°C
- Clay on Smooth — differs from interstitial by ~2.5-3°C

Attachment; Medium RH

	IntT	Clay S	B72 S	Gauze S	AT	Clay R	B72 R	Gauze R	RH
Interstitial T	*1.000*	0.712	0.587	0.616	0.824	0.690	0.510	0.536	-0.434
Clay S	0.712	*1.000*	0.980	0.980	0.958	0.994	0.958	0.954	0.188
B72 S	0.587	0.980	*1.000*	0.991	0.892	0.979	0.991	0.979	0.355
Gauze S	0.616	0.980	0.991	*1.000*	0.899	0.977	0.978	0.982	0.333
Ambient T	0.824	0.958	0.892	0.899	*1.000*	0.957	0.859	0.861	-0.036
Clay R	0.690	0.994	0.979	0.977	0.957	*1.000*	0.965	0.959	0.216
B72 R	0.510	0.958	0.991	0.978	0.859	0.965	*1.000*	0.983	0.437
Gauze R	0.536	0.954	0.979	0.982	0.861	0.959	0.983	*1.000*	0.437
Ambient RH	-0.434	0.188	0.355	0.333	-0.036	0.216	0.437	0.437	*1.000*

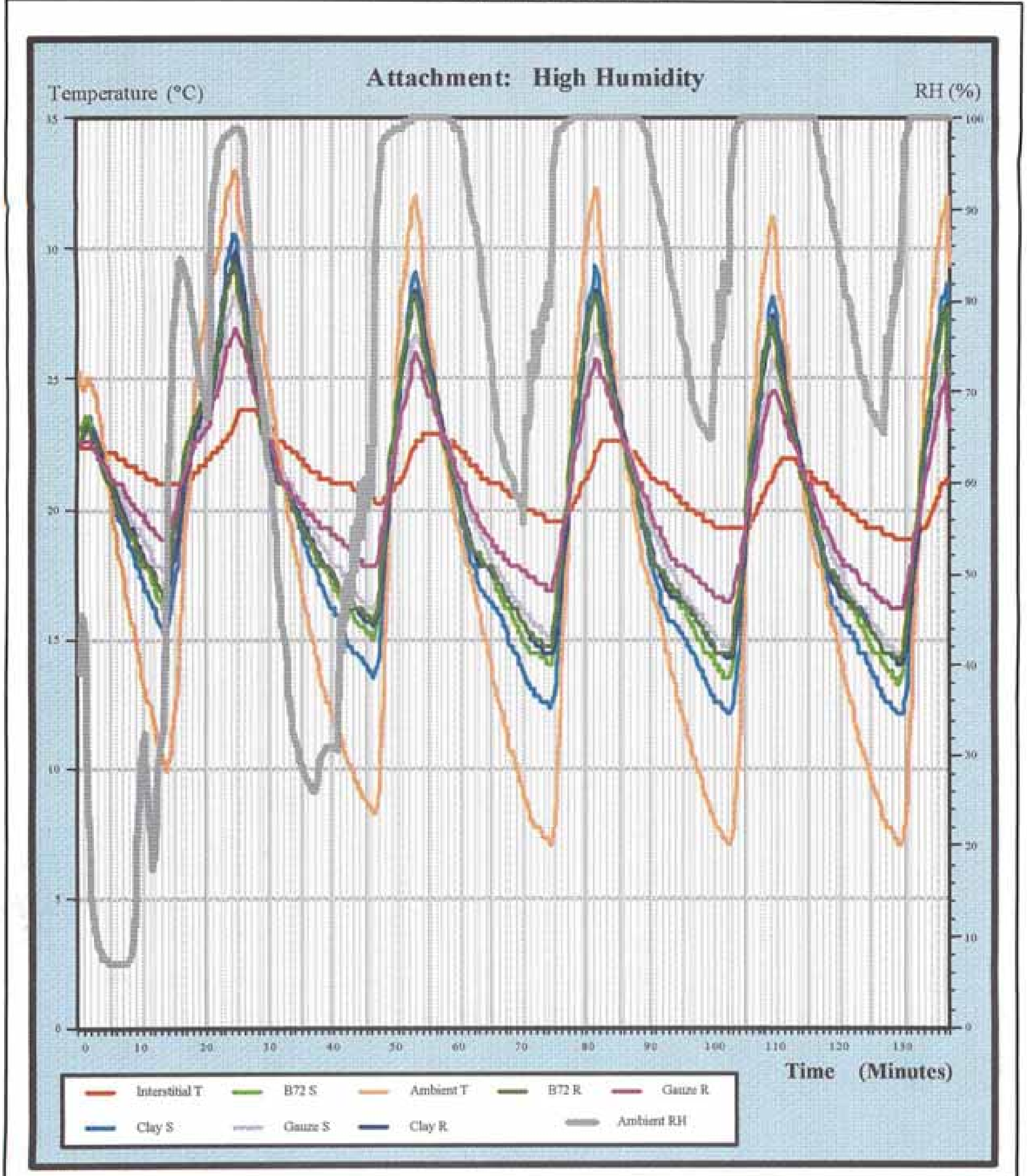
Int T		AT	
AT	0.824	Clay S	0.958
Clay S	0.712	Clay R	0.957
Clay R	0.690	Gauze S	0.899
Gauze S	0.616	B72 S	0.892
B72 S	0.587	Gauze R	0.861
Gauze R	0.536	B72 R	0.859
B72 R	0.510	Int T	0.824

Table 9: Correlations for Experiment 5; at right the values for the relationship between the ambient and the interstitial are given in descending order.

Again, the correlation coefficients show that all probes are more in phase with the ambient rather than with the interstitial temperature. There is quite a close correspondence between the same attachment methods on different surfaces.

Experiment 6 ATTACHMENT: High Humidity

The intention of this experiment was to hold a high relative humidity steady whilst varying the ambient temperature; this would have revealed any patterns of behaviour governing the operation of the attachment systems under dry conditions with widely fluctuating temperatures. In practice, however, the operation of the climate chamber is such that humidity varies as well.



Graph 7: Graph of temperature and relative humidity against time for Experiment 6.

As in Experiment 4, even the interstitial temperature cycles over a range of some 2° or 3°C in response to the deliberate cycling of ambient temperature over a range of 24°C. The effect of temperature change on the surface temperature probes appears to overwhelm that due to the changing RH (cycling over around 70%).

Once again, the sensor attached with the gauze bandage to the rough surface gives much the best response, and that of the clay on the smooth surface considerably the worst. In descending order

- Gauze on Rough differs from interstitial by ~3°C
- Gauze on Smooth differs from interstitial by ~4°C
- B72 on Rough differs from interstitial by ~4°C
- Clay on Rough differs from interstitial by ~4°C
- B72 on Smooth differs from interstitial by ~4°C
- Clay on Smooth differs from interstitial by ~5°C

Attachment; High RH

	IntT	Clay S	B72 S	Gauze S	AT	Clay R	B72 R	Gauze R	RH
Interstitial T	*1.000*	0.718	0.717	0.784	0.680	0.711	0.666	0.777	-0.103
Clay S	0.718	*1.000*	0.998	0.993	0.990	0.998	0.993	0.989	0.302
B72 S	0.717	0.998	*1.000*	0.993	0.989	0.997	0.996	0.991	0.310
Gauze S	0.784	0.993	0.993	*1.000*	0.979	0.991	0.982	0.996	0.275
Ambient T	0.680	0.990	0.989	0.979	*1.000*	0.985	0.984	0.972	0.330
Clay R	0.711	0.998	0.997	0.991	0.985	*1.000*	0.994	0.990	0.308
B72 R	0.666	0.993	0.996	0.982	0.984	0.994	*1.000*	0.984	0.340
Gauze R	0.777	0.989	0.991	0.996	0.972	0.990	0.984	*1.000*	0.278
Ambient RH	-0.103	0.302	0.310	0.275	0.330	0.308	0.340	0.278	*1.000*

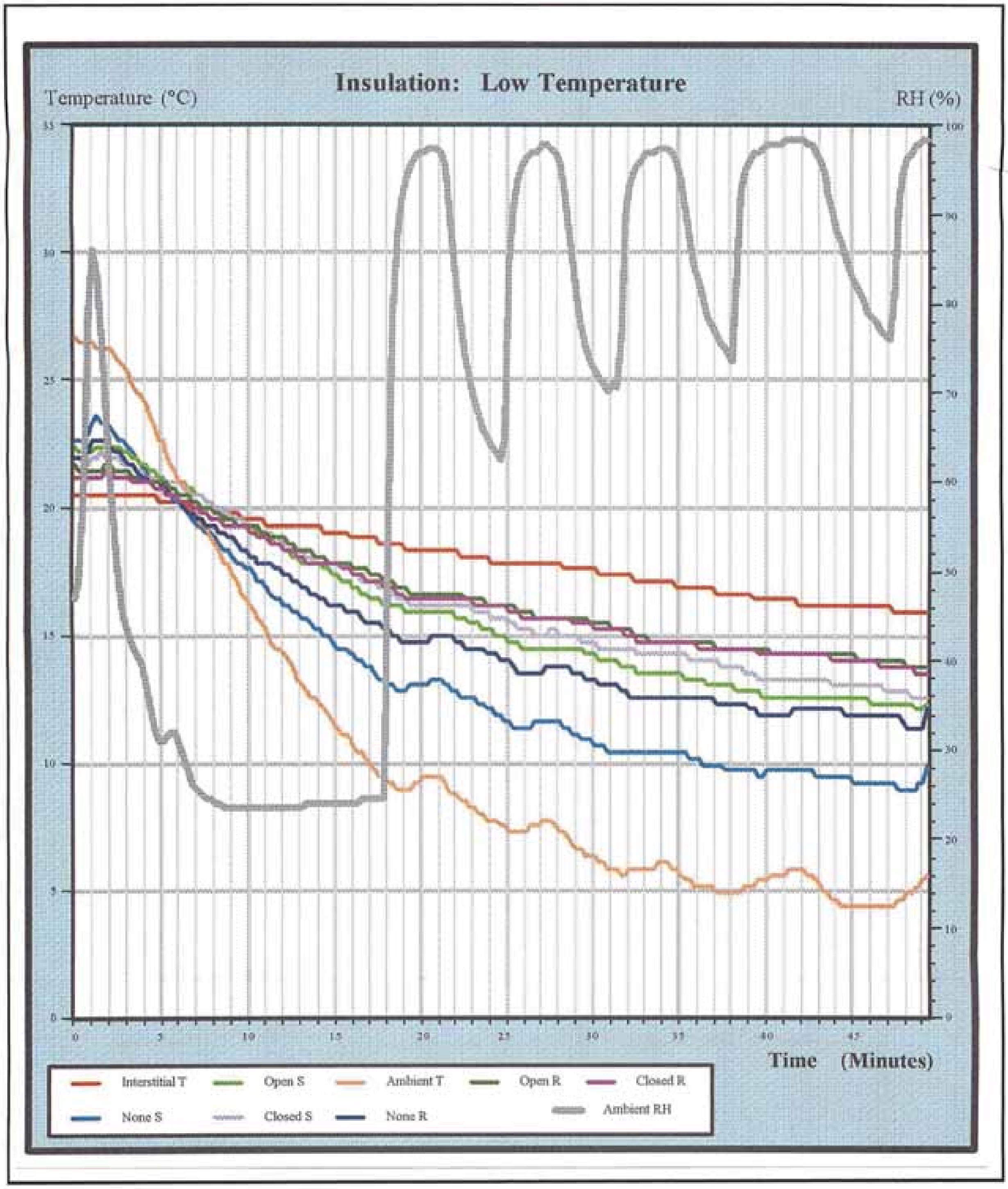
Int T		AT	
Gauze S	0.784	Clay S	0.990
Gauze R	0.777	B72 S	0.989
Clay S	0.718	Clay R	0.985
B72 S	0.717	B72 R	0.984
Clay R	0.711	Gauze S	0.979
AT	0.680	Gauze R	0.972
B72 R	0.666	Int T	0.680

Table 10: Correlations for Experiment 6; at right the values for the relationship between the ambient and the interstitial are given in descending order.

Yet again the correlation coefficients can do no more than demonstrate that all configurations tend to follow the ambient temperature.

Experiment 7 INSULATION: Low Temperature

For this experiment a low temperature was held steady and the ambient humidity was varied by adjusting the wet-bulb temperature of the climate chamber. In this way it was hoped that any patterns of behaviour governing the operation of the attachment systems under cold conditions with widely fluctuating humidities would be revealed.



Graph 8: Graph of temperature and relative humidity against time for Experiment 7.

For the insulation experiments the surface temperature sensors were reattached with B72 and Japanese tissue, and given three different insulation configurations, to whit

- a styrofoam block covering the probe, and attached directly to the surface around it (*Closed*);
- a styrofoam block covering the probe, but attached only to the probe itself and not to the surface (*Open*);
- no covering over the probe (*None*).

Under the action of the lowering ambient temperature the interstitial temperature shows a gradual decline (from some 20° to about 16°C). The cycling of the RH over a range of 28% produces some variation in the ambient temperature, ascribable to the operation of the climate chamber.

Between the values of ambient and interstitial sensors the responses of the surface temperature probes are neatly spread out, with the worst case in particular (no insulation, on a smooth surface) clearly standing out.

In descending order of accuracy, then,

- Open on Rough differs from interstitial by ~2.5°C
- Closed on Rough differs from interstitial by ~2.5°C
- Closed on Smooth differs from interstitial by ~3.5°C
- Open on Smooth differs from interstitial by ~4°C
- None on Rough differs from interstitial by ~5°C
- None on Smooth differs from interstitial by ~7.5°C

Insulation; Low T

	IntT	None S	Open S	Closed S	AT	None R	Open R	Closed R	RH
Interstitial T	*1.000*	0.954	0.980	0.985	0.924	0.962	0.982	0.981	-0.743
None S	0.954	*1.000*	0.993	0.988	0.995	0.998	0.990	0.991	-0.676
Open S	0.980	0.993	*1.000*	0.998	0.978	0.996	0.999	0.998	-0.724
Closed S	0.985	0.988	0.998	*1.000*	0.970	0.992	0.998	0.998	-0.739
Ambient T	0.924	0.995	0.978	0.970	*1.000*	0.990	0.974	0.976	-0.634
None R	0.962	0.998	0.996	0.992	0.990	*1.000*	0.994	0.994	-0.694
Open R	0.982	0.990	0.999	0.998	0.974	0.994	*1.000*	0.999	-0.735
Closed R	0.981	0.991	0.998	0.998	0.976	0.994	0.999	*1.000*	-0.730
Ambient RH	-0.743	-0.676	-0.724	-0.739	-0.634	-0.694	-0.735	-0.730	*1.000*

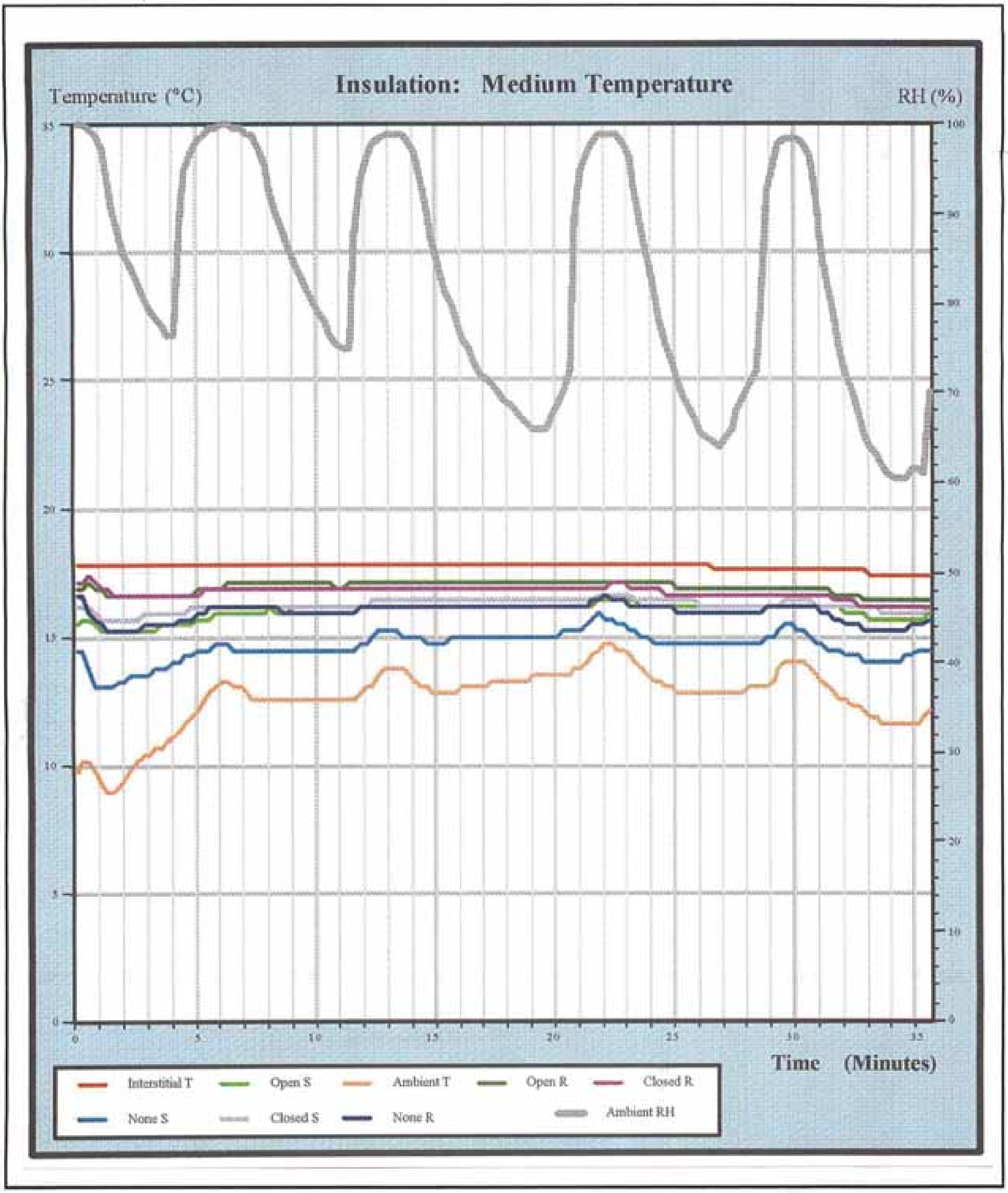
Int T		AT	
Closed S	0.985	None S	0.995
Open R	0.982	None R	0.990
Closed R	0.981	Open S	0.978
Open S	0.980	Closed R	0.976
None R	0.962	Open R	0.974
None S	0.954	Closed S	0.970
AT	0.924	Int T	0.924

Table 11: Correlations for Experiment 7; at right the values for the relationship between the ambient and the interstitial are given in descending order.

In this case, the figures for correlation indicate that both the insulated configurations are well in phase with the interstitial temperature. The uninsulated probes show both the worst correlation with the interstitial and the best correlation with the ambient temperature variation. Every insulation method shows a close correspondence between its use on a rough surface and a smooth surface.

Experiment 8 INSULATION: Medium Temperature

For this experiment a medium temperature was held steady and the ambient humidity was varied by adjusting the wet-bulb temperature of the climate chamber. In this way it was hoped that any patterns of behaviour governing the operation of the attachment systems under average temperatures, but with widely fluctuating humidities, would be revealed.



Graph 9: Graph of temperature and relative humidity against time for Experiment 8.

The interstitial temperature was very steady at around 18°C, but the ambient temperature fluctuates somewhat (over around 2°C) as the RH varies over about 35%.. The two uninsulated surface temperature sensors similarly respond to fluctuations in the ambient conditions, but the insulated probes vary rather less.

In descending order of accuracy, then,

- Open on Rough differs from interstitial by ~1°C
- Closed on Rough differs from interstitial by ~1.5°C
- Closed on Smooth differs from interstitial by ~2°C
- Open on Smooth differs from interstitial by ~2.5°C
- None on Rough differs from interstitial by ~2.5-3°C
- None on Smooth differs from interstitial by ~4°C

Insulation; Medium T

	IntT	None S	Open S	Closed S	AT	None R	Open R	Closed R	RH
Interstitial T	*1.000*	0.131	0.097	0.290	0.080	0.489	0.714	0.837	0.440
None S	0.131	*1.000*	0.867	0.891	0.935	0.810	0.610	0.334	0.164
Open S	0.097	0.867	*1.000*	0.847	0.903	0.719	0.652	0.308	-0.009
Closed S	0.290	0.891	0.847	*1.000*	0.864	0.800	0.687	0.445	0.140
Ambient T	0.080	0.935	0.903	0.864	*1.000*	0.713	0.589	0.248	0.117
None R	0.489	0.810	0.719	0.800	0.713	*1.000*	0.841	0.725	0.440
Open R	0.714	0.610	0.652	0.687	0.589	0.841	*1.000*	0.853	0.382
Closed R	0.837	0.334	0.308	0.445	0.248	0.725	0.853	*1.000*	0.556
Ambient RH	0.440	0.164	-0.009	0.140	0.117	0.440	0.382	0.556	*1.000*

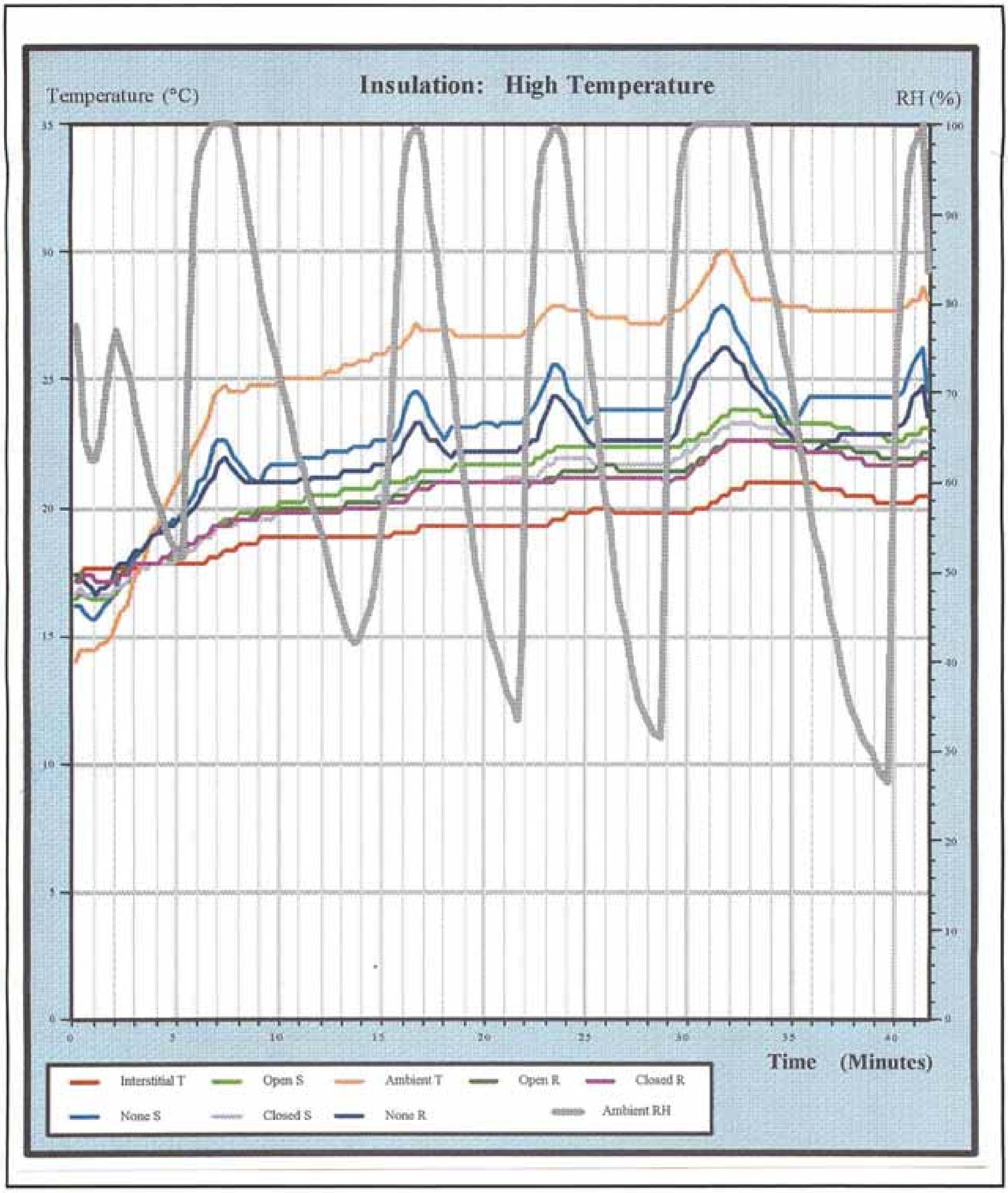
Int T		AT	
Closed R	0.837	None S	0.935
Open R	0.714	Open S	0.903
None R	0.489	Closed S	0.864
Closed S	0.290	None R	0.713
None S	0.131	Open R	0.589
Open S	0.097	Closed R	0.248
AT	0.080	Int T	0.080

Table 12: Correlations for Experiment 8; at right the values for the relationship between the ambient and the interstitial are given in descending order.

The correlation coefficients here may be compared to those in the corresponding attachment experiment (Experiment 2); it seems that where the ambient conditions are very close to those of the room, there is too little information to effectively analyse the situation in this manner. Nevertheless it is still clear that the probes on the rough surface are correlated rather more closely to the interstitial temperature than the those on the smooth surface.

Experiment 9 INSULATION: High Temperature

For this experiment a high temperature was held steady and the ambient humidity was varied by adjusting the wet-bulb temperature of the climate chamber. In this way it was hoped that any patterns of behaviour governing the operation of the attachment systems under hot conditions with widely fluctuating humidities would be revealed.



Graph 10: Graph of temperature and relative humidity against time for Experiment 9.

In this experiment the variation of RH (over some 70%) appears to affect all temperature sensors to some degree, including the interstitial (which gradually rises from around 17° to 21°C). The ambient temperature increases steadily throughout the period, from around 15° to more than 29°C. The response of the uninsulated sensors to the changing ambient conditions is much greater than for the other surface temperature probes.

In order of decreasing accuracy, then

- Closed on Rough differs from interstitial by ~2°C
- Open on Rough differs from interstitial by ~2°C
- Closed on Smooth differs from interstitial by ~2.5°C
- Open on Smooth differs from interstitial by ~3°C
- None on Rough differs from interstitial by at least 3.5°C
- None on Smooth differs from interstitial by at least 4.5°C

Insulation; High T

	IntT	None S	Open S	Closed S	AT	None R	Open R	Closed R	RH
Interstitial T	*1.000*	0.844	0.960	0.966	0.836	0.836	0.975	0.967	-0.021
None S	0.844	*1.000*	0.938	0.941	0.960	0.989	0.920	0.931	0.196
Open S	0.960	0.938	*1.000*	0.996	0.946	0.924	0.995	0.993	0.000
Closed S	0.966	0.941	0.996	*1.000*	0.934	0.932	0.994	0.993	0.040
Ambient T	0.836	0.960	0.946	0.934	*1.000*	0.937	0.929	0.934	0.066
None R	0.836	0.989	0.924	0.932	0.937	*1.000*	0.904	0.921	0.273
Open R	0.975	0.920	0.995	0.994	0.929	0.904	*1.000*	0.995	-0.010
Closed R	0.967	0.931	0.993	0.993	0.934	0.921	0.995	*1.000*	0.024
Ambient RH	-0.021	0.196	0.000	0.040	0.066	0.273	-0.010	0.024	*1.000*

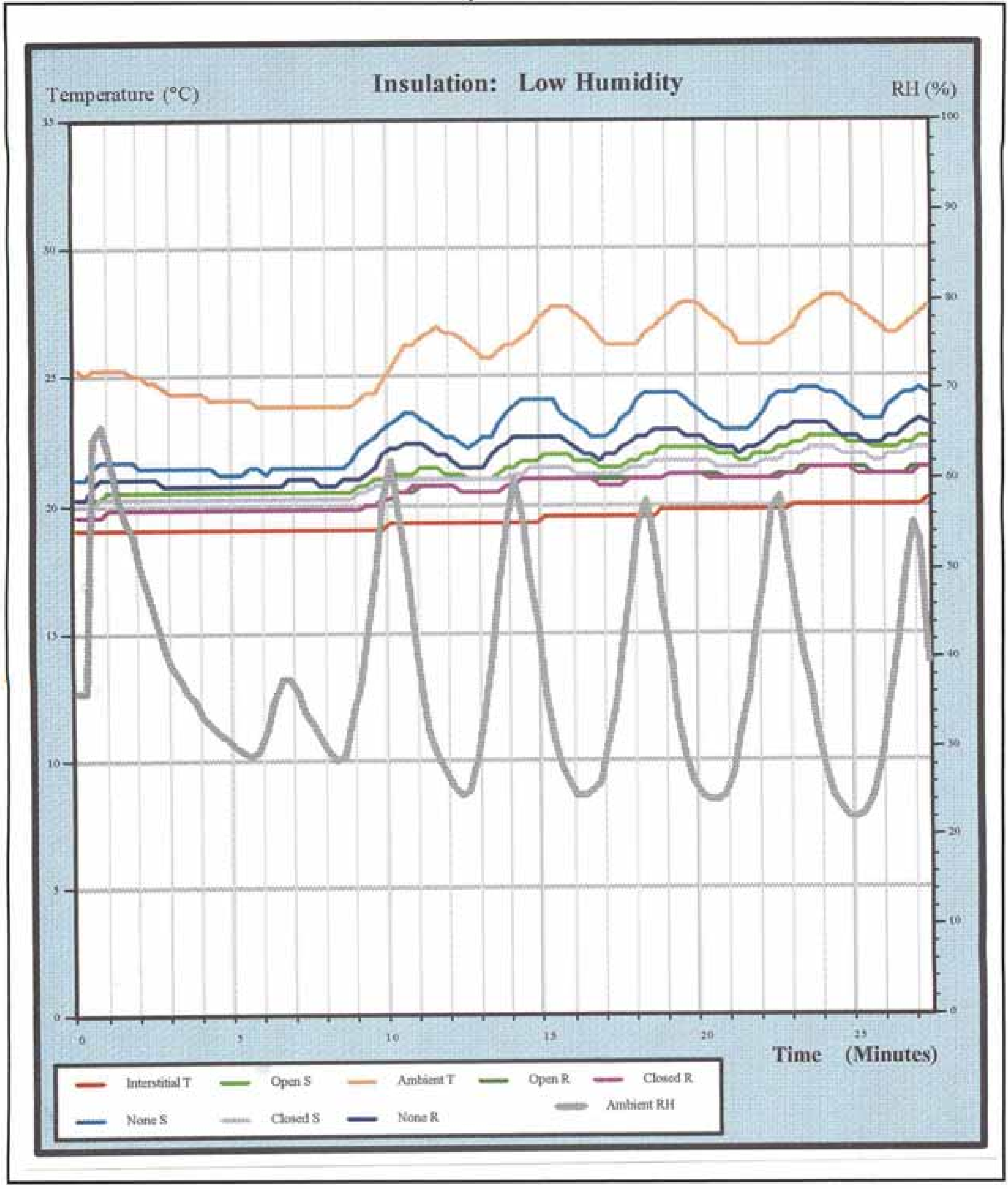
Int T		AT	
Open R	0.975	None S	0.960
Closed R	0.967	Open S	0.946
Closed S	0.966	None R	0.937
Open S	0.960	Closed S	0.934
None S	0.844	Closed R	0.934
AT	0.836	Open R	0.929
None R	0.836	Int T	0.836

Table 13: Correlations for Experiment 9; at right the values for the relationship between the ambient and the interstitial are given in descending order.

Under constant high temperatures, all the insulated probes correspond quite well to the interstitial temperature.

Experiment 10 INSULATION: Low Humidity

The intention of this experiment was to hold a low relative humidity steady whilst varying the ambient temperature; this would have revealed any patterns of behaviour governing the operation of the attachment systems under dry conditions with widely fluctuating temperatures. In practice, however, the operation of the climate chamber is such that humidity varies as well.



Graph 11: Graph of temperature and relative humidity against time for Experiment 10.

Here it becomes clear that the cycling of surface temperature probes with ambient conditions is certainly dependant on the temperature as well as the humidity: it is only when the ambient temperature itself is cycled (over some 11°C) that the fluctuations in RH (over about 35%) appear to be associated with cycling of the uninsulated sensors through a range of around 7°C. Again, the insulated probes appear to fluctuate less in the ambient conditions inside the climate chamber.

In order of decreasing accuracy, then,

- Open on Rough differs from interstitial by ~2°C
- Closed on Rough differs from interstitial by ~2°C
- Closed on Smooth differs from interstitial by ~2.5°C
- Open on Smooth differs from interstitial by ~3°C
- None on Rough differs from interstitial by at least 3.5°C
- None on Rough differs from interstitial by at least 4.5°C

Insulation; Low RH

	IntT	None S	Open S	Closed S	AT	None R	Open R	Closed R	RH
Interstitial T	*1.000*	0.831	0.957	0.955	0.848	0.860	0.930	0.923	-0.178
None S	0.831	*1.000*	0.930	0.939	0.867	0.987	0.923	0.933	0.126
Open S	0.957	0.930	*1.000*	0.989	0.912	0.948	0.979	0.979	-0.135
Closed S	0.955	0.939	0.989	*1.000*	0.901	0.955	0.980	0.980	-0.092
Ambient T	0.848	0.867	0.912	0.901	*1.000*	0.886	0.927	0.931	-0.148
None R	0.860	0.987	0.948	0.955	0.886	*1.000*	0.945	0.953	0.080
Open R	0.930	0.923	0.979	0.980	0.927	0.945	*1.000*	0.993	-0.162
Closed R	0.923	0.933	0.979	0.980	0.931	0.953	0.993	*1.000*	-0.153
Ambient RH	-0.178	0.126	-0.135	-0.092	-0.148	0.080	-0.162	-0.153	*1.000*

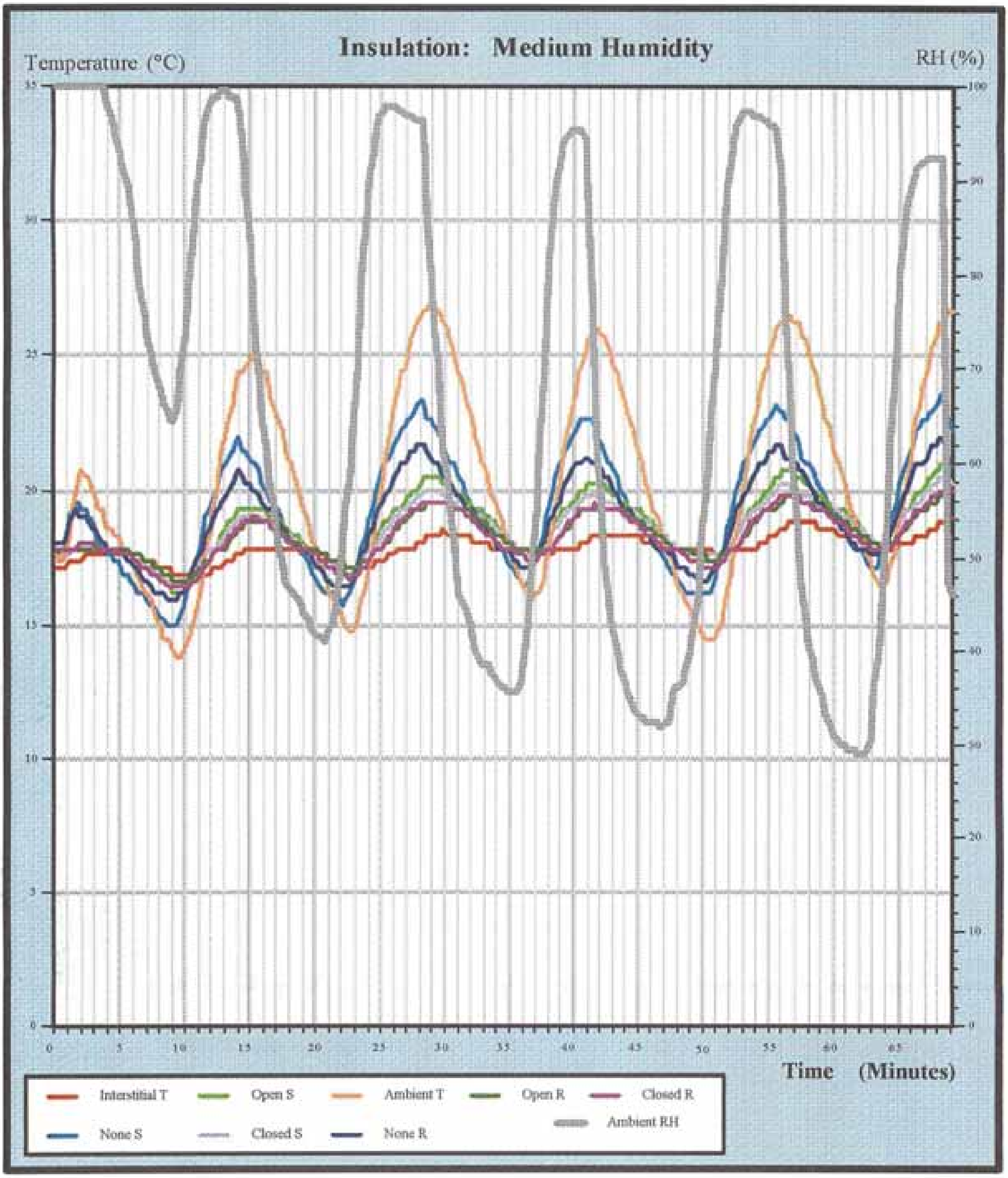
Int T		AT	
Open S	0.957	Closed R	0.931
Closed S	0.955	Open R	0.927
Open R	0.930	Open S	0.912
Closed R	0.923	Closed S	0.901
None R	0.860	None R	0.886
AT	0.848	None S	0.867
None S	0.831	Int T	0.848

Table 14: Correlations for Experiment 10; at right the values for the relationship between the ambient and the interstitial are given in descending order.

In the correlations for Experiment 10, it is clear that all the insulated probes correspond substantially better to the interstitial temperature than those which are left exposed to the ambient.

Experiment 11 INSULATION: Medium Humidity

The intention of this experiment was to hold a medium relative humidity steady whilst varying the ambient temperature; this would have revealed any patterns of behaviour governing the operation of the attachment systems under dry conditions with widely fluctuating temperatures. In practice, however, the operation of the climate chamber is such that humidity varies as well.



Graph 12: Graph of temperature and relative humidity against time for Experiment 11.

As in the examination of attachment methods, comparison of the graph of the ambient temperature (unavoidably cycled over a range of some 11 °C as RH is varied over some 65%) with those of the surface temperature sensors suggests that the materials of the surface and/or those holding the probes in place are responding strongly to the presence of water vapour as well as directly to the temperature itself.

In descending order of accuracy, then,

- Open on Rough differs from interstitial by ~1.5 °C
- Closed on Rough differs from interstitial by ~1.5 °C
- Closed on Smooth differs from interstitial by ~2 °C
- Open on Smooth differs from interstitial by ~2.5 °C
- None on Rough differs from interstitial by ~4 °C
- None on Rough differs from interstitial by ~5 °C

Insulation; Medium RH

	IntT	None S	Open S	Closed S	AT	None R	Open R	Closed R	RH
Interstitial T	*1.000*	0.573	0.852	0.862	0.700	0.619	0.891	0.845	-0.368
None S	0.573	*1.000*	0.890	0.885	0.909	0.993	0.820	0.882	0.413
Open S	0.852	0.890	*1.000*	0.993	0.943	0.914	0.979	0.983	0.005
Closed S	0.862	0.885	0.993	*1.000*	0.923	0.909	0.975	0.979	-0.001
Ambient T	0.700	0.909	0.943	0.923	*1.000*	0.931	0.921	0.952	0.146
None R	0.619	0.993	0.914	0.909	0.931	*1.000*	0.857	0.913	0.375
Open R	0.891	0.820	0.979	0.975	0.921	0.857	*1.000*	0.982	-0.094
Closed R	0.845	0.882	0.983	0.979	0.952	0.913	0.982	*1.000*	0.030
Ambient RH	-0.368	0.413	0.005	-0.001	0.146	0.375	-0.094	0.030	*1.000*

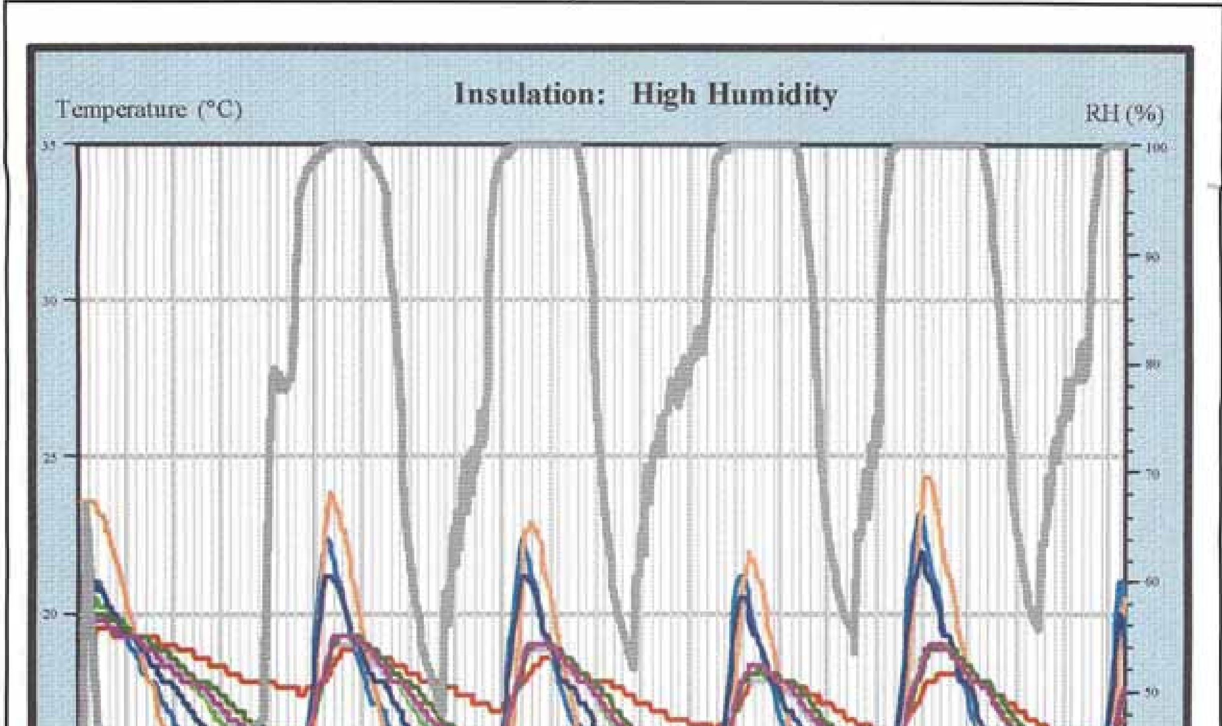
Int T		AT	
Open R	0.891	Closed R	0.952
Closed S	0.862	Open S	0.943
Open S	0.852	None R	0.931
Closed R	0.845	Closed S	0.923
AT	0.700	Open R	0.921
None R	0.619	None S	0.909
None S	0.573	Int T	0.700

Table 15: Correlations for Experiment 11, with the values for the relationship between the ambient and the interstitial given in descending order.

At these higher humidities, the correlations suggest that all configurations correspond more closely with the ambient than with the interstitial temperature. The same type of insulation used on different on different surfaces still behaves in quite a similar manner.

Experiment 12 INSULATION: High Humidity

The intention of this experiment was to hold a high relative humidity steady whilst varying the ambient temperature; this would have revealed any patterns of behaviour governing the operation of the attachment systems under dry conditions with widely fluctuating temperatures. In practice, however, the operation of the climate chamber is such that humidity varies as well.



Graph 13: Graph of temperature and relative humidity against time for Experiment 12.

Here there is some variation of interstitial temperature (over around 2°C) with the cycling of ambient temperature through some 14°C; meanwhile the 'steady' RH varies over 45%. The clear repetition of the sensor responses over each cycle again confirms the internal repeatability of the experiment.

In order of descending accuracy, then

- Open on Rough differs from interstitial by ~2°C
- Closed on Rough differs from interstitial by ~2°C
- Closed on Smooth differs from interstitial by ~2.5°C
- Open on Smooth differs from interstitial by ~2.5°C
- None on Rough differs from interstitial by ~3°C
- None on Rough differs from interstitial by ~4.5°C

Insulation; High RH

	IntT	None S	Open S	Closed S	AT	None R	Open R	Closed R	RH
Interstitial T	*1.000*	0.540	0.854	0.871	0.633	0.623	0.909	0.871	-0.344
None S	0.540	*1.000*	0.847	0.850	0.951	0.992	0.791	0.851	0.286
Open S	0.854	0.847	*1.000*	0.995	0.926	0.889	0.988	0.991	-0.018
Closed S	0.871	0.850	0.995	*1.000*	0.917	0.893	0.990	0.994	-0.038
Ambient T	0.633	0.951	0.926	0.917	*1.000*	0.960	0.881	0.920	0.224
None R	0.623	0.992	0.889	0.893	0.960	*1.000*	0.845	0.897	0.222
Open R	0.909	0.791	0.988	0.990	0.881	0.845	*1.000*	0.989	-0.076
Closed R	0.871	0.851	0.991	0.994	0.920	0.897	0.989	*1.000*	0.003
Ambient RH	-0.344	0.286	-0.018	-0.038	0.224	0.222	-0.076	0.003	*1.000*

Int T		AT	
Open R	0.909	None R	0.960
Closed R	0.871	None S	0.951
Closed S	0.871	Open S	0.926
Open S	0.854	Closed R	0.920
AT	0.633	Closed S	0.917
None R	0.623	Open R	0.881
None S	0.540	Int T	0.633

Table 16: Correlations for Experiment 12; at right the values for the relationship between the ambient and the interstitial are given in descending order.

Unusually, in this case there is an exact correlation between the visual interpretation of the graphs – that is, the comparison of the patterns of response – and the correlation coefficient; note in particular the very poor correlation between the interstitial probe and the uninsulated sensors. All configurations show quite consistent behaviour on both types of surface.

4.2.6.2.i) Attachment Methods

From the visual examination of the data in graph form, it is noticeable that in every experiment (except that holding a steady medium temperature, where the results were inconclusive) the sensor accuracy was as follows (in descending order):

- Gauze bandage on a rough surface;
- Gauze bandage on a smooth surface;
- Direct attachment with B72 acrylic resin on a rough surface;
- Synthetic clay on a rough surface;
- Direct attachment with B72 acrylic resin on a smooth surface;
- Synthetic clay on a smooth surface.

Attachment Method Test

Correlation of All Test Results

	IntT	Clay S	B72 S	Gauze S	AT	Clay R	B72 R	Gauze R	RH
Interstitial T	*1.000*	0.687	0.731	0.793	0.544	0.739	0.737	0.870	-0.330
Clay S	0.687	*1.000*	0.996	0.986	0.977	0.995	0.991	0.948	-0.208
B72 S	0.731	0.996	*1.000*	0.994	0.961	0.998	0.997	0.967	-0.204
Gauze S	0.793	0.986	0.994	*1.000*	0.934	0.993	0.991	0.986	-0.230
Ambient T	0.544	0.977	0.961	0.934	*1.000*	0.957	0.951	0.869	-0.190
Clay R	0.739	0.995	0.998	0.993	0.957	*1.000*	0.997	0.971	-0.199
B72 R	0.737	0.991	0.997	0.991	0.951	0.997	*1.000*	0.971	-0.174
Gauze R	0.870	0.948	0.967	0.986	0.869	0.971	0.971	*1.000*	-0.218
Ambient RH	-0.330	-0.208	-0.204	-0.230	-0.190	-0.199	-0.174	-0.218	*1.000*

Correlation in Order

Int T		AT	
Gauze R	0.870	Clay S	0.977
Gauze S	0.793	B72 S	0.961
Clay R	0.739	Clay R	0.957
B72 R	0.737	B72 R	0.951
B72 S	0.731	Gauze S	0.934
Clay S	0.687	Gauze R	0.869
AT	0.544	Int T	0.544

Table 17: Overall correlations for Experiments 1-6 (Attachment Methods), with the values for the relationship between the ambient and the interstitial given at right in descending order.

The order of accuracy suggested by the mathematical interpretation of the entire data series corresponds closely to the results of the visual assessment; it is clear that the gauze bandage configuration is more effective on both types of surface by a significant degree. Note that it is this configuration, too, which is least in correlation with the ambient temperature (a result suggested by the bench test). There is a fairly close correspondence between the behaviour of the same attachment methods on different surfaces.

The consistently better performance of the gauze bandage method of attachment may be interpreted in several ways: either the still air trapped beneath the probe by the gauze is a much better thermal conductor than the combination of resin and Japanese tissue or the (presumably circulating) air between the wall and the probe attached with clay, and/or the gauze overlying the back of the probe is serving to isolate it from the ambient temperature to some degree. Indeed, it seems plausible that the air trapped within the gauze over the sensor could even be acting as something of an insulator (see the results of the insulation test, summarised below).

4.2.6.2.ii) Insulation

As with the study of attachment methods, visual assessment of each experiment investigating the use of thermal insulation produced a consistent result. In order of descending accuracy, the results are

- Insulation completely sealing a rough surface, or insulation attached only to the probe on a rough surface (in one experiment open insulation would prove the better, in another it would be the closed insulation; but both were always very similar in behaviour);
- Insulation completely sealing a smooth surface;
- Insulation attached to the probe only on a smooth surface;
- No insulation on a rough surface;
- No insulation on a smooth surface.

Thermal Insulation Test

Correlation of All Test Results

	IntT	None S	Open S	Closed S	AT	None R	Open R	Closed R	RH
Interstitial T	*1.000*	0.740	0.875	0.891	0.743	0.783	0.917	0.904	-0.461
None S	0.740	*1.000*	0.955	0.950	0.982	0.995	0.928	0.945	-0.182
Open S	0.875	0.955	*1.000*	0.998	0.963	0.966	0.991	0.992	-0.354
Closed S	0.891	0.950	0.998	*1.000*	0.953	0.963	0.992	0.993	-0.365
Ambient T	0.743	0.982	0.963	0.953	*1.000*	0.979	0.938	0.951	-0.232
None R	0.783	0.995	0.966	0.963	0.979	*1.000*	0.949	0.963	-0.201
Open R	0.917	0.928	0.991	0.992	0.938	0.949	*1.000*	0.996	-0.366
Closed R	0.904	0.945	0.992	0.993	0.951	0.963	0.996	*1.000*	-0.334
Ambient RH	-0.461	-0.182	-0.354	-0.365	-0.232	-0.201	-0.366	-0.334	*1.000*

Correlation in Order

Int T		AT	
Open R	0.917	None S	0.982
Closed R	0.904	None R	0.979
Closed S	0.891	Open S	0.963
Open S	0.875	Closed S	0.953
None R	0.783	Closed R	0.951
AT	0.743	Open R	0.938
None S	0.740	Int T	0.743

Table 18: Overall correlations for Experiments 7-12 (Thermal Insulation), with the values for the relationship between the ambient and the interstitial given at right in descending order.

As with the attachment experiments, the results of the mathematical interpretation of the complete data series for the insulation experiments corresponds exactly with that derived from the visual assessment of the graphed data. All insulated probes follow the interstitial significantly better than the uninsulated sensors. Again in every case there is a close relationship between the same configuration on different surfaces.

Thus it possible to conclude that thermal insulation, although it must increase the mass of the sensor, does in fact serve to improve accuracy. Attaching the insulation directly to the surface does not appear to be necessary.

These results are somewhat curious when contrasted with the undoubtedly poor performance of the sensors fixed with synthetic clay in the attachment experiments, which is often attributed to clay causing an increase in the mass of the sensor. Clearly the factors operating are much more complex, and appear to involve moisture content to a degree perhaps not previously appreciated. Further experiment would be necessary to shed light on these issues.

4.2.6.2.iii) Overall Assessment

The series of experiments on the whole proved successful, demonstrating that the combination of a surface with a high thermal inertia and rapidly fluctuating ambient conditions can indeed serve to separate the behaviour of different measurement configurations. The difficulties of maintaining a constant relative humidity have made certain results less conclusive; in particular, the aberrant behaviour of sensors (possibly as their attachment materials adsorb atmospheric moisture) can be inferred but not clearly demonstrated. The repeatability within the five runs of each experiment proved to be outstanding, giving confidence in the results of both the visual and mathematical interpretations. Consistency among experiments was also good.

Considering the interpretation of the results, it is immediately clear the visual assessment was of greater use. The bench test had indicated the desirability of mathematically separating the overlapping responses of the sensors, but the success of the rapid cycling of ambient conditions in achieving this in conclusive visual form perhaps made the mathematics redundant. Nevertheless, since correlation expresses aspects of the relationship between such variables which are different from those discernible by eye, and is of course purely quantitative, its use is desirable in order to build up a complete picture of the behaviour of the measurement system: whilst the correlation serves to quantify 'phase-like' relationships, the graphs of temperature against time reveal patterns of behaviour and allow the straightforward assessment of error.

In order to confirm the results obtained, it would be necessary to run similar (although more selective) experiments to remove any possible influence from, for example, particular sensors or sensor locations. In addition – as observed above – it would be highly desirable to design a new investigation which could eliminate the fluctuation of humidity from the system as was originally intended, since the experiments made so far suggest that moisture plays a significant role in the behaviour of the sensor configurations. This has enormous implications for the measurement of surface temperature under humid conditions. Other desirable – and possibly related – research includes investigating the apparent contradiction between the success of insulation and the problems of clay as an attachment method, and the determination of the thermal conductivity of the standard materials used for probe attachment (such as Paraloid).

The result of the surface texture variable was particularly interesting; every configuration attached to a rough rather than a smooth surface gave a more accurate reading of surface temperature. One possible explanation for this is that there may well be more points of contact between the sensor and a rough rather than a smooth surface [see FIGURE 13]. This has pleasant implications for the environmental monitoring of wall paintings, since it suggests that, far from being a problem, the rough topography of a plaster surface may actually enhance the accuracy of contact surface temperature measurement.

It must be restated that these experiments were highly specific, concentrating as they did on one sensor type, three attachment methods, and variations of one form of insulation. Clearly, the next step is to extend the investigation to cover different types of sensor, determining how these may differ from each other under identical conditions.

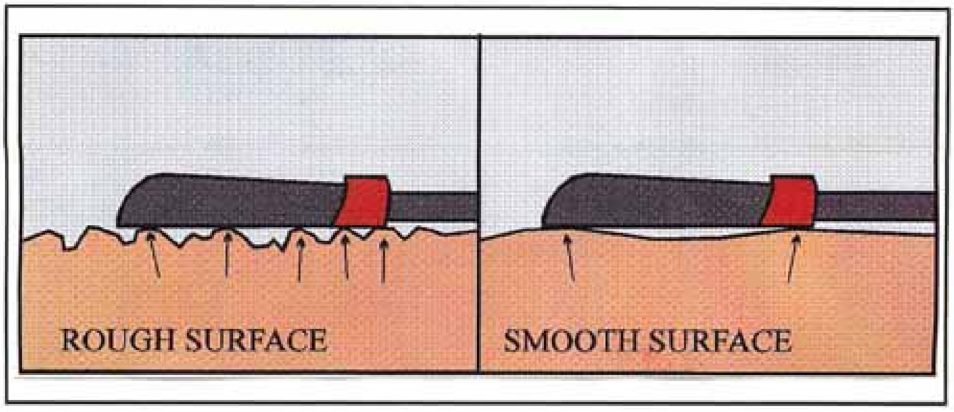


Figure 13: The presumed situations of a surface temperature probe on a rough surface and a smooth surface; note that there are more points of contact between the probe and the rough surface than between the probe and the smooth.

4.2.6.3 Summary

The repeatability and consistency within the twelve experiments gives some confidence in the following conclusions:

- of the attachment methods tested, fixing the probes to the surface with a gauze 'bandage' gave the highest accuracy, where accuracy was taken to be correspondence with the interstitial rather than with the ambient temperature. The measurements made with this type of sensor attachment were generally within 2°C of the interstitial temperature;
- fixing the probes with synthetic clay gave measurements which tended to correspond poorly to the interstitial temperature and well to the ambient temperature. The causes of this were not made clear by these preliminary experiments, but avenues which should be investigated include the effect of moisture movement in and around the attachment materials, and the effect of different exposure levels**
- applying thermal insulation (in this case, in the form of styrofoam cubes) to cover the sensor markedly improved the correspondence of the measurement to the interstitial temperature (to an estimated ±1-1.5°C). It was not necessary to bond the insulation to the surface around the sensor, equally acceptable results being achieved with shielding attached to the back of the probe only.

4.3. An Investigation into the Use of Infra-Red Thermometers

One simple result arising from the investigation of possible attachment methods for contact thermometers was that attachment directly to the painted surface is normally unacceptable: even ignoring the problems of removal, if the sensor is fixed in place well enough to be secure then the paint layer is in great danger should someone tug at the lead (whether from curiosity or by accident). Naturally, too, the areas of greatest interest when planning a programme of monitoring will typically be those showing signs of damage which might be related to surface temperature effects - that is, those very areas where the paint layer may be at its most fragile.

It is clear, therefore, that a non-contact method of measurement would be highly desirable, and for this reason it was decided to undertake a preliminary investigation into the feasibility of using infra-red pyrometers to measure the surface temperature of wall paintings.

It is immediately evident from the literature that IR measurement has several features which peculiarly fit it for use on wall paintings, over and above the advantages of avoiding the various thermal contact problems. Heimann and Mester, in their important paper from the European Conference on Temperature Measurement in 1975, note that pyrometry has particular advantages for objects with a very low thermal conductivity, or for which direct contact is impossible for reasons of inaccessibility or fragility [HEIMANN + MESTER 1975, *p220*]. In addition, as Dean Baker *et al.* [1975, *p170-192*] observe

> The geometric surface of a body can be thought of as an ideal entity, subject only to the thermal agitation of the atoms in the surface layer. This concept acquires practical significance for surface films of poorly conducting materials. Radiation methods deal precisely with this 'ideal' surface... Radiation emanates from the *surface* of a body. In consequence radiation methods always relate to surface temperatures and are hence peculiarly adapted to the measurement thereof.

There are potential problems associated with the use of pyrometers for measuring surface temperature (apart from the obvious drawback of high cost). In order to evaluate these as they might affect the monitoring of wall paintings, it is useful to review here the principles of pyrometry.

4.3.1. The Operation of Infra-Red Thermometers

Pyrometers work on the principle that heat is just another form of energy. All objects radiate heat, or thermal energy, at a rate which is proportional to their temperature. The wavelengths of the emitted radiation range from the middle infra-red to the visible region of the electromagnetic spectrum, with very hot bodies emitting at higher frequencies and thus increasingly in visible wavelengths - hence the glowing of furnaces 'red-hot' and even 'white-hot'. A pyrometer is sensitive to the infra-red wavelengths and can measure the intensity of the thermal radiation, either over the whole IR spectrum or over a selected band of wavelengths chosen as particularly characteristic of the type of object being considered (in this way it is possible to minimise the effect of neighbouring bodies – such as passing people – on the measurement). Bandwidth is a function of the type of pyrometer selected.

Since different materials absorb and emit thermal radiation at different wavelengths, before a temperature measurement can be obtained it is necessary to adjust the signal by some value related to this aspect of the surface, its emissivity. Emissivity is defined as the ratio of the amount of incident energy absorbed by the surface and the total amount of incident energy; that is:

$$\varepsilon = \text{Emissivity}$$
$$= \frac{W}{W_o}$$

where W = *the amount of incident energy absorbed by the surface*
W_o = *the incident energy*

The energy falling on a surface may be either absorbed, transmitted, or reflected, so if the total incident energy is taken to be 1, then:

$$\alpha + \rho + \tau = 1$$

where α = *Absorption*
ρ = *Reflection*
τ = *Transmittance*

A surface that absorbs all the energy falling upon it (that is, α=1 and both ρ and τ =0) is known as a blackbody – by analogy, a whitebody reflects all incident energy (ρ=1, and both α and τ =0), and a transparent surface transmits completely (τ=1, both α and ρ=0). Of course, such ideal situations are purely theoretical; in reality, surfaces show all three kinds of behaviour to some degree. A true blackbody is purely theoretic, although certain surfaces under certain conditions do approach this state. From above, the emissivity of a blackbody is

$$\varepsilon_B = \frac{W_o}{W_o} = 1$$

so the emissivity of an object may be seen as a measurement of how closely it approaches being a blackbody.

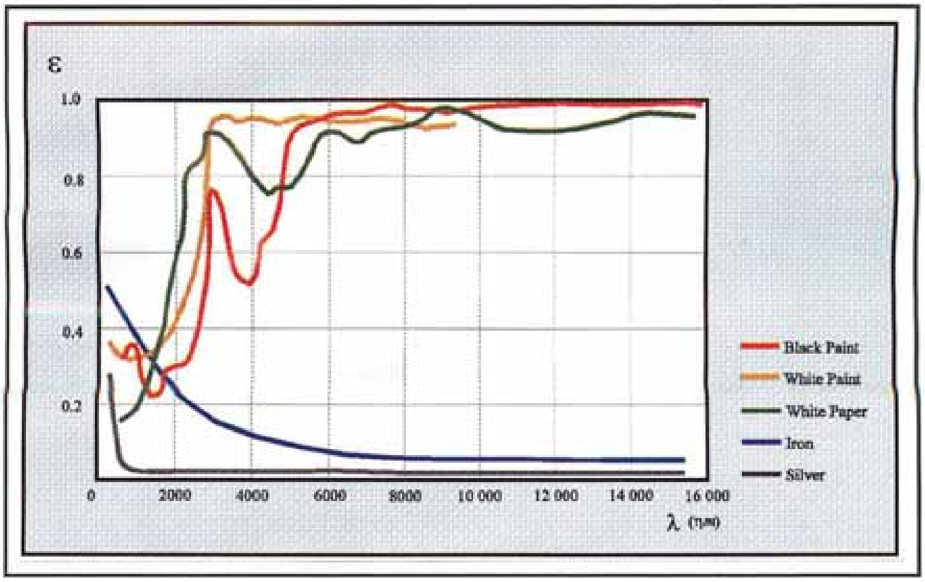


Figure 14: The emissivity of a number of common materials over a range of wavelengths from 0 to 16 000 nanometers. *After HEIMANN + MESTER [1975, p229].*

MATERIAL	EMISSIVITY
Asbestos	0.9
Asphalt	0.85
Brick	0.95
Ceramic	0.85-0.95
Concrete	0.95
Paper	0.80-0.95
Porcelain	0.9
Rubber	0.9
Textiles	0.75-0.90

Table 19: The emissivity of a number of common building materials. *After MICHALSKI [1991, p490]*

In general, manufacturers of infra-red thermometers recommend a setting of 0.9 for building materials such as plaster.

FIGURE 14 and TABLE 19 show the emissivities of a number of common materials, but it should be noted that the emissivity of an object depends not only on the material of which it is made, but also on its temperature – that is, on the wavelength of energy being emitted – and on the topography and homogeneity of its surface. Heimann and Mester [1975, *p229*] observe

...a theoretical calculation of emissivity is only feasible in very few idealised model cases. Normally, the emissivity must be determined experimentally.

and Michalski *et al.* [1991, *p159*] state

It must be stressed that uneven, rough, and grooved surfaces may have much higher values of emissivity than their specific emissivities.

(the specific emissivity is the emissivity of the material itself given an ideally smooth surface).

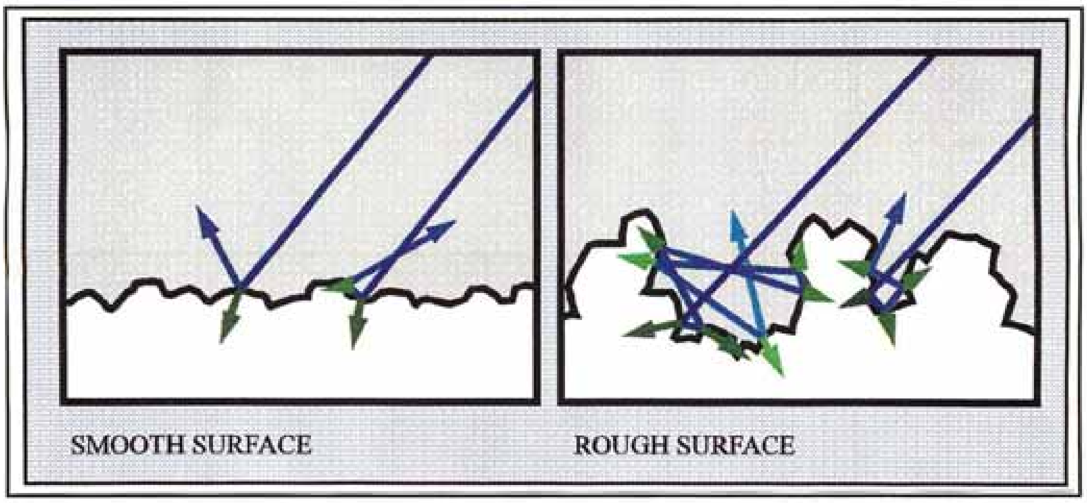


Figure 15: Light hitting a rough surface is absorbed and transmitted to a far greater degree than the same light hitting a smooth surface of the same material. In this diagram, incident and reflected light is shown with blue arrows, and light absorbed and/or transmitted is shown with a green arrow.

FIGURE 15 compares radiation falling onto smooth and rough surfaces: when light hits an ideally smooth surface it will have only one chance to interact with that surface, so there is only one point at which the energy is subjected to absorption, reflection, and transmittance. However, if the surface is rough, the reflected light will be forced to interact a number of times, each time loosing a little more of its energy to transmission and absorption by the surface. The rougher the surface, the more such interactions might be expected to occur, with the result that the reflected light finally emitted from the surface is a much smaller percentage of the original incident energy than would be expected of a smooth surface of the same material; that is, the emissivity will be considerably higher. In effect, the rougher the surface the more it will approach being a blackbody.[24]

How much do these considerations affect the measurement of the temperature of a wall painting using radiation pyrometers? Fortunately, plaster and stone and the other common materials which generally make up wall paintings and their supports have very low thermal conductivities, and thus do not vary greatly with changes in temperature especially around the ambient, allowing us to disregard the error from this source.[25] The better-quality commercial equipment available for pyrometric temperature measurement minimises the errors arising from the dependence of the emissivity on wavelength by examining a small bandwidth (chosen for stability from atmospheric effects) where these dependencies are well characterised. What is not clear is how much the type of surface - in particular its topography - and any errors in the estimation of its emissivity might affect the measurement. The literature would suggest that it is indeed important:

> An accurate temperature measurement with radiation pyrometers can only be made when the emissivity of the measured target is known.
>
> . HEIMANN + MESTER 1975, *p228*

> Surface sightings require a knowledge of surface emissivity as a function of wavelength and temperature, and... such information is rarely available, or at best is highly uncertain.
>
> BENEDICT 1977, *p259*

> The uncertainty of determining the radiation coefficient ε and the unmeasurable variations of the actual value of ε due to surface defects (soiling, ...films of varied thickness, roughness, corrosion) cause major measurement errors.
>
> TZSCHACH + BARTSCH 1984, *p514*

---

24 In fact, this principle is used to obtain blackbody conditions, as nearly as possible: a "blackbody furnace" is a spherical chamber painted matt black inside so that light energy entering through a tiny hole in the side of the furnace will be repeatedly reflected until it has been almost entirely absorbed. Such furnaces are used to measure emissivity directly (a sample installed in the centre of the chamber will affect its reading to a degree directly proportional to emissivity).

25 See DIXON 1988, *p426*

4.3.1.1. Assessing the Impact of Emissivity on IR Temperature Measurement

How can the possible error from emissivity be quantified? It is possible to use the theory to estimate the impact of errors caused by choosing an incorrect value for emissivity. Consider the Stefan-Bolzmann equation, which relates the spectral radiance of an object – the amount of energy it emits – to its temperature[26]

$$R = \text{Radiance} = \frac{\sigma}{\theta_o \pi} T^4$$

where σ *is a constant*
θ_o *is the solid angle*[G]
T *is the temperature*

For argument's sake, let us assume that there is indeed a significant difference between the assumed emissivity - call this ε_i - and the true emissivity of the surface, ε_t. Then there will also be some difference between the temperature read by the pyrometer, T_i, and the true temperature of the surface, T_t.

Radiance R is equal to the amount of energy absorbed by the surface, so the equation for emissivity can be written as

$$\varepsilon = \frac{R}{R_B}$$

where R_B *is the blackbody radiance*

Then by substitution

$$\varepsilon_i = \frac{\frac{\sigma}{\theta_o \pi} T_i^4}{\frac{\sigma}{\theta_o \pi} T_B^4} \quad and \quad \varepsilon_t = \frac{\frac{\sigma}{\theta_o \pi} T_t^4}{\frac{\sigma}{\theta_o \pi} T_B^4}$$

So the ratio of theoretical emissivity to true emissivity reduces to

$$\frac{\varepsilon_i}{\varepsilon_t} = \left(\frac{T_i}{T_t}\right)^4$$

Therefore, as the error in the estimation of emissivity becomes smaller (that is, as ε_i approaches ε_t) the measured temperature rapidly approaches the

26 See Zemansky and Dittman [1981, p94] for the derivation of this equation.

true temperature. It is possible to show this graphically by plotting the difference in temperature readings for a range of emissivities and temperatures, using the equation

$$T_i = T_t \sqrt[4]{\frac{\varepsilon_i}{\varepsilon_t}}$$

Then

$$\Delta T = T_t - T_i$$
$$= T_t\left(1 - \sqrt[4]{\frac{\varepsilon_i}{\varepsilon_t}}\right)$$

Plotting this equation with a value of 0.9 for estimated emissivity and a series of different values for the true emissivity (ranging from 0.10 to 1.00) suggests that the error in measured temperature for a 20% error in emissivity is around 10% (-2°C at 20°C) [see FIGURE 16]. What level of variation in emissivity might there in fact be across a wall painting, taking into account different surface topographies and different pigments?

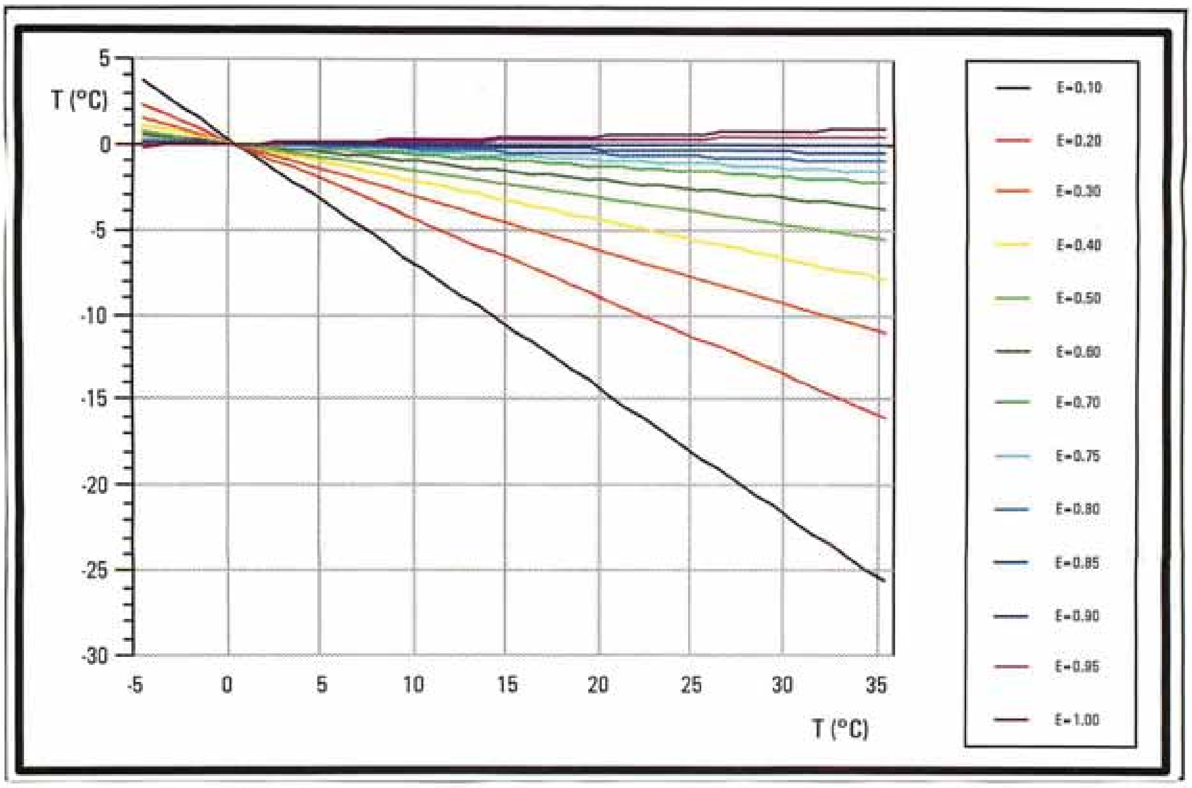


Figure 16: Based on the Stefan-Bolzmann equation, the theoretical error in the temperature measurements made by an IR Pyrometer due to incorrect assumptions about the value of the emissivity of the surface being measured can be plotted. Here, the emissivity E is the true emissivity; the assumed emissivity is 0.90; so in all cases but for E≥0.90 the measured temperature is lower than the true temperature.

4.3.2. A Test of the Impact of Emissivity on the Measurement of Surface Temperature

Unfortunately, emissivity cannot be measured directly at temperatures below about 50 °C[27], and a theoretical treatment such as that above is only approximate at best. It was therefore necessary to undertake a simple controlled test in order to obtain some idea of how - or whether - surface temperature readings from wall paintings might be affected by errors in the assumed values of ε.

It was decided that in the first instance it would be sufficient to use an infra-red pyrometer to measure different areas of wall paintings under the same conditions: that is, the temperature across the paintings could reasonably be

27 Personal Comm unication H Brown, Land Infrared, 1993.

assumed constant, and the ambient conditions comparable, so that any differences in pyrometer reading could be attributed to emissivity differences. The studio of the Courtauld Institute's Conservation of Wall Painting Department thus provided a good setting for such a test, since the students' test frescoes on the north wall could be presumed reasonably identical in temperature and moisture content (all having been completed at the same time two years ago from much the same materials). As replicas, the paintings represent a range of wall painting techniques, and consequently a good selection of topographies and paint types [see PLATE 20]. In addition, it was decided to take the opportunity to investigate the model surface used in the contact measurement experiments.

Mr Howard Brown, Technical Sales Engineer for Land Infrared was kind enough to undertake a series of measurements of these painting using a Minolta-Land Compaq 3 portable pyrometer [see APPENDIX 2 for the details of this equipment]. Unless otherwise stated, the ambient temperature was on the order of 20°C and the relative humidity about 40%; the emissivity was taken to be 0.90. The results were as follows:

4.3.2.1. Test of the Effect of Different Surface Topographies

- See FIGURE 17.

  The rough and smooth halves of the model surface used in the contact measurement experiment were also examined; the surface and ambient conditions were monitored at the same time using the datalogger.

  In the first experiment, the pyrometer measured the temperature of the smooth surface to be 18.1°C and that of the rough surface to be 18.4°C. The six contact probes at the same instant were measuring from 18.8-19.0°C. Ambient conditions were measured to be 20°C with an RH of 39.5%. The reading of the interstitial probe was 18.6°C.

  In the second experiment, made some 25 minutes later, the IR measurements were 18.5°C on the smooth and 18.7°C on the rough surface; the six contact sensors were measuring between 19.0 and 19.3°C at the same time. The ambient temperature was 20.7°C and the RH 39.0%, and the interstitial probe was reading 19.0°C.

- See FIGURES 18 to 20

  The arriccio and intonaco of a replica Etruscan tomb painting were measured in neighbouring points. The temperature of the smooth surface was measured to be 18.4°C and that of the rough 18.6°C (confirming its nearer approach to blackbody conditions). Although the instrument is actually sensitive enough to perceive such small variations, this error is well inside the pyrometer's stated accuracy of 0.5°C.

4.3.2.2. Test of the Effect of Different Paints on the Surface

- See FIGURES 21 to 23.

The lime-white painted background of a replica of an English Romanesque wall painting was compared to a neighbouring area of strong shades of ochre. Both areas were measured to be 18.5°C.

- See FIGURES 24 to 26.

Two neighbouring areas of intensive colour (one azurite in a glair medium, the other red ochre in fresco) were found to read 18.5°C for the red and 18.6°C for the blue. A gold strip between them, however, produced the result 20°C; 0.90 is not a estimate for the emissivity of a metal (especially gold).

4.3.2.3. A Further Test of the Effect of Metallic Leaf

- See FIGURES 27 to 29.

The damaged background of a replica 19th-century fresco, with fragments of gold leaf scattered over the surface, was found to read 19.1°C in comparison to a neighbouring area of rough arriccio which measured 18.8°C.

- See FIGURES 30 and 31.

The pyrometer was positioned so as to be continuously reading the same area of colour (that is, the smooth black fresco background of the replica Etruscan painting). The emissivity setting was then varied; this produced no significant response within 25% of the suggested value of 0.90 for building materials. Typical results are shown in TABLE 20.

Emissivity	Measured Temperature
0.90	20.5°C
0.84	20.4°C
0.70	20.5°C
0.10	25.0°C

Table 20: Selected results of emissivity experiment.

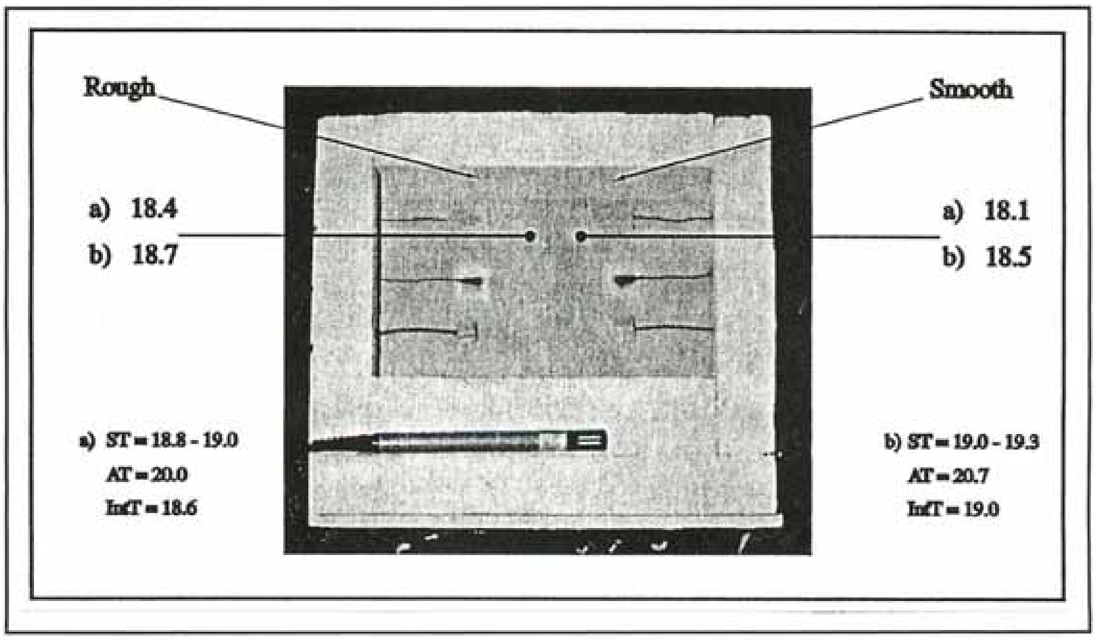


Figure 17: Model Surface. SEE SECTION 4.3.2.1. Measurements of the temperature of the rough and smooth plaster showed no significant difference from each other, but were in both cases lower than the measurements given by any of the monitoring sensors, including the interstitial probe. The reason for this is not clear without further testing, but it seems likely that the bench upon which the surface was resting during measurement may have affected the readings.
Measurements in °C.
Photo: Author 1994

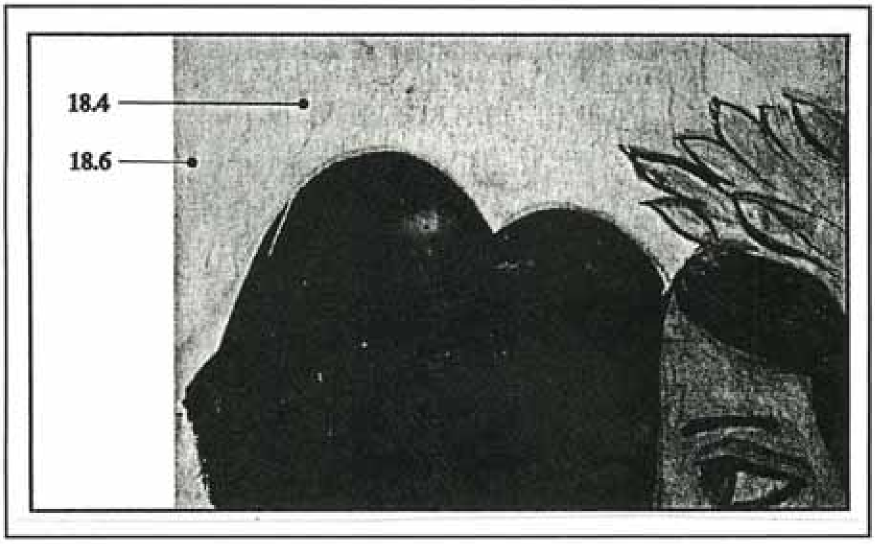


Figure 20: CWPD studio; detail of replica Etruscan wall painting. SEE SECTION 4.3.2.1. Measurements of the temperature of a rough plaster surface (the arriccio) and of a neighbouring area of smooth plaster (intonaco) showed no significant difference.
Measurements in °C.
Photo: Author 1994

Figure 18: CWPD studio; detail of north wall; replica Etruscan wall painting.
Photo: Author 1994

Figure 19: CWPD studio; detail of replica Etruscan wall painting.
Photo: Author 1994

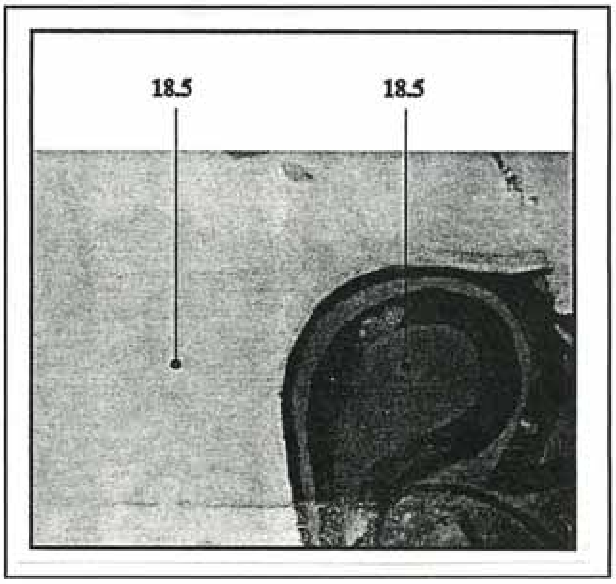


Figure 23: CWPD studio: detail of replica English medieval wall painting. SEE SECTION 4.3.2.2. Temperature measurements of white and coloured areas of the painting show no difference. Measurements in °C.
Photo: Author 1994

Figure 21: CWPD studio: detail of north wall; replica English medieval wall painting.
Photo: Author 1994

Figure 22: CWPD studio: detail of replica English medieval wall painting.
Photo: Author 1994

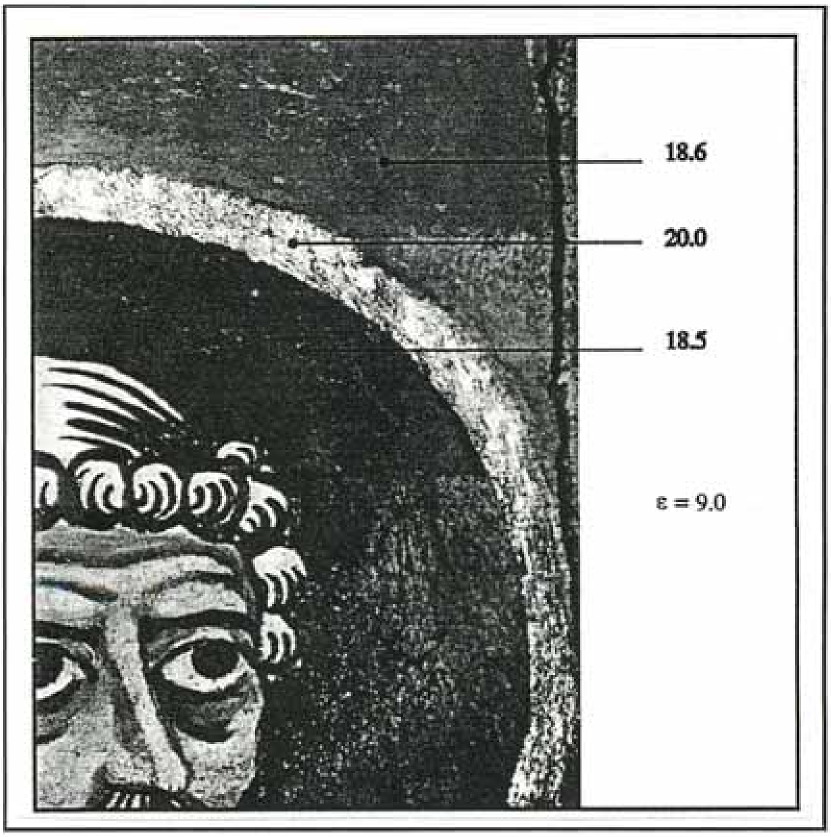


Figure 26: CWPD studio; detail of replica German medieval wall painting. SEE SECTION 4.3.2.2. Measuring the temperature of two very different paint layers - azurite in glair and red ochre in fresco - produced no noticeable difference. A significantly higher reading was gained however for the gold leaf edging the halo; unsurprising since the selected emissivity of 0.9 is highly inaccurate for gold (which is generally accorded an emissivity of 0.10).
Measurements in °C.
Photo: Author 1994

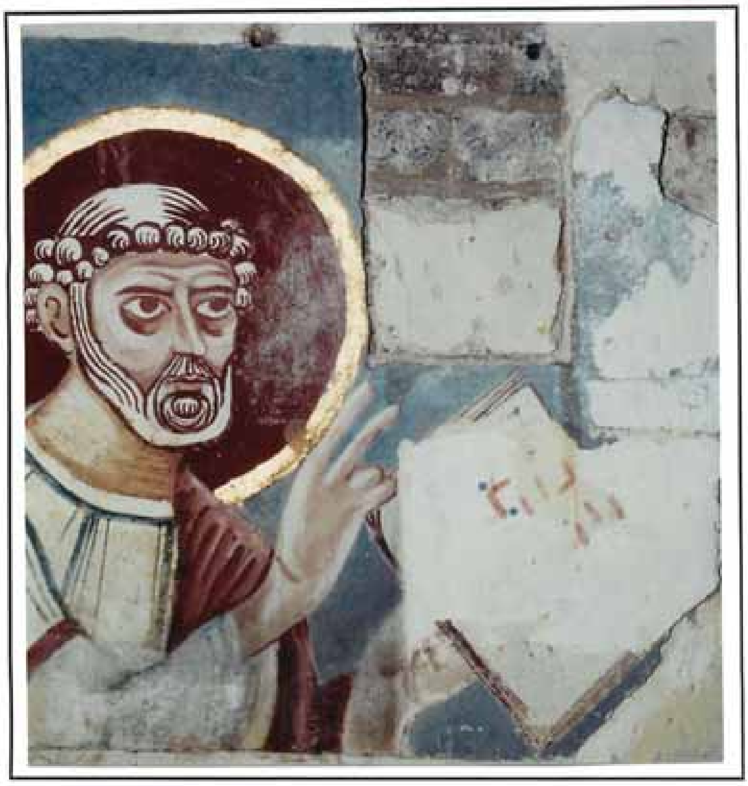


Figure 24: CWPD studio; detail of north wall; replica German medieval wall painting.
Photo: Author 1994

Figure 25: CWPD studio; detail of replica German medieval wall painting.
Photo: Author 1994

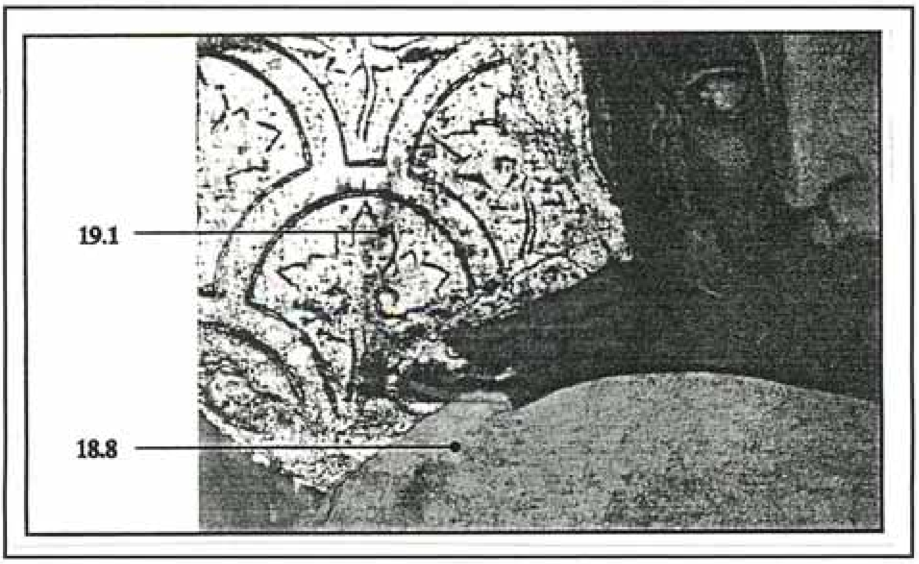


Figure 29: CWPD studio; detail of replica 19th-century wall painting. SEE SECTION 4.3.2.3. Measurements of the smooth gilded background and the rough arriccio showed that the presence of metallic foil, even in patchy condition, produces a measurable effect on the IR thermometer. Measurements in °C.
Photo: Author 1994

Figure 27: CWPD studio: detail of north wall; replica 19th-century wall painting.
Photo: Author 1994

Figure 28: CWPD studio: detail of replica 19th-century wall painting.
Photo: Author 1994

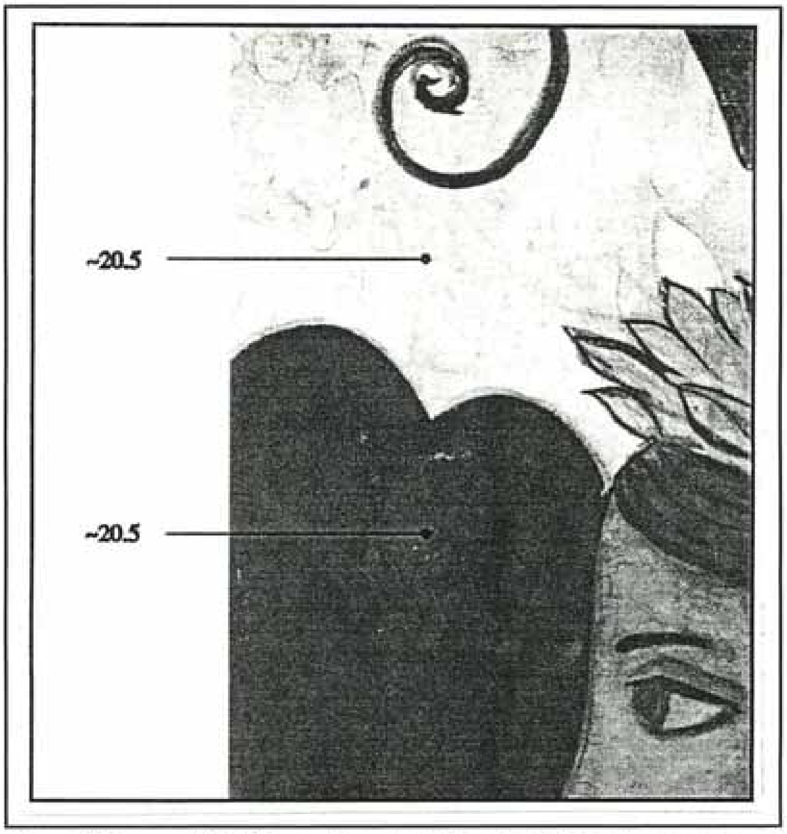


Figure 31: CWPD studio; detail of replica Etruscan wall painting. SEE SECTION 4.3.2.3. On both unpainted and painted areas, light and dark, varying the selected emissivity produced no discernible effect until emissivities of the order of those of metals were reached. For emissivities of the range 0.70 - 1.00, the IR thermometer gives consistent readings.

Measurements in °C.

Photo: Author 1994

Figure 30: CWPD studio; detail of replica Etruscan wall painting.

Photo: Author 1994

4.3.2.5. Summary of Results

Clearly, for most practical purposes the estimation of emissivity can be disregarded as a significant source of error when measuring wall paintings with infra-red thermometers: any error found was well within the stated accuracy of the pyrometer, ±2°C . The exception to this is areas with metallic leaf or paint, especially if the material is gold. Measurements on metallic coatings should be avoided, or else the emissivity must be re-estimated to give more accurate results (but it should also be noted that, with its high thermal conductivity, a metallic surface might in fact be expected to respond more rapidly and strongly to temperature changes than surrounding areas of plain or painted plaster).

It is however a simple matter to use tests similar as those above to check for potential problems before designing permanent installations. Reporting the outcome of such tests would support the results then provided by the permanent monitoring.

4.3.3. Assessment of Other Complications Involved in Using Pyrometers

Naturally, inaccuracies can also arise from sources other than emissivity estimation. Dean Baker *et al.* [1975, *p194*], for example, note that radiation pyrometers show errors from the reflected radiation received from ambient bodies, and recommend that the solid angle of measurement be limited – that is, that the spot-size be kept as small as possible. Heimann and Mester [1975, *p228*] express the same concern

> For pyrometrical measurement near the ambient temperature, thermal radiation from the surroundings considerably affects the reading... It is mandatory for exact and accurate temperature measurement near ambient temperatures to give due consideration to the influence of the temperature of the surroundings.

Fortunately the best infra-red pyrometers deal with these problems automatically, by (for instance) operating in bandwidths that maximise the contribution from the sources of interest and minimise interference from dust and haze. Good 'through-the-lens' sighting is a basic requirement, allowing the selection of small areas of the surface to monitor and limiting, for example, the solid angle (as suggested by Dean Baker *et al.* [1975, *p194*]).

5. CONCLUSIONS

5.1 Conclusions Arising from the Research

The experiments and tests undertaken in the course of this research provide a first estimate of the accuracies achievable in the measurement of the surface temperature of wall paintings. For **contact measurements**, the experiments suggested that error might be as great as ±7°C (for probes attached with synthetic clay). The main source of this error appears to be have been the thermal contact between the probe and the ambient air, as this could successfully be limited by using some form of thermal insulation such as styrofoam shields over the sensors. Of the three methods of attachment investigated, the most effective was found to be a 'bandage' of cotton gauze. The maximum accuracy achievable with such methods – where accuracy was taken to mean correspondence with the interstitial temperature – was of the order ±1°C.

For **infra-red measurements**, the experiments suggested that some inaccuracy in the estimation of emissivity was permissible; the emissivity of all wall painting components *with the exception of metallic paints, foils, and attachments* could successfully be assumed to be around 0.90. However it seems reasonable, and even advisable, to scan over the planned area of measurement with a hand-held device before installing fixed IR probes, looking for significant (and otherwise inexplicable) variations in temperature for a single setting of emissivity and for the effect of varying the emissivity reading whilst measuring those sites intended for long-term monitoring. An operator might also investigate the possible effect of radiation from neighbouring bodies; this could be done by altering the angle of incidence of the pyrometer, and/or by testing the affect of various types of shielding.

Since the positioning of sensors can so greatly affect their readings, care taken over this aspect when setting up a remote or contact monitoring system to measure surface and even ambient conditions can greatly improve the accuracy of the results.[28]

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[28] The Commissione Normal's Raccomandazioni 5/83, observes
"La scelta delle opportune condizioni di misura è particolarmente importante quando si voglia determinare la temperatura dello strato d'aria prossimo alla superficie del monumento: infatti tale temperatura può presentare un gradiente termico orizzontale e/o verticale, positivo o negativo, in funzione delle condizioni di esposizione e convezione."
The choice of the best conditions of measurement is particularly important when one wishes to determine the temperature of the layer of air near the surface of the monument: in fact the temperature may present a

It could prove helpful to consider the sensors and their attachment or positioning in terms of working properties and performance characteristics.[29] For example, perhaps a small weather-box to house an exterior RH+T probe could eliminate the errors arising from air movement and direct solar radiation; perhaps moving a surface temperature probe a few centimetres further down the wall could improve the relevance of the results to the patterns of damage on the painting.

There is a wide body of expertise in the measurement field in both science and industry which could be more efficiently tapped by conservators anxious to address those aspects peculiar to conservation. Without developing a good understanding of the problems of measurement in environmental monitoring and of their potential solutions, it will be difficult to develop consistent and repeatable results in the field.

For this same reason - consistency and repeatability - it seems vital that all environmental monitoring be clearly and (at least so far as the equipment and methodology is concerned) exhaustively published. The conservation field should be looking at establishing a consistent minimum standard for such monitoring, and for the reporting thereof.[30] For a typical case, Cather [1993, *p41*] suggests

...a minimum of one year of environmental monitoring for exterior and interior ambient temperature and relative humidity and for interior surface temperature, followed by calculation of dew-point temperatures and absolute humidities, and comparison with information on the local climate.

Eshøj and Padfield [1991, *p7*] support the inclusion of the calculated parameters of AH and DPT in any environmental monitoring, noting that without them such features of the microclimate as humidity buffering and condensation would remain hidden in the data. More is gained by limiting the amount of data collected as much as possible but in every way available maximising its value and accessibility, than by recording reams of information from dozens of probes. The more pertinent the measurement, the easier and faster it is to interpret.

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horizontal and/or vertical thermal gradient, positive or negative, as a function of the conditions of exposure and convection.

COMMISSIONE NORMAL 5/83 [1983, *p3*]

29 As an example of this, see AGNEW+LIN [1991, *p42*]; they note that sensors reliable in the laboratory yielded only intermittent results when installed on site, where dust and insect activity etc became factors.

30 "La presenzione dei dati raccolti costituesce un aspetto importante per la comprensione dei risulti della indagini.."
The presentation of the collected data constitutes an important aspect of the understanding of the results of the investigation.

FASSINA+STEVAN [1991, *p207*]

5.2 Suggestions for Future Lines of Research

As is so often the case, the experiments undertaken for this study have raised at least as many questions as they have resolved. It is important to quantify as much as possible the effect of moisture (both condensed and atmospheric water vapour) on the operation of contact sensors. The link between ambient temperature and relative humidity did not appear straightforward in the climate chamber: what exactly is happening to cause such apparent anomalies as both AT and RH rising and falling together? Is this effect limited to climate chamber conditions, or does it have any implications for any natural ambient conditions? Why exactly does synthetic clay make so poor an attachment method? Does this have implications for other types of attachment?

Although glues such as Paraloid B72 are widely used for the attachment of surface temperature sensors, there appears to be no data on the thermal conductivity of these materials, or how such conductivity might be affected by ambient temperature and humidity. Since in common with most acrylic resins B72 has a low glass-transition temperature,[31] one might expect that its thermal conductivity could vary significantly within the normal ambient temperature range.

How much information can realistically by obtained from any configuration: what is the minimum number of sensors necessary to achieve a certain level of confidence about the measurement and thus in its interpretation? Relatively common techniques such as infra-red thermography are already used to optimise the selection of surface temperature monitoring positions.[32] The strongly visual nature of thermograms certainly gives the conservator the option of using informed common sense to find a possible solution, but the possibility of exploiting the digital foundation of the images, using mathematical techniques to quantify the effect of different arrangements of sensors and thus to determine the layout of the minimum number of sensors which could still achieve the desired level of accuracy, deserves further investigation.[33]

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31 40 °C; see HORIE 1987, *p107*.

32 "...si può verificare una non uniforme distribuzione dei valori dovuta a ponti termici determinati da eterogeneità delle strutture... Una valutazione qualitativa attraverso una termografia della superficie in esame consenti di individuare i punti a temperatura più bassa per i quali è necessario un più preciso monitoraggio."
...one can confirm a non-uniform distribution of the values due to thermal points determined by the heterogeneity of the structure... A qualitative evaluation by means of the examination of a thermograph of the surface allows the detection of the points of lower temperature, for which a more accurate monitoring is necessary.
FASSINA+STEVAN [1991, *p206*]

33 The paper by Benjamin [1983, *p407*] suggests ways in which such optimisation might proceed:

Above all, however, it is important to develop reliable methods for relating monitoring data directly to the condition of the painted surface. The most significant errors in environmental monitoring are those of interpretation rather than of measurement; the latter are relatively easy to quantify and to minimise using techniques such as those discussed above, but it is the former which must be effectively addressed if the monitoring is to truly help preserve the cultural heritage. As Stefan Michalski [1990, *p584*] states

Our job [as conservators] is to explicitly predict the cost in deterioration.

Environmental monitoring is potentially a powerful tool for the conservation of all historic and artistic materials (not just of wall paintings – although they are perhaps the most difficult group to tackle in this way, combining as they do size, fragility, and immobility). If nothing else, monitoring should serve to remind the conservator of the complexity of the system of which the art work is a part. To give Arnold and Zehnder [1991, *p132*] the last word

...there is no way to preserve... paintings just by eliminating one cause or intervening in one process. The only practical way is to develop a program of concerted actions designed to minimise the decay... [A] methodical approach - combining investigations made at every level into all materials and into the forms and processes of decay - combined with the monitoring of humidity and climate... can apply to all wall paintings affected by similar decay on the condition that it is adapted to each individual case with intelligence and prudence. If we really aim to preserve monuments for the future, they must be monitored regularly.

"In order to minimise the work-load of initial measurement and subsequent signal-processing computations, the sampling points of the data field, in space, or time, or any other dimension, are normally spaced just far enough apart that the individual observations are *a priori* 'independent', ie there is no prior information on the basis of which any one observation could be even partially determined by interpolation between the others."

A powerful mathematical approach that could possibly be brought into play here is the Fast Fourier Transform, which is based on Fourier's theorem that any complex pattern can be represented by a sum of sine and cosine functions; then the number of such functions considered can be a reflection of the desired accuracy of measurement. That is, what number (and what position) of sensors give a combined pattern that mimics the true surface temperature pattern to the desired degree? For a discussion of Fourier's basic theory (as it applies to optics) see Hecht [1987].

PLATES

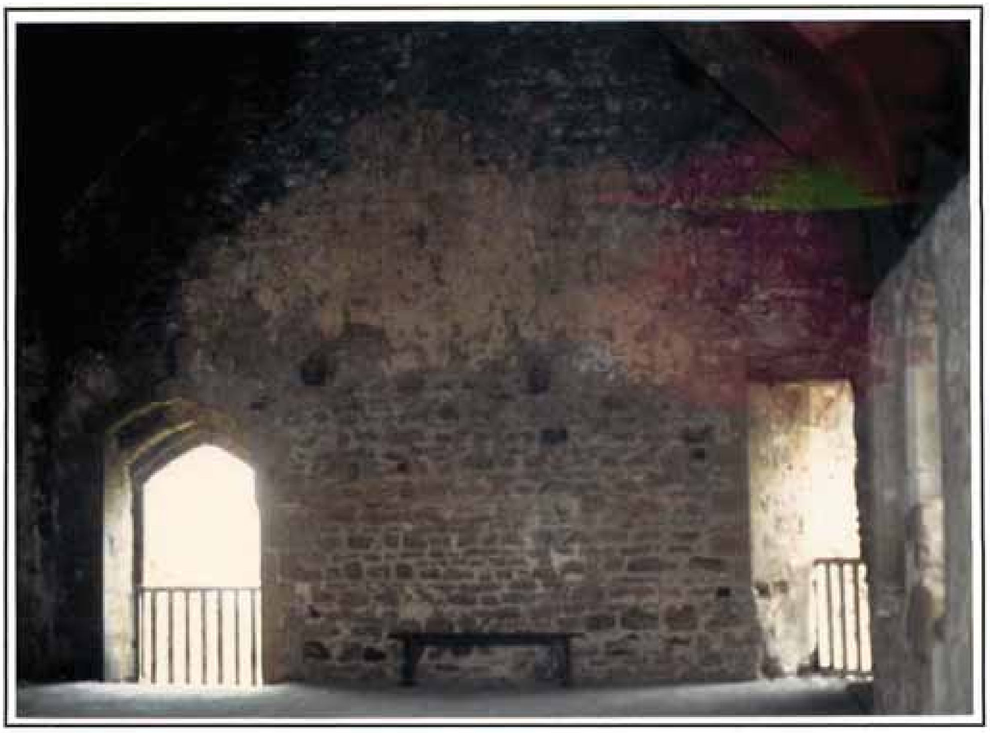


Plate 1: Cleeve Abbey, Somerset. This overall view of the north wall of the dorter (dormitory) shows the remains of a 13th-century masonry pattern. The Abbey is a ruin, and the dorter is open to the exterior environment. In addition, the close proximity of the site to the sea provides a ready source of salts. The rapid changes of ambient temperature and relative humidity virtually ensure that condensation will occur on the paint surface frequently, and the consequent cycles of moisture and evaporation provide the ideal conditions for the cycling of soluble salts [see MATTEINI 1991].
Photo: CWPD 1993

Plate 2: Cleeve Abbey; detail of the masonry pattern in the dorter. Very soluble salts can form efflorescences on the surface of the painting; the type of efflorescence is governed by environmental conditions as well as salt type [see ARNOLD + ZEHNDER, 1991].
Photo: CWPD 1993

Plate 3: Cleeve Abbey; detail of masonry pattern in dorter. Less soluble salts cause disruption (such as powdering and flaking) of the paint layer and even of the render during cycles of crystallisation and solubilisation [see MATTEINI 1991].
Photo: CWPD 1994

Plate 4: Horsham St Faith Priory, Norfolk: Detail of Foundation Scenes (St Faith). Salt damage may be related to the nature of the support; materials with particularly high thermal inertias or capable of holding large quantities of moisture will be prone to condensation events.
Photo: CWPD 1988

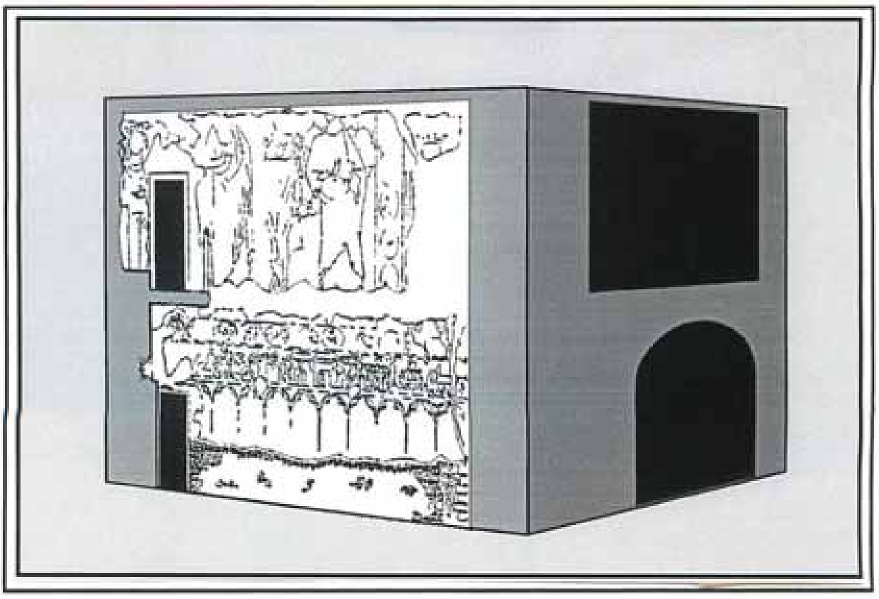


Plate 5: Horsham St Faith Priory; illustration showing relationship between the painting and the support structure. The vault of the slype is at its widest point directly behind the area of greatest damage in the Foundation Scene paintings [see JAMES 1988].
Photo: CWPD 1993

Plate 6: Horsham St Faith Priory. Foundation Scenes: detail of St Faith. Flaking of the paint layer (whether related to the original technique or to added materials) is aggravated by the cycling of salts. Fixatives (sizes) have been applied here, but have not 'taken' - probably due to the high moisture content of the surface [see JAMES 1988].
Photo: CWPD 1988

Plate 7: Horsham St Faith Priory. Detail of Foundation Scenes. The growth of salt crystals in the pores of the render can cause pitting and spalling of the paint layer [see ARNOLD + ZEHNDER, 1991].
Photo: CWPD 1988

Plate 8: Cleeve Abbey. Sacristy; detail of south wall. In its most obvious manifestation, microbiological growth may appear as a thick veil, often strongly coloured, marring the pictorial image, ugly but apparently benign. In truth, however, even the least invasive micro-organisms introduce organic by-products such as salts and oxidising agents into the painting, and more destructive forms may actively cause damage with the growth of hyphæ and mycelium into the plaster. If the micro-organisms are feeding on the materials of the paintings - such as organic binding agents - the cohesion of the paint layer will be lost or other similar damage result.
Photo: CWPD 1988

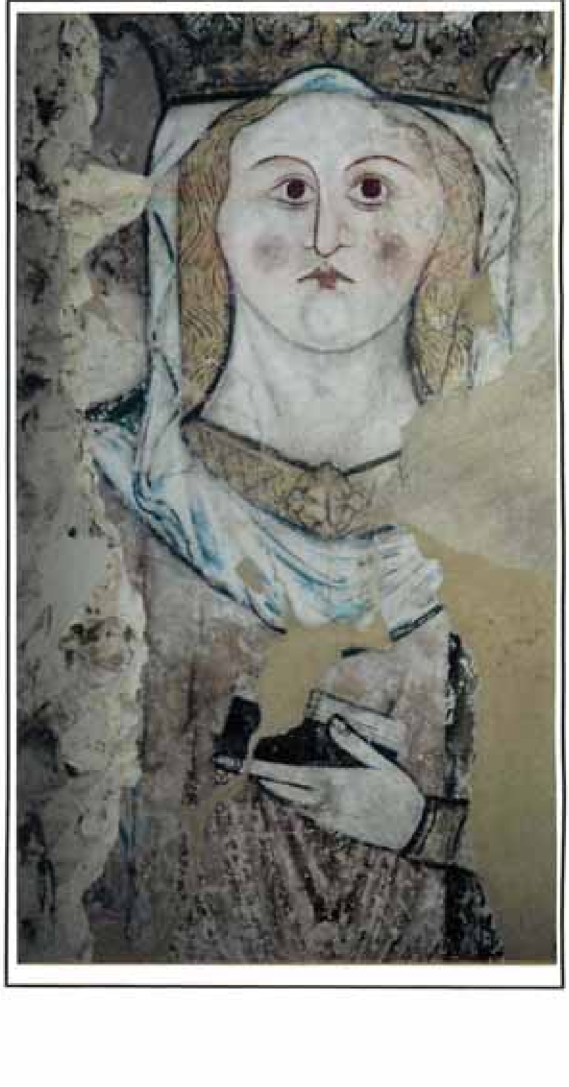


Plate 9: Horsham St Faith Priory; detail of figure of St Faith. Materials introduced into the paintings can serve as the substrate for microbiological growth. The lower part of this figure was detached in 1972, and in the environmental conditions pertaining in the former priory by 1988 the remaining glue size on the surface had allowed the establishment of a fungal colony on the painting [see JAMES 1988].
Photo: CWPD 1988

Plate 10: Horsham St Faith Priory; detail of figure of St Faith. The whitish veil formed across the painting by the fungus exactly follows in shape that of the facing used for detachment [see JAMES 1988].
Photo: CWPD 1988

Plate 11: Horsham St Faith Priory; detail of figure of St Faith. The fungus, identified as *Cladosporium*, generally appears as an off white, patchy, fibrous growth. During the reproductive stage however the fungus turns black. In addition to the serious disruption this causes to the pictorial image, the painted surfaces themselves are attacked by the growth of a vegetative mycelium within the substrate [see JAMES 1988].
Photo: CWPD 1988

Plate 12: St Gabriel's Chapel, Canterbury Cathedral: detail of lower tier on the north side of the apse. The alteration of original materials can be accelerated if not initiated by environmental conditions such as superficial humidity and temperature. In the case of the red lead cloak of this figure in St Gabriel's Chapel, the alteration product is another form of lead oxide known as cerrusite; this forms an opaque grey veil over the surface. In later stages of alteration, cerrusite itself may form plattnerite, resulting in a blackening of the paint layer [see HOWARD + CATHER, 1994].
Photo: CWPD 1992

Plate 13: Cleeve Abbey, Somerset: south wall of Sacristy. Environmental monitoring of the ambient conditions in the sacristy suggests that the west side of the wall receives considerably more radiant energy than the east side, especially in spring (note that no surface temperature measurements were made at this site). It is arguable that this differential is at least implicated in the selective way the painted border has altered.
Photo CWPD 1993

Plate 14: Cleeve Abbey, Sacristy: south wall, detail of border pattern on east side.
Photo: CWPD 1993

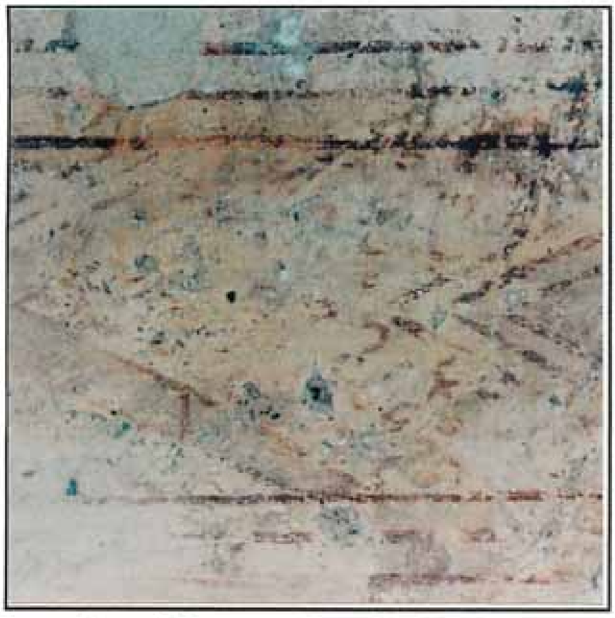


Plate 15: Cleeve Abbey, Sacristy: south wall, detail of border pattern on west side.
Photo: CWPD 1993

Comparison of the two sides of the border gives an excellent idea of how much such alteration can skew the perception of the image; here the effect is almost that of creating a negative, with the lighter areas becoming a darker colour.

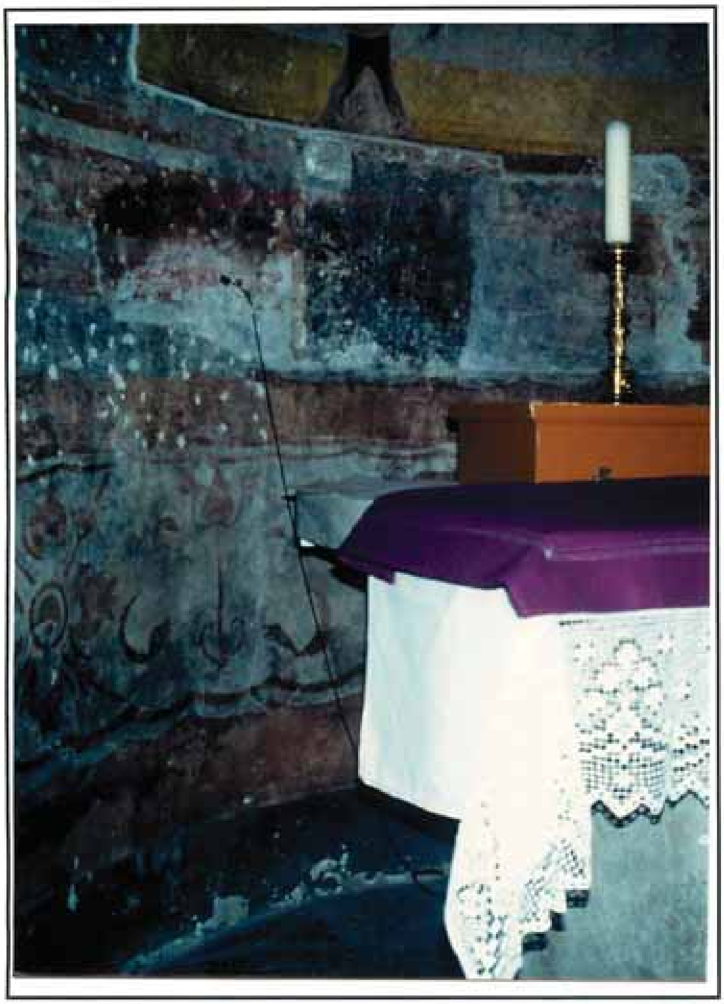
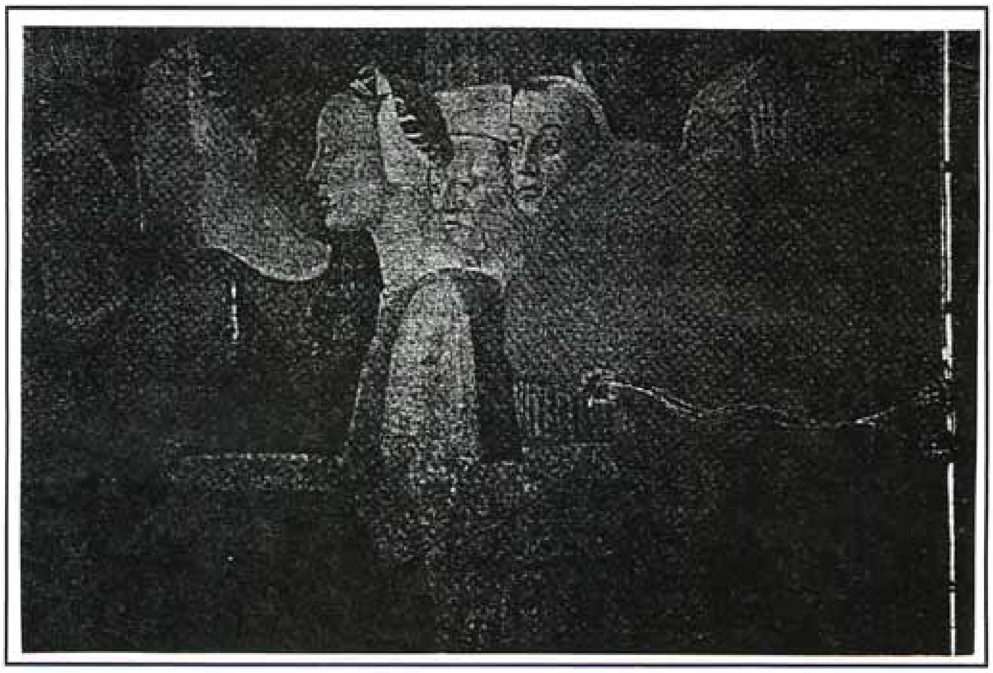


Plate 16: The convent church of Müstair, Switzerland; detail of the north apse. At Müstair the surface temperature probes were positioned over the painted surface, but not directly attached to it. The sensor element was held in place by the stiffness of the wires, attached with screws to a nearby fill.
Photo: Author 1993

Plate 17: Piero della Francesca's Cycle of the True Cross in Arezzo; detail of the south wall. Surface temperature probes were attached to fills and losses in the paint surface [see MARCHETTI, 1989].
From Un progetto per Piero 1991, p339



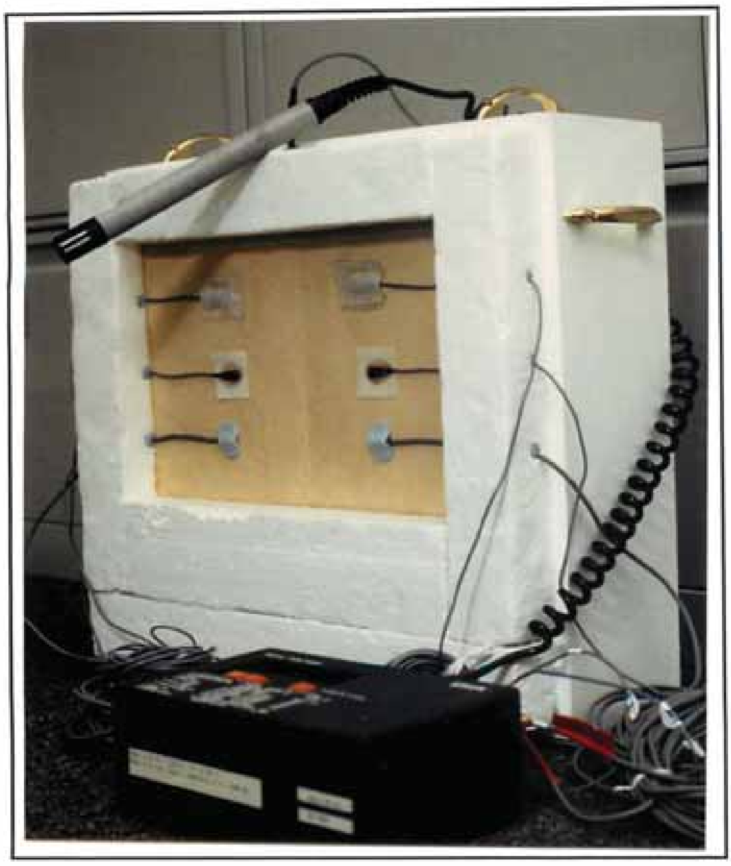


Plate 18: Model surface for testing surface temperature measurement; including sensors and datalogger. Note that the leads from the surface temperature probes are taken along presumable isotherms and then fed through the insulation material.
Photo: Author 1993

'Band-aid' of cotton gauze applied with acrylic resin →
Acrylic resin with Japanese tissue intervention layer →
'Blu-tack' synthetic clay →

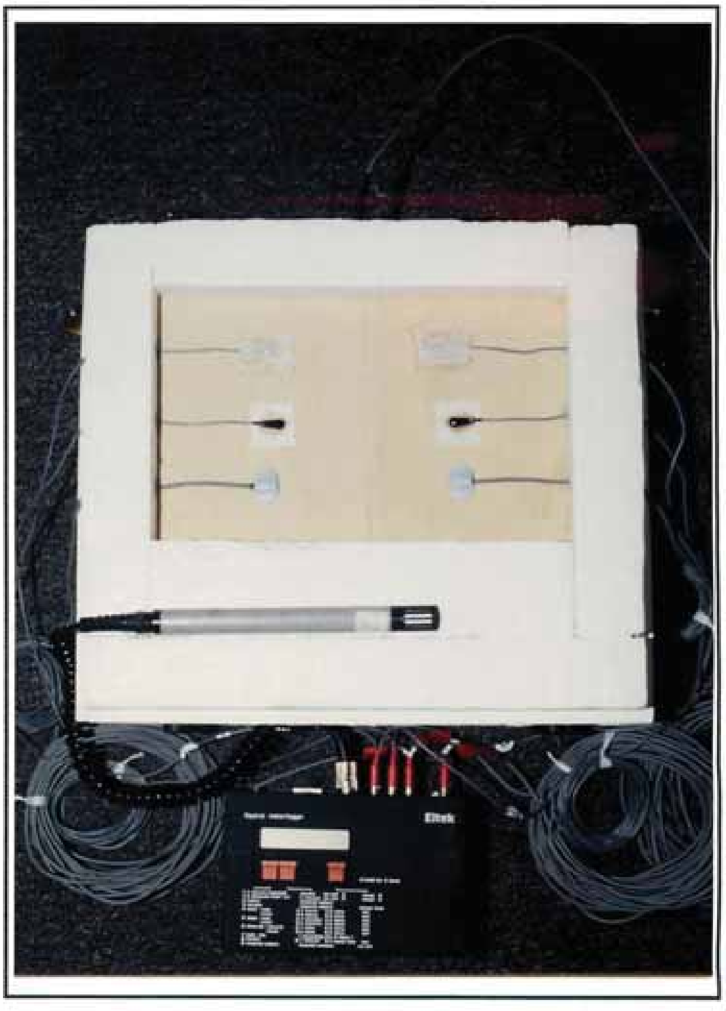


Plate 19: Model surface: detail showing attachment methods.
Photo: Author 1993

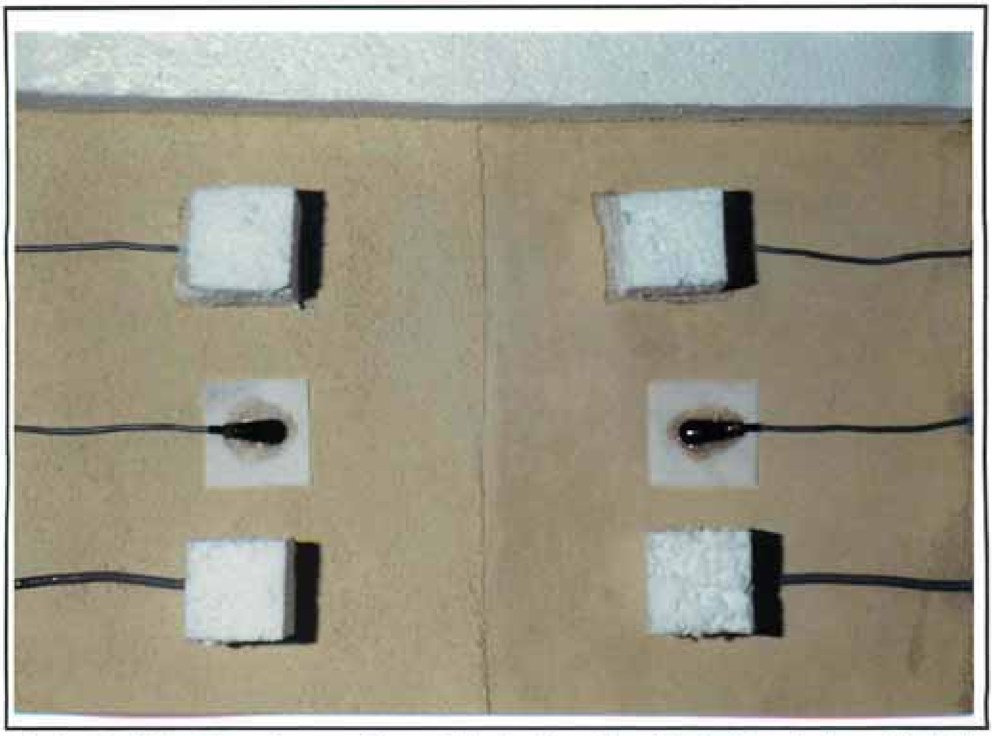


Plate 20: Model surface configured for testing the effect of insulation. Note the different surface textures of the two halves of the surface.
Photo: Author 1993

Plate 21: Conservation of Wall Paintings Department studio in Somerset House; detail of the north wall. The paintings along the wall are of approximately identical materials, and are of the same age and have met with the same conditions over time. They thus provide a good surface for the testing of infra-red temperature measurement equipment.
Photo: Author 1994

Plate 22: The climate chamber. Angelantoni UY 110 from Angelantoni Centro-sud spa.
Photo: Author 1993

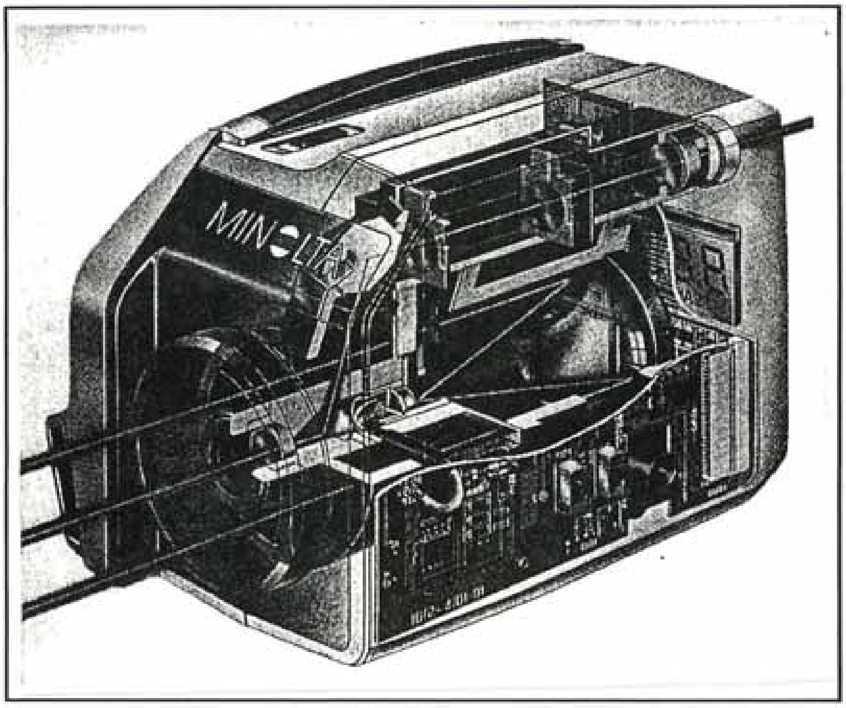


Plate 23: Cut-away view of the infra-red radiation thermometer (pyrometer). Minolta/Land Cyclops 300AF from Land Infrared.
Image courtesy of Land Infrared 1993

APPENDICES

APPENDIX 1

Results of a Surface Temperature Measurement Questionnaire sent to Leading Researchers in Conservation

The Surface Temperature Measurement of Wall Paintings - Original Questionnaire

EQUIPMENT

1. **What equipment do you use to measure surface temperature?**

❑ THERMOCOUPLES ❑ INFRA-RED THERMOGRAPHY

❑ THERMISTORS ❑ INFRA-RED THERMOMETERS

❑ RESISTANCE THERMOMETERS

❑ OTHER Please describe:--

2. **How do you record the data you acquire?**

❑ SPOT MEASUREMENTS

❑ COMPUTER DATALOGGERS What time interval(s) do you typically use between measurements? ------

----

❑ OTHER Please describe:--

3. **Do you limit measurement error by**

❑ INSULATING THE SENSOR How? --

❑ OTHER Please describe: --

----

4. **In general, how accurate do you think the surface temperature measurements are?**

❑ ±1°C ❑ ±3°C

❑ ±2°C ❑ >±3°C

POSITIONING OF SENSORS

5. **Do you attach your sensors to the**

❑ PAINTED SURFACE ❑ PLASTER REPAIRS

❑ LOSSES

❑ OTHER Please describe:--

6. **If you attach your sensors to the surface, what method(s) of attachment do you use?** Please describe: --

----

----

7. **On what basis do you decide <u>where</u> surface temperature should be measured on the painting?** Please describe:

INTERPRETATION OF THE RESULTS

8. **Do you process the data in any way (for example, by statistical analysis)?**

❑ NO

❑ YES Please describe: --

----

9. **How do you present the data ?** Please tick as many as apply.

❑ IN TABLE FORM ❑ IN GRAPH FORM

❑ IN SUMMARY FORM (THAT IS, DESCRIPTIVELY)

❑ OTHER Please describe: --

----

10. In the presentation of the data, do you directly correlate it with: Please tick as many as apply:

- ❑ THERMOHYGROMETRIC PARAMETERS:
  - ❑ RELATIVE HUMIDITY
  - ❑ AMBIENT TEMPERATURE
  - ❑ DEW POINT TEMPERATURE
  - ❑ ABSOLUTE HUMIDITY
  - ❑ OTHER Please describe --
- ❑ THE CONDITION OF THE PAINTING Please describe: ---

- ❑ OTHER FACTORS Please describe: --

List of Respondents

Dr Andreas Arnold
ETH Institut für Denkmalpflege
Expert-Centre
Hardturmstraße 181
CH-8005 Zurich
Switzerland

Ms Sharon Cather
Conservation of Wall Painting Department
Courtauld Institute of Art
Strand
London WC2R 0RN
UK

Mr Barry Knight
English Heritage
23 Savile Row
London W1X 2HE
UK

Mr Heinz Leitner
Hauptstraße 3
A-8742 Obdach
Austria

Mr Shin Maekawa
The Getty Conservation Institute
4503 Glencoe Avenue
Marina del Rey
CA 90292-6537
USA

Dr Maurizio Marabelli
Instituto Centrale per il Restauro
Piazza di San Francesco di Paola, 9
I-00184 Roma
Italy

Mr Tim Padfield
Conservation Department
The National Museum
Brede
DK-2800 Lyngby
Denmark

Dr Rolf Snethlage
Bayerisches Landesamt für Denkmalpflege
Hofgraben 4
Postfach 10 02 03
D-80076 München
Germany

Ms Sarah Staniforth
National Trust
36 Queen Anne's Gate
London SW1H 9AS
UK

Dr Marcel Stefanaggi
L R M H
29 rue de Paris
F-77420 Champs-sur-Marne
France

Dr Akito Ushida
Nara National Cultural Properties Research Institute
Centre for Archæological Operations
2-9-1 Nijo-cho Nara-shi
Nara 630
Japan

Results of Questionnaire

EQUIPMENT

1. **What equipment do you use to measure surface temperature?** 100% response

   45% THERMOCOUPLES
   46% THERMISTORS
   36% RESISTANCE THERMOMETERS
   0% OTHER
   27% INFRA-RED THERMOGRAPHY
   55% INFRA-RED THERMOMETERS

2. **How do you record the data you acquire?** 91% response

   50% SPOT MEASUREMENTS
   90% COMPUTER DATALOGGERS
   0% OTHER

   What time interval(s) do you typically use between measurements? A wide range of responses, from 1 minute to 1 hour. Most typically 15 minutes.

3. **Do you limit measurement error by** 73% response

   50% INSULATING THE SENSOR How? No respondent used thermal insulation, but several covered the sensors with (for example) aluminium foil to shield from radiant heat.

   50% OTHER One respondent uses a conductive metal plate between the sensor and the surface to ensure a good thermal contact, and several respondents mention the need to keep the sensor as small as possible to reduce thermal conduction.

4. **In general, how accurate do you think the surface temperature measurements are?** 91% response

   80% ±1°C
   10% ±2°C
   0% ±3°C
   10% >±3°C

POSITIONING OF SENSORS

5. **Do you attach your sensors to the** 91% response

   50% PAINTED SURFACE
   50% LOSSES
   40% PLASTER REPAIRS

   Most respondents use all types of surface, depending on the situation.

6. **If you attach your sensors to the surface, what method(s) of attachment do you use?** 64% response

   Responses included:

   - Using a thermocouple mounted onto a thin strip of gauze, with the strip adhered to the surface by acrylic resin to produce a 'bandage' effect.
   - Using a direct adhesive, such as glue, gum or wax, the choice of which depends on the situation.
   - Using pre-polymerised silicon rubber as a direct adhesive.
   - Avoiding the use of any introduced materials by using the stiffness of the wires to hold thermocouple sensors against the wall.
   - Using plates and screws.
   - Using clay over the sensor in a 'bandage' effect.

7. **On what basis do you decide <u>where</u> surface temperature should be measured on the painting?**

   82% response

   Most respondents pointed out the need to consider the site as a whole, as well as to take account of particular siting problems such as radiant light. One uses a thermographic map of the surface to determine the coldest (and therefore most susceptible) areas. Another observes that it is particularly important to consider the moisture content of the substrate., and a third points out the importance of measuring as closely as possible to the site of visible problems on the painted surface.

INTERPRETATION OF THE RESULTS

8. Do you process the data in any way (for example, by statistical analysis)? 55% response

Responses include

- Using the figures for surface temperature alongside measurements of ambient temperature and humidity to calculate the relative humidity at the surface.
- Calculating the ambient dew point temperature and the absolute humidity for comparison.
- Calculating average values for data presentation only.

Several respondents statistically analyse the data.

9. How do you present the data ? 73% response

50% IN TABLE FORM

88% IN GRAPH FORM

63% IN SUMMARY FORM (THAT IS, DESCRIPTIVELY)

38% OTHER

Responses include

- Plotting isotherms onto maps of the surface.
- Factorial diagrams.
- 'Calendars' showing the likelihood of dew point temperature being reached for each measurement station.

10. In the presentation of the data, do you directly correlate it with: 73% response

100% THERMOHYGROMETRIC PARAMETERS:

100% RELATIVE HUMIDITY

100% AMBIENT TEMPERATURE

100% DEW POINT TEMPERATURE

100% ABSOLUTE HUMIDITY

50% OTHER

One respondent also makes comparisons with the moisture content of the plaster, another considers micro air currents across the surface., and a third monitors salt activity.

75% THE CONDITION OF THE PAINTING

Responses include:

- Recording colour alteration and other deterioration of the painted surface.
- Comparing the results to the hygroscopicity of the plaster and the moisture content of the wall.
- Mapping the surface temperature onto condition surveys of the surface.
- Comparing to pollutant deposition and patterns of decay.
- Comparing the activity of salts and of visible micro-organisms.

25% OTHER FACTORS

Responses include:

- Correlating the results to loss of materials such as stone or wood supports.
- Relating the results to the efficiency of transport and deposition of pollutants.

APPENDIX 2

Experimental Equipment and Apparatus

The scope of the contact temperature measurement experiment was to a large extent set by the capacities of the **datalogger** used, a Grant Squirrel adjusted by Eltek to be able to record the input from seven jack sockets (used for single measurement probes such as temperature sensors) and one co-axial socket (used for dual measurement probes such as Vaisala RH and Ambient T probes). It was therefore possible to design a configuration consisting of three pairs of surface temperature sensors (one of each pair attached to a smooth surface, the other to a rough), a catheter temperature probe inserted into a hole drilled parallel to the plaster surface to give some idea of interstitial temperature variation, and a relative humidity/ temperature probe to record ambient conditions. This configuration allowed the comparison of three different attachment methods.

Similarly, the ambient cycles chosen for testing were to a large extent decided by the capabilities of the **climate chamber** used (specifically to its 2°C dew point temperature limitation). The Angelantoni 110 litre chamber is able to cycle between temperatures of -30 to 100°C and humidities from 5 to 95% (although in practice one can take it to 100% for brief periods). These ranges are curtailed however by a 2°C dew point limit; the equipment will not drop temperature to below this. In addition, the method of setting the relative humidity – via wet and dry bulb temperatures – means that holding a steady humidity whilst varying temperature is almost impossible. The speed at which the chamber can operate depends of course on the exact beginning and end points of a cycle, but in general it can attain at least 2°C per minute (cooling is of course slightly slower than heating). The humidity can be cycled across its entire range in about 15 minutes.

Each final combination of temperature and relative humidity was cycled five times, in order to decrease the statistical error in the interpretation. In every case the cycles revealed repeating patterns, giving confidence in the methodology of the experiments. By recording the run-up to the desired starting temperatures and humidities, it was also possible to gain a general idea of the dynamics of the system.

Similar tests can be envisaged to investigate other facets of surface temperature sensor attachment, such as shielding from radiant energy (not a factor in this particular experiment, since no lighting was used in the chamber).

Equipment Details

Climate Chamber

Angelantoni UY 110, 110 litre climate chamber [See PLATE 22].

T -30 - 100°C
RH 10 - 98%
Test range 5 - 95°C
2°C dewpoint limitation

Angelantoni Centro-Sud spa
I-06056 Massa Martana
Perugia
Italy

Datalogger

Grant Squirrel 8-bit datalogger SQ32-8U/4L, rebuilt to specifications by Eltek

8 jack sockets
4 co-axial sockets as alternative to 4 of the jack sockets
Recording interval 1*s* to 99*min*
Capacity 40000 bytes

Eltek Ltd
35 Barton Road
Haslingfield
Cambridgeshire CB3 7LL
UK

Sensors and Probes

<u>RH+T Sensor</u>

Vaisala Capacitative Humidity Probe VH-L

Humidity Sensor
Plastic capacitor inside a ptfe membrane filter
Voltage output
Range 0 - 100% RH in T range -40 -80°C
Error AT = 20°C 0-80% error <2%RH
80-100% error<3%RH
T coeff of RH circuits is <0.05%RH for each 1°C T difference from 20°C

Vaisala OY
PL 26
SF-00421 Helsinki
Finland

Temperature sensor

Type U thermistor

Range -50 to 150°C

Resistance of 2000Ω at 25°C

Tolerance (ie maximum deviation from standard for any individual instrument; in reality typically half this)

0 - 70°C ±0.2°C

Stability Note that manufacturers pre-cycle sensors to ensure stability

±0.02°C over 8 years at 25°C

Effect of Cable resistance

Temperature	Error per metre of cable
0°C	0.0004°C
25°C	0.0013°C
50°C	0.0050°C

Betatherm Corporation
910 Turnpike Road
Shrewsbury MA 01545
USA

Information supplied by

Grant Instruments (Cambridge) Ltd
Barrington
Cambridge CB2 5QZ
UK

Eltek Ltd
35 Barton Road
Haslingfield
Cambridgeshire CB3 7LL
UK

__Humidity Sensor Calibration__

Vaisala Humidity Calibrator HMK-11

Calibration using two saturated salt solutions: LiCl for low humidity (~11.3%), NaCl for high humidity (~76%). The ambient temperature monitored before and during calibration to ensure that this never fell below 19°C (below this temperature the nature of the LiCl solution alters permanently).

Vaisala OY
PL 26
SF-00421 Helsinki
Finland

Grant Instruments (Cambridge) Ltd
Barrington
Cambridge CB2 5QZ
UK

<u>Surface Temperature Sensors</u>

Grant Type EU probes, with sensor element Type U Mini-thermistors

Note that the sensors used were of two different batches (with, for example, different thicknesses of wire); to limit the error from this source the probes were paired, with the first and second attachment methods (gauze band-aid and B72 glue) using the newer probes with the finer wires and the last method - synthetic clay - using the older two probes.

Thermistor

See RH+T Sensor

Probe

Epoxy-coated copper, with sensor on back of disc
No response time given

Information supplied by Grant Instruments

Eltek Ltd
35 Barton Road
Haslingfield
Cambridgeshire CB3 7LL
UK

<u>Catheter Temperature Probe</u>

Grant Type FF, with Type U mini thermistor

Thermistor

See RH+T Sensor

Probe

Sensor at end of flexible nylon tubing, tip covered with epoxy coating
Response time 0.8seconds

Information supplied by Grant Instruments

Eltek Ltd
35 Barton Road
Haslingfield
Cambridgeshire CB3 7LL
UK

Other similar probes and sensors available *include those by Campbell Scientific Ltd*

Type 107 Thermistor Probe
Range -40 to +60°C
Accuracy ±0.4°C in range -33 to +48°C
Typical Accuracy ±0.2°C

Type 108 Thermistor Probe
Range -3 to +90°C
Accuracy ±0.4°C in range -3 to +90°C
Typical Accuracy ±0.2°C

Campbell Scientific Ltd
14-20 Field Street
Shepshed
Leicestershire LE12 9AL
UK

Thermistors are also used in ambient RH + T instruments by

Ancom Signatrol (UK) Ltd
Accuracy ±0.2°C over range 0-100°C

Skye Instruments Ltd
Accuracy ±0.2°C over range 0-60°C

Model Surface

Dimensions

Overall	42 × 37 × 15 *cm* + rubber feet and handles
Stone Base	26 × 31 × 5 *cm*
Surface	25 × 30 *cm*; 2 of 25 × 15 *cm* each
Foam	5 *cm* thick (double thickness at bottom)

Materials

Stone Base
York stone

Hydraulic Grout
Mixed by volume
1 part slaked lime putty : 1 part Tilcon sand (washed, sieved through 40 mesh)
Mixed together then combined with
1 part LeFarge hydraulic lime (sieved through 100 mesh)

Plaster (arriccio)
Aged for 5 years

Plaster (intonaco)
Mixed by volume
Rough
1 part slaked lime putty : 2 parts Morland sand (washed, sieved 20 mesh)
Smooth
2 parts slaked lime putty : 5 parts Morland sand (washed, sieved 60 mesh)
Aged for 6 months

Paint

Calcium Hydroxide ground with yellow ochre, applied very thinly
Aged for 6 months

Insulation

Styropor® expandable polystyrene (Registered Trademark of BASF Aktiengesellschaft)
Formed into heavy-grade insulating board of density 35-60 $^{kg}/_{m^3}$

Thermal Conductivity

Measured value at 10°C 0.036-0.038 $\frac{W}{mK}$, depending on the density of the board:

Density ($^{kg}/_{m^3}$)	Average temperature within the material (°C)		
	0	10	50
25	0.031	0.034	0.038
30-40	0.031	0.033	0.037

Specific Heat Capacity

1210 $\frac{J}{kgK}$

Water Absorption (% by volume)

0.5 -1.5% after 7 days, 1.0-3.0% after 28days

BASF PLC Plastics Division
P O Box 4
Earl Road
Cheadle Hulme
Cheadle
Cheshire SK8 6QG
UK

Frame

9*mm* thick Medium Density Fibreboard

Spray Adhesive

Bison Spray Adhesive
Composition unknown

Perfecta Chemie BV
P O Box 160
4460AD Goes
Netherlands

Sensor Attachment Materials

Acrylic Resin

The aim was to choose a soluble resin with a high 'tack' and fast set; probes are heavy and need to be fastened to the surface rapidly. A more viscous solution would also tend to remain on the surface, rather than being strongly infused into the porous substrate, and thus perhaps be more readily removed. Paraloid B72 was mixed to very high concentration in acetone using the method published by Koob [1986] (dissolve in twice the necessary amount of acetone, then evaporate the excess solvent from the mixture). Acetone was selected as the solvent despite the apparent sensitivity of polystyrene towards it because

- B72 forms a more tractable material at high concentrations in acetone than in, say, toluene, so that it is relatively easy to work with;
- B72 retains acetone for the shortest period (toluene, for example, may still be evaporating after 3-4 weeks);
- Mixtures of solvents tend to have longer setting times.

In practice it was found that the presence of the resin appears to inhibit the corrosive action of the solvent on the polystyrene.

Paraloid B-72® acrylic resin from Rohm and Haas (UK) Ltd

P(EMA/MA 70/30) ≡ Poly(ethyl methacrylate/methacrylate) co-polymer

Tg = 40°C

Bulk Density

at 25°C 0.96 $^{kg}/_{m^3}$

Mixed by weight

1 part B72:1 part Acetone(87.5% w/v)

Rohm and Haas (UK) Ltd
Lennig House
2 Mason's Avenue
Croydon CR9 3NB
UK

Synthetic Clay

Blu-Tack

Permanently plastic adhesive clay with synthetic polymer base
Approximate specific gravity 1.8
Info Sheet No.B746/3 supplied by Bostik Ltd

Bostik Ltd
Ulvercroft Road
Leicester LE4 6BW
UK

Gauze

Absorbent Cotton Gauze Type 13 Light BP Sterile
Boots First Aid Products

The Boots Company PLC
Nottingham
UK

Japanese Tissue

Zecchi 508 (17*g per m*^{2}) Japanese tissue for restoration

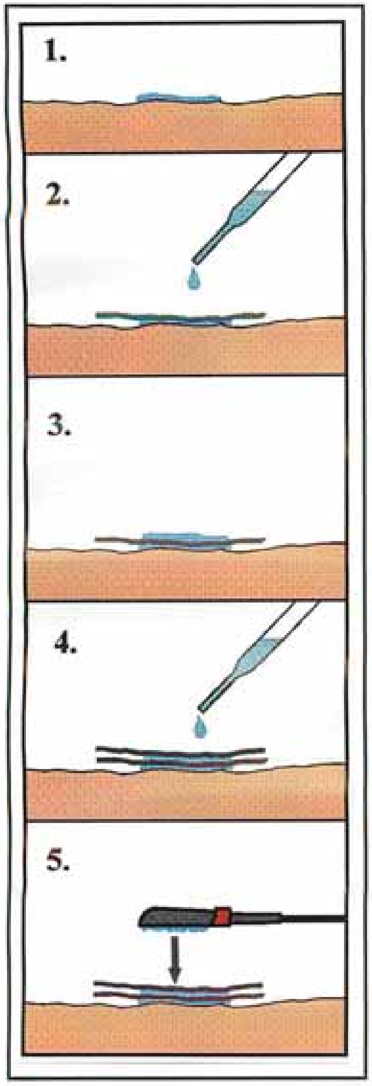
Zecchi
via dello Studio 19R
I-50122 Firenze
Italy

Sensor Attachment Methods

The methodologies chosen for attaching the probes were decided on the basis of tests on a vertical surface of the same materials as the model. Choice was largely based on the possibility of removal without damage to probe or surface.

Paraloid B72

Of greatest concern was the direct attachment method, since the adhesive between the probe and the wall is then virtually inaccessible (especially since it was feared that an effective solvent would be likely to attack the resin coating on the sensor). It was found possible to 'wick' the solvent into place by using a Japanese tissue intervention layer; a second such layer allows the detachment of the probe to be divided into two stages, the first the removal of the probe along with the outermost piece of tissue, and the second the careful removal of the remaining tissue from the probe itself. In order to do this, the conservator should use an eyedropper - or a similar tool - to saturate the tissue with acetone for at least five minutes, or until the glue loosens and the probe comes away from the surface with the tissue. On no account should any force be used, as the paint surface is then in great danger of being strappoed.



B72 acrylic resin in 87.5% solution with acetone applied to an area of surface somewhat larger than the probe.

$3cm^2$ piece of heavy Japanese tissue pressed onto acrylic resin, then a small amount of acetone added to surface to ensure a good bond between the tissue and the glue.

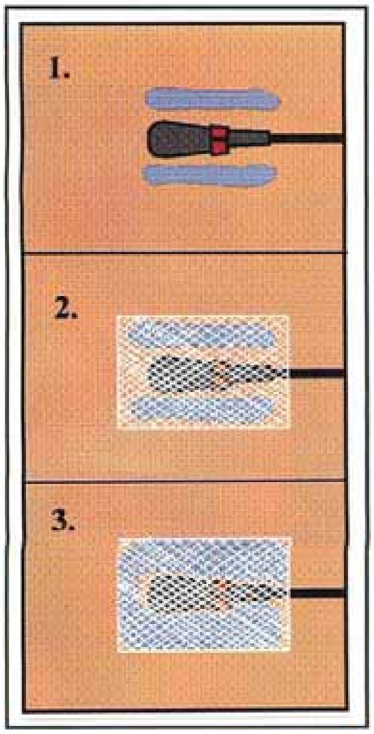
More B72 acrylic resin in 87.5% solution applied to the surface of the Japanese tissue.

A second piece of Japanese tissue is pressed on top and again close adhesion is ensured with a small amount of acetone.

B72 acrylic resin in 87.5% solution with acetone is applied to the surface of the sensor, which is then carefully pressed into position on the upper layer of Japanese tissue.

Gauze 'Band-Aid'

The method of attaching contact probes with a bandage of gauze tends to introduce a great deal of acrylic resin into the surface, and is therefore particularly unsuitable for application onto a paint layer. Care must be taken to ensure that the sensor does not twist away from the surface; the bandage must be applied tightly and the lead secured nearby. Removal is by repeated soaking with acetone, until the bond between gauze and surface is broken. There is a danger of strappoing the surface as the gauze is being pulled away.



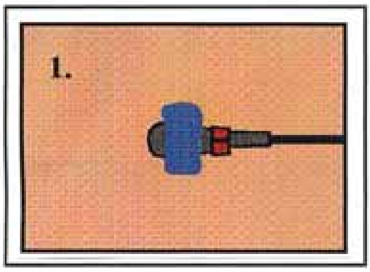
B72 acrylic resin in 87.5% solution with acetone applied to the wall on either side of the probe position.

Double layer of cotton gauze, cut into $2.5 \times 4cm$ strips, fitted tightly over probe and held in place by B72.

B72 acrylic resin in 10% solution with acetone brushed over to secure the gauze as close to the probe as possible.

Synthetic Clay

Clays, whether synthetic or natural, tend to degrade over time, becoming much less adhesive. In addition, synthetic materials tend to give off some of their solvents and plasticisers, leaving indelible greasy spots on the surface.



Blu-tack synthetic clay was weighed out into one $2g$ piece for each attachment; each piece was kneaded and shaped as nearly as possible to the same dimensions (about $2cm \times 1cm \times 3mm$) and gently pressed over the probe and onto the plaster surface on either side.

Infra-Red Experiment

Pyrometer

Minolta/Land Cyclops 300AF [see PLATE 22]

Autofocus portable infra-red radiation thermometer (≡ pyrometer)

Operational range -50 to 1000°C

Focusing range 500*mm* to infinity

8° field of view, 1° measurement area

Target diameter 9*mm* at 500*mm*

Spectral Response 8 - 13 μm

Emissivity adjustment 0.10-1.00 (in 0.01 gradations)

Response time 0.5*s*

Accuracy

Ambient T = 18-28°C, ε = 1.0

Target T = 0-200°C

Error = ±2°C

Target T < 0

Error = ±3°C

Repeatability

Target T = 30 - 100°C

Repeatability = ±0.5°C

Land IR
Dronfield
Sheffield S18 6DJ
UK

Fixed IR Measurement

This system was not tested, but does represent the type of equipment one would use for on-site continual monitoring of surface temperature.

System 3 General purpose (longer wavelength) GP(L) radiation thermometer GP30A *[see PLATE 23]*

Operating T range 10-50°C

Spectral Response 8 - 11.5μm

Response Time ~1s

Accuracy

± (1°C + 0.25% of reading)

Repeatability

± (0.15% of reading)

Output in Volts

Sighting is available as an optional extra - a single unit would be sufficient for any number of sensors, since it would be used only during configuration of the system

Land Infrared
Dronfield
Sheffield S18 6DJ
UK

Analysis

Squirrel Programmes SQLOTUS and SQTRANS for DOS

Used for downloading data from the logger onto a PC-compatible computer; stored as data file in ASCII which can then be converted into a spreadsheet-readable file.

Grant Instruments (Cambridge) Ltd
Barrington
Cambridge CB2 5QZ
UK

Microsoft Excel for Windows v.2.0
Microsoft Excel for Macintosh v4.00

Used to convert the spreadsheet-readable file from SQTRANS into a true spreadsheet; this can be used for calculation (for example to determine the values for absolute humidity and dew-point temperature from the data for relative humidity and ambient temperature), statistical comparisons (such as correlation between sets of data) and simple graphing.

Microsoft Corporation
1 Microsoft Way
Redmond Washington 98052-6399
USA

DeltaGraph for Windows v.1.0
DeltaGraph for Macintosh v2.0.2

Used for complex graphing and statistical analysis, and for formatting presentation-quality graphs such as those used in the text.

DeltaPoint, Inc.
2 Harris Court, Suite B-1
Monterey California 93940
USA

APPENDIX 3

Tables of Results Obtained

ATTACHMENT: Low Temperature

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
9:11:00	19.28	19.28	19.76	19.76	18.80	19.52	19.52	19.52	73.00
9:11:15	19.28	19.52	19.76	19.76	18.80	19.52	19.52	19.52	61.50
9:11:30	19.28	19.28	19.52	19.76	18.80	19.52	19.52	19.52	62.50
9:11:45	19.28	19.28	19.52	19.76	18.80	19.52	19.52	19.52	65.50
9:12:00	19.28	19.28	19.52	19.76	19.04	19.28	19.28	19.52	76.00
9:12:15	19.28	19.28	19.28	19.76	19.04	19.28	19.28	19.52	76.00
9:12:30	19.28	19.28	19.28	19.52	18.80	19.28	19.28	19.52	72.00
9:12:45	19.28	19.28	19.28	19.52	18.80	19.28	19.28	19.28	67.00
9:13:00	19.28	19.04	19.28	19.28	18.80	19.28	19.04	19.28	62.50
9:13:15	19.28	18.80	19.04	19.28	18.56	19.04	18.80	19.28	59.00
9:13:30	19.28	18.80	18.80	19.04	18.32	18.80	18.80	19.04	56.00
9:13:45	19.28	18.56	18.56	19.04	18.08	18.80	18.56	18.80	53.00
9:14:00	19.28	18.32	18.56	18.80	17.84	18.56	18.32	18.80	51.00
9:14:15	19.28	18.08	18.32	18.56	17.84	18.32	18.32	18.56	48.50
9:14:30	19.28	18.08	18.08	18.56	17.60	18.32	18.08	18.56	46.50
9:14:45	19.28	17.84	17.84	18.32	17.12	18.08	17.84	18.32	44.50
9:15:00	19.28	17.84	17.84	18.08	16.88	17.84	17.84	18.32	43.00
9:15:15	19.28	17.60	17.84	18.08	16.40	17.84	17.84	18.32	42.00
9:15:30	19.04	17.36	17.60	17.84	16.16	17.84	17.60	18.08	41.00
9:15:45	19.04	17.12	17.60	17.84	15.92	17.60	17.36	18.08	40.50
9:16:00	19.04	17.12	17.36	17.84	15.44	17.36	17.12	17.84	40.00
9:16:15	19.04	16.88	17.12	17.84	15.20	17.36	17.12	17.84	39.50
9:16:30	19.04	16.64	17.12	17.60	14.96	17.12	16.88	17.84	39.50
9:16:45	19.04	16.40	16.88	17.36	14.48	16.88	16.64	17.84	39.50
9:17:00	19.04	16.16	16.64	17.36	14.48	16.88	16.64	17.84	39.00
9:17:15	19.04	16.16	16.40	17.12	14.00	16.64	16.40	17.60	39.00
9:17:30	18.80	16.16	16.40	17.12	13.76	16.40	16.40	17.60	39.00
9:17:45	18.80	15.92	16.16	16.88	13.28	16.40	16.16	17.60	39.00
9:18:00	18.80	15.68	16.16	16.88	13.04	16.16	16.16	17.36	39.50
9:18:15	18.80	15.44	16.16	16.64	12.80	16.16	16.16	17.36	39.50
9:18:30	18.80	15.44	15.92	16.64	12.56	16.16	15.92	17.36	39.50
9:18:45	18.80	15.20	15.92	16.40	12.32	15.92	15.92	17.12	39.50
9:19:00	18.80	14.96	15.68	16.40	12.08	15.92	15.68	17.12	39.50
9:19:15	18.56	14.96	15.68	16.16	11.84	15.68	15.68	17.12	39.50
9:19:30	18.56	14.72	15.44	16.16	11.60	15.68	15.44	16.88	40.00
9:19:45	18.56	14.48	15.20	16.16	11.12	15.44	15.44	16.88	40.00
9:20:00	18.56	14.48	15.20	16.16	10.88	15.20	15.20	16.88	40.00
9:20:15	18.56	14.48	14.96	15.92	10.64	15.20	15.20	16.64	40.00
9:20:30	18.56	14.24	14.96	15.92	10.40	15.20	14.96	16.64	40.50
9:20:45	18.32	14.24	14.72	15.68	10.40	14.96	14.96	16.40	40.50
9:21:00	18.32	14.00	14.72	15.68	10.16	14.96	14.96	16.40	40.50
9:21:15	18.32	13.76	14.48	15.44	9.92	14.72	14.72	16.40	41.00
9:21:30	18.32	13.76	14.48	15.44	9.68	14.72	14.48	16.40	41.00
9:21:45	18.32	13.52	14.48	15.20	9.44	14.48	14.48	16.16	41.00
9:22:00	18.32	13.52	14.48	15.20	9.20	14.48	14.48	16.16	41.00
9:22:15	18.32	13.28	14.24	15.20	9.20	14.48	14.48	16.16	41.50
9:22:30	18.08	13.04	14.24	14.96	8.96	14.48	14.48	16.16	41.50
9:22:45	18.08	13.04	14.00	14.96	8.72	14.24	14.24	16.16	41.50
9:23:00	18.08	12.80	14.00	14.72	8.48	14.24	14.24	16.16	41.50
9:23:15	18.08	12.80	13.76	14.72	8.24	14.00	14.00	15.92	42.00
9:23:30	18.08	12.56	13.76	14.48	8.24	14.00	14.00	15.92	42.00
9:23:45	18.08	12.56	13.52	14.48	8.00	13.76	13.76	15.92	42.00
9:24:00	17.84	12.56	13.52	14.48	7.76	13.76	13.76	15.92	42.00
9:24:15	17.84	12.56	13.52	14.48	7.76	13.52	13.52	15.68	42.00
9:24:30	17.84	12.32	13.28	14.48	7.76	13.52	13.52	15.68	42.50
9:24:45	17.84	12.08	13.28	14.24	7.52	13.28	13.52	15.68	42.50
9:25:00	17.84	12.08	13.04	14.24	7.28	13.28	13.52	15.44	42.50
9:25:15	17.84	12.08	13.04	14.24	7.28	13.28	13.28	15.44	42.50
9:25:30	17.84	11.84	12.80	14.00	7.04	13.04	13.28	15.44	42.50
9:25:45	17.84	11.84	12.80	14.00	6.80	13.04	13.04	15.44	42.50
9:26:00	17.84	11.60	12.56	13.76	6.80	12.80	13.04	15.20	42.50
9:26:15	17.84	11.60	12.56	13.76	6.56	12.80	13.04	15.20	42.50
9:26:30	17.84	11.36	12.56	13.76	6.32	12.80	12.80	15.20	42.50
9:26:45	17.84	11.36	12.56	13.52	6.32	12.56	12.80	14.96	42.00
9:27:00	17.84	11.12	12.56	13.52	6.08	12.56	12.80	14.96	42.50
9:27:15	17.84	11.12	12.56	13.52	6.08	12.56	12.56	14.96	44.50
9:27:30	17.60	11.12	12.32	13.28	5.84	12.56	12.56	14.96	46.50
9:27:45	17.60	10.88	12.32	13.28	5.84	12.56	12.56	14.96	50.00
9:28:00	17.60	10.88	12.32	13.28	5.60	12.56	12.56	14.96	53.00
9:28:15	17.60	10.88	12.32	13.28	5.60	12.56	12.56	14.96	54.00
9:28:30	17.60	10.64	12.08	13.28	5.60	12.56	12.56	14.72	58.00
9:28:45	17.60	10.64	12.08	13.04	5.60	12.56	12.56	14.72	58.00
9:29:00	17.60	10.64	12.08	13.04	5.36	12.32	12.56	14.72	62.00
9:29:15	17.60	10.64	12.08	13.04	5.36	12.32	12.56	14.72	60.50
9:29:30	17.36	10.64	12.08	13.04	5.36	12.32	12.56	14.72	63.50
9:29:45	17.36	10.40	12.08	13.04	5.36	12.32	12.56	14.72	62.00
9:30:00	17.36	10.40	11.84	12.80	5.36	12.32	12.56	14.72	65.00
9:30:15	17.36	10.40	11.84	12.80	5.36	12.08	12.56	14.48	63.00
9:30:30	17.36	10.40	11.84	12.80	5.36	12.08	12.56	14.48	65.50
9:30:45	17.36	10.40	11.84	12.80	5.12	12.08	12.56	14.48	64.00
9:31:00	17.36	10.40	11.84	12.80	5.12	12.08	12.56	14.48	66.00

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
9:31:15	17.36	10.40	11.84	12.80	5.12	12.08	12.32	14.48	65.00
9:31:30	17.36	10.40	11.60	12.56	5.12	12.08	12.32	14.48	66.50
9:31:45	17.36	10.40	11.60	12.56	5.12	12.08	12.32	14.48	66.50
9:32:00	17.12	10.40	11.60	12.56	5.12	11.84	12.32	14.48	66.50
9:32:15	17.12	10.40	11.60	12.56	5.12	11.84	12.32	14.48	68.50
9:32:30	17.12	10.16	11.60	12.56	5.12	11.84	12.32	14.48	65.50
9:32:45	17.12	10.16	11.60	12.56	5.12	11.84	12.32	14.48	68.00
9:33:00	17.12	10.16	11.60	12.56	5.12	11.84	12.32	14.48	70.00
9:33:15	17.12	10.16	11.36	12.56	4.88	11.84	12.08	14.48	65.00
9:33:30	17.12	10.16	11.36	12.56	4.88	11.84	12.08	14.48	60.50
9:33:45	17.12	9.92	11.36	12.56	4.88	11.60	12.08	14.24	56.50
9:34:00	17.12	9.92	11.12	12.32	4.88	11.60	11.84	14.24	53.50
9:34:15	17.12	9.92	11.12	12.32	4.88	11.60	11.84	14.24	51.50
9:34:30	16.88	9.68	11.12	12.32	4.64	11.60	11.84	14.24	50.00
9:34:45	16.88	9.68	11.12	12.32	4.64	11.60	11.84	14.00	49.00
9:35:00	16.88	9.68	11.12	12.08	4.64	11.36	11.84	14.00	48.00
9:35:15	16.88	9.68	10.88	12.08	4.64	11.36	11.84	14.00	47.50
9:35:30	16.88	9.68	10.88	12.08	4.40	11.36	11.60	14.00	47.00
9:35:45	16.88	9.68	10.88	12.08	4.40	11.36	11.84	14.00	46.50
9:36:00	16.88	9.44	10.88	12.08	4.40	11.36	11.60	14.00	46.50
9:36:15	16.88	9.44	10.88	12.08	4.40	11.36	11.60	14.00	45.00
9:36:30	16.64	9.44	10.88	12.08	4.40	11.36	11.60	14.00	45.00
9:36:45	16.64	9.44	10.88	12.08	4.40	11.36	11.60	14.00	46.00
9:37:00	16.64	9.44	10.88	12.08	4.40	11.12	11.60	14.00	48.00
9:37:15	16.64	9.44	10.88	12.08	4.40	11.12	11.60	14.00	49.50
9:37:30	16.64	9.44	10.88	12.08	4.40	11.12	11.60	14.00	50.50
9:37:45	16.64	9.44	10.88	12.08	4.40	11.12	11.60	13.76	53.00
9:38:00	16.64	9.44	10.88	12.08	4.40	11.12	11.60	14.00	60.50
9:38:15	16.64	9.44	10.88	12.08	4.40	11.12	11.60	14.00	64.00
9:38:30	16.40	9.44	10.88	12.08	4.64	11.36	11.84	14.00	63.50
9:38:45	16.40	9.44	10.88	12.08	4.64	11.12	11.84	14.00	66.50
9:39:00	16.40	9.44	10.88	12.08	4.64	11.12	11.84	14.00	66.00
9:39:15	16.40	9.44	10.88	12.08	4.64	11.36	11.84	14.00	69.00
9:39:30	16.40	9.44	10.88	12.08	4.64	11.12	11.60	14.00	70.50
9:39:45	16.40	9.44	10.88	12.08	4.64	11.12	11.60	14.00	71.50
9:40:00	16.40	9.44	10.88	12.08	4.64	11.12	11.84	13.76	72.00
9:40:15	16.40	9.44	10.64	11.84	4.88	11.12	11.60	13.76	72.50
9:40:30	16.40	9.44	10.64	11.84	4.88	11.12	11.60	13.76	73.00
9:40:45	16.40	9.44	10.64	11.84	4.88	11.12	11.60	13.76	73.50
9:41:00	16.40	9.44	10.64	11.84	4.88	11.12	11.60	13.76	74.00
9:41:15	16.40	9.44	10.64	11.84	4.88	11.12	11.60	13.76	74.50
9:41:30	16.16	9.44	10.64	11.84	4.64	11.12	11.60	13.76	74.00
9:41:45	16.16	9.44	10.64	11.84	4.64	11.12	11.60	13.76	69.50
9:42:00	16.16	9.20	10.40	11.60	4.64	11.12	11.36	13.52	65.00
9:42:15	16.16	9.20	10.40	11.60	4.64	11.12	11.36	13.52	60.50
9:42:30	16.16	9.20	10.40	11.60	4.64	10.88	11.36	13.52	57.50
9:42:45	16.16	9.20	10.40	11.60	4.40	10.88	11.36	13.52	55.50
9:43:00	16.16	9.20	10.40	11.60	4.40	10.88	11.36	13.28	54.00
9:43:15	16.16	9.20	10.40	11.36	4.40	10.88	11.36	13.28	52.50
9:43:30	16.16	8.96	10.40	11.36	4.40	10.88	11.36	13.28	51.50
9:43:45	16.16	8.96	10.40	11.36	4.40	10.88	11.12	13.28	50.50
9:44:00	16.16	8.96	10.40	11.36	4.40	10.88	11.12	13.28	49.50
9:44:15	16.16	8.96	10.40	11.36	4.40	10.88	11.12	13.28	51.50
9:44:30	16.16	8.96	10.40	11.60	4.40	10.88	11.12	13.52	79.00
9:44:45	16.16	8.96	10.40	11.60	4.40	10.88	11.12	13.52	87.00
9:45:00	16.16	8.96	10.40	11.60	4.64	10.64	11.12	13.52	90.00
9:45:15	16.16	8.96	10.40	11.60	4.64	10.64	11.12	13.52	91.50
9:45:30	16.16	8.96	10.40	11.60	4.88	10.64	10.88	13.52	92.50
9:45:45	16.16	8.96	10.40	11.60	4.88	10.64	10.88	13.52	93.00
9:46:00	16.16	8.96	10.40	11.60	5.12	10.64	10.88	13.52	94.00
9:46:15	16.16	8.96	10.40	11.36	5.12	10.64	10.88	13.28	94.50
9:46:30	16.16	8.96	10.40	11.36	5.12	10.64	10.88	13.28	94.50
9:46:45	16.16	8.96	10.40	11.36	5.12	10.64	10.88	13.28	94.50
9:47:00	16.16	8.96	10.40	11.36	5.12	10.40	11.12	13.04	94.50
9:47:15	16.16	8.96	10.40	11.12	5.12	10.64	11.12	13.04	94.00
9:47:30	15.92	8.96	10.40	11.12	4.88	10.64	11.12	13.04	93.00
9:47:45	15.92	8.96	10.40	11.12	4.88	10.64	11.12	13.04	92.50
9:48:00	15.92	8.96	10.40	11.12	4.64	10.64	11.12	13.04	90.50
9:48:15	15.92	8.72	10.40	11.12	4.40	10.64	11.12	13.04	89.00
9:48:30	15.92	8.96	10.40	11.12	4.40	10.64	11.12	12.80	87.00
9:48:45	15.92	8.72	10.40	11.12	4.16	10.64	11.12	12.80	84.50
9:49:00	15.92	8.72	10.40	11.12	4.16	10.64	11.12	12.80	82.00
9:49:15	15.92	8.72	10.40	11.12	4.16	10.64	10.88	12.80	80.00
9:49:30	15.92	8.72	10.16	11.12	4.16	10.64	10.88	12.80	78.50
9:49:45	15.92	8.72	10.16	11.12	4.16	10.64	10.88	12.80	77.00
9:50:00	15.92	8.72	10.16	10.88	4.16	10.40	10.88	12.80	76.00
9:50:15	15.92	8.72	10.16	10.88	4.16	10.40	10.88	12.80	75.00
9:50:30	15.68	8.72	10.16	10.88	4.16	10.40	10.88	12.80	74.00
9:50:45	15.68	8.72	10.16	10.88	4.16	10.40	10.88	12.80	73.50
9:51:00	15.68	8.72	10.16	10.88	4.16	10.40	10.88	12.80	72.00
9:51:15	15.68	8.72	10.16	10.88	4.16	10.40	10.88	12.80	71.50

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
9:51:30	15.68	8.72	10.16	10.88	4.16	10.40	10.88	12.80	71.00
9:51:45	15.68	8.72	10.16	10.88	4.16	10.40	10.88	12.80	70.00
9:52:00	15.68	8.72	10.16	10.88	4.16	10.40	10.64	12.80	69.50
9:52:15	15.68	8.48	10.16	10.88	4.16	10.40	10.64	12.80	68.50
9:52:30	15.68	8.48	10.16	10.88	4.16	10.40	10.64	12.80	68.00
9:52:45	15.68	8.48	9.92	10.88	4.16	10.40	10.64	12.56	67.00
9:53:00	15.44	8.48	9.92	10.88	4.16	10.40	10.64	12.56	66.50
9:53:15	15.44	8.48	9.92	10.88	4.16	10.40	10.64	12.56	65.50
9:53:30	15.44	8.48	9.92	10.88	4.16	10.40	10.64	12.56	74.00
9:53:45	15.44	8.48	9.92	10.88	4.16	10.40	10.64	12.80	87.00
9:54:00	15.44	8.48	9.92	10.88	4.40	10.40	10.64	12.80	90.50
9:54:15	15.44	8.48	9.68	10.88	4.40	10.40	10.40	12.80	92.00
9:54:30	15.44	8.48	9.68	10.88	4.40	10.40	10.40	12.80	93.00
9:54:45	15.44	8.48	9.68	10.88	4.64	10.40	10.40	12.80	93.50
9:55:00	15.44	8.48	9.68	10.88	4.64	10.40	10.40	12.56	94.00
9:55:15	15.44	8.48	9.68	10.64	4.64	10.16	10.40	12.56	94.50
9:55:30	15.44	8.48	9.68	10.64	4.88	10.16	10.40	12.56	94.50
9:55:45	15.44	8.48	9.68	10.64	4.88	10.16	10.40	12.56	95.00
9:56:00	15.20	8.48	9.68	10.64	4.88	10.16	10.40	12.56	95.00
9:56:15	15.20	8.48	9.68	10.64	4.88	10.16	10.40	12.56	95.00
9:56:30	15.20	8.48	9.68	10.40	4.88	10.16	10.40	12.56	94.50
9:56:45	15.20	8.24	9.68	10.40	4.64	10.16	10.40	12.32	94.50
9:57:00	15.20	8.24	9.68	10.40	4.64	10.16	10.40	12.32	93.50
9:57:15	15.20	8.24	9.68	10.40	4.40	10.16	10.40	12.32	93.00
9:57:30	15.20	8.24	9.68	10.40	4.16	10.16	10.40	12.32	92.00
9:57:45	15.20	8.24	9.68	10.40	4.16	10.16	10.40	12.32	91.00
9:58:00	15.20	8.24	9.68	10.40	3.92	10.16	10.40	12.32	89.50
9:58:15	15.20	8.24	9.68	10.40	3.92	10.16	10.40	12.32	87.50
9:58:30	15.20	8.24	9.68	10.40	3.92	10.16	10.40	12.32	86.00
9:58:45	15.20	8.24	9.68	10.40	3.92	10.16	10.40	12.32	83.50
9:59:00	15.20	8.24	9.68	10.40	3.92	10.40	10.40	12.32	82.00
9:59:15	14.96	8.24	9.68	10.40	3.92	10.40	10.40	12.32	80.50
9:59:30	14.96	8.24	9.68	10.40	3.92	10.16	10.40	12.32	79.00
9:59:45	14.96	8.24	9.68	10.40	3.92	10.40	10.40	12.32	78.50
10:00:00	14.96	8.24	9.68	10.40	3.92	10.16	10.40	12.32	77.00
10:00:15	14.96	8.24	9.68	10.40	3.92	10.16	10.40	12.32	76.00
10:00:30	14.96	8.24	9.68	10.40	3.92	10.16	10.40	12.32	75.00
10:00:45	14.96	8.24	9.68	10.40	3.92	10.16	10.40	12.32	74.50
10:01:00	14.96	8.24	9.44	10.40	3.92	10.16	10.40	12.32	74.00
10:01:15	14.96	8.24	9.44	10.40	3.92	10.16	10.40	12.32	73.00
10:01:30	14.96	8.24	9.44	10.40	3.92	10.16	10.40	12.32	72.50
10:01:45	14.96	8.24	9.44	10.40	3.92	10.16	10.40	12.32	72.50
10:02:00	14.96	8.24	9.44	10.40	4.16	10.16	10.40	12.56	86.50
10:02:15	14.96	8.24	9.44	10.40	4.16	10.16	10.40	12.56	91.00
10:02:30	14.72	8.24	9.44	10.40	4.40	10.16	10.40	12.56	92.50
10:02:45	14.72	8.00	9.44	10.40	4.40	9.92	10.40	12.56	93.00
10:03:00	14.72	8.00	9.44	10.40	4.40	9.92	10.16	12.32	94.00
10:03:15	14.72	8.00	9.44	10.40	4.64	9.92	10.16	12.32	94.50
10:03:30	14.72	8.24	9.44	10.40	4.64	9.92	10.16	12.32	95.00
10:03:45	14.72	8.24	9.44	10.40	4.88	9.92	10.16	12.32	95.00
10:04:00	14.72	8.24	9.44	10.40	4.88	9.92	10.16	12.32	95.50
10:04:15	14.72	8.24	9.44	10.40	4.88	9.92	10.16	12.08	95.50
10:04:30	14.72	8.24	9.44	10.40	5.12	9.92	10.16	12.08	95.50
10:04:45	14.72	8.24	9.44	10.40	5.12	9.92	10.16	12.08	96.00
10:05:00	14.72	8.24	9.44	10.40	5.12	9.92	10.40	12.08	96.00
10:05:15	14.72	8.48	9.68	10.40	5.36	10.16	10.64	12.32	96.00
10:05:30	14.72	8.72	10.16	10.64	5.36	10.40	10.88	12.32	96.00
10:05:45	14.72	8.96	10.40	10.64	5.36	10.40	11.36	12.56	96.00
10:06:00	14.72	9.20	10.88	11.12	5.60	10.88	12.08	12.56	96.50

ATTACHMENT: Medium Temperature

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
0:00:00	14.96	12.32	13.76	14.24	10.40	14.00	14.96	15.20	97.50
0:00:15	15.20	12.56	14.00	14.48	10.40	14.24	14.96	15.44	97.50
0:00:30	15.20	12.56	14.00	14.48	10.64	14.24	15.20	15.44	97.50
0:00:45	15.20	12.56	13.52	14.24	10.64	14.24	14.72	15.20	97.00
0:01:00	15.20	12.08	12.80	14.00	10.40	13.76	14.00	14.72	96.00
0:01:15	15.20	11.84	12.56	13.52	9.92	13.52	13.52	14.48	95.00
0:01:30	15.20	11.60	12.56	13.28	9.44	13.28	13.28	14.48	92.50
0:01:45	15.20	11.84	12.56	13.28	9.44	13.28	13.28	14.48	89.50
0:02:00	15.20	11.84	12.56	13.28	9.44	13.28	13.52	14.48	87.50
0:02:15	15.20	12.08	12.80	13.28	9.92	13.28	13.52	14.48	85.50
0:02:30	15.20	12.08	12.80	13.28	10.16	13.28	13.52	14.48	83.50
0:02:45	15.20	12.32	12.80	13.28	10.40	13.52	13.76	14.48	82.00
0:03:00	15.20	12.32	13.04	13.28	10.64	13.52	13.76	14.48	80.50
0:03:15	15.20	12.32	13.04	13.52	10.88	13.52	13.76	14.48	79.50
0:03:30	15.20	12.56	13.04	13.52	11.12	13.52	13.76	14.48	78.50
0:03:45	15.20	12.56	13.04	13.52	11.36	13.52	13.76	14.48	77.50
0:04:00	15.20	12.56	13.28	13.52	11.36	13.52	13.76	14.48	76.50
0:04:15	15.20	12.56	13.28	13.52	11.60	13.76	14.00	14.48	75.00
0:04:30	15.20	12.56	13.28	13.52	11.60	13.76	13.76	14.48	74.50
0:04:45	15.20	12.56	13.28	13.52	11.84	13.76	14.00	14.48	73.50
0:05:00	15.20	12.56	13.28	13.52	11.84	13.76	14.00	14.48	73.00
0:05:15	15.20	12.56	13.28	13.76	12.08	13.76	14.00	14.48	72.00
0:05:30	15.20	12.56	13.28	13.76	12.08	13.76	14.00	14.48	71.50
0:05:45	15.20	12.80	13.28	13.76	12.08	13.76	14.00	14.48	70.50
0:06:00	15.20	12.80	13.52	13.76	12.32	13.76	14.00	14.48	70.00
0:06:15	15.20	12.80	13.52	13.76	12.32	13.76	14.00	14.48	69.50
0:06:30	15.20	12.80	13.52	13.76	12.32	14.00	14.00	14.48	69.00
0:06:45	15.20	12.80	13.52	13.76	12.32	14.00	14.00	14.48	75.50
0:07:00	15.20	13.04	13.52	14.00	12.56	14.00	14.24	14.48	87.00
0:07:15	15.20	13.28	13.76	14.24	12.56	14.24	14.24	14.48	92.50
0:07:30	15.20	13.28	14.00	14.48	12.80	14.24	14.48	14.72	95.00
0:07:45	15.20	13.52	14.00	14.48	13.04	14.48	14.48	14.72	96.00
0:08:00	15.20	13.76	14.24	14.48	13.28	14.48	14.48	14.96	96.50
0:08:15	15.20	13.76	14.24	14.48	13.52	14.48	14.48	14.96	97.00
0:08:30	15.20	14.00	14.24	14.48	13.76	14.48	14.48	14.96	97.00
0:08:45	15.20	13.76	14.24	14.48	13.76	14.48	14.48	14.96	97.00
0:09:00	15.20	13.76	14.24	14.48	13.76	14.48	14.48	14.96	97.00
0:09:15	15.20	13.52	14.24	14.48	13.52	14.48	14.48	14.72	96.00
0:09:30	15.20	13.52	14.00	14.48	13.28	14.48	14.48	14.72	94.00
0:09:45	15.20	13.52	14.00	14.24	13.04	14.48	14.48	14.48	90.00
0:10:00	15.20	13.52	14.00	14.24	13.04	14.48	14.48	14.48	87.00
0:10:15	15.20	13.52	14.00	14.24	13.04	14.24	14.48	14.48	85.00
0:10:30	15.20	13.52	14.00	14.24	13.04	14.24	14.48	14.48	82.50
0:10:45	15.20	13.52	14.00	14.00	12.80	14.24	14.48	14.48	80.50
0:11:00	15.20	13.52	14.00	14.00	12.80	14.24	14.48	14.48	78.50
0:11:15	15.20	13.52	14.00	14.00	12.80	14.24	14.48	14.48	76.50
0:11:30	15.20	13.52	14.00	14.00	12.80	14.24	14.48	14.48	75.00
0:11:45	15.20	13.52	14.00	14.00	12.80	14.24	14.48	14.48	73.50
0:12:00	15.20	13.52	14.00	14.00	12.80	14.48	14.48	14.48	72.00
0:12:15	15.20	13.52	14.00	14.00	12.80	14.24	14.24	14.48	71.00
0:12:30	15.20	13.52	14.00	14.00	12.80	14.24	14.48	14.48	70.00
0:12:45	15.20	13.52	14.00	14.00	12.80	14.24	14.24	14.48	69.00
0:13:00	15.20	13.52	14.00	14.00	12.80	14.24	14.24	14.48	68.00
0:13:15	15.20	13.52	14.00	14.00	12.80	14.24	14.24	14.48	67.00
0:13:30	15.20	13.52	14.00	14.00	12.80	14.24	14.48	14.48	66.00
0:13:45	15.20	13.52	14.00	14.00	12.80	14.24	14.24	14.48	65.50
0:14:00	15.20	13.52	14.00	14.24	12.80	14.48	14.24	14.48	65.00
0:14:15	15.20	13.52	14.00	14.00	12.80	14.24	14.48	14.48	64.50
0:14:30	15.20	13.76	14.00	14.24	12.80	14.48	14.48	14.48	64.00
0:14:45	15.20	13.76	14.00	14.24	13.04	14.24	14.48	14.48	78.50
0:15:00	15.20	13.76	14.24	14.48	13.04	14.48	14.48	14.48	88.50
0:15:15	15.20	14.00	14.24	14.48	13.28	14.48	14.48	14.72	93.00
0:15:30	15.20	14.00	14.48	14.48	13.52	14.48	14.48	14.96	94.50
0:15:45	15.20	14.00	14.48	14.72	13.52	14.48	14.48	14.96	95.50
0:16:00	15.20	14.24	14.48	14.72	13.76	14.48	14.72	14.96	96.00
0:16:15	15.20	14.24	14.48	14.72	14.00	14.72	14.72	14.96	96.50
0:16:30	15.20	14.48	14.48	14.72	14.24	14.72	14.72	14.96	97.00
0:16:45	15.20	14.24	14.48	14.72	14.24	14.72	14.72	14.96	97.00
0:17:00	15.20	14.24	14.48	14.72	14.24	14.72	14.72	14.96	96.50
0:17:15	15.20	14.00	14.48	14.48	14.00	14.48	14.48	14.96	96.00
0:17:30	15.20	14.00	14.48	14.48	13.76	14.48	14.48	14.72	94.00
0:17:45	15.20	14.00	14.48	14.48	13.52	14.48	14.48	14.72	91.00
0:18:00	15.20	14.00	14.48	14.48	13.28	14.48	14.48	14.48	87.50
0:18:15	15.20	13.76	14.24	14.48	13.28	14.48	14.48	14.48	84.00
0:18:30	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	80.50
0:18:45	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	78.00
0:19:00	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	75.00
0:19:15	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	73.00
0:19:30	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	71.00
0:19:45	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	69.00
0:20:00	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	67.00

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
0:20:15	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	66.00
0:20:30	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	65.00
0:20:45	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	64.00
0:21:00	15.20	13.76	14.24	14.24	13.04	14.48	14.48	14.48	65.50
0:21:15	15.20	13.76	14.24	14.48	13.04	14.48	14.48	14.48	84.00
0:21:30	15.20	14.00	14.48	14.48	13.28	14.48	14.48	14.72	91.00
0:21:45	15.20	14.24	14.48	14.48	13.52	14.48	14.48	14.96	94.50
0:22:00	15.20	14.24	14.48	14.72	13.76	14.48	14.72	14.96	95.50
0:22:15	15.20	14.48	14.48	14.72	13.76	14.72	14.72	14.96	96.00
0:22:30	15.20	14.48	14.48	14.96	14.00	14.72	14.72	15.20	96.50
0:22:45	15.20	14.48	14.72	14.96	14.24	14.72	14.96	15.20	97.00
0:23:00	15.20	14.48	14.72	14.96	14.24	14.72	14.96	14.96	97.00
0:23:15	15.20	14.48	14.48	14.72	14.24	14.72	14.72	14.96	96.50
0:23:30	15.20	14.24	14.48	14.72	14.00	14.72	14.72	14.96	95.50
0:23:45	15.20	14.24	14.48	14.48	13.76	14.48	14.48	14.72	93.00
0:24:00	15.20	14.00	14.48	14.48	13.76	14.48	14.48	14.72	88.00
0:24:15	15.20	14.00	14.48	14.48	13.52	14.48	14.48	14.48	84.00
0:24:30	15.20	14.00	14.48	14.48	13.28	14.48	14.48	14.48	80.00
0:24:45	15.20	14.00	14.48	14.48	13.28	14.48	14.48	14.48	76.50
0:25:00	15.20	14.00	14.48	14.24	13.28	14.48	14.48	14.48	73.50
0:25:15	15.20	14.00	14.24	14.24	13.28	14.48	14.48	14.48	71.00
0:25:30	15.20	14.00	14.24	14.24	13.04	14.48	14.48	14.48	68.50
0:25:45	15.20	14.00	14.24	14.24	13.04	14.48	14.48	14.48	66.00
0:26:00	15.20	14.00	14.24	14.24	13.04	14.48	14.48	14.48	65.00
0:26:15	15.20	14.00	14.24	14.24	13.04	14.48	14.48	14.48	63.50
0:26:30	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	62.50
0:26:45	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	61.50
0:27:00	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	60.50
0:27:15	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	60.00
0:27:30	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	59.50
0:27:45	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	65.00
0:28:00	14.96	14.00	14.24	14.48	13.04	14.48	14.48	14.48	83.50
0:28:15	14.96	14.00	14.24	14.48	13.28	14.48	14.48	14.72	91.00
0:28:30	14.96	14.24	14.48	14.72	13.52	14.48	14.48	14.96	94.00
0:28:45	14.96	14.24	14.48	14.72	13.76	14.48	14.48	14.96	95.50
0:29:00	14.96	14.24	14.48	14.72	13.76	14.48	14.72	14.96	96.00
0:29:15	14.96	14.48	14.48	14.96	14.00	14.72	14.72	14.96	96.50
0:29:30	14.96	14.48	14.48	14.96	14.24	14.72	14.72	14.96	97.00
0:29:45	14.96	14.48	14.48	14.96	14.24	14.72	14.72	14.96	97.00
0:30:00	15.20	14.48	14.48	14.72	14.24	14.72	14.72	14.96	96.50
0:30:15	15.20	14.24	14.48	14.72	14.00	14.48	14.72	14.96	96.00
0:30:30	15.20	14.00	14.48	14.48	14.00	14.48	14.48	14.72	94.00
0:30:45	15.20	14.00	14.48	14.48	13.76	14.48	14.48	14.72	90.00
0:31:00	15.20	14.00	14.48	14.48	13.52	14.48	14.48	14.48	85.50
0:31:15	14.96	14.00	14.48	14.48	13.28	14.48	14.48	14.48	81.00
0:31:30	15.20	14.00	14.48	14.48	13.28	14.48	14.48	14.48	77.50
0:31:45	14.96	14.00	14.24	14.24	13.28	14.48	14.48	14.48	74.50
0:32:00	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	71.50
0:32:15	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	68.00
0:32:30	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	65.50
0:32:45	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	64.00
0:33:00	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	62.50
0:33:15	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	61.00
0:33:30	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	60.00
0:33:45	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	59.00
0:34:00	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	58.50
0:34:15	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	58.00
0:34:30	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	57.00
0:34:45	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	57.00
0:35:00	14.96	14.00	14.24	14.24	13.04	14.48	14.48	14.48	63.50
0:35:15	14.96	14.00	14.24	14.48	13.28	14.48	14.48	14.48	83.50
0:35:30	14.96	14.00	14.48	14.48	13.28	14.48	14.48	14.72	91.00
0:35:45	14.96	14.24	14.48	14.72	13.52	14.48	14.48	14.96	94.00
0:36:00	14.96	14.24	14.48	14.72	13.76	14.48	14.72	14.96	95.50
0:36:15	14.96	14.48	14.48	14.96	14.00	14.72	14.72	14.96	96.00
0:36:30	14.96	14.48	14.72	14.96	14.24	14.72	14.96	15.20	96.50
0:36:45	14.96	14.48	14.72	14.96	14.48	14.72	14.96	15.20	97.00
0:37:00	14.96	14.48	14.72	14.96	14.48	14.72	14.96	15.20	97.00
0:37:15	14.96	14.48	14.96	14.96	14.48	14.96	15.20	15.20	96.00

ATTACHMENT: High Temperature

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH	Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
0:00:00	15.20	15.44	15.92	16.16	15.68	15.92	16.16	15.92	68.00	0:20:15	16.88	22.88	22.40	21.44	26.72	21.92	22.16	20.24	94.00
0:00:15	15.20	15.44	15.92	16.16	15.92	15.92	16.16	15.92	69.00	0:20:30	17.12	23.60	22.64	21.92	27.20	22.40	22.64	20.48	97.00
0:00:30	15.20	15.44	15.68	16.16	16.16	15.92	15.92	15.92	81.00	0:20:45	17.12	24.08	23.12	22.16	27.44	22.64	22.88	20.72	97.50
0:00:45	15.20	15.20	15.68	15.92	16.16	15.68	15.92	15.92	84.50	0:21:00	17.12	24.08	22.88	21.92	27.20	22.88	22.64	20.72	94.00
0:01:00	15.20	15.20	15.44	15.92	16.16	15.68	15.68	15.92	84.50	0:21:15	17.36	23.60	22.64	21.92	27.20	22.64	22.40	20.48	87.50
0:01:15	15.20	15.20	15.44	15.92	16.16	15.68	15.68	15.92	84.50	0:21:30	17.36	23.36	22.40	21.68	27.20	22.64	22.16	20.48	82.50
0:01:30	15.20	15.20	15.68	15.92	15.92	15.68	15.92	15.92	86.50	0:21:45	17.36	22.88	22.16	21.44	27.20	22.40	21.68	20.24	78.50
0:01:45	15.20	15.44	15.92	15.92	16.16	15.92	16.16	15.92	87.50	0:22:00	17.36	22.64	21.92	21.44	27.20	21.92	21.44	20.00	73.00
0:02:00	15.20	15.68	16.16	16.16	16.16	16.16	16.16	15.92	87.00	0:22:15	17.60	22.64	21.68	21.20	27.20	21.68	21.20	20.00	68.50
0:02:15	15.20	16.16	16.16	16.16	16.40	16.16	16.40	16.16	84.50	0:22:30	17.60	22.64	21.68	21.20	27.20	21.44	20.96	19.76	64.50
0:02:30	15.44	16.16	16.64	16.16	16.88	16.40	16.88	16.16	81.50	0:22:45	17.60	22.64	21.92	20.96	27.20	21.20	21.20	19.52	60.50
0:02:45	15.44	16.64	16.88	16.40	17.36	16.64	17.12	16.16	78.50	0:23:00	17.60	22.64	21.92	20.96	27.20	21.20	21.20	19.52	56.50
0:03:00	15.44	17.12	17.36	16.64	17.84	17.12	17.60	16.16	75.50	0:23:15	17.60	22.64	21.92	20.96	27.20	21.20	20.96	19.28	53.00
0:03:15	15.44	17.36	17.60	16.88	18.32	17.36	17.84	16.40	73.00	0:23:30	17.60	22.64	21.92	20.96	27.20	21.20	21.20	19.28	50.00
0:03:30	15.44	17.84	17.84	17.12	19.04	17.60	17.84	16.40	70.50	0:23:45	17.60	22.64	21.92	20.96	27.20	21.20	21.20	19.28	47.50
0:03:45	15.44	17.84	17.84	17.12	19.52	17.84	18.08	16.64	67.50	0:24:00	17.60	22.64	21.92	20.96	27.20	21.44	21.20	19.28	46.00
0:04:00	15.44	18.08	18.08	17.36	20.24	17.84	18.32	16.64	65.00	0:24:15	17.60	22.64	21.92	20.96	27.20	21.44	21.20	19.28	44.50
0:04:15	15.44	18.32	18.08	17.60	20.72	17.84	18.32	16.88	63.00	0:24:30	17.60	22.64	21.92	20.96	27.20	21.44	21.20	19.28	43.50
0:04:30	15.44	18.56	18.32	17.60	20.96	18.08	18.56	16.88	61.00	0:24:45	17.60	22.64	21.92	20.96	27.20	21.44	21.20	19.28	42.50
0:04:45	15.68	18.56	18.32	17.84	21.44	18.32	18.56	17.12	59.00	0:25:00	17.60	22.88	21.92	20.96	27.20	21.44	21.20	19.28	41.50
0:05:00	15.68	18.80	18.56	17.84	21.92	18.32	18.80	17.12	57.50	0:25:15	17.60	22.88	21.92	20.96	27.20	21.68	21.20	19.28	40.50
0:05:15	15.68	19.04	18.56	17.84	22.40	18.56	18.80	17.12	56.00	0:25:30	17.60	22.88	21.92	20.96	27.20	21.68	21.44	19.28	39.50
0:05:30	15.68	19.04	18.80	17.84	22.64	18.80	19.04	17.36	55.00	0:25:45	17.60	22.88	21.92	20.96	27.20	21.68	21.44	19.28	38.50
0:05:45	15.68	19.28	18.80	17.84	22.64	18.80	19.04	17.36	55.50	0:26:00	17.60	22.88	21.92	20.96	27.20	21.68	21.44	19.28	38.00
0:06:00	15.68	19.28	19.04	18.08	23.12	18.80	19.28	17.36	56.50	0:26:15	17.60	22.88	22.16	20.96	27.20	21.68	21.44	19.28	38.00
0:06:15	15.92	19.28	19.04	18.32	23.36	19.04	19.28	17.60	59.00	0:26:30	17.60	22.88	22.16	20.96	27.20	21.68	21.44	19.28	37.50
0:06:30	15.92	19.52	19.28	18.32	23.60	19.04	19.28	17.84	63.50	0:26:45	17.60	22.88	22.16	20.96	27.20	21.68	21.44	19.28	37.50
0:06:45	15.92	19.76	19.28	18.56	23.84	19.28	19.28	17.84	74.50	0:27:00	17.60	22.88	22.16	20.96	27.20	21.68	21.44	19.28	50.00
0:07:00	15.92	20.00	19.28	19.04	24.32	19.28	19.52	18.08	88.50	0:27:15	17.60	22.88	22.16	21.44	27.20	21.68	21.68	19.76	70.50
0:07:15	15.92	20.48	20.00	19.28	24.32	19.76	20.00	18.32	94.50	0:27:30	17.60	23.12	22.40	21.92	27.44	21.92	21.92	20.24	84.00
0:07:30	15.92	20.96	20.48	19.52	24.56	20.24	20.72	18.80	97.00	0:27:45	17.60	23.60	22.64	22.16	27.68	22.40	22.64	20.72	92.50
0:07:45	16.16	21.20	20.96	19.76	25.04	20.72	20.96	19.04	98.00	0:28:00	17.60	24.08	23.36	22.64	27.92	22.64	22.88	20.96	96.50
0:08:00	16.16	21.92	21.20	20.24	25.28	20.96	21.44	19.28	98.50	0:28:15	17.84	24.32	24.08	22.64	28.16	23.36	23.60	21.20	98.00
0:08:15	16.16	22.40	21.68	20.48	25.76	21.44	21.92	19.28	99.00	0:28:30	17.84	25.04	24.32	22.88	28.16	24.08	24.32	21.44	99.00
0:08:30	16.16	22.64	21.68	20.72	26.00	21.68	21.92	19.52	99.00	0:28:45	17.84	25.52	24.56	23.12	28.64	24.32	24.32	21.68	99.00
0:08:45	16.16	22.64	21.44	20.48	25.76	21.68	21.68	19.52	99.00	0:29:00	17.84	25.52	24.56	23.12	28.40	24.32	24.32	21.68	99.00
0:09:00	16.16	22.40	21.44	20.48	25.52	21.68	21.44	19.28	98.00	0:29:15	17.84	25.28	24.32	23.12	28.16	24.32	24.08	21.68	98.00
0:09:15	16.40	22.16	21.20	20.48	25.52	21.44	21.20	19.28	95.00	0:29:30	17.84	25.04	23.84	22.88	28.16	24.08	23.60	21.44	93.00
0:09:30	16.40	21.92	20.96	20.24	25.52	21.20	20.96	19.28	91.50	0:29:45	18.08	24.56	23.60	22.64	28.16	23.84	23.12	21.44	87.50
0:09:45	16.40	21.68	20.96	20.24	25.52	21.20	20.96	19.28	87.00	0:30:00	18.08	24.32	23.12	22.64	27.92	23.60	22.88	21.20	84.00
0:10:00	16.40	21.44	20.96	20.00	25.52	20.96	20.72	19.28	83.00	0:30:15	18.08	24.08	22.88	22.40	27.92	23.12	22.64	20.96	79.50
0:10:15	16.64	21.20	20.72	20.00	25.76	20.96	20.48	19.04	80.00	0:30:30	18.08	23.60	22.64	22.16	27.92	22.64	22.40	20.96	75.00
0:10:30	16.64	21.20	20.72	19.76	25.76	20.72	20.24	19.04	77.50	0:30:45	18.08	23.12	22.64	21.92	27.68	22.64	21.92	20.72	70.50
0:10:45	16.64	20.96	20.48	19.76	25.76	20.48	20.24	19.04	75.00	0:31:00	18.08	22.88	22.40	21.92	27.68	22.16	21.68	20.72	66.50
0:11:00	16.64	20.96	20.48	19.76	25.76	20.48	20.00	18.80	72.50	0:31:15	18.32	22.64	22.16	21.68	27.68	21.92	21.20	20.48	62.50
0:11:15	16.64	20.96	20.48	19.76	25.76	20.24	20.00	18.80	70.50	0:31:30	18.32	22.64	22.16	21.68	27.68	21.68	21.20	20.24	58.50
0:11:30	16.64	20.96	20.24	19.76	25.76	20.00	19.76	18.80	68.50	0:31:45	18.32	22.88	22.40	21.68	27.68	21.44	21.20	20.00	54.50
0:11:45	16.64	20.96	20.24	19.76	25.76	20.00	20.00	18.56	66.00	0:32:00	18.08	22.88	22.40	21.44	27.44	21.44	21.44	20.00	52.00
0:12:00	16.64	20.96	20.48	19.76	25.76	20.00	20.00	18.56	64.50	0:32:15	18.08	22.88	22.40	21.44	27.44	21.44	21.44	19.76	49.50
0:12:15	16.64	20.96	20.48	19.76	25.76	20.00	20.00	18.56	63.00	0:32:30	18.08	23.12	22.64	21.44	27.44	21.44	21.44	19.76	47.50
0:12:30	16.64	20.96	20.72	19.76	25.76	20.00	20.24	18.56	61.50	0:32:45	18.08	23.12	22.64	21.44	27.44	21.68	21.44	19.76	45.50
0:12:45	16.64	20.96	20.72	19.76	25.76	20.00	20.24	18.56	60.00	0:33:00	18.08	23.12	22.64	21.44	27.44	21.68	21.68	19.52	43.50
0:13:00	16.64	21.20	20.72	19.76	25.76	20.00	20.24	18.56	58.50	0:33:15	18.08	23.36	22.64	21.44	27.44	21.68	21.68	19.52	42.00
0:13:15	16.64	21.20	20.96	19.76	25.76	20.24	20.24	18.56	57.00	0:33:30	18.08	23.36	22.64	21.20	27.44	21.92	21.68	19.52	40.50
0:13:30	16.64	21.20	20.96	19.76	25.76	20.24	20.24	18.56	55.00	0:33:45	18.08	23.36	22.64	21.44	27.44	21.92	21.68	19.52	39.50
0:13:45	16.64	21.44	20.96	19.76	25.76	20.24	20.24	18.56	53.50	0:34:00	18.08	23.36	22.64	21.44	27.44	21.92	21.68	19.52	39.00
0:14:00	16.64	21.44	20.96	19.76	25.76	20.24	20.24	18.32	52.00	0:34:15	18.08	23.36	22.64	21.44	27.44	21.92	21.68	19.52	38.50
0:14:15	16.64	21.44	20.96	19.76	26.00	20.48	20.48	18.32	50.50	0:34:30	18.08	23.36	22.64	21.44	27.44	21.92	21.68	19.52	38.00
0:14:30	16.64	21.44	20.96	19.76	26.00	20.48	20.48	18.32	49.50	0:34:45	18.08	23.36	22.64	21.44	27.44	22.16	21.68	19.52	37.00
0:14:45	16.64	21.44	20.96	19.76	26.00	20.48	20.48	18.32	48.50	0:35:00	18.08	23.36	22.64	21.44	27.44	22.16	21.68	19.52	36.00
0:15:00	16.64	21.68	20.96	19.76	26.00	20.48	20.48	18.32	47.50	0:35:15	18.08	23.36	22.64	21.44	27.44	22.16	21.92	19.76	35.00
0:15:15	16.64	21.68	20.96	19.76	26.00	20.48	20.48	18.32	47.00	0:35:30	18.08	23.36	22.64	21.44	27.44	22.16	21.92	19.76	34.50
0:15:30	16.64	21.68	20.96	19.76	26.00	20.48	20.48	18.32	46.00	0:35:45	18.08	23.36	22.64	21.44	27.44	22.16	21.92	19.76	33.50
0:15:45	16.64	21.68	20.96	19.76	26.00	20.72	20.48	18.32	45.00	0:36:00	18.08	23.36	22.64	21.44	27.44	22.16	21.92	19.76	34.00
0:16:00	16.64	21.68	20.96	19.76	26.00	20.72	20.48	18.32	44.00	0:36:15	18.08	23.36	22.64	21.68	27.44	22.16	21.92	19.76	47.00
0:16:15	16.64	21.68	20.96	19.76	26.00	20.72	20.48	18.32	43.00	0:36:30	18.08	23.36	22.64	22.16	27.44	22.16	21.92	20.24	68.00
0:16:30	16.64	21.68	20.96	20.00	26.00	20.72	20.48	18.32	42.50	0:36:45	18.08	23.60	22.64	22.40	27.68	22.40	22.16	20.72	81.50
0:16:45	16.64	21.68	20.96	20.00	26.00	20.72	20.48	18.32	41.50	0:37:00	18.08	23.84	23.12	22.64	27.92	22.64	22.64	20.96	91.50
0:17:00	16.64	21.68	20.96	20.00	26.00	20.72	20.48	18.56	41.50	0:37:15	18.08	24.32	23.84	22.88	27.92	23.12	23.36	21.20	96.00
0:17:15	16.64	21.92	20.96	20.00	26.00	20.72	20.48	18.56	41.50	0:37:30	18.08	24.80	24.32	23.12	28.16	23.60	24.08	21.68	98.00
0:17:30	16.88	21.92	20.96	20.00	26.24	20.72	20.48	18.56	41.50	0:37:45	18.08	25.04	24.32	23.36	28.16	24.08	24.08	21.68	98.00
0:17:45	16.88	21.92	20.96	20.00	26.00	20.72	20.48	18.56	41.00	0:38:00	18.32	24.80	24.32	23.36	28.16	24.08	23.84	21.68	94.50
0:18:00	16.88	21.92	20.96	20.00	26.24	20.72	20.72	18.56	41.00	0:38:15	18.32	24.56	23.84	23.12	28.16	23.84	23.36	21.68	87.50
0:18:15	16.88	21.92	20.96	20.24	26.24	20.96	20.72	18.56	40.50	0:38:30	18.32	24.32	23.36	22.88	28.16	23.60	22.88	21.44	82.50
0:18:30	16.88	21.92	20.96	20.24	26.24	20.96	20.72	18.80	40.00	0:38:45	18.56	24.08	22.88	22.64	28.16	23.12	22.64	21.20	76.50
0:18:45	16.88	21.92	20.96	20.24	26.24	20.96	20.72	18.80	39.50	0:39:00	18.56	23.60	22.64	22.64	27.92	22.64	22.16	20.96	71.00
0:19:00	16.88	21.92	20.96	20.24	26.24	20.96	20.72	18.80	39.50	0:39:15	18.56	23.36	22.64	22.40	27.92	22.40	21.92	20.96	65.00
0:19:15	16.88	21.92	20.96	20.24	26.24	20.96	20.72	18.80	45.50	0:39:30	18.56	23.36	22.64	22.16	27.92	22.16	21.68	20.72	59.50
0:19:30	16.88	22.16	21.20	20.48	26.24	20.96	20.96	19.04	66.00	0:39:45	18.56	23.36	22.64	22.16	27.68	22.16	21.92	20.72	54.50
0:19:45	16.88	22.40	21.44	20.96	26.24	20.96	20.96	19.28	78.50	0:40:00	18.56	23.36	22.64	21.92	27.68	21.92	21.92	20.48	50.00
0:20:00	16.88	22.64	21.68	21.20	26.48	21.44	21.44	19.76	87.50	0:40:15	18.56	23.36	22.64	21.92	27.68	22.16	21.92	20.24	46.50

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
0:40:30	18.56	23.60	22.64	21.68	27.68	22.16	22.16	20.24	44.00
0:40:45	18.56	23.60	22.64	21.68	27.68	22.16	22.16	20.24	42.00
0:41:00	18.56	23.60	22.64	21.68	27.68	22.16	22.16	20.00	40.50
0:41:15	18.56	23.60	22.64	21.68	27.68	22.16	22.16	20.00	39.00
0:41:30	18.56	23.60	22.64	21.68	27.68	22.16	22.16	20.00	37.50
0:41:45	18.56	23.60	22.64	21.68	27.44	22.40	22.16	20.00	36.00
0:42:00	18.32	23.60	22.64	21.68	27.44	22.40	22.16	20.00	35.50
0:42:15	18.32	23.60	22.64	21.68	27.68	22.40	22.16	20.00	34.50
0:42:30	18.56	23.60	22.64	21.68	27.44	22.40	22.16	20.00	34.50
0:42:45	18.32	23.60	22.64	21.92	27.44	22.40	22.16	20.00	34.00
0:43:00	18.32	23.60	22.64	21.92	27.44	22.40	22.16	20.00	34.00
0:43:15	18.32	23.60	22.64	21.92	27.44	22.40	22.16	20.24	33.50
0:43:30	18.32	23.60	22.64	21.92	27.68	22.40	22.16	20.24	33.00
0:43:45	18.32	23.60	22.64	21.92	27.68	22.40	22.16	20.24	32.00
0:44:00	18.56	23.60	22.64	21.92	27.68	22.40	22.16	20.24	31.50
0:44:15	18.56	23.60	22.64	21.92	27.68	22.40	22.16	20.24	30.50
0:44:30	18.56	23.60	22.64	21.92	27.68	22.40	22.16	20.24	30.00
0:44:45	18.56	23.60	22.64	21.92	27.68	22.40	22.16	20.24	29.50
0:45:00	18.56	23.60	22.64	21.92	27.68	22.40	22.16	20.24	29.00
0:45:15	18.56	23.60	22.64	21.92	27.68	22.40	22.16	20.24	28.50
0:45:30	18.56	23.60	22.64	21.92	27.68	22.40	22.16	20.48	28.50
0:45:45	18.56	23.60	22.64	22.16	27.68	22.40	22.40	20.48	44.50
0:46:00	18.56	23.84	22.88	22.64	27.68	22.64	22.40	20.96	65.50
0:46:15	18.56	23.84	22.88	22.64	27.68	22.64	22.64	21.20	80.00
0:46:30	18.56	24.32	23.36	23.12	27.92	22.64	22.88	21.44	89.50
0:46:45	18.56	24.32	24.08	23.36	28.16	23.36	23.60	21.92	95.50
0:47:00	18.56	25.04	24.32	23.84	28.16	23.84	24.32	22.16	98.00
0:47:15	18.80	25.52	24.80	24.08	28.40	24.32	24.56	22.40	98.50
0:47:30	18.80	25.28	24.08	23.60	28.16	24.32	23.60	21.92	93.50

ATTACHMENT: Low Humidity

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
0:00:00	20.96	21.20	21.44	21.44	22.40	21.20	21.20	21.20	43.50
0:00:15	20.96	21.20	21.44	21.44	22.16	21.20	21.20	21.20	44.00
0:00:30	20.96	21.20	21.44	21.44	22.16	21.20	21.20	21.20	46.50
0:00:45	20.96	21.20	21.44	21.44	22.16	21.20	21.20	21.20	48.00
0:01:00	20.96	21.20	21.44	21.44	22.16	21.20	21.20	21.20	48.00
0:01:15	20.96	21.20	21.44	21.68	22.16	21.20	21.44	21.20	49.00
0:01:30	20.96	21.44	21.68	21.68	22.16	21.44	21.44	21.20	46.00
0:01:45	20.96	21.44	21.68	21.68	22.16	21.44	21.68	21.20	36.50
0:02:00	20.96	21.68	21.92	21.68	22.40	21.68	21.68	21.20	27.50
0:02:15	20.96	21.68	21.68	21.44	22.40	21.68	21.68	21.20	21.00
0:02:30	20.96	21.68	21.92	21.44	22.64	21.68	21.68	20.96	17.00
0:02:45	20.96	21.68	21.92	21.44	22.64	21.68	21.68	20.96	14.00
0:03:00	20.96	21.92	21.92	21.68	22.64	21.68	21.92	21.20	11.50
0:03:15	20.96	21.92	21.92	21.68	22.64	21.68	21.68	21.20	21.00
0:03:30	20.96	21.92	21.92	21.68	22.88	21.68	21.68	21.20	21.00
0:03:45	20.96	21.92	21.92	21.68	22.88	21.68	21.92	21.20	19.50
0:04:00	20.96	21.92	21.92	21.68	23.12	21.92	21.92	21.44	16.50
0:04:15	20.96	22.16	22.16	21.92	23.12	21.92	21.92	21.44	16.00
0:04:30	20.96	22.16	22.40	21.92	23.36	21.92	22.16	21.44	19.00
0:04:45	20.96	22.40	22.64	22.16	23.60	22.16	22.40	21.68	24.50
0:05:00	20.96	22.64	22.64	22.64	24.08	22.64	22.64	21.92	31.50
0:05:15	20.96	23.12	23.12	22.64	24.32	22.64	23.12	22.40	38.50
0:05:30	21.20	23.60	23.60	23.12	24.80	22.88	23.36	22.64	44.00
0:05:45	21.20	23.84	23.84	23.12	25.52	23.36	23.60	22.64	40.00
0:06:00	21.20	24.08	24.08	23.36	26.00	23.60	23.84	22.64	32.00
0:06:15	21.20	24.32	24.08	23.36	26.24	23.60	24.08	22.64	25.00
0:06:30	21.20	24.32	24.32	23.36	26.96	23.84	24.08	22.64	19.00
0:06:45	21.20	24.32	24.32	23.36	27.20	24.08	24.08	22.64	15.00
0:07:00	21.44	24.56	24.32	23.60	27.68	24.08	24.32	22.64	13.50
0:07:15	21.44	24.80	24.32	23.60	28.16	24.32	24.32	22.64	16.00
0:07:30	21.44	24.80	24.32	23.84	28.16	24.32	24.32	22.64	16.00
0:07:45	21.44	24.80	24.32	23.84	28.40	24.32	24.32	22.64	13.00
0:08:00	21.44	24.80	24.32	23.60	28.64	24.32	24.08	22.64	11.00
0:08:15	21.44	24.80	24.32	23.60	28.64	24.32	24.08	22.64	9.00
0:08:30	21.44	24.56	24.08	23.60	28.64	24.08	23.84	22.64	7.50
0:08:45	21.44	24.32	23.84	23.36	28.40	23.84	23.60	22.64	6.00
0:09:00	21.44	24.32	23.84	23.12	28.16	23.84	23.36	22.64	5.00
0:09:15	21.44	24.32	23.60	23.12	28.16	23.60	23.12	22.40	5.50
0:09:30	21.44	24.08	23.36	22.88	27.68	23.36	22.88	22.40	9.50
0:09:45	21.44	23.84	23.36	22.88	27.20	23.36	22.88	22.40	14.00
0:10:00	21.44	23.84	23.36	23.12	26.96	23.12	22.88	22.40	20.00
0:10:15	21.44	23.84	23.36	23.12	26.72	23.12	22.88	22.64	25.50
0:10:30	21.44	23.84	23.36	23.12	26.48	23.12	22.88	22.64	25.50
0:10:45	21.44	23.84	23.36	23.12	26.24	23.12	22.88	22.64	21.00
0:11:00	21.44	23.60	23.12	22.88	26.24	23.12	22.88	22.40	17.00
0:11:15	21.68	23.60	23.12	22.88	26.00	23.12	22.88	22.40	13.00
0:11:30	21.68	23.60	23.12	22.64	25.76	22.88	22.64	22.16	10.00
0:11:45	21.68	23.36	22.88	22.64	25.52	22.88	22.64	22.16	9.00
0:12:00	21.44	23.36	22.88	22.64	25.52	22.88	22.64	22.16	11.00
0:12:15	21.44	23.36	23.12	22.64	25.28	22.88	22.64	22.16	16.00
0:12:30	21.44	23.60	23.12	22.88	25.28	22.88	22.88	22.40	21.00
0:12:45	21.44	23.84	23.60	23.12	25.28	23.12	23.12	22.64	27.00
0:13:00	21.44	24.08	24.08	23.36	25.52	23.36	23.60	22.64	32.50
0:13:15	21.44	24.32	24.32	23.84	25.76	23.84	24.08	22.88	37.00
0:13:30	21.68	24.56	24.32	24.08	26.24	24.08	24.32	23.12	40.50
0:13:45	21.68	24.80	24.56	24.08	26.72	24.32	24.32	23.12	35.00
0:14:00	21.68	25.04	24.80	24.32	27.20	24.32	24.32	23.12	28.00
0:14:15	21.68	25.28	24.80	24.32	27.44	24.32	24.56	23.12	22.00
0:14:30	21.68	25.28	25.04	24.32	27.92	24.56	24.56	23.12	17.00
0:14:45	21.68	25.52	25.04	24.32	28.16	24.56	24.56	23.12	13.50
0:15:00	21.68	25.52	24.80	24.32	28.40	24.56	24.32	22.88	10.50
0:15:15	21.68	25.28	24.80	24.08	28.40	24.56	24.32	22.88	8.50
0:15:30	21.92	25.28	24.56	24.08	28.64	24.32	24.32	22.88	7.00
0:15:45	21.92	25.04	24.32	23.84	28.40	24.32	24.08	22.88	6.00
0:16:00	21.92	24.80	24.32	23.84	28.40	24.32	23.84	22.64	5.50
0:16:15	21.92	24.80	24.32	23.60	28.16	24.08	23.60	22.64	6.00
0:16:30	21.92	24.56	24.08	23.60	27.92	24.08	23.60	22.64	10.00
0:16:45	21.92	24.32	23.84	23.60	27.68	23.84	23.36	22.64	15.00
0:17:00	21.92	24.32	23.84	23.60	27.44	23.84	23.36	22.64	21.00
0:17:15	21.92	24.32	24.08	23.84	27.20	23.84	23.60	22.88	26.50
0:17:30	21.92	24.56	24.32	24.08	26.96	23.84	23.84	23.12	32.00
0:17:45	21.92	24.80	24.56	24.32	26.96	24.08	24.32	23.36	36.50
0:18:00	21.92	25.04	24.80	24.32	27.20	24.32	24.32	23.60	40.50
0:18:15	21.92	25.28	25.04	24.56	27.68	24.56	24.56	23.60	36.50
0:18:30	21.92	25.52	25.28	24.56	27.92	24.56	24.56	23.60	29.00
0:18:45	21.92	25.76	25.28	24.56	28.16	24.80	24.80	23.60	22.50
0:19:00	21.92	26.00	25.52	24.56	28.40	24.80	24.80	23.36	17.00
0:19:15	22.16	26.00	25.28	24.56	28.64	25.04	24.80	23.36	13.00
0:19:30	22.16	26.00	25.28	24.32	28.88	25.04	24.80	23.36	10.50
0:19:45	22.16	25.76	25.04	24.32	28.88	24.80	24.56	23.12	8.50
0:20:00	22.16	25.76	25.04	24.32	28.88	24.80	24.32	23.12	7.00

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
0:20:15	22.16	25.52	24.80	24.32	28.88	24.56	24.32	23.12	6.00
0:20:30	22.16	25.28	24.56	24.32	28.64	24.56	24.32	22.88	5.50
0:20:45	22.16	25.04	24.32	24.08	28.40	24.32	24.08	22.88	6.50
0:21:00	22.16	24.80	24.32	24.08	28.16	24.32	23.84	22.88	11.00
0:21:15	22.16	24.80	24.32	24.08	27.92	24.08	23.60	22.88	16.50
0:21:30	22.16	24.56	24.32	24.08	27.68	24.08	23.60	22.88	22.00
0:21:45	22.16	24.56	24.32	24.08	27.20	24.08	23.84	23.12	27.50
0:22:00	22.16	24.80	24.32	24.32	27.20	24.08	24.08	23.12	33.00
0:22:15	22.16	25.04	24.80	24.32	27.20	24.32	24.32	23.36	37.50
0:22:30	22.16	25.28	25.04	24.56	27.20	24.32	24.56	23.60	41.50
0:22:45	22.16	25.52	25.28	24.80	27.44	24.56	24.80	23.84	38.00
0:23:00	22.16	25.76	25.52	24.80	27.92	24.80	24.80	23.84	30.50
0:23:15	22.16	26.00	25.52	24.80	28.16	25.04	25.04	23.84	23.50
0:23:30	22.16	26.00	25.76	24.80	28.40	25.04	25.04	23.60	18.00
0:23:45	22.16	26.24	25.76	24.80	28.64	25.28	25.04	23.60	14.50
0:24:00	22.40	26.24	25.76	24.80	28.88	25.28	25.28	23.60	13.00
0:24:15	22.16	26.24	25.76	24.80	29.12	25.28	25.04	23.60	10.50
0:24:30	22.40	26.24	25.52	24.80	29.36	25.28	25.04	23.60	9.00
0:24:45	22.40	26.24	25.52	24.56	29.36	25.28	24.80	23.60	8.00
0:25:00	22.40	26.00	25.28	24.56	29.36	25.04	24.80	23.60	6.50
0:25:15	22.40	26.00	25.04	24.56	29.12	25.04	24.56	23.36	5.50
0:25:30	22.40	25.76	24.80	24.32	28.88	24.80	24.32	23.36	5.50
0:25:45	22.40	25.52	24.80	24.32	28.64	24.56	24.32	23.12	7.50
0:26:00	22.40	25.28	24.56	24.32	28.40	24.56	24.32	23.12	12.00
0:26:15	22.40	25.28	24.80	24.32	28.16	24.56	24.32	23.36	17.00
0:26:30	22.40	25.52	25.04	24.56	28.16	24.56	24.32	23.60	23.00
0:26:45	22.40	25.76	25.28	24.80	28.16	24.80	24.80	23.84	29.00
0:27:00	22.40	26.00	25.52	25.04	28.16	25.04	25.04	24.08	34.00
0:27:15	22.40	26.24	25.76	25.28	28.40	25.28	25.28	24.32	38.00
0:27:30	22.40	26.24	26.00	25.28	28.64	25.28	25.28	24.32	35.00
0:27:45	22.40	26.24	26.00	25.28	28.88	25.52	25.52	24.32	28.00
0:28:00	22.40	26.48	26.00	25.28	29.36	25.52	25.52	24.08	21.50
0:28:15	22.40	26.48	26.00	25.04	29.36	25.52	25.28	24.08	16.50
0:28:30	22.64	26.24	25.76	25.04	29.60	25.52	25.28	23.84	12.50
0:28:45	22.64	26.24	25.76	25.04	29.60	25.28	25.04	23.84	10.00
0:29:00	22.64	26.24	25.52	24.80	29.36	25.28	24.80	23.60	8.50
0:29:15	22.64	26.00	25.28	24.56	29.36	25.04	24.56	23.60	7.00
0:29:30	22.64	25.76	25.04	24.32	28.88	24.80	24.32	23.36	6.50
0:29:45	22.64	25.52	24.80	24.32	28.64	24.56	24.32	23.36	8.50
0:30:00	22.64	25.28	24.56	24.32	28.16	24.32	24.08	23.36	13.00
0:30:15	22.64	25.04	24.56	24.32	28.16	24.32	24.08	23.36	18.50
0:30:30	22.64	25.04	24.32	24.32	27.68	24.32	24.08	23.36	24.00
0:30:45	22.40	25.04	24.56	24.32	27.20	24.32	24.08	23.36	28.50
0:31:00	22.40	25.04	24.56	24.32	27.20	24.32	24.32	23.60	33.00
0:31:15	22.40	25.28	25.04	24.56	26.96	24.32	24.32	23.84	37.00
0:31:30	22.64	25.52	25.28	24.80	27.20	24.56	24.80	24.08	41.00
0:31:45	22.64	26.00	25.52	25.04	27.44	25.04	25.04	24.08	40.50
0:32:00	22.64	26.00	25.76	25.04	27.68	25.04	25.04	24.08	33.00
0:32:15	22.64	26.24	25.76	25.04	28.16	25.04	25.04	24.08	29.00

ATTACHMENT: Medium Humidity

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH	Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
0:00:00	22.64	24.08	23.84	23.60	25.52	23.12	22.88	22.64	35.50	0:20:15	21.92	20.48	20.96	21.20	19.28	20.96	20.72	21.20	28.00
0:00:15	22.64	24.08	23.84	23.60	25.28	23.12	22.88	22.64	35.50	0:20:30	21.92	20.48	20.72	20.96	19.04	20.72	20.72	21.20	28.00
0:00:30	22.64	24.08	23.84	23.84	25.04	23.12	22.88	22.64	35.50	0:20:45	21.92	20.24	20.48	20.96	18.80	20.72	20.48	20.96	27.50
0:00:45	22.40	24.32	24.08	23.84	25.04	23.12	23.12	22.88	40.00	0:21:00	21.92	20.00	20.48	20.96	18.56	20.48	20.48	20.96	27.50
0:01:00	22.40	24.32	24.32	24.08	25.04	23.36	23.60	22.88	36.00	0:21:15	21.92	19.76	20.24	20.96	18.08	20.48	20.24	20.96	27.50
0:01:15	22.40	24.32	24.32	24.08	25.04	23.60	23.84	22.88	28.00	0:21:30	21.92	19.76	20.24	20.72	17.84	20.24	20.24	20.96	27.00
0:01:30	22.40	24.32	24.32	23.84	25.04	23.60	23.60	22.88	20.50	0:21:45	21.92	19.52	20.00	20.72	17.84	20.24	20.00	20.96	27.00
0:01:45	22.40	24.32	24.32	23.84	25.28	23.60	23.60	22.64	15.50	0:22:00	21.68	19.52	20.00	20.48	17.60	20.00	20.00	20.96	27.00
0:02:00	22.40	24.32	24.08	23.60	25.28	23.60	23.36	22.64	12.00	0:22:15	21.68	19.28	19.76	20.48	17.36	20.00	19.76	20.96	27.50
0:02:15	22.40	24.08	23.84	23.60	25.04	23.60	23.12	22.64	10.00	0:22:30	21.68	19.28	19.76	20.48	17.12	19.76	19.76	20.72	32.50
0:02:30	22.40	24.08	23.60	23.36	25.04	23.36	23.12	22.64	9.00	0:22:45	21.68	19.28	20.00	20.48	16.88	20.00	20.24	20.96	41.00
0:02:45	22.40	23.84	23.36	23.12	24.80	23.12	22.88	22.64	8.00	0:23:00	21.68	19.52	20.48	20.72	16.88	20.00	20.48	20.96	49.50
0:03:00	22.40	23.60	23.12	23.12	24.56	22.88	22.64	22.64	7.00	0:23:15	21.68	20.00	20.96	20.96	17.36	20.48	20.96	21.20	57.00
0:03:15	22.40	23.36	22.88	22.88	24.32	22.88	22.64	22.40	7.00	0:23:30	21.68	20.48	21.20	21.20	17.84	20.72	21.20	21.44	64.00
0:03:30	22.40	22.88	22.64	22.88	23.84	22.64	22.40	22.40	6.50	0:23:45	21.68	20.96	21.68	21.68	18.08	20.96	21.68	21.68	69.50
0:03:45	22.40	22.88	22.64	22.64	23.60	22.64	22.16	22.16	6.50	0:24:00	21.68	21.20	22.16	22.16	19.04	21.44	22.16	21.92	74.50
0:04:00	22.40	22.64	22.64	22.64	22.88	22.40	22.16	22.16	6.00	0:24:15	21.68	21.68	22.64	22.40	19.76	21.92	22.64	22.40	78.00
0:04:15	22.40	22.64	22.40	22.64	22.64	22.16	21.92	22.16	6.00	0:24:30	21.68	22.40	22.88	22.64	20.72	22.40	23.12	22.64	80.50
0:04:30	22.40	22.16	22.16	22.40	22.40	22.16	21.68	21.92	6.00	0:24:45	21.68	22.64	23.36	22.88	21.68	22.64	23.36	22.64	82.00
0:04:45	22.16	21.92	21.92	22.40	21.92	21.92	21.44	21.92	6.00	0:25:00	21.92	23.12	23.60	23.12	22.64	22.88	23.84	22.88	82.50
0:05:00	22.16	21.68	21.68	22.16	21.44	21.68	21.44	21.68	5.50	0:25:15	21.92	23.36	23.84	23.36	23.36	23.12	24.08	23.12	82.50
0:05:15	22.16	21.68	21.68	21.92	20.96	21.44	21.20	21.68	6.50	0:25:30	21.92	23.84	24.08	23.60	24.32	23.60	24.32	23.12	81.50
0:05:30	22.16	21.20	21.44	21.92	20.72	21.20	20.96	21.68	9.50	0:25:45	21.92	24.08	24.32	23.84	24.80	23.84	24.32	23.36	80.50
0:05:45	22.16	20.96	21.20	21.68	20.24	21.20	20.96	21.44	14.50	0:26:00	22.16	24.32	24.32	24.08	25.52	24.08	24.32	23.60	80.00
0:06:00	22.16	20.96	20.96	21.44	19.76	20.96	20.96	21.44	18.50	0:26:15	22.16	24.32	24.32	24.08	26.24	24.32	24.56	23.60	79.00
0:06:15	22.16	20.72	20.96	21.44	19.28	20.96	20.72	21.44	22.50	0:26:30	22.16	24.56	24.56	24.32	26.48	24.32	24.56	23.60	78.50
0:06:30	22.16	20.48	20.96	21.44	19.04	20.72	20.48	21.20	25.50	0:26:45	22.16	24.80	24.80	24.32	27.20	24.32	24.80	23.84	77.50
0:06:45	21.92	20.48	20.72	21.20	18.56	20.72	20.48	21.20	28.00	0:27:00	22.40	24.80	24.80	24.32	27.44	24.56	24.80	23.84	65.00
0:07:00	21.92	20.24	20.48	21.20	18.32	20.48	20.24	21.20	29.50	0:27:15	22.40	24.80	24.56	24.08	27.92	24.56	24.56	23.60	49.50
0:07:15	21.92	20.00	20.48	20.96	17.84	20.24	20.24	21.20	28.50	0:27:30	22.40	24.80	24.32	23.84	27.92	24.32	24.32	23.12	36.50
0:07:30	21.92	19.76	20.24	20.96	17.60	20.24	20.00	20.96	25.00	0:27:45	22.40	24.56	24.32	23.60	28.16	24.32	24.32	22.88	27.50
0:07:45	21.92	19.76	20.24	20.96	17.36	20.00	20.00	20.96	21.00	0:28:00	22.40	24.32	24.08	23.36	27.92	24.32	23.84	22.64	21.50
0:08:00	21.92	19.52	20.00	20.72	17.12	20.00	19.76	20.96	17.50	0:28:15	22.40	24.32	23.84	23.12	27.68	24.08	23.60	22.64	17.50
0:08:15	21.92	19.28	19.76	20.48	16.88	19.76	19.76	20.72	15.50	0:28:30	22.40	24.08	23.60	22.88	27.44	23.84	23.36	22.64	15.00
0:08:30	21.68	19.28	19.52	20.48	16.40	19.52	19.52	20.72	16.50	0:28:45	22.40	23.84	23.12	22.88	26.96	23.60	23.12	22.40	13.00
0:08:45	21.68	19.04	19.52	20.24	16.16	19.52	19.28	20.48	21.50	0:29:00	22.40	23.60	22.88	22.64	26.48	23.36	22.64	22.40	12.00
0:09:00	21.68	18.80	19.28	20.24	15.92	19.28	19.28	20.48	26.00	0:29:15	22.40	23.12	22.64	22.64	26.00	23.12	22.64	22.40	11.00
0:09:15	21.68	18.80	19.28	20.24	15.68	19.28	19.28	20.48	33.00	0:29:30	22.40	22.88	22.64	22.64	25.52	22.88	22.40	22.16	10.50
0:09:30	21.68	18.80	19.52	20.24	15.68	19.28	19.52	20.72	39.50	0:29:45	22.40	22.64	22.40	22.40	24.80	22.64	22.16	22.16	10.00
0:09:45	21.68	19.28	20.00	20.48	15.68	19.52	20.00	20.96	46.50	0:30:00	22.40	22.64	22.16	22.40	24.32	22.64	21.92	21.92	9.50
0:10:00	21.68	19.28	20.48	20.96	15.92	19.76	20.48	20.96	52.50	0:30:15	22.16	22.40	22.16	22.16	23.84	22.40	21.68	21.92	9.50
0:10:15	21.68	19.76	20.96	20.96	16.16	20.24	20.96	21.20	57.50	0:30:30	22.16	22.16	21.92	21.92	23.12	22.16	21.68	21.68	9.00
0:10:30	21.68	20.24	21.20	21.20	16.88	20.72	21.20	21.44	62.00	0:30:45	22.16	21.68	21.68	21.92	22.64	21.92	21.44	21.68	9.00
0:10:45	21.68	20.72	21.68	21.68	17.84	20.96	21.68	21.68	65.50	0:31:00	22.16	21.44	21.44	21.68	22.16	21.68	21.20	21.68	9.00
0:11:00	21.68	21.20	22.16	22.16	18.56	21.44	22.40	21.92	68.00	0:31:15	22.16	21.20	21.20	21.68	21.68	21.44	20.96	21.44	11.00
0:11:15	21.68	21.68	22.64	22.40	19.28	21.92	22.64	22.40	70.50	0:31:30	22.16	20.96	20.96	21.44	21.20	21.20	20.96	21.44	15.00
0:11:30	21.68	22.40	22.88	22.64	20.48	22.40	23.12	22.64	71.50	0:31:45	22.16	20.96	20.96	21.20	20.72	20.96	20.72	21.20	18.50
0:11:45	21.68	22.64	23.36	22.88	21.44	22.64	23.36	22.64	71.50	0:32:00	22.16	20.72	20.72	21.20	20.24	20.96	20.48	21.20	22.00
0:12:00	21.68	22.88	23.60	23.12	22.40	22.88	23.84	22.64	71.50	0:32:15	21.92	20.48	20.48	20.96	19.52	20.72	20.48	21.20	25.00
0:12:15	21.92	23.36	23.84	23.36	23.12	23.12	24.08	22.88	71.00	0:32:30	21.92	20.24	20.48	20.96	19.28	20.48	20.24	21.20	28.00
0:12:30	21.92	23.84	24.08	23.60	24.08	23.60	24.08	23.12	70.50	0:32:45	21.92	20.00	20.24	20.96	18.80	20.48	20.24	20.96	30.50
0:12:45	21.92	24.08	24.32	23.84	24.80	23.84	24.32	23.12	70.00	0:33:00	21.92	19.76	20.24	20.96	18.32	20.24	20.00	20.96	32.50
0:13:00	21.92	24.32	24.32	23.84	25.52	24.08	24.32	23.36	69.50	0:33:15	21.92	19.52	20.00	20.72	17.84	20.00	20.00	20.96	34.00
0:13:15	22.16	24.32	24.32	24.08	26.24	24.32	24.32	23.60	69.00	0:33:30	21.92	19.52	19.76	20.72	17.60	20.00	19.76	20.96	34.50
0:13:30	22.16	24.56	24.56	24.32	26.48	24.32	24.56	23.60	68.50	0:33:45	21.68	19.28	19.76	20.48	17.36	19.76	19.76	20.96	33.50
0:13:45	22.16	24.56	24.56	24.32	27.20	24.32	24.56	23.60	65.00	0:34:00	21.68	19.28	19.76	20.48	17.12	19.76	19.76	20.96	32.50
0:14:00	22.16	24.80	24.56	24.32	27.44	24.32	24.56	23.60	49.50	0:34:15	21.68	19.28	20.00	20.48	16.88	19.76	20.00	20.96	35.00
0:14:15	22.40	24.80	24.56	24.08	27.92	24.32	24.32	23.36	35.00	0:34:30	21.68	19.28	20.24	20.72	16.64	20.00	20.24	20.96	41.00
0:14:30	22.40	24.56	24.32	23.84	27.92	24.32	24.32	23.12	25.50	0:34:45	21.68	19.76	20.48	20.96	16.88	20.24	20.72	20.96	48.00
0:14:45	22.40	24.32	24.32	23.60	27.92	24.32	24.08	22.88	19.50	0:35:00	21.68	20.00	20.96	20.96	17.12	20.48	20.96	21.20	55.50
0:15:00	22.40	24.32	23.84	23.36	27.68	24.08	23.84	22.64	17.00	0:35:15	21.68	20.48	21.20	21.44	17.84	20.96	21.44	21.44	62.50
0:15:15	22.40	24.08	23.60	23.12	27.44	23.84	23.36	22.64	18.00	0:35:30	21.68	20.96	21.68	21.68	18.08	21.20	21.92	21.68	68.00
0:15:30	22.40	23.84	23.36	23.12	26.96	23.60	23.12	22.64	21.50	0:35:45	21.68	21.44	22.16	22.16	19.04	21.44	22.40	22.16	72.00
0:15:45	22.40	23.36	22.88	22.88	26.48	23.36	22.88	22.64	25.50	0:36:00	21.68	21.92	22.64	22.40	19.76	21.92	22.64	22.40	75.00
0:16:00	22.40	23.12	22.64	22.88	26.24	23.12	22.64	22.64	28.50	0:36:15	21.68	22.40	22.88	22.64	20.96	22.40	23.12	22.64	77.50
0:16:15	22.40	22.88	22.64	22.64	25.52	22.88	22.64	22.64	30.00	0:36:30	21.92	22.64	23.36	22.88	21.68	22.64	23.60	22.64	78.50
0:16:30	22.40	22.64	22.64	22.64	25.04	22.64	22.40	22.40	31.50	0:36:45	21.92	23.12	23.60	23.12	22.64	23.12	23.84	22.88	78.50
0:16:45	22.40	22.64	22.40	22.64	24.32	22.64	22.16	22.40	32.00	0:37:00	21.92	23.60	24.08	23.60	23.36	23.36	24.08	23.12	78.50
0:17:00	22.40	22.40	22.40	22.64	24.08	22.40	22.16	22.40	32.00	0:37:15	21.92	23.84	24.08	23.60	24.32	23.60	24.32	23.12	78.50
0:17:15	22.40	22.40	22.16	22.40	23.60	22.40	21.92	22.16	32.00	0:37:30	22.16	24.08	24.32	23.84	25.04	23.84	24.32	23.36	78.00
0:17:30	22.16	22.16	22.16	22.40	22.88	22.16	21.92	22.16	31.50	0:37:45	22.16	24.32	24.32	24.08	25.76	24.08	24.32	23.60	77.50
0:17:45	22.16	21.92	21.92	22.16	22.64	21.92	21.68	21.92	31.50	0:38:00	22.16	24.56	24.56	24.08	26.24	24.32	24.56	23.60	77.00
0:18:00	22.16	21.68	21.68	22.16	22.16	21.92	21.44	21.92	31.00	0:38:15	22.16	24.56	24.56	24.32	26.72	24.32	24.56	23.84	75.50
0:18:15	22.16	21.68	21.68	21.92	21.92	21.68	21.44	21.92	30.50	0:38:30	22.16	24.80	24.56	24.32	27.20	24.32	24.56	23.60	64.50
0:18:30	22.16	21.44	21.44	21.92	21.44	21.44	21.20	21.68	30.50	0:38:45	22.40	24.80	24.56	24.08	27.44	24.32	24.56	23.36	47.50
0:18:45	22.16	21.20	21.44	21.68	20.96	21.44	21.20	21.68	30.00	0:39:00	22.40	24.80	24.32	23.84	27.68	24.32	24.32	23.12	34.50
0:19:00	22.16	20.96	21.20	21.44	20.96	21.20	20.96	21.68	29.50	0:39:15	22.40	24.56	24.32	23.60	27.92	24.32	24.32	22.88	25.50
0:19:15	22.16	20.96	21.20	21.44	20.48	21.20	20.96	21.44	29.50	0:39:30	22.40	24.32	24.08	23.36	27.68	24.32	23.84	22.64	19.50
0:19:30	22.16	20.96	20.96	21.44	20.24	20.96	20.96	21.44	29.00	0:39:45	22.40	24.32	23.84	23.12	27.44	24.08	23.60	22.64	15.50
0:19:45	22.16	20.72	20.96	21.20	19.76	20.96	20.96	21.44	29.00	0:40:00	22.40	24.08	23.60	22.88	27.20	23.84	23.36	22.64	13.00
0:20:00	22.16	20.72	20.96	21.20	19.52	20.96	20.96	21.20	28.50	0:40:15	22.40	23.84	23.12	22.88	26.72	23.60	22.88	22.40	11.50

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
0:40:30	22.40	23.36	22.88	22.64	26.24	23.12	22.64	22.40	10.50
0:40:45	22.40	23.12	22.64	22.64	26.00	22.88	22.64	22.16	9.50
0:41:00	22.40	22.88	22.64	22.64	25.28	22.64	22.40	22.16	9.00
0:41:15	22.40	22.64	22.40	22.40	24.80	22.64	22.16	22.16	8.50
0:41:30	22.16	22.40	22.16	22.16	24.32	22.40	21.92	21.92	8.50
0:41:45	22.16	22.16	21.92	22.16	23.84	22.16	21.68	21.92	8.00
0:42:00	22.16	21.92	21.68	21.92	23.12	21.92	21.44	21.68	8.00
0:42:15	22.16	21.68	21.44	21.68	22.64	21.68	21.20	21.68	8.50
0:42:30	22.16	21.44	21.20	21.68	22.16	21.44	20.96	21.44	10.50
0:42:45	22.16	21.20	20.96	21.44	21.44	21.20	20.96	21.44	14.50
0:43:00	22.16	20.96	20.96	21.44	20.96	20.96	20.96	21.44	18.50
0:43:15	22.16	20.72	20.96	21.20	20.48	20.96	20.72	21.20	22.00
0:43:30	21.92	20.48	20.72	21.20	20.00	20.96	20.48	21.20	25.00
0:43:45	21.92	20.24	20.48	20.96	19.28	20.72	20.24	21.20	28.00
0:44:00	21.92	20.00	20.48	20.96	19.04	20.48	20.24	21.20	30.00
0:44:15	21.92	20.00	20.24	20.96	18.56	20.48	20.00	20.96	32.00
0:44:30	21.92	19.76	20.00	20.96	18.08	20.24	20.00	20.96	34.00
0:44:45	21.92	19.52	20.24	20.72	17.84	20.24	20.00	20.96	40.50
0:45:00	21.92	19.76	20.24	20.96	17.60	20.24	20.24	20.96	48.00
0:45:15	21.68	20.00	20.72	20.96	17.60	20.48	20.72	21.20	55.00
0:45:30	21.68	20.24	20.96	21.20	17.84	20.72	20.96	21.44	61.50
0:45:45	21.68	20.72	21.44	21.44	18.08	20.96	21.44	21.68	67.50
0:46:00	21.68	20.96	21.92	21.92	18.56	21.20	21.92	21.92	73.00
0:46:15	21.68	21.44	22.40	22.16	19.28	21.68	22.40	22.16	76.50
0:46:30	21.92	22.16	22.64	22.64	20.00	22.16	22.64	22.40	78.50
0:46:45	21.92	22.64	23.12	22.88	20.96	22.64	23.12	22.64	80.00
0:47:00	21.92	22.88	23.60	23.12	21.68	22.88	23.60	22.64	80.50
0:47:15	21.92	23.36	23.84	23.36	22.64	23.12	23.84	22.88	80.00
0:47:30	21.92	23.84	24.08	23.60	23.60	23.60	24.08	23.12	79.50
0:47:45	22.16	24.08	24.32	23.84	24.32	23.84	24.32	23.12	78.50
0:48:00	22.16	24.32	24.32	24.08	25.04	24.08	24.32	23.36	78.00
0:48:15	22.16	24.32	24.56	24.08	25.76	24.32	24.56	23.60	77.00
0:48:30	22.16	24.56	24.56	24.32	26.24	24.32	24.56	23.60	76.00
0:48:45	22.40	24.80	24.80	24.32	26.72	24.32	24.80	23.84	75.50
0:49:00	22.40	25.04	24.80	24.32	27.20	24.56	24.80	23.84	75.00
0:49:15	22.40	25.04	25.04	24.32	27.68	24.56	25.04	23.84	74.50
0:49:30	22.40	25.28	25.04	24.56	28.16	24.80	25.04	24.08	74.00
0:49:45	22.40	25.52	25.28	24.56	28.16	25.04	25.04	24.08	73.50
0:50:00	22.64	25.52	25.28	24.80	28.64	25.04	25.28	24.08	73.00
0:50:15	22.64	25.76	25.52	24.80	28.88	25.28	25.28	24.08	67.50
0:50:30	22.64	25.76	25.52	24.56	29.12	25.28	25.28	24.08	55.00
0:50:45	22.64	25.76	25.28	24.32	29.12	25.04	25.04	23.84	43.00
0:51:00	22.64	25.52	25.04	24.32	29.12	25.04	24.80	23.60	33.50
0:51:15	22.64	25.52	24.80	24.32	29.12	25.04	24.56	23.36	26.00
0:51:30	22.64	25.28	24.56	24.08	28.88	24.80	24.32	23.12	20.50
0:51:45	22.64	25.04	24.56	23.84	28.64	24.56	24.32	22.88	16.50
0:52:00	22.64	24.80	24.32	23.84	28.40	24.32	24.08	22.88	13.50
0:52:15	22.64	24.56	24.32	23.60	28.16	24.32	23.84	22.88	11.50
0:52:30	22.64	24.32	24.08	23.60	27.68	24.08	23.60	22.64	10.00
0:52:45	22.64	24.32	23.84	23.36	27.20	23.84	23.36	22.64	9.00
0:53:00	22.64	24.08	23.60	23.12	26.72	23.84	23.12	22.64	8.00
0:53:15	22.64	23.84	23.36	23.12	26.24	23.60	22.88	22.64	7.50
0:53:30	22.64	23.60	23.12	22.88	26.00	23.36	22.64	22.64	7.00
0:53:45	22.64	23.36	22.88	22.88	25.28	23.12	22.64	22.40	6.50
0:54:00	22.64	23.12	22.64	22.64	24.80	22.88	22.64	22.40	6.50
0:54:15	22.40	22.88	22.64	22.64	24.32	22.64	22.40	22.40	6.00
0:54:30	22.40	22.64	22.64	22.64	24.08	22.64	22.16	22.16	6.00
0:54:45	22.40	22.64	22.40	22.40	23.60	22.40	21.92	22.16	6.00
0:55:00	22.40	22.40	22.16	22.40	22.88	22.40	21.92	21.92	5.50
0:55:15	22.40	22.16	21.92	22.16	22.64	22.16	21.68	21.92	7.50
0:55:30	22.40	21.92	21.68	21.92	22.16	21.92	21.44	21.68	10.50
0:55:45	22.40	21.44	21.44	21.92	21.68	21.68	21.20	21.68	15.00
0:56:00	22.16	21.20	21.20	21.68	20.96	21.44	20.96	21.68	18.50
0:56:15	22.16	20.96	20.96	21.68	20.72	21.20	20.96	21.68	22.00
0:56:30	22.16	20.96	20.96	21.44	20.00	20.96	20.72	21.44	25.00
0:56:45	22.16	20.72	20.96	21.20	19.52	20.96	20.72	21.44	27.50
0:57:00	22.16	20.48	20.72	21.20	19.28	20.72	20.48	21.44	29.50
0:57:15	22.16	20.24	20.72	20.96	18.80	20.72	20.48	21.20	31.50
0:57:30	22.16	20.24	20.48	20.96	18.32	20.48	20.24	21.20	32.50
0:57:45	21.92	20.00	20.24	20.96	17.84	20.48	20.24	20.96	33.50
0:58:00	21.92	19.76	20.24	20.96	17.84	20.24	20.24	20.96	34.50
0:58:15	21.92	19.76	20.48	20.96	17.60	20.24	20.24	20.96	39.50
0:58:30	21.92	20.00	20.72	20.96	17.36	20.48	20.72	21.20	46.00
0:58:45	21.92	20.24	20.96	21.20	17.60	20.72	20.96	21.20	53.00
0:59:00	21.92	20.72	21.20	21.44	17.84	20.96	21.20	21.68	60.00
0:59:15	21.92	20.96	21.68	21.92	18.08	21.20	21.68	21.92	66.50
0:59:30	21.92	21.44	22.16	22.16	18.80	21.68	22.40	22.16	71.50
0:59:45	21.92	21.92	22.64	22.64	19.52	22.16	22.64	22.40	75.00
1:00:00	21.92	22.64	23.12	22.64	20.48	22.64	23.12	22.64	78.00
1:00:15	21.92	22.88	23.60	23.12	21.20	22.64	23.60	22.88	78.50
1:00:30	22.16	23.12	23.84	23.36	22.40	23.12	23.84	22.88	78.50
1:00:45	22.16	23.60	24.08	23.60	22.88	23.36	24.08	23.12	78.50
1:01:00	22.16	24.08	24.32	23.84	24.08	23.84	24.32	23.36	78.50
1:01:15	22.16	24.32	24.32	24.08	24.56	24.08	24.32	23.60	77.50
1:01:30	22.16	24.32	24.56	24.32	25.52	24.32	24.56	23.60	77.00
1:01:45	22.40	24.56	24.80	24.32	26.00	24.32	24.56	23.84	76.00
1:02:00	22.40	24.80	24.80	24.32	26.48	24.32	24.80	23.84	75.50
1:02:15	22.40	25.04	25.04	24.32	26.96	24.56	24.80	23.84	75.00
1:02:30	22.40	24.80	24.32	24.32	27.44	24.32	24.32	23.36	43.50
1:02:45	22.64	24.32	24.08	23.84	27.68	24.32	23.84	22.88	39.00

ATTACHMENT: High Humidity

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH	Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
0:00:00	22.40	22.88	22.64	22.64	25.28	22.64	22.64	22.40	39.00	0:20:15	21.92	24.32	24.32	23.60	28.16	24.32	24.32	23.12	67.00
0:00:15	22.40	22.88	22.64	22.64	24.80	22.64	22.64	22.40	39.50	0:20:30	21.92	24.32	24.32	23.84	28.16	24.32	24.32	23.36	71.50
0:00:30	22.40	23.12	23.12	22.88	24.80	22.64	22.64	22.64	45.50	0:20:45	21.92	24.56	24.32	24.08	28.40	24.32	24.56	23.60	84.50
0:00:45	22.40	23.36	23.36	23.12	24.56	22.88	23.12	22.64	44.50	0:21:00	22.16	25.04	24.80	24.32	28.88	24.56	24.80	24.08	90.50
0:01:00	22.40	23.60	23.60	23.12	24.80	23.12	23.36	22.64	39.50	0:21:15	22.16	25.52	25.28	24.56	29.12	25.04	25.28	24.32	93.50
0:01:15	22.40	23.60	23.60	23.12	24.80	23.12	23.36	22.64	31.50	0:21:30	22.16	26.00	25.76	25.04	29.36	25.52	25.76	24.32	95.00
0:01:30	22.40	23.60	23.60	23.12	25.04	23.12	23.12	22.64	24.00	0:21:45	22.40	26.24	26.24	25.28	29.60	26.00	26.24	24.56	96.00
0:01:45	22.40	23.60	23.36	22.88	25.04	23.12	23.12	22.64	18.50	0:22:00	22.40	26.96	26.24	25.52	29.84	26.24	26.48	24.80	97.00
0:02:00	22.40	23.36	23.12	22.64	24.80	23.12	22.88	22.40	14.50	0:22:15	22.40	27.44	26.96	25.76	30.32	26.72	26.96	25.04	97.00
0:02:15	22.40	23.12	22.88	22.64	24.80	22.88	22.64	22.40	12.00	0:22:30	22.64	27.92	27.44	26.24	30.80	27.20	27.44	25.28	97.50
0:02:30	22.40	22.88	22.64	22.64	24.32	22.64	22.64	22.16	10.50	0:22:45	22.64	28.16	27.92	26.24	31.04	27.68	27.92	25.52	98.00
0:02:45	22.40	22.64	22.64	22.64	24.32	22.64	22.40	22.16	9.50	0:23:00	22.64	28.64	28.16	26.72	31.52	28.16	28.16	26.00	98.00
0:03:00	22.40	22.64	22.40	22.40	23.84	22.64	22.16	21.92	9.00	0:23:15	22.64	29.36	28.40	27.20	31.76	28.40	28.40	26.24	98.00
0:03:15	22.40	22.40	22.16	22.40	23.60	22.40	21.92	21.92	8.50	0:23:30	22.88	29.60	28.88	27.44	32.24	28.88	28.64	26.24	98.50
0:03:30	22.40	22.16	21.92	22.16	23.12	22.16	21.68	21.92	8.00	0:23:45	22.88	30.08	29.12	27.68	32.48	29.12	29.12	26.48	98.50
0:03:45	22.40	21.92	21.92	21.92	22.64	21.92	21.68	21.68	7.50	0:24:00	23.12	30.32	29.36	27.92	32.72	29.36	29.12	26.72	99.00
0:04:00	22.16	21.68	21.68	21.92	22.40	21.68	21.44	21.68	7.50	0:24:15	23.12	30.56	29.60	28.16	32.96	29.60	29.36	26.72	99.00
0:04:15	22.16	21.44	21.44	21.68	21.68	21.68	21.20	21.68	7.50	0:24:30	23.36	30.56	29.60	28.16	32.96	29.84	29.36	26.96	99.00
0:04:30	22.16	21.20	21.20	21.44	21.20	21.44	20.96	21.44	7.00	0:24:45	23.60	30.32	29.12	28.16	32.72	29.60	28.88	26.72	99.00
0:04:45	22.16	20.96	20.96	21.44	20.96	21.20	20.96	21.44	7.00	0:25:00	23.60	29.84	28.64	27.92	32.00	29.12	28.40	26.72	99.00
0:05:00	22.16	20.96	20.96	21.20	20.48	20.96	20.96	21.20	7.00	0:25:15	23.84	29.36	28.40	27.68	31.28	28.88	28.16	26.48	99.00
0:05:15	22.16	20.72	20.96	21.20	20.00	20.96	20.72	21.20	7.00	0:25:30	23.84	28.88	28.16	27.44	30.80	28.40	27.68	26.24	98.50
0:05:30	22.16	20.48	20.72	20.96	19.52	20.96	20.48	21.20	7.00	0:25:45	23.84	28.40	27.68	27.20	30.56	28.16	27.44	26.24	97.00
0:05:45	22.16	20.24	20.48	20.96	19.28	20.72	20.48	20.96	7.00	0:26:00	23.84	28.16	27.20	26.72	30.32	27.68	26.96	26.00	94.00
0:06:00	21.92	20.00	20.48	20.96	18.80	20.48	20.24	20.96	7.00	0:26:15	23.84	27.68	26.96	26.48	30.32	27.20	26.48	25.76	90.50
0:06:15	21.92	19.76	20.24	20.72	18.32	20.48	20.00	20.96	7.00	0:26:30	23.84	27.20	26.48	26.24	30.08	26.72	26.24	25.52	88.50
0:06:30	21.92	19.52	20.00	20.72	18.08	20.24	20.00	20.96	7.00	0:26:45	23.84	26.72	26.24	26.00	29.60	26.24	25.76	25.28	87.00
0:06:45	21.92	19.52	19.76	20.48	17.84	20.00	19.76	20.96	7.00	0:27:00	23.84	26.24	25.76	25.76	29.36	26.00	25.52	25.04	82.50
0:07:00	21.92	19.28	19.76	20.48	17.36	19.76	19.52	20.72	7.00	0:27:15	23.84	26.00	25.52	25.52	28.88	25.76	25.04	24.80	79.50
0:07:15	21.92	19.28	19.52	20.24	16.88	19.76	19.52	20.72	7.00	0:27:30	23.84	25.52	25.04	25.28	28.40	25.28	24.56	24.56	77.00
0:07:30	21.68	19.04	19.28	20.00	16.64	19.52	19.28	20.48	7.00	0:27:45	23.84	25.04	24.80	25.04	28.16	24.80	24.32	24.32	74.50
0:07:45	21.68	18.80	19.28	20.00	16.16	19.28	19.28	20.48	7.50	0:28:00	23.60	24.56	24.32	24.56	27.92	24.32	24.08	24.32	72.50
0:08:00	21.68	18.56	19.28	19.76	16.16	19.28	19.28	20.48	7.50	0:28:15	23.60	24.32	24.32	24.32	27.44	24.32	23.60	24.08	71.50
0:08:15	21.68	18.56	19.04	19.52	15.68	19.28	19.04	20.24	8.00	0:28:30	23.60	24.08	23.84	24.32	26.96	23.84	23.36	23.84	71.00
0:08:30	21.68	18.32	18.80	19.52	15.44	19.28	19.04	20.24	10.50	0:28:45	23.36	23.60	23.60	24.08	26.48	23.36	22.88	23.60	69.00
0:08:45	21.68	18.08	18.80	19.28	14.96	19.04	18.80	20.00	15.00	0:29:00	23.36	23.12	23.12	23.84	26.24	23.12	22.64	23.36	67.00
0:09:00	21.44	17.84	18.56	19.28	14.72	18.80	18.56	20.00	20.00	0:29:15	23.36	22.88	22.88	23.60	25.76	22.64	22.40	23.12	65.00
0:09:15	21.44	17.84	18.32	19.28	14.48	18.56	18.32	20.00	23.50	0:29:30	23.12	22.64	22.64	23.36	25.28	22.64	21.92	22.64	63.00
0:09:30	21.44	17.60	18.08	19.28	14.00	18.56	18.32	19.76	26.50	0:29:45	23.12	22.64	22.40	23.12	24.80	22.16	21.68	22.64	61.50
0:09:45	21.44	17.36	18.08	19.04	13.76	18.32	18.08	19.76	29.00	0:30:00	23.12	22.40	22.40	22.88	24.32	21.92	21.44	22.64	60.50
0:10:00	21.44	17.36	17.84	19.04	13.28	18.32	18.08	19.76	31.50	0:30:15	22.88	22.40	22.40	22.64	24.08	21.68	21.20	22.40	58.50
0:10:15	21.44	17.12	17.84	18.80	13.04	18.08	18.08	19.76	32.50	0:30:30	22.88	22.16	22.40	22.64	23.60	21.68	21.20	22.16	56.50
0:10:30	21.44	16.88	17.84	18.80	12.80	18.08	17.84	19.52	29.50	0:30:45	22.88	22.16	22.16	22.40	23.12	21.44	21.20	21.92	54.00
0:10:45	21.20	16.88	17.84	18.56	12.56	17.84	17.84	19.52	25.50	0:31:00	22.64	21.92	22.16	22.16	22.64	21.20	21.20	21.68	51.00
0:11:00	21.20	16.64	17.60	18.56	12.56	17.84	17.84	19.28	22.00	0:31:15	22.64	21.92	21.92	22.16	22.40	21.20	20.96	21.44	49.00
0:11:15	21.20	16.40	17.60	18.32	12.32	17.84	17.84	19.28	19.00	0:31:30	22.64	21.68	21.92	21.68	21.92	21.20	20.96	21.20	47.00
0:11:30	21.20	16.40	17.36	18.08	12.08	17.60	17.60	19.28	17.50	0:31:45	22.64	21.44	21.68	21.68	21.44	20.96	20.96	21.20	45.00
0:11:45	21.20	16.16	17.12	18.08	11.84	17.60	17.36	19.28	18.50	0:32:00	22.64	21.44	21.44	21.44	20.96	20.96	20.96	20.96	43.50
0:12:00	21.20	16.16	17.12	17.84	11.36	17.36	17.36	19.04	22.00	0:32:15	22.40	21.20	21.20	21.20	20.72	20.96	20.96	20.96	42.00
0:12:15	20.96	15.92	16.88	17.84	11.12	17.12	17.12	19.04	26.00	0:32:30	22.40	20.96	21.20	21.20	20.24	20.96	20.72	20.96	39.50
0:12:30	20.96	15.68	16.64	17.84	10.88	17.12	17.12	19.04	29.50	0:32:45	22.40	20.96	20.96	20.96	19.76	20.96	20.72	20.72	37.00
0:12:45	20.96	15.44	16.40	17.84	10.64	16.88	16.88	18.80	31.50	0:33:00	22.40	20.72	20.96	20.96	19.52	20.72	20.48	20.72	35.50
0:13:00	20.96	15.44	16.40	17.60	10.40	16.88	16.88	18.80	33.00	0:33:15	22.16	20.48	20.72	20.96	19.28	20.48	20.24	20.48	34.00
0:13:15	20.96	15.20	16.16	17.60	10.40	16.64	16.64	18.80	34.50	0:33:30	22.16	20.24	20.48	20.96	18.80	20.48	20.00	20.48	33.00
0:13:30	20.96	15.20	16.16	17.60	10.16	16.64	16.88	18.80	42.50	0:33:45	22.16	20.00	20.24	20.72	18.56	20.24	20.00	20.48	32.00
0:13:45	20.96	15.20	16.40	17.60	9.92	16.64	17.12	18.80	50.50	0:34:00	22.16	19.76	20.00	20.48	18.08	20.00	19.76	20.48	31.00
0:14:00	20.96	15.44	16.88	17.84	10.16	16.88	17.36	19.04	58.50	0:34:15	21.92	19.52	20.00	20.48	17.84	20.00	19.52	20.24	30.50
0:14:15	20.96	15.92	17.36	17.84	10.40	17.12	17.84	19.28	65.50	0:34:30	21.92	19.28	19.76	20.24	17.60	19.76	19.52	20.24	29.50
0:14:30	20.96	16.16	17.84	18.32	10.64	17.60	18.08	19.28	71.50	0:34:45	21.92	19.28	19.52	20.24	17.12	19.52	19.28	20.24	29.00
0:14:45	20.96	16.40	18.08	18.56	11.36	17.84	18.56	19.52	75.50	0:35:00	21.92	19.04	19.28	20.00	16.64	19.52	19.28	20.24	28.50
0:15:00	20.96	17.12	18.56	19.04	12.08	18.08	19.28	19.76	79.00	0:35:15	21.68	18.80	19.28	19.76	16.40	19.28	19.28	20.00	28.00
0:15:15	20.96	17.60	19.04	19.28	12.80	18.56	19.52	20.00	81.50	0:35:30	21.68	18.56	19.28	19.76	16.16	19.28	19.04	20.00	27.50
0:15:30	20.96	17.84	19.28	19.52	14.00	19.04	20.00	20.48	83.00	0:35:45	21.68	18.56	19.04	19.52	15.92	19.28	19.04	20.00	27.00
0:15:45	20.96	18.56	19.76	20.00	14.72	19.28	20.48	20.72	84.00	0:36:00	21.68	18.32	18.80	19.52	15.68	19.04	18.80	19.76	27.00
0:16:00	20.96	19.28	20.48	20.24	15.92	19.76	20.96	20.96	84.50	0:36:15	21.44	18.08	18.80	19.28	15.20	18.80	18.80	19.76	26.50
0:16:15	20.96	19.52	20.96	20.72	16.88	20.48	21.44	20.96	84.00	0:36:30	21.44	17.84	18.56	19.28	14.96	18.80	18.56	19.76	26.00
0:16:30	20.96	20.24	21.20	20.96	17.84	20.96	21.68	21.20	84.00	0:36:45	21.44	17.84	18.32	19.28	14.72	18.56	18.56	19.52	26.00
0:16:45	20.96	20.72	21.68	21.20	19.28	21.20	22.16	21.44	83.00	0:37:00	21.44	17.84	18.32	19.04	14.48	18.56	18.32	19.52	26.00
0:17:00	20.96	20.96	21.92	21.44	20.24	21.44	22.64	21.68	82.00	0:37:15	21.44	17.60	18.08	19.04	14.24	18.32	18.32	19.52	27.00
0:17:15	21.20	21.44	22.16	21.92	20.96	21.92	22.64	21.92	80.50	0:37:30	21.44	17.36	17.84	18.80	14.00	18.32	18.08	19.52	29.00
0:17:30	21.20	21.92	22.40	22.16	22.16	22.16	22.88	22.16	79.50	0:37:45	21.20	17.12	17.84	18.80	13.76	18.08	18.08	19.28	29.50
0:17:45	21.20	22.16	22.64	22.40	22.88	22.40	23.12	22.40	78.00	0:38:00	21.20	17.12	17.84	18.56	13.28	18.08	17.84	19.28	30.00
0:18:00	21.44	22.64	22.64	22.64	23.84	22.64	23.36	22.40	76.00	0:38:15	21.20	16.88	17.84	18.56	13.04	17.84	17.84	19.28	30.50
0:18:15	21.44	22.64	22.88	22.64	24.32	22.88	23.60	22.64	75.00	0:38:30	21.20	16.64	17.84	18.32	12.80	17.84	17.84	19.28	31.00
0:18:30	21.44	22.88	23.12	22.64	25.04	23.12	23.60	22.64	73.50	0:38:45	21.20	16.64	17.60	18.32	12.56	17.84	17.84	19.28	31.00
0:18:45	21.44	23.12	23.36	22.88	25.76	23.12	23.84	22.64	72.00	0:39:00	21.20	16.40	17.60	18.32	12.56	17.84	17.84	19.28	31.00
0:19:00	21.68	23.36	23.60	22.88	26.24	23.36	23.84	22.64	71.50	0:39:15	21.20	16.16	17.36	18.08	12.56	17.60	17.60	19.28	31.00
0:19:15	21.68	23.60	23.60	23.12	26.48	23.60	24.08	22.88	70.50	0:39:30	20.96	16.16	17.36	18.08	12.32	17.60	17.60	19.04	31.00
0:19:30	21.68	23.84	23.84	23.36	26.96	23.84	24.32	22.88	69.50	0:39:45	20.96	16.16	17.12	17.84	12.08	17.36	17.60	19.04	31.00
0:19:45	21.68	24.08	24.08	23.36	27.44	23.84	24.32	23.12	68.50	0:40:00	20.96	16.16	17.12	17.84	11.84	17.36	17.36	19.04	31.00
0:20:00	21.92	24.32	24.08	23.60	27.68	24.08	24.32	23.12	67.50	0:40:15	20.96	15.92	16.88	17.84	11.60	17.36	17.12	19.04	31.00

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH	Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
0:40:30	20.96	15.92	16.88	17.84	11.60	17.12	17.12	18.80	30.50	1:00:45	21.92	19.04	19.28	20.24	18.08	19.28	19.28	20.72	94.00
0:40:45	20.96	15.68	16.64	17.84	11.36	16.88	16.88	18.80	45.00	1:01:00	21.92	18.56	19.28	20.24	17.84	19.28	19.04	20.48	93.00
0:41:00	20.96	15.44	16.40	17.60	11.12	16.88	16.88	18.80	43.00	1:01:15	21.92	18.32	19.04	20.00	17.84	19.04	18.80	20.24	91.50
0:41:15	20.96	15.20	16.40	17.60	10.88	16.64	16.64	18.80	41.50	1:01:30	21.68	18.08	18.80	19.76	17.60	18.80	18.56	20.24	90.50
0:41:30	20.96	15.20	16.16	17.36	10.64	16.64	16.64	18.56	48.50	1:01:45	21.68	17.84	18.56	19.52	17.36	18.56	18.56	20.00	89.50
0:41:45	20.96	14.96	16.16	17.36	10.40	16.64	16.64	18.56	45.00	1:02:00	21.68	17.84	18.32	19.52	16.88	18.32	18.32	19.76	88.50
0:42:00	20.96	14.96	16.16	17.36	10.40	16.40	16.40	18.56	49.00	1:02:15	21.68	17.60	18.32	19.28	16.64	18.08	18.32	19.76	88.00
0:42:15	20.96	14.72	16.16	17.12	10.16	16.40	16.40	18.56	50.00	1:02:30	21.44	17.36	18.32	19.28	16.40	18.08	18.32	19.52	87.00
0:42:30	20.96	14.72	16.16	17.12	10.16	16.16	16.40	18.32	46.50	1:02:45	21.44	17.12	18.32	19.28	16.16	17.84	18.32	19.52	86.00
0:42:45	20.72	14.48	15.92	17.12	9.92	16.16	16.40	18.32	55.00	1:03:00	21.44	16.88	18.32	19.04	15.92	17.84	18.08	19.28	84.50
0:43:00	20.72	14.48	15.92	16.88	9.68	16.16	16.16	18.32	51.00	1:03:15	21.20	16.88	18.08	18.80	15.68	17.84	18.08	19.28	82.50
0:43:15	20.72	14.48	15.68	16.88	9.44	16.16	16.16	18.32	50.50	1:03:30	21.20	16.88	18.08	18.80	15.20	17.84	17.84	19.28	80.50
0:43:30	20.72	14.48	15.68	16.64	9.44	16.16	16.16	18.08	56.00	1:03:45	21.20	16.64	17.84	18.56	14.96	17.84	17.84	19.04	78.50
0:43:45	20.72	14.48	15.68	16.64	9.20	16.16	16.16	18.08	52.50	1:04:00	21.20	16.64	17.84	18.32	14.72	17.84	17.84	19.04	77.50
0:44:00	20.72	14.24	15.44	16.64	9.20	15.92	16.16	18.08	60.00	1:04:15	20.96	16.64	17.84	18.32	14.48	17.84	17.84	19.04	76.00
0:44:15	20.72	14.24	15.44	16.40	8.96	15.92	16.16	18.08	57.00	1:04:30	20.96	16.40	17.84	18.08	14.24	17.60	17.84	18.80	74.50
0:44:30	20.48	14.24	15.44	16.40	8.96	15.92	16.16	17.84	54.00	1:04:45	20.96	16.40	17.60	18.08	14.00	17.60	17.84	18.80	73.00
0:44:45	20.48	14.00	15.44	16.40	8.72	15.68	15.92	17.84	60.50	1:05:00	20.96	16.40	17.36	17.84	13.52	17.60	17.60	18.56	71.50
0:45:00	20.48	14.00	15.20	16.16	8.72	15.68	15.92	17.84	57.00	1:05:15	20.96	16.16	17.36	17.84	13.28	17.36	17.60	18.56	69.50
0:45:15	20.48	13.76	15.20	16.16	8.48	15.68	15.92	17.84	64.00	1:05:30	20.96	16.16	17.12	17.84	13.04	17.36	17.36	18.56	67.50
0:45:30	20.48	13.76	15.20	16.16	8.48	15.68	15.92	17.84	61.50	1:05:45	20.96	16.16	16.88	17.84	12.80	17.36	17.36	18.32	66.00
0:45:45	20.48	13.76	15.20	16.16	8.48	15.68	15.68	17.84	58.50	1:06:00	20.96	15.92	16.88	17.60	12.56	17.12	17.12	18.32	65.00
0:46:00	20.48	13.52	14.96	16.16	8.24	15.44	15.68	17.84	65.00	1:06:15	20.96	15.92	16.64	17.36	12.32	17.12	17.12	18.32	64.50
0:46:15	20.48	13.52	14.96	16.16	8.24	15.44	15.68	17.84	69.00	1:06:30	20.72	15.68	16.40	17.36	12.08	16.88	16.88	18.32	63.50
0:46:30	20.24	13.76	15.20	16.16	8.24	15.68	15.92	17.84	86.00	1:06:45	20.72	15.44	16.40	17.36	11.84	16.88	16.88	18.08	63.00
0:46:45	20.24	14.00	15.68	16.64	8.72	15.92	16.16	18.08	92.50	1:07:00	20.72	15.44	16.16	17.12	11.60	16.64	16.64	18.08	62.00
0:47:00	20.24	14.48	16.16	17.12	9.44	16.16	16.88	18.56	95.50	1:07:15	20.72	15.20	16.16	17.12	11.36	16.64	16.40	18.08	61.50
0:47:15	20.24	14.96	16.64	17.60	10.40	16.40	17.60	18.80	97.00	1:07:30	20.72	14.96	16.16	16.88	11.12	16.40	16.40	18.08	61.50
0:47:30	20.24	15.68	17.36	17.84	11.84	17.12	18.08	19.28	97.50	1:07:45	20.48	14.72	16.16	16.88	10.64	16.40	16.40	17.84	61.00
0:47:45	20.48	16.40	17.84	18.32	13.04	17.84	18.80	19.52	98.00	1:08:00	20.48	14.72	15.92	16.64	10.64	16.16	16.16	17.84	60.50
0:48:00	20.48	17.36	18.56	19.04	14.72	18.32	19.28	19.76	98.00	1:08:15	20.48	14.48	15.68	16.64	10.40	16.16	16.16	17.84	60.00
0:48:15	20.48	18.08	19.28	19.28	16.40	19.04	20.24	20.24	98.00	1:08:30	20.48	14.48	15.68	16.40	10.16	16.16	16.16	17.84	59.00
0:48:30	20.48	19.28	20.24	20.00	18.08	19.52	20.96	20.72	98.50	1:08:45	20.48	14.48	15.44	16.40	10.16	16.16	16.16	17.84	58.50
0:48:45	20.48	20.00	20.96	20.48	19.52	20.48	21.68	20.96	98.50	1:09:00	20.24	14.24	15.44	16.40	9.68	15.92	15.92	17.84	58.50
0:49:00	20.72	20.96	21.44	20.96	21.20	21.20	22.40	21.44	98.50	1:09:15	20.24	14.00	15.20	16.16	9.44	15.92	15.92	17.84	58.00
0:49:15	20.72	21.68	22.40	21.44	22.64	21.92	22.64	21.92	99.00	1:09:30	20.24	14.00	15.20	16.16	9.44	15.68	15.68	17.60	57.50
0:49:30	20.96	22.64	22.88	21.92	24.08	22.64	23.36	22.16	99.00	1:09:45	20.24	13.76	14.96	16.16	9.20	15.68	15.68	17.60	57.00
0:49:45	20.96	23.36	23.36	22.40	25.04	23.12	24.08	22.64	99.00	1:10:00	20.24	13.76	14.96	16.16	8.96	15.68	15.68	17.60	55.50
0:50:00	20.96	24.08	23.84	22.64	26.24	23.84	24.32	22.88	99.00	1:10:15	20.00	13.52	14.72	15.92	8.72	15.44	15.44	17.60	67.00
0:50:15	20.96	24.56	24.32	23.12	26.96	24.32	24.80	23.12	99.00	1:10:30	20.00	13.28	14.72	15.92	8.48	15.20	15.20	17.36	66.00
0:50:30	21.20	25.28	24.80	23.84	27.92	24.80	25.28	23.60	99.00	1:10:45	20.00	13.28	14.48	15.92	8.24	15.20	15.20	17.36	67.50
0:50:45	21.20	25.76	25.28	24.32	28.40	25.52	25.76	23.84	99.00	1:11:00	20.00	13.04	14.48	15.68	8.00	14.96	15.20	17.36	73.00
0:51:00	21.44	26.24	25.76	24.32	28.88	26.00	26.24	24.08	99.50	1:11:15	20.00	13.04	14.48	15.68	8.00	14.96	15.20	17.36	71.50
0:51:15	21.68	26.72	26.24	24.80	29.60	26.24	26.48	24.32	99.50	1:11:30	20.00	13.04	14.48	15.68	7.76	14.96	14.96	17.36	71.50
0:51:30	21.68	27.20	26.48	25.28	30.08	26.72	26.72	24.56	99.50	1:11:45	19.76	12.80	14.48	15.44	7.76	14.96	14.96	17.36	76.50
0:51:45	21.92	27.68	26.96	25.52	30.80	27.20	27.20	24.80	99.50	1:12:00	19.76	12.80	14.48	15.44	7.76	14.72	14.96	17.12	72.00
0:52:00	22.16	28.16	27.44	26.00	30.80	27.44	27.68	25.04	99.50	1:12:15	19.76	12.80	14.48	15.44	7.76	14.72	14.96	17.12	76.00
0:52:15	22.16	28.40	27.92	26.24	31.52	27.92	28.16	25.52	100.00	1:12:30	19.76	12.56	14.24	15.44	7.52	14.72	14.96	17.12	78.50
0:52:30	22.40	28.88	28.16	26.48	31.76	28.16	28.16	25.76	100.00	1:12:45	19.76	12.56	14.24	15.20	7.52	14.72	14.96	17.12	75.50
0:52:45	22.40	29.12	28.16	26.72	32.00	28.40	28.16	26.00	100.00	1:13:00	19.76	12.56	14.24	15.20	7.28	14.48	14.72	17.12	79.50
0:53:00	22.64	29.12	28.16	26.72	32.00	28.40	28.16	26.00	100.00	1:13:15	19.52	12.56	14.24	15.20	7.28	14.48	14.72	17.12	78.00
0:53:15	22.64	28.64	27.68	26.48	31.28	28.16	27.68	25.76	100.00	1:13:30	19.52	12.56	14.24	15.20	7.28	14.48	14.72	16.88	79.00
0:53:30	22.64	28.16	27.20	26.24	30.80	27.92	27.20	25.52	100.00	1:13:45	19.52	12.56	14.00	14.96	7.28	14.48	14.72	16.88	82.00
0:53:45	22.64	27.92	26.72	26.24	30.08	27.44	26.48	25.28	100.00	1:14:00	19.52	12.32	14.00	14.96	7.04	14.48	14.72	16.88	79.50
0:54:00	22.88	27.44	26.48	26.00	29.12	26.96	26.24	25.04	100.00	1:14:15	19.52	12.56	14.00	15.20	7.04	14.48	14.72	16.88	88.50
0:54:15	22.88	26.96	26.24	25.76	28.40	26.48	26.00	24.80	100.00	1:14:30	19.52	12.56	14.24	15.44	7.28	14.48	14.96	17.12	94.00
0:54:30	22.88	26.48	26.00	25.52	27.92	26.24	25.76	24.56	100.00	1:14:45	19.52	12.80	14.48	15.68	7.76	14.72	15.68	17.36	96.50
0:54:45	22.88	26.24	25.52	25.28	27.20	26.00	25.28	24.32	100.00	1:15:00	19.52	13.28	15.20	16.16	8.48	15.20	16.16	17.60	98.00
0:55:00	22.88	26.00	25.28	25.04	26.72	25.52	25.04	24.32	100.00	1:15:15	19.52	14.00	15.68	16.40	9.68	15.68	16.64	17.84	98.50
0:55:15	22.88	25.52	25.04	24.80	26.24	25.28	24.80	24.32	100.00	1:15:30	19.52	14.48	16.16	16.88	10.88	16.16	17.36	18.08	99.00
0:55:30	22.88	25.28	24.56	24.56	25.76	25.04	24.32	24.08	100.00	1:15:45	19.52	15.44	16.88	17.36	12.32	16.64	17.84	18.56	99.00
0:55:45	22.88	24.80	24.32	24.32	25.28	24.56	24.32	23.84	100.00	1:16:00	19.52	16.16	17.84	17.84	14.00	17.36	18.56	19.04	99.00
0:56:00	22.88	24.32	24.32	24.32	24.56	24.32	23.84	23.60	100.00	1:16:15	19.52	17.12	18.32	18.32	15.44	18.08	19.28	19.28	99.00
0:56:15	22.88	24.32	24.08	24.08	24.32	24.08	23.60	23.60	100.00	1:16:30	19.76	17.84	19.04	18.80	16.88	18.80	19.76	19.52	99.50
0:56:30	22.88	23.84	23.60	23.84	23.84	23.84	23.36	23.36	100.00	1:16:45	19.76	18.80	19.52	19.28	18.32	19.28	20.48	20.00	99.50
0:56:45	22.88	23.60	23.36	23.60	23.36	23.60	23.12	23.12	100.00	1:17:00	19.76	19.52	20.48	19.76	20.00	20.24	21.20	20.48	99.50
0:57:00	22.64	23.12	23.12	23.36	22.88	23.12	22.88	22.88	100.00	1:17:15	20.00	20.72	20.96	20.48	21.44	20.96	21.92	20.96	99.50
0:57:15	22.64	22.88	22.88	23.12	22.64	22.88	22.64	22.64	100.00	1:17:30	20.00	21.44	21.68	20.96	22.64	21.68	22.40	21.20	100.00
0:57:30	22.64	22.64	22.64	22.88	22.16	22.64	22.40	22.64	100.00	1:17:45	20.24	22.16	22.40	21.44	24.08	22.40	22.88	21.68	100.00
0:57:45	22.64	22.40	22.40	22.64	21.68	22.40	22.16	22.64	100.00	1:18:00	20.24	22.88	22.88	21.92	25.04	22.88	23.60	22.16	100.00
0:58:00	22.64	21.92	22.16	22.64	21.20	22.16	21.92	22.40	99.50	1:18:15	20.48	23.60	23.60	22.40	26.24	23.36	24.08	22.40	100.00
0:58:15	22.64	21.68	21.92	22.40	20.96	21.92	21.68	22.16	99.50	1:18:30	20.48	24.32	24.08	22.64	26.96	24.08	24.32	22.64	100.00
0:58:30	22.64	21.44	21.68	22.16	20.72	21.68	21.44	21.92	99.50	1:18:45	20.72	24.80	24.32	23.12	27.68	24.56	25.04	22.88	100.00
0:58:45	22.64	20.96	21.44	21.92	20.24	21.20	20.96	21.92	99.50	1:19:00	20.96	25.52	24.80	23.60	28.16	25.04	25.52	23.36	100.00
0:59:00	22.40	20.96	20.96	21.68	19.76	20.96	20.96	21.68	99.00	1:19:15	20.96	26.00	25.28	24.08	28.88	25.52	26.00	23.60	100.00
0:59:15	22.40	20.72	20.96	21.44	19.52	20.96	20.72	21.44	99.00	1:19:30	20.96	26.48	26.00	24.32	29.60	26.00	26.24	24.08	100.00
0:59:30	22.40	20.24	20.72	21.20	19.28	20.72	20.48	21.20	99.00	1:19:45	21.20	26.96	26.24	24.56	30.08	26.24	26.48	24.32	100.00
0:59:45	22.16	20.00	20.24	20.96	19.04	20.24	20.24	21.20	98.50	1:20:00	21.20	27.44	26.48	25.04	30.56	26.72	26.72	24.32	100.00
1:00:00	22.16	19.52	20.24	20.96	18.80	20.00	20.00	20.96	98.00	1:20:15	21.44	27.92	26.96	25.52	30.80	27.20	27.20	24.56	100.00
1:00:15	22.16	19.28	19.76	20.72	18.56	19.76	19.52	20.96	97.00	1:20:30	21.44	28.16	27.44	25.76	31.28	27.68	27.44	25.04	100.00
1:00:30	22.16	19.28	19.52	20.48	18.32	19.52	19.28	20.96	95.50	1:20:45	21.68	28.40	27.92	26.24	31.76	27.92	27.92	25.28	100.00

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
1:21:00	21.92	28.88	28.16	26.48	32.00	28.16	28.16	25.52	100.00
1:21:15	22.16	29.36	28.16	26.72	32.24	28.40	28.16	25.76	100.00
1:21:30	22.16	29.12	28.16	26.72	32.24	28.40	28.16	25.76	100.00
1:21:45	22.40	28.88	27.68	26.48	31.52	28.16	27.68	25.52	100.00
1:22:00	22.40	28.40	27.44	26.24	30.80	27.92	27.20	25.28	100.00
1:22:15	22.64	28.16	26.96	26.24	30.32	27.44	26.72	25.04	100.00
1:22:30	22.64	27.68	26.48	26.00	29.36	26.96	26.24	25.04	100.00
1:22:45	22.64	27.20	26.24	25.52	28.64	26.72	26.00	24.80	100.00
1:23:00	22.64	26.72	26.00	25.52	28.16	26.24	25.76	24.56	100.00
1:23:15	22.64	26.24	25.76	25.04	27.68	26.00	25.28	24.32	100.00
1:23:30	22.64	26.00	25.28	25.04	26.96	25.76	25.04	24.32	100.00
1:23:45	22.64	25.76	25.04	24.56	26.24	25.28	24.80	24.08	100.00
1:24:00	22.64	25.28	24.56	24.32	26.00	25.04	24.32	23.84	100.00
1:24:15	22.64	24.80	24.32	24.32	25.28	24.56	24.32	23.84	100.00
1:24:30	22.64	24.56	24.32	24.32	24.80	24.32	24.08	23.60	100.00
1:24:45	22.64	24.32	24.08	24.08	24.32	24.08	23.60	23.36	100.00
1:25:00	22.64	24.08	23.84	23.84	24.08	23.84	23.36	23.12	100.00
1:25:15	22.64	23.60	23.36	23.60	23.60	23.60	22.88	22.88	100.00
1:25:30	22.64	23.36	23.12	23.12	22.88	23.12	22.64	22.64	100.00
1:25:45	22.40	22.88	22.64	22.88	22.64	22.88	22.64	22.64	100.00
1:26:00	22.40	22.64	22.64	22.64	22.16	22.64	22.40	22.64	100.00
1:26:15	22.40	22.40	22.40	22.64	21.68	22.40	22.16	22.40	100.00
1:26:30	22.40	21.92	22.16	22.40	21.44	22.16	21.68	22.16	100.00
1:26:45	22.16	21.68	21.68	22.16	20.96	21.92	21.44	21.92	100.00
1:27:00	22.16	21.44	21.44	21.92	20.72	21.44	21.20	21.68	100.00
1:27:15	22.16	20.96	21.20	21.68	20.24	21.20	20.96	21.68	100.00
1:27:30	22.16	20.96	20.96	21.44	19.76	20.96	20.96	21.44	100.00
1:27:45	21.92	20.72	20.96	21.20	19.28	20.96	20.72	21.20	100.00
1:28:00	21.92	20.24	20.72	20.96	19.28	20.48	20.24	20.96	100.00
1:28:15	21.92	20.00	20.24	20.96	18.80	20.24	20.00	20.96	99.50
1:28:30	21.68	19.52	20.00	20.72	18.32	20.00	19.76	20.96	99.50
1:28:45	21.68	19.28	19.76	20.48	18.08	19.76	19.52	20.72	99.50
1:29:00	21.68	19.28	19.52	20.24	17.84	19.28	19.28	20.48	99.00
1:29:15	21.44	18.80	19.28	20.00	17.60	19.28	19.28	20.48	98.50
1:29:30	21.44	18.56	19.28	19.76	17.36	19.04	18.80	20.24	98.00
1:29:45	21.44	18.32	18.80	19.52	17.12	18.80	18.56	20.00	97.00
1:30:00	21.20	17.84	18.56	19.28	17.12	18.56	18.32	19.76	95.50
1:30:15	21.20	17.84	18.32	19.28	16.88	18.32	18.08	19.52	94.50
1:30:30	21.20	17.60	18.08	19.28	16.64	18.08	17.84	19.52	93.50
1:30:45	21.20	17.36	17.84	19.04	16.40	17.84	17.84	19.28	92.50
1:31:00	20.96	17.12	17.84	18.80	16.16	17.84	17.84	19.28	91.50
1:31:15	20.96	16.88	17.60	18.56	15.92	17.60	17.60	19.28	90.50
1:31:30	20.96	16.40	17.36	18.56	15.68	17.36	17.60	19.04	89.50
1:31:45	20.96	16.16	17.36	18.32	15.44	17.36	17.60	18.80	88.50
1:32:00	20.96	16.16	17.12	18.08	14.96	17.12	17.60	18.80	88.00
1:32:15	20.96	16.16	17.12	18.08	14.72	17.12	17.36	18.56	87.00
1:32:30	20.96	15.92	17.12	17.84	14.48	16.88	17.36	18.56	86.00
1:32:45	20.72	15.68	17.12	17.84	14.48	16.88	17.12	18.32	84.50
1:33:00	20.72	15.68	16.88	17.84	14.00	16.88	17.12	18.32	84.00
1:33:15	20.72	15.68	16.88	17.60	13.76	16.64	17.12	18.08	82.50
1:33:30	20.72	15.68	16.88	17.60	13.52	16.64	16.88	18.08	81.50
1:33:45	20.48	15.44	16.64	17.36	13.28	16.64	16.88	18.08	80.50
1:34:00	20.48	15.44	16.64	17.36	13.04	16.64	16.88	17.84	80.00
1:34:15	20.48	15.44	16.40	17.12	12.56	16.64	16.88	17.84	78.50
1:34:30	20.48	15.20	16.40	17.12	12.56	16.40	16.64	17.84	78.00
1:34:45	20.24	15.20	16.16	16.88	12.32	16.40	16.64	17.84	76.50
1:35:00	20.24	15.20	16.16	16.88	12.08	16.40	16.40	17.84	75.50
1:35:15	20.24	14.96	16.16	16.64	11.84	16.40	16.40	17.84	75.00
1:35:30	20.24	14.96	16.16	16.64	11.60	16.16	16.16	17.60	73.50
1:35:45	20.00	14.72	15.92	16.40	11.36	16.16	16.16	17.60	72.00
1:36:00	20.00	14.72	15.68	16.40	11.12	16.16	16.16	17.60	71.50
1:36:15	20.00	14.48	15.68	16.16	10.88	16.16	16.16	17.60	70.50
1:36:30	20.00	14.48	15.44	16.16	10.64	15.92	16.16	17.60	69.00
1:36:45	20.00	14.48	15.44	16.16	10.40	15.92	15.92	17.36	68.50
1:37:00	19.76	14.24	15.20	16.16	10.40	15.92	15.92	17.36	68.00
1:37:15	19.76	14.24	15.20	16.16	10.16	15.68	15.68	17.36	67.50
1:37:30	19.76	14.00	14.96	15.92	9.92	15.68	15.68	17.36	67.00
1:37:45	19.76	13.76	14.96	15.92	9.68	15.44	15.44	17.12	66.50
1:38:00	19.76	13.76	14.72	15.92	9.44	15.44	15.44	17.12	66.50
1:38:15	19.52	13.52	14.72	15.68	9.20	15.20	15.20	17.12	66.00
1:38:30	19.52	13.52	14.48	15.68	8.96	15.20	15.20	17.12	66.00
1:38:45	19.52	13.28	14.48	15.44	8.72	14.96	15.20	16.88	65.50
1:39:00	19.52	13.28	14.48	15.44	8.72	14.96	14.96	16.88	65.50
1:39:15	19.52	13.04	14.48	15.44	8.48	14.96	14.96	16.88	65.00
1:39:30	19.52	12.80	14.24	15.20	8.24	14.72	14.96	16.88	65.00
1:39:45	19.28	12.80	14.24	15.20	8.00	14.72	14.72	16.64	72.00
1:40:00	19.28	12.56	14.00	15.20	8.00	14.48	14.48	16.64	75.00
1:40:15	19.28	12.56	14.00	14.96	7.76	14.48	14.48	16.64	73.00
1:40:30	19.28	12.56	14.00	14.96	7.76	14.48	14.48	16.64	76.50
1:40:45	19.28	12.56	13.76	14.96	7.76	14.48	14.48	16.64	81.00
1:41:00	19.28	12.56	13.76	14.96	7.52	14.48	14.48	16.64	76.00

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
1:41:15	19.28	12.32	13.76	14.72	7.28	14.48	14.48	16.64	78.50
1:41:30	19.28	12.32	13.52	14.72	7.28	14.48	14.48	16.40	84.00
1:41:45	19.28	12.32	13.52	14.72	7.28	14.24	14.48	16.40	82.00
1:42:00	19.28	12.08	13.52	14.72	7.04	14.24	14.48	16.40	81.00
1:42:15	19.28	12.08	13.52	14.48	7.04	14.24	14.48	16.40	85.50
1:42:30	19.28	12.08	13.52	14.72	7.04	14.24	14.48	16.40	91.50
1:42:45	19.28	12.32	13.76	14.96	7.28	14.24	14.48	16.64	95.50
1:43:00	19.28	12.56	14.24	15.20	7.76	14.48	14.96	16.88	97.50
1:43:15	19.28	12.80	14.48	15.44	8.24	14.72	15.68	17.12	98.50
1:43:30	19.28	13.52	15.20	15.92	9.20	15.20	16.16	17.36	99.00
1:43:45	19.28	14.24	15.92	16.16	10.40	15.92	16.64	17.84	99.50
1:44:00	19.28	14.72	16.16	16.88	11.84	16.16	17.36	17.84	99.50
1:44:15	19.28	15.68	17.12	17.36	13.28	16.88	17.84	18.32	100.00
1:44:30	19.28	16.40	17.84	17.84	14.72	17.60	18.56	18.80	100.00
1:44:45	19.28	17.36	18.32	18.32	16.16	18.08	19.28	19.28	100.00
1:45:00	19.28	18.08	19.28	18.80	17.84	18.80	20.00	19.52	100.00
1:45:15	19.28	19.28	19.76	19.28	19.28	19.52	20.72	20.00	100.00
1:45:30	19.28	20.00	20.72	19.76	20.96	20.48	21.20	20.48	100.00
1:45:45	19.52	20.96	21.20	20.48	22.16	20.96	21.92	20.72	100.00
1:46:00	19.52	21.68	21.68	20.96	23.36	21.68	22.40	20.96	100.00
1:46:15	19.76	22.40	22.40	21.20	24.32	22.40	22.88	21.20	100.00
1:46:30	19.76	22.88	22.88	21.68	25.28	22.64	23.36	21.68	100.00
1:46:45	20.00	23.60	23.36	22.16	26.24	23.36	24.08	21.92	100.00
1:47:00	20.24	24.32	24.08	22.64	26.96	24.08	24.32	22.40	100.00
1:47:15	20.24	24.80	24.32	22.88	27.92	24.32	24.80	22.64	100.00
1:47:30	20.48	25.28	24.80	23.60	28.40	25.04	25.28	22.88	100.00
1:47:45	20.48	26.00	25.28	23.84	28.88	25.28	25.76	23.36	100.00
1:48:00	20.72	26.24	25.76	24.32	29.60	26.00	26.24	23.60	100.00
1:48:15	20.96	26.72	26.24	24.56	30.08	26.24	26.48	24.08	100.00
1:48:30	20.96	27.44	26.48	25.04	30.56	26.48	26.72	24.32	100.00
1:48:45	20.96	27.92	26.96	25.28	30.80	26.96	27.20	24.32	100.00
1:49:00	21.20	28.16	27.20	25.76	31.28	27.44	27.20	24.56	100.00
1:49:15	21.20	28.16	26.72	25.76	31.04	27.44	26.96	24.56	100.00
1:49:30	21.44	27.68	26.48	25.52	30.80	27.20	26.48	24.56	100.00
1:49:45	21.68	27.44	26.24	25.28	30.08	26.72	26.24	24.32	100.00
1:50:00	21.68	26.96	26.00	25.04	29.36	26.48	25.76	24.32	100.00
1:50:15	21.68	26.48	25.52	24.80	28.40	26.24	25.28	24.08	100.00
1:50:30	21.92	26.24	25.04	24.56	27.92	25.76	25.04	23.84	100.00
1:50:45	21.92	25.76	24.80	24.32	27.20	25.28	24.56	23.60	100.00
1:51:00	21.92	25.28	24.56	24.32	26.48	25.04	24.32	23.36	100.00
1:51:15	21.92	24.80	24.32	24.08	26.24	24.56	24.08	23.12	100.00
1:51:30	21.92	24.56	24.08	23.84	25.52	24.32	23.84	23.12	100.00
1:51:45	21.92	24.32	23.84	23.60	25.04	24.08	23.36	22.88	100.00
1:52:00	21.92	23.84	23.36	23.12	24.32	23.84	23.12	22.64	100.00
1:52:15	21.92	23.60	23.12	22.88	24.08	23.36	22.88	22.64	100.00
1:52:30	21.92	23.12	22.64	22.88	23.36	22.88	22.64	22.40	100.00
1:52:45	21.92	22.64	22.64	22.64	22.88	22.64	22.40	22.40	100.00
1:53:00	21.68	22.64	22.40	22.64	22.64	22.64	22.16	22.16	100.00
1:53:15	21.68	22.16	22.16	22.16	22.16	22.16	21.92	21.92	100.00
1:53:30	21.68	21.92	21.68	22.16	21.68	21.92	21.44	21.68	100.00
1:53:45	21.68	21.44	21.44	21.68	21.20	21.68	21.20	21.44	100.00
1:54:00	21.68	21.20	21.20	21.68	20.96	21.20	20.96	21.44	100.00
1:54:15	21.44	20.96	20.96	21.44	20.48	20.96	20.96	21.20	100.00
1:54:30	21.44	20.72	20.96	21.20	20.00	20.96	20.72	20.96	100.00
1:54:45	21.44	20.48	20.48	20.96	19.52	20.72	20.48	20.96	100.00
1:55:00	21.44	20.00	20.48	20.96	19.28	20.24	20.00	20.96	100.00
1:55:15	21.20	19.76	20.00	20.72	19.04	20.00	19.76	20.72	100.00
1:55:30	21.20	19.52	19.76	20.48	18.56	19.76	19.52	20.48	100.00
1:55:45	21.20	19.28	19.52	20.24	18.32	19.52	19.28	20.24	99.50
1:56:00	20.96	19.04	19.28	20.00	18.08	19.28	19.28	20.24	99.00
1:56:15	20.96	18.80	19.28	19.76	17.84	19.04	19.04	20.00	98.00
1:56:30	20.96	18.56	19.04	19.52	17.84	18.80	18.80	19.76	96.50
1:56:45	20.96	18.08	18.56	19.28	17.60	18.56	18.32	19.52	95.50
1:57:00	20.96	17.84	18.32	19.28	17.36	18.32	18.08	19.28	94.50
1:57:15	20.96	17.84	18.08	19.04	17.12	18.08	17.84	19.28	93.50
1:57:30	20.96	17.36	17.84	18.80	16.88	17.84	17.84	19.28	92.50
1:57:45	20.72	17.12	17.84	18.80	16.40	17.84	17.84	19.28	91.50
1:58:00	20.72	16.88	17.60	18.56	16.16	17.60	17.60	19.04	90.50
1:58:15	20.72	16.64	17.36	18.32	16.16	17.36	17.60	18.80	90.00
1:58:30	20.48	16.16	17.36	18.32	15.68	17.36	17.60	18.80	89.00
1:58:45	20.48	16.16	17.36	18.08	15.44	17.12	17.60	18.56	88.00
1:59:00	20.48	16.16	17.12	17.84	15.20	17.12	17.36	18.32	87.00
1:59:15	20.48	15.92	17.12	17.84	14.72	16.88	17.36	18.32	86.00
1:59:30	20.24	15.92	17.12	17.84	14.48	16.88	17.12	18.32	84.50
1:59:45	20.24	15.92	16.88	17.60	14.48	16.64	17.12	18.08	84.00
2:00:00	20.24	15.68	16.88	17.60	14.00	16.64	16.88	18.08	83.00
2:00:15	20.24	15.68	16.64	17.36	13.76	16.64	16.88	17.84	82.00
2:00:30	20.00	15.44	16.64	17.12	13.52	16.64	16.88	17.84	80.50
2:00:45	20.00	15.44	16.40	17.12	13.04	16.40	16.64	17.84	80.50
2:01:00	20.00	15.44	16.40	16.88	12.80	16.40	16.64	17.84	79.50
2:01:15	20.00	15.20	16.16	16.88	12.56	16.40	16.64	17.84	78.50

Time	Int T	Clay S	B72 S	Gze S	AT	Clay R	B72 R	Gze R	RH
2:01:30	19.76	15.20	16.16	16.64	12.56	16.40	16.40	17.60	78.00
2:01:45	19.76	15.20	16.16	16.64	12.32	16.16	16.40	17.60	76.50
2:02:00	19.76	14.96	16.16	16.40	11.84	16.16	16.16	17.60	75.50
2:02:15	19.76	14.96	15.92	16.40	11.60	16.16	16.16	17.60	75.00
2:02:30	19.52	14.72	15.92	16.16	11.36	16.16	16.16	17.36	73.50
2:02:45	19.52	14.48	15.68	16.16	11.12	16.16	16.16	17.36	72.50
2:03:00	19.52	14.48	15.44	16.16	10.88	16.16	15.92	17.12	71.50
2:03:15	19.52	14.48	15.44	16.16	10.64	15.92	15.92	17.12	71.50
2:03:30	19.52	14.48	15.20	16.16	10.40	15.92	15.68	17.12	70.50
2:03:45	19.28	14.24	15.20	15.92	10.40	15.68	15.68	17.12	69.50
2:04:00	19.28	14.00	14.96	15.92	10.16	15.68	15.44	17.12	69.00
2:04:15	19.28	14.00	14.96	15.92	9.92	15.44	15.44	16.88	68.50
2:04:30	19.28	13.76	14.72	15.68	9.68	15.44	15.44	16.88	68.00
2:04:45	19.28	13.76	14.72	15.68	9.44	15.20	15.20	16.88	67.50
2:05:00	19.28	13.52	14.48	15.44	9.20	15.20	15.20	16.88	67.50
2:05:15	19.28	13.52	14.48	15.44	8.96	14.96	14.96	16.64	66.50
2:05:30	19.28	13.28	14.48	15.44	8.96	14.96	14.96	16.64	66.50
2:05:45	19.28	13.04	14.48	15.20	8.72	14.96	14.96	16.64	66.50
2:06:00	19.28	13.04	14.24	15.20	8.48	14.72	14.72	16.64	66.00
2:06:15	19.28	12.80	14.24	14.96	8.24	14.72	14.72	16.40	66.00
2:06:30	19.04	12.80	14.00	14.96	8.00	14.48	14.48	16.40	65.50
2:06:45	19.04	12.56	14.00	14.96	8.00	14.48	14.48	16.40	72.00
2:07:00	19.04	12.56	14.00	14.72	7.76	14.48	14.48	16.40	76.00
2:07:15	19.04	12.56	13.76	14.72	7.76	14.48	14.48	16.40	72.50
2:07:30	19.04	12.56	13.76	14.72	7.76	14.48	14.48	16.16	76.50
2:07:45	19.04	12.32	13.76	14.72	7.52	14.24	14.48	16.16	80.50
2:08:00	19.04	12.32	13.52	14.48	7.52	14.24	14.48	16.16	78.50
2:08:15	18.80	12.32	13.52	14.48	7.28	14.24	14.24	16.16	80.50
2:08:30	18.80	12.08	13.52	14.48	7.28	14.24	14.24	16.16	84.00
2:08:45	18.80	12.08	13.28	14.48	7.04	14.00	14.24	16.16	81.50
2:09:00	18.80	12.08	13.28	14.48	7.04	14.00	14.24	16.16	82.50
2:09:15	18.80	12.08	13.52	14.48	7.04	14.00	14.24	16.16	90.50
2:09:30	18.80	12.08	13.76	14.48	7.28	14.24	14.48	16.16	95.00
2:09:45	18.80	12.56	14.00	14.96	7.52	14.48	14.72	16.40	97.50
2:10:00	18.80	12.80	14.48	15.20	8.00	14.48	15.44	16.88	98.50
2:10:15	18.80	13.28	14.96	15.68	9.20	14.96	15.92	17.12	99.00
2:10:30	18.80	14.00	15.68	16.16	10.40	15.44	16.40	17.36	99.50
2:10:45	18.80	14.48	16.16	16.40	11.60	16.16	17.12	17.84	100.00
2:11:00	18.80	15.44	16.64	16.88	12.80	16.40	17.84	17.84	100.00
2:11:15	18.80	16.16	17.36	17.60	14.48	17.12	18.32	18.32	100.00
2:11:30	18.80	17.12	18.08	17.84	15.92	17.84	19.04	18.80	100.00
2:11:45	19.04	17.84	18.80	18.56	17.60	18.56	19.52	19.28	100.00
2:12:00	19.04	18.80	19.52	19.04	19.04	19.28	20.48	19.52	100.00
2:12:15	19.04	19.76	20.48	19.52	20.48	20.00	20.96	20.00	100.00
2:12:30	19.28	20.72	20.96	20.24	21.92	20.96	21.68	20.48	100.00
2:12:45	19.28	21.44	21.68	20.72	23.12	21.44	22.40	20.96	100.00
2:13:00	19.28	22.16	22.16	20.96	24.32	22.16	22.64	20.96	100.00
2:13:15	19.28	22.64	22.64	21.44	25.28	22.64	23.12	21.44	100.00
2:13:30	19.52	23.36	23.12	21.92	26.24	23.12	23.84	21.68	100.00
2:13:45	19.76	24.08	23.60	22.40	26.96	23.84	24.32	22.16	100.00
2:14:00	19.76	24.56	24.32	22.64	27.68	24.32	24.56	22.40	100.00
2:14:15	20.00	25.28	24.56	23.12	28.16	24.80	25.04	22.64	100.00
2:14:30	20.24	25.76	25.04	23.60	28.88	25.28	25.28	23.12	100.00
2:14:45	20.24	26.24	25.52	24.08	29.36	25.76	26.00	23.36	100.00
2:15:00	20.48	26.72	26.00	24.32	30.08	26.24	26.24	23.60	100.00
2:15:15	20.48	27.20	26.24	24.80	30.56	26.48	26.48	24.08	100.00
2:15:30	20.72	27.68	26.72	25.04	30.80	26.96	26.72	24.32	100.00
2:15:45	20.96	28.16	27.20	25.52	31.28	27.20	27.20	24.56	100.00
2:16:00	20.96	28.16	27.68	26.00	31.52	27.68	27.68	24.80	100.00
2:16:15	20.96	28.64	27.68	26.00	32.00	27.92	27.68	25.04	100.00
2:16:30	21.20	27.68	25.76	25.04	31.28	26.96	25.52	24.08	100.00
2:16:45	21.20	26.24	24.32	24.08	29.36	25.76	24.08	23.12	100.00

INSULATION: Low Temperature

Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH	Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:00:00	20.48	22.64	22.40	21.92	26.72	21.92	21.68	21.20	47.00	0:20:15	18.32	13.04	15.92	16.16	9.44	14.72	16.64	16.40	97.50
0:00:15	20.48	22.64	22.16	21.92	26.48	21.92	21.44	21.20	49.00	0:20:30	18.32	13.28	15.92	16.16	9.44	14.96	16.64	16.40	97.50
0:00:30	20.48	22.64	22.16	21.68	26.48	21.92	21.44	21.20	58.50	0:20:45	18.32	13.28	15.92	16.16	9.44	14.96	16.64	16.40	97.50
0:00:45	20.48	22.88	22.16	21.68	26.48	22.16	21.44	21.20	79.50	0:21:00	18.32	13.28	15.92	16.16	9.44	14.96	16.64	16.40	97.00
0:01:00	20.48	23.36	22.16	21.92	26.48	22.64	21.44	21.20	86.00	0:21:15	18.32	13.04	15.92	16.16	9.20	14.96	16.64	16.40	95.50
0:01:15	20.48	23.60	22.40	21.92	26.24	22.64	21.44	21.20	83.00	0:21:30	18.32	13.04	15.92	16.16	8.96	14.96	16.64	16.40	92.00
0:01:30	20.48	23.36	22.40	22.16	26.24	22.64	21.44	21.20	76.00	0:21:45	18.32	12.80	15.92	16.16	8.72	14.96	16.64	16.40	87.00
0:01:45	20.48	23.36	22.40	21.92	26.24	22.64	21.68	21.44	67.50	0:22:00	18.32	12.80	15.68	16.16	8.72	14.72	16.64	16.40	82.00
0:02:00	20.48	23.12	22.40	21.92	26.24	22.40	21.68	21.44	60.00	0:22:15	18.08	12.56	15.68	16.16	8.48	14.72	16.64	16.40	77.50
0:02:15	20.48	22.88	22.40	21.92	26.00	22.16	21.44	21.20	54.00	0:22:30	18.08	12.56	15.68	16.16	8.48	14.48	16.40	16.40	74.00
0:02:30	20.48	22.64	22.40	21.92	25.76	22.16	21.44	21.20	49.00	0:22:45	18.08	12.56	15.44	16.16	8.24	14.48	16.40	16.40	71.50
0:02:45	20.48	22.64	22.16	21.68	25.52	21.92	21.44	21.20	45.00	0:23:00	18.08	12.56	15.44	15.92	8.24	14.48	16.40	16.16	69.00
0:03:00	20.48	22.40	22.16	21.68	25.28	21.68	21.44	21.20	43.00	0:23:15	18.08	12.32	15.44	15.92	8.00	14.48	16.40	16.16	67.50
0:03:15	20.48	22.16	21.92	21.68	24.80	21.68	21.20	20.96	41.50	0:23:30	18.08	12.32	15.20	15.92	8.00	14.48	16.40	16.16	66.00
0:03:30	20.48	21.92	21.92	21.44	24.56	21.44	21.20	20.96	40.50	0:23:45	18.08	12.08	15.20	15.92	7.76	14.24	16.16	16.16	65.00
0:03:45	20.48	21.68	21.68	21.44	24.32	21.20	20.96	20.96	39.50	0:24:00	17.84	12.08	15.20	15.68	7.76	14.24	16.16	16.16	64.00
0:04:00	20.48	21.44	21.68	21.20	24.08	21.20	20.96	20.96	37.00	0:24:15	17.84	11.84	14.96	15.68	7.76	14.24	16.16	16.16	63.50
0:04:15	20.48	21.20	21.44	21.20	23.60	20.96	20.96	20.96	34.50	0:24:30	17.84	11.84	14.96	15.68	7.52	14.00	16.16	16.16	62.50
0:04:30	20.48	20.96	21.44	21.20	23.12	20.96	20.96	20.72	32.00	0:24:45	17.84	11.60	14.96	15.68	7.52	14.00	16.16	16.16	65.00
0:04:45	20.24	20.96	21.20	20.96	22.64	20.96	20.96	20.72	31.00	0:25:00	17.84	11.60	14.72	15.44	7.28	14.00	16.16	15.92	84.50
0:05:00	20.24	20.96	21.20	20.96	22.64	20.72	20.96	20.72	31.00	0:25:15	17.84	11.36	14.72	15.44	7.28	13.76	16.16	15.92	91.00
0:05:15	20.24	20.72	20.96	20.96	22.16	20.72	20.96	20.48	31.50	0:25:30	17.84	11.36	14.72	15.20	7.28	13.52	15.92	15.92	94.00
0:05:30	20.24	20.48	20.96	20.96	21.68	20.48	20.72	20.48	32.00	0:25:45	17.84	11.36	14.48	15.20	7.28	13.52	15.92	15.68	95.50
0:05:45	20.24	20.24	20.96	20.96	21.44	20.48	20.72	20.48	32.00	0:26:00	17.84	11.36	14.48	15.20	7.28	13.52	15.92	15.68	96.50
0:06:00	20.24	20.24	20.96	20.96	20.96	20.24	20.48	20.24	30.50	0:26:15	17.84	11.36	14.48	15.20	7.52	13.52	15.92	15.68	97.00
0:06:15	20.24	20.00	20.96	20.72	20.96	20.00	20.48	20.24	29.00	0:26:30	17.84	11.60	14.48	14.96	7.52	13.52	15.68	15.68	97.00
0:06:30	20.00	19.76	20.72	20.72	20.48	19.76	20.48	20.24	27.50	0:26:45	17.84	11.60	14.48	14.96	7.52	13.52	15.68	15.68	97.50
0:06:45	20.00	19.52	20.72	20.48	20.24	19.76	20.24	20.00	26.00	0:27:00	17.84	11.60	14.48	14.96	7.76	13.52	15.68	15.68	98.00
0:07:00	20.00	19.28	20.48	20.48	19.76	19.52	20.24	20.00	25.50	0:27:15	17.84	11.60	14.48	14.96	7.76	13.76	15.68	15.68	98.00
0:07:15	20.00	19.28	20.48	20.48	19.28	19.52	20.00	19.76	25.00	0:27:30	17.84	11.60	14.48	15.20	7.76	13.76	15.68	15.68	97.50
0:07:30	20.00	19.04	20.24	20.24	19.28	19.28	20.00	19.76	24.50	0:27:45	17.84	11.60	14.48	15.20	7.52	13.76	15.68	15.68	97.00
0:07:45	20.00	19.04	20.24	20.24	18.80	19.28	20.00	19.52	24.50	0:28:00	17.84	11.60	14.48	14.96	7.28	13.76	15.68	15.68	96.00
0:08:00	19.76	18.80	20.00	20.00	18.56	19.28	19.76	19.52	24.00	0:28:15	17.60	11.36	14.48	14.96	7.28	13.76	15.68	15.68	93.00
0:08:15	19.76	18.56	19.76	20.00	18.32	19.04	19.76	19.52	24.00	0:28:30	17.60	11.36	14.48	14.96	7.04	13.76	15.68	15.68	88.50
0:08:30	19.76	18.32	19.76	19.76	17.84	19.04	19.52	19.28	23.50	0:28:45	17.60	11.12	14.48	14.96	6.80	13.52	15.68	15.44	84.50
0:08:45	19.76	18.32	19.52	19.76	17.84	18.80	19.52	19.28	23.50	0:29:00	17.60	11.12	14.48	14.96	6.56	13.52	15.68	15.44	80.50
0:09:00	19.76	18.08	19.52	19.52	17.36	18.80	19.52	19.28	23.50	0:29:15	17.60	10.88	14.48	14.72	6.56	13.52	15.68	15.44	77.00
0:09:15	19.76	17.84	19.28	19.52	17.12	18.56	19.28	19.28	23.50	0:29:30	17.60	10.88	14.24	14.72	6.32	13.28	15.68	15.44	75.00
0:09:30	19.52	17.84	19.28	19.52	16.64	18.32	19.28	19.28	23.50	0:29:45	17.60	10.88	14.24	14.72	6.32	13.28	15.44	15.44	73.50
0:09:45	19.52	17.60	19.28	19.28	16.40	18.32	19.28	19.28	23.50	0:30:00	17.60	10.64	14.24	14.72	6.32	13.28	15.44	15.20	72.50
0:10:00	19.52	17.60	19.28	19.28	16.16	18.08	19.28	19.04	23.50	0:30:15	17.36	10.64	14.00	14.48	6.08	13.04	15.44	15.20	71.50
0:10:15	19.52	17.36	19.28	19.28	15.92	18.08	19.28	19.04	23.50	0:30:30	17.36	10.64	14.00	14.48	6.08	13.04	15.44	15.20	71.00
0:10:30	19.52	17.12	19.04	19.28	15.68	17.84	19.28	18.80	23.50	0:30:45	17.36	10.40	14.00	14.48	5.84	13.04	15.44	15.20	70.00
0:10:45	19.52	17.12	19.04	19.04	15.44	17.84	19.04	18.80	23.50	0:31:00	17.36	10.40	14.00	14.48	5.84	13.04	15.20	15.20	71.00
0:11:00	19.28	16.88	18.80	19.04	15.20	17.84	19.04	18.80	23.50	0:31:15	17.36	10.40	14.00	14.48	5.84	13.04	15.20	15.20	70.50
0:11:15	19.28	16.64	18.80	19.04	14.72	17.84	18.80	18.56	23.50	0:31:30	17.36	10.40	13.76	14.48	5.60	12.80	15.20	15.20	76.00
0:11:30	19.28	16.40	18.56	18.80	14.48	17.60	18.80	18.56	23.50	0:31:45	17.36	10.40	13.76	14.48	5.60	12.80	15.20	14.96	90.00
0:11:45	19.28	16.40	18.56	18.80	14.48	17.60	18.80	18.56	23.50	0:32:00	17.36	10.40	13.76	14.48	5.84	12.56	15.20	14.96	93.50
0:12:00	19.28	16.16	18.32	18.56	14.24	17.36	18.80	18.32	23.50	0:32:15	17.12	10.40	13.76	14.48	5.84	12.56	14.96	14.96	95.00
0:12:15	19.28	16.16	18.32	18.56	14.00	17.36	18.56	18.32	23.50	0:32:30	17.12	10.40	13.52	14.24	5.84	12.56	14.96	14.72	95.50
0:12:30	19.28	15.92	18.08	18.56	13.76	17.12	18.56	18.32	23.50	0:32:45	17.12	10.40	13.52	14.24	5.84	12.56	14.96	14.72	96.00
0:12:45	19.28	15.92	18.08	18.32	13.28	17.12	18.32	18.08	23.50	0:33:00	17.12	10.40	13.52	14.24	5.84	12.56	14.96	14.72	97.00
0:13:00	19.28	15.68	17.84	18.32	13.04	16.88	18.32	18.08	23.50	0:33:15	17.12	10.40	13.52	14.24	5.84	12.56	14.72	14.72	97.00
0:13:15	19.28	15.68	17.84	18.08	12.80	16.88	18.32	17.84	24.00	0:33:30	17.12	10.40	13.52	14.24	5.84	12.56	14.72	14.72	97.00
0:13:30	19.28	15.44	17.84	18.08	12.56	16.64	18.32	17.84	24.00	0:33:45	17.12	10.40	13.52	14.24	6.08	12.56	14.72	14.72	97.50
0:13:45	19.28	15.20	17.84	17.84	12.56	16.64	18.08	17.84	24.00	0:34:00	17.12	10.40	13.52	14.24	6.08	12.56	14.72	14.72	97.50
0:14:00	19.28	15.20	17.84	17.84	12.32	16.40	18.08	17.84	24.00	0:34:15	17.12	10.40	13.52	14.24	6.08	12.56	14.72	14.72	97.50
0:14:15	19.04	14.96	17.60	17.84	12.08	16.40	18.08	17.84	24.00	0:34:30	17.12	10.40	13.52	14.24	5.84	12.56	14.72	14.72	97.00
0:14:30	19.04	14.96	17.60	17.84	11.84	16.16	17.84	17.84	24.00	0:34:45	16.88	10.40	13.52	14.24	5.84	12.56	14.72	14.72	96.00
0:14:45	19.04	14.72	17.36	17.84	11.60	16.16	17.84	17.84	24.00	0:35:00	16.88	10.40	13.52	14.24	5.60	12.56	14.72	14.72	94.00
0:15:00	19.04	14.48	17.36	17.84	11.36	16.16	17.84	17.84	24.00	0:35:15	16.88	10.40	13.28	14.24	5.36	12.56	14.72	14.72	90.50
0:15:15	19.04	14.48	17.12	17.60	11.12	16.16	17.84	17.60	24.00	0:35:30	16.88	10.16	13.28	14.00	5.36	12.56	14.72	14.72	87.00
0:15:30	19.04	14.48	17.12	17.60	11.12	15.92	17.84	17.60	24.00	0:35:45	16.88	10.16	13.28	14.00	5.12	12.56	14.72	14.72	84.00
0:15:45	18.80	14.24	17.12	17.60	10.88	15.92	17.84	17.60	24.00	0:36:00	16.88	10.16	13.28	14.00	5.12	12.56	14.72	14.48	82.50
0:16:00	18.80	14.24	16.88	17.36	10.64	15.92	17.60	17.36	24.00	0:36:15	16.88	9.92	13.28	14.00	5.12	12.56	14.72	14.48	80.50
0:16:15	18.80	14.00	16.88	17.36	10.40	15.92	17.60	17.36	24.00	0:36:30	16.88	9.92	13.04	14.00	5.12	12.56	14.72	14.48	78.50
0:16:30	18.80	14.00	16.64	17.12	10.40	15.68	17.60	17.36	24.50	0:36:45	16.88	9.92	13.04	14.00	5.12	12.56	14.72	14.48	77.50
0:16:45	18.80	13.76	16.64	17.12	10.16	15.44	17.60	17.12	24.50	0:37:00	16.64	9.92	13.04	14.00	4.88	12.32	14.48	14.48	76.50
0:17:00	18.80	13.76	16.40	17.12	9.92	15.44	17.36	17.12	24.50	0:37:15	16.64	9.92	13.04	13.76	4.88	12.32	14.48	14.48	75.50
0:17:15	18.80	13.52	16.40	17.12	9.68	15.44	17.36	17.12	24.50	0:37:30	16.64	9.68	13.04	13.76	4.88	12.32	14.48	14.48	75.00
0:17:30	18.56	13.28	16.40	16.88	9.44	15.44	17.36	17.12	24.50	0:37:45	16.64	9.68	13.04	13.76	4.88	12.32	14.48	14.48	74.00
0:17:45	18.56	13.28	16.16	16.88	9.44	15.20	17.12	16.88	24.50	0:38:00	16.64	9.68	13.04	13.76	4.88	12.32	14.48	14.48	73.50
0:18:00	18.56	13.04	16.16	16.64	9.20	15.20	17.12	16.88	55.50	0:38:15	16.64	9.68	12.80	13.76	4.88	12.32	14.48	14.48	82.50
0:18:15	18.56	13.04	16.16	16.64	9.20	14.96	17.12	16.88	78.50	0:38:30	16.64	9.68	12.80	13.76	4.88	12.32	14.48	14.48	92.50
0:18:30	18.56	12.80	16.16	16.40	8.96	14.96	16.88	16.64	87.50	0:38:45	16.64	9.68	12.80	13.52	5.12	12.32	14.48	14.48	95.00
0:18:45	18.56	12.80	16.16	16.40	8.96	14.72	16.88	16.64	91.50	0:39:00	16.64	9.68	12.80	13.52	5.12	12.08	14.48	14.48	96.00
0:19:00	18.32	12.80	15.92	16.40	8.96	14.72	16.88	16.40	94.00	0:39:15	16.40	9.68	12.80	13.52	5.12	12.08	14.48	14.48	97.00
0:19:15	18.32	13.04	15.92	16.16	8.96	14.72	16.64	16.40	95.50	0:39:30	16.40	9.44	12.80	13.28	5.36	11.84	14.48	14.24	97.00
0:19:30	18.32	13.04	15.92	16.16	9.20	14.72	16.64	16.40	96.50	0:39:45	16.40	9.44	12.56	13.28	5.36	11.84	14.48	14.24	97.50
0:19:45	18.32	13.04	15.92	16.16	9.20	14.72	16.64	16.40	97.00	0:40:00	16.40	9.68	12.56	13.28	5.36	11.84	14.48	14.24	98.00
0:20:00	18.32	13.04	15.92	16.16	9.44	14.72	16.64	16.40	97.00	0:40:15	16.40	9.68	12.56	13.28	5.60	11.84	14.24	14.24	98.00

Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:40:30	16.40	9.68	12.56	13.28	5.60	11.84	14.24	14.24	98.00
0:40:45	16.40	9.68	12.56	13.28	5.60	11.84	14.24	14.24	98.00
0:41:00	16.40	9.68	12.56	13.28	5.60	11.84	14.24	14.24	98.50
0:41:15	16.40	9.68	12.56	13.28	5.84	11.84	14.24	14.24	98.50
0:41:30	16.40	9.68	12.56	13.28	5.84	12.08	14.24	14.24	98.50
0:41:45	16.16	9.68	12.56	13.28	5.84	12.08	14.24	14.24	98.50
0:42:00	16.16	9.68	12.56	13.28	5.84	12.08	14.24	14.24	98.50
0:42:15	16.16	9.68	12.56	13.28	5.60	12.08	14.24	14.24	98.00
0:42:30	16.16	9.68	12.56	13.28	5.60	12.08	14.24	14.24	98.00
0:42:45	16.16	9.44	12.56	13.28	5.36	12.08	14.24	14.24	97.00
0:43:00	16.16	9.44	12.56	13.28	5.12	12.08	14.24	14.24	96.00
0:43:15	16.16	9.44	12.56	13.28	4.88	12.08	14.24	14.24	94.50
0:43:30	16.16	9.44	12.56	13.28	4.88	12.08	14.24	14.24	92.50
0:43:45	16.16	9.44	12.56	13.04	4.64	12.08	14.24	14.00	90.50
0:44:00	16.16	9.44	12.56	13.04	4.64	12.08	14.24	14.00	88.00
0:44:15	16.16	9.44	12.56	13.04	4.40	12.08	14.24	14.00	87.00
0:44:30	16.16	9.44	12.56	13.04	4.40	11.84	14.24	14.00	85.00
0:44:45	16.16	9.44	12.56	13.04	4.40	11.84	14.24	14.00	83.50
0:45:00	16.16	9.20	12.56	13.04	4.40	11.84	14.24	14.00	82.50
0:45:15	16.16	9.20	12.56	13.04	4.40	11.84	14.00	14.00	81.50
0:45:30	16.16	9.20	12.56	13.04	4.40	11.84	14.00	14.00	80.50
0:45:45	16.16	9.20	12.56	13.04	4.40	11.84	14.00	14.00	79.00
0:46:00	16.16	9.20	12.32	13.04	4.40	11.84	14.00	14.00	78.50
0:46:15	16.16	9.20	12.32	13.04	4.40	11.84	14.00	14.00	78.00
0:46:30	16.16	9.20	12.32	13.04	4.40	11.84	14.00	13.76	77.00
0:46:45	16.16	9.20	12.32	12.80	4.40	11.84	14.00	13.76	76.50
0:47:00	16.16	9.20	12.32	12.80	4.40	11.84	14.00	13.76	76.00
0:47:15	15.92	9.20	12.32	12.80	4.40	11.84	14.00	13.76	81.00
0:47:30	15.92	8.96	12.32	12.80	4.64	11.84	14.00	13.76	91.50
0:47:45	15.92	8.96	12.32	12.80	4.64	11.60	14.00	13.76	95.00
0:48:00	15.92	8.96	12.32	12.80	4.88	11.36	13.76	13.76	96.50
0:48:15	15.92	8.96	12.32	12.56	4.88	11.36	13.76	13.76	97.00
0:48:30	15.92	8.96	12.08	12.56	5.12	11.36	13.76	13.52	98.00
0:48:45	15.92	9.20	12.08	12.56	5.12	11.36	13.76	13.52	98.00
0:49:00	15.92	9.20	12.08	12.56	5.36	11.36	13.76	13.52	98.50
0:49:15	15.92	9.92	12.32	12.56	5.60	12.08	13.76	13.52	98.50

INSULATION: Medium Temperature

Time	IntT	None S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:00:00	17.84	14.48	15.44	16.16	9.68	16.64	16.88	17.12	100.00
0:00:15	17.84	14.48	15.68	16.16	10.16	16.64	16.88	17.12	100.00
0:00:30	17.84	13.76	15.68	16.16	10.16	15.92	17.12	17.36	99.50
0:00:45	17.84	13.04	15.44	15.92	9.68	15.68	16.88	17.12	99.00
0:01:00	17.84	13.04	15.20	15.68	9.20	15.44	16.88	16.88	97.50
0:01:15	17.84	13.04	15.20	15.68	8.96	15.20	16.64	16.88	94.50
0:01:30	17.84	13.04	15.20	15.68	8.96	15.20	16.64	16.64	90.50
0:01:45	17.84	13.28	15.20	15.68	9.20	15.20	16.64	16.64	87.50
0:02:00	17.84	13.28	15.20	15.68	9.44	15.20	16.64	16.64	85.50
0:02:15	17.84	13.52	15.20	15.68	9.92	15.20	16.64	16.64	84.00
0:02:30	17.84	13.52	15.20	15.68	10.16	15.20	16.64	16.64	82.50
0:02:45	17.84	13.52	15.20	15.92	10.40	15.44	16.64	16.64	80.50
0:03:00	17.84	13.52	15.20	15.92	10.40	15.44	16.64	16.64	79.50
0:03:15	17.84	13.76	15.20	15.92	10.64	15.44	16.64	16.64	78.50
0:03:30	17.84	13.76	15.44	15.92	10.64	15.44	16.64	16.64	77.50
0:03:45	17.84	13.76	15.44	15.92	10.88	15.44	16.64	16.64	76.50
0:04:00	17.84	14.00	15.44	15.92	11.12	15.44	16.64	16.64	76.50
0:04:15	17.84	14.00	15.44	15.92	11.36	15.68	16.64	16.64	88.50
0:04:30	17.84	14.24	15.44	15.92	11.60	15.68	16.64	16.64	95.00
0:04:45	17.84	14.24	15.44	16.16	11.84	15.68	16.64	16.64	97.00
0:05:00	17.84	14.48	15.68	16.16	12.08	15.92	16.88	16.64	98.50
0:05:15	17.84	14.48	15.68	16.16	12.56	15.92	16.88	16.88	99.00
0:05:30	17.84	14.48	15.68	16.16	12.80	16.16	16.88	16.88	99.50
0:05:45	17.84	14.72	15.92	16.16	13.04	16.16	16.88	16.88	99.50
0:06:00	17.84	14.72	15.92	16.16	13.28	16.16	16.88	16.88	100.00
0:06:15	17.84	14.72	15.92	16.16	13.28	16.16	17.12	16.88	100.00
0:06:30	17.84	14.48	15.92	16.16	13.04	16.16	17.12	16.88	99.50
0:06:45	17.84	14.48	15.92	16.16	13.04	16.16	17.12	16.88	99.50
0:07:00	17.84	14.48	15.92	16.16	12.80	16.16	17.12	16.88	99.00
0:07:15	17.84	14.48	15.92	16.16	12.56	16.16	17.12	16.88	99.00
0:07:30	17.84	14.48	15.92	16.16	12.56	16.16	17.12	16.88	97.50
0:07:45	17.84	14.48	15.92	16.16	12.56	16.16	17.12	16.88	95.50
0:08:00	17.84	14.48	16.16	16.16	12.56	16.16	17.12	16.88	92.50
0:08:15	17.84	14.48	15.92	16.16	12.56	16.16	17.12	16.88	90.00
0:08:30	17.84	14.48	15.92	16.16	12.56	15.92	17.12	16.88	88.00
0:08:45	17.84	14.48	15.92	16.16	12.56	15.92	17.12	16.88	86.50
0:09:00	17.84	14.48	16.16	16.16	12.56	15.92	17.12	16.88	84.50
0:09:15	17.84	14.48	16.16	16.16	12.56	15.92	17.12	16.88	83.00
0:09:30	17.84	14.48	16.16	16.16	12.56	15.92	17.12	16.88	81.50
0:09:45	17.84	14.48	16.16	16.16	12.56	15.92	17.12	16.88	80.50
0:10:00	17.84	14.48	16.16	16.16	12.56	15.92	17.12	16.88	79.00
0:10:15	17.84	14.48	16.16	16.16	12.56	15.92	17.12	16.88	78.00
0:10:30	17.84	14.48	16.16	16.16	12.56	15.92	17.12	16.88	76.50
0:10:45	17.84	14.48	16.16	16.16	12.56	15.92	16.88	16.88	75.50
0:11:00	17.84	14.48	16.16	16.16	12.56	15.92	16.88	16.88	75.00
0:11:15	17.84	14.48	16.16	16.16	12.56	15.92	17.12	16.88	75.00
0:11:30	17.84	14.48	16.16	16.16	12.56	15.92	17.12	16.88	87.50
0:11:45	17.84	14.72	16.16	16.16	12.80	16.16	17.12	16.88	94.00
0:12:00	17.84	14.72	16.16	16.16	13.04	16.16	17.12	16.88	96.50
0:12:15	17.84	14.96	16.16	16.40	13.04	16.16	17.12	16.88	98.00
0:12:30	17.84	15.20	16.16	16.40	13.52	16.16	17.12	16.88	98.50
0:12:45	17.84	15.20	16.16	16.40	13.76	16.16	17.12	16.88	99.00
0:13:00	17.84	15.20	16.16	16.40	13.76	16.16	17.12	16.88	99.00
0:13:15	17.84	15.20	16.16	16.40	13.76	16.16	17.12	16.88	99.00
0:13:30	17.84	14.96	16.16	16.40	13.76	16.16	17.12	16.88	99.00
0:13:45	17.84	14.96	16.16	16.40	13.52	16.16	17.12	16.88	98.00
0:14:00	17.84	14.96	16.16	16.40	13.28	16.16	17.12	16.88	97.00
0:14:15	17.84	14.96	16.16	16.40	13.04	16.16	17.12	16.88	94.00
0:14:30	17.84	14.72	16.16	16.40	13.04	16.16	17.12	16.88	90.00
0:14:45	17.84	14.72	16.16	16.40	12.80	16.16	17.12	16.88	87.00
0:15:00	17.84	14.72	16.16	16.40	12.80	16.16	17.12	16.88	84.00
0:15:15	17.84	14.72	16.16	16.40	12.80	16.16	17.12	16.88	81.50
0:15:30	17.84	14.96	16.16	16.40	12.80	16.16	17.12	16.88	80.00
0:15:45	17.84	14.96	16.16	16.40	12.80	16.16	17.12	16.88	78.50
0:16:00	17.84	14.96	16.16	16.40	13.04	16.16	17.12	16.88	76.00
0:16:15	17.84	14.96	16.16	16.40	13.04	16.16	17.12	16.88	75.00
0:16:30	17.84	14.96	16.16	16.40	13.04	16.16	17.12	16.88	73.50
0:16:45	17.84	14.96	16.16	16.40	13.04	16.16	17.12	16.88	72.00
0:17:00	17.84	14.96	16.16	16.40	13.04	16.16	17.12	16.88	71.50
0:17:15	17.84	14.96	16.16	16.40	13.28	16.16	17.12	16.88	71.00
0:17:30	17.84	14.96	16.16	16.40	13.28	16.16	17.12	16.88	70.00
0:17:45	17.84	14.96	16.16	16.40	13.28	16.16	17.12	16.88	69.00
0:18:00	17.84	14.96	16.16	16.40	13.28	16.16	17.12	16.88	68.50
0:18:15	17.84	14.96	16.16	16.40	13.28	16.16	17.12	16.88	68.00
0:18:30	17.84	14.96	16.16	16.40	13.28	16.16	17.12	16.88	67.00
0:18:45	17.84	14.96	16.16	16.40	13.28	16.16	17.12	16.88	66.50
0:19:00	17.84	14.96	16.16	16.40	13.52	16.16	17.12	16.88	66.00
0:19:15	17.84	14.96	16.16	16.40	13.52	16.16	17.12	16.88	66.00
0:19:30	17.84	14.96	16.16	16.40	13.52	16.16	17.12	16.88	66.00
0:19:45	17.84	14.96	16.16	16.40	13.52	16.16	17.12	16.88	67.50
0:20:00	17.84	14.96	16.16	16.40	13.52	16.16	17.12	16.88	68.50

Time	No S	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:20:15	17.84	15.20	16.16	16.40	13.52	16.16	17.12	16.88	70.00
0:20:30	17.84	15.20	16.16	16.40	13.52	16.16	17.12	16.88	72.50
0:20:45	17.84	15.20	16.16	16.40	13.76	16.16	17.12	16.88	89.50
0:21:00	17.84	15.20	16.16	16.40	13.76	16.16	17.12	16.88	95.00
0:21:15	17.84	15.44	16.16	16.40	14.00	16.16	17.12	16.88	97.00
0:21:30	17.84	15.68	16.16	16.40	14.24	16.40	17.12	16.88	98.00
0:21:45	17.84	15.92	16.40	16.64	14.48	16.40	17.12	16.88	99.00
0:22:00	17.84	15.68	16.40	16.64	14.72	16.64	17.12	16.88	99.00
0:22:15	17.84	15.68	16.40	16.64	14.72	16.40	17.12	17.12	99.00
0:22:30	17.84	15.44	16.40	16.64	14.48	16.40	17.12	17.12	99.00
0:22:45	17.84	15.44	16.40	16.64	14.48	16.40	17.12	17.12	98.00
0:23:00	17.84	15.20	16.40	16.64	14.24	16.16	17.12	16.88	96.50
0:23:15	17.84	15.20	16.40	16.40	14.00	16.16	17.12	16.88	93.00
0:23:30	17.84	14.96	16.16	16.40	13.76	16.16	17.12	16.88	88.50
0:23:45	17.84	14.96	16.16	16.40	13.52	16.16	17.12	16.88	85.00
0:24:00	17.84	14.72	16.16	16.40	13.28	16.16	17.12	16.88	81.50
0:24:15	17.84	14.72	16.16	16.40	13.28	16.16	17.12	16.88	78.50
0:24:30	17.84	14.72	16.16	16.40	13.04	16.16	17.12	16.64	75.50
0:24:45	17.84	14.72	16.16	16.40	13.04	16.16	17.12	16.64	73.50
0:25:00	17.84	14.72	16.16	16.40	12.80	15.92	16.88	16.64	71.50
0:25:15	17.84	14.72	16.16	16.40	12.80	15.92	16.88	16.64	69.50
0:25:30	17.84	14.72	16.16	16.40	12.80	15.92	16.88	16.64	68.00
0:25:45	17.84	14.72	16.16	16.40	12.80	15.92	16.88	16.64	67.00
0:26:00	17.84	14.72	16.16	16.16	12.80	15.92	16.88	16.64	65.50
0:26:15	17.84	14.72	16.16	16.16	12.80	15.92	16.88	16.64	65.00
0:26:30	17.60	14.72	16.16	16.16	12.80	15.92	16.88	16.64	64.50
0:26:45	17.60	14.72	16.16	16.16	12.80	15.92	16.88	16.64	64.00
0:27:00	17.60	14.72	16.16	16.16	12.80	15.92	16.88	16.64	65.00
0:27:15	17.60	14.72	16.16	16.16	12.80	15.92	16.88	16.64	66.00
0:27:30	17.60	14.72	16.16	16.16	12.80	15.92	16.88	16.64	68.00
0:27:45	17.60	14.72	16.16	16.16	12.80	15.92	16.88	16.64	69.50
0:28:00	17.60	14.72	16.16	16.16	13.04	15.92	16.88	16.64	71.00
0:28:15	17.60	14.72	16.16	16.16	13.04	15.92	16.88	16.64	72.50
0:28:30	17.60	14.72	16.16	16.16	13.04	15.92	16.88	16.64	80.50
0:28:45	17.60	14.96	16.16	16.16	13.04	16.16	16.88	16.64	92.50
0:29:00	17.60	14.96	16.16	16.16	13.28	16.16	16.88	16.64	96.00
0:29:15	17.60	15.20	16.16	16.16	13.76	16.16	16.88	16.64	98.00
0:29:30	17.60	15.44	16.16	16.40	14.00	16.16	16.88	16.64	98.50
0:29:45	17.60	15.44	16.16	16.40	14.00	16.16	16.88	16.64	98.50
0:30:00	17.60	15.20	16.16	16.40	14.00	16.16	16.88	16.64	98.50
0:30:15	17.60	15.20	16.16	16.40	14.00	16.16	16.88	16.64	98.00
0:30:30	17.60	14.96	16.16	16.40	13.76	16.16	16.88	16.64	96.50
0:30:45	17.60	14.72	16.16	16.16	13.52	16.16	16.88	16.64	91.50
0:31:00	17.60	14.72	16.16	16.16	13.28	15.92	16.88	16.64	86.00
0:31:15	17.60	14.48	16.16	16.16	13.04	15.92	16.88	16.64	82.00
0:31:30	17.60	14.48	16.16	16.16	12.80	15.68	16.64	16.40	78.50
0:31:45	17.60	14.48	16.16	16.16	12.56	15.68	16.64	16.40	75.00
0:32:00	17.60	14.24	15.92	16.16	12.56	15.44	16.64	16.40	72.00
0:32:15	17.60	14.24	15.92	16.16	12.32	15.44	16.64	16.40	70.00
0:32:30	17.60	14.24	15.92	16.16	12.32	15.44	16.64	16.16	67.50
0:32:45	17.60	14.00	15.92	16.16	12.08	15.20	16.40	16.16	65.50
0:33:00	17.36	14.00	15.68	16.16	11.84	15.20	16.40	16.16	64.00
0:33:15	17.36	14.00	15.68	16.16	11.84	15.20	16.40	16.16	63.00
0:33:30	17.36	14.00	15.68	15.92	11.60	15.20	16.40	16.16	62.00
0:33:45	17.36	14.00	15.68	15.92	11.60	15.20	16.40	16.16	61.00
0:34:00	17.36	14.00	15.68	15.92	11.60	15.20	16.40	16.16	60.50
0:34:15	17.36	14.00	15.68	15.92	11.60	15.20	16.40	16.16	60.50
0:34:30	17.36	14.24	15.68	15.92	11.60	15.20	16.40	16.16	60.50
0:34:45	17.36	14.24	15.68	15.92	11.60	15.44	16.40	16.16	61.50
0:35:00	17.36	14.48	15.68	15.92	11.60	15.44	16.40	16.16	61.50
0:35:15	17.36	14.48	15.68	15.92	11.84	15.44	16.40	16.16	61.00
0:35:30	17.36	14.48	15.92	16.16	12.08	15.68	16.40	16.16	70.00

INSULATION: High Temperature

Time	IntT	None S	Op S	Cl S	AT	No R	Op R	Cl R	RH	Time	No S	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:00:00	17.36	16.16	16.40	16.64	14.00	17.36	17.12	17.12	77.50	0:20:15	19.28	23.36	21.68	20.96	26.72	22.16	20.96	20.96	42.50
0:00:15	17.36	16.16	16.64	16.88	14.48	17.36	17.36	17.12	72.50	0:20:30	19.28	23.12	21.68	20.96	26.72	22.16	20.96	20.96	40.50
0:00:30	17.60	15.92	16.64	16.64	14.48	17.12	17.36	17.36	65.00	0:20:45	19.28	23.36	21.68	20.96	26.72	22.16	20.96	20.96	38.50
0:00:45	17.60	15.68	16.40	16.64	14.48	16.88	17.36	17.36	62.50	0:21:00	19.28	23.36	21.68	21.20	26.72	22.16	20.96	20.96	36.50
0:01:00	17.60	15.68	16.40	16.64	14.48	16.64	17.12	17.12	62.50	0:21:15	19.28	23.36	21.68	21.20	26.72	22.16	20.96	20.96	35.00
0:01:15	17.60	15.92	16.40	16.64	14.72	16.88	17.12	17.12	65.00	0:21:30	19.28	23.36	21.68	21.20	26.72	22.16	20.96	20.96	33.50
0:01:30	17.60	16.16	16.40	16.64	14.72	16.88	17.12	17.12	69.50	0:21:45	19.28	23.36	21.68	21.20	26.72	22.40	20.96	20.96	42.00
0:01:45	17.60	16.40	16.64	16.64	14.96	17.12	17.12	17.12	74.50	0:22:00	19.28	23.60	21.68	21.20	26.96	22.40	20.96	20.72	69.00
0:02:00	17.60	16.88	16.64	16.88	15.44	17.60	17.36	17.12	77.00	0:22:15	19.28	23.84	21.68	21.20	26.96	22.64	20.96	20.96	82.50
0:02:15	17.60	17.36	16.88	16.88	15.92	17.84	17.36	17.36	75.00	0:22:30	19.28	24.08	21.92	21.20	27.20	22.64	20.96	20.96	92.00
0:02:30	17.60	17.60	17.12	17.12	16.16	17.84	17.60	17.36	72.50	0:22:45	19.28	24.56	21.92	21.44	27.44	23.36	20.96	20.96	97.00
0:02:45	17.60	17.84	17.12	17.36	16.88	18.08	17.60	17.60	70.50	0:23:00	19.28	25.04	22.16	21.68	27.68	23.84	21.20	20.96	98.50
0:03:00	17.60	18.08	17.36	17.36	17.36	18.32	17.84	17.84	67.50	0:23:15	19.52	25.52	22.16	21.68	27.92	24.32	21.20	20.96	99.50
0:03:15	17.60	18.32	17.60	17.60	17.84	18.32	17.84	17.84	64.50	0:23:30	19.52	25.52	22.40	21.92	27.92	24.32	21.20	21.20	99.50
0:03:30	17.60	18.56	17.60	17.60	18.32	18.56	17.84	17.84	62.00	0:23:45	19.52	25.28	22.40	21.92	27.92	24.08	21.44	21.20	98.50
0:03:45	17.84	18.80	17.84	17.84	19.04	18.80	17.84	17.84	59.50	0:24:00	19.76	24.56	22.40	21.92	27.68	23.84	21.44	21.20	94.00
0:04:00	17.84	19.04	17.84	17.84	19.28	19.04	17.84	17.84	57.50	0:24:15	19.76	24.32	22.40	21.92	27.68	23.60	21.44	21.20	88.50
0:04:15	17.84	19.28	17.84	17.84	19.76	19.04	18.08	18.08	56.00	0:24:30	19.76	24.08	22.40	21.92	27.68	23.12	21.44	21.20	84.00
0:04:30	17.84	19.28	17.84	17.84	20.24	19.28	18.08	18.08	54.00	0:24:45	19.76	23.60	22.40	21.92	27.68	22.88	21.44	21.20	79.50
0:04:45	17.84	19.52	18.08	17.84	20.72	19.28	18.32	18.32	52.50	0:25:00	19.76	23.36	22.40	21.92	27.68	22.64	21.44	21.20	75.00
0:05:00	17.84	19.52	18.08	18.08	20.96	19.52	18.32	18.32	51.50	0:25:15	20.00	23.60	22.40	21.68	27.44	22.40	21.44	21.20	69.50
0:05:15	17.84	19.76	18.32	18.08	21.44	19.52	18.32	18.56	51.50	0:25:30	20.00	23.84	22.40	21.68	27.44	22.64	21.68	21.20	64.50
0:05:30	17.84	20.24	18.56	18.32	21.92	19.76	18.56	18.56	78.00	0:25:45	20.00	23.84	22.40	21.68	27.44	22.64	21.68	21.20	59.50
0:05:45	17.84	20.48	18.56	18.32	22.40	20.00	18.56	18.56	90.00	0:26:00	20.00	23.84	22.40	21.68	27.44	22.64	21.68	21.20	55.00
0:06:00	17.84	20.96	18.80	18.56	22.64	20.24	18.80	18.80	96.50	0:26:15	19.76	23.84	22.40	21.68	27.44	22.64	21.68	21.20	50.50
0:06:15	17.84	21.20	18.80	18.80	23.12	20.72	18.80	18.80	98.50	0:26:30	19.76	23.84	22.40	21.68	27.44	22.64	21.44	21.20	46.50
0:06:30	18.08	21.68	19.04	18.80	23.60	20.96	19.04	19.04	99.50	0:26:45	19.76	23.84	22.40	21.68	27.44	22.64	21.44	21.20	43.50
0:06:45	18.08	22.40	19.28	19.04	24.32	21.20	19.28	19.28	100.00	0:27:00	19.76	23.84	22.40	21.68	27.20	22.64	21.44	21.20	40.50
0:07:00	18.08	22.64	19.28	19.28	24.56	21.68	19.28	19.28	100.00	0:27:15	19.76	23.84	22.40	21.68	27.20	22.64	21.44	21.20	37.50
0:07:15	18.32	22.64	19.52	19.28	24.80	21.92	19.28	19.28	100.00	0:27:30	19.76	23.84	22.40	21.68	27.20	22.64	21.44	21.20	35.50
0:07:30	18.32	22.40	19.52	19.28	24.56	21.68	19.28	19.52	100.00	0:27:45	19.76	23.84	22.40	21.68	27.20	22.64	21.44	21.20	34.00
0:07:45	18.32	21.92	19.52	19.28	24.56	21.44	19.52	19.52	99.50	0:28:00	19.76	23.84	22.40	21.68	27.20	22.64	21.44	21.20	33.00
0:08:00	18.56	21.68	19.76	19.52	24.56	21.20	19.52	19.52	95.50	0:28:15	19.76	23.84	22.40	21.68	27.20	22.64	21.44	21.20	32.00
0:08:15	18.56	21.44	19.76	19.52	24.56	20.96	19.52	19.52	92.50	0:28:30	19.76	23.84	22.40	21.68	27.20	22.64	21.44	21.20	31.50
0:08:30	18.56	21.20	19.76	19.52	24.80	20.96	19.52	19.52	88.50	0:28:45	19.76	23.84	22.40	21.68	27.44	22.64	21.44	20.96	55.50
0:08:45	18.56	20.96	19.76	19.52	24.80	20.96	19.76	19.52	84.00	0:29:00	19.76	24.08	22.40	21.68	27.44	22.64	21.44	20.96	76.50
0:09:00	18.80	20.96	20.00	19.52	24.80	20.96	19.76	19.76	80.50	0:29:15	19.76	24.32	22.40	21.92	27.68	22.88	21.44	21.20	88.50
0:09:15	18.80	21.44	20.00	19.52	24.80	20.96	19.76	19.76	78.50	0:29:30	19.76	24.80	22.40	21.92	27.68	23.60	21.44	21.20	95.50
0:09:30	18.80	21.68	20.00	19.52	24.80	20.96	19.76	19.76	75.50	0:29:45	19.76	25.52	22.64	22.16	27.92	24.08	21.44	21.20	98.50
0:09:45	18.80	21.68	20.00	19.76	24.80	20.96	19.76	19.76	73.50	0:30:00	19.76	26.00	22.64	22.16	28.16	24.56	21.68	21.44	99.50
0:10:00	18.80	21.68	20.24	19.76	25.04	20.96	20.00	19.76	71.00	0:30:15	20.00	26.24	22.64	22.40	28.40	25.04	21.68	21.68	100.00
0:10:15	18.80	21.68	20.24	19.76	25.04	20.96	20.00	19.76	68.00	0:30:30	20.00	26.72	22.88	22.64	28.64	25.28	21.92	21.68	100.00
0:10:30	18.80	21.68	20.24	19.76	25.04	20.96	20.00	19.76	66.00	0:30:45	20.00	26.96	22.88	22.64	29.12	25.52	21.92	21.92	100.00
0:10:45	18.80	21.68	20.24	19.76	25.04	20.96	20.00	19.76	63.50	0:31:00	20.24	27.44	23.12	22.64	29.36	25.76	22.16	22.16	100.00
0:11:00	18.80	21.92	20.24	19.76	25.04	21.20	20.00	19.76	61.50	0:31:15	20.24	27.68	23.36	22.88	29.84	26.00	22.40	22.16	100.00
0:11:15	18.80	21.92	20.48	19.76	25.04	20.96	20.00	19.76	59.00	0:31:30	20.48	27.92	23.60	23.12	30.08	26.24	22.40	22.40	100.00
0:11:30	18.80	21.92	20.48	19.76	25.04	21.20	20.00	19.76	57.50	0:31:45	20.48	27.68	23.60	23.12	30.08	26.24	22.64	22.64	100.00
0:11:45	18.80	21.92	20.48	20.00	25.04	21.20	20.00	19.76	55.50	0:32:00	20.72	27.44	23.84	23.36	29.84	26.00	22.64	22.64	100.00
0:12:00	18.80	21.92	20.48	20.00	25.04	21.20	20.00	19.76	53.50	0:32:15	20.72	26.96	23.84	23.36	29.36	25.76	22.64	22.64	100.00
0:12:15	18.80	22.16	20.48	20.00	25.28	21.20	20.00	19.76	51.00	0:32:30	20.72	26.48	23.84	23.36	28.88	25.52	22.64	22.64	100.00
0:12:30	18.80	22.16	20.48	20.00	25.28	21.20	20.00	19.76	49.00	0:32:45	20.96	26.24	23.84	23.36	28.40	25.04	22.64	22.64	100.00
0:12:45	18.80	22.16	20.48	20.00	25.28	21.20	20.00	19.76	46.50	0:33:00	20.96	25.76	23.84	23.36	28.16	24.80	22.64	22.64	97.00
0:13:00	18.80	22.16	20.72	20.00	25.52	21.44	20.00	20.00	44.50	0:33:15	20.96	25.28	23.84	23.12	28.16	24.56	22.64	22.64	92.00
0:13:15	18.80	22.16	20.72	20.24	25.52	21.44	20.24	20.00	43.00	0:33:30	20.96	25.04	23.60	23.12	28.16	24.32	22.64	22.64	88.00
0:13:30	18.80	22.40	20.72	20.24	25.52	21.44	20.24	20.00	42.00	0:33:45	20.96	24.56	23.60	23.12	28.16	24.08	22.64	22.64	84.50
0:13:45	18.80	22.40	20.72	20.24	25.76	21.44	20.24	20.00	42.50	0:34:00	20.96	24.32	23.60	23.12	28.16	23.84	22.64	22.40	81.50
0:14:00	18.80	22.40	20.72	20.24	25.76	21.44	20.24	20.00	44.00	0:34:15	20.96	24.08	23.60	22.88	28.16	23.36	22.64	22.40	78.50
0:14:15	18.80	22.40	20.72	20.24	25.76	21.44	20.24	20.00	46.00	0:34:30	20.96	23.84	23.36	22.88	27.92	23.12	22.64	22.40	75.00
0:14:30	18.80	22.64	20.72	20.24	26.00	21.68	20.24	20.00	48.50	0:34:45	20.96	23.36	23.36	22.88	27.92	22.88	22.64	22.40	72.00
0:14:45	18.80	22.64	20.96	20.48	26.00	21.68	20.24	20.00	52.50	0:35:00	20.96	23.36	23.36	22.88	27.92	22.64	22.64	22.40	68.50
0:15:00	18.80	22.64	20.96	20.48	26.00	21.68	20.24	20.24	58.50	0:35:15	20.96	23.60	23.36	22.64	27.92	22.64	22.64	22.16	65.00
0:15:15	18.80	22.64	20.96	20.48	26.24	21.68	20.24	20.24	64.00	0:35:30	20.96	24.08	23.36	22.64	27.92	22.16	22.64	22.16	60.50
0:15:30	19.04	22.64	20.96	20.48	26.24	21.92	20.48	20.24	76.50	0:35:45	20.96	24.32	23.36	22.64	27.68	22.16	22.64	22.16	57.00
0:15:45	19.04	23.12	20.96	20.72	26.24	22.16	20.48	20.24	92.00	0:36:00	20.96	24.32	23.36	22.64	27.68	22.16	22.64	22.16	54.00
0:16:00	19.04	23.84	20.96	20.72	26.48	22.64	20.48	20.24	97.00	0:36:15	20.72	24.32	23.36	22.64	27.68	22.40	22.64	22.16	51.50
0:16:15	19.04	24.32	21.20	20.96	26.72	22.88	20.48	20.48	99.00	0:36:30	20.72	24.32	23.36	22.64	27.68	22.64	22.64	22.16	49.00
0:16:30	19.04	24.56	21.20	20.96	27.20	23.36	20.72	20.72	99.50	0:36:45	20.72	24.32	23.36	22.64	27.68	22.64	22.40	22.16	45.50
0:16:45	19.28	24.32	21.44	20.96	26.96	23.36	20.96	20.72	99.00	0:37:00	20.72	24.32	23.12	22.64	27.68	22.64	22.40	22.16	42.50
0:17:00	19.28	24.08	21.44	20.96	26.96	22.88	20.96	20.72	95.50	0:37:15	20.72	24.32	23.12	22.64	27.68	22.88	22.40	22.16	39.50
0:17:15	19.28	23.60	21.44	20.96	26.96	22.64	20.96	20.72	89.50	0:37:30	20.48	24.32	23.12	22.64	27.68	22.88	22.40	21.92	37.00
0:17:30	19.28	23.12	21.44	20.96	26.96	22.64	20.96	20.96	85.50	0:37:45	20.48	24.32	23.12	22.40	27.68	22.88	22.40	21.92	35.00
0:17:45	19.28	22.88	21.44	20.96	26.96	22.40	20.96	20.96	80.50	0:38:00	20.48	24.32	22.88	22.40	27.68	22.88	22.16	21.92	33.50
0:18:00	19.28	22.64	21.44	20.96	26.96	22.16	20.96	20.96	76.50	0:38:15	20.48	24.32	22.88	22.40	27.68	22.88	22.16	21.92	32.00
0:18:15	19.28	23.12	21.44	20.96	26.96	21.92	20.96	20.96	72.50	0:38:30	20.48	24.32	22.88	22.40	27.68	22.88	22.16	21.68	31.00
0:18:30	19.28	23.12	21.68	20.96	26.72	22.16	20.96	20.96	67.50	0:38:45	20.48	24.32	22.88	22.40	27.68	22.88	22.16	21.68	30.00
0:18:45	19.28	23.12	21.68	20.96	26.72	22.16	20.96	20.96	63.00	0:39:00	20.24	24.32	22.88	22.40	27.68	22.88	22.16	21.68	28.50
0:19:00	19.28	23.12	21.68	20.96	26.72	22.16	20.96	20.96	58.00	0:39:15	20.24	24.32	22.88	22.40	27.68	22.88	21.92	21.68	27.50
0:19:15	19.28	23.12	21.68	20.96	26.72	22.16	20.96	20.96	54.50	0:39:30	20.24	24.32	22.64	22.40	27.68	22.88	21.92	21.68	26.50
0:19:30	19.28	23.12	21.68	20.96	26.72	22.16	20.96	20.96	50.50	0:39:45	20.24	24.32	22.64	22.40	27.68	22.88	21.92	21.68	52.00
0:19:45	19.28	23.36	21.68	20.96	26.72	22.16	20.96	20.96	47.50	0:40:00	20.24	24.32	22.64	22.40	27.68	23.12	21.92	21.68	73.50
0:20:00	19.28	23.36	21.68	20.96	26.72	22.16	20.96	20.96	45.00	0:40:15	20.24	24.56	22.64	22.40	27.92	23.36	21.92	21.68	85.50

Time	Int T	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:40:30	20.24	25.04	22.88	22.40	27.92	23.60	21.92	21.68	93.50
0:40:45	20.24	25.52	22.88	22.64	28.16	24.32	21.92	21.68	97.50
0:41:00	20.48	26.00	22.88	22.64	28.16	24.56	21.92	21.92	99.00
0:41:15	20.48	26.24	23.12	22.64	28.64	24.80	22.16	21.92	100.00
0:41:30	20.48	24.56	23.12	22.64	28.16	23.60	22.16	21.92	83.50

INSULATION: Low Humidity

Time	IntT	None S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:00:00	19.04	20.96	20.24	20.00	25.28	20.24	19.52	19.52	36.00
0:00:15	19.04	20.96	20.24	20.00	25.04	20.24	19.52	19.52	36.00
0:00:30	19.04	21.44	20.24	20.00	25.28	20.72	19.52	19.52	64.50
0:00:45	19.04	21.68	20.24	20.24	25.28	20.96	19.52	19.52	66.00
0:01:00	19.04	21.68	20.48	20.24	25.28	20.96	19.76	19.76	63.00
0:01:15	19.04	21.68	20.48	20.24	25.28	20.96	19.76	19.76	58.00
0:01:30	19.04	21.68	20.48	20.24	25.28	20.96	19.76	19.76	55.50
0:01:45	19.04	21.68	20.48	20.24	25.04	20.96	19.76	19.76	53.50
0:02:00	19.04	21.44	20.48	20.24	25.04	20.96	19.76	19.76	50.50
0:02:15	19.04	21.44	20.48	20.24	24.80	20.96	19.76	19.76	47.00
0:02:30	19.04	21.44	20.48	20.24	24.80	20.96	19.76	19.76	44.50
0:02:45	19.04	21.44	20.48	20.24	24.56	20.72	19.76	19.76	41.00
0:03:00	19.04	21.44	20.48	20.24	24.32	20.72	19.76	19.76	39.00
0:03:15	19.04	21.44	20.48	20.24	24.32	20.72	19.76	19.76	37.50
0:03:30	19.04	21.44	20.48	20.24	24.32	20.72	19.76	19.76	36.00
0:03:45	19.04	21.44	20.48	20.24	24.32	20.72	19.76	19.76	35.00
0:04:00	19.04	21.44	20.48	20.24	24.32	20.72	19.76	19.76	33.50
0:04:15	19.04	21.44	20.48	20.24	24.08	20.72	19.76	19.76	32.50
0:04:30	19.04	21.20	20.48	20.24	24.08	20.72	19.76	19.76	31.50
0:04:45	19.04	21.20	20.48	20.24	24.08	20.72	19.76	19.76	31.00
0:05:00	19.04	21.20	20.48	20.24	24.08	20.72	19.76	19.76	30.00
0:05:15	19.04	21.20	20.48	20.24	24.08	20.72	19.76	19.76	29.50
0:05:30	19.04	21.44	20.48	20.24	24.08	20.72	19.76	19.76	29.00
0:05:45	19.04	21.44	20.48	20.24	23.84	20.72	19.76	19.76	29.50
0:06:00	19.04	21.20	20.48	20.24	23.84	20.72	19.76	19.76	32.00
0:06:15	19.04	21.44	20.48	20.24	23.84	20.72	19.76	19.76	35.00
0:06:30	19.04	21.44	20.48	20.24	23.84	20.72	19.76	19.76	37.50
0:06:45	19.04	21.44	20.48	20.24	23.84	20.96	19.76	19.76	37.50
0:07:00	19.04	21.44	20.48	20.24	23.84	20.96	19.76	19.76	36.00
0:07:15	19.04	21.44	20.48	20.24	23.84	20.96	19.76	19.76	34.00
0:07:30	19.04	21.44	20.48	20.24	23.84	20.96	19.76	19.76	32.50
0:07:45	19.04	21.44	20.48	20.24	23.84	20.72	19.76	19.76	31.00
0:08:00	19.04	21.44	20.48	20.24	23.84	20.72	19.76	19.76	29.50
0:08:15	19.04	21.44	20.48	20.24	23.84	20.72	19.76	19.76	28.50
0:08:30	19.04	21.44	20.48	20.24	23.84	20.96	19.76	19.76	29.00
0:08:45	19.04	21.68	20.48	20.24	23.84	20.96	19.76	19.76	33.00
0:09:00	19.04	22.16	20.72	20.48	24.08	20.96	19.76	19.76	37.00
0:09:15	19.04	22.40	20.72	20.48	24.32	21.20	20.00	20.00	42.50
0:09:30	19.04	22.64	20.96	20.72	24.32	21.44	20.00	20.00	50.00
0:09:45	19.04	22.88	20.96	20.72	24.80	21.92	20.24	20.24	57.50
0:10:00	19.28	23.12	20.96	20.96	25.28	22.16	20.24	20.24	62.00
0:10:15	19.28	23.36	21.20	20.96	25.76	22.16	20.48	20.48	56.50
0:10:30	19.28	23.60	21.20	20.96	26.24	22.40	20.48	20.48	50.50
0:10:45	19.28	23.60	21.20	20.96	26.24	22.40	20.48	20.72	43.50
0:11:00	19.28	23.36	21.44	20.96	26.48	22.40	20.72	20.72	36.00
0:11:15	19.28	23.12	21.44	20.96	26.72	22.16	20.72	20.72	31.50
0:11:30	19.28	22.88	21.44	20.96	26.96	21.92	20.72	20.72	29.00
0:11:45	19.28	22.64	21.20	20.96	26.72	21.92	20.72	20.72	27.00
0:12:00	19.28	22.64	21.20	20.96	26.72	21.68	20.72	20.72	25.50
0:12:15	19.28	22.40	21.20	20.96	26.48	21.44	20.48	20.48	24.50
0:12:30	19.28	22.16	20.96	20.96	26.24	21.44	20.48	20.48	25.00
0:12:45	19.28	22.40	20.96	20.96	26.00	21.44	20.48	20.48	28.50
0:13:00	19.28	22.64	20.96	20.96	25.76	21.44	20.48	20.48	33.50
0:13:15	19.28	22.64	20.96	20.96	25.76	21.92	20.48	20.48	41.00
0:13:30	19.28	23.12	21.20	20.96	26.00	22.16	20.48	20.48	48.50
0:13:45	19.28	23.60	21.44	20.96	26.24	22.40	20.72	20.72	56.00
0:14:00	19.28	23.84	21.44	21.20	26.24	22.64	20.72	20.72	60.00
0:14:15	19.28	24.08	21.68	21.20	26.48	22.64	20.96	20.96	55.00
0:14:30	19.28	24.08	21.68	21.44	26.72	22.64	20.96	20.96	49.00
0:14:45	19.28	24.08	21.68	21.44	27.20	22.64	20.96	20.96	43.50
0:15:00	19.52	24.08	21.92	21.44	27.44	22.64	20.96	20.96	36.00
0:15:15	19.52	24.08	21.92	21.44	27.68	22.64	20.96	20.96	31.00
0:15:30	19.52	23.60	21.92	21.44	27.68	22.64	20.96	20.96	28.00
0:15:45	19.52	23.36	21.92	21.44	27.68	22.40	20.96	20.96	26.00
0:16:00	19.52	23.12	21.68	21.20	27.44	22.16	20.96	20.96	24.50
0:16:15	19.52	22.88	21.68	21.20	27.20	21.92	20.96	20.96	24.50
0:16:30	19.52	22.64	21.68	21.20	26.96	21.92	20.96	20.96	25.00
0:16:45	19.52	22.64	21.44	21.20	26.48	21.68	20.96	20.72	26.00
0:17:00	19.52	22.64	21.44	21.20	26.24	21.92	20.96	20.72	30.00
0:17:15	19.52	22.88	21.44	21.20	26.24	21.92	20.96	20.72	34.50
0:17:30	19.52	23.36	21.44	21.20	26.24	22.16	20.96	20.72	41.00
0:17:45	19.52	23.60	21.68	21.44	26.24	22.40	20.96	20.96	48.50
0:18:00	19.52	24.08	21.68	21.44	26.24	22.64	20.96	20.96	55.00
0:18:15	19.52	24.32	21.92	21.44	26.72	22.64	20.96	20.96	57.50
0:18:30	19.52	24.32	21.92	21.68	26.96	22.88	20.96	20.96	52.00
0:18:45	19.76	24.32	22.16	21.68	27.20	22.88	20.96	20.96	46.00
0:19:00	19.76	24.32	22.16	21.68	27.44	22.88	21.20	21.20	40.00
0:19:15	19.76	24.32	22.16	21.68	27.68	22.88	21.20	21.20	33.00
0:19:30	19.76	24.08	22.16	21.68	27.92	22.64	21.20	21.20	28.50
0:19:45	19.76	23.84	22.16	21.68	27.92	22.64	21.20	21.20	26.00
0:20:00	19.76	23.60	22.16	21.68	27.68	22.64	21.20	21.20	24.50

Time	No S	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:20:15	19.76	23.36	22.16	21.68	27.44	22.40	21.20	20.96	24.00
0:20:30	19.76	23.12	21.92	21.44	27.20	22.16	21.20	20.96	24.00
0:20:45	19.76	22.88	21.92	21.44	26.96	22.16	20.96	20.96	24.50
0:21:00	19.76	22.88	21.92	21.44	26.72	22.16	20.96	20.96	27.00
0:21:15	19.76	22.88	21.68	21.44	26.24	21.92	20.96	20.96	31.50
0:21:30	19.76	22.88	21.68	21.44	26.24	22.16	20.96	20.96	36.00
0:21:45	19.76	23.12	21.92	21.44	26.24	22.16	20.96	20.96	43.00
0:22:00	19.76	23.60	21.92	21.68	26.24	22.40	20.96	20.96	49.50
0:22:15	19.76	24.08	21.92	21.68	26.24	22.64	20.96	20.96	56.50
0:22:30	19.76	24.32	22.16	21.68	26.48	22.88	21.20	20.96	58.00
0:22:45	19.76	24.32	22.16	21.92	26.72	22.88	21.20	21.20	52.00
0:23:00	20.00	24.32	22.40	21.92	26.96	23.12	21.20	21.20	46.00
0:23:15	20.00	24.56	22.40	21.92	27.44	23.12	21.44	21.20	41.00
0:23:30	20.00	24.56	22.64	22.16	27.68	23.12	21.44	21.44	36.50
0:23:45	20.00	24.56	22.64	22.16	27.92	23.12	21.44	21.44	31.50
0:24:00	20.00	24.32	22.64	22.16	28.16	23.12	21.44	21.44	27.00
0:24:15	20.00	24.32	22.64	22.16	28.16	22.88	21.44	21.44	24.50
0:24:30	20.00	24.08	22.64	21.92	28.16	22.64	21.44	21.44	23.00
0:24:45	20.00	23.84	22.40	21.92	27.92	22.64	21.44	21.44	22.00
0:25:00	20.00	23.60	22.40	21.92	27.68	22.64	21.44	21.20	22.00
0:25:15	20.00	23.36	22.40	21.92	27.44	22.40	21.44	21.20	22.50
0:25:30	20.00	23.36	22.16	21.68	27.20	22.40	21.20	21.20	24.50
0:25:45	20.00	23.36	22.16	21.68	26.96	22.40	21.20	21.20	29.00
0:26:00	20.00	23.84	22.16	21.92	26.72	22.64	21.20	21.20	34.50
0:26:15	20.00	24.08	22.16	21.92	26.72	22.64	21.20	21.20	41.50
0:26:30	20.00	24.32	22.40	21.92	26.96	22.88	21.20	21.20	49.00
0:26:45	20.00	24.32	22.40	22.16	27.20	23.12	21.44	21.20	55.00
0:27:00	20.00	24.56	22.64	22.16	27.44	23.36	21.44	21.44	53.00
0:27:15	20.24	24.32	22.64	22.16	27.68	23.12	21.44	21.44	39.50

INSULATION: Medium Humidity

Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:00:00	17.12	17.60	17.36	17.36	17.60	18.08	17.84	17.84	100.00
0:00:15	17.12	17.60	17.60	17.36	17.36	18.08	17.84	17.84	100.00
0:00:30	17.12	17.60	17.60	17.60	17.36	18.08	17.84	17.84	100.00
0:00:45	17.12	17.60	17.60	17.60	17.60	18.08	17.84	17.84	100.00
0:01:00	17.36	19.04	17.60	17.60	18.32	18.80	17.84	17.84	100.00
0:01:15	17.36	19.28	17.84	17.84	19.28	19.04	17.84	17.84	100.00
0:01:30	17.36	19.52	17.84	17.84	20.00	19.28	17.84	17.84	100.00
0:01:45	17.36	19.52	17.84	17.84	20.48	19.04	17.84	18.08	100.00
0:02:00	17.36	19.28	18.08	17.84	20.72	19.04	17.84	18.08	100.00
0:02:15	17.60	19.28	18.08	18.08	20.48	19.04	17.84	18.08	100.00
0:02:30	17.60	19.04	18.08	18.08	20.48	18.80	17.84	18.08	100.00
0:02:45	17.60	18.80	18.08	17.84	20.00	18.56	17.84	18.08	100.00
0:03:00	17.60	18.56	18.08	17.84	19.76	18.56	17.84	17.84	100.00
0:03:15	17.60	18.08	17.84	17.84	19.28	18.32	17.84	17.84	100.00
0:03:30	17.60	17.84	17.84	17.84	19.28	18.08	17.84	17.84	100.00
0:03:45	17.60	17.84	17.84	17.84	18.80	18.08	17.84	17.84	99.00
0:04:00	17.60	17.60	17.84	17.84	18.56	17.84	17.84	17.84	98.00
0:04:15	17.60	17.60	17.84	17.84	18.56	17.84	17.84	17.84	96.50
0:04:30	17.60	17.36	17.84	17.84	18.32	17.84	17.84	17.84	95.00
0:04:45	17.60	17.36	17.84	17.84	18.32	17.84	17.84	17.84	93.50
0:05:00	17.60	17.12	17.84	17.60	18.08	17.60	17.84	17.60	92.00
0:05:15	17.60	16.88	17.60	17.60	17.84	17.60	17.84	17.60	91.00
0:05:30	17.60	16.88	17.60	17.60	17.84	17.36	17.84	17.60	89.50
0:05:45	17.60	16.64	17.60	17.60	17.60	17.36	17.60	17.60	87.50
0:06:00	17.36	16.40	17.36	17.36	17.12	17.12	17.60	17.36	84.00
0:06:15	17.36	16.16	17.36	17.36	16.88	17.12	17.60	17.36	80.50
0:06:30	17.36	16.16	17.36	17.36	16.64	16.88	17.60	17.12	78.00
0:06:45	17.36	16.16	17.12	17.12	16.16	16.64	17.36	17.12	75.50
0:07:00	17.36	15.92	17.12	17.12	16.16	16.64	17.36	17.12	73.00
0:07:15	17.36	15.68	17.12	17.12	15.92	16.40	17.36	16.88	71.50
0:07:30	17.36	15.68	16.88	16.88	15.44	16.16	17.12	16.88	69.50
0:07:45	17.12	15.44	16.88	16.88	15.20	16.16	17.12	16.88	69.00
0:08:00	17.12	15.20	16.64	16.88	14.96	16.16	17.12	16.64	67.50
0:08:15	17.12	15.20	16.64	16.64	14.48	16.16	16.88	16.64	66.50
0:08:30	17.12	14.96	16.40	16.64	14.48	15.92	16.88	16.40	65.50
0:08:45	17.12	14.96	16.40	16.40	14.24	15.92	16.88	16.40	64.50
0:09:00	16.88	14.96	16.16	16.40	14.00	15.92	16.64	16.40	64.50
0:09:15	16.88	14.96	16.16	16.40	13.76	15.92	16.64	16.40	66.00
0:09:30	16.88	15.20	16.16	16.40	13.76	16.16	16.64	16.40	69.50
0:09:45	16.88	15.68	16.16	16.40	14.00	16.16	16.64	16.40	73.00
0:10:00	16.88	16.16	16.40	16.64	14.24	16.40	16.64	16.40	76.00
0:10:15	16.88	16.40	16.64	16.64	14.48	16.64	16.64	16.40	80.00
0:10:30	16.88	16.88	16.64	16.88	14.96	17.12	16.88	16.64	84.50
0:10:45	16.88	17.36	16.88	17.12	15.44	17.36	16.88	16.64	88.50
0:11:00	16.88	17.84	17.12	17.12	16.16	17.60	17.12	16.88	92.50
0:11:15	16.88	18.32	17.36	17.36	16.88	17.84	17.12	17.12	95.50
0:11:30	16.88	19.04	17.60	17.60	17.84	18.32	17.36	17.12	97.00
0:11:45	16.88	19.28	17.84	17.84	18.32	18.56	17.36	17.36	98.50
0:12:00	17.12	19.52	17.84	17.84	19.28	18.80	17.60	17.60	99.00
0:12:15	17.12	20.00	17.84	17.84	20.00	19.28	17.84	17.84	99.00
0:12:30	17.12	20.48	18.08	18.08	20.72	19.28	17.84	17.84	99.50
0:12:45	17.12	20.72	18.32	18.08	21.44	19.52	17.84	17.84	99.50
0:13:00	17.36	20.96	18.56	18.32	22.16	19.76	17.84	18.08	99.50
0:13:15	17.36	21.20	18.80	18.56	22.64	20.00	18.08	18.32	99.00
0:13:30	17.36	21.44	18.80	18.56	23.12	20.24	18.32	18.32	99.00
0:13:45	17.60	21.68	19.04	18.80	23.84	20.48	18.32	18.56	99.00
0:14:00	17.60	21.92	19.28	18.80	24.32	20.72	18.56	18.56	97.50
0:14:15	17.60	21.44	19.28	19.04	24.32	20.48	18.56	18.80	93.00
0:14:30	17.84	21.44	19.28	19.04	24.56	20.24	18.80	18.80	88.50
0:14:45	17.84	21.20	19.28	19.04	24.80	20.24	18.80	18.80	84.00
0:15:00	17.84	20.96	19.28	19.04	25.04	20.00	18.80	19.04	78.00
0:15:15	17.84	20.96	19.28	19.04	24.80	20.00	18.80	19.04	73.00
0:15:30	17.84	20.72	19.28	19.04	24.80	19.76	18.80	18.80	69.00
0:15:45	17.84	20.24	19.28	18.80	24.32	19.52	18.80	18.80	65.00
0:16:00	17.84	20.00	19.28	18.80	24.32	19.28	18.80	18.80	61.50
0:16:15	17.84	19.76	19.04	18.80	23.84	19.28	18.80	18.80	58.50
0:16:30	17.84	19.52	19.04	18.80	23.36	19.28	18.56	18.56	57.00
0:16:45	17.84	19.28	19.04	18.56	22.88	19.04	18.56	18.56	54.50
0:17:00	17.84	19.28	18.80	18.56	22.64	18.80	18.56	18.32	51.50
0:17:15	17.84	18.80	18.80	18.56	22.16	18.56	18.32	18.32	49.50
0:17:30	17.84	18.56	18.56	18.32	21.68	18.56	18.32	18.32	47.50
0:17:45	17.84	18.32	18.56	18.32	21.20	18.32	18.32	18.08	47.00
0:18:00	17.84	18.08	18.32	18.32	20.96	18.08	18.08	18.08	46.50
0:18:15	17.84	18.08	18.32	18.08	20.48	18.08	18.08	17.84	46.00
0:18:30	17.84	17.84	18.32	18.08	20.00	17.84	18.08	17.84	45.50
0:18:45	17.60	17.84	18.08	18.08	19.52	17.84	17.84	17.84	45.00
0:19:00	17.60	17.60	18.08	17.84	19.28	17.84	17.84	17.84	44.00
0:19:15	17.60	17.36	17.84	17.84	18.80	17.60	17.84	17.84	43.50
0:19:30	17.60	17.12	17.84	17.84	18.32	17.60	17.84	17.60	42.50
0:19:45	17.60	16.88	17.84	17.84	18.08	17.36	17.84	17.60	42.00
0:20:00	17.60	16.64	17.84	17.84	17.84	17.12	17.84	17.60	41.50

Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:20:15	17.60	16.40	17.60	17.60	17.36	17.12	17.60	17.36	41.50
0:20:30	17.60	16.16	17.60	17.60	16.88	16.88	17.60	17.36	41.00
0:20:45	17.36	16.16	17.60	17.60	16.64	16.64	17.60	17.12	41.50
0:21:00	17.36	16.16	17.36	17.36	16.16	16.64	17.36	17.12	42.50
0:21:15	17.36	16.16	17.36	17.36	15.92	16.40	17.36	17.12	43.00
0:21:30	17.36	15.92	17.12	17.12	15.68	16.40	17.36	16.88	45.50
0:21:45	17.36	15.92	17.12	17.12	15.44	16.40	17.12	16.88	49.00
0:22:00	17.36	15.68	17.12	17.12	15.20	16.40	17.12	16.88	52.50
0:22:15	17.12	15.92	16.88	17.12	14.96	16.40	17.12	16.88	55.50
0:22:30	17.12	16.16	16.88	17.12	14.72	16.40	17.12	16.64	59.00
0:22:45	17.12	16.40	16.88	17.12	14.72	16.64	17.12	16.88	63.50
0:23:00	17.12	16.88	17.12	17.12	14.96	17.12	17.12	16.88	69.00
0:23:15	17.12	17.36	17.12	17.36	15.44	17.36	17.12	16.88	75.00
0:23:30	17.12	17.84	17.36	17.36	15.92	17.60	17.36	17.12	81.00
0:23:45	17.12	18.32	17.60	17.60	16.40	17.84	17.36	17.12	86.50
0:24:00	17.12	18.80	17.84	17.84	17.12	18.32	17.36	17.36	90.50
0:24:15	17.12	19.28	17.84	17.84	17.84	18.56	17.60	17.60	93.00
0:24:30	17.36	19.76	18.08	17.84	18.80	19.04	17.84	17.84	95.50
0:24:45	17.36	20.24	18.32	18.08	19.28	19.28	17.84	17.84	97.00
0:25:00	17.36	20.72	18.56	18.32	20.24	19.52	17.84	17.84	97.50
0:25:15	17.36	20.96	18.80	18.56	20.96	19.76	18.08	18.08	98.00
0:25:30	17.60	21.20	18.80	18.56	21.92	20.00	18.08	18.32	98.00
0:25:45	17.60	21.44	19.04	18.80	22.64	20.24	18.32	18.32	98.00
0:26:00	17.60	21.68	19.28	19.04	23.12	20.48	18.56	18.56	98.00
0:26:15	17.84	21.92	19.28	19.04	23.84	20.72	18.56	18.80	97.50
0:26:30	17.84	22.16	19.28	19.28	24.32	20.96	18.80	18.80	97.50
0:26:45	17.84	22.40	19.52	19.28	24.56	20.96	18.80	19.04	97.00
0:27:00	17.84	22.64	19.76	19.28	25.04	21.20	19.04	19.04	97.00
0:27:15	17.84	22.64	19.76	19.52	25.52	21.44	19.04	19.28	97.00
0:27:30	17.84	22.88	20.00	19.52	26.00	21.44	19.28	19.28	96.50
0:27:45	18.08	23.12	20.00	19.76	26.24	21.68	19.28	19.28	96.50
0:28:00	18.08	23.36	20.24	19.76	26.48	21.68	19.28	19.52	96.50
0:28:15	18.08	23.12	20.48	20.00	26.72	21.68	19.28	19.52	92.50
0:28:30	18.32	22.64	20.48	20.00	26.72	21.44	19.52	19.52	85.50
0:28:45	18.32	22.64	20.48	20.00	26.96	21.20	19.52	19.52	80.00
0:29:00	18.32	22.40	20.48	20.00	26.72	20.96	19.52	19.52	74.50
0:29:15	18.32	22.16	20.48	20.00	26.72	20.96	19.52	19.52	70.50
0:29:30	18.32	21.92	20.48	20.00	26.48	20.72	19.52	19.52	65.50
0:29:45	18.56	21.68	20.24	19.76	26.24	20.48	19.52	19.52	61.50
0:30:00	18.32	21.20	20.24	19.76	26.00	20.48	19.52	19.52	58.50
0:30:15	18.32	20.96	20.24	19.52	25.52	20.24	19.52	19.28	55.50
0:30:30	18.32	20.96	20.00	19.52	25.04	20.00	19.28	19.28	51.50
0:30:45	18.32	20.72	20.00	19.52	24.56	19.76	19.28	19.28	48.50
0:31:00	18.32	20.48	19.76	19.28	24.32	19.76	19.28	19.28	46.00
0:31:15	18.32	20.24	19.76	19.28	23.84	19.52	19.28	19.28	45.00
0:31:30	18.32	19.76	19.52	19.28	23.36	19.28	19.28	19.04	44.50
0:31:45	18.32	19.52	19.52	19.28	22.88	19.28	19.28	19.04	43.00
0:32:00	18.08	19.28	19.28	19.28	22.64	19.28	19.04	18.80	41.50
0:32:15	18.08	19.28	19.28	19.04	21.92	19.04	19.04	18.80	40.00
0:32:30	18.08	19.04	19.28	19.04	21.44	18.80	18.80	18.56	39.00
0:32:45	18.08	18.80	19.28	19.04	20.96	18.56	18.80	18.56	38.50
0:33:00	18.08	18.56	19.04	18.80	20.72	18.56	18.80	18.32	38.50
0:33:15	18.08	18.32	19.04	18.80	20.24	18.32	18.56	18.32	38.50
0:33:30	17.84	18.32	18.80	18.80	19.76	18.32	18.56	18.32	37.50
0:33:45	17.84	18.08	18.80	18.56	19.52	18.08	18.32	18.08	37.00
0:34:00	17.84	17.84	18.56	18.56	19.28	17.84	18.32	18.08	36.50
0:34:15	17.84	17.84	18.56	18.32	18.80	17.84	18.32	17.84	36.00
0:34:30	17.84	17.60	18.32	18.32	18.32	17.84	18.08	17.84	36.00
0:34:45	17.84	17.36	18.32	18.32	18.08	17.84	18.08	17.84	35.50
0:35:00	17.84	17.12	18.08	18.08	17.84	17.60	18.08	17.84	35.50
0:35:15	17.84	17.12	18.08	18.08	17.36	17.36	17.84	17.84	35.50
0:35:30	17.84	16.88	17.84	17.84	17.12	17.36	17.84	17.60	35.50
0:35:45	17.84	16.64	17.84	17.84	16.64	17.12	17.84	17.60	36.50
0:36:00	17.84	16.40	17.84	17.84	16.40	17.12	17.84	17.60	38.50
0:36:15	17.84	16.40	17.84	17.84	16.16	17.12	17.84	17.36	42.50
0:36:30	17.60	16.88	17.84	17.84	16.16	17.12	17.84	17.36	46.50
0:36:45	17.60	17.12	17.84	17.84	15.92	17.36	17.60	17.36	50.50
0:37:00	17.60	17.60	17.84	17.84	16.16	17.60	17.84	17.36	55.00
0:37:15	17.60	17.84	17.84	17.84	16.16	17.84	17.84	17.60	62.00
0:37:30	17.60	18.32	17.84	17.84	16.64	18.08	17.84	17.60	69.50
0:37:45	17.60	19.04	18.08	18.08	17.36	18.32	17.84	17.84	75.50
0:38:00	17.60	19.28	18.32	18.32	17.84	18.80	17.84	17.84	81.50
0:38:15	17.60	20.00	18.56	18.56	18.56	19.04	17.84	17.84	86.50
0:38:30	17.84	20.48	18.80	18.56	19.28	19.28	18.08	18.08	89.50
0:38:45	17.84	20.96	19.04	18.80	20.24	19.52	18.32	18.32	92.00
0:39:00	17.84	20.96	19.28	19.04	20.96	20.00	18.32	18.32	94.00
0:39:15	17.84	21.44	19.28	19.04	21.68	20.24	18.56	18.56	94.50
0:39:30	17.84	21.68	19.28	19.28	22.40	20.48	18.56	18.80	95.00
0:39:45	17.84	21.92	19.52	19.28	22.88	20.72	18.80	18.80	95.50
0:40:00	17.84	22.16	19.52	19.28	23.60	20.96	19.04	19.04	95.50
0:40:15	17.84	22.40	19.76	19.52	24.32	20.96	19.04	19.28	95.50

Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:40:30	18.08	22.64	20.00	19.52	24.56	20.96	19.28	19.28	95.50
0:40:45	18.08	22.64	20.00	19.76	25.04	21.20	19.28	19.28	94.50
0:41:00	18.08	22.64	20.24	19.76	25.52	21.20	19.28	19.28	87.00
0:41:15	18.32	22.64	20.24	19.76	25.76	20.96	19.28	19.28	77.50
0:41:30	18.32	22.40	20.24	19.76	25.76	20.96	19.28	19.52	69.00
0:41:45	18.32	21.92	20.24	19.76	26.00	20.96	19.28	19.28	61.50
0:42:00	18.32	21.68	20.24	19.76	25.76	20.72	19.28	19.52	55.00
0:42:15	18.32	21.44	20.24	19.52	25.76	20.48	19.28	19.28	50.00
0:42:30	18.32	20.96	20.00	19.52	25.28	20.48	19.28	19.28	46.00
0:42:45	18.32	20.96	20.00	19.52	25.04	20.24	19.28	19.28	43.50
0:43:00	18.32	20.72	19.76	19.52	24.56	20.00	19.28	19.28	42.00
0:43:15	18.32	20.48	19.76	19.28	24.32	19.76	19.28	19.28	40.00
0:43:30	18.32	20.00	19.52	19.28	23.84	19.52	19.28	19.28	38.00
0:43:45	18.32	19.76	19.52	19.28	23.36	19.28	19.28	19.04	37.00
0:44:00	18.32	19.52	19.52	19.28	22.88	19.28	19.04	19.04	35.50
0:44:15	18.32	19.28	19.28	19.28	22.64	19.28	19.04	18.80	35.00
0:44:30	18.32	19.28	19.28	19.28	22.16	19.04	19.04	18.80	34.00
0:44:45	18.32	19.04	19.28	19.04	21.68	18.80	18.80	18.80	33.50
0:45:00	18.32	18.80	19.28	19.04	21.20	18.80	18.80	18.56	33.00
0:45:15	18.08	18.56	19.04	18.80	20.72	18.56	18.80	18.56	33.00
0:45:30	18.08	18.32	19.04	18.80	20.24	18.32	18.56	18.32	32.50
0:45:45	18.08	18.32	18.80	18.80	19.76	18.32	18.56	18.32	32.50
0:46:00	18.08	18.08	18.80	18.56	19.28	18.08	18.56	18.32	32.50
0:46:15	18.08	17.84	18.56	18.56	19.04	17.84	18.32	18.08	32.50
0:46:30	18.08	17.84	18.56	18.32	18.80	17.84	18.32	18.08	32.00
0:46:45	17.84	17.60	18.32	18.32	18.32	17.84	18.32	17.84	32.00
0:47:00	17.84	17.36	18.32	18.32	17.84	17.84	18.08	17.84	32.50
0:47:15	17.84	17.12	18.08	18.08	17.60	17.60	18.08	17.84	32.50
0:47:30	17.84	16.88	18.08	18.08	17.36	17.60	17.84	17.84	35.50
0:47:45	17.84	16.88	17.84	17.84	16.88	17.36	17.84	17.84	36.00
0:48:00	17.84	16.64	17.84	17.84	16.40	17.12	17.84	17.84	36.00
0:48:15	17.84	16.40	17.84	17.84	16.16	17.12	17.84	17.60	36.50
0:48:30	17.84	16.16	17.84	17.84	15.92	17.12	17.84	17.60	38.00
0:48:45	17.84	16.16	17.84	17.84	15.68	16.88	17.84	17.36	39.50
0:49:00	17.84	16.16	17.60	17.84	15.44	16.88	17.84	17.36	41.50
0:49:15	17.84	16.16	17.60	17.60	14.96	16.88	17.60	17.36	43.00
0:49:30	17.84	16.16	17.60	17.60	14.96	16.64	17.60	17.36	46.00
0:49:45	17.84	16.16	17.36	17.60	14.72	16.64	17.60	17.12	52.50
0:50:00	17.84	16.16	17.36	17.60	14.48	16.64	17.60	17.12	56.50
0:50:15	17.84	16.16	17.36	17.60	14.48	16.64	17.36	17.12	59.50
0:50:30	17.84	16.16	17.36	17.60	14.48	16.88	17.36	17.12	65.00
0:50:45	17.60	16.64	17.36	17.60	14.48	17.12	17.36	17.12	70.50
0:51:00	17.60	17.12	17.36	17.60	14.72	17.36	17.36	17.12	75.00
0:51:15	17.60	17.60	17.60	17.60	14.96	17.60	17.60	17.36	80.50
0:51:30	17.60	17.84	17.84	17.84	15.68	17.84	17.60	17.36	86.00
0:51:45	17.60	18.56	17.84	17.84	16.16	18.08	17.84	17.60	89.50
0:52:00	17.84	19.04	17.84	18.08	16.88	18.56	17.84	17.84	92.50
0:52:15	17.84	19.52	18.08	18.08	17.60	18.80	17.84	17.84	94.50
0:52:30	17.84	20.00	18.32	18.32	18.32	19.28	17.84	17.84	96.00
0:52:45	17.84	20.48	18.56	18.56	19.28	19.52	18.08	18.08	97.00
0:53:00	17.84	20.96	18.80	18.80	20.00	19.76	18.32	18.32	97.50
0:53:15	17.84	21.20	19.04	19.04	20.96	20.00	18.32	18.56	97.50
0:53:30	17.84	21.44	19.28	19.04	21.68	20.24	18.56	18.80	97.50
0:53:45	17.84	21.68	19.28	19.28	22.40	20.48	18.80	18.80	97.00
0:54:00	17.84	21.92	19.52	19.28	22.88	20.72	18.80	19.04	97.00
0:54:15	18.08	22.16	19.52	19.28	23.60	20.96	19.04	19.04	97.00
0:54:30	18.08	22.40	19.76	19.52	24.32	20.96	19.28	19.28	96.50
0:54:45	18.08	22.64	20.00	19.52	24.56	21.20	19.28	19.28	96.50
0:55:00	18.32	22.64	20.00	19.76	25.04	21.44	19.28	19.28	96.00
0:55:15	18.32	22.88	20.24	19.76	25.52	21.44	19.28	19.52	96.00
0:55:30	18.32	23.12	20.48	20.00	26.00	21.68	19.28	19.52	95.50
0:55:45	18.56	22.88	20.48	20.24	26.24	21.68	19.52	19.76	90.50
0:56:00	18.56	22.88	20.72	20.24	26.24	21.44	19.52	19.76	82.50
0:56:15	18.56	22.64	20.72	20.24	26.48	21.20	19.76	19.76	75.00
0:56:30	18.80	22.64	20.72	20.24	26.48	21.20	19.76	19.76	67.50
0:56:45	18.80	22.16	20.72	20.00	26.24	20.96	19.76	19.76	60.50
0:57:00	18.80	21.92	20.48	20.00	26.24	20.96	19.76	19.76	54.50
0:57:15	18.80	21.68	20.48	20.00	26.24	20.72	19.76	19.76	50.00
0:57:30	18.80	21.20	20.48	19.76	25.76	20.72	19.52	19.52	47.00
0:57:45	18.80	20.96	20.24	19.76	25.52	20.48	19.52	19.52	43.50
0:58:00	18.80	20.96	20.24	19.76	25.04	20.24	19.52	19.52	40.50
0:58:15	18.80	20.72	20.00	19.76	24.56	20.00	19.52	19.28	39.00
0:58:30	18.80	20.48	20.00	19.52	24.32	19.76	19.28	19.28	37.00
0:58:45	18.56	20.24	19.76	19.52	23.84	19.52	19.28	19.28	36.50
0:59:00	18.56	20.00	19.76	19.28	23.12	19.52	19.28	19.28	35.00
0:59:15	18.56	19.76	19.52	19.28	22.64	19.28	19.28	19.28	33.50
0:59:30	18.56	19.28	19.52	19.28	22.40	19.28	19.28	19.04	32.50
0:59:45	18.56	19.28	19.28	19.28	21.92	19.04	19.28	19.04	32.00
1:00:00	18.56	19.28	19.28	19.28	21.44	19.04	19.04	18.80	31.00
1:00:15	18.32	19.04	19.28	19.28	20.96	18.80	19.04	18.80	30.50
1:00:30	18.32	18.80	19.28	19.04	20.72	18.56	18.80	18.80	30.00
1:00:45	18.32	18.56	19.28	19.04	20.24	18.56	18.80	18.56	30.00
1:01:00	18.32	18.32	19.04	19.04	19.76	18.32	18.80	18.56	29.50
1:01:15	18.32	18.08	19.04	18.80	19.28	18.08	18.56	18.32	29.50
1:01:30	18.32	17.84	18.80	18.80	19.04	18.08	18.56	18.32	29.50
1:01:45	18.32	17.84	18.80	18.56	18.56	17.84	18.56	18.32	29.00
1:02:00	18.32	17.84	18.56	18.56	18.32	17.84	18.32	18.08	29.00
1:02:15	18.08	17.60	18.56	18.56	17.84	17.84	18.32	18.08	29.00
1:02:30	18.08	17.36	18.32	18.32	17.60	17.84	18.32	18.08	29.50
1:02:45	18.08	17.12	18.32	18.32	17.36	17.60	18.08	17.84	30.50
1:03:00	18.08	17.12	18.08	18.08	16.88	17.60	18.08	17.84	36.00
1:03:15	18.08	17.12	18.08	18.08	16.64	17.60	18.08	17.84	39.50
1:03:30	18.08	17.60	18.08	18.08	16.40	17.84	17.84	17.84	42.50
1:03:45	18.08	17.84	18.08	18.08	16.40	17.84	17.84	17.84	47.00
1:04:00	17.84	18.08	18.32	18.32	16.64	18.08	18.08	17.84	54.00
1:04:15	17.84	18.80	18.32	18.32	17.12	18.32	18.08	17.84	62.00
1:04:30	17.84	19.28	18.56	18.56	17.60	18.80	18.08	18.08	69.00
1:04:45	17.84	19.52	18.80	18.80	18.08	19.04	18.32	18.08	75.00
1:05:00	18.08	20.24	19.04	18.80	18.80	19.28	18.32	18.32	80.50
1:05:15	18.08	20.72	19.28	19.04	19.52	19.76	18.56	18.56	84.50
1:05:30	18.08	20.96	19.28	19.28	20.24	20.00	18.56	18.80	87.50
1:05:45	18.08	21.44	19.28	19.28	20.96	20.48	18.80	18.80	89.50
1:06:00	18.08	21.68	19.52	19.28	21.92	20.72	19.04	19.04	90.50
1:06:15	18.32	22.16	19.76	19.52	22.64	20.96	19.04	19.28	91.50
1:06:30	18.32	22.40	20.00	19.52	23.12	20.96	19.28	19.28	92.00
1:06:45	18.32	22.64	20.00	19.76	23.84	20.96	19.28	19.28	92.00
1:07:00	18.32	22.64	20.24	20.00	24.32	21.20	19.28	19.52	92.50
1:07:15	18.56	22.88	20.48	20.00	24.80	21.44	19.52	19.52	92.50
1:07:30	18.56	22.88	20.48	20.24	25.28	21.68	19.52	19.76	92.50
1:07:45	18.56	23.12	20.72	20.24	25.76	21.68	19.52	19.76	92.50
1:08:00	18.80	23.36	20.72	20.48	26.24	21.92	19.76	20.00	92.50
1:08:15	18.80	23.60	20.96	20.48	26.24	21.92	19.76	20.00	92.50
1:08:30	18.80	22.88	20.96	20.48	26.48	21.68	20.00	20.00	65.00
1:08:45	19.04	22.64	20.96	20.48	26.72	21.20	20.00	20.24	47.50
1:09:00	19.04	22.16	20.96	20.24	26.72	20.96	20.00	20.00	46.00

INSULATION: High Humidity

Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH	Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:00:00	19.28	20.48	20.00	19.76	23.60	20.48	19.76	19.52	33.00	0:20:15	17.84	12.08	15.20	15.68	8.00	14.48	16.16	15.92	78.50
0:00:15	19.28	20.48	20.00	19.76	23.60	20.48	19.76	19.52	50.00	0:20:30	17.84	12.08	14.96	15.68	8.00	14.48	16.16	15.92	79.50
0:00:30	19.28	20.96	20.00	19.76	23.60	20.72	19.76	19.52	67.00	0:20:45	17.60	12.32	14.96	15.44	8.00	14.48	16.16	15.92	78.50
0:00:45	19.28	20.96	20.24	20.00	23.60	20.96	20.00	19.76	66.50	0:21:00	17.60	12.32	14.96	15.44	7.76	14.48	16.16	15.92	79.00
0:01:00	19.28	20.96	20.24	20.00	23.60	20.96	20.00	19.76	62.00	0:21:15	17.60	12.32	14.96	15.44	7.76	14.48	16.16	15.92	77.50
0:01:15	19.28	20.96	20.24	20.00	23.60	20.96	20.00	19.76	56.50	0:21:30	17.60	12.08	14.96	15.44	7.76	14.24	16.16	15.92	78.50
0:01:30	19.28	20.96	20.24	20.00	23.60	20.96	20.00	19.76	51.50	0:21:45	17.60	12.08	14.96	15.44	7.76	14.24	16.16	15.92	77.50
0:01:45	19.52	20.96	20.48	20.00	23.36	20.72	20.00	19.76	47.50	0:22:00	17.60	12.08	14.72	15.44	7.76	14.24	16.16	15.92	78.50
0:02:00	19.52	20.96	20.24	20.00	23.12	20.72	20.00	19.76	44.00	0:22:15	17.60	11.84	14.72	15.20	7.76	14.24	16.16	15.68	78.50
0:02:15	19.52	20.72	20.24	20.00	23.12	20.72	20.00	19.76	41.50	0:22:30	17.60	11.84	14.72	15.20	7.76	14.24	16.16	15.68	80.50
0:02:30	19.52	20.48	20.24	20.00	22.88	20.48	20.00	19.76	39.50	0:22:45	17.60	11.84	14.72	15.20	7.76	14.00	16.16	15.68	88.50
0:02:45	19.52	20.48	20.24	19.76	22.64	20.48	20.00	19.76	38.00	0:23:00	17.60	12.32	14.72	15.20	7.76	14.48	15.92	15.68	92.50
0:03:00	19.52	20.24	20.24	19.76	22.64	20.24	20.00	19.52	36.50	0:23:15	17.36	12.80	14.72	15.20	8.24	14.48	16.16	15.68	95.00
0:03:15	19.52	20.00	20.00	19.76	22.16	20.24	19.76	19.52	35.50	0:23:30	17.36	13.52	14.96	15.44	8.96	14.96	16.16	15.92	96.50
0:03:30	19.28	20.00	20.00	19.76	21.92	20.00	19.76	19.52	34.50	0:23:45	17.36	14.48	15.20	15.68	10.16	15.44	16.16	15.92	97.00
0:03:45	19.28	19.76	20.00	19.76	21.68	20.00	19.76	19.52	34.00	0:24:00	17.60	14.96	15.44	15.92	11.12	16.16	16.16	16.16	98.00
0:04:00	19.28	19.52	19.76	19.52	21.44	19.76	19.76	19.28	33.50	0:24:15	17.60	16.16	15.68	16.16	12.56	16.64	16.40	16.16	98.00
0:04:15	19.28	19.52	19.76	19.52	20.96	19.52	19.76	19.28	33.00	0:24:30	17.60	17.12	16.16	16.40	14.00	17.12	16.64	16.64	98.50
0:04:30	19.28	19.28	19.76	19.52	20.96	19.52	19.52	19.28	32.50	0:24:45	17.60	17.84	16.16	16.64	15.44	17.84	16.88	16.88	98.50
0:04:45	19.28	19.28	19.76	19.52	20.72	19.52	19.52	19.28	32.50	0:25:00	17.60	19.04	16.64	17.12	17.12	18.56	17.12	17.12	99.00
0:05:00	19.28	19.28	19.52	19.52	20.24	19.28	19.52	19.28	32.00	0:25:15	17.84	20.00	17.12	17.36	18.56	19.28	17.36	17.60	99.00
0:05:15	19.28	19.04	19.52	19.28	20.00	19.28	19.52	19.28	32.00	0:25:30	17.84	20.96	17.36	17.84	20.00	19.76	17.60	17.84	99.00
0:05:30	19.28	18.80	19.28	19.28	19.76	19.28	19.28	19.28	31.50	0:25:45	17.84	21.68	17.84	17.84	21.44	20.72	17.84	17.84	99.50
0:05:45	19.28	18.80	19.28	19.28	19.28	19.28	19.28	19.28	31.50	0:26:00	17.84	22.40	18.08	18.32	22.64	21.20	18.08	18.32	99.50
0:06:00	19.28	18.56	19.28	19.28	19.28	19.04	19.28	19.28	31.50	0:26:15	18.08	22.40	18.32	18.56	23.36	21.20	18.32	18.56	99.50
0:06:15	19.28	18.56	19.28	19.28	19.04	19.04	19.28	19.04	31.00	0:26:30	18.08	22.16	18.80	18.80	23.84	21.20	18.56	18.80	100.00
0:06:30	19.28	18.32	19.28	19.28	18.80	18.80	19.28	19.04	31.00	0:26:45	18.32	21.92	18.80	18.80	23.84	21.20	18.80	19.04	100.00
0:06:45	19.28	18.08	19.28	19.28	18.32	18.80	19.28	19.04	31.00	0:27:00	18.32	21.68	19.04	19.04	23.60	20.96	19.04	19.28	100.00
0:07:00	19.28	18.08	19.28	19.04	18.08	18.80	19.28	18.80	31.00	0:27:15	18.56	21.20	19.04	19.04	23.36	20.96	19.04	19.28	100.00
0:07:15	19.28	17.84	19.04	19.04	17.84	18.56	19.28	18.80	31.00	0:27:30	18.56	20.96	19.28	19.04	23.12	20.72	19.28	19.28	100.00
0:07:30	19.28	17.84	19.04	19.04	17.84	18.32	19.04	18.80	31.00	0:27:45	18.80	20.72	19.28	19.04	22.64	20.48	19.28	19.28	100.00
0:07:45	19.28	17.84	19.04	19.04	17.60	18.32	19.04	18.80	31.00	0:28:00	18.80	20.24	19.28	19.04	22.64	20.24	19.28	19.28	100.00
0:08:00	19.28	17.60	18.80	18.80	17.12	18.32	19.04	18.56	31.00	0:28:15	18.80	20.00	19.28	19.04	22.16	20.00	19.28	19.28	100.00
0:08:15	19.28	17.60	18.80	18.80	16.88	18.08	19.04	18.56	31.00	0:28:30	18.80	19.52	19.28	19.04	21.68	19.52	19.28	19.28	100.00
0:08:30	19.04	17.36	18.80	18.80	16.64	18.08	18.80	18.56	31.00	0:28:45	18.80	19.28	19.28	19.04	21.20	19.28	19.28	19.28	100.00
0:08:45	19.04	17.12	18.56	18.56	16.40	17.84	18.80	18.32	30.50	0:29:00	18.80	19.04	19.04	19.04	20.96	19.28	19.28	19.28	100.00
0:09:00	19.04	17.12	18.56	18.56	16.16	17.84	18.80	18.32	30.50	0:29:15	18.80	18.80	19.04	19.04	20.72	19.04	19.28	19.28	100.00
0:09:15	19.04	16.88	18.56	18.56	16.16	17.84	18.80	18.32	30.50	0:29:30	19.04	18.56	19.04	18.80	20.24	19.04	19.28	19.04	100.00
0:09:30	19.04	16.88	18.32	18.32	15.92	17.84	18.56	18.32	30.50	0:29:45	18.80	18.32	19.04	18.80	19.76	18.80	19.28	19.04	100.00
0:09:45	19.04	16.64	18.32	18.32	15.68	17.60	18.56	18.08	30.50	0:30:00	18.80	18.08	19.04	18.80	19.28	18.56	19.04	19.04	99.50
0:10:00	19.04	16.40	18.32	18.32	15.44	17.60	18.56	18.08	30.50	0:30:15	18.80	17.84	18.80	18.80	19.04	18.32	19.04	19.04	99.50
0:10:15	19.04	16.40	18.08	18.32	15.20	17.60	18.56	18.08	30.50	0:30:30	18.80	17.60	18.80	18.56	18.80	18.32	19.04	18.80	99.00
0:10:30	18.80	16.16	18.08	18.08	14.96	17.36	18.32	18.08	30.50	0:30:45	18.80	17.36	18.80	18.56	18.32	18.08	19.04	18.80	99.00
0:10:45	18.80	16.16	17.84	18.08	14.72	17.36	18.32	17.84	30.50	0:31:00	18.80	17.12	18.56	18.56	17.84	18.08	18.80	18.80	98.50
0:11:00	18.80	16.16	17.84	18.08	14.48	17.12	18.32	17.84	30.50	0:31:15	18.80	17.12	18.56	18.32	17.60	17.84	18.80	18.56	98.00
0:11:15	18.80	15.92	17.84	17.84	14.48	17.12	18.08	17.84	30.50	0:31:30	18.80	17.12	18.32	18.32	17.36	17.84	18.80	18.56	98.00
0:11:30	18.80	15.92	17.84	17.84	14.24	16.88	18.08	17.84	30.50	0:31:45	18.56	17.12	18.32	18.32	16.88	17.84	18.56	18.32	97.00
0:11:45	18.80	15.68	17.84	17.84	14.00	16.88	18.08	17.84	30.50	0:32:00	18.56	16.88	18.32	18.08	16.40	17.84	18.56	18.32	96.50
0:12:00	18.80	15.68	17.60	17.84	13.76	16.88	18.08	17.84	30.50	0:32:15	18.56	16.88	18.08	18.08	16.16	17.84	18.56	18.32	95.50
0:12:15	18.56	15.44	17.60	17.84	13.52	16.64	17.84	17.84	29.50	0:32:30	18.56	16.64	18.08	18.08	16.16	17.60	18.32	18.08	93.50
0:12:30	18.56	15.44	17.60	17.84	13.28	16.64	17.84	17.60	28.50	0:32:45	18.56	16.40	17.84	17.84	15.92	17.60	18.32	18.08	90.50
0:12:45	18.56	15.20	17.36	17.60	13.04	16.40	17.84	17.60	27.00	0:33:00	18.56	16.16	17.84	17.84	15.92	17.36	18.32	17.84	87.50
0:13:00	18.56	14.96	17.36	17.60	12.80	16.40	17.84	17.60	26.00	0:33:15	18.32	16.16	17.84	17.84	15.92	17.12	18.08	17.84	86.00
0:13:15	18.56	14.96	17.36	17.36	12.56	16.16	17.84	17.60	26.00	0:33:30	18.32	16.16	17.84	17.84	15.68	17.12	18.08	17.84	82.50
0:13:30	18.56	14.72	17.12	17.36	12.56	16.16	17.84	17.36	26.50	0:33:45	18.32	16.16	17.84	17.84	15.44	16.88	18.08	17.84	78.50
0:13:45	18.32	14.48	17.12	17.36	12.32	16.16	17.84	17.36	28.00	0:34:00	18.32	15.92	17.60	17.84	15.20	16.88	17.84	17.84	74.00
0:14:00	18.32	14.48	16.88	17.12	12.08	16.16	17.60	17.36	30.50	0:34:15	18.32	15.68	17.60	17.60	14.96	16.64	17.84	17.84	70.00
0:14:15	18.32	14.48	16.88	17.12	11.84	15.92	17.60	17.12	33.50	0:34:30	18.32	15.44	17.36	17.60	14.72	16.40	17.84	17.60	66.50
0:14:30	18.32	14.24	16.64	17.12	11.60	15.92	17.60	17.12	35.50	0:34:45	18.08	15.20	17.36	17.36	14.48	16.40	17.84	17.60	64.00
0:14:45	18.32	14.24	16.64	16.88	11.36	15.68	17.36	17.12	36.50	0:35:00	18.08	15.20	17.12	17.36	14.48	16.16	17.84	17.36	62.00
0:15:00	18.32	14.00	16.40	16.88	11.12	15.68	17.36	16.88	37.50	0:35:15	18.08	14.96	17.12	17.12	14.24	16.16	17.60	17.36	60.00
0:15:15	18.32	14.00	16.40	16.88	10.88	15.68	17.36	16.88	38.50	0:35:30	18.08	14.72	16.88	17.12	14.00	16.16	17.60	17.12	58.00
0:15:30	18.08	13.76	16.40	16.64	10.64	15.44	17.12	16.88	39.00	0:35:45	18.08	14.48	16.88	17.12	13.76	16.16	17.60	17.12	57.00
0:15:45	18.08	13.76	16.16	16.64	10.40	15.44	17.12	16.64	40.00	0:36:00	17.84	14.48	16.64	16.88	13.28	15.92	17.36	17.12	55.50
0:16:00	18.08	13.52	16.16	16.40	10.40	15.44	17.12	16.64	40.50	0:36:15	17.84	14.48	16.64	16.88	13.04	15.92	17.36	16.88	54.50
0:16:15	18.08	13.52	16.16	16.40	10.16	15.20	17.12	16.64	41.00	0:36:30	17.84	14.24	16.40	16.64	12.80	15.68	17.36	16.88	53.50
0:16:30	18.08	13.28	16.16	16.40	9.92	15.20	16.88	16.64	42.00	0:36:45	17.84	14.24	16.40	16.64	12.56	15.68	17.12	16.88	52.50
0:16:45	18.08	13.28	16.16	16.16	9.68	14.96	16.88	16.40	42.50	0:37:00	17.84	14.00	16.40	16.64	12.56	15.44	17.12	16.64	52.00
0:17:00	17.84	13.04	15.92	16.16	9.68	14.96	16.88	16.40	43.50	0:37:15	17.84	14.00	16.16	16.40	12.32	15.44	17.12	16.64	51.00
0:17:15	17.84	13.04	15.92	16.16	9.44	14.96	16.88	16.40	44.50	0:37:30	17.84	13.76	16.16	16.40	12.08	15.20	16.88	16.40	50.50
0:17:30	17.84	12.80	15.92	16.16	9.20	14.96	16.64	16.40	45.00	0:37:45	17.84	13.76	16.16	16.16	11.84	15.20	16.88	16.40	50.00
0:17:45	17.84	12.80	15.92	16.16	9.20	14.72	16.64	16.16	45.50	0:38:00	17.84	13.52	16.16	16.16	11.60	15.20	16.88	16.40	49.50
0:18:00	17.84	12.80	15.68	16.16	8.96	14.72	16.64	16.16	46.00	0:38:15	17.84	13.28	15.92	16.16	11.36	14.96	16.64	16.40	49.00
0:18:15	17.84	12.56	15.68	16.16	8.96	14.72	16.40	16.16	46.50	0:38:30	17.60	13.28	15.92	16.16	11.12	14.96	16.64	16.16	48.00
0:18:30	17.84	12.56	15.68	15.92	8.72	14.48	16.40	16.16	47.00	0:38:45	17.60	13.04	15.68	16.16	10.88	14.72	16.40	16.16	59.00
0:18:45	17.84	12.56	15.44	15.92	8.72	14.48	16.40	16.16	47.00	0:39:00	17.60	12.80	15.68	15.92	10.64	14.72	16.40	16.16	56.00
0:19:00	17.84	12.56	15.44	15.92	8.48	14.48	16.40	16.16	47.50	0:39:15	17.60	12.80	15.68	15.92	10.64	14.72	16.40	16.16	60.50
0:19:15	17.84	12.56	15.44	15.92	8.24	14.48	16.40	16.16	47.50	0:39:30	17.60	12.80	15.44	15.92	10.40	14.48	16.40	16.16	65.00
0:19:30	17.84	12.32	15.20	15.68	8.24	14.48	16.40	16.16	47.50	0:39:45	17.60	12.56	15.44	15.92	10.40	14.48	16.16	15.92	61.50
0:19:45	17.84	12.32	15.20	15.68	8.24	14.48	16.16	16.16	56.00	0:40:00	17.36	12.56	15.44	15.68	10.16	14.48	16.16	15.92	66.50
0:20:00	17.84	12.32	15.20	15.68	8.00	14.48	16.16	16.16	69.50	0:40:15	17.36	12.56	15.20	15.68	9.92	14.48	16.16	15.92	63.00

Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH	Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
0:40:30	17.36	12.56	15.20	15.68	9.68	14.48	16.16	15.92	66.50	1:00:45	17.12	12.56	14.96	15.44	10.16	14.24	15.92	15.68	67.00
0:40:45	17.36	12.56	15.20	15.44	9.68	14.48	16.16	15.92	71.00	1:01:00	16.88	12.56	14.96	15.44	9.92	14.24	15.92	15.68	71.00
0:41:00	17.36	12.56	14.96	15.44	9.44	14.48	16.16	15.68	66.50	1:01:15	16.88	12.56	14.96	15.20	9.68	14.24	15.92	15.44	72.50
0:41:15	17.36	12.32	14.96	15.44	9.20	14.24	16.16	15.68	71.50	1:01:30	16.88	12.32	14.72	15.20	9.44	14.00	15.92	15.44	71.50
0:41:30	17.36	12.32	14.96	15.20	9.20	14.24	16.16	15.68	68.00	1:01:45	16.88	12.32	14.72	15.20	9.44	14.00	15.68	15.44	75.00
0:41:45	17.12	12.32	14.72	15.20	8.96	14.24	15.92	15.68	72.00	1:02:00	16.88	12.32	14.72	14.96	9.20	14.00	15.68	15.44	71.50
0:42:00	17.12	12.08	14.72	15.20	8.96	14.24	15.92	15.68	70.00	1:02:15	16.88	12.32	14.72	14.96	9.20	14.00	15.68	15.44	75.00
0:42:15	17.12	12.08	14.72	15.20	8.72	14.00	15.92	15.44	71.50	1:02:30	16.88	12.08	14.48	14.96	8.96	14.00	15.68	15.44	75.50
0:42:30	17.12	12.08	14.72	15.20	8.72	14.00	15.92	15.44	75.50	1:02:45	16.64	12.08	14.48	14.96	8.96	13.76	15.68	15.20	75.50
0:42:45	17.12	12.08	14.48	14.96	8.48	14.00	15.92	15.44	72.50	1:03:00	16.64	12.08	14.48	14.96	8.72	13.76	15.68	15.20	78.50
0:43:00	17.12	12.08	14.48	14.96	8.48	14.00	15.68	15.44	76.00	1:03:15	16.64	12.08	14.48	14.72	8.72	13.76	15.44	15.20	76.50
0:43:15	17.12	12.08	14.48	14.96	8.48	14.00	15.68	15.44	78.50	1:03:30	16.64	11.84	14.48	14.72	8.72	13.76	15.44	15.20	78.50
0:43:30	17.12	12.08	14.48	14.96	8.48	14.00	15.68	15.44	87.50	1:03:45	16.64	11.84	14.48	14.72	8.48	13.76	15.44	15.20	76.00
0:43:45	16.88	12.56	14.48	14.96	8.48	14.24	15.68	15.44	93.00	1:04:00	16.64	11.84	14.48	14.72	8.48	13.76	15.44	15.20	79.50
0:44:00	16.88	13.04	14.72	14.96	8.72	14.48	15.68	15.44	96.50	1:04:15	16.64	11.84	14.48	14.72	8.48	13.76	15.44	14.96	77.00
0:44:15	16.88	13.76	14.72	15.20	8.96	14.96	15.92	15.44	98.00	1:04:30	16.64	11.84	14.48	14.48	8.24	13.76	15.44	14.96	80.50
0:44:30	16.88	14.48	14.96	15.44	9.68	15.44	15.92	15.68	98.50	1:04:45	16.64	11.84	14.48	14.48	8.24	13.52	15.44	14.96	78.00
0:44:45	16.88	15.20	15.44	15.68	10.40	15.92	16.16	15.92	99.00	1:05:00	16.40	11.60	14.24	14.48	8.24	13.52	15.20	14.96	80.00
0:45:00	17.12	16.16	15.68	15.92	11.36	16.40	16.16	16.16	99.00	1:05:15	16.40	11.60	14.24	14.48	8.00	13.52	15.20	14.96	81.50
0:45:15	17.12	17.12	15.92	16.16	12.32	17.12	16.40	16.16	99.00	1:05:30	16.40	11.60	14.24	14.48	8.00	13.52	15.20	14.96	80.50
0:45:30	17.12	17.84	16.16	16.40	13.52	17.84	16.64	16.64	99.50	1:05:45	16.40	11.60	14.24	14.48	8.00	13.52	15.20	14.96	83.00
0:45:45	17.12	19.04	16.40	16.88	14.72	18.32	16.88	16.88	99.50	1:06:00	16.40	11.60	14.24	14.48	8.00	13.52	15.20	14.96	81.50
0:46:00	17.36	19.52	16.88	17.12	16.16	19.28	17.12	17.12	99.50	1:06:15	16.40	11.60	14.24	14.48	8.00	13.52	15.20	14.72	82.00
0:46:15	17.36	20.48	17.36	17.60	17.36	19.76	17.36	17.60	100.00	1:06:30	16.40	11.36	14.00	14.48	7.76	13.28	15.20	14.72	81.00
0:46:30	17.60	21.20	17.60	17.84	18.56	20.24	17.60	17.84	100.00	1:06:45	16.40	11.36	14.00	14.48	7.76	13.28	14.96	14.72	84.50
0:46:45	17.60	21.92	17.84	17.84	19.76	20.96	17.84	18.08	100.00	1:07:00	16.40	11.36	14.00	14.48	7.76	13.28	14.96	14.72	88.50
0:47:00	17.84	22.40	18.08	18.32	20.96	21.20	18.08	18.32	100.00	1:07:15	16.40	11.84	14.00	14.48	7.76	13.52	14.96	14.72	94.00
0:47:15	17.84	22.40	18.56	18.56	21.92	21.20	18.32	18.56	100.00	1:07:30	16.16	12.32	14.00	14.48	8.00	14.00	14.96	14.72	96.50
0:47:30	17.84	21.92	18.56	18.80	22.64	21.20	18.56	18.80	100.00	1:07:45	16.16	12.80	14.24	14.48	8.48	14.24	15.20	14.96	98.00
0:47:45	18.08	21.68	18.80	18.80	22.64	20.96	18.80	19.04	100.00	1:08:00	16.16	13.52	14.48	14.72	8.96	14.72	15.20	14.96	99.00
0:48:00	18.08	21.20	18.80	18.80	22.88	20.96	18.80	19.04	100.00	1:08:15	16.40	14.48	14.48	14.96	9.68	15.20	15.44	15.20	99.00
0:48:15	18.32	20.96	19.04	18.80	22.64	20.72	19.04	19.04	100.00	1:08:30	16.40	15.20	14.72	15.20	10.40	15.68	15.68	15.44	99.50
0:48:30	18.32	20.72	19.04	18.80	22.64	20.48	19.04	19.04	100.00	1:08:45	16.40	16.16	15.20	15.44	11.60	16.16	15.92	15.68	99.50
0:48:45	18.32	20.24	19.04	18.80	22.40	20.00	19.04	19.04	100.00	1:09:00	16.40	17.12	15.44	15.92	12.56	17.12	15.92	16.16	99.50
0:49:00	18.56	20.00	19.04	18.80	22.16	19.76	19.04	19.04	100.00	1:09:15	16.64	17.84	15.92	16.16	14.00	17.60	16.16	16.16	100.00
0:49:15	18.56	19.52	18.80	18.80	21.68	19.52	19.04	19.04	100.00	1:09:30	16.64	18.80	16.16	16.16	14.96	18.32	16.40	16.40	100.00
0:49:30	18.56	19.28	18.80	18.80	21.20	19.28	19.04	19.04	100.00	1:09:45	16.64	19.52	16.40	16.64	16.16	19.04	16.64	16.88	100.00
0:49:45	18.56	19.04	18.80	18.80	20.96	19.28	19.04	19.04	100.00	1:10:00	16.88	20.48	16.88	16.88	17.60	19.52	16.88	17.12	100.00
0:50:00	18.56	18.80	18.80	18.80	20.72	19.04	19.04	18.80	100.00	1:10:15	16.88	20.96	17.12	17.36	18.80	20.24	17.12	17.36	100.00
0:50:15	18.56	18.56	18.80	18.56	20.24	18.80	19.04	18.80	100.00	1:10:30	17.12	21.20	17.60	17.60	19.76	20.48	17.60	17.84	100.00
0:50:30	18.56	18.32	18.80	18.56	19.76	18.56	18.80	18.80	100.00	1:10:45	17.36	21.20	17.84	17.84	20.96	20.48	17.84	17.84	100.00
0:50:45	18.56	18.08	18.80	18.56	19.28	18.32	18.80	18.80	100.00	1:11:00	17.36	20.96	17.84	17.84	21.20	20.48	17.84	18.08	100.00
0:51:00	18.56	17.84	18.56	18.56	19.04	18.08	18.80	18.56	100.00	1:11:15	17.60	20.72	17.84	17.84	21.68	20.24	17.84	18.08	100.00
0:51:15	18.56	17.60	18.56	18.32	18.80	17.84	18.80	18.56	100.00	1:11:30	17.60	20.48	18.08	17.84	21.92	19.76	18.08	18.32	100.00
0:51:30	18.32	17.36	18.56	18.32	18.32	17.84	18.56	18.56	100.00	1:11:45	17.84	20.00	18.08	17.84	21.68	19.52	18.08	18.32	100.00
0:51:45	18.32	17.12	18.32	18.32	17.84	17.84	18.56	18.32	100.00	1:12:00	17.84	19.52	18.08	17.84	21.68	19.28	18.08	18.32	100.00
0:52:00	18.32	16.88	18.32	18.08	17.84	17.60	18.56	18.32	100.00	1:12:15	17.84	19.28	18.08	17.84	21.20	19.28	18.08	18.32	100.00
0:52:15	18.32	16.64	18.32	18.08	17.36	17.60	18.56	18.32	100.00	1:12:30	17.84	19.04	18.08	17.84	20.96	19.04	18.32	18.32	100.00
0:52:30	18.32	16.40	18.08	18.08	16.88	17.60	18.32	18.08	100.00	1:12:45	17.84	18.80	18.08	17.84	20.96	18.80	18.32	18.32	100.00
0:52:45	18.32	16.40	18.08	17.84	16.40	17.36	18.32	18.08	100.00	1:13:00	17.84	18.32	18.08	17.84	20.48	18.56	18.08	18.32	100.00
0:53:00	18.08	16.40	17.84	17.84	16.16	17.36	18.32	17.84	99.50	1:13:15	17.84	18.08	17.84	17.84	20.00	18.32	18.08	18.08	100.00
0:53:15	18.08	16.40	17.84	17.84	15.92	17.12	18.08	17.84	98.50	1:13:30	17.84	17.84	17.84	17.84	19.52	18.08	18.08	18.08	100.00
0:53:30	18.08	16.16	17.84	17.84	15.44	17.12	18.08	17.84	97.00	1:13:45	17.84	17.84	17.84	17.84	19.28	17.84	18.08	18.08	100.00
0:53:45	18.08	16.16	17.84	17.84	14.96	17.12	18.08	17.84	95.00	1:14:00	17.84	17.60	17.84	17.84	19.04	17.84	18.08	18.08	100.00
0:54:00	18.08	16.16	17.84	17.60	14.72	16.88	17.84	17.84	92.50	1:14:15	17.84	17.36	17.84	17.84	18.56	17.60	18.08	17.84	100.00
0:54:15	17.84	15.92	17.60	17.60	14.72	16.88	17.84	17.60	89.50	1:14:30	17.84	16.88	17.84	17.84	18.08	17.60	18.08	17.84	100.00
0:54:30	17.84	15.68	17.60	17.36	14.72	16.64	17.84	17.60	87.00	1:14:45	17.84	16.64	17.84	17.84	17.84	17.36	17.84	17.84	100.00
0:54:45	17.84	15.68	17.36	17.36	14.72	16.40	17.84	17.36	82.50	1:15:00	17.84	16.40	17.84	17.84	17.60	17.12	17.84	17.84	100.00
0:55:00	17.84	15.44	17.36	17.36	14.48	16.16	17.84	17.36	77.00	1:15:15	17.84	16.16	17.84	17.60	17.12	17.12	17.84	17.84	100.00
0:55:15	17.84	15.20	17.12	17.12	14.48	16.16	17.60	17.36	73.00	1:15:30	17.84	16.16	17.60	17.60	16.88	16.88	17.84	17.84	100.00
0:55:30	17.84	14.96	17.12	17.12	14.48	16.16	17.60	17.12	70.50	1:15:45	17.84	15.92	17.60	17.36	16.40	16.88	17.84	17.60	100.00
0:55:45	17.84	14.96	16.88	17.12	14.24	16.16	17.36	17.12	67.50	1:16:00	17.84	15.92	17.36	17.36	16.16	16.88	17.84	17.60	100.00
0:56:00	17.84	14.72	16.88	16.88	14.00	15.92	17.36	16.88	65.00	1:16:15	17.60	15.92	17.36	17.36	15.68	16.64	17.84	17.36	100.00
0:56:15	17.84	14.48	16.64	16.88	13.76	15.92	17.36	16.88	63.00	1:16:30	17.60	15.92	17.36	17.36	15.44	16.64	17.60	17.36	99.50
0:56:30	17.84	14.48	16.64	16.64	13.52	15.68	17.12	16.88	61.00	1:16:45	17.60	15.68	17.12	17.12	14.96	16.40	17.60	17.36	99.00
0:56:45	17.60	14.48	16.40	16.64	13.28	15.68	17.12	16.64	59.50	1:17:00	17.60	15.68	17.12	17.12	14.48	16.40	17.60	17.12	98.00
0:57:00	17.60	14.24	16.40	16.40	13.04	15.44	16.88	16.64	58.50	1:17:15	17.60	15.44	16.88	16.88	14.48	16.16	17.36	17.12	96.00
0:57:15	17.60	14.24	16.16	16.40	12.80	15.44	16.88	16.40	57.00	1:17:30	17.60	15.20	16.88	16.88	14.00	16.16	17.36	16.88	93.50
0:57:30	17.60	14.00	16.16	16.40	12.56	15.20	16.88	16.40	56.50	1:17:45	17.36	15.20	16.88	16.64	14.00	16.16	17.36	16.88	91.00
0:57:45	17.60	13.76	16.16	16.16	12.56	15.20	16.64	16.40	55.50	1:18:00	17.36	14.96	16.64	16.64	14.00	16.16	17.12	16.88	88.50
0:58:00	17.36	13.76	16.16	16.16	12.32	14.96	16.64	16.16	54.50	1:18:15	17.36	14.72	16.64	16.64	14.00	15.92	17.12	16.64	85.50
0:58:15	17.36	13.52	15.92	16.16	12.08	14.96	16.40	16.16	54.00	1:18:30	17.36	14.72	16.40	16.40	13.76	15.92	16.88	16.64	80.00
0:58:30	17.36	13.28	15.92	16.16	11.84	14.72	16.40	16.16	53.50	1:18:45	17.12	14.48	16.40	16.40	13.52	15.68	16.88	16.40	75.50
0:58:45	17.36	13.28	15.68	16.16	11.60	14.72	16.40	16.16	53.00	1:19:00	17.36	14.48	16.16	16.40	13.52	15.44	16.88	16.40	72.50
0:59:00	17.36	13.04	15.68	15.92	11.36	14.48	16.16	16.16	52.00	1:19:15	17.12	14.48	16.16	16.16	13.28	15.44	16.64	16.40	70.00
0:59:15	17.12	12.80	15.44	15.92	11.12	14.48	16.16	16.16	60.50	1:19:30	17.12	14.24	16.16	16.16	13.04	15.20	16.64	16.16	67.50
0:59:30	17.12	12.80	15.44	15.68	10.88	14.48	16.16	15.92	60.50	1:19:45	17.12	14.00	16.16	16.16	12.80	15.20	16.40	16.16	65.00
0:59:45	17.12	12.56	15.44	15.68	10.64	14.48	16.16	15.92	65.00	1:20:00	17.12	14.00	15.92	16.16	12.56	14.96	16.40	16.16	63.50
1:00:00	17.12	12.56	15.20	15.68	10.40	14.48	16.16	15.92	62.50	1:20:15	17.12	13.76	15.92	16.16	12.56	14.96	16.40	16.16	62.00
1:00:15	17.12	12.56	15.20	15.44	10.40	14.48	16.16	15.68	66.00	1:20:30	16.88	13.52	15.68	15.92	12.32	14.72	16.16	16.16	61.00
1:00:30	17.12	12.56	15.20	15.44	10.40	14.24	16.16	15.68	70.50	1:20:45	16.88	13.28	15.68	15.92	12.08	14.72	16.16	15.92	60.00

Time	IntT	No S	Op S	Cl S	AT	None F	Open F	Closed	RH
1:21:00	16.88	13.28	15.68	15.68	11.84	14.48	16.16	15.92	59.00
1:21:15	16.88	13.04	15.44	15.68	11.60	14.48	16.16	15.92	58.00
1:21:30	16.88	13.04	15.44	15.68	11.36	14.48	16.16	15.68	57.00
1:21:45	16.64	12.80	15.20	15.44	11.12	14.48	16.16	15.68	56.50
1:22:00	16.64	12.56	15.20	15.44	10.88	14.24	15.92	15.68	56.00
1:22:15	16.64	12.56	14.96	15.44	10.88	14.24	15.92	15.44	55.50
1:22:30	16.64	12.56	14.96	15.20	10.64	14.24	15.92	15.44	55.00
1:22:45	16.64	12.56	14.96	15.20	10.40	14.00	15.68	15.44	53.50
1:23:00	16.40	12.32	14.72	14.96	10.40	14.00	15.68	15.20	64.50
1:23:15	16.40	12.32	14.72	14.96	10.16	13.76	15.68	15.20	64.00
1:23:30	16.40	12.08	14.48	14.96	9.92	13.76	15.44	15.20	65.00
1:23:45	16.40	12.08	14.48	14.72	9.68	13.76	15.44	14.96	70.00
1:24:00	16.40	12.08	14.48	14.72	9.44	13.76	15.44	14.96	66.00
1:24:15	16.40	11.84	14.48	14.72	9.44	13.76	15.20	14.96	71.00
1:24:30	16.16	11.84	14.48	14.72	9.20	13.52	15.20	14.96	72.50
1:24:45	16.16	11.84	14.48	14.48	8.96	13.52	15.20	14.96	70.50
1:25:00	16.16	11.60	14.24	14.48	8.96	13.28	15.20	14.72	75.00
1:25:15	16.16	11.60	14.24	14.48	8.72	13.28	15.20	14.72	72.50
1:25:30	16.16	11.60	14.24	14.48	8.72	13.28	14.96	14.72	86.00
1:25:45	16.16	11.84	14.24	14.48	8.72	13.52	14.96	14.72	92.50
1:26:00	16.16	12.32	14.24	14.48	8.72	13.76	14.96	14.72	96.00
1:26:15	16.16	12.80	14.48	14.48	8.96	14.24	14.96	14.72	98.00
1:26:30	16.16	13.76	14.48	14.72	9.44	14.48	15.20	14.96	99.00
1:26:45	16.16	14.48	14.48	14.96	10.16	15.20	15.44	15.20	99.50
1:27:00	16.16	15.20	14.96	15.20	10.88	15.68	15.44	15.44	99.50
1:27:15	16.16	16.16	15.20	15.44	11.84	16.16	15.68	15.68	100.00
1:27:30	16.16	17.12	15.68	15.92	12.80	16.88	15.92	15.92	100.00
1:27:45	16.16	17.84	15.92	16.16	14.24	17.60	16.16	16.16	100.00
1:28:00	16.40	18.80	16.16	16.40	15.44	18.32	16.16	16.40	100.00
1:28:15	16.40	19.52	16.40	16.64	16.40	18.80	16.64	16.64	100.00
1:28:30	16.64	20.72	16.88	17.12	17.84	19.52	16.88	17.12	100.00
1:28:45	16.88	21.20	17.36	17.36	19.04	20.24	17.12	17.36	100.00
1:29:00	16.88	22.16	17.60	17.84	20.24	20.96	17.36	17.60	100.00
1:29:15	17.12	22.64	17.84	17.84	21.44	21.20	17.84	17.84	100.00
1:29:30	17.12	23.12	18.08	18.08	22.64	21.68	17.84	18.08	100.00
1:29:45	17.36	23.12	18.56	18.32	23.36	21.92	18.08	18.32	100.00
1:30:00	17.60	22.64	18.56	18.56	24.08	21.68	18.32	18.56	100.00
1:30:15	17.60	22.40	18.80	18.80	24.32	21.44	18.56	18.80	100.00
1:30:30	17.84	22.16	18.80	18.80	24.32	21.20	18.56	18.80	100.00
1:30:45	17.84	21.68	19.04	18.80	24.32	20.96	18.80	19.04	100.00
1:31:00	17.84	21.20	19.04	18.80	24.08	20.96	18.80	19.04	100.00
1:31:15	17.84	20.96	19.04	18.80	23.60	20.48	18.80	19.04	100.00
1:31:30	18.08	20.72	19.04	18.80	23.12	20.24	18.80	19.04	100.00
1:31:45	18.08	20.24	19.04	18.80	22.64	20.00	18.80	19.04	100.00
1:32:00	18.08	20.00	19.04	18.80	22.40	19.52	18.80	18.80	100.00
1:32:15	18.08	19.52	19.04	18.80	21.92	19.28	18.80	18.80	100.00
1:32:30	18.08	19.28	19.04	18.80	21.44	19.28	18.80	18.80	100.00
1:32:45	18.08	19.28	18.80	18.80	21.20	19.28	18.80	18.80	100.00
1:33:00	18.08	19.04	18.80	18.80	20.96	19.04	18.80	18.56	100.00
1:33:15	18.08	18.80	18.80	18.56	20.48	18.80	18.80	18.56	100.00
1:33:30	18.08	18.32	18.80	18.56	20.00	18.56	18.80	18.56	100.00
1:33:45	18.08	18.08	18.56	18.56	19.52	18.32	18.56	18.32	100.00
1:34:00	18.08	17.84	18.56	18.56	19.28	18.08	18.56	18.32	100.00
1:34:15	17.84	17.84	18.56	18.32	19.04	17.84	18.56	18.32	100.00
1:34:30	17.84	17.60	18.32	18.32	18.56	17.84	18.32	18.08	100.00
1:34:45	17.84	17.36	18.32	18.08	18.08	17.60	18.32	18.08	100.00
1:35:00	17.84	16.88	18.32	18.08	17.84	17.60	18.32	17.84	100.00
1:35:15	17.84	16.64	18.08	18.08	17.60	17.36	18.08	17.84	100.00
1:35:30	17.84	16.40	18.08	17.84	17.12	17.12	18.08	17.84	100.00
1:35:45	17.84	16.16	17.84	17.84	16.88	16.88	18.08	17.84	100.00
1:36:00	17.84	16.16	17.84	17.84	16.40	16.64	17.84	17.84	100.00
1:36:15	17.84	15.92	17.84	17.84	16.16	16.40	17.84	17.60	99.50
1:36:30	17.84	15.68	17.84	17.60	15.92	16.16	17.84	17.60	98.50
1:36:45	17.60	15.68	17.84	17.60	15.44	16.16	17.84	17.60	97.50
1:37:00	17.60	15.68	17.60	17.36	15.20	16.16	17.84	17.36	96.00
1:37:15	17.60	15.68	17.60	17.36	14.96	16.16	17.60	17.36	94.00
1:37:30	17.60	15.44	17.36	17.12	14.96	16.16	17.60	17.12	91.50
1:37:45	17.36	15.44	17.12	17.12	14.72	16.16	17.36	17.12	89.50
1:38:00	17.36	15.20	17.12	16.88	14.72	16.16	17.36	16.88	86.50
1:38:15	17.36	14.96	16.88	16.88	14.48	15.92	17.36	16.88	82.50
1:38:30	17.36	14.96	16.88	16.64	14.48	15.92	17.12	16.64	79.50
1:38:45	17.12	14.72	16.64	16.64	14.48	15.92	17.12	16.64	76.50
1:39:00	17.12	14.72	16.64	16.40	14.24	15.68	16.88	16.40	74.00
1:39:15	17.12	14.48	16.40	16.40	14.00	15.68	16.88	16.40	71.50
1:39:30	17.12	14.48	16.40	16.16	13.76	15.44	16.88	16.16	69.00
1:39:45	17.12	14.48	16.16	16.16	13.52	15.44	16.64	16.16	66.50
1:40:00	16.88	14.24	16.16	16.16	13.28	15.20	16.64	16.16	64.50
1:40:15	16.88	14.00	16.16	16.16	13.04	15.20	16.40	16.16	63.00
1:40:30	16.88	13.76	15.92	16.16	12.80	14.96	16.40	16.16	61.50
1:40:45	16.88	13.76	15.92	15.92	12.56	14.72	16.16	16.16	60.00
1:41:00	16.64	13.52	15.68	15.92	12.56	14.72	16.16	15.92	59.00

Time	IntT	No S	Op S	Cl S	AT	No R	Op R	Cl R	RH
1:41:15	16.64	13.28	15.68	15.68	12.32	14.48	16.16	15.92	58.00
1:41:30	16.64	13.04	15.44	15.68	12.08	14.48	16.16	15.68	57.50
1:41:45	16.64	13.04	15.44	15.68	11.84	14.48	16.16	15.68	56.50
1:42:00	16.64	12.80	15.20	15.44	11.60	14.48	15.92	15.68	56.00
1:42:15	16.40	12.56	15.20	15.44	11.36	14.48	15.92	15.44	55.50
1:42:30	16.40	12.56	14.96	15.20	11.12	14.24	15.92	15.44	63.50
1:42:45	16.40	12.56	14.96	15.20	10.88	14.24	15.68	15.20	63.50
1:43:00	16.40	12.56	14.96	14.96	10.64	14.00	15.68	15.20	66.50
1:43:15	16.16	12.32	14.72	14.96	10.40	14.00	15.68	15.20	69.50
1:43:30	16.16	12.32	14.72	14.96	10.40	14.00	15.44	15.20	67.00
1:43:45	16.16	12.32	14.48	14.96	10.40	13.76	15.44	15.20	71.50
1:44:00	16.16	12.32	14.48	14.72	10.16	13.76	15.44	14.96	73.00
1:44:15	16.16	12.08	14.48	14.72	9.92	13.76	15.44	14.96	71.00
1:44:30	16.16	12.08	14.48	14.72	9.68	13.76	15.20	14.96	75.00
1:44:45	16.16	12.08	14.48	14.72	9.68	13.76	15.20	14.96	74.50
1:45:00	16.16	12.08	14.48	14.48	9.44	13.76	15.20	14.96	75.00
1:45:15	16.16	11.84	14.48	14.48	9.44	13.76	15.20	14.72	78.50
1:45:30	16.16	11.84	14.24	14.48	9.20	13.52	15.20	14.72	75.00
1:45:45	16.16	11.84	14.24	14.48	9.20	13.52	14.96	14.72	78.50
1:46:00	16.16	11.84	14.24	14.48	8.96	13.52	14.96	14.72	78.50
1:46:15	16.16	11.60	14.24	14.48	8.96	13.52	14.96	14.72	78.50
1:46:30	16.16	11.60	14.24	14.48	8.72	13.52	14.96	14.72	81.50
1:46:45	16.16	11.60	14.00	14.48	8.72	13.28	14.96	14.48	78.50
1:47:00	16.16	11.60	14.00	14.48	8.72	13.28	14.96	14.48	82.00
1:47:15	16.16	11.60	14.00	14.24	8.48	13.28	14.96	14.48	79.00
1:47:30	16.16	11.36	14.00	14.24	8.48	13.28	14.72	14.48	80.50
1:47:45	16.16	11.36	14.00	14.24	8.48	13.28	14.72	14.48	86.00
1:48:00	15.92	11.60	13.76	14.24	8.48	13.28	14.72	14.48	92.50
1:48:15	15.92	12.08	14.00	14.24	8.48	13.52	14.72	14.48	95.50
1:48:30	15.92	12.56	14.00	14.48	8.72	14.00	14.72	14.48	98.00
1:48:45	15.92	13.28	14.24	14.48	9.20	14.48	14.96	14.72	99.00
1:49:00	15.92	14.24	14.48	14.48	9.92	14.72	14.96	14.72	99.50
1:49:15	16.16	14.96	14.48	14.96	10.64	15.44	15.20	14.96	99.50
1:49:30	16.16	15.92	14.72	15.20	11.60	16.16	15.44	15.20	100.00
1:49:45	16.16	16.64	15.20	15.44	12.56	16.40	15.68	15.68	100.00
1:50:00	16.16	17.60	15.44	15.92	13.76	17.36	15.92	15.92	100.00
1:50:15	16.16	18.56	15.92	16.16	14.72	17.84	16.16	16.16	100.00
1:50:30	16.16	19.52	16.16	16.16	16.16	18.56	16.16	16.40	100.00
1:50:45	16.40	20.24	16.40	16.64	17.36	19.28	16.40	16.64	100.00
1:51:00	16.40	20.96	16.88	17.12	18.80	20.00	16.88	17.12	100.00
1:51:15	16.64	20.96	17.36	17.36	19.76	19.76	17.12	17.36	100.00
1:51:30	16.64	19.28	17.36	17.36	20.48	19.04	17.36	17.60	100.00
2:11:45	19.04	17.84	18.80	18.56	17.60	18.56	19.52	19.28	100.00
2:12:00	19.04	18.80	19.52	19.04	19.04	19.28	20.48	19.52	100.00
2:12:15	19.04	19.76	20.48	19.52	20.48	20.00	20.96	20.00	100.00
2:12:30	19.28	20.72	20.96	20.24	21.92	20.96	21.68	20.48	100.00
2:12:45	19.28	21.44	21.68	20.72	23.12	21.44	22.40	20.96	100.00
2:13:00	19.28	22.16	22.16	20.96	24.32	22.16	22.64	20.96	100.00
2:13:15	19.28	22.64	22.64	21.44	25.28	22.64	23.12	21.44	100.00
2:13:30	19.52	23.36	23.12	21.92	26.24	23.12	23.84	21.68	100.00
2:13:45	19.76	24.08	23.60	22.40	26.96	23.84	24.32	22.16	100.00
2:14:00	19.76	24.56	24.32	22.64	27.68	24.32	24.56	22.40	100.00
2:14:15	20.00	25.28	24.56	23.12	28.16	24.80	25.04	22.64	100.00
2:14:30	20.24	25.76	25.04	23.60	28.88	25.28	25.28	23.12	100.00
2:14:45	20.24	26.24	25.52	24.08	29.36	25.76	26.00	23.36	100.00
2:15:00	20.48	26.72	26.00	24.32	30.08	26.24	26.24	23.60	100.00
2:15:15	20.48	27.20	26.24	24.80	30.56	26.48	26.48	24.08	100.00
2:15:30	20.72	27.68	26.72	25.04	30.80	26.96	26.72	24.32	100.00
2:15:45	20.96	28.16	27.20	25.52	31.28	27.20	27.20	24.56	100.00
2:16:00	20.96	28.16	27.68	26.00	31.52	27.68	27.68	24.80	100.00
2:16:15	20.96	28.64	27.68	26.00	32.00	27.92	27.68	25.04	100.00
2:16:30	21.20	27.68	25.76	25.04	31.28	26.96	25.52	24.08	100.00
2:16:45	21.20	26.24	24.32	24.08	29.36	25.76	24.08	23.12	100.00

APPENDIX 4

Error Assessment

Basically, errors are of two kinds: random (statistical errors, which are best handled statistically - that is, by taking more measurements so that an average can be found) and systematic (related to the actual equipment and to the way it is being used). Before beginning any monitoring, it is wise to clearly list the possible sources of systematic error, for example

- Inaccuracies in the sensor itself;
- The location of sensor (especially with regard to the exact parameter one wishes to measure);
- The way in which the sensor is fitted, for example the way in which a surface sensor is attached to the wall;
- The way in which the sensor is connected to the rest of the equipment;
- Changes in the system over time (such as dirt accumulation, different angles of sunshine, etc);
- The way in which the data is processed for assessment.

These sources may be further divided into subcatagories, and the conservator will certainly find that each individual site adds new concerns to the list. When the possible sources of error have been clearly identified, their relative importance can be assessed. What is the maximum error likely from, for example, an incorrectly placed sensor? Many errors will pale into insignificance beside the most important problems. The next step, then, is to go about minimising each sizeable error as far as possible. Can a better sensor type be chosen for the particular demands of the site? Can the sensor be placed in such a way that strong radiant energy never hits it? Can losses through wiring be minimised by using shorter cables or telemetry? Effort should be directly related to the significance of the error within the final result.

Error can never be entirely removed from a measurement, but by taking care during the setting up it is possible to become reasonably confident about the degree to which the results will be affected. All assessment should be included when the monitoring is reported to allow other researchers to use the results with confidence.

GLOSSARY

Absolute Humidity
The amount of moisture held by the air, in units of weight per volume.

Ambient Temperature
The temperature of the surrounding air.

Conduction
The process of heat transfer by direct contact between the bodies.

Convection
The process of heat transfer via the movement of a liquid or gas between the bodies.

Datalogging
The storage of monitored signals as digital data on some form of computerised unit. Dataloggers generally convert electrical signals from sensors into the units of interest.

Dew Point Temperature
The temperature at which water will condense from the ambient air; DPT is a function of the absolute humidity.

Isothermal
An equality of temperature, as in an (imaginary) line connecting two neighbouring points which lie at the same temperature.

Monitoring
The recording of information so as to allow comparison over time.

Probe
A unit comprising a sensor and its housing.

Pyrometer
A thermometer operating by measuring radiant energy (especially from the infra-red part of the spectrum).

Radiant Power
The strength of the radiant energy in units of energy per area per time.

Radiation
The transfer of heat via electromagnetic waves.

Relative Humidity
The ratio of the actual amount of water vapour in the ambient air with the amount it could theoretically hold at the same temperature, in units of percent.

Sensor
The sensitive element which registers the value of the parameter of interest (eg temperature or humidity); often used to include the housing as well [see Probe].

Solid Angle

An angle in three dimensions, ie. a cone with the apex at the point from which the angle is being taken.

Thermal Conductivity

The ability of a material to diffuse heat through itself.

Thermal Contact Resistance

The resistance to heat transfer between a surface temperature sensor and the surface being measured. It depends upon factors such as the smoothness and cleanliness of the surface, the elasticities of the sensor and surface materials, and the force with which the sensor is pressed against the surface.

Thermal Equilibrium

Occurs when two bodies in contact are at the same temperature; that is, there can be no more transfer of heat between them.

Thermohygrograph

A mechanical device for measuring temperature and humidity (using a thermocouple and a hair hygrometer); records data on a cylindrical chart powered by clockwork.

Thermophoretic

Being moved by heat transfer due to temperature differences.

Vapour Pressure

The pressure that molecules of (water) vapour in the ambient air can exert at the air temperature; saturated vapour pressure is the maximum possible such force before water will begin to be condensed out of the air.

BIBLIOGRAPHY

Agnew N Lin P *Environmental monitoring of the Paphos mosaics.*
in
Ed Stanley Price N
The Conservation of the Orpheus Mosaic at Paphos, Cyprus
GCI Marina del Rey 1991 *pp42-5*

Agnoletto L Baggio P Romagnoni P Rossi R Stevan A G
Studio numerico del comportamento termico e fluidinamico dell'aria ambiente all'interno della Basilica di San Francesco in Arezzo per la conservazione degli affreschi di Piero della Francesca.
in
3rd International Congress on Non-Destructive Testing, Microanalytical Methods and Environment Evaluation for Study and Conservation of Works of Art
Viterbo 1992 *pp1117-29*

Arnold A Zehnder K
Monitoring wall paintings affected by soluble salts.
in
Ed Cather S
The Conservation of Wall Paintings
Proceedings of a symposium organised by the Courtauld Institute of Art and the Getty Conservation Institute London 1987
GCI Marina del Rey 1991 *pp103-35*

Arnold A Zehnder K Küng A Emmenegger O
Wandmalereizerfall, Salze und Raumklima in der Klosterkirche von Müstair.
in
Zeitschrift für Kunsttechnologie und Konservierung
5 (2) 1991 *pp171-200*

Barlow R J Statistics: A Guide to the Use of Statistical Methods in the Physical Sciences
Chichester 1989

Bartoli G Blasi C Chiaguri A Gusella V
Il monitoraggio della Cupola del Brunelleschi a Firenze.
in
3rd International Congress on Non-Destructive Testing, Microanalytical Methods and Environment Evaluation for Study and Conservation of Works of Art
Viterbo 1992 *pp113-130*

Benedict R P Fundamentals of Temperature, Pressure, and Flow Measurements
New York 1977

Benjamin R *Signal space, the key to signal processing.*
in
The Radio and Electronic Engineer
53 (11-12) 1983 *pp407-22*

Berling H *Orientierungsmessungen von Außen- und Raumklimadaten sowie von Oberflächentemperaturen*
in
Schäden an Wandmalereien und ihre Ursachen Ein Forschungsprojekt des Bundesministers für Forschung und Technologie
Arbeitshefte zur Denkmalpflege in Niedersachen 8
Hannover 1990 *pp122-28*

Bernardi A Camuffo D
Microclimatic problems of Orvieto Cathedral
in
Ed Zezza F
Proceedings of the 1st Symposium on the Conservation of Monuments in the Mediterranean Basin
Bari 1989 *pp407-9*

Bernardi A Camuffo D Ongaro A van Doorn W
Microclimate and air pollution at the Ara Pacis in Rome.
in
2nd International Congress on Non-Destructive Testing, Microanalytical Methods and Environment Evaluation for Study and Conservation of Works of Art
Perugia 1988 *ppIII/3.1-3.17*

Brunet J L Vouvé J Malaurent P H
The conservation of subterranean historic and man-made monuments: the importance of the environment and microclimate.
in
Conservation of Ancient Sites on the Silk Road
Abstracts and Program of the International Conference on the Conservation of Grotto Sites
GCI Marina del Rey 1993 *pp85-94*

Campbell P *Philosophy and the art of structural assessment with particular reference to buildings.*
in
Ed Garas F K Clarke J L Armer G S T
Structural Assessment: The Use of Full and Large-scale Testing
London 1987

Caneva G Salvadori O
Biodeterioration of stone
in
Ed Lazzarini L Pieper R
The Deterioration and Conservation of Stone
Studies and Documents on the Cultural Heritage No.16
Paris 1988 *pp89-110*

Caneva G Nugari M P Salvadori O
Biology in the Conservation of Works of Art
Rome 1991

Cather S
Conservation principles and practices: complexity and communication.
in
Conservation of Ancient Sites on the Silk Road
Abstracts and Program of the International Conference on the Conservation of Grotto Sites
GCI Marina del Rey 1993 *pp39-44*

Cather S Howard H
Romanesque wall paintings in the apse of St Gabriel's Chapel, Canterbury Cathedral: their technique, condition, and environment reassessed.
in
Forschungsprojekt Wandmalerei-Schäden
Arbeitshefte zur Denkmalpflege in Niedersachen 11
Hannover 1994 *pp141-156*

Christoforou C S Salmon L G Cass G R
Deposition of atmospheric particles within the Yungang grottoes.
in
Conservation of Ancient Sites on the Silk Road
Abstracts and Program of the International Conference on the Conservation of Grotto Sites
GCI Marina del Rey 1993 *pp95*

Commissione Normal
Raccomendazione 5/83: misure dei parametri ambientali
Instituto Centrale Rome 1983

Daws L F
Movement of air streams indoors.
in
Journal of the Institute of Heating and Ventilating Engineers
37 (2) 1970 *pp243-53*

Dean Baker H Ryder E A Baker N H
Temperature Measurement in Engineering Vols I + II
Stamford Conn 1975

Dixon J
Instrument science and technology: radiation thermometry.
in
Journal of Physics Engineering: Scientific Instruments
21 1988 *pp425-36*

Dutt M
Practical applications of platinum resistance sensors.
in
Ed Plumb H H *et al*
Temperature: Its Measurement and Control in Science and Industry
4 (2) *pp1013-19*
Instrument Society of America Pittsburg 1972

Eshøj B Padfield T
Gundsømagle Church, Zealand, Denmark: An investigation of the microclimate in the choir.
Unpublished Report
School of Conservation of the Royal Danish Academy of Arts
Dept of Conservation, National Museum of Denmark 1991

Fassina V Stevan A G
Influenza dell'ambiente sui fenomini di alterazione dei dipinti murali.
in
Ed Danti C Matteini M Moles A
Le pitture murali: tecniche, problemi, conservazione
Florence 1991 *pp203-216*

Galán E Guerrero M A Vázquez M A Zezza F
Progressive deterioration of marble columns by thermal changes in relation to their state of superficial decay.
in
Ed Delgado Rodrigues J Henriques F Telmo Jeremias F
Proceedings of the 7th International Congress on Deterioration and Conservation of Stone
Lisbon 1992 *pp905-913*

Grant C Hunter C A Flannigan B Bravery A F
The moisture requirements of molds isolated from domestic dwellings
in
International Biodeterioration
25 (4) 1989 *pp259-84*

Hammer I
The conservation in situ of the the Romanesque wall paintings of Lambach
in
Ed Cather S
The Conservation of Wall Paintings
Proceedings of a symposium organised by the Courtauld Institute of Art and the Getty Conservation Institute London 1987
GCI Marina del Rey 1991 *pp43-55*

Hatfield L
Electronic data loggers for conservation studies.
in
Ed Child R E
Electronic Environmental Monitoring in Museums
Proceedings of a Conference held at the Welsh Folk Museum, National Museum of Wales, 1992
Clwyd 1993 *pp29-35*

Hecht E
Optics
Reading, Massachusetts 1987

Heimann W Mester U
Non-contact determination of temperatures by measuring the infrared radiation emitted from the surface of a target.
in
Ed Billing B F Quinn T J
Temperature Measurement, 1975 Invited and contributed papers from the European Conference on Temperature Measurement
National Physical Laboratory Teddington 1975 *pp219-37*

Henderson I A McGhee J
Classical taxonomy: an holistic perspective of temperature measuring instruments.
in
Proceedings of the Institute of Electrical Engineers
140 (4) 1993 *pp263-68*

Horie C V
Materials for Conservation: Organic Consolidants, Adhesives and Coatings
Oxford 1987

James J
The Wall Paintings of Horsham St Faith Priory, Norfolk: An Investigation of Environmental Causes of Decay
Unpublished Dissertation
Courtauld Institute of Art 1988

Kinzie P A
Thermocouple Temperature Measurement
New York 1973

Koob S P
The use of Paraloid B72 as an adhesive: its application for archæological ceramics and other materials.
in
Studies in Conservation
31 (1) 1986 *pp7-14*

Krumbein W E Petersen K
Mikroorganisen beschleunigen den Zerfall mittelalterlicher Wandgemälde.
in
Schäden an Wandmalereien und ihre Ursachen Ein Forschungsprojekt des Bundesminister für Forschung und Technologie
Arbeitshefte zur Denkmalpflege in Niedersachen 8
Hannover 1990 *pp115-21*

Küng A
Messung des Raumklimas im Zusammenhang mit Schäden an Wandmalereien.
in
Proceedings of the Sitzung des Arbeitskreises
'Naturwissenschaftliche Forschung an Kunstgütern aus Stein'
Ludwigsburg 1986 *pp109-19*

Kwasny-Echterhagen R
Durability and long-term properties of polymers in construction engineering.
in
IBAC Institut für Bauforschung 1992 Report
Aachen 1992 *pp25-31*

McGee T D Principles and methods of temperature measurement
New York 1988

Macías A de Frutos J Blanco M T Puertas F
The deterioration of mortars in Toledo's Cathedral: studies on thermal and hygric expansion.
in
Ed Delgado Rodrigues J Henriques F Telmo Jeremias F
Proceedings of the 7th International Congress on Deterioration and Conservation of Stone
Lisbon 1992 *pp1213-1221*

Maekawa S *Visitors' impact on the micro-climate of a cave at the Mogao Grottoes: results of controlled experiments in Cave 323.*
in
Conservation of Ancient Sites on the Silk Road
Abstracts and Program of the International Conference on the Conservation of Grotto Sites
GCI Marina del Rey 1993 *pp99*

Marchetti L *Indagini ambientali.*
in
Un progetto per Piero della Francesca: Indagini diagnostico-conoscitive per la conservazione della 'Leggenda della Vera Croce' e della 'Madonna del Parto'
Florence 1989 *pp297-342*

Massari I *Some aspects of humidity protection in historic buildings.*
in
Ed Lazzarini L Pieper R
The Deterioration and Conservation of Stone
Studies and Documents on the Cultural Heritage No.16
Paris 1988 *pp89-110*

Michalski L Eckersdorf K McGhee J
Temperature Measurement
John Wiley + Sons Chichester 1991

Michalski S *Towards specific lighting guidelines.*
in
Preprints of the 9th Triennial Meeting of ICOM
Dresden 1990 *pp583-88*

Padfield T Bøllingtoft P Eshøj B Christensen M C
The wall paintings of Gundsømagle church, Denmark
in
Preprints of the IIC Congress Ottawa 1994 [Forthcoming]

Preobrazhensky V P
Measurements and Instruments in Heat Engineering Vol I
Moscow 1980

Preston-Thomas H
The International Temperature Scale of 1990 (ITS-90).
in
Metrologia
27 (1) 1990 *pp4-10*

Stevan A G Strada M
Le indagini relative al clima degli ambienti confinati nelle operazioni di diagnosi per la conservazione dei dipinti murali.
in
2nd International Congress on Non-Destructive Testing, Microanalytical Methods and Environment Evaluation for Study and Conservation of Works of Art
Perugia 1988 *ppIII/14.1-14.17*

Thomas S *Measuring temperature electronically.*
in
Ed Child R E
Electronic Environmental Monitoring in Museums
Proceedings of a Conference held at the Welsh Folk Museum, National Museum of Wales, 1992
Clwyd 1993 *pp1-12*

Torraca G *Deterioration processes of mural paintings.*
in
Ed Young W
The Application of Science in Examination of Works of Art
Boston 1970 *pp170-175*

Torraca G Porous Building Materials: Materials Science for Architectural Conservation
3rd Edition
ICCROM Rome 1988

Tzschach F Bartzsch H W
Experiences made by applying copper-constantan thermocouples for precise measuring of surface temperature.
in
International Measurement Confederation Technical Committee 12 Temperature Measurement
Proceedings of the 2nd Symposium on Temperature Measurement in Industry and Science
Suhl 1984 *pp513-21*

Vos B H *Moisture in monuments.*
in
Ed Young W
The Application of Science in Examination of Works of Art
Boston 1970 *pp147-153*

Vos B H *Suction of groundwater.*
in
Studies in Conservation
16 1971 *pp129-244*

Vouvé J van der Maele M E Vidal P
Étude climatologique et hydrogéologique d'un tunnel des laves orné sous climate subtropical cas de la caverne peinte d'Ana Kay Tangate.
in
Preprints of the 9th Triennial Meeting of ICOM
Dresden 1990 *pp793-7*

Yong Lie Q Li Fang G
Analysis of surface temperature measurement error due to variation in thermal resistance and a measuring method with bithermocouples.
in
Temperature Measurement: Proceedings of the International Symposium on Temperature Measurement in Industry and Science
Beijing 1986 *pp350-55*

Zemansky M W Dittman R H
Heat and Thermodynamics: an Intermediate Textbook
6th Edition
Tokyo 1981