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The Multi-Purpose Low Pressure Conservation Table

Anthony Reeve, Paul Ackroyd and Ann Stephenson-Wright

History

Anthony Reeve

The prototype table, installed in the Gallery in 1983, was first described in 1984 [1]. The following article gives an account of the finalized design of this table which has now been thoroughly tested. Some treatments of National Gallery paintings using the equipment have been included in the last section to illustrate some of its uses.

Pursuing a development of this kind as an aid to conservation stems from our many years of experience with paste lining and other conservation treatments carried out at the National Gallery. The combination of heat, moisture, aqueous glues and minimal pressure has for a long time proved useful in the relaxation, regeneration and consolidation of paintings on canvas.

Canvas has been used as a support for painting since the fourteenth century, and later to a great extent replaced the wooden panels favoured in Northern Europe and Italy.

Flax (linen), being strong and resilient, became the most widely used fibre in canvas making. However, canvases are prone to accidental damage and with time they become embrittled and too weak to support the ground and paint. Since the early eighteenth century the standard method of treatment for these problems has been to attach another canvas to the back of the original using an adhesive, mostly aqueous.

This treatment was intended to reduce the deterioration and consolidate the canvas, ground and paint layers and proved satisfactory in most cases. However, sometimes it resulted in flattened impasto and brushstrokes, burnt, blistered and crushed areas of paint. As with other adhesives, over-impregnation also sometimes caused changes in the refractive index of the paint. These hand lining methods were carried out using heavy steel irons which were heated on stoves and then cooled in buckets of water. In the last thirty years the principles have not changed a great deal, but the methods and equipment have undergone considerable improvements.

These large steel irons have been replaced first by adapted ordinary domestic irons and then by custom-made, thermostatically-controlled ones. The latter supply a source of controllable heat. In current practice the painting is ironed through protective layers, where the weight of the iron is taken by the user, rather than in pressing the painting.

Adhesives such as rabbit-skin glue and fish glue have also been modified by reducing their strength and extending them with flour to obtain the minimum effective bonding, making them easily reversible.

The use of paste lining has particularly suited the National Gallery Collection, as almost all of the pictures have been previously treated with composition linings of one kind or another. Relining with paste regenerates the remains of previous lining adhesives, and also helps to relax and reconsolidate the original glue sizing.

Wax–resin adhesives were introduced in the nineteenth century and were applied using hot irons and chilled with even heavier steel irons. The disadvantages of this method highlighted the need for larger, more efficient heated surfaces for even, overall heating. Hot blankets were introduced in the nineteenth century but pressure was still needed during the process to achieve a good bond between lining canvas and the original. The first hot-tables were then introduced in the mid-1950s. These were large flat areas of stainless steel or aluminium, electrically heated to a range of temperatures, and then cooled by blowing air beneath the top, chilling the adhesive until a bond was formed. A vacuum to hold the painting flat during the process was applied by extracting air using a pump. The National Gallery Conservation Department is sceptical of change and will not adopt any new treatment until well tried and tested; the hot-table was no exception. However, tests had been carried out on a water-heated and cooled model.

This was not developed further and a hot-table was not acquired until the 1970s. By this time conservators were aware of the problems of hot-tables. If wrongly used pictures could be over-impregnated with adhesive by excessive heating, and impasto areas could become flattened or pushed into the picture, especially when paintings were treated face-down. Also, weave emphasis or weave interference could be a difficulty due to excessively high pressures and unsuitable choices of lining fabric.

Wax lining in the Gallery was used only on the pictures judged to be unsafe for paste lining, but in vital need of consolidation. The wax–resin method continues to be used when no other alternative is considered more suitable, although consolidation and lining are now generally treated as separate processes. Nap-bond linings using Beva 371 [2] are occasionally carried out after consolidation. The first use of this synthetic resin adhesive was only employed after extensive tests had been made in connection with the support work for the transfer of the Cima altarpiece *The Incredulity of S. Thomas* (No.816) [3]. Using moisture and aqueous glues for consolidation on the low pressure table has in most instances removed the need for impregnation of the painting.

To overcome some of the problems of the hot-table, vacuum-envelope lining was introduced in 1973 [4,5]. The object and new support were placed in a sealed envelope and the air evacuated. Because the pressure above and beneath the painting is balanced, risk of weave interference is reduced. Heating was carried out

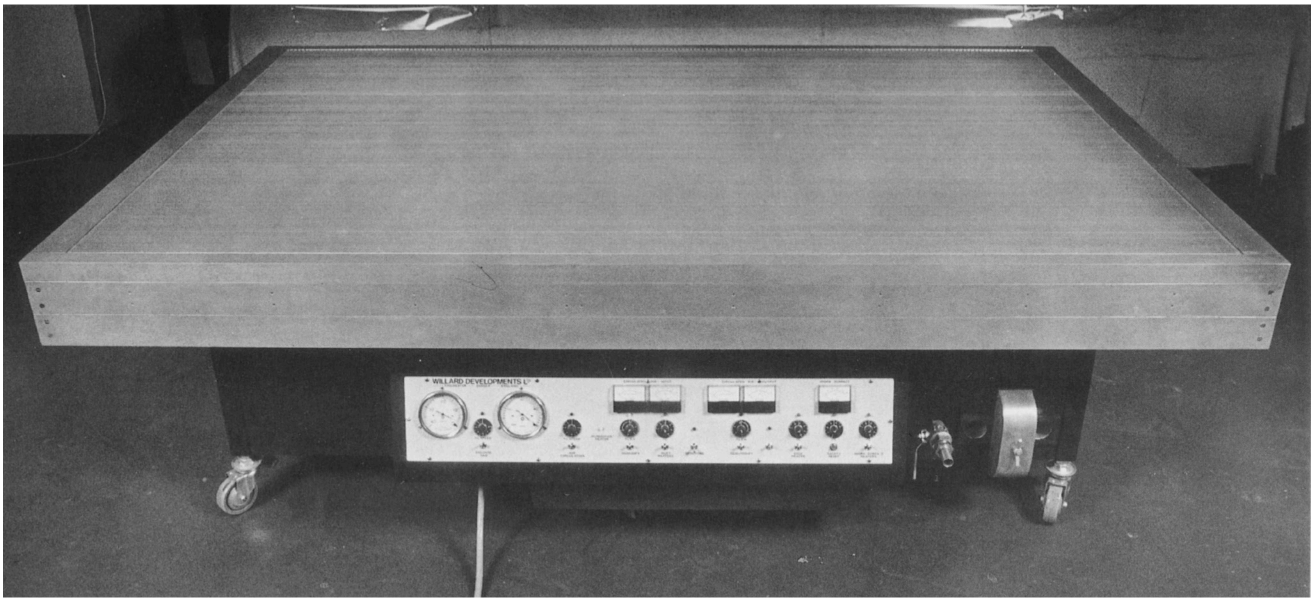
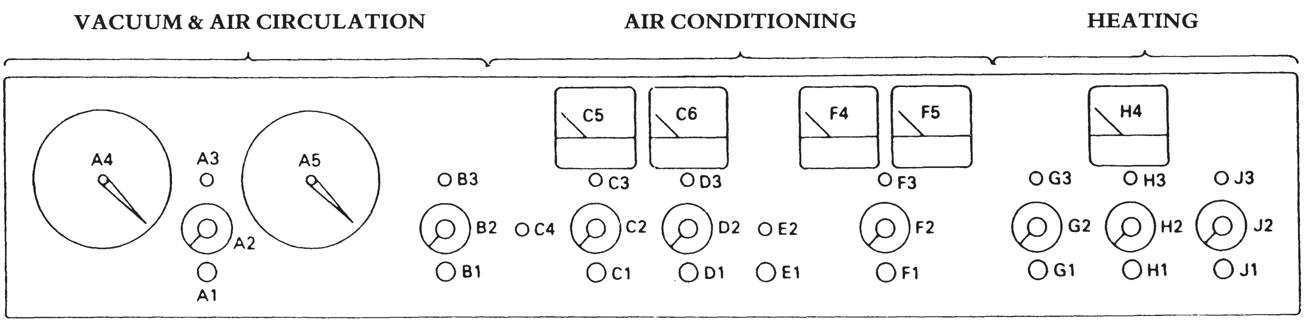


Figure 1 The improved multi-purpose low pressure table.



Vacuum & Air Circulation

A1 On, Off, Main Vacuum

A2 Speed Control for Main Vacuum

A3 Red Indicator Light Main Vacuum On

A4 Vacuum Gauge 0 – 40 mbs

A5 Vacuum Gauge 0–160 mbs

B1 On, Off, Circulatory Fan

B2 Speed Control for Circulatory Fan

B3 Red Indicator Light Circulatory Fan On

Air Conditioning

C1 On, Off, Humidifier

C2 Relative Humidity Setting, calibrated using wet bulb depression scale

C3 Opal Indicator Light Humidity On

C4 Opal Indicator for Humidifier Heater

C5 Wet bulb depression Gauge 0 – 20°C Relative Humidity Input

C6 Gauge 0 – 100°C Temperature Input

D1 On, Off, Duct and auxiliary Duct Heaters

D2 Dial 0 – 100°C for Duct Heaters

D3 Red Indicator Light Duct Heaters On

E1 On, Off, Monitors

E2 Red Indicator Light Monitoring On

F1 On, Off, De-Humidifier Unit

F2 % R.H. setting for De-Humidifier, calibrated using wet bulb depression scale

F3 Red Indicator Light De-Humidifier On

F4 Wet bulb depression Gauge 0 – 20°C R.H. Output

F5 Gauge 0 – 100°C Temperature Output

Heating

G1 On, Off, Edge Heater

G2 Dial 0 – 100°C Edge Heaters

G3 Red Indicator Light Edge Heaters On

H1 Reset Button Heating Safety Control

H2 Dial 0 – 100°C Safety Control for Heating System

H3 Amber Light Safety System (Off when set)

H4 Gauge 0 – 100°C Main Heaters

J1 On, Off Main Heaters

J2 Dial 0 – 100°C for Main Heaters

J3 Red Indicator Light Main Heaters On

Figure 2 Diagram of the control panel.

by using either a movable infra-red heater or by placing the envelope onto a hot-table for a short time and then removing the envelope from the heat source whilst maintaining a vacuum until the adhesive had cooled.

Materials were also undergoing development: natural and synthetic products were being used as lining fabrics and as adhesives.

The degree of heating applied and the reversibility of the lining were given more attention during the early 1970s. Mehra developed the 'cold lining table' which involved the use of low pressures created by a rapid air flow beneath a perforated work surface. This gave quicker and more even drying of the picture, which was important since Mehra at first used aqueous synthetic adhesives which set without heat [6,7,8].

Moisture relaxation treatments had also been carried out on ordinary hot-tables using porous interleaves carrying alcohol and water mixtures. Though proving successful these treatments were less easy to control and the results more variable.

Contact or electrostatic-hold lining [9] was also used. The method consisted of a lining material coated with a silicone-based adhesive, either pushed with mild pressure, by slight warming, or by solvent activation of the adhesive to form the bond.

At the same time as these developments were taking place a low pressure vacuum table similar in concept to Mehra's design but equipped with heating, was being developed by B. Hacke in Denmark [10,11,12]. More recently, Hacke has been working on a separate system of moisture circulation for his table, although at present it is usually supplied by a moist interleaf between two perforated aluminium sheets.

Through our work in the Conservation Department we have been able to assess the advantages and disadvantages of most forms of lining treatments using natural and synthetic adhesives, and so the development of an adaptable piece of equipment that could perform nearly all of these processes was judged necessary. There was also a requirement for such a table to give the restorer better control of heating, moisture and pressure. This was the initial impetus for the design of the multi-purpose low pressure table. The prototype was built by Willard Developments, to the specification judged necessary to perform hot-table (nap-bond) linings and assisted hand linings, local or general consolidation treatments, moisture or moisture and solvent treatments and in addition controllable drying of the painting [10].

The range of treatments carried out in the Department has been extended through using the table. It has been particularly helpful in the treatments of certain difficult paintings and has in some cases removed the need for lining. Since the prototype table was installed in the Conservation Department, a number of modifications have been made over a period of four years which have culminated in a finalized design [13]. The majority of these alterations were concerned with the humidity and air-circulation systems. A humidifier was installed within the circulation system in place of an external steam generator used in the prototype. Also new wet/dry hygrometers replaced the electrical capacitance monitors to improve precision and reliability in measuring RH.

The improved multi-purpose low pressure table

The equipment is shown in Fig.1, and the controls and electrical instruments in Fig.2. The standard size is 8 ft × 5 ft (2.44 m × 1.52 m), though smaller or larger sizes can be manufactured. The table frame consists of tubular, square-section steel. All parts forming the vacuum chamber and air systems are of non-ferrous materials. The top surface of the table can accommodate a number of interchangeable perforated sheets which fit into a rebated surround (Fig.3).

On larger tables the main perforated sheet may be manufactured in one piece, or can be joined, in which case it may be screwed or glued to the supporting open louvre panels. These sheets can have various perforations ranging from hole sizes 0.5–2 mm diameter (usually supplied with 1.50 mm holes), with an open area of up to 30%. In addition, an unperforated or solid metal sheet is supplied for the conventional hot-table function. There is a gap of 1 mm around the edges of the sheets for air extraction.

The surface sheets are supported by open louvre panels which have larger open spaces at the lowermost layer for better distribution of the air. The stainless steel, mineral insulated, heating elements are situated between the two layers of the open louvre panels. The edge heaters are separately controlled and run around the perimeter to compensate for heat loss. The main and edge heaters are controlled by a safety thermostat for automatic cut-out in the event of component failure. There are additional heaters in the ducting, which may be used as a sole source of heating the table during moisture treatments. The duct heater switch also controls an auxiliary duct heater which is situated directly before the humidifier (heater *e* in Fig.4). This heater helps to compensate for the reduction in air temperature when the dehumidifier is used for drying. It also helps to raise the air temperature when humidifying, in order to obtain increased levels of humidity in the table. (When the temperature is raised the air is able to hold more moisture.)

The variable-speed fan on the main vacuum has two vacuum gauges scaled 0–40 mbars and 0–160 mbars, which are located on the control panel. These enable fine regulation of pressures to within 1 mbar. There is a variable-speed fan on the separate circulatory system for circulating air through the internal ducting. The humid or dry air is introduced from each alternate duct (those marked positive in Fig.4), and extracted by the negative ducts. The result of this system is a series of small eddies across the table top which give an even air distribution.

The humidifier is incorporated in the circulatory system and consists of a preheated metal block onto which water is allowed to drip. The RH is controlled by wet/dry bulb hygrometers in the ducting before and after moisture introduction to the table top. These can be set to the required humidity (using the wet bulb depression scale), and monitored at the control panel. There is a change-over valve in the ducting to reverse the air flow between the positive and negative ducts to enhance the even distribution of moisture. This may also

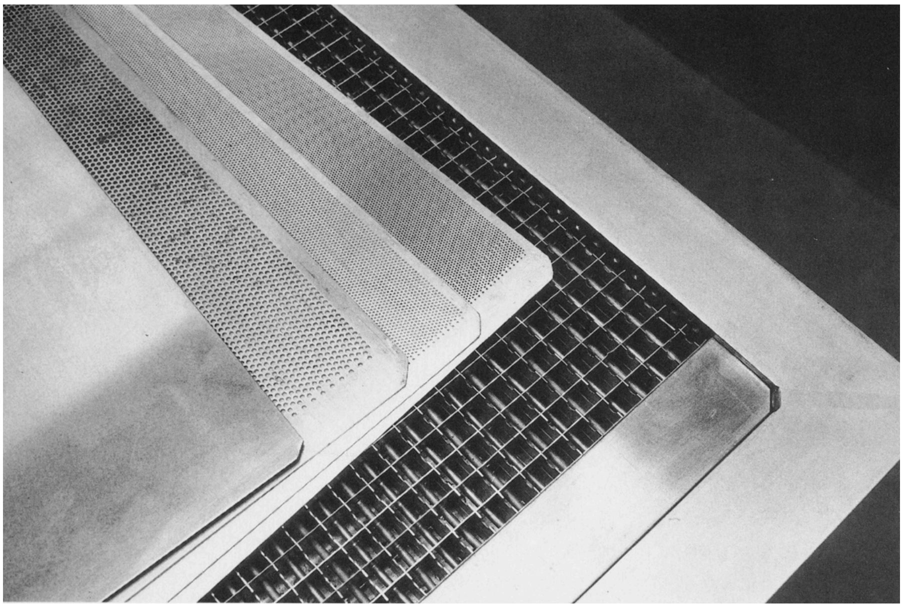
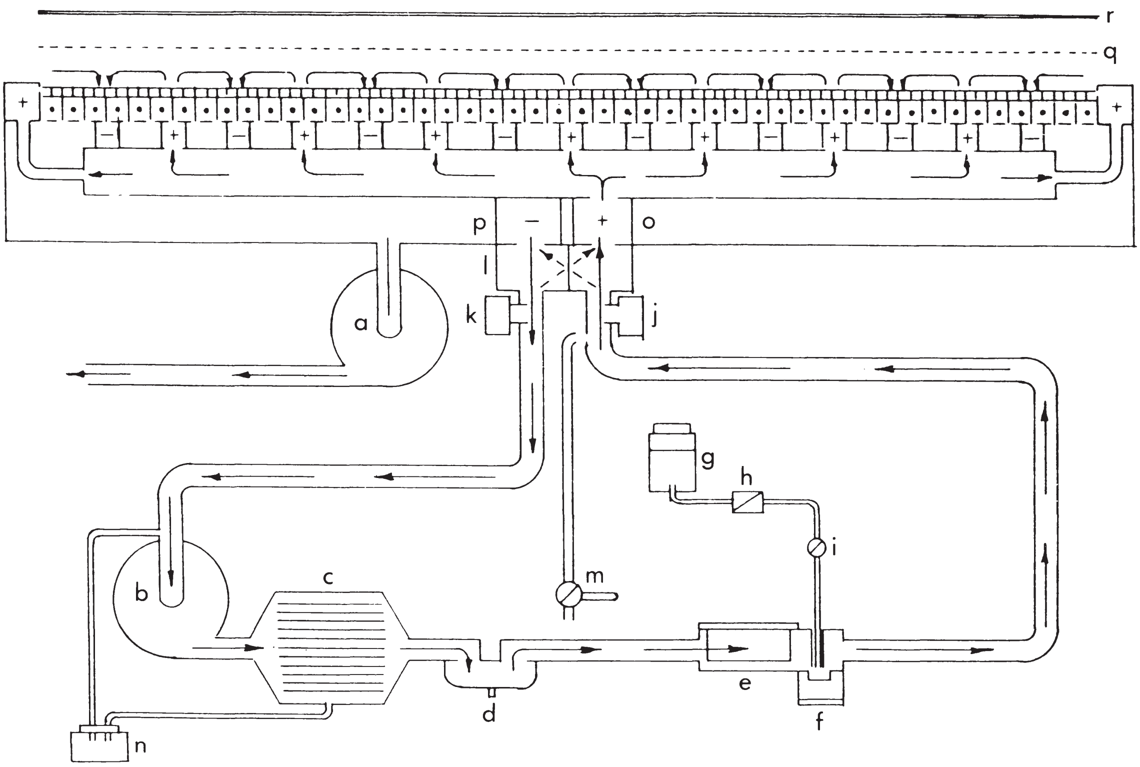


Figure 3
Interchangeable perforated aluminium sheets.

Figure 4 (Below)
Schematic diagram of a section through the table.



Legend

- **a** Main Vacuum Fan
- **b** Air Circulation Fan
- **c** Dehumidifier Coil
- **d** Swivel Valve for Venting Dehumidifier Coil
- **e** Auxiliary Heater
- **f** Humidifier
- **g** Humidifier Reservoir containing distilled water
- **h** Magnetic Valve, connected to the humidistat on the input sensor
- **i** Manual Valve for adjustment of the drip rate
- **j** Wet/Dry Bulb Sensor for Input Air
- **k** Wet/Dry Bulb Sensor for Output Air
- **l** Change-Over Valve for reversing the air flow in the ducts
- **m** Vacuum Leak Valve/External Connection for Humidifier
- **n** Water Drainage Bottle
- **o** Positive Pressure (Input Air) Manifold
- **p** Negative Pressure (Output Air) Manifold
- **q** Perforated Aluminium Worktop
- **r** Solid Aluminium Worktop

quicken humidification during the initial stages. Dehumidification is achieved in two ways, either with a swivelling valve which takes air directly into the circulatory system through one entrance port and out of the other, or using the refrigeration plant complete with water collection and drainage. The humidity setting during dehumidification is controlled by the output wet and dry bulb sensor.

Hot-table function

The surface sheeting is of solid, unperforated aluminium. There is a 1 mm slot around the perimeter of the sheet for extracting the air and maintaining the vacuum. This allows the vacuum to be established easily and enables immediate access to the object during treatment as the vacuum can be re-established immediately. Cooling is carried out using the swivel inlet and extract point on the circulatory system which introduces room air. Some adjustment of the main fan speed may be necessary to maintain the required surface pressure. An alternative way of cooling is simply to use the dehumidifier and circulatory fan which passes chilled air beaneath the top surface.

Low pressure function

The size of the holes in the perforated sheets can be varied according to the object to be treated. For canvas pictures 1.50 mm has proved to be most useful. The hole size is important in relation to the percentage of open area of the perforated sheet, as this may affect the humidification time. The ducting is heated to prevent the occurrence of condensation when humidifying. The drip-feed humidifier has been incorporated in the air circulation system in order to allow more gradual, and more controllable increases in humidity.

Drying may be carried out, when the painting is covered by a non-porous membrane (for example Melinex), by opening the swivel valve in order to blow out the humid air and to take in room air. Alternatively, the membrane can be removed from the surface area of the object and air drawn through. During this drying process the main vacuum has to be increased to compensate for the drop in pressure as the membrane over the picture is removed.

Testing the multi-purpose table

Paul Ackroyd

Before treatments to paintings could be carried out on the table, the controls for pressure, temperature and humidity needed to be checked. The humidification system was the most complicated aspect of the table's function, largely because of the difficulty in obtaining accurate and reliable instruments to measure humidity. The following is a brief summary of the conclusions drawn from these tests.

Pressure

Pressure measurements were checked using a simple water-column barometer which was placed at different positions across the work surface. There did not appear to be any discrepancies between the water-column measurements at the table top and those given at the table's control panel.

Temperature

Temperature was checked using thermocouples which were placed at a number of points across the top of the table. Both the perforated sheet and the solid metal plate were tested. It was important to establish how long it took for the table to achieve certain temperatures and how long it took to cool down. These aspects were found to be satisfactory — the table could be heated to the desired temperature more rapidly than the ordinary vacuum hot-table, and was able to cool to temperatures a little above ambient within a reasonable amount of time (slightly quicker than the standard hot-table). For example, using the solid hot-table plate, the table could be heated to 65°C in 12 minutes and then cooled to 22–3°C after 1½ hours.

Whether cooling in the hot-table mode was achieved by circulating chilled air from the dehumidifier, or whether room air was drawn into the table by opening a valve in the circulation system (*d* in Fig.4), made little difference to the rate of cooling.

The thermocouples showed that the distribution of heat across the plates was even during lining, humidification and dehumidification processes.

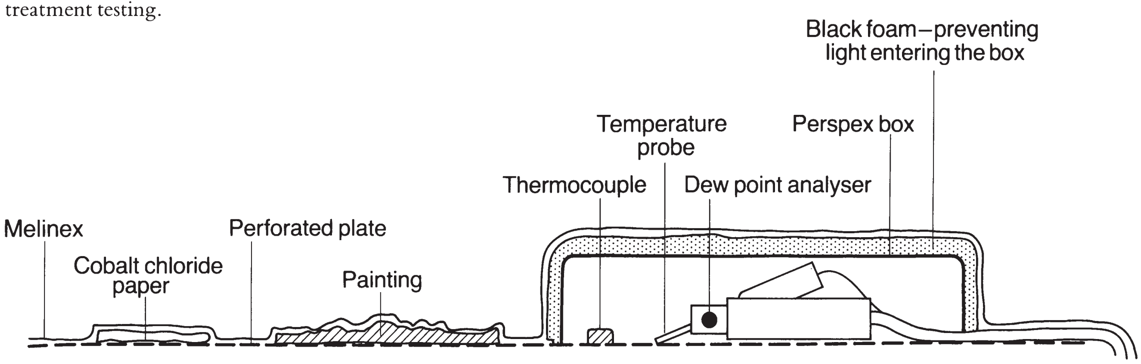
As with all types of lining table equipped with heating elements, there were discrepancies between the temperatures measured just beneath the work surfaces (the readings shown on the main heating dial at the control panel), and the temperature measurements taken on the top of the work surfaces. It is simple to calibrate the table top temperatures in comparison with those given on the main heating dial. The calibrations below were made when the table was set up in the hot-table mode using the main and edge heaters.

Table Top Temperatures (°C)	*Main Heating Temperatures* (°C)
30	32
35	40
40	46
45	51
50	56

Humidification processes

The wet/dry bulb hygrometers were checked alongside a dew-point analyser for varying temperatures and humidities, and were found to be reasonably accurate. The latter instrument is probably the most precise means of measuring relative humidity (RH) and temperature. Readings from the wet/dry bulbs were unaffected by increases or decreases in the air circulation speeds used in

Figure 5 Diagram of the apparatus used during moisture treatment testing.



the table — unless the speed setting on the circulation fan was so low (below mark 10) that there was hardly any movement of air.

The amounts of moisture entering the system are regulated by the input hygrometer situated beneath the table. The conditions of the work surface are not monitored and the temperatures and humidities below the top bear no relation to the conditions at which the painting is treated. The dew-point analyser was used to measure the humidities at the top in order to find out the conditions to which a picture would be exposed over a wide range of temperatures, and RH preset at the control panel. These tests were set up in the manner illustrated in Fig.5 and were intended to simulate a 'standard' moisture treatment.

The results were plotted in a series of graphs which compared the absolute humidities of the input and output hygrometers with the readings taken from the dew-point analyser placed next to the painting. From these graphs it was evident that the humidification system had some limitations. Firstly, although most humidities could be achieved, those above 90% RH at 40°C and above 85% RH at 50°C were difficult to attain because the humidifier could not cope with producing such large quantities of moisture. Secondly, humidities above 90% RH at 30°C and 40°C, and above 85% RH at 50°C were difficult to control for long periods without condensation occurring across the work surface. This happened because the top surface is always a little cooler than the air in the circulation system beneath the top.

In order to remedy these problems the following accessory items have been recommended to the manufacturer:

1. A Perspex hood that can be placed over the table top. This would provide some thermal insulation over the surface and reduce the occurrence of condensation.

2. An ultrasonic humidifier that can be attached to an already existing valve in the air circulation system, (valve *m* in Fig.4). This would provide a boost to the table's humidifier at times when additional moisture is required, or could replace the present humidifier.

Both these remedies are inexpensive and simple to put into effect. It should be stressed that it is unrealistic to expect any form of air conditioning, which is basically what the table's humidification plant is, to control conditions with exact precision for long periods of time, especially when temperatures above ambient and high humidities are considered.

Using controlled conditions of RH is one method of humidifying the picture; the other means of achieving the same result is to allow condensation to form over the plate at timed exposures. For this purpose the humidistat is turned up to produce 100% RH at the required temperature. Tests were made to establish the quantities of moisture absorbed by samples from a nineteenth-century, commercially prepared, finely woven, canvas painting that was particularly vulnerable to shrinkage. One such sample was first sprayed with increasing amounts of water (measured by weighing) to find out the quantity of moisture that was needed to produce canvas shrinkage and subsequent cleavage of the paint and ground layers. Other samples from the same picture were then moistened on the table by producing condensation across the top. These were weighed after 10, 15, 20, 25 and 30 minutes, at 22°, 30° and 40°C (set on the main heating dial). The 'safety margin' (or the quantity of moisture that had been found to produce shrinkage in these samples) was exceeded after 20 minutes at 22° and 30°C, and at a 15 minutes exposure at 40°C. It was evident that humidification using this particular method should not last longer than 20 minutes at 22° and 30°C and no longer than 15 minutes at 40°C.

The distribution of moisture across the perforated plate was checked using blotting papers impregnated with cobalt chloride solution. These change colour from pink when wet, to blue when dry. There were no problems with uneven patches of moisture when air circulation speeds were moderately low — speeds between mark 20–30 on the air circulation dial were thought to produce the best results. As the air circulation was increased to rates above mark 50, damper longitudinal lines, corresponding with the topmost layer of ducts marked positive in Fig.4, were detectable on the cobalt chloride papers.

The cobalt chloride papers proved to be a reliable indication of the moisture content of canvases treated on the table. It would be recommended that these be used during actual treatments to give some idea of the conditions to which paintings are exposed.

Drying processes

Having tested the table's performance during the humidification process it was then necessary to establish the best methods of drying a painting. It was important that pictures should not be dried below their ambient moisture contents as this may embrittle some of their components. Also, drying should be carried out gradually so as to avoid sudden stresses, but it should be completed within a reasonable amount of time, approximately 60–90 minutes.

Tests using identical painting samples dampened with known weights of water were dried using each different method. The samples were weighed at timed intervals during each process.

Methods using the table's dehumidifier were found to be too efficient for drying paintings as the samples were dried well below their ambient moisture contents after approximately 20 minutes. Allowing room air into the table (by opening valve *d* in Fig.4), thus maintaining the vacuum by means of a rapid air flow, produced good results when no heating was used. However, when the table was heated the samples were again dried below their ambient moisture contents.

The best methods of drying were those where interleaf materials such as blotting paper were used between the painting and the plate and a rapid air flow was produced as described above. These tended to retard the process and prevented desiccation of the painting even when the table was heated. Removing a window of Melinex over the picture area also produced good results. This technique allowed room air to be drawn through the painting, rapidly cooling the picture when heat was used.

Treatments on the multi-purpose table

Ann Stephenson-Wright

Introduction

National Gallery paintings have been treated both on the prototype table and, since the above test programme started, on the updated version. The humidification and heating systems have been used to relax cupped and blistered paint and canvas deformations, and the dehumidification and air circulation systems to extract moisture evenly when lining with aqueous glue paste. In this latter case the multi-purpose table enables the benefits of traditional paste lining by hand to be achieved under controlled conditions which can be monitored. The following examples illustrate some of the treatments carried out on National Gallery paintings.

Paste lining

The lining canvas for *Ruins with Figures* by Panini (No.138) was severely degraded and embrittled; it no longer provided adequate support and the painting required relining. After facing the painting and removing the old lining canvas and glue adhesive, paste was applied to the original canvas. The painting was placed face-up onto the loomed lining canvas and then onto an interleaf (one sheet of Eltoline tissue laid on to a single sheet of medium weight blotting paper) on the perforated sheet of the table. A sheet of Melinex with a window cut to expose the painting (Fig.6) covered the table so that a low vacuum could be used to hold down the painting. With the circulatory fan on (to extract moisture as it soaked into the lining canvas), the table set at 25°C and the iron at 50°C the painting was hand ironed for about 15 minutes (Fig.7). The lined painting was then left to dry naturally on the loom for several hours (Fig.8) before being ironed for a second time on the table in a similar manner. After being left to dry out thoroughly overnight, beeswax was ironed into the back as a moisture barrier and the painting restretched onto its stretcher.

Another painting which has been hand paste lined on the table is *The Necromancer* by Le Prince (No.5848).

Moisture treatment

Ships Lying near Dordrecht (No.815) painted by Clays in 1870, and unlined, was in reasonable condition with a sound canvas, and turnover edges mostly intact. However, the thick paint in the areas of shadow below the two boats was very badly cupped (Fig.9). Although the cupped paint and ground were reasonably well attached to the canvas (which had closely conformed to the deformations in the paint layers (Fig.10)) the edges of the elevated cracks were brittle and had already suffered some losses. In addition, areas of heavy craquelure in the sky and lower edge were visually disturbing (Fig.11).

The painting was removed from the stretcher and the turnover edges flattened. Areas of cupped paint were treated with a 5% solution of sturgeon glue and a warmed spatula, and although this improved adhesion little relaxation of the paint or canvas deformations was achieved [14,15].

To treat the painting on the table, a layer of thin blotting paper was sprayed with water and laid on to the perforated sheet (the table having been preheated to 35°C), and the painting laid onto this face-up (it had not been possible to sand the back of the canvas because of the fragility of the paint). The table was covered with a sheet of Melinex and the vacuum fan set at 10 mbar. The painting was humidified under these conditions for one hour, and then dried using the dehumidifier with the vacuum increased to 15 mbar (RH levels are not reported here as the readings taken were probably inaccurate; they were measured on the table's original sensors before the current wet/dry bulb sensors were installed, and before we had access to a dew-point analyser to accurately measure the RH). When the painting had returned to its ambient moisture content a window was cut in the Melinex and the cupped areas of paint again treated with warmed sturgeon glue, which was drawn into the fissures by the mild vacuum.

Some days later the painting was moisture treated again at 35°C and 15 mbar. After forty minutes the vacuum was increased to 25 mbar and the dehumidifier used to dry the painting. Moisture treatment was immediately followed by further blister treatment as

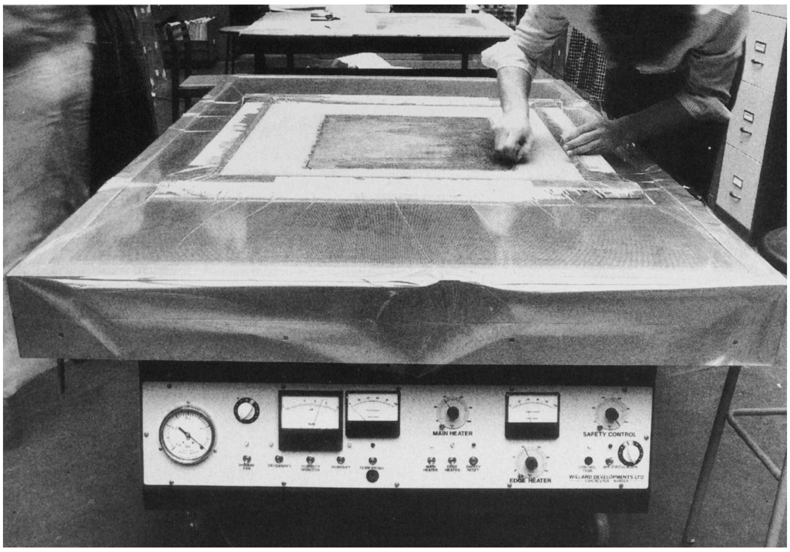


Figure 6 The painting being prepared for paste lining on the original version of the table.

Figure 7 The picture during hand ironing.

Figure 8 The picture after the first ironing, before being left to dry.

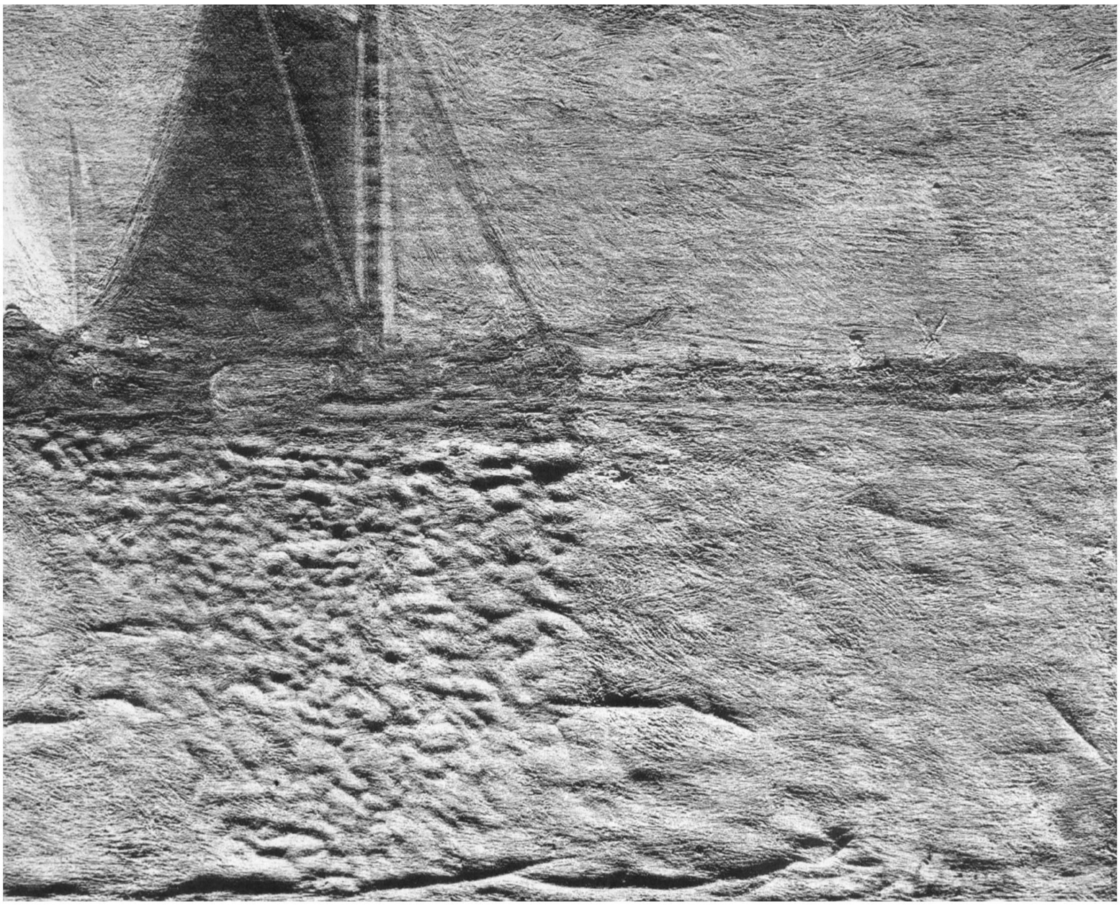


Figure 9 Clays, *Ships Lying near Dordrecht* (No.815), detail taken in raking light before moisture treatment.

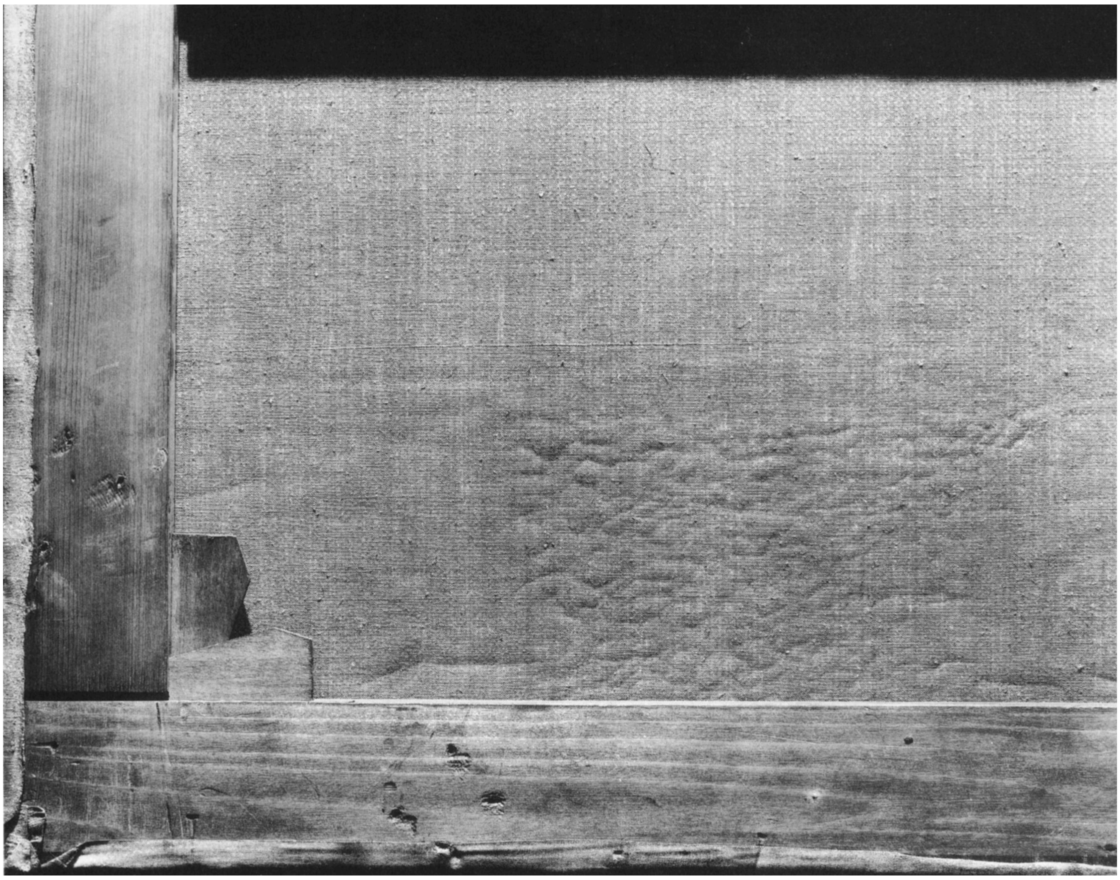


Figure 10 Clays, *Ships Lying near Dordrecht* (No.815), detail taken in raking light before moisture treatment showing deformations produced in the canvas by the cupped paint.

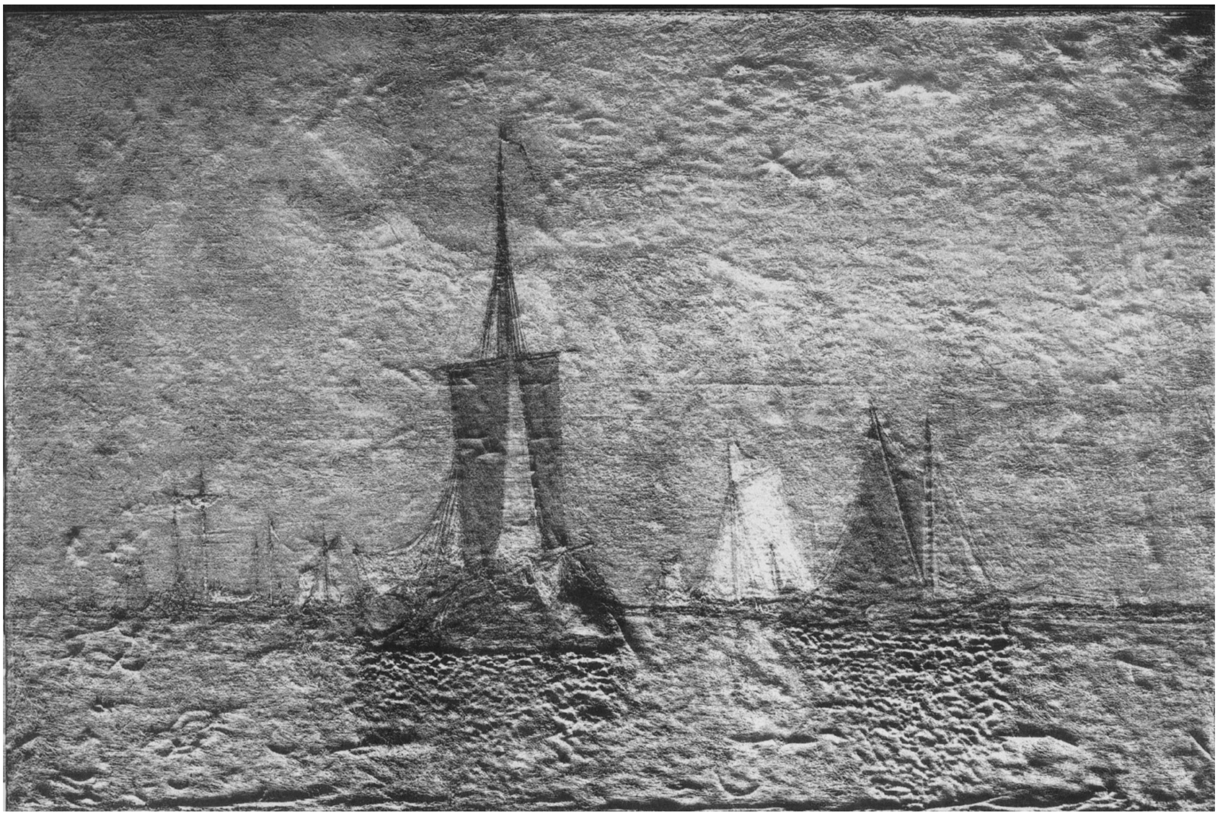


Figure 11 The whole painting photographed in raking light showing areas of heavily raised craquelure.

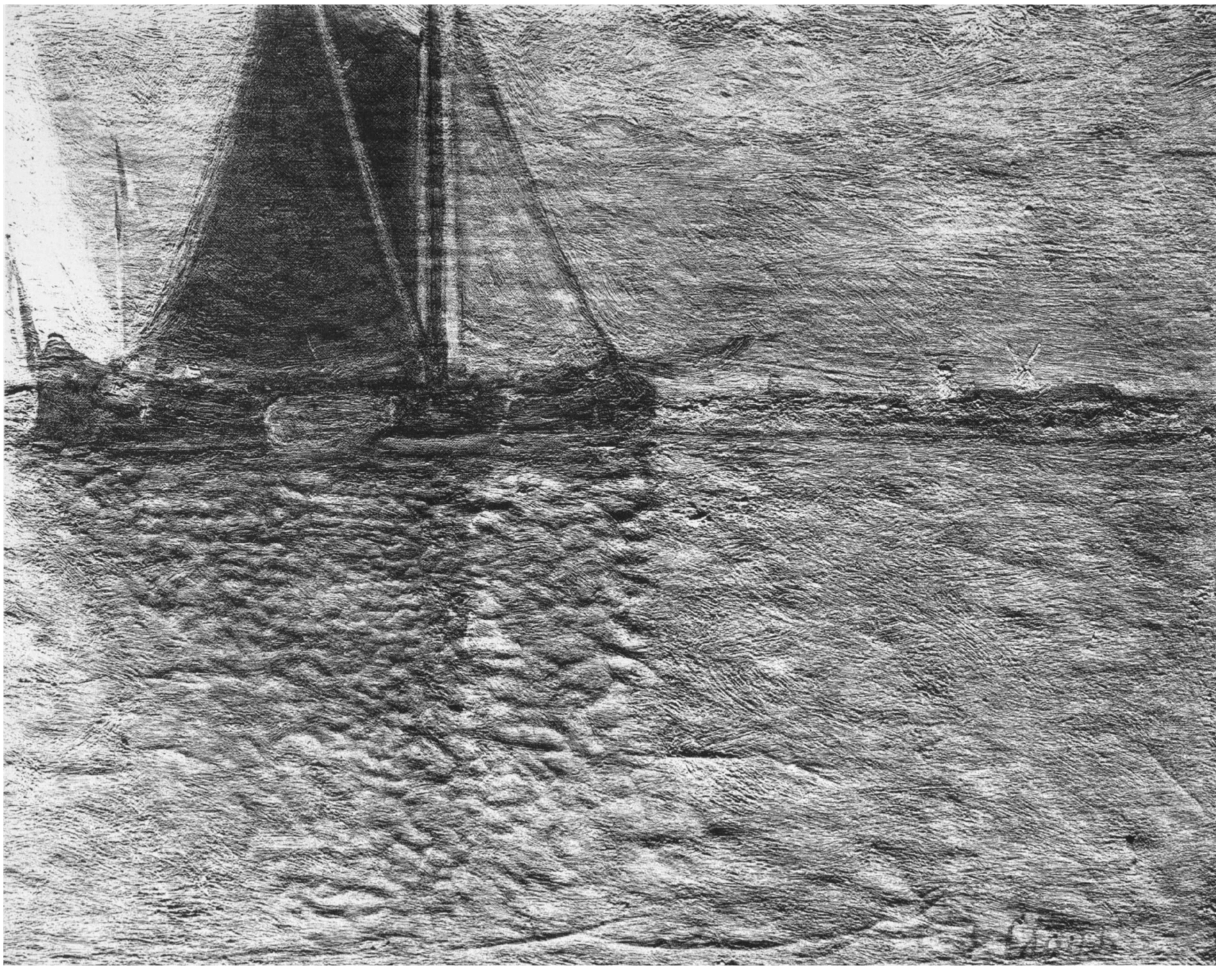


Figure 12 Detail taken in raking light after moisture treatment.

before, using an interleaf of the thinnest blotting paper as a release layer. To increase the penetration of the adhesive, extra Melinex pieces were used to mask off the open area and reduce the window opening, so increasing the pressure on the surface above the set value of 15 mbar.

Following straight on from the blister treatment, the painting was humidified for a third time with the table set at 35°C and the pressure increased to 20 mbar, again for forty minutes, and then cooled and dried out. The painting was left to reach ambient conditions under a pressure of 30 mbar, after which the surface appeared much improved and areas of heavy raised paint seemed relaxed and less brittle (Fig.12). A linen canvas impregnated with beeswax was stretched onto the stretcher as a loose lining before restretching the painting.

Another unlined painting it was judged would benefit from moisture treatment on the multi-purpose table was *Storm at Honfleur* by Stevens (No.3966), painted in 1890 or 1891 and still on its original stretcher (Fig.13). Although the fine canvas was in very good condition there were pronounced stretcher-bar marks and some bulges, probably caused by the painting hanging slack on the stretcher over a long period. Neither an earlier attempt to key-out the stretcher nor removing the painting from the stretcher and laying it flat had produced much visible improvement.

Before the painting was treated on the multi-purpose table the turnover edges were flattened and two small areas of filling on the reverse (covering old damages) were scraped off. The back of the canvas was lightly sanded. The painting was placed face-up on an interleaf on the table and covered with Melinex. The moisture treatment was carried out with the table set at 35°C and 15 mbar for ten minutes and then dried out to ambient under pressure. As this only partially reduced the distortions the process was repeated the next day under

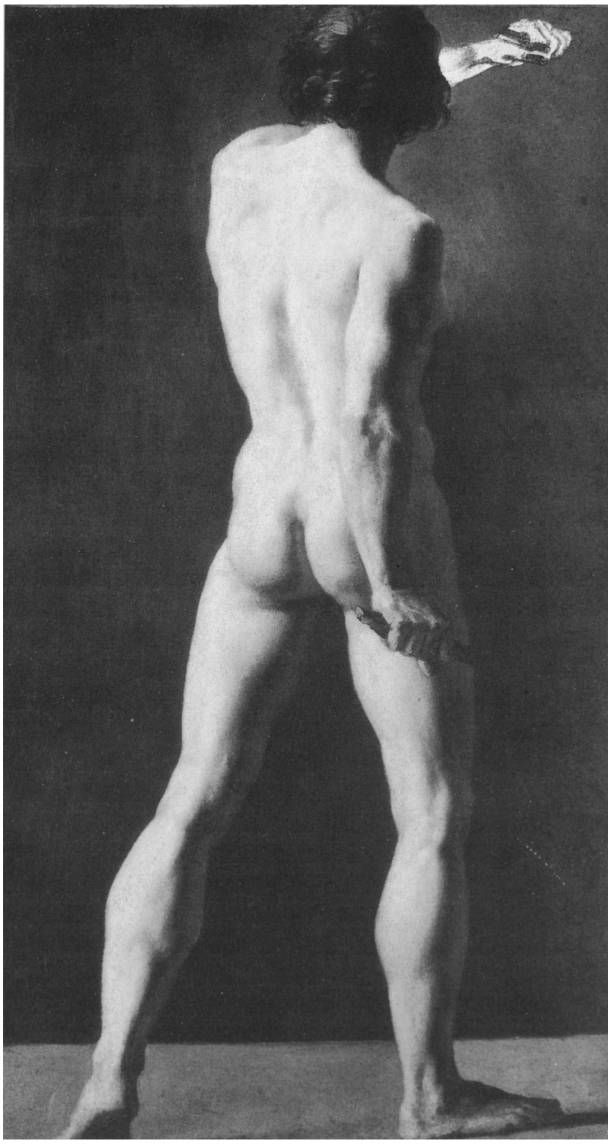


Figure 14 (Right, above) Ascribed to Gericault, *An Académie* (No.3391).

Figure 13 (Right) Stevens, *Storm at Honfleur* (No.3966).

the same conditions, but with a longer drying time. This successfully removed the deformations. After treatment Beva-impregnated polyester net was tack bonded to the turnover edges to protect them from damage during restretching.

Two other unlined paintings which have undergone similar moisture treatments are *Mr and Mrs Thomas Coltman* (No.6496) by Joseph Wright of Derby [16] and Van Gogh's *Sunflowers* (No.3863) [17], which was also consolidated on the table.

A lined painting which benefited from moisture and heat induced relaxation was the early nineteenth century *An Académie* (No.3391), ascribed to Gericault (Fig.14). This was painted on paper, which had at some time been stuck down onto a larger piece of canvas. The surface was stiff and badly buckled, with an old indentation at the bottom edge. The canvas was very successfully relaxed, without the need to remove the lining and then nap-bonded onto a Beva-impregnated lining canvas.

These few treatments of National Gallery paintings were carried out during a period when extensive tests were being conducted on painted canvas samples, the results of which enabled treatment methods to be continually revised and modified. The tests investigated detachment of canvas linings from both canvas and paper, removal of glue from paper by swelling the glue under controlled conditions, and consolidation of paint at different temperatures and pressures.

The testing programme is continuing with the assessment of reactions to and results of moisture treatments, and also with an evaluation of looming methods and materials. A further important area for investigation is the use of domes on top of the table [18]. These enable humid atmospheres to be created above the paint surface and encourage relaxation of the paint through plastic deformation. They also enable vacuum pressure to be maintained without requiring a membrane to be in direct contact with the picture surface.

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The National Gallery's experience with the low pressure table showed that if the many different functions of the table were to be fully used, a series of practical experiments would be required. It was estimated that this research would occupy one person for a year. No member of the Gallery's small Conservation Department could be spared from their normal duties for this period, and the research was made possible by a generous grant from the Leverhulme Trust. The one-year research project, carried out by Paul Ackroyd, was a vital stage in the development of the low pressure table.

Notes and references

1. Reeve, A.M., 'A New Multi-Purpose Low Pressure Conservation Table for the Treatment of Paintings', *Studies in Conservation*, **29** (1984), pp.124–28.

2. Beva 371 is a heat-seal adhesive, the description and exact formulation of which are given by Berger, G.A., 'Formulating Adhesives for the Conservation of Paintings', in *Conservation and Restoration of Pictorial Art*, N. Bromelle and P. Smith (eds.), Butterworths (London 1976), pp. 169–81.

3. Wyld, M. and Dunkerton, J. 'The Transfer of Cima's "The Incredulity of S. Thomas"', *National Gallery Technical Bulletin*, **9** (1985), pp.38–59.

4. Hedley, G.A., Hackney, S. and Cummings, A.J., 'Lining in a Vacuum Envelope with a Traversing Infra-Red Heat Source', *Preprints for the Conference on Comparative Lining Techniques*, National Maritime Museum, Greenwich (1974).

5. Chittenden, R., Lewis, G. and Percival-Prescott, W., 'Prestretched Low Pressure Lining Methods', *Preprints for the Conference on Comparative Lining Techniques*, National Maritime Museum, Greenwich (1974).

6. Mehra, V., 'Further Developments in Cold Lining' *Preprints of ICOM Committee for Conservation*, 4th Triennial Meeting, Venice (1975), 75/11/5.

7. Mehra, V., 'Cold Lining and the Care of the Paint Layer in a Triple Stretcher System', *Preprints of ICOM Committee for Conservation*, 5th Triennial Meeting, Zagreb (1978), 78/2/5.

8. Mehra, V., 'Cold Lining of Paintings', *The Conservator*, **5** (1981), pp.12–14.

9. Fieux, R. E., 'Electrostatic Hold: A New Technique of Lining', *Preprints of ICOM Committee for Conservation*, 5th Triennial Meeting, Zagreb (1978), 78/2/12.

10. Hacke, B., 'A Low Pressure Apparatus for the Treatment of Paintings', *Preprints of ICOM Committee for Conservation*, 5th Triennial Meeting, Zagreb (1978), 2/12/1.

11. Hacke, B., 'Low Pressure, Heat, Moisture, Stretching. Notes on Further Developments', *Preprints of ICOM Committee for Conservation*, 6th Triennial Meeting, Ottawa (1981), 81/2/8.

12. Hacke, B., 'Über die Entwicklung und die Möglichkeiten des Niederdruckapparates', *Maltechnik*, **4** (1983), pp.257–68.

13. The authors would like to acknowledge the invaluable collaboration of Mr Jack Willard and his company, Willard Developments, for their continuing efforts and research on technology for conservation.

14. Mecklenburg, M.F., 'Some Aspects of the Mechanical Behaviour of Fabric-Supported Paintings', *Report to the Smithsonian Institute* (February 1982).

15. Hedley, G., 'Relative Humidity and the Stress/Strain Response of Canvas Paintings', *Studies in Conservation*, **33**, 3 (1988), pp. 133–47.

16. Wyld, M. and Thomas, D., 'Wright of Derby's "Mr and Mrs Thomas Coltman"', *National Gallery Technical Bulletin*, **10** (1986), p.30.

17. Leighton, J., Reeve, A.M., Roy, A. and White, R., 'Vincent Van Gogh's "A Cornfield, with Cypresses"', *National Gallery Technical Bulletin*, **11** (1987), pp.46–50.

18. Albano, A., 'Development of a General Purpose Table Top Humidification/Suction System', *Preprints of ICOM Committee for Conservation*, 7th Triennial Meeting, Copenhagen (1984), 84/2/1.