3

Technical Bulletin

December 1980

Canadian Conservation Institute

National Museums of Canada

Recommended Environmental Monitors for Museums, Archives and Art Galleries

Raymond H. Lafontaine

Recommended Environmental Monitors for Museums, Galleries and Archives

by
Raymond H. Lafontaine

CCI TECHNICAL BULLETINS

1. *Relative Humidity: Its Importance, Measurement and Control in Museums* by K. J. Macleod
2. *Museum Lighting* by K. J. Macleod
3. *Recommended Environmental Monitors for Museums. Archives and Art Galleries* by Raymond H. Lafontaine
4. *Care of Musical Instruments in Canadian Collections* by R. L. Barclay
5. *Environmental Norms for Canadian Museums, Art Galleries and Archives* by Raymond H. Lafontaine
6. *The Care of Black and White Photographic Collections: Identification of Processes* by Siegfried Rempel
7. *Fluorescent Lamps* by Raymond H. Lafontaine and Patricia A. Wood
8. *The Care of Wooden Objects* by R. Barclay, R. Eames and A. Todd
9. *The Care of Black and White Photographic Collections: Cleaning and Stabilization* by Siegfried Rempel

(*TB's # 10-12 in progress.*)

For free Technical Bulletins, please fill out enclosed detachable post card and return to CCI.

Canadian Conservation Institute (CCI)
National Museums of Canada

Technical Bulletin No. 3

Recommended Environmental Monitors for Museums, Archives and Art Galleries

by
Raymond H. Lafontaine

Editor and Layout: Janet Denton
Printed by the Canadian Government Printing Office: Bruce Broadfoot, Planner

ISSN 0706-4152
ISBN 0-662-50405-4
DSS Cat. No. NM 95-55/3-1980
First printing, August 1975
Revised, July 1978
Revised, December 1980

Technical Bulletins are published at intervals by the Canadian Conservation Institute in Ottawa as a means of disseminating information on current techniques and principles of conservation of use to curators and conservators of Canada's cultural artifacts. The authors welcome comments.

ABSTRACT

Instruments for monitoring museum environmental conditions—including relative humidity, temperature, lighting and air pollution—are described here in detail. Recognizing that not all institutions can maintain high quality continuous records of their environmental conditions due to limited budgets, potential users are divided into three practical categories. A "kit" of recommended instrumentation is described for each category and should be simultaneously available at an institution. Sample forms for reporting environmental conditions are also shown.

Credits:

Illustrations: Bo-Kim Louie.
Fig. 2: Glen Sisk.

Location shots courtesy of the National Gallery of Canada, Ottawa

TABLE OF CONTENTS

AUTHOR

Raymond Lafontaine demonstrates use of a monitoring instrument in a museum.
Photo by James Stark

Raymond H. Lafontaine is Chief of the Environment and Deterioration Research Division at the Canadian Conservation Institute (CCI) in Ottawa. He studied chemistry at the University of Ottawa, receiving a B.Sc. Honours degree in 1972, and joined CCI the same year. He is now investigating the effects of light and relative humidity on artifacts, with particular interest in developing techniques to reduce the deterioration of these materials.

I. Introduction

It is well known that variations in relative humidity, high temperatures, intense lighting and air pollution have serious effects on museum objects. The dimensions of a canvas will change when subjected to variations in relative humidity (RH), inevitably resulting in the cleavage of the pigment layers of the painting. Intense lighting can cause fading of pigments—especially in watercolours, archival materials, pastels and textiles. The corrosion of metal objects (i.e., bronze disease, varnish bloom) is frequently a direct consequence of, or severely aggravated by, pollutants present in the air. Therefore, the importance of environmental control in an art gallery, museum or archive cannot be overemphasized.

Unfortunately, it is often not possible for a small institution to acquire a large and expensive system of instrumentation in order to achieve excellent control of the environment in the building. Certain small steps can be taken without spending large sums of money, however. For example, the building's temperature can be kept at lower values, between 20° and 21°C (68°-70°F), in the winter months, which will help avoid dessication due to low RH. Inexpensive portable humidifiers can be used to maintain sufficient RH. Works of art can be kept away from direct sunlight coming through windows. Inexpensive filters can be used on fluorescent tubes to absorb their ultraviolet (UV) output. Lighting throughout the institution can be kept at relatively low and safe levels, and floodlights can be properly placed in order to minimize heating effects on the object displayed. This is only a small list of precautions one can take.

To assess the effectiveness of these and other environmental controls, it is necessary to monitor environmental conditions within the institution. The four areas of concern are temperature, humidity, lighting and air pollution. We recognize the high cost of necessary equipment prevents some institutions from maintaining the highest quality continuous records. Therefore, we suggest three practical categories for potential users of monitoring equipment:

Type A) An institution which needs simple and reliable but inexpensive equipment to monitor conditions only occasionally.

Type B) An institution undertaking to maintain continuous records of various conditions, particularly of RH, temperature, and perhaps lighting.

Type C) An institution which undertakes to maintain complete, accurate, and continuous records of all environmental conditions.

As shall be seen subsequently, the measurement of relative humidity, temperature or lighting level is usually a quite straightforward procedure. Surface rise in the temperature of objects due to strong spotlights can be measured, but the more sensitive and accurate instruments required are rather expensive. The determination of pollutants in the air at normal ambient levels also requires expensive instrumentation.

II. Relative Humidity Monitors

In this and subsequent descriptions of monitors, the usual format will be to start with the least expensive and work our way up to the most expensive. A summary of recommended instruments for Type A, B and C institutions is found in Appendix A, which follows the detailed descriptions.

To avoid confusion, it is best to first define the types of instruments. Any instrument that measures relative humidity may be called a hydrometer. A psychrometer, on the other hand, is an instrument that measures only wet bulb and dry bulb temperatures.

An instrument that is extensively used because of its low cost and simplicity is the sling psychrometer (Figure 1). It is comprised of two thermometers (held in a common base or body), one of which has its bulb covered with a cotton wick which is wetted before being used. The "wet bulb" thermometer will indicate a lower temperature than the "dry bulb" thermometer, due to the cooling effect caused by evaporation of the water. The rate of evaporation is directly related to the amount of water (moisture) in the air. One reads the dry bulb temperature (the actual temperature in the room) and the wet bulb temperature; then the relative humidity is obtained from psychrometric tables (usually available with the instrument) using these two temperature values.

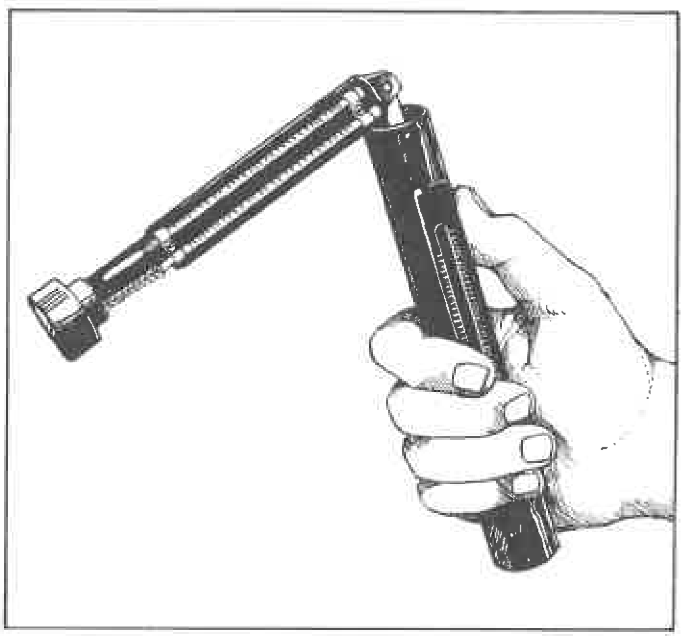


FIGURE 1. Typical sling psychrometer. Notice the cotton wick covering one thermometer.

In order for this method to produce accurate results, there must be adequate air flow around the two thermometer bulbs. With the sling psychrometer, one rotates the thermometers (mounted to an attached handle) for about three minutes at a constant speed of two or three revolutions per second.

Several types of sling psychrometers are available and can be purchased at any Fisher Scientific[1] or Canadian Laboratory Supplies[2] outlet in Canada for about $20 to $25.* Because the sling psychrometer generally gives inaccurate results for RH below 25% or 30%, it is not recommended for museum use. To minimize these errors, an improved psychrometer is available which includes a built-in fan and motor. This instrument (e.g., the Bendix[3] "Psychron" psychrometer) works on the same principle as the sling psychrometer, except that a small electric motor and fan produces the required air flow across the two bulbs (Figure 2). The motor is powered by three size-D, 1.5 volt batteries. A small light behind the thermometers makes it easy to use when working in dark areas. The usual procedure is to start the Bendix psychrometer and wait at least two minutes before actually taking a reading. This will assure sufficient time for the wet bulb to reach its proper temperature. This instrument is reliable, accurate, trouble-free and easy-to-use, and for these reasons it is certainly the better instrument for all institutions, large or small. The Bendix psychrometer sells for about $200 at any scientific instrument distributor; e.g., Fisher or Canlab (see References).

The advantage of any psychrometer is that it gives the ambient temperature (dry bulb temperature) of the room. In this way, both temperature and relative humidity can be monitored with the same instrument. In general, there are no problems encountered with the use of psychrometers, except that one must make sure the wet bulb does not dry up or become contaminated with salts while in use. Replacement cotton wicks usually come with the instruments. Regular changing of the wick assures good results.

It is possible to monitor relative humidity by using electronic devices which read directly in % RH. These hygrometers utilize different types of sensors, most of them showing electrical properties which vary depending on the relative humidity surrounding the sensor.

One such instrument on the market is the Beckman[4] "Humi-chek" (Figure 3). It is very easy to operate, and reads directly in % RH at the press of a button. There is no bulb to wet. A 9-volt transistor radio battery, which should be changed about every six months, produces power for the electronic components. An accuracy of ±2% in the measured RH is claimed over a range of 15% to 95% RH. These accuracies are under controlled conditions inside constant humidity chambers. A more realistic figure would be ±3%–4% for various conditions of RH and temperature. We have been using a Humi-chek in our laboratories for several years and have found that readings obtained with it are never more than ±3%–4% different from those obtained with our dewpoint hygrometer (to be discussed later in this bulletin). Indeed, in the range of 30% to 65%, the error was usually not more than ±3% RH. This is surely quite adequate for most purposes. It does take a few

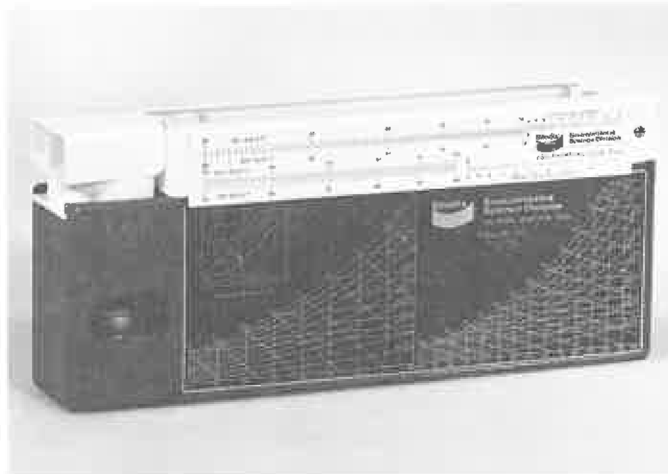


FIGURE 2. The Bendix "Psychron" psychrometer. A small motor and fan arrangement provides air circulation.

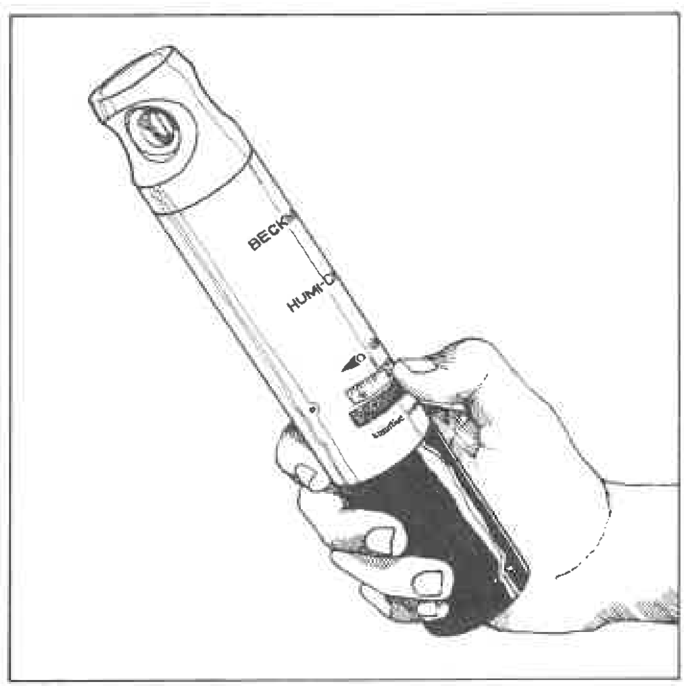


FIGURE 3. The versatile Beckman "Humi-check". The knurled wheel is rotated with the thumb until two small lights are off. The RH is read directly on the wheel.

* "All prices listed in this bulletin are approximate quotations."

FIGURE 4. Some electronic hygrometers have an output for connecting a strip chart recorder to give continuous readings. The "Humeter" uses a separate sensor.

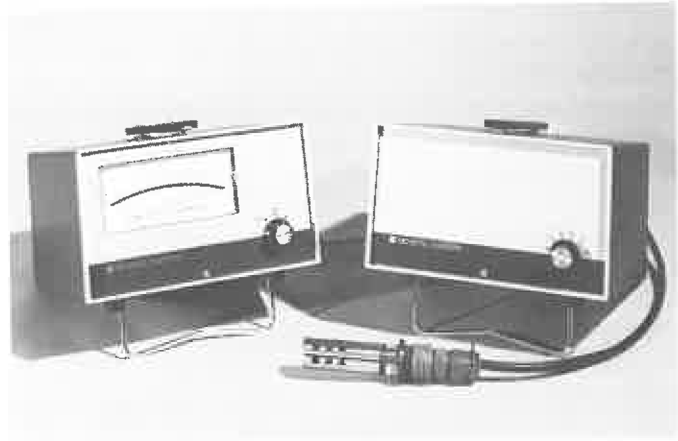


FIGURE 5. The General Eastern Model 400C with multi-probe module. Up to six different sensors can be connected at one time using this special attachment.

minutes for the instrument to equilibrate to new RH conditions, so one should always wait one-or-two minutes before taking the final reading.

A more recent version, the Humi-chek II Deluxe, features a calibration adjustment screw and a special calibrator. The latter is placed over the sensing element of the Humi-chek II for a period of half an hour. The instrument is then adjusted to read the correct RH as specified by the calibrator. The cost of the new version is approximately $350, and includes a carrying case and a calibrator.

The "Humeter", produced by Phys-Chemical Research Corporation[5], utilizes a separate sensor and control module (Figure 4). It is semi-portable and operates on 120 volts AC. The price of this instrument is about $1000. It does not outperform the Humi-chek II, which costs roughly one-third as much and is completely portable. On the other hand, it does offer an advantage in that a recorder can be attached for continuous recording of RH.

The model 400C Humidity Temperature Indicator (about $1000) made by General Eastern[6] is similar in design to the Humeter (Figure 5). It is pre-calibrated at the factory, but can be readjusted at regular intervals. This instrument should be accurate for about a year, depending on the type of conditions to which it is subjected. Preliminary studies in our laboratories have shown that it could well be used as a reference instrument for calibrating other more inexpensive instruments. Both RH and temperature can be measured by the instrument, which has a recorder output.

The Shaw mini-hygrometer[7] (about $500) is small and portable. The dial reading is translated to % RH by reading off a calibration graph; estimated accuracy is ±2%–5%. It, too, suffers in a cost comparison with the Humichek. The one we have been using has shown itself to be quite unreliable and inaccurate.

In addition, there are many other electronic hygrometers available on the maket. It is advisable to check the specifications carefully before deciding on a purchase. For those who want the ultimate in instrumentation range and accuracy, there are electronic dew-point hygrometers. This type of instrument measures the dew-point temperature and ambient temperature of the surroundings which, with the use of tables, are converted to % RH. Their accuracy is about ±2% to 3% in the complete range of RH and repeatability is in the ±1% range. However, dew-point instruments are expensive. The "Vapor-Mate II" manufactured by EG & G[8] costs about $3000, and is presently being used in our laboratory with excellent results (Figure 6). Another model, the "Panametrics"[9], is in the same price range.

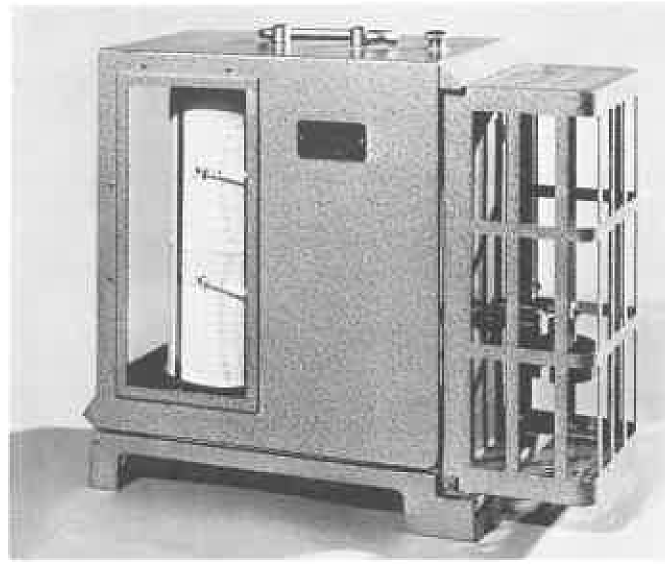
None of the instruments discussed above give continuous records of % RH by themselves. In some cases, recorder outputs are provided, but the additional cost of a recorder (several hundred dollars) makes this a costly method.

Instruments in another category, which employ the dimensional changes of organic materials with changes in RH, can be conveniently designed to produce continuous records. This type of recording hygrometer (commonly referred to as the ***hygrograph***) often also records temperature, and so is called a ***hygrothermograph*** (Figure 7a).

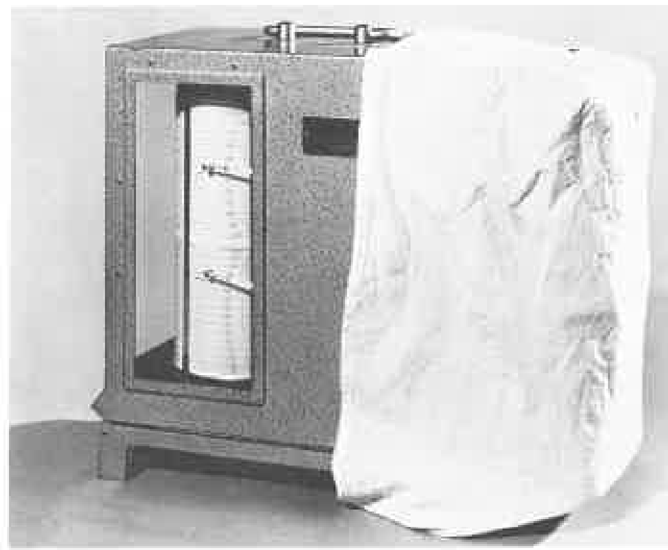
One popular model uses as its sensing element small bundles of human hair. The length of the hair will vary depending on the RH around it. This motion is transferred by means of a lever mechanism to a pen which draws out a continuous record of RH on a chart driven by a clockwork mechanism. Another model utilizes a special RH sensitive membrane. Most often the temperature is recorded by the use of a bimetallic strip or Bourdon tube element.

6.

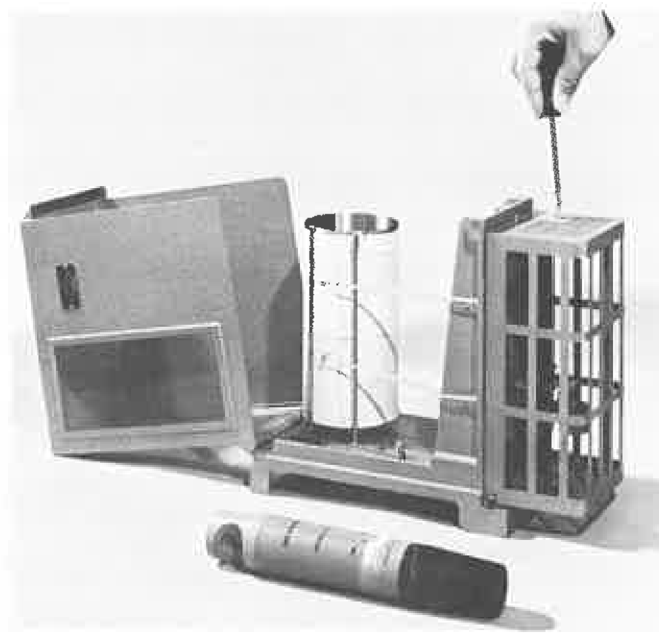
7a.



7b.



7c.



The hair hygrothermograph seems to be the more reliable instrument. Belfort offers a model for about $600 which is very easy to use and will record RH and temperature over 7-day or 30-day periods. We have several of these in use and we are satisfied with the results obtained. Every week or month the chart must be changed and ink added to the pens. Every 2-4 months or so, a wet cloth should be placed around the cage holding the sensing element for about an hour. Applicable to all models of hygrothermographs, this treatment rejuvenates the hair, especially if low RH conditions were encountered during that period of time (Figure 7b). It is calibrated (one day after the wet cloth has been removed) using a psychrometer (Bendix is recommended) or a hygrometer (e.g., Humi-chek) in an RH condition of between 35% and 65% (Figure 7c). It is very important to perform this rejuvenation and calibration if accurate readings are to be obtained. Other hair hygrothermographs are available from Serdex[11], Honeywell[12], Sigma[13], Fisher[2], Canlab[2], and Cole-Parmer[16].

FIGURE 6. *Calibration of the EG & G "Vapor-Mate II" dew-point hygrometer is traceable to the National Bureau of Standards. It is an excellent reference instrument for calibrating others.*

FIGURE 7a. *The hygrothermograph can continuously record RH and temperature over 7-day or 30-day periods. Note the round bimetallic strip thermometer and the five bundles of human hair used as the humidity sensor on this particular model.*

FIGURE 7b. *A wet cloth is placed around the cage of the hygrothermograph for about one hour, in order to rejuvenate the human hair.*

FIGURE 7c. *Turning a small screw adjusts the RH reading to give the correct value as indicated by a hygrometer (e.g., Humi-chek). The drum-type recorder is rotated by a clock mechanism.*

The membrane type instrument was found to be considerably inaccurate in the upper and lower ranges of RH (30% and 70%). The ***hysteresis*** effect (the fact that the present state of a system will depend on its preceding history, or "memory" of previous RH conditions) appears larger with membrane type instruments. For example, at 50% RH, one model we tested read 60% if it had been subjected previously to a low RH (approximately 30%), and 49% if subjected previously to a high RH (approximately 70%).

Recording psychrometers are available (e.g., Powers[14]). These tend to be bulky and expensive. They incorporate a motor and a fan for air circulation, as well as a built-in recorder.

It is possible to set up a more elaborate system which can monitor an entire museum building. For example, a sensing element (the type used for the electronic hygrometers) could be placed in each room and these elements connected to a central control module and recorder where the RH of each location would be continuously monitored. Such a system can be individually designed by a firm such as Honeywell[12] to meet the specific needs of a particular institution.

Many of the RH monitors we have described have been compared in our laboratories using a controlled humidity chamber. Table I gives a comparison of eight of these instruments. The dew-point hygrometer is taken as the reference value. Sufficient time was allowed for each instrument to equilibrate to conditions inside the chamber. Usually an average of two or more readings was taken.

Inexpensive dial hygrometers ($5 to $75) are also available from various distributors. Some use a simple coiled paper element as a humidity sensor. These were relatively accurate in the moderate RH range of 35-65%, but suffer in the lower and upper regions. They often lack the response and sensitivity required and are not recommended. The more expensive models ($75) use human hair bundles or, sometimes, special fibre elements (see References 16, 30 and 31). These are relatively accurate throughout the RH range (0-100%) and can be used in museums, galleries and archives if they are calibrated regularly with a psychrometer.

TABLE 1: *Comparison of RH monitors with standard reference hygrometer.*

	% Relative humidity				
Dew-point hygrometer (EG & G)*	11	31	51	80.5	72
Fuess hygrothermograph	7	30	50	—	71
Serdex hygrothermograph (membrane type)	0	22	44	—	65
Amlab hygrometer	24	32	52	—	80
Bendix psychrometer	12	33	54	—	73
Humi-chek	—	30	52	84	—
Humeter	—	36.5	—	83	—
Shaw hygrometer	—	33	—	75	—

* Standard reference hygrometer to which others are compared.

III. Temperature Monitors

Temperature is also an important criterion of museum environment and therefore should be monitored. One should take into account both the ambient (room) temperature and the surface temperature of objects for, although room temperature may be at 21°C (70°F), strong spotlights can raise the surface temperature of artifacts and works of art by many degrees.

Room temperature is best measured by a mercury thermometer or a bimetallic strip thermometer. As was noted earlier, psychrometers and hygrothermographs will also give a measure of the room temperature.

The measurement of surface temperature is not quite so simple. Surface temperature probes can be purchased for this operation. A small unit with two different probes, one for surface temperature and the other for ambient temperature, is available form Aotek[15] for about $200 (Figure 8). Other models can be obtained from Fisher[1], Cole-Parmer[16], Canlab[2] and others, with prices ranging from $100 to $600 (Figure 9).

Since intimate contact with the surface of the object is necessary with these probes, extreme care must be taken when measuring the surface temperature.

8.

FIGURE 8. A scientist measures the surface temperature of a painting with the Aotek thermometer. Extreme care is needed so as not to damage the surface of the painting with the probe.

9.

FIGURE 9. The "Digitec" digital thermometer. Both a surface and an ambient temperature probe are shown.

There are also instruments which measure surface temperature by utilizing emitted infrared radiation (Figures 10(a) and (b). These infrared thermometers are easy to operate, requiring only that the instrument be pointed at the surface and the temperature be read on a scale. Readings from a spot or broad surface areas and over various temperature ranges are possible.

Barnes Engineering[17] and Mikron[18] both manufacture portable units which sell for about $1000. The model we are presently using at CCI—Barnes Engineering model PRT-10L Portable Infrared Thermometer—has a 2.8° field of view: spot size or measuring area is 3 cm diameter at 30 cm from the instrument, 8 cm diameter at 1 meter from the instrument, and 18 cm diameter at 3 meters. The temperature scale of −10° to 60°C (14° to 140°F) provides a good working range for our applications. An accuracy of ±1°C is possible. Unfortunately, it is not possible to measure through the glass or plastic windows of display cases.

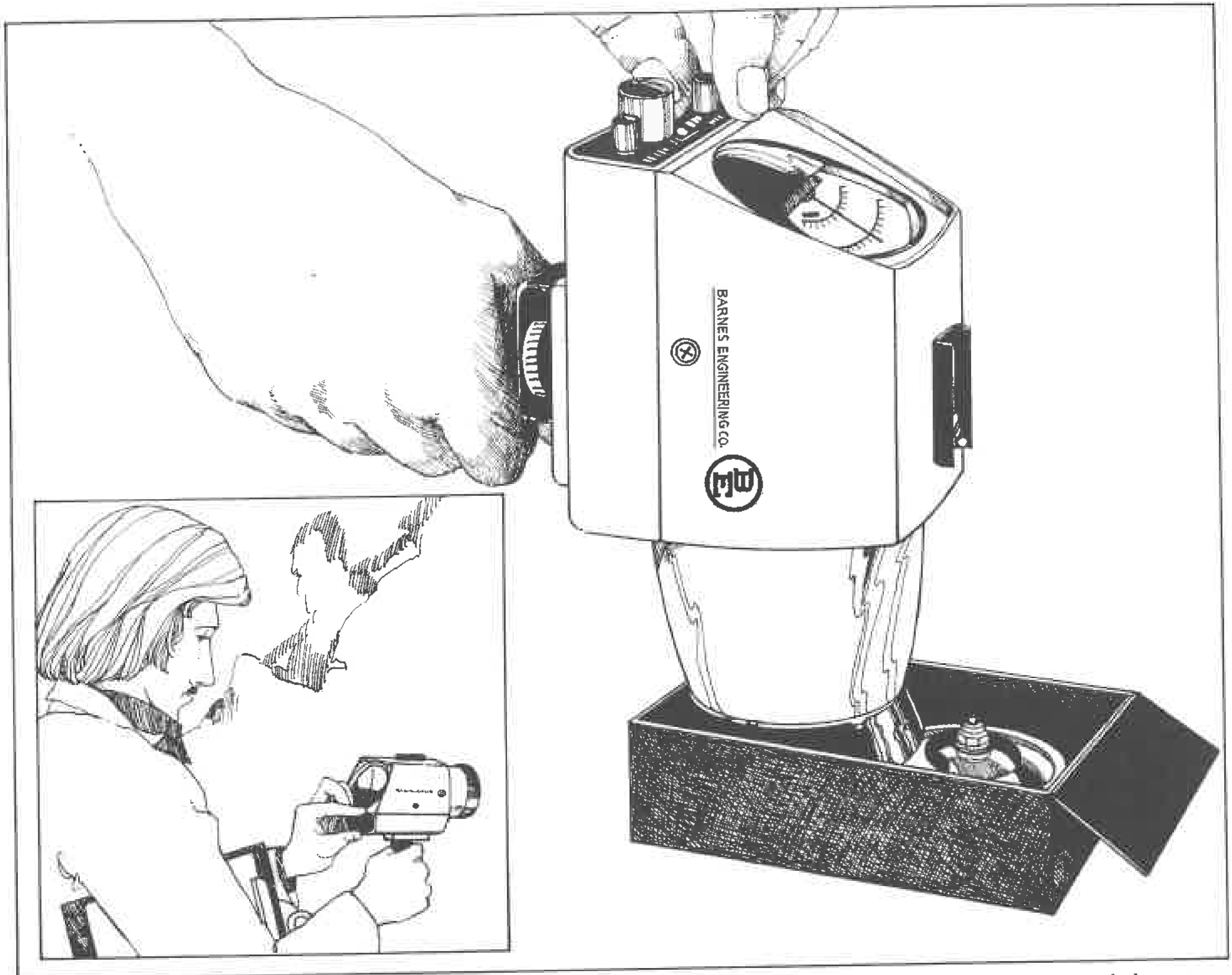
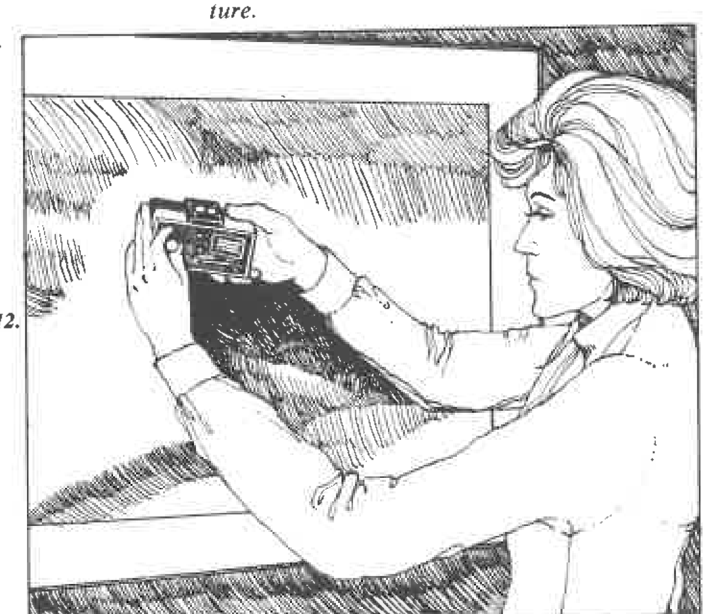


FIGURE 10(a). The infrared thermometer measures the surface temperature of a painting.

FIGURE 10(b). The Barnes Engineering infrared thermometer is adjusted, using a reference surface temperature.

11.



12.

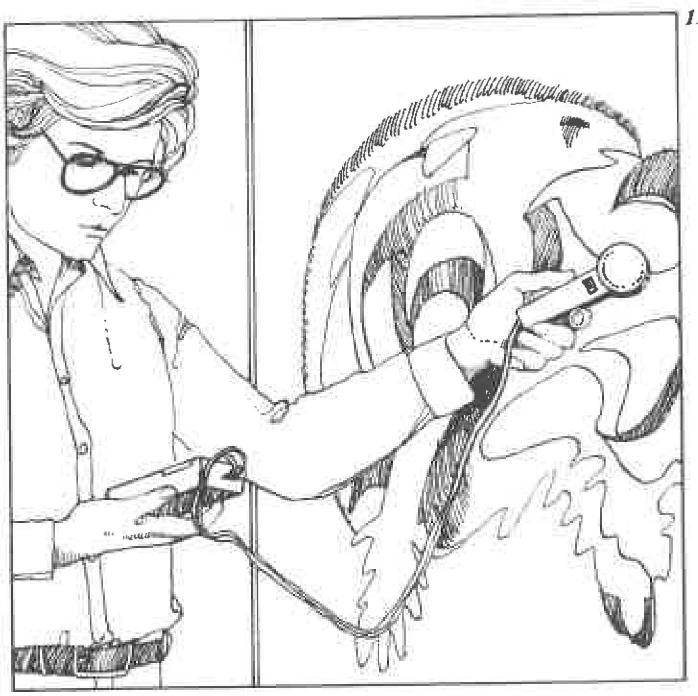


FIGURE 11. A Panlux Electronic luxmeter measures the illumination falling on a painting.

FIGURE 12. The Crawford Type 760 monitor measures the amount of ultraviolet radiation on a painting.

IV. Light Monitors

While it is obviously important to keep lighting at intensity levels that will permit people to observe the objects with little or no eye strain, it is a fact that high intensities are unnecessary since the human eye can readily accommodate itself to lower illuminations.* Recommended lighting levels have been suggested for different types of works of art. The normally accepted maximum values have been set at about 50 lux** for sensitive objects: fugitive pigments, pastels, watercolours, archival materials, both dyed and undyed textiles, etc. For most other objects levels of 150 lux are quite acceptable, although levels of 300 lux may be acceptable for stone and metal objects when fine details are to be viewed. Therefore, it is essential to measure the amount of light in exhibition areas.

Many photometers, luxmeters and foot-candle meters are available (Chauvin Arnoux[19], Gossen[20], Tektronix[21] or Gamma Scientific[22]) at prices ranging from about $100 to $1500 (Figure 11). It is imperative that the response curve of these meters be the same as the human eye response (photopic response). Also, one should make certain that the meter is sensitive enough to measure amounts as low as 25 to 50 lux with a reasonable degree of accuracy (10% or better). Some photographic meters are often good only for higher levels of illumination and will not give accurate readings for levels we are interested in determining (50 to 300 lux). Better meters will have accuracies well within acceptable limits; i.e., 10% or better. They usually measure either in lux or in foot-candles (1 foot-candle equals 10.76 lux).

Regardless of which instrument is used to measure light intensities, standard procedures should be followed. One always measures the light incident on the object. It is important that the sensor is always in full light and is not, for example, shadowed by a hand or body. For two-dimensional objects (e.g., a painting), the sensor should be parallel to the face of the object. In cases of three-dimensional objects (e.g., sculpture, artifacts), the sensor must be aimed toward the light source. Readings should be taken at different points on the object so that variations in illumination on the same object can be noted.

Since the ultraviolet component of light sources can be responsible for photochemically induced deterioration, it is often necessary to measure the UV energy radiating on a work of art. For this purpose, a UV monitor is needed. Until recently, most instruments of this type were expensive due to the higher cost of producing a sensing element which would respond only to UV and would be sensitive enough to measure the amounts usually encountered in typical lighting situations.

The newly introduced Crawford UV monitor Type 760[29] was tested in Ottawa's CCI laboratories and was found to be precise and extremely easy to use (Figure 12). For many institutions, a good luxmeter and the Crawford UV monitor are ideal for light and UV measurements, and are less costly than an elaborate radiometer system. Gamma Scientific[22], PBL/International[23], Optronic[24] and United Detector[25] all manufacture more expensive radiometers.

A Gamma Scientific Model 900 Portable Photometer/Radiometer was tested at the Institute. Two separate detector heads, one for measuring illumination in lux and the other for UV radiation from 300nm to 400nm in microwatts per square centimetre ($\mu W/cm^2$), are used (see Figure 13). Unfortunately, interpretation of the resulting data is sometimes beyond the scope of museum personnel, so this instrument is not recommended.

A less expensive instrument, called a "Black Ray" UV meter, is available from Canlab[2] for about $150. However, its sensitivity is not high enough to measure the amounts of UV ordinarily encountered. It is used for monitoring UV or germicidal lamps, as well as others which have high UV output. It is, therefore, not recommended for our purposes.

FIGURE 13. Gamma Scientific Model 900. Left detector head measures illumination; the other measures UV intensity from 300nm to 400nm.

* See Lafontaine, R.H. and Macleod, K.J., "A Statistical Survey of Lighting Conditions and the Use of Ultraviolet Filters in Canadian Museums, Archives and Galleries", Journal of the Canadian Conservation Institute Vol. 1 (1976), pp. 41-44.

** The lux is a measure of the light level as perceived by the human eye. For details see Macleod, K.J., "Museum Lighting", Technical Bulletin No. 2, Canadian Conservation Institute. : May 1978.

Whether or not one can afford to purchase UV monitoring equipment, it is essential to provide exhibition and storage conditions which minimize the UV component of any illumination. In designing new lighting systems or modifying existing ones, it is important, therefore, to realize that many fluorescent lamps (cool white and daylight) emit roughly 2 to 3 times more UV than incandescent lamps, and that daylight contains approximately ten times more UV than incandescent lamps.

Infrared radiation (IR) emitted by incandescent lamps is also a cause of deterioration. It has the effect of increasing the surface temperature of the object it illuminates and so increases the rates of most deterioration processes. Measurement of IR intensity is usually not practical. It is far easier to measure the increase in surface temperature (this has been discussed earlier and will not be repeated here). It is important that surface heating should not exceed a few degrees; excessive surface heating must be corrected by changes in the illuminating system.

There is another method for evaluating safety of the illumination level in a particular installation. Specially dyed textiles are produced for determining the lightfastness of materials. They are made in such a way that the more sensitive standard textile will achieve just "appreciable fading" in half the time needed for the next most sensitive standard to do so, and so on. There are eight such standards:

a) Reference standards nos. 1 to 8 (British Standards)
b) Blue Wool light fastness standards L2 to L9 (American Standards)

The smaller numbered standards are the most sensitive.

It is possible to obtain an "after the fact" result by using the more sensitive standards and leaving one set on the wall of an exhibition area and another in darkness. Checking periodically, one may determine if any fading is occurring. The time taken to cause just "appreciable fading" on the most sensitive standard should be noted (i.e., the time it takes for the difference in contrast between the exposed and unexposed standards to become equal to the difference in contrast illustrated by step 4 of the International Geometric Gray Scale—which is obtained with the standards).

If the time required to cause fading is relatively short (several weeks), then the illumination is too strong. On the other hand, if very little fading takes place over a period of several months, the installation may be considered safe.

As with other types of instruments, lightmeters can be sent to the Canadian Conservation Institute in Ottawa for calibration verification.

V. Air Pollution Monitoring

The last subject to be discussed is air pollution monitoring. In Canada, fortunately, there are not yet serious problems of air pollution, except perhaps in certain urban and heavily industrialized regions.

It is possible to obtain the levels of pollutants in the air from the National Air Pollution Surveillance monthly summary. This report, compiled by the Air Pollution Control Directorate (Environment Canada), lists daily concentrations of major pollutants in some 34 centres across the country. The pollutants of greatest concern to museums and galleries are sulphur dioxide (SO_2), hydrogen sulphide (H_2H), nitrogen oxide (NO_x) and ozone (O_3).

We feel it is unnecessary for any institution to do its own monitoring of these pollutants. If an institution believes it has some problems with air pollutants, please contact the Canadian Conservation Institute in Ottawa for advice. However, for those who intend to carry on some kind of monitoring, there is a wide selection of commercially available instruments. Major scientific companies such as Fisher[1], Bendix[3], Mast[9], Royco[9], Research Appliance Company[28] and Beckman[4] manufacture good instrumentation.

It must be noted that pollutant concentrations in the air usually vary from approximately 0.01 ppm* in unindustrialized areas to about 0.50 ppm in heavily industrialized regions. Since concentrations inside the museum should not exceed approximately 0.01 ppm, monitors must be able to detect concentrations of 0.01 to 0.02 ppm if they are to be of any value in ambient air monitoring.

There are simple kits for the evaluation of pollutant concentrations which are inexpensive (100 to $150) and are very easy to use. The Bendix-Unico 400 Precision Gas Detector is one example of this type of instrument. However, these are not meant for measuring low levels of pollutants, but are designed for uses such as monitoring inside industrial plants where sulphur dioxide or hydrogen sulphide levels are high, due to manufacturing processes. They are useless for measuring levels generally found in museums and art galleries.

VI. Recommended Instrumentation

With the three categories of institutions defined earlier in mind, recommendations for purchasing equipment are given (see Appendix 1). The recommended instruments constitute a "kit" and should be simultaneously available at an institution.

Even with rather inexpensive instruments, much can be learned about environmental conditions within a building, especially the relative humidity and temperature levels. These, and excessive light, are still the major causes of deterioration. If certain steps are taken, such as using the simple kits for recording environmental conditions, then it will be possible for curators and conservators to implement action that will prevent damage which results from humidity that is either too high or too low, from extreme temperatures or from intense lighting.

* ppm is parts per million

Appendix A: Recommended Monitoring Equipment.

Institution A (low budget)
Relative humidity: Bendix psychrometer ($200).
Temperature (ambient): Bendix psychrometer gives room temperature (dry bulb).
Temperature (surface): monitoring not recommended; inexpensive equipment is not available.
Light: Panlux luxmeter, made by Gossen (ca. $300).

Institution B (modest budget)
Relative humidity: hygrothermograph (e.g., Belfort, $600) plus Bendix psychrometer or Humi-chek for calibration.
Temperature (ambient): hygrothermograph gives continuous temperature readings.
Temperature (surface): Aotek thermometer or similar version available from Fisher or Canlab ($100 to $200).
Light: Panlux luxmeter, made by Gossen; Crawford Type 760 UV monitor ($275).

Institution C (ample budget)
Relative humidity: hygrothermographs which are placed in several locations within museum or art gallery and Bendix psychrometer, Humi-chek or General Electric Model 400C Humidity/Temperature Indicator ($800), or a complete electronic monitoring system (Honeywell) with master control module designed specifically for the institution.
Temperature (ambient): hygrothermograph or monitoring included in a full-scale system.
Temperature (surface): infrared thermometer (Barnes or Mikron).
Light: Panlux luxmeter, made by Gossen; Crawford Type 760 UV monitor.

Appendix B: CCI Environmental Monitoring Kit.

The CCI's Environment and Deterioration Research Division has put together an Environmental Monitoring Kit using equipment tested at the Institute. The following parameters can be measured with this kit: illumination (in lux); ultraviolet radiation from lighting; relative humidity (two methods); and temperature.

The kit is available on loan from CCI in Ottawa. Instructions included with the kit are written so that untrained personnel can obtain accurate and meaningful readings. However, as this project has been only recently initiated, some unforeseen problems may arise. If this happens, let us know so we can try to remedy such situations for future users of the kit.

Appendix C: Sample Forms for Reporting Environmental Conditions.

Relative humidity and temperature should be recorded daily at different locations in the building. Since conditions may change during the day, it is also advisable to take measurements at different times throughout one day each week. If continuous records are kept, as with a hygrothermograph, minimum and maximum values can be transcribed on the form for regular time intervals. The instrument used should be identified on the form, and if a particular instrument requires periodic calibration, the date and procedure of the calibration should be noted.

Since artificial illumination does not alter significantly with time, a lighting report need only be done once for a particular exhibition or installation unless deliberate changes in lighting levels are made. However, when daylight is a component of the illumination, then several readings should be made at different times during one day each week in order to take into account the variation in intensities of daylight. The use of filters should also be noted.

When strong spotlights or floodlights are used, the surface temperature of the illuminated object should be measured and compared to the actual room temperature. This is also reported on the form.

Two examples are presented within the text showing suggested layout of a form for a relative humidity and temperature report, and another for an exhibition lighting report.

FIGURE 14. Environmental Monitoring Kit available on loan.

References: Sources of Supply

1. Outlets in Canada for Fisher Scientific Co., Ltd.:

Edmonton: 10720 178 Street
Edmonton, Alberta T5S 1J3
(403) 483-2123
Telex 0372797

Halifax: 21 Gurholt Drive
Dartmouth, Nova Scotia B3B 1J8
(902) 469-9891
Telex 01921617

Montréal: 8505, chemin Devonshire, C.P. 1020
Montréal, Québec H3C 2X3
(514) 735-2621
Telex 012980

Ottawa: 2660 Southvale Crescent
Ottawa, Ontario K1B 4W5
(613) 731-0470
Telex 0533190

Québec: 2480, chemin Ste-Foy
Ste-Foy, Québec G1V 1T6
(418) 656-9962
Telex 0113439

Toronto: 184 Railside Road
Don Mills, Ontario M3A 1A9
(416) 445-2121
Telex 06966672

Vancouver: 196 W Third Avenue
Vancouver, British Columbia V5Y 1E9
(604) 872-7641
Telex 0453334

Winnipeg: 18 Plymouth Street
Winnipeg, Manitoba R2X 2V7
(204) 633-8880
Telex 0757298

2. Outlets in Canada for Canadian Laboratory Supplies (Canlab):

Halifax: S12—10 Morris Drive
Burnside Industrial Park
Dartmouth, Nova Scotia B3B 1K8
(902) 463-8270
Telex 01931504

Toronto: 80 Jutland Road
Toronto, Ontario, M8Z 2H4
(416) 252-5151
Telex 06219893

Winnipeg: 590 Moray Street
Winnipeg, Manitoba R3J 3V9
(204) 885-6606
Telex 07587631

Québec: S214—399, rue Morse
Ste-Foy, Quebec, G1N 4M3
(418) 688-8810

Montreal: 8655, chemin Delmeade
Town of Mount Royal,
Québec, Québec J4T 1M3
(514) 731-9651
Telex 05825862

Vancouver: 235-7080 River Road
Richmond, British Columbia V6X 1X5
(604) 237-7733
Telex 04355740

Edmonton: 14104-128A Avenue
Edmonton, Alberta T5L 4R7
(403) 453-3921
Telex 9373797

Ottawa: 2710 Lancaster Road
Ottawa, Ontario K1B 4T7
(613) 523-7440

3. Bendix, Environmental Science Division
1400 Taylor Avenue
Baltimore, MD 21204
(301) 825-5200

4. Beckman Instruments Inc.,
Helipot Division
901 Oxford Street
Toronto, Ontario M8Z 5T2
(416) 251-5251

5. Phys-Chemical Research Corp.
36 W 20th Street
New York, NY 10003
(212) 924-2070

6. General Eastern Corp.
36 Maple Street
Watertown, MA 02172
(617) 923-2386

7. Shaw hygrometers available from:
Pall (Canada) Ltd.
4880, rue Hickmore
St. Laurent, Québec H4T 1K7
(514) 735-5311
Telex 01-20474

8. EG & G available from:
Willer Engineering Ltd.
1800 Avenue Road
Toronto, Ontario M5M 3Z1
(416) 783-3373
Telex 0622151

9. Panametrics, Mast, Royco are available from:
Ralph E. Benner Ltd.
620 Supertest Road
Downsview, Ontario M3T 2M8
(416) 661-9400

10. Belfort Instrument Company
1600 S Clinton Street
Baltimore, MD 21224
Also available from:
Carleton Instruments Ltd.
2414 Holly Lane
Ottawa, Ontario K1V 7P1
(613) 731-4703
11. Serdex hygrothermographs are available from any Fisher Scientific outlet.
12. Honeywell Controls Ltd.
740 Ellesmere Road
Scarborough, Ontario M1P 2V9
(416) 293-8111 (Head Office)
(416) 491-1300 (Sales/Service)
13. Sigma Instruments (Canada) Ltd.
55 Six Point Road
Toronto, Ontario M8Z 2X3
(416) 239-8161
14. Powers Regulator Company Ltd.
2410 Holly Lane
Ottawa, Ontario K1V 2P1
(613) 733-9781
15. Aotek-Fritysching Inc.
1600 Dewey Avenue
Rochester, NY 14615
16. Cole-Parmer Instrument Company
7425 N Oak Park Avenue
Chicago, IL 60648
(312) 647-0272
17. Barnes Engineering available from:
Ahearn and Soper Ltd.
31 Enterprise Road
Rexdale, Ontario M9W 1C4
(416) 247-7141
18. Mikron available from:
Tubefit Ltd.
109 Eddystone Avenue
Downsview, Ontario
(416) 743-1661
19. Chauvin Arnoux
190 rue Championet
75018 Paris 18e, France
20. Gossen instruments are available from most photographic stores.
21. Tektronix Canada Ltd.
900, rue Selkirk
Pointe Claire, Québec H9R 3S3
(514) 697-9110 (Sales)
(514) 697-9103 (Service)
22. Gamma Scientific available from:
Technical Marketing Associates
3218 Wharton Way
Mississauga, Ontario L4X 2C1
(416) 625-7844
23. PBL/International Inc.
Box 108
Newburyport, MA 01950
(617) 462-8830
24. Optronic Laboratories Inc.
7676 Fenton Street
Silver Spring, MD 20910
(301) 587-2255
25. United Detector Technology Inc.
1732 30th Street
Santa Monica, CA 90404
(213) 396-3175
26. British Standards available from:
CSA (Canadian Standards Assn.)
320 Queen Street
Ottawa, Ontario K1K 1W9
(613) 235-1463
27. American Association of Textile Chemists and Colorists
Box 12215
Research Triangle Park, NC 27709
(919) 549-8141
28. Research Appliance Company products available from:
Hoskin Scientific Ltd.
1096, rue Victoria
St. Lambert, Québec J4R 1P2
(514) 672-1754
Telex 0525497
29. The Littlemore Scientific Engineering Company Ltd.
Railway Lane
Littlemore, Oxford 0X4 4PZ England
30. Comeau Technique Ltd.
S505—6550, rue Sherbrooke ouest
Montréal, Québec H4B 1N6
(514) 481-7515
31. Watrous and Company, Inc.
172 Euston Road
Garden City, NY 11530
(516) 746-1716

Relative Humidity and Temperature Report

INSTITUTION: Week:

Instrument(s) Used:

Date of Last Calibration:

Calibration Procedure:

Day	Time	Room	RH%	Temp. °C	Remarks

Continuous Records Included Yes ☐ No ☐

Comments on Records:

Exhibition Illumination Report

INSTITUTION:

EXHIBITION: Date:

A - Lighting Levels

Instrument(s) Used:

Location	Time	Type of Lighting (Filters)	Light Level (Units)	Recommended Level	UV-Component	Remarks

B - Surface Temperature

Instrument(s) Used:

Location	Time	Object Illuminated	Type of Lighting	Distance from Light Source	Surface Temp.	Remarks

— Notes —