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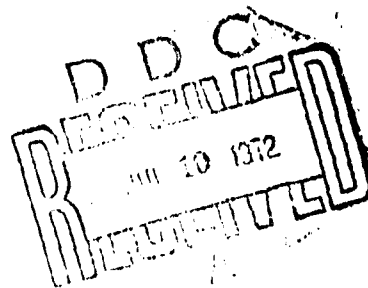
EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

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The Effect of Temperature and Relative Humidity on
the Accumulation of Electrostatic Charges on Fabrics
and Primary Explosives

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WALTHAM ABBEY
ESSEX



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by

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(Third Conference on Static Electrification, London,
May 1971, Paper 19)

FOREWORD

The generation and accumulation of electrostatic charges on explosive powders and fabrics constitutes a potential hazard situation, especially in the handling and manufacture of primary explosives. This paper reviews the relationship between relative humidity, temperature and the development of electrostatic charges and proposes standards of temperature and relative humidity appropriate for working with these materials.

February 1972

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The effect of temperature and relative humidity on the accumulation of electrostatic charges on fabrics and primary explosives

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Abstract. Measurements of the electrical resistance of six fabrics, and the electrostatic potential attained by three primary explosives on pouring at relative humidities of 20 to 80% and temperatures of 10 to 40 °C, have resulted in a series of relative humidity/temperature values which will give an adequate safety factor from the electrostatic point of view. For temperatures of 10, 15, 20, 25, 30, 35 and 40 °C respectively, the recommended minimum relative humidities are 76, 70, 65, 61, 57, 54 and 52%. These figures do not correspond to a constant vapour pressure of water.

1. Introduction

In the handling of primary explosives which are very sensitive to discharges of static electricity it is important to avoid hazardous potentials resulting from the friction and separation of surfaces. This can be done by providing an adequately low resistance path to earth, that is, by making as many items of equipment as possible, including the flooring and footwear of operators, of conductive or antistatic material. However since the leakage to earth often includes fairly high resistance paths through normally dry contacts and since some materials, for example, fabrics used for clothing and the primary explosives themselves are fairly resistant, it is specified that operations with these sensitive materials should also be carried out in an atmosphere of minimum relative humidity of 65%. This particular value was proposed as a result of observations presumably at an ambient temperature of 20 °C (A R Ubbelohde and W D E Thomas 1951, unpublished; Bulgin 1953). With most materials the surface leakage due to sorption of moisture is much more rapid at 65% and above than at a value of 55% or less. Other materials particularly hydrophobic ones, for example polythene show a less rapid rate at a higher humidity level.

It has been Ordnance Factory practice to fix a minimum of 65% and a maximum of 75% relative humidity to cover the whole temperature range, the minimum being required for antistatic precautions and the maximum to avoid too high a moisture content of the composition and to avoid discomfort to personnel. It was pointed out to us (E B Hancock, private communication) that the water content of the atmosphere varied considerably over the whole temperature range, that it was possible that some conditions now used were not entirely safe electrostatically, and that other conditions now considered unsuitable might be usable. At about the same time a request was received for advice on whether in very hot countries the ambient relative humidity of somewhat less than 65% was adequate.

Previous work on electrification of primary explosives (D B Scaife 1959, unpublished) had been carried out at various humidities but at only one temperature. In the textile field a considerable amount of work on the moisture regain as a function of humidity and temperature has been reported (Hearle and Peters 1960 p14). In addition the electrical resistance has been shown to be a measure of the moisture content under certain specified conditions (Hearle and Peters 1960 p126) and to be related to static electrification properties (Wilson 1963). There does not, however, appear to have been any direct study of the combined effects of humidity and temperature on electrostatic properties.

Thus two series of experiments were undertaken to see what effect these two variables exerted. The first investigation was into the changes of electrical resistance of a variety of fabrics and the second was the effect on the electrification of primary explosives as a result of pouring from one container to another. In this way it was hoped to determine the simultaneous effect of temperature and humidity on each process so that proposals could be made for humidity requirements at a specified temperature rather than continue to use the fixed figures for all temperatures.

2. Experimental

2.1. Temperature and humidity control

The resistance and electrification tests were carried out in a thermostatically controlled cabinet at temperatures ranging from 10 to 40°C. The relative humidity was maintained at the desired value by enclosing in the cabinet a large tray containing a saturated solution of one of a number of salts (Richardson and Malthus 1955, O'Brien 1948) to cover the range 20-80 % relative humidity.

For convenience the actual humidity at the time of each test was compared with that given by a hair hygrometer placed in the chamber, but since this type of hygrometer is of doubtful reliability, the observations were checked at frequent intervals against a whirling hygrometer and always after a change from a low to a high humidity or vice versa. It was found that the resistance values reached equilibrium after 2 to 4 h depending on the extent of the change from the previous working conditions. However after prolonged use there was some evidence of contamination from the spray of these solutions particularly on the insulated connections. Consequently in the work on the pouring of lead azide, where the material reached equilibrium in an hour or less, it was found more convenient to increase the humidity by the evaporation of the requisite quantity of water in the tray. For the work on the pouring of lead and barium styphnates, a longer period was required for equilibrium and the salt solutions were used again.

2.2. Resistance measurements on textile fabrics

The resistance measurements were made using a Vibron Model 33B vibrating reed electrometer, using an applied potential of 120 V from an ht battery. The electrodes consisted of brass strips 12 mm by 25 mm, one pair being used to suspend each sample from an earthed bar across the chamber. A similar pair of electrodes were clamped to the lower end of each sample by means of a spring clip, so that the effective dimensions of the sample were 76 mm by 25 mm. The insulated connection (coaxial screened cable) from the electrometer unit outside the cabinet was attached to each spring clip

electrode system in turn and the resistance measured. The humidity and/or temperature were then changed and after allowing time for the samples to reach equilibrium again, a further set of measurements were made.

2.3. Electrification on pouring of primary explosives

It was found earlier (D B Scaife 1959, unpublished) that for reasonable reproducibility, crystalline powders should be poured from a wide edged tray on to a similarly shaped receiver through a height of a few centimetres. In this way the majority of the particles leave the tray edge and do not fall off other particles. This process applies to a 275 mm wide tray up to about 0.5 g, that is, the charge attained per gram remains constant. With quantities greater than this a larger proportion of particles roll over each other as they leave the tray and the charge per gram value falls off. The pourer and receiver were originally made of brass which was cleaned chemically, but these were changed to a chromium plated surface which could be cleaned easily with acetone and water, thus avoiding the more vigorous treatment required for the brass. A further improvement in the apparatus was to make the pourer and receiver interchangeable and this is illustrated in figures 1 and 2.

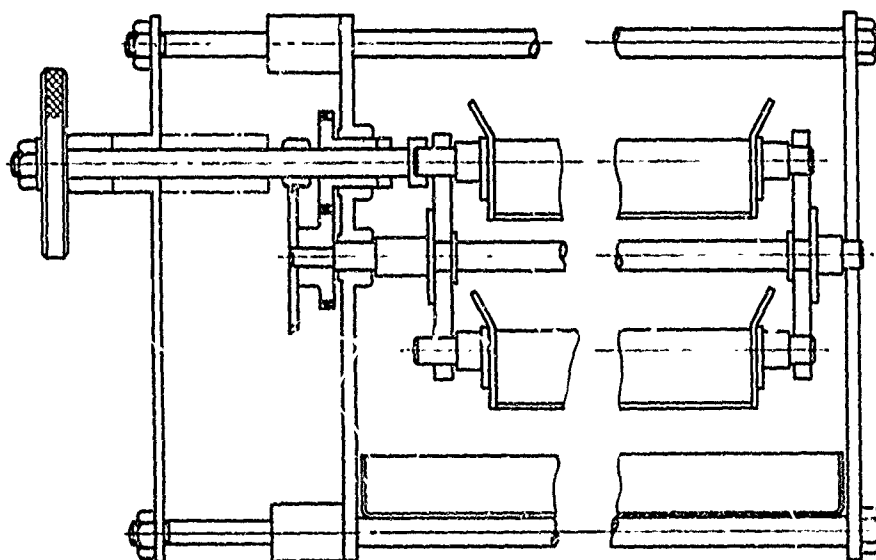


Figure 1. Pouring apparatus. Front view.

The trays were operated by means of a single control knob operating separate movements by means of dog clutches. In the first movement of the upper tray, the explosive was poured into the lower tray locked in a fixed position. Retracting the control knob engaged separate dogs which on rotation transposed the upper and lower trays without further pouring, ready for the next cycle. In this way the charge on pouring was measured without the superfluous intermediate pouring and consequent loss of material by scattering. The upper tray was earthed and the lower tray connected to the Lindemann electrometer by means of a spring contact and screened cable. Pouring particularly of the last traces of material was assisted by means of an air operated ball vibrator operating on the upper tray. As in the early work, 0.4 g of

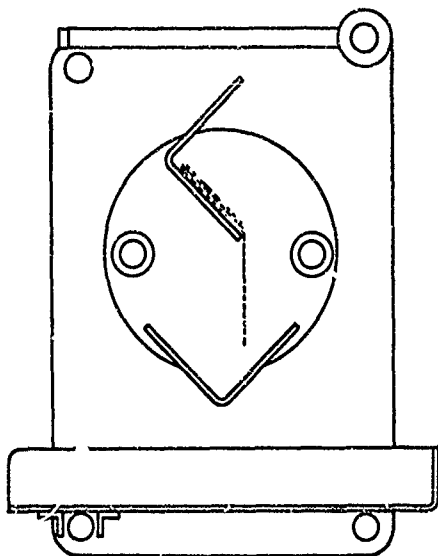


Figure 2. Pouring apparatus. End view.

explosive was used. The total capacitance of the apparatus and electrometer was 420 pF.

2.4. Bulk pouring of primary explosives

As pointed out in the previous section the method of pouring was selected to give the maximum charge for a given quantity of poured material, the charge generation process being mainly due to separation of the particles of primary explosive from the metal surface. In order to simulate more closely the operation of pouring under factory conditions a limited number of tests were carried out with 28 g of material poured from a heap on a polished stainless steel tray into an aluminium pot, diameter 76 mm and depth 65 mm. The dimensions of these vessels are similar to those used in a factory. The receiving pot was insulated and connected to a 1500 V electrostatic voltmeter (the Lindemann electrometer was too sensitive). The total capacitance of the system was estimated to be 50 pF. Barium styphnate was chosen as a relatively insensitive primary explosive for this phase of the tests in order to avoid undue hazards. It was not possible to carry out these tests under such closely controlled temperature and humidity as those described in the previous sections, because the cabinet was not suitable for the larger quantity of explosive. They were carried out in a room capable of being heated and humidified, the temperature and humidity being measured at the time of pouring.

3. Results

Resistances of six fabric, khaki serge, terylene, cotton drill, woollen flannel, viscose rayon and a Hypalon/nylon were measured. All were tested in the 'as received' condition except for the wool and cotton which had been washed. In most cases the values were obtained (i) at four temperatures, that is, 15, 20, 25 and 30 °C with an

extra determination at 40°C on cotton drill and viscose rayon and (ii) at five relative humidities ranging from about 20 to 80%.

When the logarithm of the resistance is plotted against the relative humidity for each material at a given temperature the usual linear relationship (Hearle and Peters 1960 p126) holds over the humidity range given above. Furthermore as the temperature is raised or lowered within the range 15 to 40°C, similar relationships are found giving a series of parallel lines, the resistance decreasing at a given humidity as the temperature is increased. Figures 3 and 4 show two typical sets of results for cotton drill and viscose rayon respectively.

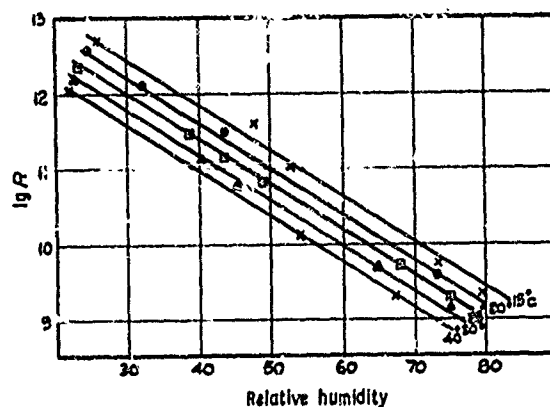


Figure 3. Variation of resistance of cotton drill with humidity and temperature.

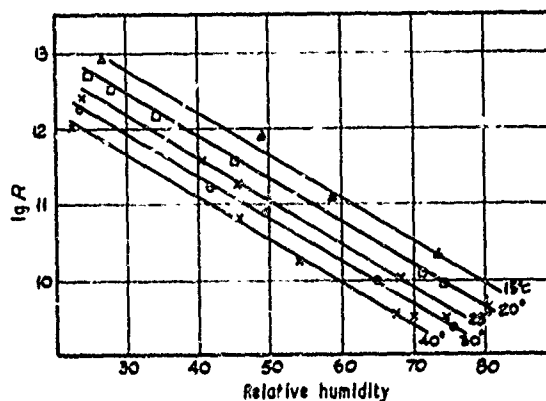


Figure 4. Variation of resistance of viscose rayon with humidity and temperature.

The pouring experiments gave the same type of results. When the potential observed on the Lindemann electrometer after pouring 0.4 g of either lead styphnate, lead azide or barium styphnate is plotted against the relative humidity at a fixed temperature, a straight line is obtained. Parallel lines are obtained for other temperatures. Figure 5 shows the results for lead styphnate. Similar results were found for lead azide and barium styphnate except that the voltages obtained at 65% relative humidity and 20°C were roughly one tenth and one third that for lead styphnate

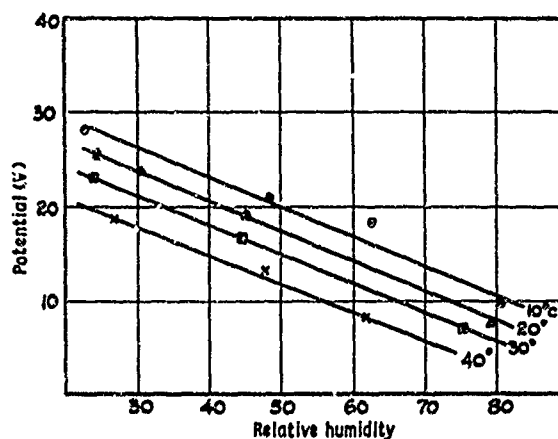


Figure 5. Variation of potential on pouring lead styphnate with humidity and temperature.

respectively. The line for lead azide at 10°C also tended to diverge from the other lines.

If we accept that a minimum relative humidity of 65% at a temperature of 20°C provides an adequate safety factor, then it can be deduced from these simple relationships what other combination of humidity and temperature will give the same fabric resistance or the same potential on pouring as obtained at the acceptable value of 65% and 20°C. As expected, the six textiles and the three explosives do not give quite the same results when compared in this way. Table 1 gives the appropriate value of the humidity for temperatures of 10, 15, 25, 30 and 40°C with the value of 65% at 20°C. These values have been plotted and when due consideration is given for weighting on the higher side on grounds of safety the recommended figures are shown in the last line.

It is interesting to note that the values for 'as received' Terylene which has the highest resistance of the six fabrics, fit in quite well with the others, being rather similar to those for wool. The results for the bulk pouring experiments with barium styphnate are shown in table 2.

It is noticeable that where the humidity was higher than the value recommended in

Table 1. Values of temperature and humidity for safe working

Material	Temperature (°C)						L.R. R, 65% relative humidity, 20°C
	10	15	20	25	30	40	
Cotton drill	—	68	65	61	58	54	10.1
Terylene	—	71	65	58	53	—	13.8
Hypalon/nylon	—	70	65	60	55	—	11.1
Khaki serge	—	70	65	59	56	—	11.1
Viscose rayon	—	70	65	61	57	52	10.4
Woollen flannel	—	71	65	59	52	—	12.0
Lead styphnate	72	—	65	—	57	46	—
Lead azide	72	—	65	—	56	49	—
Barium styphnate	—	—	65	—	58	49	—
Average value	72	70	65	60	56	50	—
Recommended value	76	70	65	61	57	52	—

Table 2. Potentials attained on pouring 28 g of barium styphnate

Temperature (°C)	Relative humidity	Potential (V)
13	65	250
15	60	200
21	44	200
27	36	300
28	36	300
24	75	< 50

table 1, that is the 75% value at 24°C, the observed potential was small. In all the other cases appreciable potentials were observed. Apart from this however, the values do not provide any useful information to add to the results of the controlled pourings because of (i) the limited range of humidity and temperature and (ii) the variable number of particles rolling over other particles as compared with those rolling off the metal surface.

4. Discussion

The relative humidity specification used up to now for the handling of primary explosives entails a minimum value of 65% irrespective of temperature. The term relative humidity is used because it is the most convenient way of expressing the amount of moisture in the air. The moisture content of the air however varies considerably with temperature, and if a constant value of 65% relative humidity is taken, the actual vapour pressure of water in the atmosphere will rise from approximately 6 mm at 10°C to approximately 37 mm at 40°C. It will be realized that though the recommended humidity/temperature values will correspond to different vapour pressures, they also will not be such as to give a constant vapour pressure over the whole temperature range. In fact the vapour pressure at a temperature of 10°C and 76% relative humidity is approximately 7 mm, and that at a temperature of 40°C and 52% relative humidity is approximately 29 mm. This noncorrespondence is hardly surprising since we are concerned with the surface properties of the fabric or explosive rather than the properties of the surrounding air, though these are obviously interrelated. The conductivity of moist air is very little different from that of dry air and electrostatic charges only leak away through moisture films adsorbed on the surfaces involved.

These results, particularly at temperatures above 20°C should be of considerable interest to anyone having to operate at these comparatively high humidities, as the attainment and maintenance of such humidities is not without difficulty unless one has a properly engineered installation. Furthermore at the higher temperatures the reduction in the required humidity will lessen the discomfort to personnel. It should be noted however that if the working conditions involve temperatures below 20°C then it is necessary to increase the humidity above 65%.

5. Acknowledgment

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