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The accuracy of London Weather Centre forecasts of temperature for the gas industry

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Summary

Routine forecasts of temperature are prepared several times daily by forecasters at London Weather Centre for British Gas. Verification of the accuracy of these forecasts shows them to be, on average, better than persistence. Mean errors are generally less than 2 °C and there is a tendency to underforecast night minima in autumn and winter and to overforecast day maxima in spring and summer. The May–June period appears to be a particularly difficult season for forecasting beyond 24 hours ahead.

1. Introduction

British Gas has a contract with the Meteorological Office for the provision of weather forecasts several times daily for a number of places around the United Kingdom. The most important element in the forecast is temperature because gas demand by industrial and domestic consumers is most sensitive to variations in temperature. The format and times of issue of the forecasts (called MET GAS forecasts) are essentially the same at all the issuing meteorological offices and this paper evaluates the accuracy of the temperature forecasts prepared by London Weather Centre (LWC).

The temperature forecasts prepared by LWC are for LWC itself in two-hour steps for periods ranging from up to 24 to 36 hours ahead. The forecasts are updated every four hours as routine but amendments may be issued at shorter intervals if significant changes are envisaged as a result of fresh ideas or information. In general a change of at least 2 °C to a forecast temperature necessitates an amendment or special advisory message.

The regions which receive the LWC forecasts are Eastern Gas, North Thames Gas and Southeast Gas. The most important forecast is the 1530 h issue (day 1) which covers the period up to 0500 h (day 3), i.e. approximately a 36-hour forecast. This particular forecast is used to assess gas demand for the 24-hour period commencing 0600 h (day 2) and the regions have to place their orders for gas with British Gas (central London) by 1630 h on day 1. British Gas, in turn, then order their gas from the offshore companies before 1800 h on the same day. (The symbol h indicates clock time.)

Gas demand is split between domestic and industrial consumers with the balance varying from region to region. Domestic demand has two peaks, 0700–1000 h and 1700–2300 h, and British Gas estimates that a change of 1 °C during these times can affect demand by some 2–3%. Exactly how these estimates are quantified is not known because it is certain that wind, both speed and direction, sunshine and rain also have some effect on demand except where the gas supply is entirely thermostatically controlled.

Although Gas regions attach great value to the temperature forecasts they also give a significant weighting to persistence. This is partly because there is a tendency for demand by the consumer to lag behind changes in the weather. For this reason orders for gas always take into account yesterday's and today's temperatures as well as the forecast for tomorrow. Public holidays create other problems in anticipating demand and there can be a good deal of subjectivity in predicting the demand for gas more than a few hours ahead.

Under most circumstances the Gas Controllers are grateful for any information or advice that the forecaster can give; for example, temperatures may vary across the region and LWC may not be representative in certain situations. It is important that when there is doubt in the forecast this should be communicated to the Controllers who can take precautionary action.

Because of the importance of temperature forecasts to the gas industry and the need to quantify the usefulness of the forecasts, a verification procedure is carried out at London Weather Centre, chiefly on the 1530 h daily issue. Additional verification data have been acquired from North Thames Gas which usefully supplements the LWC studies. Three years' data are considered in this report—1978–80.

2. Forecasting the temperature

Methods of predicting surface temperature are well documented in the *Handbook of weather forecasting*, Chapter 14 (Meteorological Office 1975) and also in the *Forecasters' reference book* (Meteorological Office 1970). Essentially, the prediction process takes place in three stages. Firstly the low-level air mass changes must be correctly predicted, including the moisture content; secondly the amount of medium and upper cloud must be evaluated, including the presence of precipitation; and thirdly the surface wind field must be adequately forecast.

Outstation forecasters in the Meteorological Office receive a good deal of direct assistance from the output of the operational 10-level numerical model as well as the surface prognoses and the General Synoptic Reviews issued by the Central Forecasting Office at Bracknell. For most of the period of this study the direct assistance consisted of analyses and forecasts of airflow at several levels in the troposphere. The 1000–500 mb total thickness fields were used to assess air mass changes and characteristics.

Since August 1980 direct numerical support to outstations has been extended to include 850 mb wet-bulb potential temperature and 700 mb relative humidity fields. The former are used to identify air mass changes and, by making use of Belasco's work (1952) on air masses, it is possible to relate the 850 mb data to surface temperatures. The 700 mb data are used to assess the likelihood of cloud and precipitation. As LWC also receives computer forecasts of surface wind (Morris 1981) to assist with forecasting for the offshore industry, these wind fields may be used in temperature prediction.

The period during which the extra computer guidance has been available is too short to assess separately as part of this particular study but the effects on the accuracy of temperature forecasts will be an interesting study in two years' time.

3. Verification of temperature forecasts

(a) *1530 h issue*

The 1978–80 period was divided into two-month seasons, January–February, March–April etc., i.e. for each season there were six complete calendar months. For each of the (approximately) 180 forecast temperature sequences in each season four quantities were noted or calculated:

(1) forecast temperature at each step, i.e. 1700, 1900, 2100 h, etc.,

(2) actual temperature at each step,

(3) modulus error of the forecast at each step, and

(4) modulus error of a persistence forecast at each step.

The persistence forecast was based upon the last recorded temperature for the appropriate time, e.g. for 1700 h on day 1 the forecast would be actual temperature at 1700 h on day −1, etc.

Values for each time-step were meaned over the four-month period.

The only purpose in comparing (1) and (2) is to see if any systematic errors show up in temperature prediction for inner London.

Table I demonstrates the mean systematic bias in the forecasts throughout the 36-hour period for each of the six 'seasons'. Most of the bias is negative, i.e. underforecasting of the LWC temperature, peaking at almost 2 °C at the end of the forecast period in the winter. On the other hand there is a clear tendency to overforecast the maximum temperatures on day 2 during the early and high summer. However, inspection of the figures for the forecast period as a whole and also the more important sections of the period shows clearly that the most significant bias is negative between September and the following February. The underforecasting at night is presumably due to the heat island effect which prevents inner London from cooling as much as it would otherwise do but for the high density of large buildings. The overforecasting of maximum day temperatures during the summer is more puzzling but it may be due to greater mixing of air on the LWC roof than otherwise allowed for, particularly as winds rarely fall below 5 knots.

Table II contains mean modulus forecast errors for the odd-numbered hours of the period and also an indication of performance compared with persistence forecasts. Mean forecast errors are below 2 °C except at the end of the period in the two winter seasons. Over the period as a whole and in most of the important sections the improvement over persistence is at least ½ °C. It is gratifying to see the relatively large improvements for the period 1700–2300 h on day 2.

Table III depicts year-to-year trends in mean modulus errors for the whole forecast period and comparisons with persistence. The errors are remarkably consistent from year to year although there is some suggestion that 1979 was the most difficult year.

Summing up, there appear to be two broad patterns of forecast error. Between September and February the largest errors occur in the prediction of night minimum temperature in the early hours of day 3 and there is evidence of a significant systematic component to these errors. Between March and August the largest errors occur in the prediction of the day 2 maximum of temperature and there is some (though less than in the winter period) evidence of a systematic component here too.

Counteracting the systematic error. An exercise has been carried out on all of the 1530 h forecasts prepared in 1980. The forecasts for the periods 0700–1000 h and 1700–2300 h (day 2) were amended by an amount equal and opposite to the systematic error in Table I. The effect upon the accuracy of the forecasts is shown in Table IV. There are some improvements in most seasons although amounts are not generally large.

(b) '*Average*' *temperature*

North Thames Gas Board (NTGB) calculate an 'average' temperature based upon the 24 hours commencing 0600 h on day 2. The actual temperatures, at two-hourly intervals throughout the period, are meaned to yield the 'average' temperature. Forecast values are meaned similarly and daily errors are calculated from sets of these two figures.

Table I. *Mean values* (3 *years*) *of mean* (*seasonal*) *forecast minus mean* (*seasonal*) *actual temperature* (°C) *at London Weather Centre for the period* 1978–80 *inclusive.*

	Time (hours)																					
	Day 1				Day 2												Day 3			Mean of whole period	Mean 07 (day 2)–05 (day 3)	Mean 07–10 day 2	Mean 17–23 day 2
Season	(17	19	21	23)	(01	03	05	07	09	11	13	15	17	19	21	23)	(01	03	05)				
Jan.–Feb.	−0·2	−0·2	−0·5	−0·8	−0·8	−1·0	−1·2	−1·1	−0·8	−0·6	−0·2	−0·4	−0·6	−0·8	−1·1	−1·4	−1·6	−1·7	−1·9	−0·9	−1·0	−0·9	−1·0
Mar.–Apr.	−0·2	−0·2	−0·2	−0·4	−0·7	−0·7	−0·7	−0·4	−0·4	0·0	0·2	0·3	0·0	0·0	0·0	−0·4	−0·7	−0·8	−0·8	−0·3	−0·3	−0·4	−0·1
May–June	0·2	0·1	0·1	−0·1	−0·2	−0·5	−0·7	−0·1	−0·1	0·3	0·9	0·9	0·5	0·2	0·2	−0·2	−0·6	−0·8	−1·0	0·0	0·0	−0·1	0·2
July–Aug.	0·3	0·2	0·1	−0·2	−0·5	−0·6	−0·8	−0·2	−0·2	−0·4	0·5	0·6	0·8	0·3	0·3	−0·3	−0·8	−1·2	−1·2	−0·2	−0·1	−0·2	0·3
Sept.–Oct	0·3	0·4	0·7	−0·4	−0·6	−0·8	−0·9	−0·8	−0·6	−0·5	−0·2	0·2	0·0	0·2	−0·7	−0·5	−0·9	−1·3	−1·5	−0·4	−0·6	−0·7	−0·3
Nov.–Dec.	0·0	−0·1	−0·4	−0·7	−0·9	−1·1	−1·3	−0·8	−0·8	−0·8	−0·1	0·0	0·0	−0·4	−0·7	−1·0	−1·3	−1·2	−1·3	−0·7	−0·7	−0·8	−0·5

Table II. *Mean modulus errors in forecast temperatures* (°C) *and associated improvement over corresponding persistence forecast temperatures for the period* 1978–80 *inclusive.*

		Time (hours)																					
		Day 1				Day 2												Day 3			Mean of whole period	Mean 07 (day 2)–05 (day 3)	Mean 07–10 day 2	Mean 17–23 day 2
		(17	19	21	23)	(01	03	05	07	09	11	13	15	17	19	21	23)	(01	03	05)				
Jan.–	A	0·6	0·8	1·0	1·2	1·3	1·4	1·5	1·5	1·6	1·4	1·5	1·5	1·5	1·6	1·8	1·9	2·0	2·0	2·4	1·5	1·7	1·5	1·7
Feb.	B	1·2	0·8	0·8	0·6	0·5	0·4	0·5	0·6	0·4	0·3	0·5	0·9	0·8	0·7	0·7	0·4	0·3	0·3	0·2	0·6	0·5	0·5	0·7
Mar.–	A	0·6	0·8	1·0	1·0	1·1	1·2	1·2	1·4	1·4	1·6	1·8	1·9	1·9	1·5	1·7	1·5	1·5	1·6	1·6	1·4	1·6	1·4	1·7
Apr.	B	1·7	1·2	1·0	1·0	0·6	0·6	0·7	0·5	0·3	0·3	0·3	0·4	0·9	1·2	1·0	1·1	1·0	0·7	0·6	0·8	0·7	0·4	1·1
May–	A	0·7	1·1	1·2	1·2	1·1	1·2	1·2	1·1	1·2	1·7	1·9	2·1	1·9	1·9	1·7	1·5	1·6	1·5	1·6	1·4	1·6	1·1	1·7
June	B	1·5	1·0	0·8	0·5	0·5	0·4	0·3	0·3	0·2	0·3	0·6	0·6	1·3	1·1	0·8	0·7	0·7	0·8	0·4	0·7	0·8	0·3	1·0
July–	A	1·0	1·0	1·1	1·0	1·1	1·0	1·1	1·0	1·1	1·4	1·7	1·8	1·9	1·7	1·4	1·3	1·3	1·4	1·5	1·3	1·5	1·1	1·6
Aug.	B	1·4	0·9	0·6	0·3	0·3	0·3	0·3	0·4	0·3	0·2	0·3	0·5	1·2	1·0	0·7	0·6	0·4	0·2	0·2	0·5	0·5	0·3	0·9
Sept.–	A	0·7	0·7	0·9	1·0	1·2	1·2	1·3	1·3	1·3	1·4	1·4	1·5	1·5	1·4	1·4	1·5	1·6	1·8	1·9	1·3	1·5	1·3	1·5
Oct.	B	1·0	0·7	0·6	0·5	0·4	0·5	0·7	0·8	0·5	0·3	0·1	0·2	0·8	0·6	0·6	0·6	0·5	0·5	0·6	0·5	0·5	0·7	0·7
Nov.–	A	0·6	0·7	1·0	1·3	1·4	1·5	1·5	1·5	1·5	1·5	1·3	1·4	1·4	1·6	1·7	1·9	2·0	2·2	2·4	1·5	1·7	1·5	1·7
Dec.	B	1·4	1·3	1·1	0·7	0·7	0·6	0·7	0·7	0·8	0·7	1·0	0·7	1·1	1·1	1·0	0·5	0·4	0·2	0·3	0·7	0·7	0·7	0·9

A—Mean forecast error
B—Mean improvement over persistence forecasts

Table III. *Trend in mean modulus forecast and persistence errors* (°C) *over the three years* 1978–80.

Season		1978	1979	1980
January–February	F	1·4	1·5	1·5
	P	2·0	2·2	2·0
March–April	F	1·3	1·6	1·3
	P	2·2	2·4	2·0
May–June	F	1·6	1·5	1·4
	P	2·2	2·2	2·0
July–August	F	1·3	1·3	1·3
	P	1·6	1·9	2·0
September–October	F	1·3	1·4	1·2
	P	1·9	1·9	1·8
November–December	F	1·4	1·5	1·5
	P	2·1	2·3	2·4

F—Forecast error
P—Persistence error

Table IV. *Mean modulus forecast temperature errors* (°C) *for* 1980. *Modified forecasts include effects of countering systematic errors* (1978–80).

	07–10 h		17–23 h	
Season	Original	Modified	Original	Modified
January–February	1·5	1·3	1·8	1·5
March–April	1·3	1·1	1·6	1·5
May–June	0·9	0·8	1·9	1·9
July–August	1·1	1·1	1·5	1·3
September–October	1·1	1·1	1·4	1·3
November–December	1·6	1·3	1·5	1·4

Daily errors in forecasts of 'average' temperature have been supplied by NTGB to LWC for the period April 1978 to December 1980. Five forecast issues are considered: 1530 h on day 1, 0001 h, 0800 h and 1530 h on day 2, and 0001 h on day 3. The forecast 'average' temperature calculated using the 0800 h day 2 issue, 1530 h day 2 etc., onwards, included an increasing number of actual temperatures. Thus the 1530 h day 2 forecast included some 10 hours of actual temperature and only 14 hours of forecast temperature, whilst the 0001 h day 3 'forecast' included some 18 hours of actual temperature and only 6 hours of forecast temperature.

Table V contains the mean modulus errors in forecast average temperature for each forecast issue, averaged over each two-month season.

Mean errors are well below 2 °C in all seasons but the May–June period is highlighted as a difficult forecasting season. The first three forecast issues in Table V may be regarded as genuine forecasts whereas the last two forecasts contain an increasingly large element of observed temperatures.

Table VI reveals on how many occasions the 'forecast average temperature' errors reached 3 °C or more in each of the three years.

There appears to be a distinct reduction in the number of large errors between the 1530 h and 0001 h issues. The most important new factor to cause a revision of the temperature forecasts during that period must be the availability of forecast wind, humidity and temperature fields based upon 1200 GMT analysed data.

Table V. *Mean modulus errors in average temperature forecasts* 1978–80 (°C).

	Season					
Time of issue	Jan.–Feb.	Mar.–Apr.	May–June	July–Aug.	Sept.–Oct.	Nov.–Dec.
1530 h day 1	1·6	1·3	1·5	1·0	1·1	1·4
0001 h day 2	1·2	1·1	1·3	1·0	1·0	1·2
0800 h day 2	0·8	0·7	1·0	0·8	0·7	0·8
1530 h day 2	0·5	0·5	0·5	0·4	0·5	0·6
0001 h day 3	0·2	0·2	0·1	0·1	0·2	0·1

Table VI. *Number of occasions when forecast average temperature errors were greater than or equal to* 3 °C *in the period* 1978–80.

	Season																	
	Jan.–Feb.			Mar.–Apr.			May–June			July–Aug.			Sept.–Oct.			Nov.–Dec.		
Time of issue	78	79	80	78	79	80	78	79	80	78	79	80	78	79	80	78	79	80
1530 h day 1	—	8	9	—	6	2	10	4	4	0	2	1	3	5	2	8	4	5
0001 h day 2	—	3	2	—	3	2	5	3	2	3	1	0	0	4	0	6	2	4
0800 h day 2	—	0	1	—	1	0	1	2	0	3	0	0	0	1	0	0	0	1
1530 h day 2	—	0	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0001 h day 3	—	0	0	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0

A study of the major errors (i.e. $\geqslant$3 °C) in forecast average temperature revealed that most could be ascribed to three factors:

(1) Errors in timing and general speed of transition from one air mass to another. In these cases a measure of uncertainty in the forecast would usually be commented on to the Gas Controller.

(2) Systematic errors peculiar to London as demonstrated in Table I.

(3) Errors in the predicted rate of cooling or warming between the maximum and minimum, or minimum and maximum, temperature despite often quite accurate predictions of the extremes. It appears that the rate of change of temperature often approximates to a straight line rather than to a curve, which leads to inaccuracies in several forecast temperatures during these periods of normal temperature changes.

(c) *Conclusions*

(1) Temperature forecasts for inner London issued at 1530 h for up to 36 hours ahead are, on average, demonstrably better than persistence. Mean forecast errors are generally less than 2 °C. Part of the

forecast error appears to be systematic with underforecasting of night minima in autumn and winter and overforecasting of day maxima in spring and summer.

(2) The May–June period appears to be a particularly difficult season for prediction of temperature for periods of 24 hours and longer ahead.

(3) There is a substantial reduction in the number of large errors (⩾3 °C) between the 1530 h (day 1) and 0001 h (day 2) forecast issues in most seasons. However, at what stage after 1530 h this improvement becomes significant is not known. Further research is required to establish this important point.

(4) It is also necessary to establish the impact of weather variables other than temperature upon gas demand.

Acknowledgements

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Weather and the spoon-gassing of rabbits

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Summary

One of the main methods of rabbit control is 'spoon-gassing', involving the transfer of a cyanogenetic powder by spoon to the rabbit burrow which is then sealed. The period of transfer to the burrow is hazardous to the operator in wet or windy conditions (MAFF 1978b). The paper briefly reviews the problems caused by a large rabbit population and assesses the time available for the gassing operation to be carried out safely.

1. Introduction

The European rabbit (*Oryctolagus cuniculus*) was introduced into England during the eleventh or twelfth century and for many years was highly valued as a source of fresh meat and fur by lords of the manor, and poaching by villagers was severely punished. Farmers, however, became increasingly aware that its destructiveness to crops of all kinds far outweighed the value of its carcass and by the mid-nineteenth century the rabbit was recognized as the most destructive vertebrate pest of agriculture (MAFF 1978a).

The virus disease myxomatosis first spread to Britain from France in 1953 and over the next two years it killed 99% of the rabbit population. Less virulent strains of the myxoma virus have since predominated and during the past 15 to 20 years the rabbit population has increased (Ross 1972).

Mature rabbits (weighing up to 2 kg) may eat up to 0·5 kg of green food over an 8-hour nocturnal grazing period (forests and orchards are also at risk through 'ring barking' and the eating of seedlings). Close inspection of retarded cereal crops and grassland in spring will often reveal that rabbit-grazing is to blame. Plate I shows clearly the contrast between a 'protected' control area of winter cereals in an early stage of growth and the rest of the rabbit-grazed field. Rabbits prefer to live where there is harbourage, e.g. woodland, scrub and rough areas, in close proximity to neighbouring pasture, cereals, etc. (MAFF 1978a). A suitable harbourage is seen in the background in Plate I.

2. Control

Control programs are planned for the November to March period when herbage has died back (allowing large infestations to be located easily) and before young litters are produced. Although trapping, shooting, ferreting, netting, snaring, fencing and dazzling are used on a small scale (producing saleable carcasses!), gassing is considered the most humane and efficient control measure (MAFF 1978a). The method involves driving underground as many rabbits lying out as possible and injecting a sufficient quantity of fumigant (in the form of powdered cyanide compounds) into the warren. In contact with moist air the powder evolves a poisonous gas from which death is rapid. Several methods of administering the powder are currently in use:

* Ministry of Agriculture, Fisheries and Food.

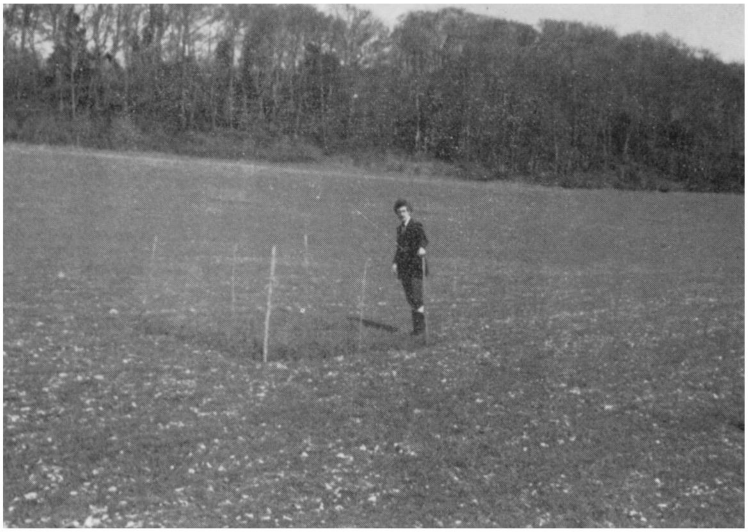

Plate I. Showing the contrast between a 'protected' control area of winter cereals in an early stage of growth and the rest of the rabbit-grazed field.

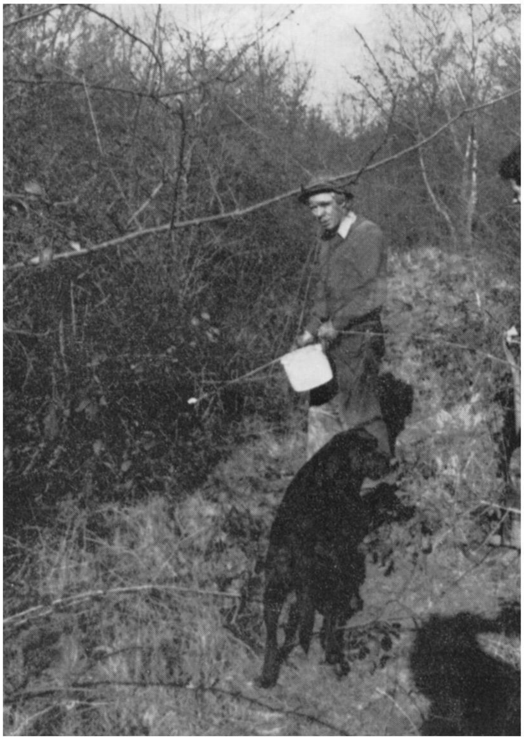

Plate II. Spoon-gassing of rabbits. The operator spoons the poison into the burrow entrance.

(a) Power gassing—whereby the powder is blown into the burrow system by a powered fan. A method suitable for large, well-populated warrens with many holes.

(b) Hand-operated pumps—for smaller warrens.

A moderate airflow is necessary in both (a) and (b) to ensure an even distribution of gas throughout the burrow system; both methods are 'labour intensive', requiring two or three people.

(c) Spoon-gassing—particularly suited to small infestations. It is widely used amongst farmers and professional operators. A small quantity of powder is spooned into the burrow entrance (Plate II) which is then sealed. The concentration of poisonous gas builds up and kills rabbits which attempt to dig out of the burrow.

3. Assessment of the time available for spoon-gassing

Limitations imposed by the weather will vary according to the field situation; control carried out in open fields and exposed hedgerows is likely to be more weather sensitive than similar work being carried out within a woodland.

The Worplesdon Laboratory is currently assessing the effectiveness of spoon-gassing in three study areas represented by the meteorological sites at Honington, Cardington and Boscombe Down, the selection being limited to those stations with at least eight years of hourly observations. Analysis was restricted to the daylight hours over the control period October to April in studies (3.1 to 3.4) relating to the surroundings in which the gassing was to be carried out.

3.1 *The potential number of (daylight) working hours in an area of open ground*

This study gives the maximum possible number of hours available to an operator concentrating solely on spoon-gassing and who is prepared to work every hour if the weather conditions are suitable.

Work would not proceed during wet or windy weather, where wet weather is defined to be any hour when rain has fallen or when snow is lying on the ground. Elementary studies in outdoor conditions indicated that wind speeds of about 10 kn at 0·5 m (the working level) could blow powder from the spoon. To allow for an adequate safety margin (and taking into account work on relationships between mean wind speed and gusts reported by Hardman *et al.* (1973)) mean wind speeds less than or equal to 8 and 12 kn at 10 m (roughly 5 and 7 kn at 0·5 m) were taken as 'ideal' and 'practical' working conditions respectively. The 8 kn limit would permit an operator to use heaped spoonfuls with little risk from inhalation while the 12 kn limit represented a 'practical' limit for the seasoned operator, prepared perhaps to shelter the heaped spoon with his body.

The criteria for a potential gassing hour were taken to be:

(a) no precipitation,

(b) no snow or melting snow lying (state of ground code 5–9 inclusive), and

(c) mean hourly wind speed at 10 m $\leqslant 8$ or $\leqslant 12$ kn.

An hourly frequency program was run for daylight hours during the months October to April for Boscombe Down (1969–78), Honington (1969–78) and Cardington (1971–78) to extract the hours when these criteria were satisfied. Hourly reports of 'state of ground' were not available (the total error introduced by omitting this criterion anyway are estimated at only 3% at Boscombe Down; however, since most snow fell during a few months in 1969–71 and in 1978, larger errors for these months may occur). Approximately one-third of hours limited by state of ground were also limited by virtue of the wind and precipitation criteria. It was finally decided to allow for hours intermediate to the synoptic hours (00, 03 . . . . 21) by assuming that state of ground unsuitable on two consecutive hours was also unsuitable during intermediate hours and that unsuitable ground conditions at only one synoptic hour were unsuitable for one hour either side of that hour.

Day length was calculated from times of sunrise and sunset; hourly observations occurring just before sunrise or just after sunset were included in the analysis.

The potential time available at each station is shown in Figs 1, 2 and 3.

3.2 *The number of half-day periods suitable for gassing along a woodland periphery available to an operator who uses local weather forecasts*

The majority of operators contemplating spoon-gassing are unlikely to start work unless they are confident of several hours of good 'gassing-weather'. This study concerns those operators who contact their local forecasting office each day to find out whether or not the weather will be conducive to work for part or all of that day. The method supposes that three consecutive hours with 'appropriate' gassing criteria satisfied during the morning or afternoon would enable the operator to get out and do the job and that each occasion would have been correctly forecast. The hour 1200–1300 GMT has been designated a lunch break and is not included.

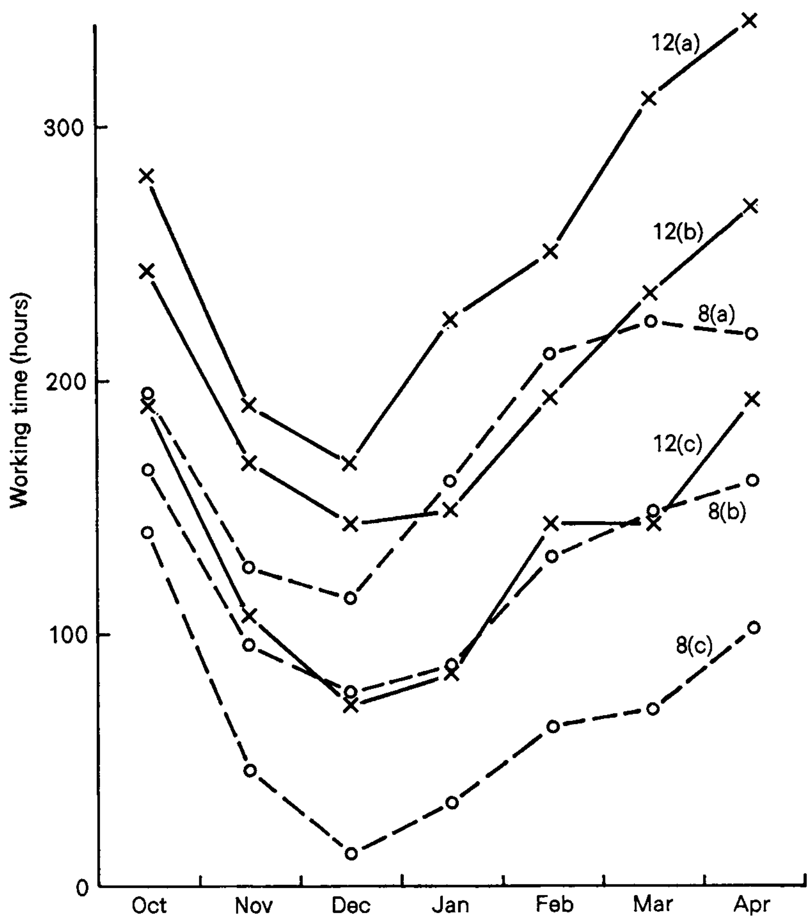

Figure 1. Potential number of daylight hours during the month when spoon-gassing in an area of open ground was possible at Cardington, 1971–78. 8 and 12 denote critical wind speeds; (a), (b) and (c) denote maximum, mean and minimum working times.

Wind is less restrictive than in case 3.1 and the wind criterion was modified to allow for shelter by the hedgerow such that a critical wind speed of 16 kn at 10 m (approximately 10 kn at 0·5 m) represents acceptable working conditions; a 20 kn wind at 10 m (approximately 12 kn at 0·5 m) is perhaps more appropriate to the operator willing to accept some degree of risk in order to get the job finished.

A half work-day is defined as three consecutive hours during the morning or afternoon with:

(a) no precipitation,

(b) no snow or melting snow lying on the ground (the assumptions used in study 3.1 for intermediate hours still hold), and

(c) mean hourly wind speed at 10 m $\leqslant$16 or $\leqslant$20 kn.

Hourly data for Cardington were extracted (daylight hours) for 1971–78 to determine the number of half-day periods suitable for gassing and these are presented in Fig. 4.

An intensive gassing program at a particular site would often last for only a couple of weeks, so each month was sub-divided into two to enable the most favourable two-week period for gassing to be established within the limited sample of years studied. As the data were analysed manually the average day lengths (rounded up to the nearest hour) for each month were used (see Table I).

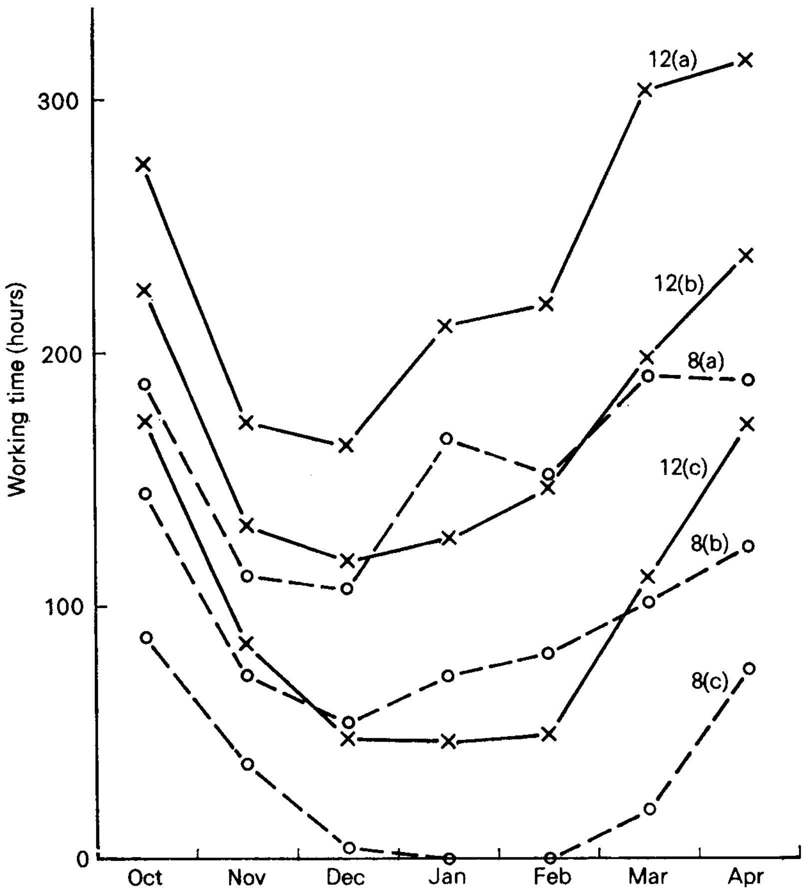

Figure 2. Potential number of daylight hours during the month when spoon-gassing in an area of open ground was possible at Honington, October 1969–December 1978. 8 and 12 denote critical wind speeds; (a), (b) and (c) denote maximum, mean and minimum working times.

Table I. *Average day lengths and the total number of daylight hours each month at Cardington.*

	GMT	Total daylight hours
October	0700–1700	310
November	0800–1600	240
December	0900–1600	217
January	0900–1600	217
February	0800–1700	252
March	0700–1800	341
April	0600–1900	390

3.3 *The number of half-day periods when a start to spoon-gassing along a woodland periphery might be made by an operator who does not use local weather forecasts*

This study relates to those operators who tend to take little more than a passing interest in weather forecasts and plan their work based on their own subjective decision on whether to work or not, depending on the weather situation first thing in the morning and straight after lunch.

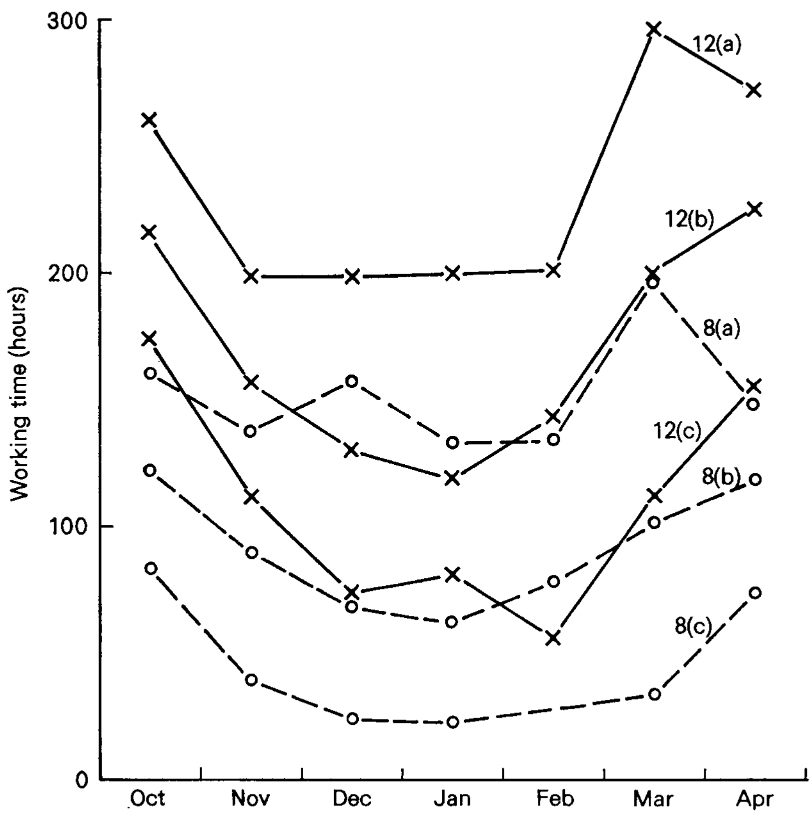

Figure 3. Potential number of daylight hours during the month when spoon-gassing in an area of open ground was possible at Boscombe Down, 1969–78. 8 and 12 denote critical wind speeds; (a), (b) and (c) denote maximum, mean and minimum working times.

Hourly data for 0800 GMT (0900 GMT in December and January) and 1300 GMT were extracted for Cardington; acceptable conditions for a start to work at either of these hours were taken to be defined by the criteria of case 3.2. The results are given in Fig. 5.

3.4 *The potential number of (daylight) working hours within a dense woodland*

Large rabbit infestations may be found in dense harbourage, where the tree canopy may significantly reduce the free wind flow and afford some shelter from precipitation.

Hours suitable for spoon-gassing are suggested to be those with:

(a) precipitation ⩽1 mm,
(b) mean 10 m wind speed ⩽30 kn, and
(c) no state-of-ground limitation.

An hourly frequency program employing these criteria was run for the daylight hours (calculated from times of sunrise and sunset) during October to April for Cardington, 1971–78 and the results are shown in Fig. 6.

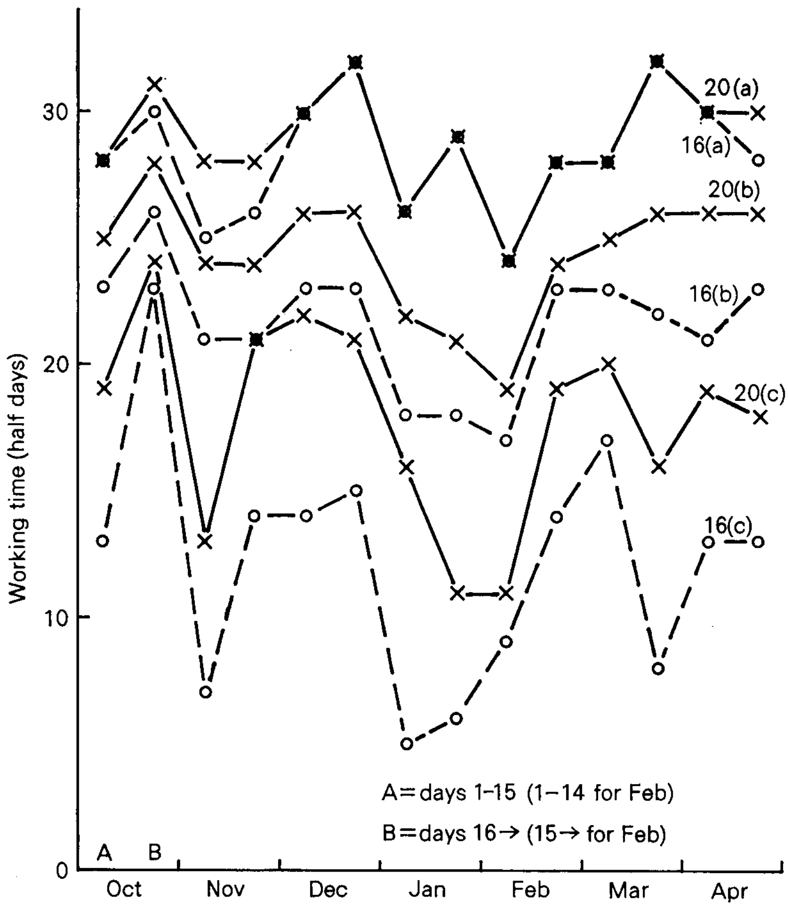

Figure 4. Number of half work-days (during daylight hours) when spoon-gassing was possible along a woodland periphery at Cardington, 1971–78, for the operator who obtains local weather forecasts. 16 and 20 denote critical wind speeds; (a), (b) and (c) denote maximum, mean and minimum working times.

4. Discussion

Over relatively open ground, Cardington has potentially the most time available for gassing owing possibly to the more frequent rainfall at Boscombe Down and comparatively more severe winters at Honington (with many days of snow cover). Ideal conditions (10 m wind ⩽8 kn) prevailed for approximately 40–50% of the daylight hours at Cardington depending upon the month, while at Honington only 30% of the time was suitable for work. Under less stringent criteria (wind ⩽12 kn) 50–80% of the time was suitable for gassing. October and April are consistently the best months with relatively high mean values and a small range while December and January are less reliable. These figures were derived for well-exposed sites and may vary appreciably from site to site depending upon the influence of local topography on wind and rainfall regimes. It is of course a theoretical consideration and the time available to the operator who is not prepared to work every hour possible is probably much less.

Along a woodland periphery regularly over 20 half-days (mornings or afternoons) per fortnight provided good gassing weather (mean value) indicating that the weather is unlikely to be a problem. The second half of October, all December and mid-February to mid-March seem to be the most favourable periods while the first two weeks in November and January to mid-February are less so.

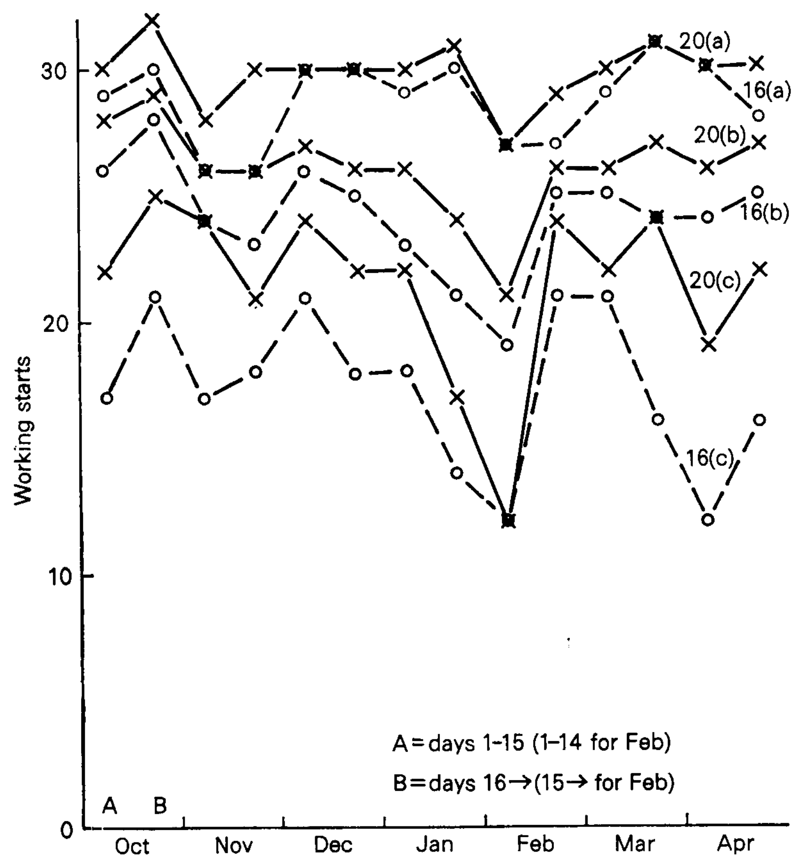

Figure 5. Number of work starts (during daylight hours) for spoon-gassing along a woodland periphery at Cardington, 1971–78, by the operator who does not use local weather forecasts. 16 and 20 denote critical wind speeds; (a), (b) and (c) denote maximum, mean and minimum working hours.

Comparison of Figs 4 and 5 might suggest superficially that the operator who takes meteorological advice achieves less work than the operator who relies simply upon his own assessment of whether conditions are suitable for a start to work. In the latter case, however, many of the work periods have to be abandoned fairly soon because of deteriorating weather so that in fact the operator achieves fewer uninterrupted work periods than shown in Fig. 4. In January, for example, approximately 1 in 5 of the starts to work at Cardington had to be abandoned on average, with as many as three-quarters being false starts in one particular year. One must suspect also that the operator is at greater risk during these circumstances owing to some inclination to continue with the job in hand regardless of the weather.

The potential time available within a dense woodland is over 90% of the maximum possible in all months at Cardington, assuming that the tree canopy greatly reduces the effects of the weather. This figure will alter slightly from place to place, coniferous trees affording more protection from strong winds and falling precipitation than deciduous trees during the winter months (although an intricate network of leafless branches offers some shelter).

5. Conclusions

Although taken over a short period (8–9 years) the results clearly indicate that gassing carried out within, or bordering, a woodland, where most control programs will be based, is unlikely to be greatly restricted except, perhaps, in severe winters such as 1968–69 and 1978–79.

One would suggest that the findings of this study could be applied to inland areas of south-east, central southern and eastern England where wind and rainfall regimes are likely to be similar to the

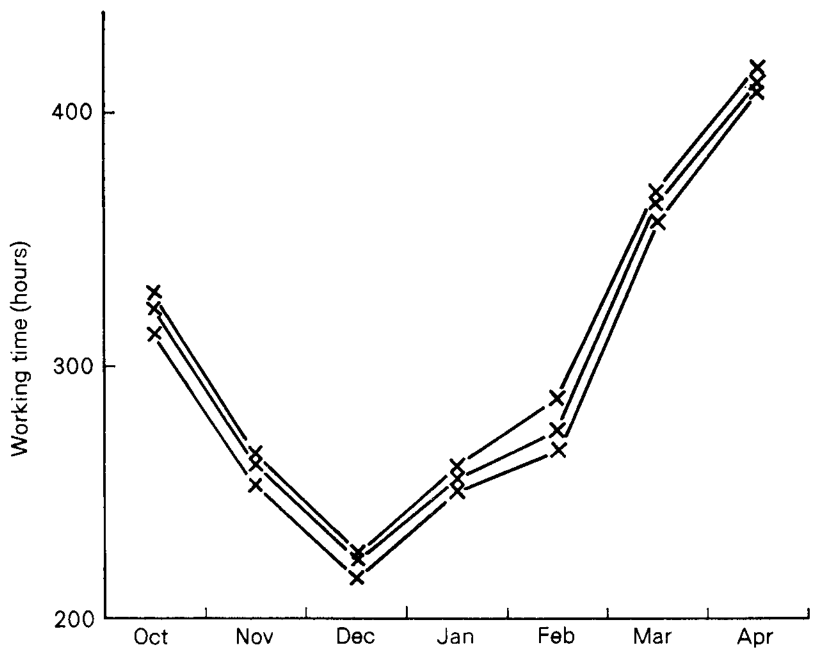

Figure 6. Potential number of daylight hours during the month when spoon-gassing in an area of woodland was possible at Cardington, 1971–78. Critical wind speed is 30 kn; maximum, mean and minimum working times are shown.

sites considered here. In most other parts of the country rabbit control using this technique could be more limited by the weather.

(It is emphasized that this work only considered the effects of the weather on the time available to carry out spoon-gassing and makes no attempt to comment on the effectiveness of spoon-gassing as a control technique once the powder has been placed in the burrows.)

Acknowledgements

We should like to thank Mr P. Butt, Agricultural Development and Advisory Service (ADAS), Oxford, and Mr P. E. Sayers, ADAS, Reading, for providing much of the background information. Thanks also go to Dr J. Starr and Mrs S. Morris from this office for their many useful contributions and to the computing division of the Agricultural Meteorology Section (Met O 8a), Bracknell, for providing the computer analyses. We are indebted to ICI Chemicals Ltd for providing a sample of the base compound of the gassing powder (magnesium sulphate).

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BBC Television weather forecasts—audience research results

By R. D. Hunt

(Meteorological Office, Bracknell)

Summary

Early in 1981, the BBC Broadcasting Research Section carried out a survey of audience reaction to the BBC 1 weather forecasts. The results, some of which are summarized in this note, reveal the importance of the television forecasts to the viewers and the high regard in which the service is held by those taking part in the survey.

The BBC has recently published the results of a study carried out by the BBC Broadcasting Research Section on audience reaction to the weather forecasts broadcast on BBC 1. The results, which are based on a sample of 945 members of the Viewing Panel, provide a very favourable comment on the service provided by the Meteorological Office to BBC Television. The main findings of the survey are summarized below.

Of those asked, 92% thought that weather forecasts are at least quite an important service for BBC Television to provide; most thought that they are very important. When asked to mark their overall attitude to them on a five-point scale ranging from 'very well worth hearing' (A) to 'not worth hearing at all' (E), 42% of the sample gave an A marking compared to a negligible 1% who responded with an E. The general level of satisfaction is even better demonstrated by the 80% who gave an A or B mark, compared to the 3% whose response was D or E.

The viewers, 90% of whom watched the forecasts out of general interest as opposed to professional interest (4%), were asked to state the importance of various types of weather information to them; the response is given in full in Table I. Note that the list includes 'road conditions' which, of course, are not part of the weather information as such and are only explicitly mentioned in the forecasts if ice is expected to form on roads. Nevertheless, the replies under that heading demonstrate that some of the most important users of forecasts are those intending to travel by road. Noting the importance of frost forecasts, one can perhaps deduce that gardeners are another important group. It is of interest to see that far more people want to know whether they will feel warm or cold than want to know the forecast temperature.

Table I. *Relative importance of types of weather information to members of the Viewing Panel.*

Information	Very important %	Quite important %	Not very important %	Not at all important %
Frost or not	41	35	18	6
Road conditions	39	36	17	8
Wet or dry	33	46	16	5
Foggy or clear	30	39	23	8
Feeling warm or cold	24	48	23	5
Actual temperature	14	36	40	10
Wind strength	14	31	40	15
Humidity	7	24	44	25

The popularity of the weatherman (or, more accurately, weather person) was revealed by the fact that 70% of the sample preferred seeing a weatherman with a chart, compared to only 9% who preferred a brief script being read by a BBC announcer over the display of a caption chart. Of the 70% who preferred the person in vision over half wanted to see a weatherman after both main news bulletins every day of the week—at the time of the survey there was only one live weather broadcast on Saturday and Sunday evenings. In fact, since these results were published, a weatherman slot has been installed in the peak viewing period after the late Saturday evening news on BBC 1.

Other questions in the research paper concerned technical aspects of the weather forecast. Generally speaking, there was a reasonable degree of understanding of the weather charts claimed by the sample, with about half of those questioned 'completely understanding isobars and fronts'. A further third claimed a partial understanding of isobars and fronts, leaving only a small number who were left completely nonplussed by the Atlantic chart; a stubborn 2% saw no reason to understand in any case.

As would have been expected, the large majority of the audience found the satellite pictures displayed at least sometimes helpful with only 18% finding them confusing or unnecessary. Bearing in mind the rather poor quality of the pictures sometimes shown this result is encouraging. The standard of pictures should improve in the months to come, with a new facsimile machine to be installed in the weatherman's office at the BBC Television Centre, and with Meteosat 2 working satisfactorily.

Table II gives the response to a question which is of particular interest to the Meteorological Office at present. Since the end of 1979, when BBC Midlands began taking a service of live forecasts once daily using staff from the Nottingham Weather Centre, many BBC regions have expressed an interest in a more detailed regional forecast than the brief script most of them were receiving from their nearest forecast office; in many cases they have considered a similar live weatherman slot, usually in the regional 'opt-out' time at 1800 on BBC 1. BBC South and BBC West have already taken such a service (as indeed have ATV). Clearly the vast majority of those questioned in the survey wanted to see a mixture of regional and national forecasts. The system of providing detailed regional forecasts by a Meteorological Office forecaster following the national weatherman's presentation after the Early Evening News on BBC 1 seems to be the most satisfactory way of meeting this demand.

Table II. '*Would you like to see only a national forecast, only a forecast for your own region, or a mixture of both?*'

National forecast only	13%
Regional forecast only	9%
Mixture of both	78%

One question related to a topic which has been under discussion for many years, within both the Office and the BBC, is of particular interest. Of those asked, 73% thought that the forecasts were of the right length; 22% would prefer them to be longer. No specific mention was made in the question to the fact that the various routine forecasts are of different lengths, ranging from 45 seconds in the early evening to about 3 minutes in some lunch-time forecasts. Nevertheless, generally speaking the sample was obviously not unhappy with the amount of time given to weather forecasts. On the other hand, in answer to the question 'Do you think that the right amount of time is spent on past weather and future weather?', 9% wanted more past weather and 42% wanted more future weather. It is not clear whether these 51% wanted the extra information within the current time limits.

Two other topics raised in the questionnaire are worthy of mention. Firstly, 79% of the sample realized that the weathermen were members of the Meteorological Office staff, 19% thought that they were BBC staff, while an undiscerning 2% thought that they were fully fledged actors.

The other interesting topic concerns the long-running Centigrade/Fahrenheit issue. Thirty-one per cent indicated that it made no difference to them whether temperature was given in degrees Centigrade or degrees Fahrenheit. Fahrenheit was preferred by 49%, while only 20% preferred Centigrade. This continuing preference for the Fahrenheit scale almost certainly reflects a resistance to changing from well-known units, particularly in an area which impinges on the lives of most people for only a few seconds each day. But perhaps credit can be given to the public for appreciating that the Fahrenheit scale is better suited to the range of temperatures usually quoted in a UK weather forecast than is the Centigrade scale. The weatherman frequently refers to 'temperatures in the seventies' rather than 'temperatures between 21 and 26 degrees Centigrade'. Certainly the former phrase trips off the tongue better than the latter.

Perhaps the most fitting summary of the survey is provided by reproducing the answers to the question 'On the whole, do you think the television weathermen do a good job?' Eighty per cent of the sample said 'Yes, most of the time', 15% said 'Yes, some of the time' and 5% said 'No, none of the time'. Clearly the viewing public are very satisfied with the BBC weather forecasts. To quote from the survey report: '[The viewers] considered the forecasts a very important service for television to provide and their content and presentation were held in high regard'.

Acknowledgement

The British Broadcasting Corporation has kindly given us permission to publish this note, which is based on a BBC Broadcasting Research paper entitled 'Weather forecasts on BBC Television'.

Review

The precipitation of Pakistan, by Bilquis Azmat Gauhar. 230 mm × 150 mm, pp. 153, *illus.* Asian Publishing Company, London, 1980. £9.95.

This is a monograph on the rainfall of a relatively small part of the Indian subcontinent, and as such will not have wide appeal to climatologists, most of whom would be more interested in a general account of rainfall for the whole subcontinent.

The work is divided into seven chapters. The first is concerned with topographical influences. Chapters 2 to 5 describe the general climatic conditions and seasonal changes at the surface and in the upper air over southern Asia during the traditional seasons: winter, pre-monsoon, monsoon and post-monsoon. Many diagrams are brought together from well-known sources and these will be familiar to most readers. During the winter, western disturbances bring light to moderate rainfall to Pakistan and, even in the pre-monsoon period of April and May, they give some thundery showers and occasional very cold bursts. The author gives one synoptic example of a cold burst in April, but none of a western disturbance during winter.

Most of the rainfall in Pakistan is brought by monsoon depressions from the Bay of Bengal, and the author discusses these in relation to weak and active monsoon conditions but gives no synoptic examples. And surely a table of annual amounts of monsoon rainfall for Pakistan as a whole for the past 100 years might have been provided.

Chapter 5 discusses the post-monsoon season, with its lack of rainfall. Chapter 6 discusses the statistics of variability of annual rainfall and of rainfall probability maps prepared by the author. Chapter 7 describes the author's subdivision of Pakistan into rainfall zones.

Although the book gathers together useful information from many sources, it cannot be recommended as a source of new information or ideas.

A. F. Jenkinson

Notes and news

In memoriam

A wreath was laid by Mr P. G. Rackliff, of the Defence Services Branch of the Meteorological Office, at the Commonwealth Air Forces Memorial, Runnymede, on 8 November 1981, in memory of the crews of 517 and 518 Long-range Meteorological Reconnaissance Squadrons who lost their lives on operations during the period 1943–45.

The wreath was obtained through donations given by former Air Observers of 517 and 518 Squadrons, now working at Bracknell and Heathrow. It is intended to make this a regular feature of the annual Remembrance Service.

Obituary

We regret to record the death on 2 October 1981 of Mr R. Stansfield, Senior Scientific Officer, Upavon. Mr Stansfield joined the Office in 1947 as an Assistant and was promoted to Assistant Experimental Officer in 1950. He served at a number of outstations in the United Kingdom and also had tours of duty in Ocean Weather Ships, and at Cyprus and Gan.

He was promoted to Senior Experimental Officer in 1971 and, after working in that grade at Manby and Little Rissington, was posted to Upavon in 1976. During the last few years he was Senior Meteorological Officer of the forecasting team at Southern Sector, Bristol, which is part of the UK Monitoring Organization.

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NOTICES

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