BMS

METEOROLOGICAL OFFICE
INVESTIGATIONS DIVISION TECHNICAL NOTE NO 1

RELIABILITY OF AMBIENT AIR TEMPERATURES AS DETERMINED BY CONCORDE 002

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1. Estimates of ambient air temperature are presently determined on the Concorde prototype from sensors situated in engine air intakes. Large corrections to the sensor observations are needed to arrive at the ambient air temperature and these corrections depend on the aircraft speed. The speed, or Mach number, is determined from measurements of dynamic and of static pressure, so that the temperature estimates depend on assumptions made concerning the static pressure. Since these assumptions are somewhat in doubt it is desirable that a separate check be made on the reliability of the derived ambient air temperatures.

2. Direct comparison of Concorde temperatures against other reliable measurements of temperature cannot be made readily nor are absolute measurements of the air temperature easily obtained. This note attempts to compare Concorde temperatures with those deduced from synoptic charts based on radiosonde measurements, but it must be noted that the absolute accuracy of radiosonde temperatures has not been adequately established and indeed the synoptic charts show many inconsistencies and discontinuities in radiosonde values especially between neighbouring countries. Systematic differences occur between the French and British radiosondes, particularly at midday when no correction is made for radiation effects on the French sondes which appear to be some 3 to 5 ^{o}C warmer than the British sondes at the heights of interest here.

3. The airborne data computer output of Concorde 002 as supplied by the British Aircraft Company was available for a number of flights during the period June-July 1971. The output contained information on the time, position, height, Mach number and estimated ambient temperature. Data were normally given only for heights above 45000 ft and were supplied at intervals of one minute though a few extra reports were included when the position was also noted. Knowing the aircraft positions, reference was then made to synoptic charts and to the radiosonde height-temperature distributions to assess, using necessary interpolation in time and space, the radiosonde temperatures corresponding to the Concorde times and positions. Cross-sections of the temperature-height field were drawn as necessary to facilitate the interpolation. In general, the radiosonde network permitted confident assessment to be made of the temperatures for the Concorde fixes though on some flights, notably those of 13 and 14 July, the large temperature gradients, both in the vertical and the horizontal, associated with the near presence of a strong jet stream and of the tropopause made the interpolation difficult.

4. A total of 507 individual comparisons of Concorde temperatures with estimated corresponding radiosonde temperatures was made, using data obtained from 14 flights. It was quickly evident that the Concorde temperature was normally several degrees Centigrade colder than the radiosonde temperature. Scatter diagrams showed that the difference tended to increase with Mach number and with height though the scatter was less with Mach number than with height. Similarly there was a correspondence between temperature difference and temperature, but again less marked than with Mach number. Since Mach number, height and temperature were closely linked it seemed that these variations were mainly dependent on the aircraft Mach number. Figure 1 summarises the variation of the Concorde-radiosonde temperature difference with Mach number and shows, for five ranges of Mach number, the mean temperature difference and the standard deviation of the differences about the mean value. The relevant ranges of Mach

number are:- less than or equal to 1.3, exceeding 1.3 and up to 1.5, exceeding 1.5 and up to 1.7, exceeding 1.7 and up to 1.9, and exceeding 1.9.

5. Figure 1 suggests that there is a systematic difference between the Concorde and radiosonde temperatures which ranges from about +1.5°C (Concorde minus radiosonde value) at Mach 1.1 to about -6.3°C at Mach 2. Additionally the figure indicates that there is a random difference which corresponds to a standard deviation near to 1.5°C throughout the range of Mach numbers.

6. In considering the implications of Figure 1 it must be noted that the temperature differences assessed do not represent entirely independent observations. On a given flight there was a tendency for the values to be persistent so that the relatively small number of flights may affect the results. For example most of the values between Mach numbers 1.7 and 1.9 were obtained on 4 flights only and for those flights there were few values above 1.9 Mach - this may account for a slight shift of the mean temperature difference for the range 1.7 to 1.9 relative to that for the range exceeding 1.9. Nevertheless the results show a certain consistency and it may be observed that the random differences, of standard deviation 1.5°C, are in accord with the probable accuracy of temperatures estimated from synoptic charts and with the likely accuracy of the Concorde computations. In a note (FAUSST V WP 528) on the assessment of temperature information for the SST between New York and Europe, Crossley produced a table which, for levels between 100 and 200 mb, gave a value of 1.3°C as the standard (random) error obtained using current radiosondes - systematic sonde errors would not be reflected by this figure but would affect the mean Concorde-radiosonde value. A BAC memorandum (F.T.M No 265/11 dated 8 Dec 1970) on the accuracy of flight test measurements indicates that the random error in ambient temperature has a root mean square value of about 0.8°C.

7. To summarise the above, it is considered that the results depicted in Figure 1 are a good appreciation of the accuracy of Concorde ambient air temperatures. By comparison with radiosonde values it seems that the Concorde values are too low by around 6.3°C for speeds around Mach 2. Although the absolute accuracy of radiosondes is not known, previous comparisons of British and American sondes by night indicate that they agree well and may serve as a reasonable standard. It might therefore be of value to attempt a comparison similar to the present one, which included only day time flights, for a series of flights made during darkness.

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FIGURE 1. DIFFERENCE BETWEEN CONCORDE DERIVED TEMPERATURE AND THE CORRESPONDING RADIOSONDE TEMPERATURE AGAINST AIRCRAFT MACH NUMBER