Airconditioning Surveys in the UK Retail Sector, or 'Keeping the Cold in'

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Abstract

It is known that airconditioning use in some sectors of the UK's non-domestic building stock, is increasing rapidly and may be approaching saturation, but exact reliable figures are scarce. It is important also to know the reasons for such an increase and if energy efficiency measures are being used effectively to limit the power required by AC (Air-conditioning) units. Systems exist primarily for the comfort of customers and staff, also for stock preservation in the case of food, but the same effect can be achieved with much less energy use, particularly in temperate climates such as in the UK. Typical energy efficiency measures in the retail sector may include more efficient use of display lighting, more and non-arbitrary setting of cooling temperatures combined with self closing doors or air curtains.

The results presented in this paper are from a broad-brush (low data depth, but from a large sample) pilot survey of around 700 retail premises from in 4 UK towns and cities. This was found to be a very effective way of gathering key data for a statistically valid, large sample, in a matter of days, helping surveys to coincide, for example, with favourable weather. Although the surveying process was largely qualitative there was also some quantitative sampling. To assess the intensity of cooling energy use, a sub sample of about 20 retail premises was probed for temperature and relative humidity. The results reported in this paper show that, in some cases, temperatures could be set higher improving thermal comfort and contributing towards a more efficient use of the air conditioning units.

Lessons learnt from the pilot survey and details of a follow-on major survey, numbering thousands of premises, primarily in order to provide longitudinal data, are described. The results gathered so far are cause for concern, and show that despite the increased energy costs involved, very few UK retail outlets adopt any strategy of energy saving for air conditioning use.

Keywords: Air conditioning, energy efficiency, retail, commercial buildings, energy surveys

1. Introduction

Since the early 1970s the rate of growth in UK energy consumption in the service sector, (i.e. commercial and public buildings), has increased by approximately 30% compared with a 25% increase in the domestic sector [1]. Of the total UK energy consumption of 6,695PJ in 2000, 880PJ was used by the service sector, of which 160PJ or 15% was consumed by the retail sector [2]. Increasing floor space in the service sector has been accompanied by rising energy intensity. In office buildings, demand for air conditioning has grown rapidly alongside a dramatic increase in CO2 emissions [3]. In the EU as a whole, the growth in AC use by treated floor area has

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increased by almost 400% since 1980 [4]. For the UK in 2000, total area air conditioned in all buildings, under both cooling and reverse systems, was estimated to have almost doubled (188%) from over the previous decade to 204 Mm^2 and is projected to nearly double again (196%) by 2020 to more than 400 Mm^2 [5]. This corresponds to an increase in energy consumption from 8.5PJ in 2000, to almost 16PJ in 2020 and a rise from 826kt to 1540kt in CO2 emissions. Detailed figures for UK energy consumption by sub-sector or by air conditioning system, are sparse. However by the end of 1994, about 11%, or approximately 10 Mm^2, of retail area was estimated as being air conditioned [6]. By 2000 ventilation and cooling was calculated as accounting for about 8PJ or 5% of annual energy consumption in the retail sector, with rapid growth expected particularly for packaged rather than central air conditioning systems [5;6].

The UK has a temperate climate without large seasonal extremes of temperature, summers are cool and winters are mild. However, eight out of the ten warmest years recorded in England happened in the last 16 years. AC usage in the UK's retail sector is a relatively recent phenomenon but as the global climate warming, the sudden growth of AC usage is something to be concerned about.
The low depth survey was carried out because it is believed that a statistically large number of premises, can provide an indicator to the growth of AC use in the UK within the retail sector. Of additional interest, are the longitudinal possibilities of such a survey, whereby once most of the database is populated the same sites can be re visited in the next years, and the growth of AC use examined year on year. So in addition to examining this growth, the energy efficiency measures applied were also assessed.
Typical energy efficiency measures may include air curtains, traditionally used in the UK to isolate a heated area from the outside in winter, but increasingly finding application in commercial refrigeration [7]. Self-closing, or automatically closing doors may also be useful in keeping the cooled air from venting to the outside. There has been some previous work in the areas of AC and retail, particularly with a view to reducing energy consumption. A survey of 4 shopping centres in Hong Kong, [8], found that air conditioning and electric lighting were the major electricity end uses, accounting for around 85% of the total building energy use. Work in Turkey [9] aimed to reduce energy consumption by defining new HVAC control strategies and tuning control loops in a shopping centre. New strategies were implemented with the help of the existing building management system (BMS) and about 22% energy saving was achieved.

2. Methodology

2.1. Low depth surveys

Surveys were carried out in many cases by examination of installed airconditioning and energy efficiency measures from outside. When airconditioning use was unclear, the survey was extended in depth by entering the retail premises, frequently briefly interviewing shop staff. Towns were chosen primarily to view a reasonable range of sizes, and secondarily on the basis of accessibility. All surveys were carried out in August and early September 2005. Temperatures varied considerably during survey days, but were typically in the range 18 - 23°C. The cities chosen are located in two distinct climatic regions, Leicester, Chesterfield and Stamford, having cooler summers when compared with London. The regional cooling degree-days for England's Midlands is below 50 whilst for the Thames Valley region it is between 50 to 100.

Stamford, a small market town in the Midlands degree days region of England with a population of 18000, was the first town to be surveyed. Of particular interest in this town was widespread use of standalone pedestal fans for cooling. Special note was also taken of shop lighting types, which may prove particularly useful data to gather during future surveys.

The next town to be surveyed was Leicester, with a population of 280,000, although it is the main local commercial centre for around 0.6 million. In the central urban regions, several streets were surveyed, mostly in the city centre. Care was taken to ensure a mix of shopping areas (e.g. low

cost areas, prestige city centre, financial district, etc.). Almost 100% of the premises have been photographed, such that building age, construction, and other details can be gauged from pictures at a later stage. The Leicester portion of the dataset is currently the largest, and is growing in depth, since we are finding extra streams of incoming data with which we can add functionality to the dataset as a whole, usually post-survey. A good example of this is that UK Government Valuation Office data is being connected to the Leicester Shop AC data, for computation of floor areas.

London is located in the Thames Valley region where the greatest concentration of air-conditioning is found in the UK. Being in the South East of England its climate is largely influenced by the continental proximity and the added urban heat island effect. Summer temperatures can occasionally climb to more than 30°C. London has a population of around 8 million. London's West End has a high density of retail premises and is arguably one of the busiest in the EU. Primarily the central Charing Cross Road and Covent Garden areas were surveyed, taking in the retail districts around Oxford Street and Covent Garden, as well as the fashionable café and bookshop populated areas to the East of the districts of Theatreland, and Soho.

Chesterfield is a larger market town, with a population of 100,000, towards the North of England, which is some 20 miles south of the city of Sheffield. It was chosen as a particularly average UK town. Chesterfield is generally not considered as a 'commuter town' such as towns of this size further towards the South East of the UK may be, and has a more average mix of population than Leicester. During these surveys information such as the shop's location, building orientation, presence of air conditioners, air curtains, fans and lighting types was collected.

2.2. Air conditioning usage intensity assessment

Temperature and RH probing was conducted in 20 different high street shops in London, on a hot summer's day, with an outdoor temperature of around 24°C. To proceed with the measurements the surveyor walked around the shops carrying two portable data loggers inside of a small well ventilated hanging fishnet bag. The loggers were set to record every 5 seconds. Each survey took an average of 10 minutes, to allow for the response time of the data loggers.

3. Results

The results shown in this section are drawn from a dataset of 607 premises. A reduction on the originally surveyed figure of 698 is imposed for the purposes of accuracy. This is because uncertain results, where even shop staff could not determine if air-conditioning was used on the premises, and results for premises in shopping centres which may be centrally air-conditioned and do not face the street, have been removed. Figure 1, shows the distribution of NESW orientation for ACs. Furthermore, AC use is fairly evenly distributed for orientation, with solar gains for South facing buildings, for example, apparently having little effect on the spread of results.

Figure 1 - North, East, South, West Distribution

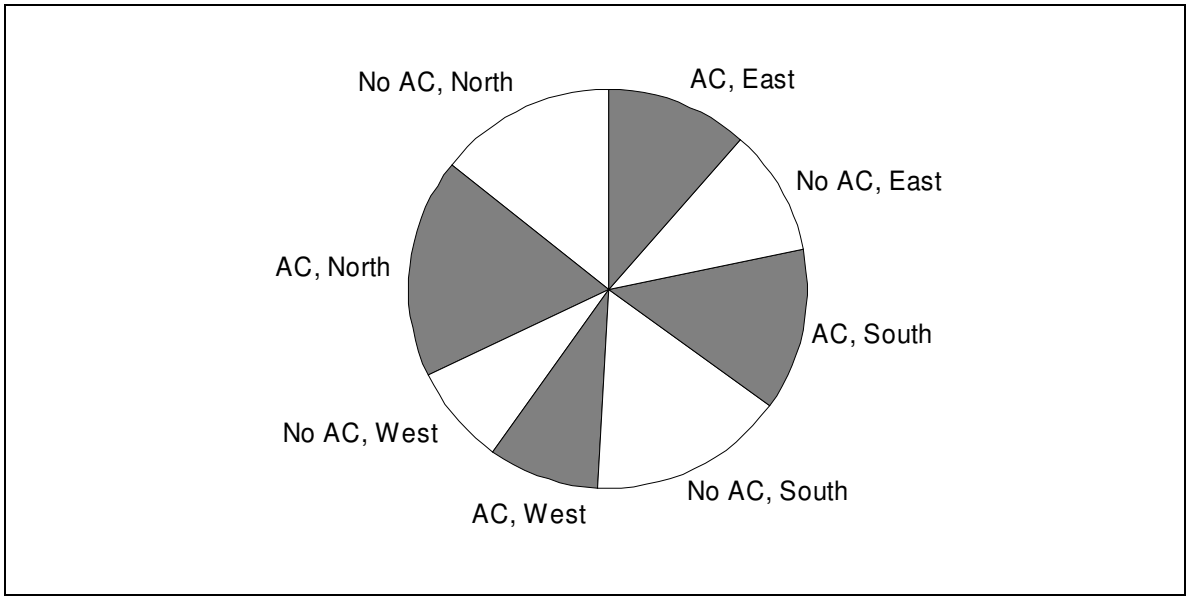

Figure 2, shows distribution of shops for chain/local types. Some franchises are more conformist than others, but it is unlikely that energy management is as strict as in large chains. Typically, chain shops are larger, than locally owned shops, but this is not a definite rule.

Figure 2 - Distribution between chain and locally owned shop AC use

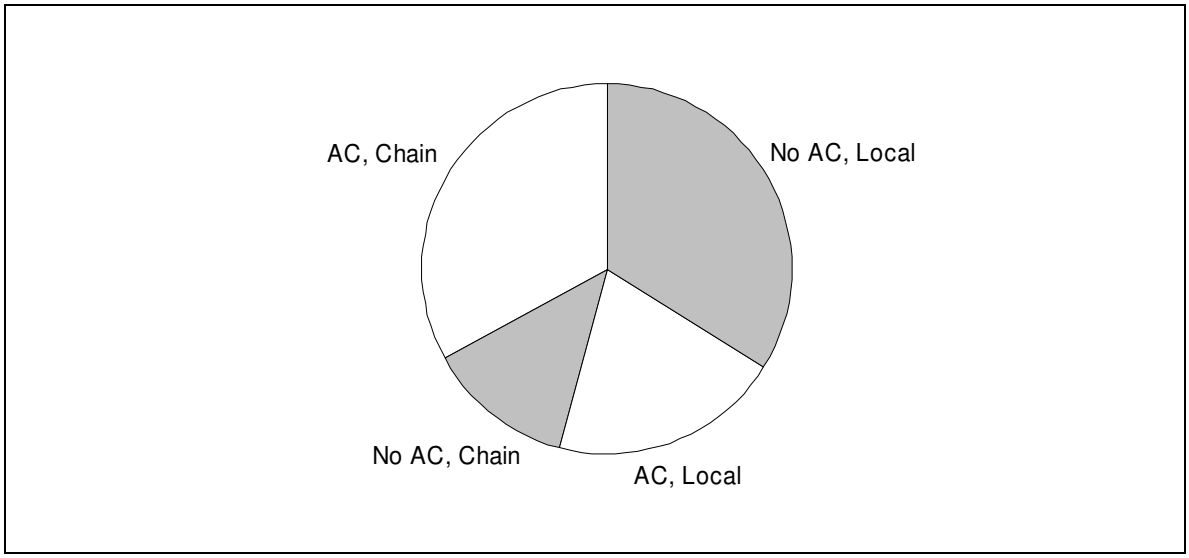

Figure 3, shows the instances of AC use by town. It is interesting that the proportion of AC use in London greatly exceeds that of the other towns. Also of note, is the small sample size for Stamford, which is limited by the number of retail premises in the town. Finally, the proportion of premises using AC / no AC for Leicester and Chesterfield are fairly even.

Figure 3 - AC vs. no AC by Town

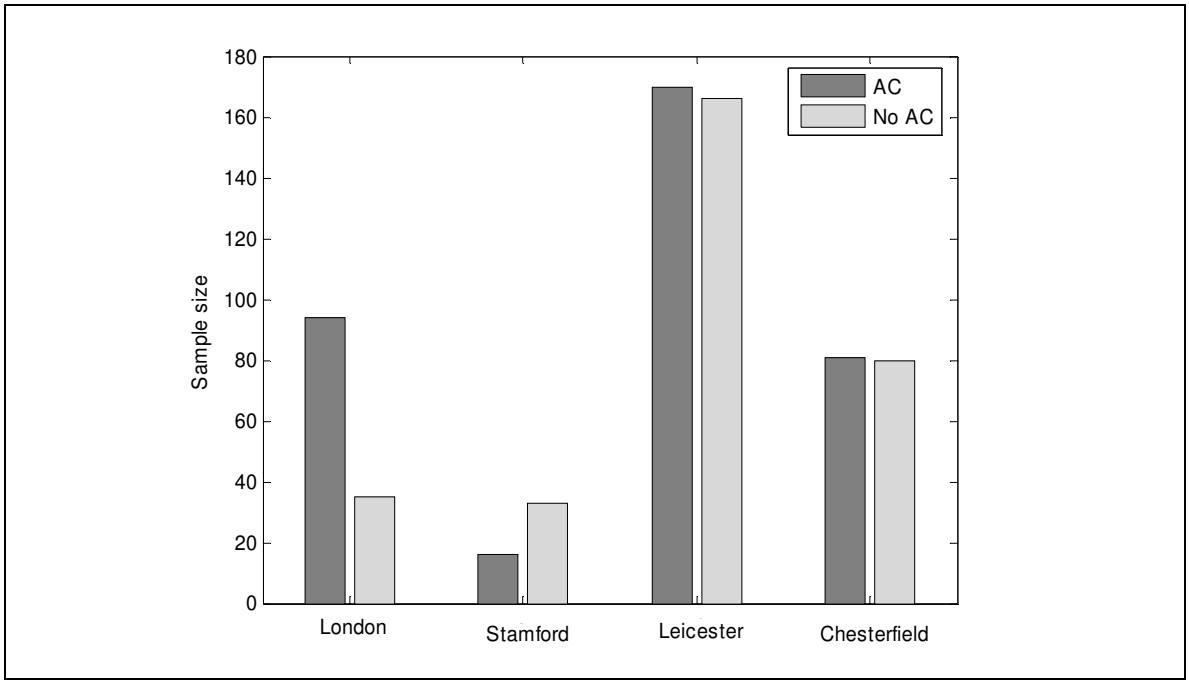

Figure 4, shows the proportions of AC configuration and installation from the dataset for shops which are not in shopping malls. Rapid savings in energy could be made just by switching the air curtains on which are present in many doorways, to a 'cold' setting. A summary of these results is given in Table 1.

Figure 4 - Proportion of shops with AC, no AC, and Energy Conserving Measures

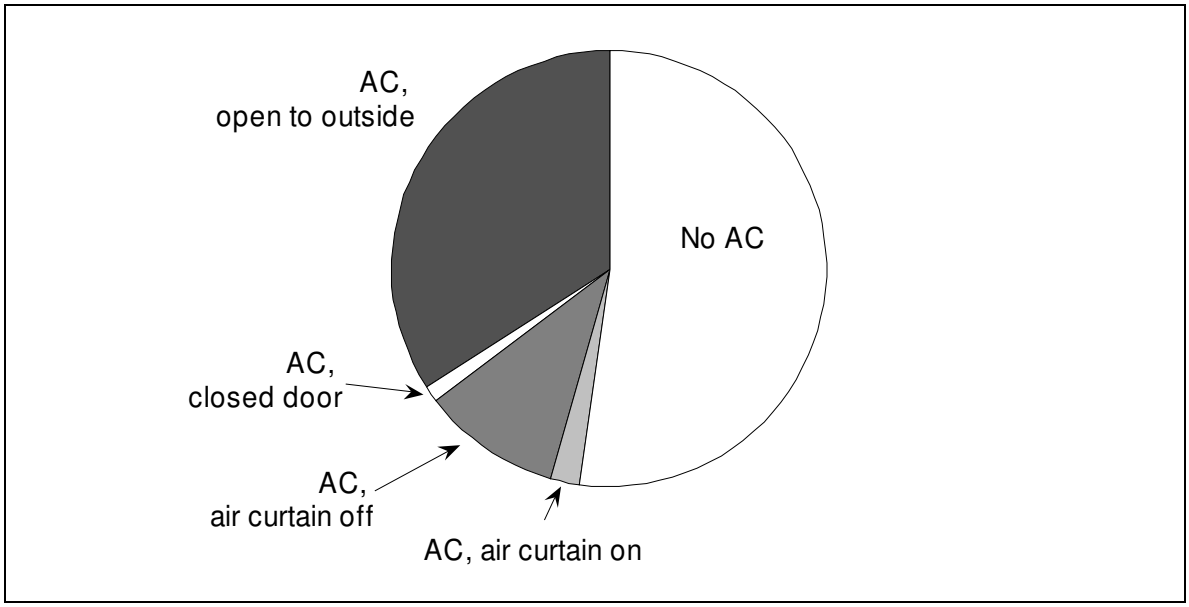

Table 1 - Summary of results

AC configuration	Number of samples	Percentage of total
No AC	317	52
AC, Air Curtain Off	62	10
AC, Air, Curtain, On	13	2.1
AC, Closed Door	8	1.3
AC, Open to Outside	207	3.4

Figure 5, shows the evolution of indoor air temperature and RH against time for some of the shops surveyed, as recorded by a datalogger. The lighter and darker curves show temperature and RH evolution respectively. Measurement periods inside air conditioned premises are characterised by a fast drop in temperature and a rise of RH. It is believed that the temperature drop would in some cases become even more pronounced if the dataloggers had a quicker response time. Each period indoors was identified with a letter. The upright lines were drawn to ease interpretation of the graph, and to outline each one of the periods. It should be noted that whilst outdoors the dataloggers were sometimes exposed to solar radiation leading to a rise of the recorded temperature above the ambient temperature.

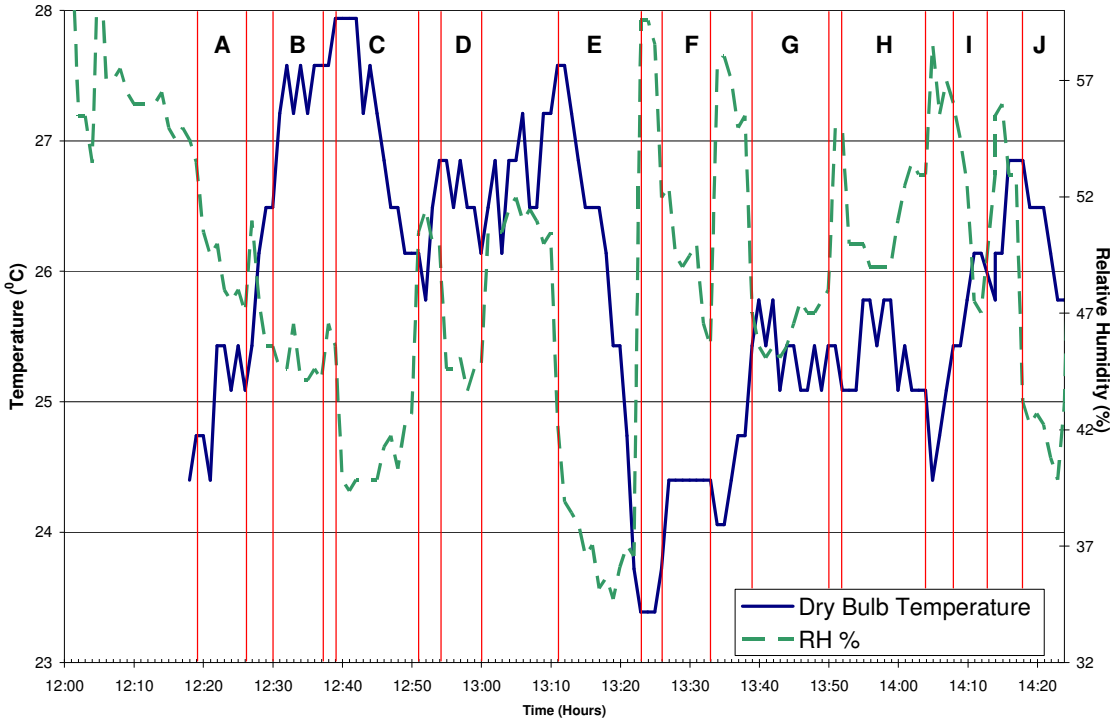

Figure 5 - Air temperature and RH variation

The graph clearly shows a marked drop of temperature in some retail premises, i.e. shop E, indicating how heavily air conditioned they were. It was found that supermarkets generally registered the lowest indoor temperatures as a result of intensive use of air conditioning combined with open display refrigerators. The measured indoor air temperatures were found to be in some cases, well below generally accepted thermal comfort standards. This may eventually be designed to slow down the decay of perishable goods and to ensure a longer shelf live while retaining ready access to displayed goods. On the other hand, by setting air conditioners at lower temperatures, in fact the energy efficiency is decreased without any real improvement of the indoor environmental quality. The findings of this investigation were compared with datasets from

different sources that show that energy intensity in supermarkets is in fact about twice than that of other retail stores.

4. Discussion and future work

It must be remembered that this is a pilot survey, and the first of its kind. The next step is to design a much larger follow-on to the 2005 AC survey. This would have two purposes Firstly to re-visit the same sites, and secondly, to look at the spread, or otherwise, of AC usage, and to expand the survey to include more premises and more towns.

Two additional types of survey could be carried out, in order to populate the existing dataset with useful extra data. 'After dark surveys' - looking at usage of display lighting etc, but also *after shop closing* - i.e. Sunday evening, to examine which premises have many lights burning. 'Winter surveys' of the same properties may also be carried out, to examine energy saving measures employed during the cooling season. Of particular concern, is accidental use of cooling by retail premises during the heating season. Both heating and cooling systems are, in effect, in competition. Indeed, it is not unknown for occupants of some offices to use AC's in winter in overheated rooms, since they have no heating control, or openable windows, and we may find a similar situation in retail.

Tests have started to be carried out using high resolution Infrared (IR) cameras. The aim is to investigate not only the use of air conditioning in retail premises but also whole blocks of buildings. Eventually aerial IR photos will be taken in the future if it is found that rooftop heat dissipation units are distinctly visible from relatively long distances. Heat leakage through open doors and windows in air conditioned buildings is also to be investigated and by using CFD techniques could eventually be quantified.

5. Conclusions

In this paper are presented results from a survey that is believed to be statistically representative. Nevertheless it was a fairly small survey of UK retail premises and larger follow-on surveys are to be conducted during the summer of 2006. Future research will investigate the effects on energy consumption of the energy management practices observed. This work will include obtaining floorspace data for the surveyed premises and modelling energy use to estimate incremental energy consumption. These early results however, show that the use of air-conditioning in retail premises in the UK is extensive, and in some cases excessive, where temperatures are uncomfortably low. The results show that the use of energy saving measures during the cooling season, such as closing external doors, or using air curtains, is minimal.

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