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Energy efficiency in buildings

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Before the oil crisis in the early 1970s energy was generally taken for granted with little concern for the cost or the needs of future generations. The quadrupling of oil prices almost overnight forced industry to consider its energy usage in a completely new light. Fortunately, the environmental controls industry had been incorporating the latest microprocessor techniques into its products for some years before this change in circumstances. With greater potential savings the controls companies invested even more in the latest technology and this gave rise to the birth of 'energy management' as we know it today

In most buildings energy can be drastically reduced by relatively simple (and sometimes free) actions such as closing doors and windows and improving insulation. Having taken these steps, significant further savings can be made by improving the control of the buildings' heating and/or cooling system. This can be broken down into three areas:

☐ Monitoring
☐ Targeting
☐ Control

Before any savings can be quantified, it is necessary to monitor what is actually happening in the building. Initially this is part of the full internal audit but, as improved controls are adopted, the monitoring must be an ongoing process.

Accurate targeting can be achieved once the performance of the building has been determined. It is now possible to target energy usage in just the same way that all other business costs are targeted. The control of heating, ventilating and air conditioning systems has improved dramatically since the 1970s and here the key is a comfortable environment at minimum cost.

The benefits, therefore, of adopting the latest environment controls or energy management systems are twofold: improved comfort at significantly lower cost. The ability of these systems to monitor energy consumption together with the intelligence of a central processing unit, allows all items of plant machinery, and indeed the building itself, to be constantly checked for optimum performance. With traditional controls it is possible for a good commissioning engineer to adjust the equipment to an optimum but after even only a few weeks things can drift. For example, boilers can suffer from reduced efficiency for a number of reasons and it is far cheaper to pay for a service visit when the performance is reduced than suffer up to 20 to 30% inefficiency for months on end before the next regular service visit.

Technology advances

The advance of technology as yet shows no signs of abatement. Improvements in microelectronic performance have taken the vast majority of control systems out of the domain of the mechanical engineer. Similar advances in material science, chemical science and biotechnology are beginning to make a major contribution in the energy sector. Most cost effective materials for insulation, indeed some insulating materials that have satisfactory structural properties, are already available. Processes to convert the sun's energy into a useful form have improved by an order of magnitude over the last decade. The prospect of the 'living' building controlled by biochemistry should no longer be regarded as science fiction.

My business was founded in 1974 specifically to address the problems of energy efficiency. In 1982 when we outgrew our premises a purpose-built, low energy factory in Hazel Grove, Stockport was built. The building used the latest technology in all respects and even today it has the lowest energy consumption per square foot than any other building in the UK. The building has a fully glazed south facade. In the centre of this is a two storey high atrium that contains the boiler and control plant. The glazed wall is a sun trap to capture solar radiation and the top of the atrium serves as a collection point for the solar heated air. From this point the air is transferred to the production area directly or, if necessary, after being heated by heated batteries. The atrium also has mechanically activated louvres which allow fresh air into the production area in the heating season and allow hot air to be exhausted in the summer. The latest hi-tech controls designed and manufactured in this very factory control the environment comfortably and efficiently, summer and winter and achieve a 50% saving of energy per year.

Many industrial processes discharge heat at a relatively low temperature. The temperature is often too low for direct use in other stages of the process or for direct heating. In many cases this energy can be saved either by raising its temperature by a heat pump or by passing it through a heat exchanger to pre-heat cold incoming fresh air to the building.

In recent years several excellent software packages

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Managing the process

The introduction of the latest technology will not in itself provide maximum savings. It is essential that personnel within the organisation are eduated about the need to conserve energy: energy equals costs. Even the smallest organisation should appoint an energy manager even if this is only part of an individual's responsibilities. An efficient energy management system will allow the energy manager to monitor and target his costs and to advise personnel on energy saving matters. The industry is striving to inform energy managers of the latest technology and the ways in which it can be used to best effect in their businesses. The National Energy Managers' Exhibition and Conference to be held at the Birmingham Metropole in December 1988 is such a forum and a number of workshops and seminars will be held with the needs of the energy manager specifically in mind.

It is deplorable that so few organisations have the vision to appoint an energy manager. They would operate without a production, sales or purchasing manager? It is time that industry woke up to the fact that the energy is a controllable and expensive cost and that at the moment it is simply being wasted. This is money down the drain straight off the bottom line. In some cases the energy managers who are appointed are simply ill-equipped to do the job. The energy manager should be regarded as a professional and, like any other professional, he will need regular exposure to the latest technology and how this can benefit his company.

Outlook

For many years during the 1960s and early 1970s the 'greens' had considerable success in persuading society that conservation of energy was essential for our successors. While this played on the conscience of many of us, little was done by industry to reduce the massive wastage. The artificial oil crisis has undoubtedly helped to reduce energy wastage but purely for financial reasons. All thought of conservation for the future seems to have been put aside. Fossil fuels are less plentiful today than they were a decade ago and it is only a matter of time before society rediscovers the environmentalist message; we must conserve our fossil resources for the sake of our grandchildren. It will not be long before today's blatant waste of energy is regarded as anti-social as tobacco smoking is seen today. It is unacceptable to continue to squander the earth's resources when technology today is able to reduce wastage to a minimum.

Integrating energy controls with other disciplines

Building controls can be broadly split into two categories: foreground services that relate directly to the occupants; business and background services that are virtually invisible to the occupant until things go wrong. Fire, security, environmental and lighting control systems form a basis of the background services. Regardless of how busy the operation or within reason the nature of the occupants business, the need for background services will be very similar. Also, a problem in any one of these background disciplines will require third party action; call the fire brigade, police or the HVAC maintenance contractor. The method of alerting the appropriate service is very similar for each discipline. All three services need to be monitored continuously and the electronic technology required to do this is almost identical. For this reason there has been a tendency to specify integrated systems particularly for larger buildings. The main problem for the industry is that traditional suppliers to these markets have been quite distinct and consequently people trained in one discipline have little or no experience of the other disciplines. For this reason there have been a number of almost catastrophic installations.

There are very real benefits in integrating the background services: not only is there a significant reduction in cabling and other 'overhead' costs but the information can be clearly displayed on one workstation. Alarms can be prioritised so that relatively junior staff can take the appropriate action with a minimum of staff training. The process of integrating these systems gives, in itself, real potential benefits to everyone from the supplier to the end user. A single package can be tailored to meet the exact requirements of the building and its users. Distributed intelligence and control from a central processor allows flexibility hitherto unavailable and integrated systems can be easily modified to suit changing requirements either of the building or its occupants as required. A single source of supply means fewer contractual problems during the design, installation and commissioning phases and also allows one service call to be made in the event of malfunction.

Standards

While the fire and security systems industry is well controlled by rigorous standards the environmental and lighting controls industry is virtually unregulated. This has led to many problems regarding compatibility of systems manufactured by different suppliers. The client is concerned that he might be locked into a particular manufacturer for future extensions or renewals and maintenance engineers are not familiar with products of different manufacture. The problem facing the industry is that advances are being made all the time. While it would be perfectly practical to lay down minimum performance standards, any attempt to standardise systems so that components would be totally interchangeable could inhibit innovation.

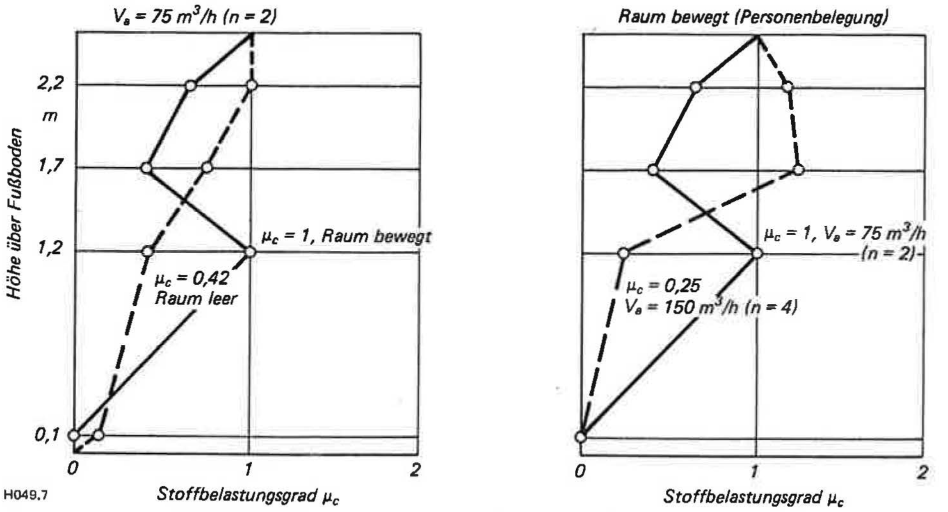

Bild 7: Stoffbelastungsgrad bei unterschiedlichem Luftwechsel im besetzten und unbesetzten Raum (nach [31])

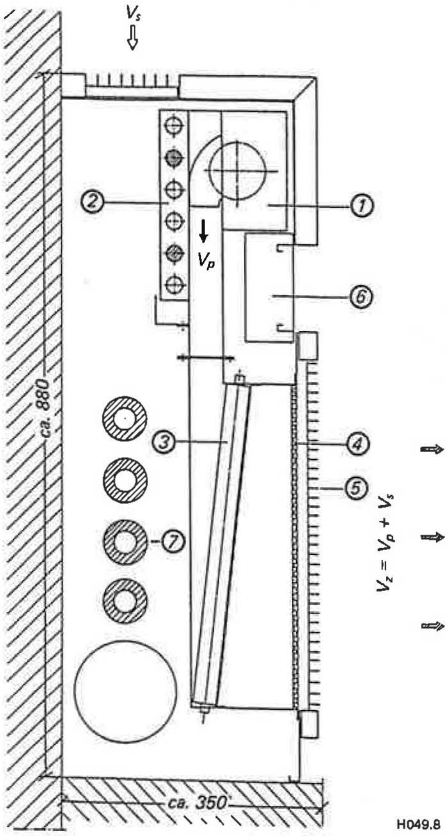

Bild 8: Rox Quelluft-Induktionsgerät Typ KVQ, Brüstungseinbau
① Primärluftverteiler, ② Wärmeaustauscher Kühlen-Heizen, ③ Gleichrichter, ④ Laminarisator, ⑤ Austrittsgitter, ⑥ Kabelkanal, ⑦ Versorgungsleitungen

niedriger Austrittsgeschwindigkeit (ca. 0,15 bis 0,2 m/s) der Aufenthaltszone zuführt (Anlage 11 nach *Bild 3*). Diese Art der Luftführung hat ihren Ursprung in neueren Untersuchungen, die in Skandinavien durchgeführt wurden [30; 31]. Das System wurde in Deutschland bereits praktisch erprobt und labormäßig untersucht.

Bild 6 zeigt einen Ausschnitt aus Meßergebnissen, die von *Esdorn* auf der INDOOR AIR 87 vorgelegt wurden [32]. Die Luft (V_z = 78 m^3/h für zwei Personen) wurde seitlich mit einer Temperatur von ca. 17 °C dem Raum zugeführt und verteilt sich, ähnlich wie eine Flüssigkeit, in einer relativ dünnen Grenzschicht über den gesamten Boden. Auf dem Weg zur Aufenthaltszone (beginnend in ca. 1 m Abstand zur Fassade) erwärmt sich die Zuluft auf ca. 20 bis 22 °C. Dies ist im wesentlichen durch den ca. 23 °C warmen Fußboden bedingt, der sich durch Strahlungseinfluß der Umgebung (Wände, Decke, Personen u.a.) auf diesen Wert erwärmt (Deckentemperatur über 25 °C). Da die Strahlung bei dieser Luftführung eine wesentliche Rolle spielt (durch die geringeren Luftgeschwindigkeiten verringert sich die konvektive Wärmeabgabe von Personen, Terminals u. dergl., die Wärmeabgabe durch Strahlung steigt entsprechend an), müssen bei Laborversuchen die Begrenzungswände des Testraumes unterschiedlich temperiert werden, um die sich im geplanten Gebäude später einstellenden, berechenbaren Strahlungsverhältnisse (Oberflächentemperatur der Wände, Decke, Boden und Wärmequellenverteilung) simulieren zu können, und es muß der Testraum sorgfältig gegen die Umgebung isoliert werden (Kalorimeter-Raum), um einen Zu- oder Abfluß von Wärme zu verhindern. Denn die Wärmebilanz muß stimmen: im Beharrungszustand muß sich die Kühllast in der Temperaturdifferenz zwischen Abluft und Zuluft wiederfinden (s. Gl. (3)).

Die noch unterkühlte Zuluft füllt dann, sich allmählich erwärmend, den Raum von unten nach oben bis zu einer gewissen Höhe, die abhängig ist von Zuluftleistung und Kühllast (siehe hierzu auch die eingehenden Betrachtungen in [37]). Sie steigt danach im Bereich der Wärmequellen bis in Kopfhöhe auf ca. 24 °C an (die Temperaturdifferenz zwischen Kopf und Fuß bleibt dabei unter den zulässigen Werten von 3 K, wie sie in [33] ermittelt wurden). Die Raumluftgeschwindigkeiten lagen im Bereich von 0,05 m/s und der Turbulenzgrad unter 0,1. Die Luftbewegung im Raum war damit noch niedriger als in einem unbelüfteten Raum mit konventioneller Heizung.

Im weiteren Aufstieg bis zur Decke erwärmt sich die Luft auf ca. 26 °C (Ablufttemperatur). Der thermische Belastungsgrad beträgt damit $\mu_t = 24 - 17/26 - 17 = 0{,}78$. Mehr als 20% der Kühllast werden also eingespart. Die mit dem Luftwechsel von 2,7 gedeckte Kühllast erreichte 24 W/m^2.

Im realen Gebäude läßt sich dieser Wert unter sonst gleichen Bedingungen noch erhöhen, da sich durch die aus der Atmosphäre einstrahlende Sonnenenergie, durch übliche Anordnung einer Deckenbeleuchtung und durch den Wärmefluß im Boden (Deckentemperatur > Bodentemperatur) die Bodentemperatur erhöht, die Deckentemperatur niedriger wird. Trotzdem werden die erreichbaren Lasten den Wert 30 W/m^2 nicht wesentlich überschreiten, das System bleibt damit auf Anlagen mit relativ niedriger Kühllast beschränkt. *Esdorn* [32] schlägt daher eine zusätzliche Kühlung der Decke vor, mit der nicht nur die thermische Last erheblich gesteigert, sondern durch die Veränderung der Strahlungseinflüsse auch mit einer höheren thermischen Behaglichkeit gerechnet werden kann, möglicherweise jedoch zu Lasten der Luftgüte (Anstieg des Stoff-Belastungsgrades).

Der Stoff-Belastungsgrad liegt vermutlich noch weit tiefer als der thermische Belastungsgrad. Untersuchungen von