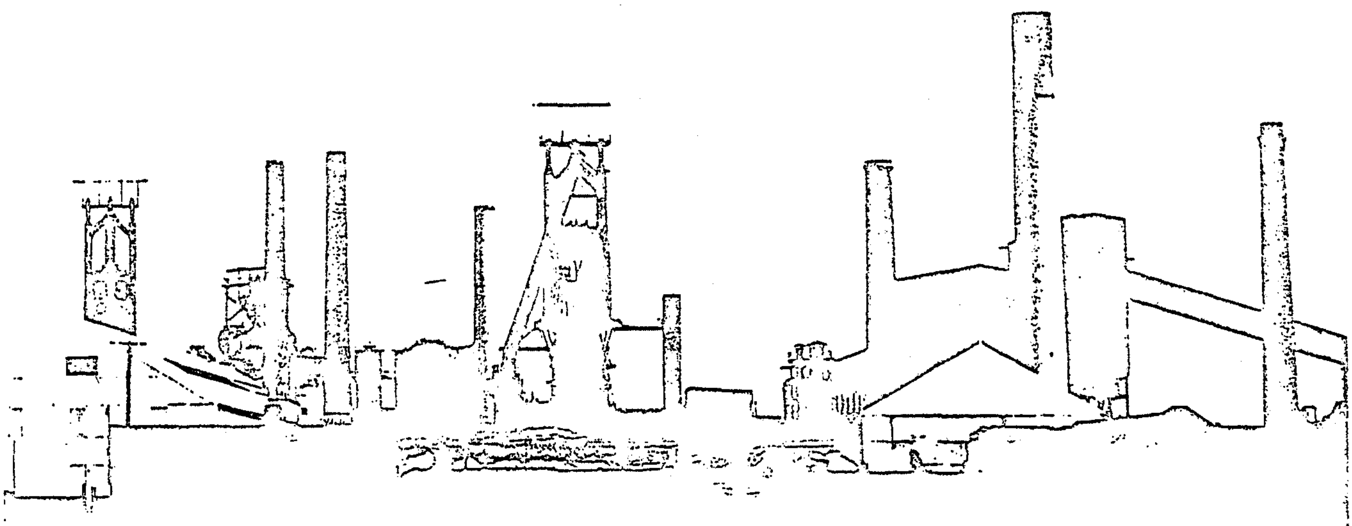
FACTORIES

Where there's muck there's brass – true once but nowadays where there's muck there is also likely to be industrial strife and wasted energy. The factory of tomorrow will be clean, comfortable and energy conscious. The implications for those who will design and supply the services are enormous.



FEWER BUT BETTER

Keith Mainstone predicts big changes in the factories needed

We seem to be living at a "crossroads" of greater significance than any that I remember since the last war. Our actions in the immediate future will have a profound effect in shaping the future in the 1980s and towards 2000. McMillan's "wind of change" of the 1960s will, I am sure, increase in force in the 1980s.

Social growth since 1945 has been achieved by the post war "bulge" — an increase in birthrate which worked its way through our society for 20 years affecting our programme for housing, schools, health service and hospitals as well as consumer output from industry. More recently (and totally unforecast) was the effect of the "pill" causing a levelling in birthrate and stabilization of population growth and a levelling of industrial consumer growth. Improvements in the efficiency of our health service have extended life expectancy, and extended higher education has delayed the date of starting work for our younger population. The Registrar of Births & Deaths has had to rewrite all his forecasts and so have the actuaries. The obvious results to our population are higher intelligence, longer life, more being educated or retired and fewer working directly to support the system. Better education has also resulted in a desire for more job interest with even fewer to do the monotonous jobs. Technology has taken over, or alternatively the "lower" jobs are now priced at a premium thus upsetting the established wage structure. I can not see any reversal of these factors and think that these trends will continue in the 1980s producing a smaller working population, greater mechanisation, more automation and greater dependance on the fewer wage earners. The retired and particularly the non-working population will present social dangers if inactive and consequently it is vital for the welfare of the country as a whole that non-working outlets (ie sports, unpaid welfare activities) are developed, and financed where necessary by the working minority.

Economic changes have also had a profound effect on society and industry. The Second World War left almost all economies in tatters with millions changing overnight from soldier to civilian worker. A vision of a new world was about us and looking back it is a salutory lesson that countries could cope with such immense changes compared with the resistance to minor social changes today. The vision gradually faded and there followed an acceptance of decline in our national prestige as colonies were dispensed with, our economy sagged, we were overtaken by our international competitors and we were spoken to firmly by the Gremlins of Zurich. The bubble burst in 1973, pricked by the nouveau riche from the Middle East.

Since 1973 we have, I think, been living in a wilderness of decline, unable to extricate ourselves and in a low state of national moral. Industrial activities have declined and we have part faced the reality that we are not working hard enough and living above our means. The developer boom also ended in 1973 and the restricted capacity of the home market has forced production and service industries alike to begin to look to the world market to compete with our international neighbours.

Industry has always been sensitive to the political situation and here we are much influenced by international forces outside our control. The acceptance of the reality of these forces with policies by our new Government to manoeuvre or overcome them are vital to industry. The industrial recovery in Germany, France, USA, Japan and Korea present a large bag of success stories where industrial recovery has been impressive and, despite the same difficulties, governments have financially encouraged enterprise and management and workers have responded. Our home market has withered under competition from the far points of the globe and underlying our industrial sector we have a top level moral problem and an underlying complacency due to minimum exposure in our cushioned and self protective economy.

We have the industrial ability, the intelligence and the population to respond enthusiastically to any international challenge if given recognition and just financial reward. As we move into the 1980s, therefore, I hope most of all that these forces will be released. The incredible reality of the 3 day week was that the challenge of working in candlelight in sweaters in emergency conditions in many cases improved productivity. The shift in balance from state control to private enterprise, the reduction of taxation and the moves towards parity in the European Community are moves in the right direction and could form a valuable springboard towards a more responsive industry.

In industry and technology we have a sad history of failure to exploit new ideas with a will to win. In 1945 we were in a leading position in the world in technology, in the fields of aviation, motor industry, nuclear knowhow, ship building, steel and textiles. Each industry has since declined and we have been relegated to the position of sub-contractor or joint venturers. If we are to reverse this trend and survive again, we must gain ground early in the 1980s. This is probably one of the most important factors to isolate, recognise and act on and will in itself largely dictate the future form and shape of industry including its buildings. A number of large industrial outlets have been irrevocably lost but, if we start to back the future winners now, we can hope to survive. Such fields might include microprocessing, telecommunications, computer technology, nuclear technology, coal technology and marine oil exploitation with emphasis also on the secondary industries and markets that will unfold. It seems therefore that we are moving towards higher technology and our international survival will depend on staying "up market" with house specialities that will be marketable to the third world. The industrial revolution from an agrarian based economy to an industrial economy in the last century was proof that we can succeed.

I have dwelt at some length on the social, economic and political factors. I should, however, at this stage shorten my sights a little to deal more specifically with the effects on industrial development at present and likely changes in the 1980s. Also of the quality of development in terms of environment and the type of services which may be demanded from the design industry.

If we accept the premise that the bulk of industry will tend to move "up market" and be science based, factory premises will be smaller. The era of "mass production" of multicomponents by macro machines operated by a high labour force is in decline. New technology for instance in injection moulding of plastics is replacing the need for complex metal pressing assemblies. Also the approach to component design is changing; for instance the assembly of a washing machine used to be based on a mechanical design which was subsequently wired electrically almost as one would wire a house. Such wiring is now done by microcircuit or "chip" which means the machine is implanted in one simple operation with a small brain. Trade involvements are reduced and component assembly is speeded up.

The concept of the "goods in production" and "goods out" factory is also changing. New high speed motorways with Euro service and distribution centres may largely replace the domestic provision of these facilities by the industrialist. Thus the need for space consuming and costly parts of the factory is dispensed with and the cost of stock in hand is reduced by an instant supply and distribution service.

The factory of the 1980s is therefore likely to provide mainly for the production process and, due to the greater scientific skills, will be serviced by fewer tradesmen and more technologists and scientists. This will in turn mean that office accommodation will increase in proportion to production area. All areas are likely to be better serviced and more akin to laboratories. A more scientific workforce will demand better social facilities and amenities. Such new industrial developments will be able to attract and afford better qualified workers and this will throw into sharp relief older and less organised units, which will be under pressure to renew.

If this trend is correct, industrial premises will become less of an eyesore and less space consuming. In this event I see a trend for industrial revival in the community and a move away from the concept of the out of town industrial estate. The storage elements now dispensed with will however be located nearer to the motorways and this is not inconsistent with energy savings on two counts. First the community factory will be near at hand and will reduce or possibly in some cases eliminate fuel consumption for factory personnel. The management will not have large storage areas to heat and maintain. On the other hand distribution centres on major roadways will have few operatives due to automated handling and spaces will be more effectively utilised and much smaller in aggregate than if dispensed into individual industries as has previously been the case.

My thesis about smaller industries in communities applies in the main to medium and small industries. There will still remain a trend for larger high technology plants to be located out of built up areas and near motorways. This trend is much in evidence in the M4.

The optimum factory of the future will still require flexibility for change and is likely to be a simply rectilinear form of sufficient height to allow an interdeck to be used or inserted at a subsequent stage. Car parking will continue to be a problem and I can see no obvious change in this sector. A particular trend that may happen to science based industires is a reversion to the 19th century concept with multi-floor use. This is feasible with precision work using small components and is economic in land use. Such factories could also be rectilinear but with obstructive elements (stairs, ducts etc) outside the envelope. Such low rise factories could shield car parking at ground level and be low in energy consumption.

All our industrial work will, of course, be more internationally orientated in the future and multi-national companies (hopefully many British based) will have to comply with international standards of design and organisation. The British market has some leeway to make up in this respect so we may expect changes in the next few years.

I have not mentioned the effect of dearer energy and energy conservation partly because this effect on industry is more predictable. The specification of building envelopes and the limit in glazed areas will be part of the new concept of factory design and the premium set on oil as a chemical rather than a fuel may mean a resurgency of coal and nuclear power plants.

The changes in concept of the factory will effect the provision of electrical and mechanical services. The better environment required for higher technology will require more sophisticated individual services, but the overall volume of industrial space is likely to be less. This will, however, be partly offset by the increased need to improve efficiency in existing plants and to renew certain sections of industry on the spot. The trend in existing industry will therefore be for improvement and renewal.

I have tried to predict some of the industrial trends in the UK consequent on the structural changes in industry itself. We must remember, however, that design consultancy is in itself an "up market" design industry. It seems unlikely that we will ourselves have a large enough market in the 1980s to provide full employment (more particularly as a ratio of design industry personnel per head of population in the UK is significantly higher than in Europe or the USA).

This market must be fulfilled therefore by continuing to enlarge our share of the foreign market thus earning wealth through exporting professional services. Here the reality comes home that we are all "industries" and the traditional concept of industry as a producer is now merging with industry as a service; architects, engineers, bankers, doctors and all other professional services who can contribute towards selling their services or wares abroad will play a vital part in earning the wealth we as a country need to survive.

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HORSES FOR COURSES

David Lush and Mike Holmes look at heating options for new factories

Factories and industrial buildings account for 40-45% of the total energy consumption in the UK. It is known that in many existing industrial buildings sufficient energy is available from the processes in the factory to maintain the required environmental conditions. Unfortunately, this is normally discharged as waste heat, without any effort to recover it, and the environmental energy systems frequently provide energy which is, or should be, unnecessary.

On one topic, designers consistently agree: the difficulties in formulating a well defined brief with the client caused by the client's broadly expressed view of what he needs and/or the designer's ability to phrase all the questions in a precise form which the client can comprehend. This may be due to poor communications between the parties and also frequently because, at the brief stage, the client is not in a position to provide all the answers. What then does the designer do? The problem is complicated by the fact that whereas commercial buildings for speculative developers do not often vary markedly in usage from those for direct users this is not the case for industrial buildings. Consider figure 1 which indicates some of the principles in the design process and parameters for the brief. While developer and user have a standard set of basic parameters the additional requirements of the user could have a marked impact on the building services design and the layout of the utilities. Good design requires detailed questions and answers for each parameter.

The developer's building will undoubtedly be aimed at providing the greatest flexibility for the widest range of possible users at the lowest first cost. If, in addition, the occupier is going to pay the fuel bills the developer may well request

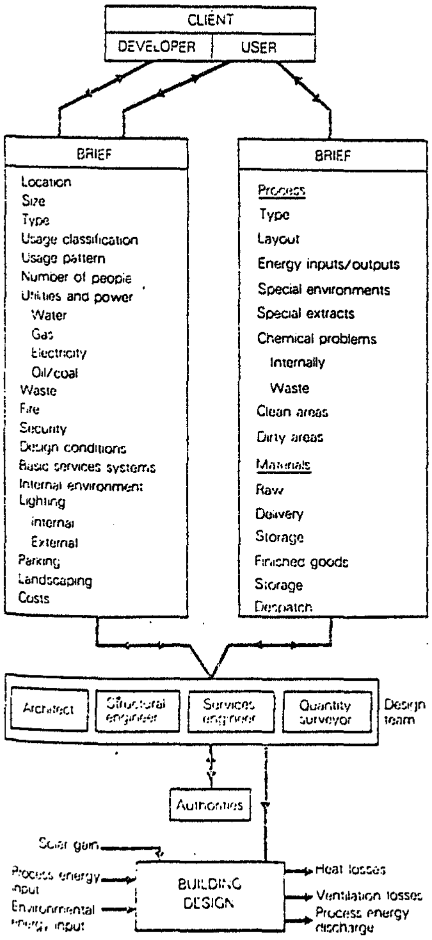

Figure 1. Factory design – the brief and principals involved.

that the insulation standards only meet the mandatory minimum requirements. While this attitude may be deplorable the present regulations are no encouragement to energy conservation. Occasionally process gains are so great and efficiently utilised that a well insulated building would be an embarrassment but this is unlikely to be the norm.

In principle the insulation standards need to be drastically and rapidly improved even if there are some consequential problems with building practices. Such an improvement would be of benefit to both speculative and direct user developments and is certainly in the national interest. If it is accepted that the first priority for industrial buildings is to improve the performance of the envelope the other major factor affecting heat losses, which requires attention, is the ventilation rate.

Designers use ventilation rates from standard guides and reference books of which the *CIBS Guide* is probably the most commonly used in the UK. If the various references are compared, a wide divergence can sometimes be found in recommended air change rates for particular types of building and further checking reveals a lack of validated data. If one then examines the volume of industrial buildings, the activities carried on within them and the recommended air change rates there appears to be a massive overprovision above what is strictly necessary. The most logical conclusion to be drawn from this would be that, historically, industrial buildings were draughty and what had to be accepted several decades ago, because there was no means of control, has been carried over to the present time.

Work has recently been carried out on both the theoretical and practical levels* to check the effect of holes in the fabric. This may not be directly applicable to large buildings and more work is necessary to validate basic data and produce design techniques. It is therefore essential that modern industrial buildings are designed with an envelope which permits ventilation to be controlled. In terms of basic design, the parameters to be considered are detailed in the *CIBS Building Energy Code Part 1*.

A dichotomy again exists for heating and ventilating plant between speculative buildings and those designed for direct users. In the former, the heating and ventilation systems have to be designed in ignorance of the potential process and internal gains. There is little likelihood of anything more than the simplest system required to satisfy the Factories Act. In the present climate of opinion this is not a satisfactory solution, but without some regulatory conditions regarding energy conservation it is likely to continue.

The Department of the Environment has made proposals covering controls for preheating in buildings and thermostatic control of zones, areas and the domestic

* Lee, B E *et al.*: A method for the assessment of the wind induced natural ventilation forces acting on low rise building arrays. Department of Building Science, University of Sheffield. BS 50, March 1979

EXTRACT OF ZINC

Extensive fume extraction equipment for a £350 000 plating shop at Brush Switchgear, Loughborough, has been fabricated in pvc/grp by Electroloid (Plymouth) to service two new automatic zinc plating lines as well as plant refurbished by Brush for acid pickling, chemical backing, tinning and silver plating. Five external fans give a total extraction capacity of 57 000 ft^3/min and the systems include stacks, internal ducting and lip exhausts.

hot water storage. These proposals are awaiting Ministerial approval prior to implementation in the Building Regulations. They will ensure that basic energy conservation measures are built into all system designs whether the factories be for speculative or direct user requirements. There are a number of techniques which can be adopted to improve basic systems. Depending on the size of the factory complex some of them may also be applied to existing buildings although the costs for the measures may be higher than for new buildings and, consequently, the cost effectiveness may not be as attractive.

Excessive infiltration has often been suggested as the cause of high energy consumption. In some cases this is undoubtedly true (see for example R C Kirkwood in the June 1977 *Building Services Engineer*) but to generalise would be dangerous. It is in fact improbable that very large air change rates can occur in large industrial buildings for a very simple reason: most leakage must occur at the perimeter. An air change rate of 1 per hour for a 10 000 m^2 factory would imply a perimeter air change of at least 10. Complaints from workers in the perimeter area would occur; irrespective of whether the leaks were at high or low level, and management would be obliged to rectify the problem. It is also unlikely that the perimeter heating capacity is sufficient to cater for the load imposed by such a large air change rate.

The most significant loads imposed by infiltration probably occur through open loading bays (see figure 2). The best way to overcome this is some form of double door lobby at all such points of access to the outside. Even then, door heaters will undoubtedly be required but their output will be only a small fraction of that necessary for a single door. The lobbies should be of sufficient size to avoid both doors being open at once. In summer of course the doors may be held open to create a through draught for cooling.

As insulation standards are improved the fresh air load will become more important. One problem faced by the designer is that it can never be zero. As already mentioned there is very little available information on acceptable fresh air quantities for general industrial work, ie where processes do not produce toxic fumes. The most suitable data are probably those for offices with heavy smoking. This would yield a design air change of about 0.25 per hour in the 10 000 m^2 factory.

The manner in which this air is introduced is important. If natural ventilation is used, there may be complaints of feeling cold on the perimeter. Forced ventilation systems offer a better solution. In this case advantage should be taken of the relatively large temperature gradients in many factories (measurements indicate vertical gradients in the region of 1.5°C/m. Outside air should be mixed with high level air before being discharged into the working space. This has two advantages:

- □ tempering of the outside air may be unnecessary;
- □ temperature gradients may be slightly reduced and consequently better use made of internal gains.

Admittedly the second point contradicts the principle of tempering the outside air by means of the "hot layer", but it is unlikely that the momentum in the supply air jet will be sufficient to reduce gradients by more than half.

Very high levels of insulation may cause more problems than they solve. Investigations being carried out as part of a study for the National Engineering Laboratory, East Kilbride, indicate heat gains in general of 40-60 W/m^2. With a mean roof U-value of 2.0, overheating may occur when the outside temperature is as low as 8°C (this allows for some radiant gain and infiltration). Thus cooling would be required for much of the year.

The rise in temperature due to internal gains is not just a matter of the loading per square metre of floor area. Temperature gradients and the ratio of radiant to convective gain are also important. This is indicated in figures 3-5. Thus the optimum roof insulation level will vary with process and heating/air distribution systems, the former being responsible for the radiant convective split and the latter having an influence on the resultant temperature gradients. While the roof loss comprises a large percentage of the design fabric heat loss, the level of insulation at the walls may be important under working conditions, and as the wall insulation is improved floor loss in the perimeter region will be more significant.

In many cases internal gains will occur away from the side walls, so little effect will be felt by workers on the perimeter. They may therefore be exposed to large cool wall areas and consequently experience discomfort unless local heating is

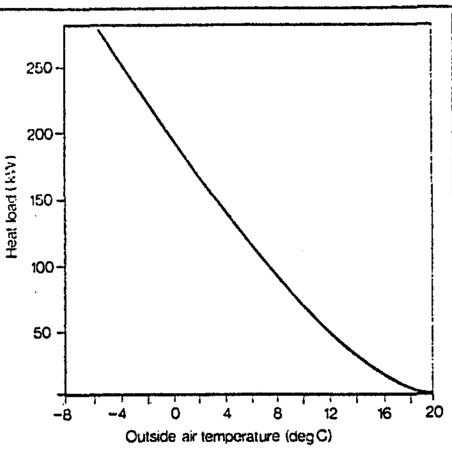

Figure 2. Theoretical heat loss through open 6 m × 4 m loading bay door with remainder of building sealed (still day).

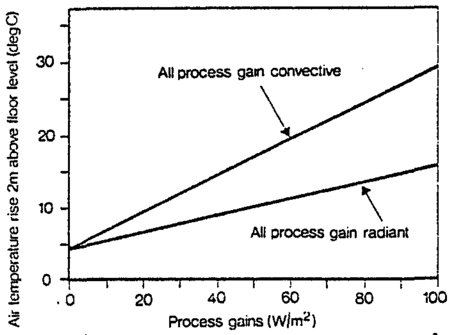

Figure 3. Theoretical temperature rise due to internal gains in 7 m high factory, roof mean U-value 2.9 $W/m^{2o}C$, temperature gradient 0.5°C/m, air change rate 0.25/h, lighting (base load) 25 W/m^2.

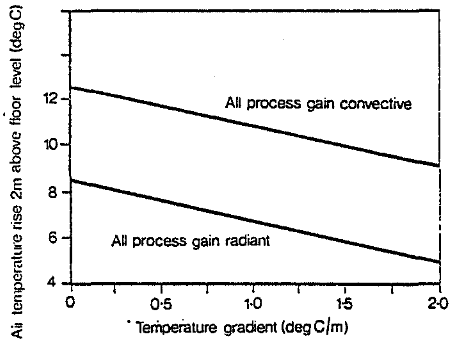

Figure 4. Effect of temperature gradient on temperature rise, conditions as figure 3, process gain 30 W/m^2.

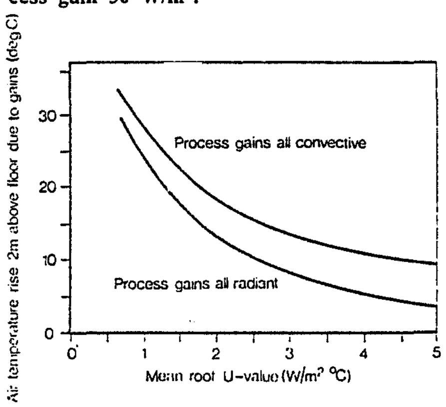

Figure 5. Effect of roof U-value on temperature rise in core area, conditions as figures 2 and 3, temperature gradient 1°C/m. Roof U-value area weighted average of opaque fabric and glazing.

provided. To obtain comfort with a controlled air temperature of 20°C, minimum wall temperatures of 15°C are probably necessary when the heating is off. Figure 6

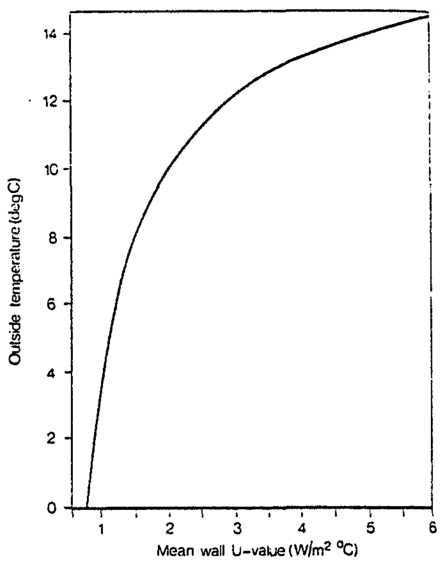

Figure 6. Approximate outside air temperature to hold inner wall surface at 15°C, air temperature 20°C, environmental temperature 16.7°C, dry resultant temperature 17.5°C. Roof U-value area weighted average of opaque fabric and glazing.

shows a relationship between outside air temperature and mean wall U-value to maintain a surface temperature of 15°C. The calculation is necessarily approximate because of the difficulty in calculating a true internal heat transfer temperature under these conditions.

Studies on existing buildings have indicated that inadequate controls are responsible for excessive energy consumption and that compensation could reduce the annual space heating fuel consumption by 30%, with installation of thermostats within the core achieving another 15% on top of this.

The simplest effective control system should have both thermostats (more than one please!) and compensation. The latter should prevent excessive opening of windows, especially around the perimeter, and the former should take full advantage of internal gains. In many cases it will be necessary to provide an independent perimeter heating system.

The ideal factory heating system would therefore possess the following features:

- □ perimeter and core separately treated;
- □ external temperature compensation of the heating medium; different slopes may be required for perimeter and core zones;
- □ suitably located thermostats;
- □ mechanical ventilation, with the outside air mixed with warm "roof level" air unless this air contains materials or gases that would give rise to a health hazard. In this case heat reclaim should be considered. The same mechanical system could be used for cooling in summer;
- □ an air distribution system that minimises space temperature gradients, to take full advantage of internal gains. It will of course be necessary to carry out some form of optimisation if the principles outlined above are to be followed;
- □ a design which takes maximum advantage of heat recovery from process equipment, ie heat treatment plant; and
- □ where relevant, adequate automatic starting and stopping of hvac plant.

Once a factory has been occupied the production requirements normally become paramount. But the services equipment will remain in a state of high efficiency only if maintenance is planned as thoroughly as the production process. In many factories an energy manager is present who can develop systems to achieve a high degree of energy conservation, but he will have great difficulty implementing them without suitable technical staff. For example, a boiler system in a 10 000 m² factory operates at 70% full load efficiency instead of the 80% design figure. At a boiler fuel cost of £25 000 per annum at 70% efficiency, there is a saving of £3000 obtainable for up to one man-week of work per annum.

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CUTTING COSTS NOW

Harry Weston suggests ways of cutting fuel bills by up to 20%

Table 1. Typical industrial boiler operating conditions

Fuel	Theoretical CO_2 (%)	Range of average CO_2 (%)	Excess air (%)	Flue gas temperature (°C)	Sensible heat loss in waste gas (%)
Natural gas	12.0	5.0-10.5	130-15	195-237	8.7-15.0
Oil	15.6	8.0-10.5	90-40	203-325	10.9-20.7
Coal	18.0	5.6-10.6	210-70	202-318	14.0-32.3

Table 2. Results of tests on heating boilers ranging from 1700 kW to 2900 kW, fuel heavy oil

Burner type	Purging and standing loss (%)	Stack loss (%)	Radiation loss (%)	Thermal efficiency (%)	Load factor (%)
A modulating	5.2	16.1	12.0	66.7	15.5
B modulating	3.1	15.3	5.4	76.2	28.2
C modulating	3.4	16.1	14.2	66.3	11.3
D high/low	11.7	24.2	5.0	59.1	34.1

One of the most effective ways of encouraging rational thinking on building energy is to ensure that those responsible are thoroughly acquainted with its cost and the cost of inefficiency, but regrettably the true cost of heating is often very obscure even at Management level. Figure 1 gives some idea of the price movement of the principal energy forms and it would seem that the only way to halt the upward trend and its crippling inflationary effect is to reduce demand. Architects, systems engineers and maintenance engineers all have a vital role to play for often energy inefficiency is "built-in" and subsequent upgrading can be very costly.

The fuel prices in Figure 1 are "as-delivered", but the actual cost of energy supplied, taking into account conversion efficiency in the boilerhouse, can be taken today at typically 25p/therm, ie at the boiler stop valve or header. For those with steam heating systems this equates to approximately 25p/100 lb of steam for fuel cost only. The cost of raising heat obviously varies with the type and size of plant but the following breakdown of cost is realistic for boiler plant in the 2-3 MW capacity range: fuel 75.0% of total cost, labour 8.0%, maintenance 3.4%, services 6.6%, capital charges 7.0%. Thus, if we exclude capital charges the fuel cost represents about 81% of the total and underlines the importance of maintaining high thermal efficiency. One of the problems with space heating plant is the very poor load factor due not only to seasonal variation but also to variation over the day. Under such conditions good burner turn-down ratio is important and effective isolating dampers are necessary to prevent undue cooling during "off" periods. Automatic burners are good when set up properly but regular checking of combustion efficiency and flue gas temperature is necessary to ensure that the plant performance is maintained at optimum. Table 1 shows the range of values outlined for a considerable number of small industrial boilers; there is clearly scope for combustion improvement and reduction in waste gas loss. Modern boilers are capable of efficiencies of over 80% but often operate considerably below this due to factors mentioned above.

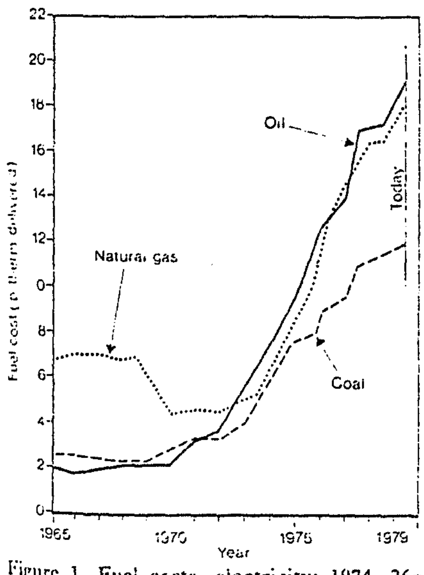


Figure 1. Fuel costs, electricity: 1974, 26p/therm, 1977, 56p/therm, 1979, 70p/therm.

Some years ago the author carried out detailed tests on some heating boilers and Table 2 shows the extent of actual measured losses and that all these boilers were capable of operating at over 80% on test. The figures show the extent of purging and standing loss occasioned by poor load factor and emphasise the importance of judicious selection of boiler and burner type.

Cleaning of heat transfer surfaces is vital to ensure that efficiency is maintained and this is often regrettably neglected; an increase in flue gas temperature of only 16°C will increase fuel consumption by 1% and it takes only a thin soot scale to do this.

In view of the above it might seem surprising that a great many industrial heating boilers are not even provided with rudimentary instruments for allowing performance to be systematically checked. No matter how good the specification and design, if regular maintenance is not carried out waste will ensue. In this respect the maintenance management team has a special role. Energy saving may not attract much glamour for much of it is seemingly mundane but attention to detail is vital. The following examples illustrating the point are from recent survey reports across a wide section of industry, and indicate the failings commonly found.

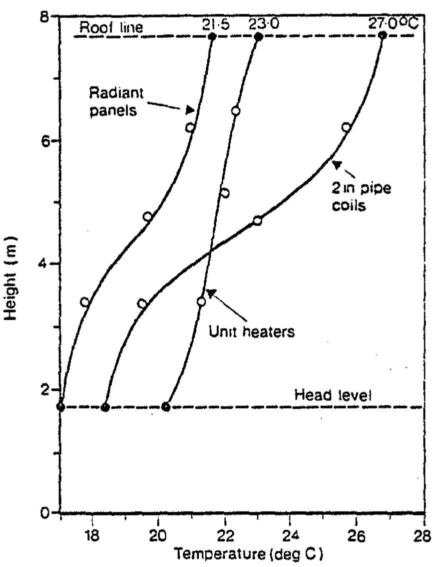


Figure 2. Effect on temperature gradient of using various forms of heating in a factory space, including effect of roof losses.

Steam pipes supplying heater batteries, unit heaters etc are invariably uninsulated in the belief that they contribute to space heating. Normally such lines are at high level and simply increase the roof temperature gradient. Figure 2 gives some idea of the extent of this in one factory which utilised three different systems in various parts of the building and indicates the extent to which roof losses can be increased. This is by no means the worst case and the gradient is easily checked in practice. Unlagged supply lines are wasteful and cause unnecessary condensate load on steam traps. 30 m of 50 mm pipe will waste approximately £400 during a heating season and the remedy is obvious — distribution loss from unlagged supply lines can account for 15% of the heating load. High level pipe coil heating still abounds in industry and produces steep temperature gradients, and yet pipe reflectors or "ray-strip" can markedly increase the downward radiant component and reduce roof loss. Where high roof temperature permits though, recirculating units are often recommended to effect better distribution to working level.

In steam systems recovery of flash steam and condensate from heating system traps is frequently mentioned. Steam is still the commonest form of heating in industry

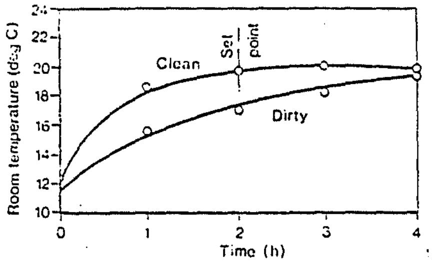


Figure 3. Effect of cleaning convector filters.

and often all that is needed to effect a cure is a simple flash vessel and make-up reducing valve. For example, at 50 lb/in^2 gauge some 9% of the steam supplied to the battery is flashed off at the trap discharge or blown into the condensate receiver causing excessive cavitation of the condensate pumps. Low pressure flash steam can be utilised in low pressure heaters or sometimes for supplying hot air curtain batteries.

Returning condensate from heating systems saves not only heat but also water, water treatment cost and blow-down. At 50 lb/in^2 gauge the loss of heat alone is just over 11% so that if both flash steam and condensate are discharged to waste the total loss is nearly 20% of the total heat supplied. Yet this is still a very common defect.

It is surprising how often one sees the recommendation "fit thermostatic control on heating system". Yet 1°C overheating will increase energy consumption by 7% if the outside/inside temperature difference is 14°C. A common comment is "check thermostats by thermometer" because of suspected overheating, or replace faulty thermostats or fit tamper-proof ones and reset them to not more than 20°C.

Heating systems do not produce goods, and are therefore often the poor relation until the poor heating standard brings a sharp reaction from the work-force! How often are space heating batteries, unit heaters or convector matrices examined for fouling? How many are designed for easy examination? This is often referred to in survey reports.

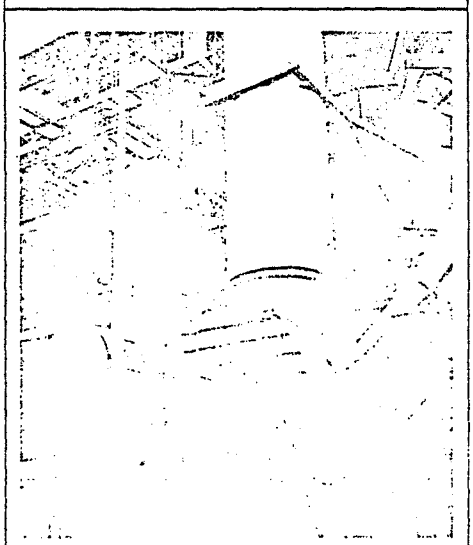
Figure 3 shows the effect of cleaning office convector matrices: the heating-up time is roughly halved. In many instances unit heaters on close examination are found badly fouled-up. In one instance "cold blowing" was put down to back-pressure on steam traps but inspection showed the heater battery to be almost completely blocked. Steam pressure had been pushed up from 20 to 40 lb/in^2 gauge to overcome the problem (unsuccessfully) and this simply increased trap losses. Washing out the battery effected an instant cure. Factory atmospheres are often heavily dust laden but in this case the deposit was salt — the factory being on the coast. Unit heaters are usually mounted "well up" and out of sight as often are steam traps.

Recommendations for partial recirculation of air in plenum systems are fairly common. Ventilation rate is often excessive and it is surprising that many air systems are still in use with no provision for recirculation, even where no fume probably exists. The installation of a local extraction system on an offending process or machine is frequently suggested to reduce materially the overall air-change rate in the factory; over-heating is serious in the energy sense but so is over-ventilation, but how often, if at all, is air-change measured?

High level unit heaters arranged for 100% fresh air or recirculation are a common source of waste: during summer they are used for fresh air supply and the dampers are often not reset in winter to give recirculation — so the system operates on 100% fresh air supply all the year round. Savings of up to 20% by recirculation are frequently quoted.

The installation of pvc or rubber doors to reduce air influx is prominent in most survey reports and recommendations to install small, self-closing personnel access doors to facilitate closure of double doors is common, as is the suggestion to motorise loading doors. It is curious that during the Second World War door extensions with air locks to prevent light emission were commonplace as an air-raid precaution but were gleefully born down on cessation of hostilities. The author has often pondered the enormous energy saving which would have accrued had these been left in situ.

It is important to get priorities right and it must be said that direct leakage from valve spindles, blowing joints and defective steam traps are a serious matter and all too often referred to in survey work. At 25p/100 lb steam it can be readily shown that a leaking valve spindle will cost about £25/week and a faulty trap may cost over £50/week. Damaged steam traps should always be examined to ascertain the basic defect. For example, carry-over of boiler salts from improperly maintained boilers can seriously gum up the trap mechanism and here the cure is at the boilerhouse.



This radial fan was designed for the specific conditions found in a large refuse incinerator. For protection against corrosion due to the sulphuric acid contained in the flue gases at about 75°C and for reasons of stability, the 2250 mm diameter fan impeller is of pure titanium. The inside of the casing is also rubberised for corrosion protection. Volume flow is 151 000 m^3/h and fan speed is 1490 rev/min, though Piller has in the past constructed fans for volume flows of over 360 000 m^3/h and pressures up to 100 kPa.

Other common propositions are: use local heating instead of heating the entire shop where only a few operatives occupy the premises; install time clocks instead of manual control to the heating; fit inside/outside compensating control to an office block; fit optimum time start controls on an administration building; use matt black paint on radiant panels and strip to improve emission instead of sprayed aluminium; check combustion and flue gas temperature on free-standing oil heaters (I have yet to see evidence of any user having done this); re-use heat of compressor cooling system for space heating, replace broken glazing and seal gaps at gutter level to reduce ventilation loss.

This short article can scarcely do justice to the sheer number of comparatively mundane measures which can be implemented quickly to save energy. A great number of recommendations are concerned with recovery of waste process heat for space-heating, use of heat wheels on exhaust air, run-a-round coils, roof and building insulation, new boilers, centralised control etc. Energy savings of up to 20% are commonly quoted as being achievable by attention to the sort of measures mentioned. 20% of the industrial heating load is worth nearly £100 million/annum to the nation and any Chancellor of the Exchequer would welcome that! It ought to be welcome in industry too and it is all the more sad to see the oft repeated statement in survey reports: "Energy monitoring and records are practically non-existent and to achieve real progress in cost savings this omission must be rectified."

H B Weston CEng AHWC MIMechE FInstE is chief engineer, National Industrial Fuel Efficiency Service.

LIGHT ON THE JOB

Robin Aldworth asks for more interest to be taken in factory lighting

For some time I have had the impression that industrial lighting receives scant attention. Few articles are to be found on the subject. This is surprising when it is realised that one third of the UK work force is employed on the factory floor.

It is probably true to say that most factory workers are called on to perform more exacting visual tasks, in unpleasant environmental conditions, than any other group of workers. The work is often physically demanding, repetitive and boring. It seems reasonable to conclude, therefore, that considerations of quality and effectiveness in industrial lighting would result in improvements in safety, morale and labour relations. These factors in turn could be reflected in improved productivity.

The lighting installation which provides not only the right quantity but more important the right quality of lighting, benefits visual performance and that is sufficient justification for giving far more detailed consideration to industrial lighting problems.

It is high time that the overwhelming influence of the accountant and that recently spawned profession, the energy manager, was challenged when it comes to the selection of a lighting scheme. Cost and energy saving considerations have led to an increasing use of high efficiency discharge lamps and luminaires in industry, and have also tempted some lighting engineers to stretch the system to a point where the quality and effectiveness of the lighting design is impaired.

Take the example of high bay industrial lighting systems 40 years ago, or thereabouts, when this system was first devised using tungsten or high pressure mercury lamps, a concentrating reflector was used to give high utilance and acceptable glare control. This meant that the luminaires were installed on a 1:1 spacing/mounting-height ratio. Little light reached the walls and roof, but as these were usually dark in colour, either by design or dirt, there was little point in trying to light these surfaces. These installations produced a uniform horizontal illuminance, but the vertical plane illuminance was low and the installations often looked gloomy, because of the "tunnel effect" caused by the dark walls and roof.

Then the tubular fluorescent lamp came along, with its much higher efficacy. Except for very high mounting heights of 12 m or more, the fluorescent trough reflector, with its wider intensity distribution took over the industrial lighting field. With this large area, low brightness source, glare was not a serious problem. The high efficacy of the lamp justified the cost of installing more lighting points, particularly when lighting trunking systems were introduced, and we could afford to throw more light on to those dark walls and roof areas, which in spite of their low reflectance did respond to the lumens they received. These industrial areas lit with fluorescent equipment tended to look less gloomy and over-bearing, even when the horizontal illuminance had not been increased. The lighting was uniform and relatively shadow free. This lack of shadow was a major sales point of fluorescent in its industrial hey-day.

In recent years the high wattage tungsten lamp and the uncorrected mercury lamp have been superseded by high efficacy colour corrected mercury lamps, followed by metal halide and high pressure sodium lamps. As a result the merits of high bay lighting systems have been rediscovered and at first the new lamps were installed in old BZ1 high bay reflectors.

The pressure to reduce costs and save energy has led to further developments which sprang from a logical train of thought, which runs as follows:

- The higher the wattage of the discharge lamp, the more efficient it becomes in converting electrical energy into light.
- The higher the lamp wattage of each circuit, the lower the proportion of control gear losses.
- To produce the same horizontal illuminance from these high lumen packages, the luminaires must be spaced further apart which in turn reduces installation costs.
- To control glare and maintain unifor-

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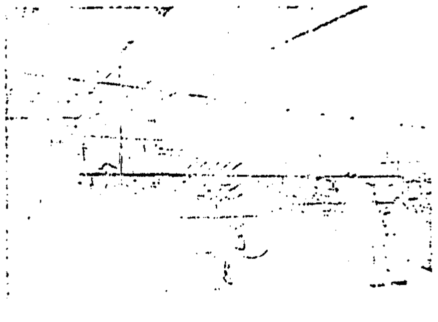
RADIATING WARMTH

L C Clayton and F R Morgan discuss radiant heating systems

In a building having a mainly convective heating system the mean radiant temperature is always less than the air temperature because the surrounding surfaces are predominantly cooler than the inside air. With a mainly radiant heating system the conditions are quite different: the mean radiant temperature always exceeds the air temperature since most of the heat is delivered by radiation into the building volume. So a radiant system employs a lower air temperature to maintain a given indoor environment. Ventilation losses are directly proportional to the difference between internal and external air temperatures. Typically a radiant system raises the mean radiant temperature until it is about 3-11°C above the air temperature, the differential depending principally on the heat load per unit floor area, and savings of up to around 50% in energy demand can be achieved.

Further advantages arise because the enclosing surfaces are warmed when they absorb the radiant energy. A diffuse secondary source of heat is thereby established which not only eliminates temperature stratification but also provides for rapid recovery of the internal environment after a period of shut-down or high ventilation. These features are particularly valuable in industrial buildings with bare concrete floors and massive equipment. The environment within loading bays and other localities intermittently exposed to outdoor conditions rapidly recovers when the doors are closed.

The radiant space-heating system marketed by Radiant Tube combines the technological advantages of radiant heating and the practical advantages of convective systems by using air as the heat-transfer medium. A direct fired air heat exchanger



Radiant heating can always be arranged to avoid roof lights and high level services.

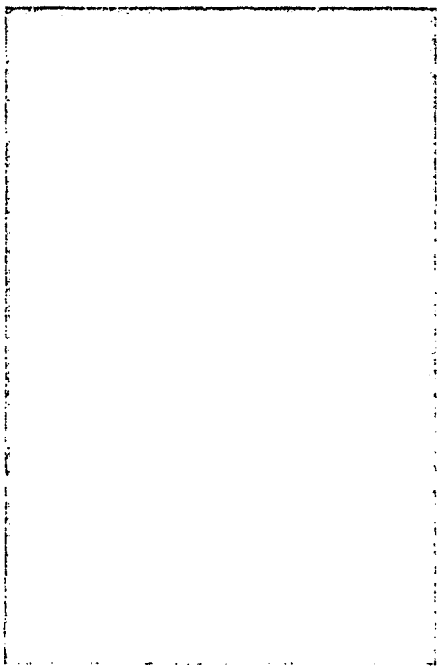
burning oil or gas is connected to a closed-circuit of ordinary sheet metal ducts. The hot air is circulated by centrifugal fan at a rate which ensures substantially uniform heating of the ductwork: heated to temperatures in the region of 200°C (390°F) the ducts become extended sources of infra-red radiation directed almost wholly downwards into the working areas.

There is a limit to the intensity of radiation which can be tolerated without discomfort but the maximum is difficult to define because it depends not only on the direction and uniformity of the incident radiation but also on environmental factors such as air movement and temperature. Guidelines can, however, be established and matters are usually arranged so that the floor surface temperature is some 5-10°C above the air temperature.

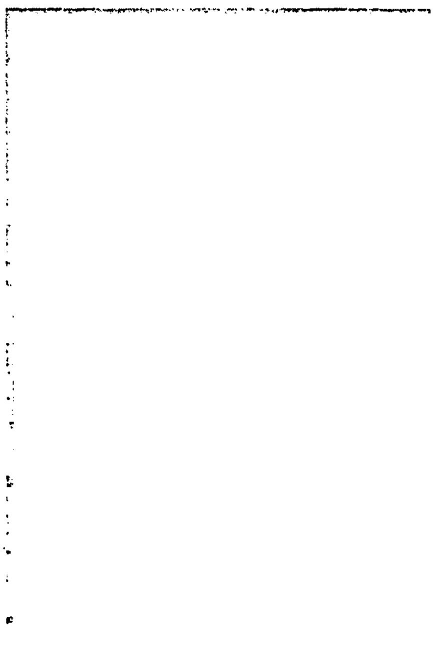
There are now many working installations, and these confirm not only the practicality and usefulness but also the energy efficiency of radiant systems in general and air-heated radiant systems in particular.

Improvements are under investigation, and at present replacement of ambient air by process air containing low-grade heat to improve the overall system efficiency is under active examination.

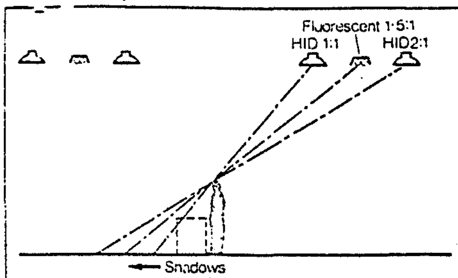
L C Clayton is with Radiant Tube Systems; F R Morgan is with Wimpey Laboratories.



High bay discharge luminaires at 1:1 spacing: mounting height ratio.



Low bay discharge luminaires at about 2:1 spacing: mounting height ratio.



Body shadows on the task.

Industrial lighting systems.

Spacing and type	*Mean* E_v/E_h	*Mean* E_{ir}/E_h	*Obstruction losses* Direct	*Obstruction losses* Direct + inter-reflected
HID 1:1	0.18	0.08	41%	38%
HID 2:1	0.31	0.08	45%	42%
Fluorescent 1.5:1 transverse 1.1 axial	0.33	0.12	24%	21%

E_{ir} = inter-reflected component

mity, the reflector must produce a batwing distribution.

There is no flaw in this logic and the lighting system derived from it has produced some excellent industrial lighting installations at low cost and high energy utiliance.

This solution, however, is not without its pitfalls for the unwary. If we consider a 30 m by 60 m industrial area with a mounting height of 5 m and a 30% wall and ceiling reflectance, lit with:

- High intensity discharge (HID) lamps in BZ1 reflectors spaced at 1:1;
- Higher wattage HID lamps in batwing reflectors spaced at 2:1; and
- Fluorescent reflector luminaires spaced at 1.5:1; with all three systems designed to give the same horizontal illuminance, the quality of lighting provided by each is significantly different.

Comparing the mean E_v/E_h, ie the proportion of vertical plane illuminance to horizontal plane illuminance, the 1:1 HID installation gives 18% E_v, whereas in the 2:1 spaced installation the E_v is 31% of the E_h value. This is similar to the 33% given by the fluorescent system.

Another important difference is in the type of shadows cast by the different luminaires. The greatest cause of obstruction loss is the worker himself. A person standing mid-way between rows of luminaires in the three types of installation will cause obstruction to the horizontal illuminance on the floor or the work bench, as well as the all important vertical surfaces in front of the operator. The shadow patterns cast by the three types of installation are shown in figure 1.

Inter-reflected light reduces the direct obstruction loss. Although the effect of inter-reflections will vary due to different conditions at each task position, column 2 of Table 1 shows an average value of 8% inter-reflected illuminance for both HID schemes and 12% for the fluorescent scheme. The last column shows the slight reduction in obstruction loss given by including the inter reflected component.

The worker's body is not the only cause of obstruction. Just to redress the balance slightly, the shadow of, for example a drill stand on the task area could be caused by overhead fluorescent lighting so it is certainly not true to claim that this lighting system is entirely shadow free.

On assembly lines, conveyors and component storage are a common cause of serious light obstruction, but if obstruction is overcome by the use of local lighting, without reducing the value of general lighting, then the overall running costs of the installation will be increased.

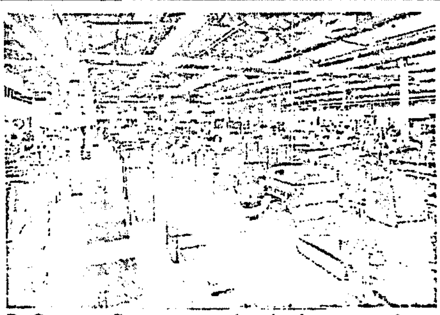
Detail in shiny surfaces, such as a scribed line on metal, is seen either when the detail shows up as dark against a bright surface, which reflects an image of the luminaires or when the scribed line produces brighter specular reflections than the surface. This effect is dependent not on the illuminance on the surface, but on the position of the sources, the eye and the orientation of the surface. Where the sources are small and widely spaced, the chance of seeing such an image is reduced. When the image can be seen, the high luminance associated with such sources may be too bright and result in reflected glare or dazzle, which degrades the viewing conditions. For this type of visual task, which is fairly common in industry, the large area, low brightness sources are usually more effective.

There is one other practical disadvantage of using widely spaced HID luminaires: the failure of one lamp affects a large area of the factory floor.

In spite of these problems associated with HID industrial lighting, it must be stressed that for some visual tasks, shadow free lighting does not assist vision. The revealing power of directional lighting with well defined shadows is well known and I am certainly not arguing that fluorescent lighting is a universal panacea for all industrial tasks, rather that the source and luminaire must be chosen first and foremost to suit the range of visual tasks in an installation.

The importance of cost effectiveness and energy saving is undeniable and the accountant and energy manager must have their say, but lighting systems chosen on the basis of these factors alone will not necessarily provide the correct lighting. If the installation does not aid vision, then it cannot be claimed to be either cost or energy effective. It is up to the lighting engineer to put his case as effectively as the accountant and energy manager, even if they do happen to be current blue-eyed boys of management.

R C Aldworth FCIBS is chief lighting engineer with Thorn Lighting.



Reflector fluorescent luminaires at about 1.5:1 spacing: mounting height ratio.

GOVERNMENT AID

Grants, loans and advice for building owners.

Money is available from government in substantial quantities to help save energy in factories. It is not always easy to find this money however and the effects of the various schemes are not always as simple as they seem. Brief details of the major schemes and addresses for further information are given below as a starting point.

DEPARTMENT OF ENERGY: Energy Conservation Division, Thames House South, Millbank, London SW1P 4QJ (01-211 7074).

Energy conservation demonstration schemes

Promote better use of energy via full-scale installations of new or existing energy conservation technologies. About 20 schemes have been approved so far.

Up to 25% of capital installation costs given plus up to 100% of costs incurred because the project is a demonstration.

The scheme is open to all non-nationalised industrial companies and organisations. Schemes are judged on specified criteria and applied for by sending a proposal to the Energy Technology Support Unit, Harwell, or the Energy Conservation Section, National Engineering Laboratory, East Kilbride.

Energy Survey Scheme

Encourages industrialists to have an energy survey carried out.

Up to £75 paid towards consultant's (from an approved list) one-day visit on production of invoice and report.

Extended Energy Survey Scheme

You don't get much for £75, but having had a one-day survey a detailed audit can be carried out on approval of the DEn.

Up to 50% of audit cost is payable.

Energy Quick Advisory Service

For non-domestic energy users, dial 100 and ask for Freefone 3140. The service passes you on to "Professional consultants acting on behalf of the DEn who will deal in confidence with your energy saving enquiries at no cost".

DEPARTMENT OF INDUSTRY: Energy Conservation Section, Abell House, John Islip Street, London SW1P 4LN (01-211 3000).

Energy Conservation Scheme

Aims to improve boiler installations.

50% of consultancy fees are payable; 25% of costs of boiler replacement and provision of ancillary equipment if the existing boiler is less than 70% thermally efficient, up to £15 000; 25% of the cost of ancillary equipment to an existing boiler, up to £5000; 25% of cost of insulating premises if the average U-value is worse than 3 W/m^2°C; a normal minimum of £100 000 for replacing existing heat supply systems with modern, or improved, combined heat and power installations.

1965 Science and Technology Act

Sponsors research and development with 25% grant or 50% loan. Supports schemes worth £25 000 plus for improved production processes with 25% grant or 50% loan.