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Condensing Boilers in UK Housing – An Opportunity for Energy Saving Investment

M J B Trim BSc

The paper outlines the design concept of the condensing boiler and its application in domestic heating systems and discusses the energy savings, investment opportunities and other benefits that can be realised. It also examines the potential market for condensing boilers and some initiatives that are aimed at promoting them in regard to both the end user and the heating designer and installer.

Introduction

Condensing boilers have been well deployed in Europe and North America since their introduction by the Dutch in the late 1970s. But in the UK these appliances have been slow to gain acceptance. In an effort to stimulate the market for the condensing boiler the Energy Efficiency Office is sponsoring a programme to encourage the wider application of these appliances.

The paper introduces the broad design concepts of the condensing boiler and its application in domestic heating systems. The energy savings and other benefits and the opportunities for investment are discussed with reference to monitored case studies in family and sheltered housing.

The potential market for this type of appliance and some initiatives that are aimed at promoting the condensing boiler in regard to both the end user and the heating designer and installer are also described.

Condensing boiler design

The objective of any heating appliance in a wet central heating system is to extract heat from the products of combustion and transfer it to the heating system. If the combustion gases are below a certain temperature, the dew point, small quantities of condensate will start to appear on the walls of the heat exchanger. Impurities such as sulphur products, react when burnt with air to produce acid. When combined with the condensate the acid forms a corrosive mixture which can attack the heat exchanger surface and lead to corrosion within the appliance. Therefore, conventional practice has tended to keep temperatures within the boiler high enough to avoid corrosion, thereby limiting the efficiency of a conventional boiler to around a maximum of 78%. This cannot be significantly improved because 19% of the combustion energy is lost through the flue and the remainder through the appliance casing.

Flue gas temperatures can be as high as 200–250°C in conventional boilers to provide the necessary buoyancy to draw gases up the flue and to ensure safe combustion to prevent condensation forming within the heat exchanger. However, in the condensing boiler the intention is to achieve as much condensation as possible – exactly the opposite to conventional design.

St Clement's Court, Manchester

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Please contact:
Enquiries Bureau
BRECSU
Building Research Establishment
Garston,
Watford WD2 7JR
Telephone: 0923 664258

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Improving efficiency

One way to achieve this is to significantly cool the flue gases using an enlarged (or secondary) heat exchanger surface. This extracts much more of the sensible heat from the flue gases and improves the efficiency of the boiler by about 7–8%. The remaining flue gases have lost most of their buoyancy, and an electric fan is necessary to induce them to escape through the flue. In the condensing boiler the process of extracting sensible heat is known as the 'non-condensing' mode of operation and it takes place at all times, making these boilers always more efficient than conventional boilers.

About 10% of the total heat energy of the fuel is in the form of latent (or hidden) heat, retaining the water in the vapour phase. This heat can be recovered by cooling the combustion products to a suitably low temperature, the dew point. To extract latent heat it is necessary to reduce the flue gas temperature to below 54°C, and this in turn requires that the return water temperature is reduced to the same level.

If these conditions are achieved the efficiency of the boiler will be further improved by 8–9%, giving an overall bench efficiency of 94–95%. By contrast a conventional boiler is relatively unaffected by return water temperature, and the effect can be seen in Fig. 1.

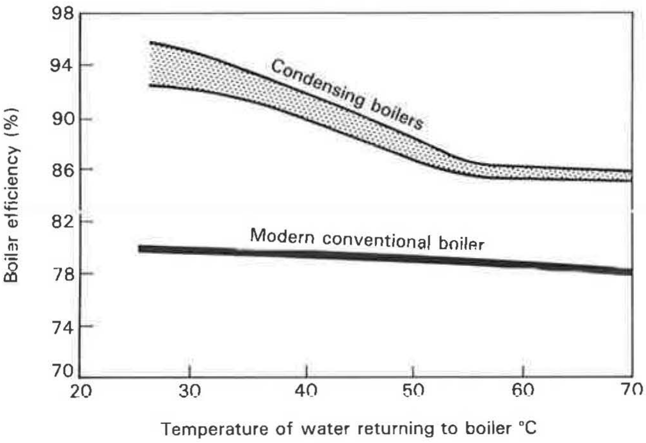

Fig. 1 The effect of return water temperature on boiler efficiency

Condensate

When extracting latent heat the boiler is operating in the 'condensing' mode – hence the name 'condensing' boiler. Operating in this mode produces condensate and this must be continously removed through a permanent drain in the bottom of the appliance. The water that condenses out of the flue gases combines with the remaining gases to produce a mildly acidic substance. To prevent this attacking the flue and heat exchanger these components are made of suitably corrosion resistant materials, usually aluminium or stainless steel.

The condensate is not acidic enough to damage the normal domestic drain, especially as household waste is slightly alkaline and the net result is a neutralising effect. Other measures, such as an insulated outer case, can improve the bench efficiency still further to about 96–97%.

System considerations

Bench efficiencies are useful for comparison purposes but of greater importance to the heating designer is the overall system efficiency. To obtain optimum performance the design of condensing boiler heating systems should take account of the following factors:

Return water temperature

To ensure operation in the condensing mode this should be below the dew point, 54°C.

Appliance size ratio

All boilers show a fall-off in efficiency at low loads, although in condensing boiler systems the effect is less pronounced. Good design practice requires that the boiler should be sized closely to the design heat loss of the building, with due allowance for domestic hot water, intermittent heating and other factors. Unnecessary over-sizing leads to reduced efficiency and increased capital costs.

Sizing of heat emitters

Over-sizing the radiators will achieve a lowering of return water temperature, improving the efficiency but at an increased cost and probably at the expense of room space.

Flow rates

The overall system design temperature difference commonly falls between 11–17°C. Lower flow rates are possible, but greater accuracy in balancing the heat emitter system will be necessary to ensure full flow rate and hence full output from each emitter. Different radiators have different characteristics as their flow rate is reduced. Emitters will generally be more effective when operated at, or near, their design conditions.

Controls

Controls should always be selected to cover adequately the control strategy required by the system designer. For domestic installations the minimum controls are confined to temperature sensors and a time clock. For larger installations external weather compensation or optimum start may be preferred options.

Installation

Installing condensing boilers should not present any difficulty to an experienced heating engineer, providing the manufacturer's instructions are followed. A connection to the household drain is essential to remove condensate and this can be run through a 'U' trap. To avoid freezing in cold weather the drain should be either run within the building, or alternatively a small syphon can be used. A sufficient drop on all pipe runs should be allowed to prevent blockage.

Condensing boilders can in certain conditions be prone to 'pluming' from the flue terminal and this can be excessive in large installations. In general it is better to site flue stubs away from doors and windows, as far as possible.

Economic assessment

A new housing scheme built by Manchester City Council featured Stelrad 'Ideal Turbo' condensing boilers[1,2]. For purposes of the demonstration the houses were divided into three groups of 10. Each of the houses contained a full wet central heating and domestic hot water system. Group A, the 'control' group, contained a modern conventional cast-iron boiler. The two test groups, B and C, were both fitted with Stelrad condensing boilers. Group C was especially enhanced to optimise system performance, and comprised 100% over-sized radiators and a high efficiency hot water cylinder.

Fig. 2 shows the relative savings made by the condensing boiler groups in relation to group A. Group C (the enhanced group) showed the highest energy saving over the monitoring period, averaging 24 GJ per year (25%). Group B showed a slightly smaller saving of 21 GJ per year (22%). In cash terms the annual savings are worth £77 and £86 for groups B and C respectively, based on the gas price of £3.65 per GJ.

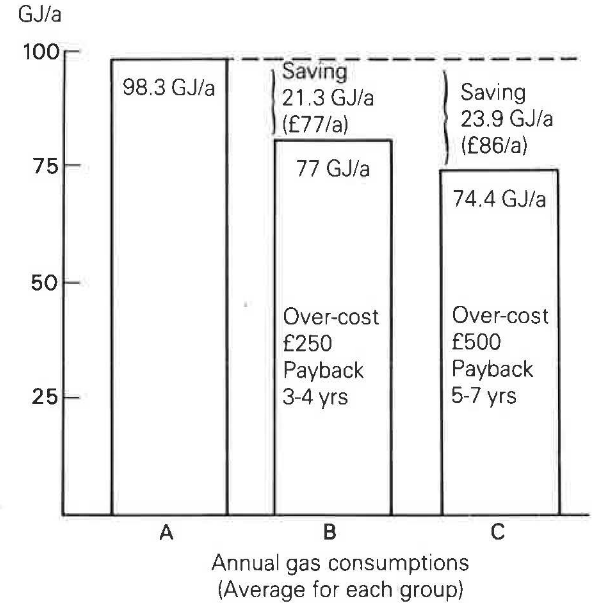

Fig. 2 Relative savings compared with group A

System efficiency

The annual system efficiencies averaged 86.5% and 88.9% for groups B and C compared with 67.2% for group A. The relationship between boiler input and efficiency is shown in Fig. 3. The condensing boiler groups are relatively unaffected by load, except at very low loads; but the conventional group showed a marked fall off in performance as the load decreased.

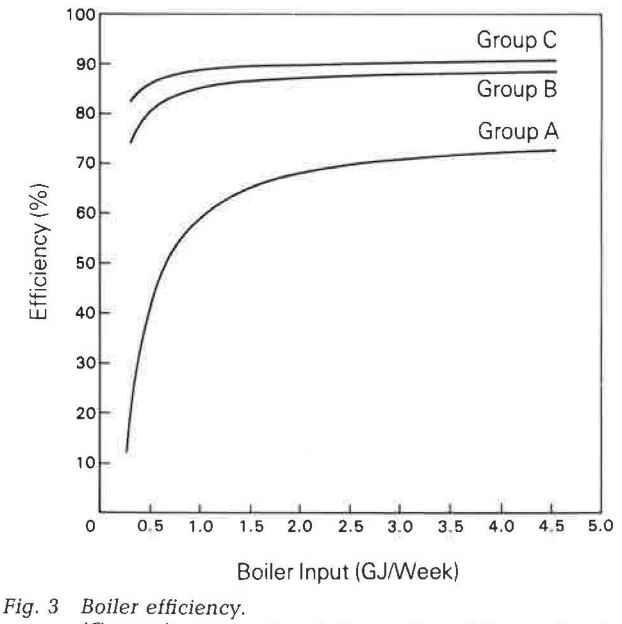

Fig. 3 Boiler efficiency.
(Group A – conventional, Groups B and C – condensing)

Simple payback

Simple payback, relates the over-cost of the equipment to the annual savings achieved[3]. In the case of group B the over-cost of £250 is entirely due to the use of the condensing boiler. On the annual savings achieved (£77), the payback for group B is 3.4 years. The savings for group C are higher (£86) but so is the over-cost (£500) due primarily to the extra cost of over-sized radiators. The simple payback for the enhanced system of group C is nearly 6 years. Within the anticipated life of the boiler (16 years) even a payback of 6 years is a very attractive investment.

Internal temperatures

The monitoring also showed that all three groups maintained broadly similar internal temperatures, about 18.5°C averaged over a 24-hour period.

Replacement of 1970s plant

A sheltered housing site at Irlam, Manchester, owned by the Anchor Housing Association, has provided the opportunity for a demonstration involving the retrofitting of condensing boilers. The accommodation comprises two identical sheltered blocks each with 31 flats, a warden's flat, common room and laundry. Each block has a plant room with centralised heating services providing space and domestic hot water heating.

One block, St Clement's Court, is equipped with modern, conventional dual Potterton boilers for space heating and two rapid recovery hot water heaters for domestic hot water. The second block, Holly Court, contains two Broag condensing boilers for space heating and similar domestic hot water heaters manufactured by Andrews Industrial Ltd. The space heating and domestic hot water boilers are separately flued.

Monitoring has shown that the condensing boilers in Holly Court have used about 22% less gas for space heating than the conventional boilers in St Clement's Court. In terms of gas consumption this represents a saving of 235 GJ per year, worth nearly £860 at the gas price of £3.65. Based on the energy savings so far achieved this is expected to lead to a payback on over-costs (£2,500) in about 3 years. Fig. 4 shows the monthly gas consumption for space heating in each block during a typical year.

Marketing opportunities

Cost-effective investment

Condensing boilers can be a cost-effective and worthwhile investment both for the private and public sector investor. In the private sector the owner occupier is likely to pay the fuel bills and will benefit directly. In the public sector the tenant will benefit through reduced fuel bills. But the building owner also benefits because the tenant is provided with heating at a more affordable price and is less likely to complain because of inadequate heating standards. In addition the tenant is more disposed to take greater care and interest in the home and also of the immediate environment. The reduced heating cost may be taken in better comfort standards with elimination of mould growth, for example. In both cases the tenants are more contented and complaints are reduced.

In extreme cases for homes that are classified as 'hard to heat' the condensing boiler may be the only practical energy efficient measure to employ. The cases of litigation for the provision of inadequate heating standards in public sector housing are increasing. The condensing boiler is a relatively simple solution to improving standards where other measures may be less practical.

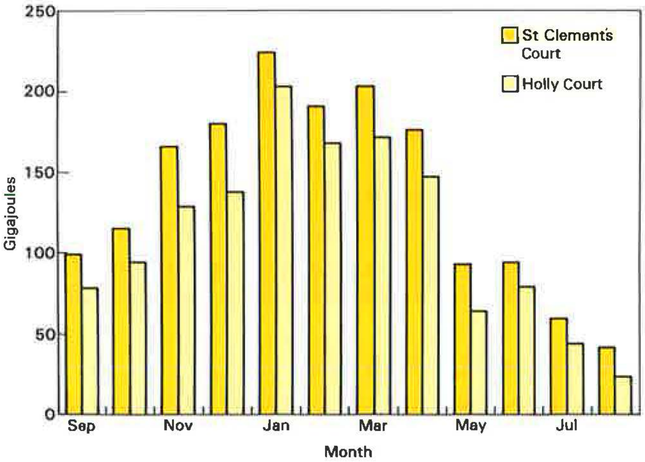

Fig. 4 Typical monthly gas consumption (Condensing boiler in Holly Court only)

Replacement market

The largest market for the immediate future is the replacement market. It is estimated that by the early 1990s there will be well over one million boilers sold in the UK each year, of which about 700,000 will be gas boilers. Most of these boilers will be required by the replacement market and it is likely that a large proportion could usefully employ a condensing boiler. It is in the interest of the users that their boilers are replaced by the most energy efficient appliances available.

The future strategy is to ensure that the industry and the end user are receptive to the condensing boiler. This means that the user must be educated into knowing about the fuel saving advantages of condensing boilers. The trade must be suitably equipped to supply and install condensing boilers, and there must be a range of suitably sized appliances at competitive prices.

Fortunately, the manufacturers have a well developed and comprehensive range of domestic gas-fired condensing boilers. On the commercial scene the list of manufacturers offering condensing boilers increases each year. Many of these boilers are imported from the continent and the relaxing of trade restrictions in 1992 may see other manufacturers looking at the UK as a valuable potential market.

Marketing objectives

Users

To open up the market in the UK two major activities must be implemented: the education of users, and providing the trade with the tools to do the job. The user has to be in a position to demand that a condensing boiler is installed, rather than a direct replacement boiler. To be able to do this the user has to be sufficiently familiar with the choice of products on the market and to know something of their potential savings. Several approaches have already been used to raise user awareness, for example a collaboration with the Consumers' Association to produce a guide on energy saving home improvements for subscribers to *'Which?'*[4].

Installers

In the case of the installer, there is also a fundamental need to raise the level of awareness. To target the heating industry, seminars on the subject of condensing boilers have been held at different venues around the country. The seminars included presentations on various topics including case studies of well monitored applications and an exhibition of boilers and related products. The results indicate that these seminars provide a useful and unbiased appraisal of the technology for potential installers and specifiers.

Various publications are also in preparation, largely aimed at the installer. These will take the form of guides, produced in collaboration with the representative bodies for the industry, e.g. CIBSE and HVCA. One has already been produced in conjunction with CIBSE and other guides are planned[5].

Conclusions

Condensing boilers are more efficient than conventional boilers. Substantial energy savings are possible with the resulting reduction in fuel bills and the recovery of the investment over-cost in a few years, well within the boiler's lifetime. A large potential market has been identified for these appliances. But in order to take advantage of this market there is a need to educate the end user and to ensure that the building services trades are sufficiently knowledgeable to specify and install condensing boilers when the demand arises.

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