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Nitrous oxide reduction with the Weishaupt flue gas recirculation (FGR) system

A report from the Weishaupt Research and Development Institute for Oil and Gas Firing

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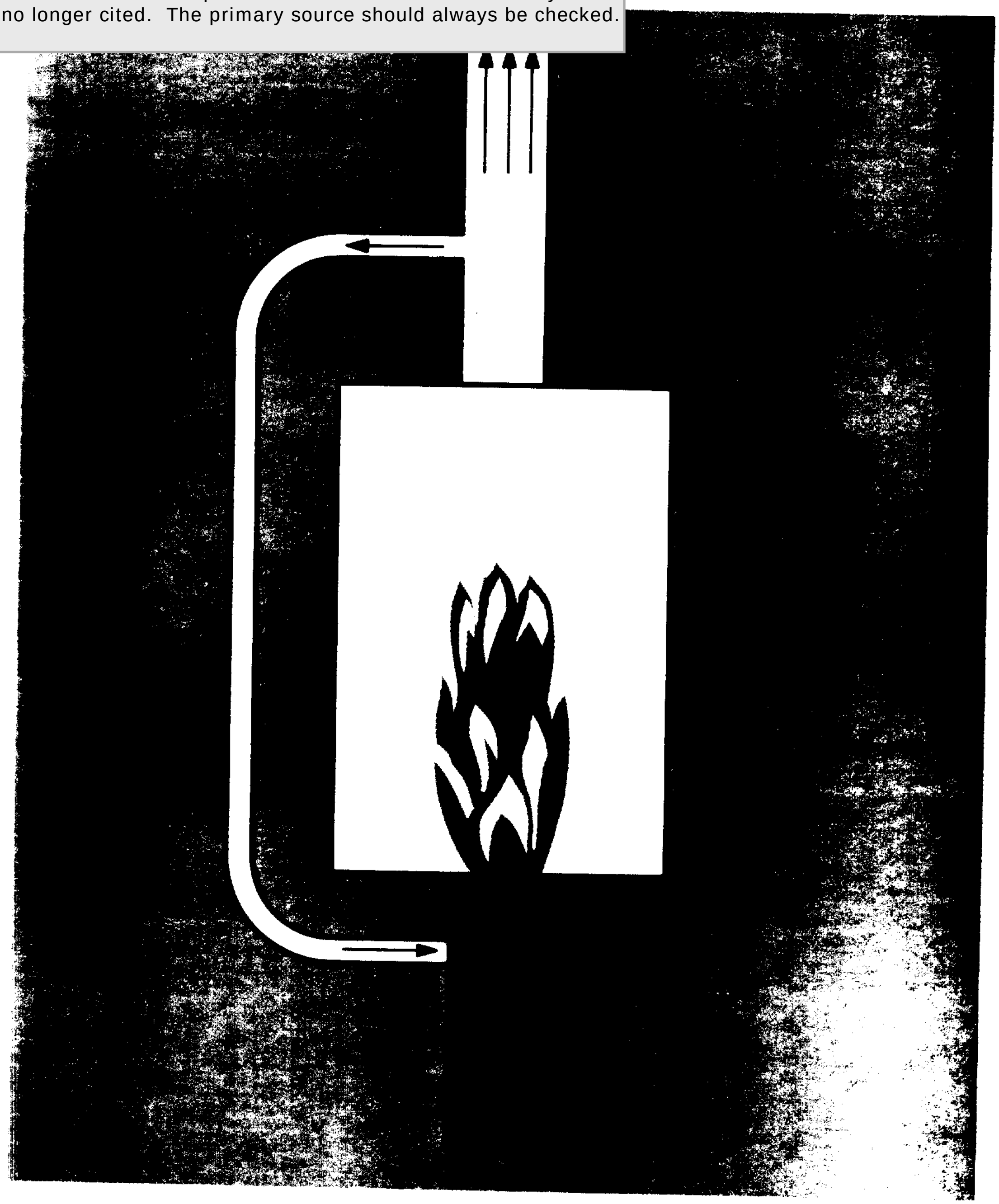

Introduction

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One of the results of burning fossil fuels is that nitrous oxides (NO_x) are formed. These contribute to the pollution of the environment. Nitrous oxides usually consist of approx 95% nitrogen monoxide (NO) and approx 5% nitrogen dioxide (NO_2). Basically with gas oil and gas, the nitrous oxides are thermally formed at temperatures over approx 1300°C by the oxydation of the nitrogen in the combustion air. The free oxygen concentrations during combustion are mainly responsible for this so-called thermal NO formation.

NO can also be formed by the oxydation of the nitrogen compounds in the liquid fuel. In comparison to residual oil S, in gas oil the amount of nitrogen is low. The nitrogen content in gas oil is on average 130 mg/kg, as numerous oil sample tests have shown.

As far as oil and gas combustion systems are concerned, the amount of NO_x as a proportion of the total pollution is relatively small. On the basis of information available for 1984, the amount of NOx emitted by all combustion systems with gas oil totalled 2.4% of the total emission, to which those oil fired installations not requiring approval (domestic and small consumers) only contributed 2%. The amount of NO_x emitted by gas fired installations was 3% of the total emission. Gas fired installations in the domestic and small consumer sector had a share of about 1.1%.

Although oil and gas fired systems are only responsible for a small part of the total nitrous oxides emitted, Weishaupt have been increasing their endeavours to reduce NO_x emissions. This started at the beginning of 1985 with an intensification of development in this field.

Principles and experiences

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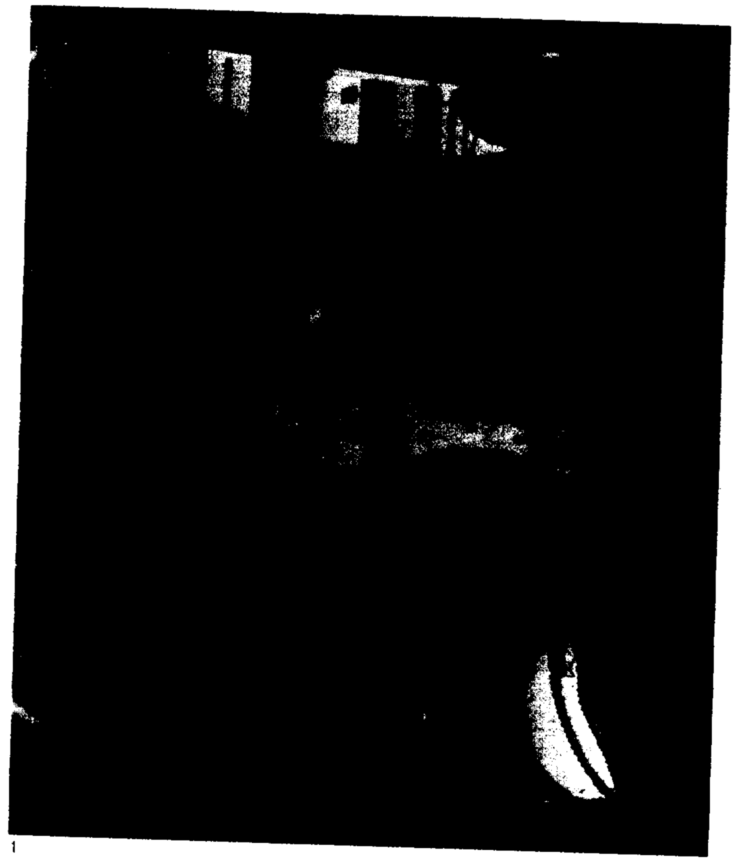
There are basically two different methods of reducing nitrous oxide emissions: primary and secondary methods.

The primary method prevents the formation of NO during the combustion process, whereas the secondary method removes the nitrogen from the flue gas by suitable subsequent treatment, without affecting the combustion process.

Primary methods of reducing NO_x in oil and gas combustion systems are utilised for reasons of cost. One of these methods is the so-called flue gas recirculation (FGR), where part of the flue gas is returned to the burner. This flue gas recirculation on the one hand reduces the flame temperature and, by adding flue gas which contains relatively little oxgyen, the percentage of oxygen decreases (reduction of O_2 partial pressure). This quite considerably reduces the thermal NO formation which occurs with this type of combustion. This method of flue gas recirculation for reduction of NO_x has been known for a long time and has often been used on combustion engines and combustion installations. In 1985 we carried out tests at our Weishaupt Research and Development Institute on an industrial burner type WK40 rated at approx 2500 kW, in order to investigate the affect of flue gas recirculation on the formation of NO on oil and gas burners of medium or small ratings (Fig. 1).

The photo shows how the test was constructed. Part of the flue gas behind the boiler was removed by means of a fan and supplied to the burner. The tests were carried out with natural gas and gas oil EL at various flue gas recirculation rates. It was possible to reduce NO_x emissions with gas oil and natural gas by 40%, at a flue gas recirculation rate of under 20% (Fig 2).



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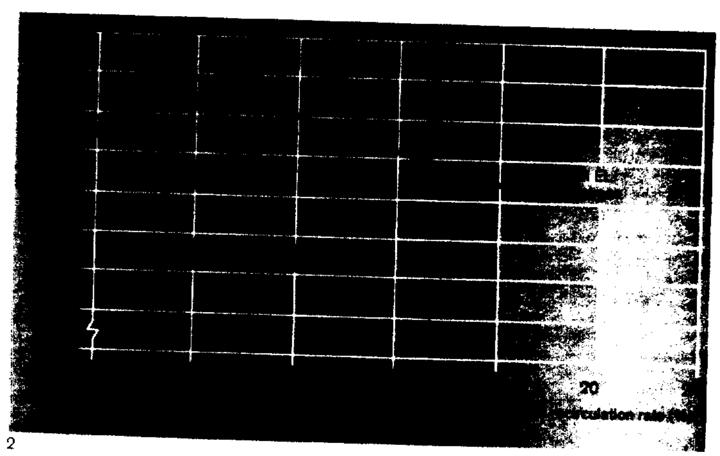

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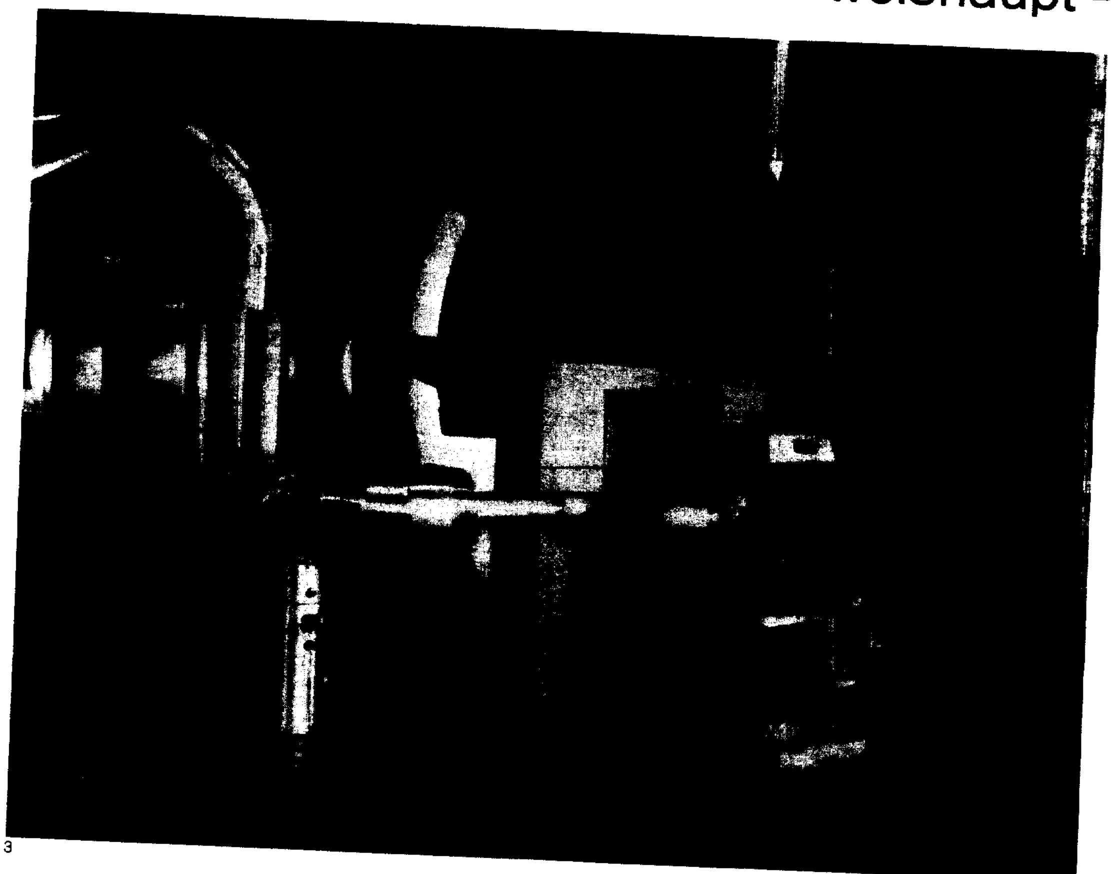

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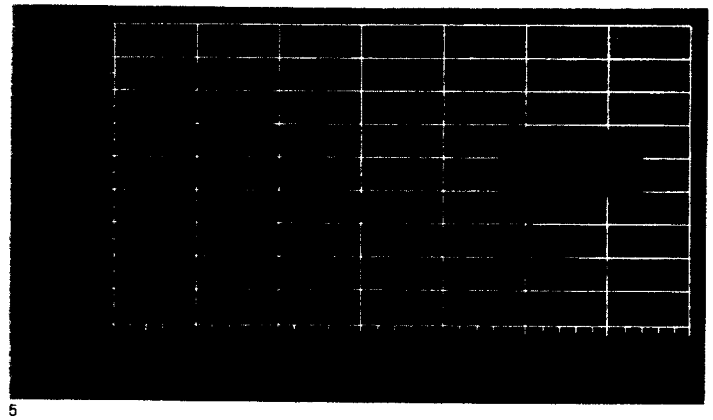
On the basis of these test results, a dual gas burner (natural gas and liquid gas) type WKG3 rated at 8.9 MW and fitted with flue gas recirculation (FGR), was supplied in October 1985 to the gas suppliers Filstal mbH in Göppingen (GVF) and was commissioned at the beginning of 1986.

The plant consisted of a total of three boilers each with a rating of 8 MW and provided heat for the US barracks in Göppingen. Each boiler was fitted with a WKG3 dual gas burner (Fig. 3,4).

On boiler 1 with external flue gas recirculation (FGR), part of the flue gas was added to the combustion air on the pressure side of the burner by means of a flue gas return fan.

NO_x figures of 110 to 140 mg/m$_n^3$ were recorded for natural gas with standard burner settings. These figures were well below the limit of 200 mg/m$_n^3$ set by TA-Luft. With liquid gas operation, NO_x figures ranging from 180 – 230 mg/m$_n^3$ were obtained according to the burner rating. During commissioning of boiler 1 with flue gas recirculation, the effect of the recirculated flue gas on the formation of NO_x at various ratings was investigated first (Fig. 5). As can be seen from the chart, the NO_x emission on natural gas operation could be reduced by 70% with the aid of the flue gas recirculation, with limiting figures of up to 35 mg/m$_n^3$ being recorded for NO_x. These figures were obtained at the maximum possible flue gas recirculation rate, at which the flame was still stable.

After these basic tests with both fuels, the flue gas quantity was then set in relation to the burner rating via a cam. The results are shown in Fig. 6. Allowing for optimum combustion behaviour for both fuels, a flue gas recirculation rate of 16% in relation to the standard condition was obtained at full load. An NO_x figure of about 70 mg/m$_n^3$ was recorded with natural gas. This figure is already approx 30% below the limit required to obtain the "Blue Angel" environmental award for forced draft gas burners in combination with boilers.



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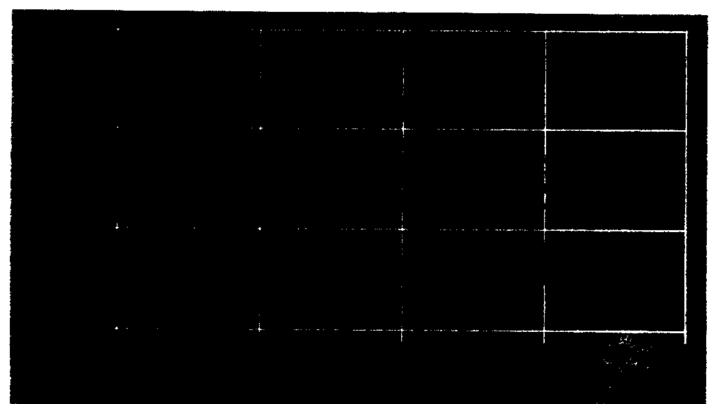

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Using flue gas recirculation, NO_x figures of 85 to 120 mg/m$_n^3$ were recorded for liquid gas (propane). These figures were clearly below the limit set by TA Luft. The installation at Filstal has been running since the beginning of 1986 without problems.

The installation, as described above, has shown that it is possible to reduce NO_x emissions by adding part of the flue gas to the combustion air. This type of flue gas recirculation on the one hand involves considerable commissioning expense, particularly with multiple fuel combustion and it can also have an adverse effect on contamination, corrosion and flame monitoring depending on flue gas temperature and quality. That is why Weishaupt have developed a new FGR system which has considerable advantages over the method described above and can be used on both mono- and duobloc burners.

As well as this "Weishaupt FGR system", Weishaupt also offer a "Simplifed FGR system", which can be used on gas burners of small and medium ratings in particular.

The "Weishaupt FGR system"

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With this system, part of the flue gas (approx 15 – 20% at full load) is introduced into an intermediate flange (between burner flange and burner assembly plate) using a recirculation fan (Fig. 7). The flue gas flows through the space between the flame tube and a second tube. It enters the flame direct via drilled radial holes. The recirculated flue gas quantity is adjusted in relation to the burner rating by a control valve via a parallel controller.

With this method of introducing the flue gas, the burner and all its moving and monitoring parts do not come into contact with the flue gas. It remains clean and dry, irrespective of the flue gas temperature and quality. Partial condensation of the flue gases in the burner is not possible with this system and therefore corrosion is not a problem.

Due to the optimised addition of the flue gases to the flame, the combustion air and fuel mixing process remains unaffected. There are no problems with flame stability. As the flue gases are not introduced until after the mixing head, a reduction in capacity of only about 5% can be expected, which is due to the increase in boiler resistance.

The system has been tested at the Weishaupt Research and Development Institute on the RGL70 burner (Fig 8), since when it has been supplied several times. Fig. 9 shows a schematic diagram of the FGR system. Fig 10 shows the results obtained on the RGL70 burner with gas oil EL, natural gas H and liquid gas (propane). At a burner rating of 9000 kW, NO_x figures of about 145 mg/m_n^3 were recorded for gas oil EL, for natural gas H 65 mg/m_n^3 and for propane 130 mg/m_n^3. The reduction rates were about 35% for gas oil EL and about 50% for gas at full load. At partial or intermediate load, the NO_x figures could be reduced by 70% depending on the type of fuel.

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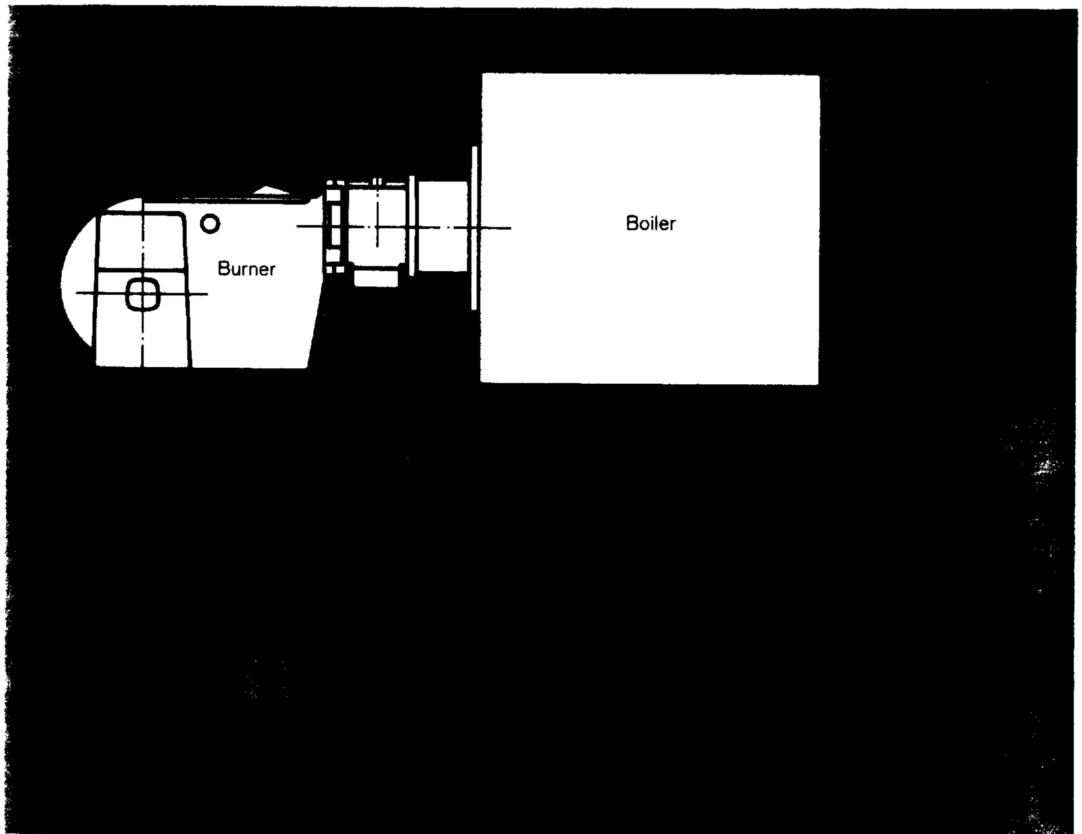

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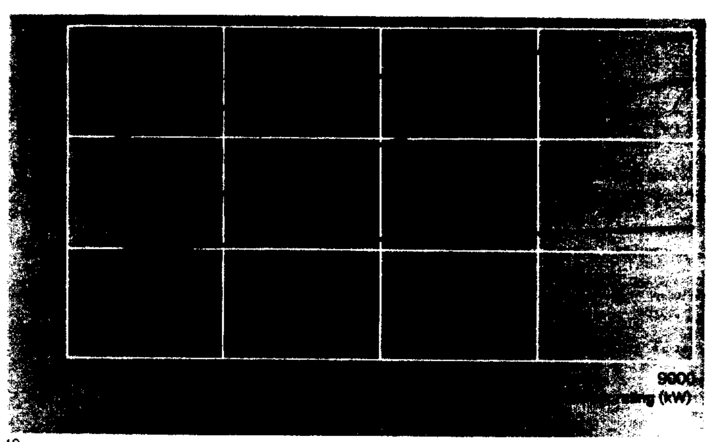

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Schematic diagram of Weishaupt FGR system

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NO_x emission in relation to burner rating on RGL70 with FGR

——— Natural gas H
– – – Propane
- - - - - Gas oil EL

The "Simplified FGR system"

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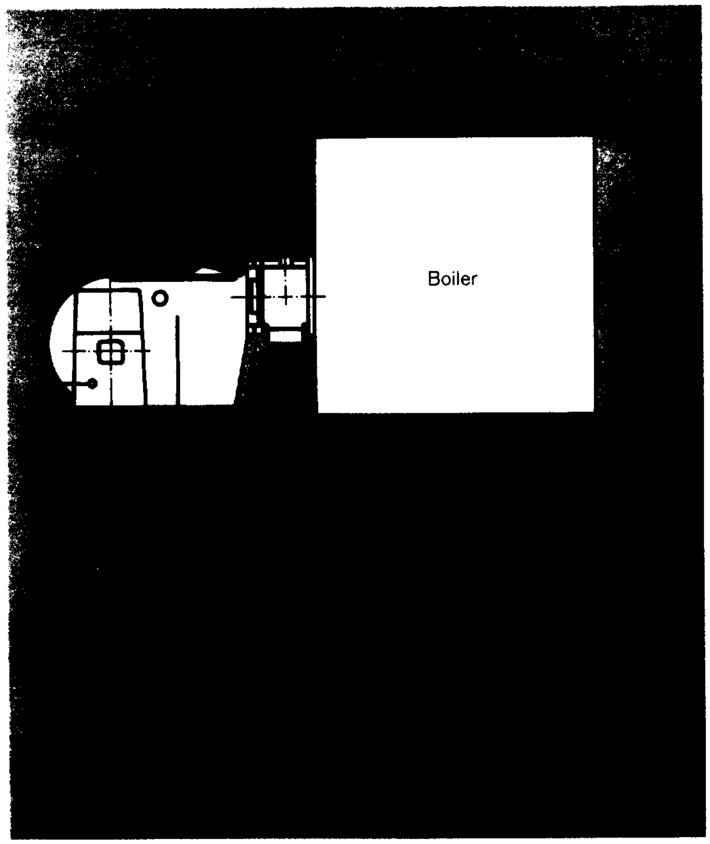
With this system, part of the flue gas is taken in by the integral burner fan and added to the combustion air (Fig. 11). The recirculated flue gas quantity is essentially determined by the negative pressure in the suction area of the air fan. The application of this system is basically limited to gas burners due to the danger of corrosion and contamination. Even with gas combustion, it can be expected that the temperature in the burner will fall below dew point, depending on the air temperature and humidity as well as the flue gas temperature and recirculation rate. Whereas with the gas burners that are controlled on the pressure side, such as the G1 and G3, the flue gas quantity does not have to be controlled in relation to the capacity, on burners controlled on the suction side (from size G5), the flue gas quantity must also set by a control valve.

Fig 12 shows an example of the NO_x figures for a G3 burner with flue gas recirculation. For natural gas the NO_x figure of 110 mg/m_n^3 (62 ppm "oxygen free dry") at full load without FGR was reduced to a figure of 56 mg/m_n^3 (32 ppm "air free dry") due to the use of FGR.

It must be stated in conclusion, that a substantial reduction in NO_x emission is possible using the FGR system. With the introduction of two systems, Weishaupt are making their contribution towards a reduction in the environmental pollution caused by the combustion of oil and gas, even though this is already low.



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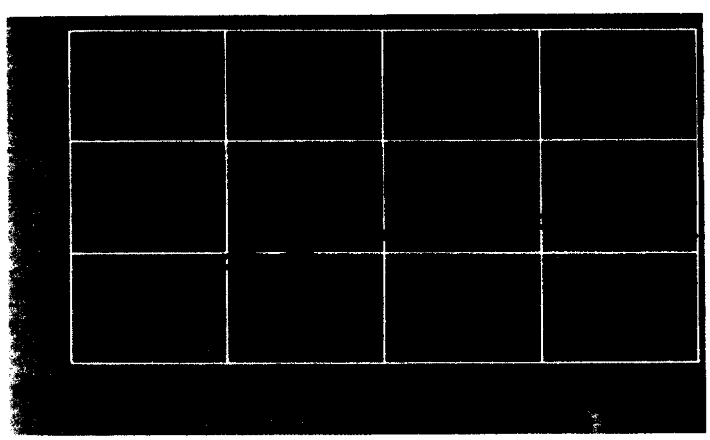

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11
Diagram of the simplified FGR system

12
Results of G3 gas burner with FGR

——— Natural gas H
— — — Propane