Coal Research. The authors wish to acknowledge the efforts of Dr. W. E. Young in directing the small scale test program and of Mr. James Pavel in obtaining the data from the full scale combustor rig.

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DISCUSSION

G. P. Wachtell[3]

The development of systems whereby coal may be used to supply the fuel for gas turbines is of great importance because it offers the possibility of retaining the advantages of gas turbines for peaking electric generating stations while using a plentiful fuel in place of natural gas, for which supplies are scarce. The authors are to be commended for their detailed study of the effect of the heating value of the gas on emission of CO and NO_x. It is encouraging that production of NO_x is found to be reduced by using a low-Btu gas.

The authors' discussion of Fig. 7 shows that even with low exit temperature, there is sufficient residence time for burnout of CO, provided enough oxygen is present. On the other hand, a high flame temperature tends to produce NO_x. Clearly the maximum temperature in the combustion chamber must be at least as high as the exit temperature. This suggests that NO_x production can be minimized by seeing to it that the temperature never exceeds the exit temperature. This can be accomplished by premixing the fuel gas and combustion air. Premixing of a lean mixture will ensure that oxygen is present throughout the combustor, so that the maximum opportunity for burnout of CO is provided. Premixing requires that the velocity of the gas mixture be high enough to prevent burning between the point of mixing and the intended flame location, and would have to be done over a range of operating conditions. It may, therefore, be easier said than done. Nevertheless, it could be worth looking into. One might consider premixing some fuel and air, and admitting other fuel and/or air separately as a way to accommodate varying load conditions.

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While increasing the exit temperature results in generating more NO_x (Fig. 13), it will also result in producing less CO (Fig. 7), provided that the increase in exit temperature can be accomplished without having a large rich zone. The authors' conclusions suggest measures that will have this result; namely, heated fuel gas and supplementary firing of high heating value fuel. To this, one may add the suggestion of enriching the combustion air with oxygen. For a given fuel/oxygen ratio, this is equivalent to removing nitrogen, and will therefore yield a higher temperature.

Finally, one may consider heating the compressed air to the highest temperature that is economically practical by means of a coal-fired air heater. This would reduce the amount of fuel gas required, thereby ensuring a lean mixture. It would also reduce the size of the gasification plant needed for a given turbine, compensating at least in part for the cost of the coal-fired heater.

Authors' Closure

The authors wish to add a cautionary note to Wachtel's favorable comments regarding the use of low heating value coal gas in gas turbines for peaking service. The cost of a gasification plant is sufficiently large that operation in the vicinity of at least 3000 hr per year is recommended in order to justify installation. Through use of a heat recovery steam generator in the gas turbine exhaust, plant efficiency is high enough to make such intermediate duty service practical.

It is agreed that premixing of air and fuel offers a promising long-term solution to the problem of NO_x emission from oil or natural gas fired combustors. It does not appear that this step will be necessary when the fuel is low heating value coal gas, however, since little NO_x is formed in burning such gas. Wachtel suggests adding oxygen to the combustion air or preheating it with a coal fired heater to assure CO burn-out in the gas turbine combustor. The authors prefer the concept of heating the fuel gas instead, as a more attractive solution economically.