BEST PRACTICE BROCHURE

Longannet Power Station

FEBRUARY 2000

dti
Department of Trade and Industry

CLEANER COAL TECHNOLOGY PROGRAMME

Best Practice Brochure 001

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Best Practice Brochure: Longannet Power Station

Figure 1. Longannet Power Station (Courtesy of ScottishPower)

INTRODUCTION

Coal currently meets more than one quarter of the world's energy needs, with about 37% of the world's electricity supply being produced from coal. Power station consumption from coal increased by 136% between 1971 and 1995, and is forecast to increase by a further 110% between now and 2020. Combustion of any fossil fuel releases significant quantities of carbon dioxide (CO_2), as well as oxides of sulphur (SO_x) and nitrogen (NO_x), and particulate matter. Furthermore, there are emissions of trace metals and toxic organic compounds to deal with when using and returning used water to natural sources and disposing of incombustible material.

The environmental implications of fossil fuel combustion have led governments to develop policies for reducing these impacts. Limits for particulate matter, SO_2 and NO_x have been established in many countries. Due to this, power generators continue to actively investigate various ways of reducing emissions. Reductions can be achieved by installing very expensive state-of-the-art technologies or simply by operating plant at optimal conditions to improve the overall efficiency.

This best practice publication describes the techniques and technologies used by Longannet Power Station in Scotland to operate the plant within legislative requirements, and the resulting benefits.

LONGANNET POWER STATION

ScottishPower became operational in 1990 as part of the restructuring of the electricity supply industry in the UK. The company has 15 power stations, utilising a variety of generating technologies: hydroelectric, wind farms, gas turbines and coal combustion. The flexible variety of fuel gives ScottishPower an established and varied generating capacity, which is backed up by a transmission and distribution system.

Longannet Power Station is ScottishPower's largest pulverised fuel (pf) plant. It was built in the mid-1960's and was fully operational by 1973. It is on 30 hectares of land that was reclaimed from the River Forth using fuel-ash from Kincardine Power Station situated upstream. This location was selected because of the availability of water for use in the cooling system and the availability of coal.

Scottish Coal's Longannet Mine Complex is the major supplier of coal to the station, which can consume up to 4.5 million tonnes of coal annually. Coal is delivered directly from the mine to the coal store, which can hold over 2 million tonnes, while the conveyor system linking the coal store and the boiler house is capable of carrying 3500 tonnes per hour. All coal carried by the conveyor system is automatically weighed and sampled, magnetically searched for tramp iron and passed through trash screens to remove large items. Coal can also be delivered by road or rail. The conveyors feed the coal bunkers that are located at a high level in the boiler house. The bunkers feed directly to the roller mills before the pf is fed to the burners.

Longannet has four 600MW Foster Wheeler front-wall-fired boilers, each serviced by eight 40 tonne per hour roller mills. The boilers currently burn ~250 tonnes per hour at full load. Each unit has two 300MW GEC generators, two forced draft (FD) fans and two induced draft (ID) fans. The load factor is about 50%. All four units have been fitted with low-NO_x burners, supplied by ABB Combustion Ltd. There are four rows of burners, each with eight burners on the front wall. The burners are rated at $67MW_{th}$ each.

Generation efficiency is ~37% in net calorific value (CV). Approximately 1800 tonnes per hour of high-temperature steam is produced at a pressure of 168bar and a temperature of 568ºC, making Longannet a subcritical pf plant. The heated steam passes to the turbines, each consisting of two $300MW_e$ generators.

Table 1. Calculating costs associated with improving plant efficiency

No. of hours' operation in a year at 60% availability	364 x 24hrs/day x 0.6 = 5,256hrs
Heat input in a year with 38% thermal efficiency	$\frac{600MW \times 5{,}256\ hrs \times 3{,}600\ s/hr}{0.38} = 2.9876 \times 10^{10} MJ$
Heat input in a year with 37% thermal efficiency	$\frac{600MW \times 5{,}256\ hrs \times 3{,}600\ s/hr}{0.37} = 3.0684 \times 10^{10} MJ$
Savings between 37% and 38% efficiency	$3.068 - 2.9876 = 807 \times 10^6 MJ$
Savings in coal	$807 \times 10^6 MJ \times \frac{kg}{24{,}000\ kJ} \times \frac{1000\ kJ}{MJ} \times \frac{tonne}{1000\ kg} = 33{,}640\ te$
Savings in cost of fuel, assuming coal is £30/tonnes, per unit	33,640tonnes x £30 = £1.01 million per annum
% saving in fuel	$\left(\frac{3.0684 - 2.9876}{3.0684}\right) \times 100 = 2.6\%$

Approximately 327,000m^3 of condenser-cooling water can be drawn from the Forth River every hour. This water is passed through coarse screens, before being circulated by four electrically-driven pumps. On its discharge from the station, the cooling water is fed via a mile-long cooling channel into a wide part of the Forth, where the heat acquired in the station is dissipated and has no harmful effect. The demineralised water circulated in the boiler tubes is operated on a closed cycle. Losses are made up from a semi-automatic de-ionisation plant, which is capable of treating 218m^3 of water every hour.

WHY BEST PRACTICE?

Improved Efficiency

A good way to show why best practice is important with regard to thermal efficiency is by calculating savings. Table 1 shows the effect of increasing the efficiency of the unit by 1% (eg from 37% to 38%). In the example, a 600MW$_e$ unit has a load factor of 60%, availability of 90% and uses coal that has a CV of 24,000MJ tonne^{-1}. This unit can expect a saving of about £1.02 million per annum in coal costs alone for a 1% increase in efficiency.

In conjunction with the fuel savings, best practice can also lead to other improvements, eg:

- improved environmental performance
- reduced production costs
- reduced energy consumption
- improved availability.

These are discussed below.

Improved Environmental Performance

Using Table 1, it can be assumed that 2 tonnes of CO_2 is produced from 1 tonne of coal during combustion; therefore CO_2 emissions would be reduced by ~67,000 tonnes per annum.

In conjunction with this, various new technologies are now available that assist with the reduction of both particulate and gaseous emissions.

Reduced Production Costs

Fuel accounts for about 45-55% of the cost of electricity generated and 60-80% of the operating cost in a pf power plant. As shown in the example in Table 1, there would be a reduction in the cost of fuel (~£1.0 million per annum for one unit).

Reduced Energy Consumption

Energy consumption can be reduced by good practice through a good maintenance and operation strategy. A well-maintained plant, for example, will have reduced excess air due to well-sealed ducts and boiler plant components. A good operation strategy will ensure that the plant is operated at optimum conditions, thus getting the maximum energy out of the fuel as cost-effectively as possible.

Improved Availability

Availability refers to the amount of time the plant is actually operational. Good practice will inevitably lead to a power plant that is in good working condition and that will therefore have good availability. Plant that is continuously monitored, perhaps through a programme of condition monitoring, will ensure that forced outages through tube leaks or wear and tear in the mills are kept to a minimum.

Although each of the issues above have been discussed as separate items, in a well maintained and well operated plant, good availability means the plant is operating longer and more income is generated. Keeping the production costs down means more income is generated. Also, the plant will not have to drop load to operate within the emission limits, leading to increased income generation.

WHAT IS GOOD PRACTICE IN THIS CASE?

Longannet is a fairly old plant in terms of the number of years it has been generating electricity. However, as a result of the substantial technological and operational improvements that have been made over the years, Longannet is capable of generating electricity for a further 20-25 years, thus exceeding the normal life expectancy of a fossil fuel power plant. The major technological advances at Longannet include:

- installation of low-NO_x burners
- installation of gas reburn for NO_x reduction
- major electrostatic precipitator (ESP) refurbishment.

In conjunction with major technological changes, Longannet has also installed a number of systems for improved plant operation. These include:

- upgrading the boiler control rooms
- installation of the Ultramax® boiler optimisation system
- installation of the Longannet Operational Management Improvement System (LOMIS).

These various technological and operational improvements are discussed in more detail below.

TECHNOLOGIES

Particulate Reduction: Electrostatic Precipitators (ESPs)

Most power plant use ESPs for the removal of particulate emissions. The horizontal flow type is the most widely used. Figure 2 shows the general features of an ESP. The ESP contains collector plates that are positively charged. The negatively charged discharge electrodes are suspended midway between the collector plates and are energised to approximately 70kV. This produces an electric field between the collector and discharge electrodes. When the flue gas passes through the ESP, particles of ash collide with the negative ions from the discharge electrodes and acquire a negative charge.

They are driven by the electric field to the positively charged collector plates where they are held by adhesion. Periodically the plates are mechanically rapped and the particles are discharged into the hoppers.

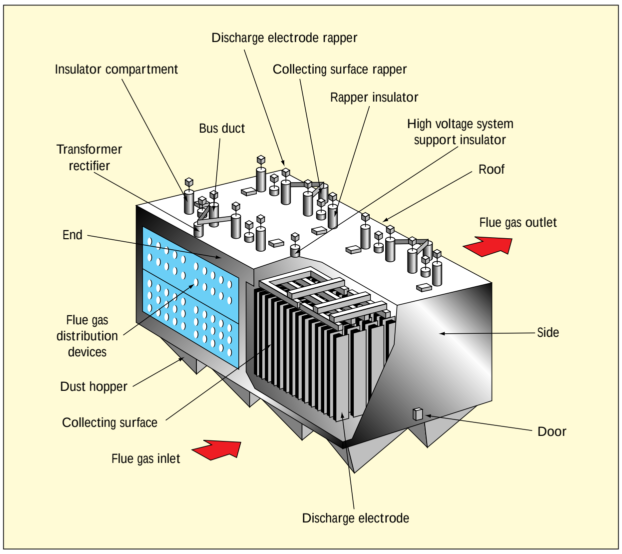

Figure 2. General layout of an ESP

The efficiency of the ESP is dependent on a number of factors, generally summarised by the Deutsch-Anderson equation.

$$e = 1 - exp\left(- \left(\omega k * \frac{A}{V}\right)^k \right)$$

where:

e = fractional ESP collection efficiency

A = collecting surface area (m^2)

V = gas flow rate ($m^3\ s^{-1}$)

ωk = effective particle migration velocity ($m\ s^{-1}$), k = 0.5 is a common value for fly-ash from coal firing.

Particulate Reduction: Sulphur Trioxide (SO_3) Injection

ESPs are capable of removing >99.5% of particulate emissions, which is normally sufficient to meet legislative requirements. ESPs are generally not effective with coals with a low sulphur content (<1%). This is due to the fly-ash particles having a high electrical resistivity (ie the ability the particle has to maintain its charge). Where this situation arises, flue gas can be conditioned by injection of SO_3, which then increases the dew-point level closer to flue gas temperature and decreases the resistivity. Figure 3 shows the relationship between fly-ash resistivity and flue gas temperature for flue gases with different dew-point temperatures.

SO_3 injection enhances the condensation of sulphuric acid (H_2SO_4) on the surface of the fly-ash and the reaction of the condensing H_2SO_4 on the fly-ash surface changes the particle surface electrical conduction characteristics. SO_3 is generally produced on site, by burning elemental sulphur to sulphur dioxide (SO_2) and passing the gas over a catalyst. Catalytic conversion is chosen mainly because it minimises the risks involved with handling the hazardous materials used in the system. Liquid sulphur is generally delivered by truck to a power station and the liquid sulphur is stored on site.

Prior to 1989, SO_3 conditioning equipment was installed on all the units at Longannet because they were unable to maintain the allowable particulate limits. After installation the limits were reached, but then from 1989 to 1994 the ESPs underwent a substantial refurbishment programme. This involved:

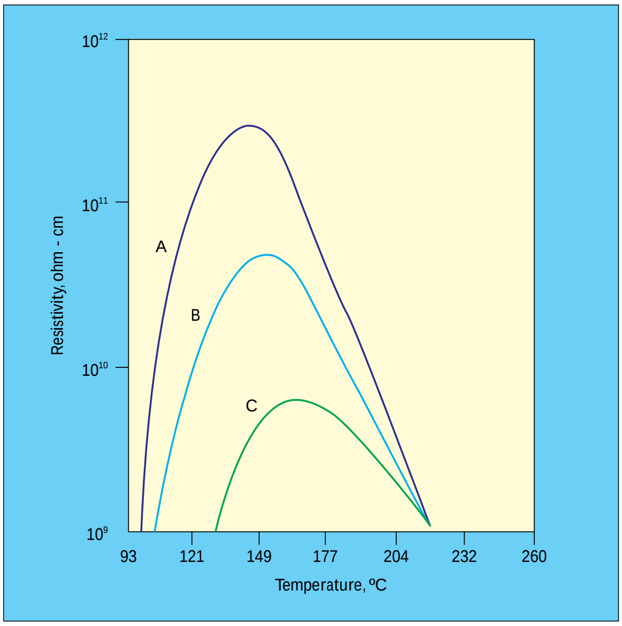

Figure 3. Relationship between resistivity and flue-gas temperature

- Replacing the internals of the ESP with new ones with wider spacing. The gap between the collector plates was increased from 200mm to 400mm.
- Installing new ESP digital controllers that make use of full-cycle pulse modulation. These replaced the old analogue controllers.
- The original transformer rectifiers (TRs) were replaced with new TRs, which increased the voltage ratings from 40kV to 70kV.

Results and Benefits

In most cases the removal efficiency of the ESP is increased and the emissions are reduced by a factor of ten when SO_3 conditioning is used.

After the ESP refurbishments, Longannet was able to meet the particulate emission limits more cost-effectively and without the use of SO_3 injection. This was due to a reduction in the auxiliary power to the ESP resulting from the installation of the new controller equipment and the reduction in auxiliary power for the SO_3 injection equipment.

Although SO_3 conditioning is effective in reducing particulate emissions, there is the problem of managing the production of SO_2 and SO_3, which are considered hazardous substances. Being able to run the ESPs without SO_3 removes this problem.

SO_2 Reduction

Longannet burns Scottish coal, which typically contains about 0.5% sulphur, compared to the average 1.6% sulphur in coal from elsewhere in the UK. This results in lower than expected SO_2 emissions. However, looking to the future, a number of different flue gas desulphurisation (FGD) methods have been investigated, which can remove up to 90% of SO_2 from the flue gases. Planning permission has been granted for the installation of seawater scrubbing (SWS), which was endorsed by the Scottish Environmental Protection Agency (SEPA) as the Best Environmental Option (BEO) and is likely to be fitted in Longannet in future years.

Results and Benefits

Although FGD is not required at this stage, once emission legislation becomes more stringent, FGD installation may be required. Longannet's location to the Forth and the sulphur content of the fuel makes it an ideal candidate for SWS, which has a number of positive environmental advantages over the more conventional limestone gypsum FGD processes. There is no requirement for a solid sorbent (like limestone), and therefore there will be no solid byproduct. This minimises the environmental issues relating to solids handling.

The other main advantages are that the design is simpler, and would be expected to have a lower capital and operating cost compared with the other traditional FGD processes.

NO_x Reduction: Low-NO_x Burners

Conventional pf burners have been developed over the years to give rapid mixing of the pf and air and to achieve high flame temperatures, with a view to achieving both combustion intensity and high combustion efficiency. The conditions are, however, favourable for the formation of NO_x.

NO_x emissions from all boilers (tangentially- and wall-fired) can be reduced by retrofitting low-NO_x burners. During the development of these burners, attempts were made to reduce temperature and oxygen availability by various means. Staged supply of air to the burners was found to be effective and this was used in the first generation of low-NO_x burners. Figure 4 shows the general principles of a low-NO_x burner.

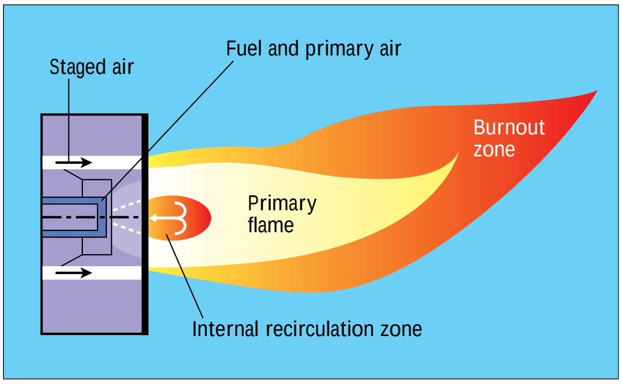

Figure 4. Principles of a low-NO_x burner

Generally, these burners are designed to delay combustion by the way in which the air and fuel are introduced. Oxygen is reduced in zones that are critical for NO_x formation and the amount of fuel burnt at peak temperature is also decreased. By staging the addition of air, coal is devolatilised under conditions of low stoichiometry, therefore promoting the conversion of fuel nitrogen to molecular nitrogen.

Results and Benefits

Several designs of low-NO_x burners have been developed. All units at Longannet have been installed with first-generation twin register swirl burners designed by ABB Alstom Power. The installation was completed in 1996 and NO_x emissions have been reduced by over 40% from their previous levels (See Figure 5).

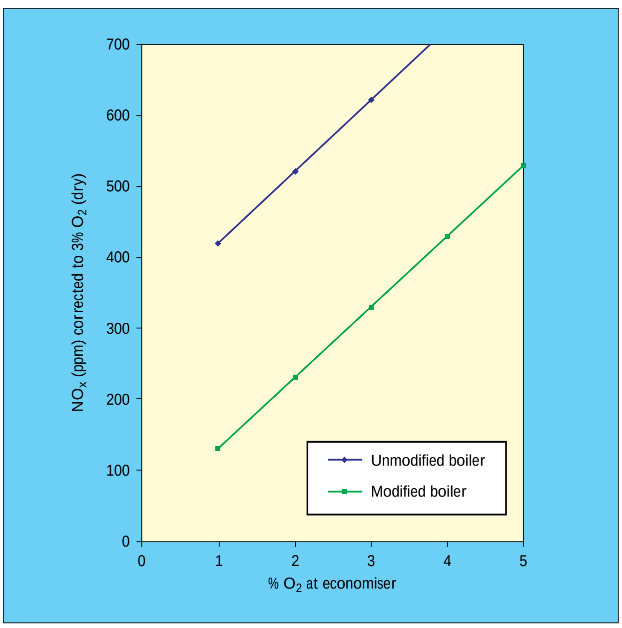

Figure 5. NO_x performance; unmodified vs modified (with low NO_x burners) 500MW wall-fired boiler

NO_x Reduction: Gas Reburn

A multi-partner European project led by ScottishPower aimed to demonstrate the economic and technical viability of gas-reburn technology. In 1996, Unit 2 was retrofitted with this technology, making it the largest application of the technology in the world and the first on a front-wall-fired boiler in Europe. This was made possible by funding received from the European Commission under the THERMIE Demonstration Programme in 1994.

Prior to installation of gas reburn, an initial assessment of technical and economic merits of NO_x-reduction technologies concluded that the performance characteristics of the Longannet boilers favoured gas-reburn technologies rather than selective non-catalytic reduction (SNCR)

In the gas-reburn process, the heat input by coal into the primary combustion zone of the boiler furnace is reduced to 80% of normal levels. The balance of heat required is injected (as natural gas) into the furnace above the primary combustion zone to create a fuel-rich reburn zone. The nitrogen oxide (NO) produced in the primary zone is reduced in the reburn zone, via a series of complex chemical reactions, to molecular nitrogen. Overfire air (OFA) is admitted to the boiler above the reburn zone to complete the combustion of any unreacted fuel (see Figure 6).

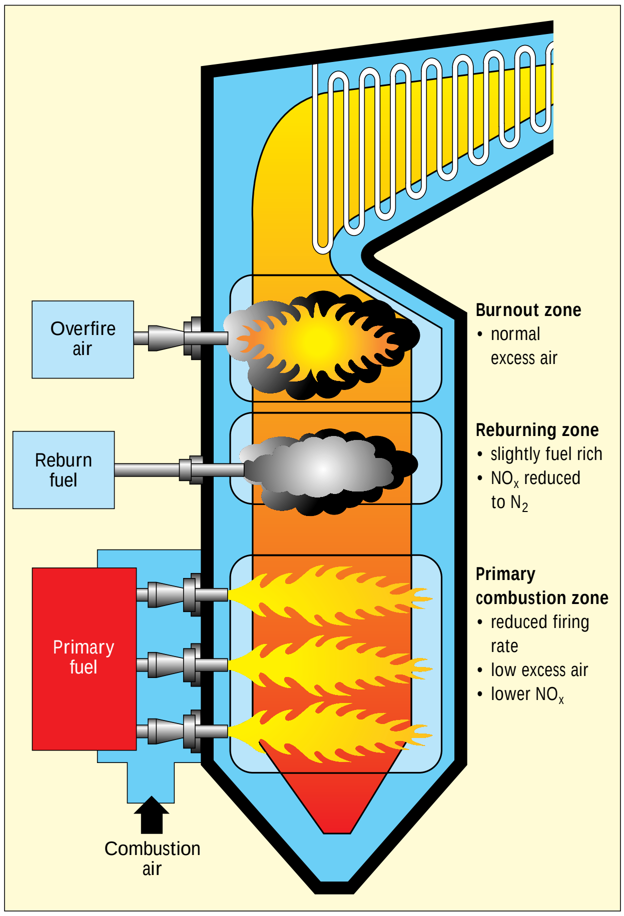

Figure 6. Principles of gas reburn

On Unit 2, eight gas injectors are installed on the front wall and 16 on the rear wall above the level of the top burner row. There are two OFA fans providing a supply of air from the existing boilers' secondary air system. The fans feed 16 OFA ports (12 on the front wall and two on each of the two side walls) which are situated on the level above the gas-reburn injection ports. The OFA ports supply excess air for the burning zone.

To increase the penetration of the reburn natural gas jets, about 6% recirculated flue gas (at a temperature of ~330ºC) from the boiler is also applied to the gas injectors. This flue gas comes from the boiler exhaust via a single flue-gas reticulation fan after passing through a grit arrestor.

NO_x reduction of up to 50% has been achieved with the installation of gas reburn, but the technology also brings other benefits in terms of reduced CO_2 and SO_2 through fuel substitution. An added bonus with the gas-reburn installation was that more stable combustion resulted from the system, yielding a flatter radiant superheater temperature profile and low carbon-in-ash concentrations.

Results and Benefits

The process design was validated at Longannet and has reached the anticipated levels of NO_x reduction ie NO_x reductions of up to 50%.

The technology brings other benefits in terms of reduced CO_2 and SO_2 through fuel substitution. For example, if 15-20% of coal is substituted for natural gas, a 6-9% reduction in CO_2 could be expected. It is expected that SO_2 could be reduced by up to 20%.

Natural gas contains no ash; therefore with gas reburning, the particulate loading is reduced (up to ~20%) in direct proportion to the amount of coal being displaced.

The commercial performance of the boiler has not been compromised by the installation.

More stable combustion resulted from the system, yielding a flatter radiant superheater temperature profile and low carbon-in-ash concentrations

OPERATION

Central Control Room

The nerve centre of operations is the central control room that has been refurbished since the early days of Longannet, to bring the benefits of modern computerised control to daily operations.

The room is fitted with the unit supervisory desks each provided with sufficient operating equipment to allow the main generating plant to come on-stream, to shut-down and for normal operation. Units are equipped with computer-based automatic boiler controls, on-line data processing equipment and alarm systems which serve to monitor continuously and rectify deviations from target conditions to achieve the most efficient operation of the plant.

The new boiler supervisory desks are equipped with the fully integrated APACS® low-cost, self-contained control system, developed by Moore Products Co. It provides a robust control solution that unifies the best features of DCS (continuous control) and PLC (discrete requirements), and simplifies the process automation. The APACS systems include APACS ProcessSuite process automation software and the APACS controller. An integral part of this operating system is the LOMIS.

Longannet Operational Management Improvement System (LOMIS)

The aim of the LOMIS system is to optimise the performance of Longannet Power Station. This system has now been installed on Units 1 and 3 (see Figures 7 and 8). Optimisation has been achieved through various processes.

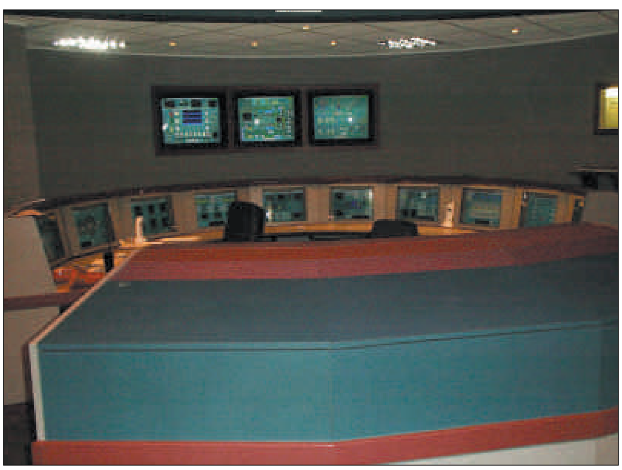

Figure 7. Unit 3 control desk with LOMIS installed (Courtesy of ScottishPower)

Plant Operation

A Plant Information (PI) computer system, capable of storing operational plant information on-line for over a year, was used to capture the best operational practice from each shift team. These processes were transferred into various software programmes, eg those described below.

Plant sequences
A number of operational plant sequences are being developed in the form of software to ensure items of plant are brought into and out of service gracefully and automatically with little plant stress.

Plant managers
This software makes use of the plant sequences by grouping them together to form more complex tasks. For example, *the turbine run-up manager (TRUM)* will manage the run-up requirements of the turbo-generator during the run-up to the synchronising phase throughout the entire range of possible thermal conditions.

The *boiler-firing manager (BFM)* is designed to manage the firing requirement of the boiler during start-up conditions up to synchronisation. The BFM cannot function without the existence of the *boiler drains manager (BDM)*, which manages the drainage requirements during the same step. These two managers, working in tandem, will manage both the steam pressure and the temperature-raising activities for most start-up conditions, and both are designed to be used with the *plant orchestrator (PO)*. The PO is a Windows NT software product providing facilities for the definition and activation of strategies which perform on the plant according to a timed schedule. A hot start on a conventional coal-fired power station is an example of such a strategy.

Maintenance

The new concept for controlling the plant has led to the installation of a distributed control system: the interface with the plant is now through locally installed plant cubicles, of which there are 28 installed. Information is now collected and distributed through a combination of local copper-wiring from plant to cubicle and fibre-optic network system between cubicles and the main computer system in the control room. This modern approach has led to much quicker and easier maintenance and fault-finding techniques.

Performance

On-line 'real-time' plant efficiency calculations are carried out every 5 minutes and delivered to the operator for information and for plant-tuning action. More 'live and historical' plant information is available to allow for better optimisation of the running plant. A fault-tolerant input system means that automatic controls have the ability to control some of the inputs if they become faulty.

Engineering

The installation of the PI system has allowed the engineering departments to analyse plant performance in a more accurate way. The engineers now turn this data into information, which leads to better engineering decisions.

Staff Training

With the installation of the LOMIS system, achieving best practice in a number of key areas called for a new look at all aspects of operation, maintenance and overall running of the plant. The main impact was the cultural changes brought about by the introduction of the new technology. These cultural changes had to be carefully managed as they affected all working groups within the power station.

What assisted this cultural change was that the various teams helping with the installation and commissioning of the equipment worked together in partnership with the contractor to deliver the best solution. The local technical and geographical knowledge, combined with innovative technical ideas from the contractor played a key role in bringing this about.

The Operations Department was also heavily involved in producing a 'soft desk' which was designed with ~130 active displays. Each display contains elements of an individual operational plant area and each relates to best plant operational practice. This has created the perfect training environment. Operations training can take place either off-line on a computer in the training room, or on-line on the live unit.

Figure 8. Unit 1 control desk with the new LOMIS systems installed

Results and Benefits

The installation of LOMIS on Units 1 & 3 has provided the following benefits:

Staff reductions

Due to the success of the smart manager programmes and the control systems there will be a phased reduction in manpower, in step with the installation of LOMIS on each of the other units. This is an improvement on the original proposal where the majority of manpower savings would only be achieved on completion of the fourth unit.

The system has also clearly demonstrated, through success of the modulating control strategy, that further enhancement can be made, thus removing the need for operator intervention. When the sequence strategy is fully developed, the need for staffing may be further reduced by using the control and communications technology that this system offers.

Asset care and reliability

Where unit capability *was* measured prior to system conversion and compared with current performance it is apparent that generation availability is enhanced. With regards to asset care, systems are now operated close to optimum operational thresholds thus providing maximum achievable efficiency combined with minimum plant life utilisation.

Due to interactive ability of 4MATION (Moores Products Co.) logic/plant device mimic display, repair time scales have been substantially reduced, increasing availability and reliability of generating units. Further, through the use of Sequence of Events loggers, technicians have been better equipped to pursue intermittent defects which are often difficult to diagnose.

Fuel savings

Efficiency savings in excess of 0.3% have been demonstrated. The LOMIS system is yielding on a like for like basis of between £280k to £340k per annum saving, as control systems are developed. Following the implementation and testing of Smart Advanced Control System (SACS) on the LOMIS platform, the system has demonstrated reduction in NO_X emissions up to 20% of current operating values. It is anticipated that with the use and development of this system when applied to Unit efficiency optimisation further operating cost benefits will be achieved.

Fast start

Fast start-up fuel-conservation techniques are currently under development. These are being progressed as the current business generation portfolio management allows. When NETA and RoSTA are implemented, plant flexibility and reliability will be essential in order to maximise income and minimise exposure to balancing market effects of plant unreliability. In addition to delivering a more fuel-efficient return to service this will also significantly reduce plant thermal cycling stress parameters.

Year 2000 compliant

Installation of LOMIS on all four units at Longannet, replaced control systems that were not Y2K compliant, therefore there were no Y2K implications.

Flexibility

LOMIS has an enhanced ancillary service response which continues to be developed and improved in line with System Operator/NGC requirements.

Due to the open architecture of LOMIS control strategies can be readily changed and adapted to new plant and equipment at minimal cost and disruption to generation. This leads to a more flexible generation capacity and competitive advantage in changing markets.

LOMIS units have also demonstrated more stable and predictable generation throughout all unit operating regimes. This is largely due to successful intervention of the control system eliminating the need for operator participation ie downskilling effect.

Increased coal generation within IPC constraints

Preliminary results from SACS software strategy tests show a substantive reduction in NO_X emission levels of up to 20%.

Reduction in operating costs

Further tests are planned to improve unit heat rates using SACS following successful implementation of NO_X reduction trials as previously described. Due to the clarity in presentation to the plant operator through LOMIS HMI (Human Machine Interfaces), it is now possible to evaluate generation restrictions and performance issues with increased effect and efficiency.

As the HMI is in a flexible soft presentation format, it offers an opportunity to optimise and improve operator information presentation at minimum cost and with no impact on generation capacity. Soft desk with good plant layout screens makes operator training much easier and more effective.

Improved ash quality

Boiler combustion has been optimised; therefore resulting an improved quality ash product for ash business. Again through the use of SACS tests will be commissioned to investigate flexible strategy to gain best operating constraints on a real time basis with regard to combustion product and heat rates when related to this business.

The LOMIS system has proved to be of great value and will be installed on other units at Longannet Power Station, as well as on other ScottishPower plant.

Boiler optimisation - Ultramax® System

To optimise boiler operation, Longannet has installed Ultramax® dynamic optimisation software, developed and marketed by Ultramax Corporation of Cincinnati, Ohio. This system is distributed in Europe by Inflo.

Ultramax® models the boiler's performance, making use of real-time data to learn how to improve it. At installation of this software, the boiler operator is consulted about the various adjustable and controllable parameters that will be used in the model, eg typical mill bias, oxygen requirements and secondary air. Uncontrollable inputs, eg coal quality, can also be used to improve the combustion model. The measured output values which are the steady-state result of combustion processes are also identified (eg economiser temperature, economiser oxygen, carbon-in-ash, NO_X levels). The boiler operator can apply limits to these parameters which should not be exceeded. The aim of this software package is to achieve multiple objectives, eg increasing boiler efficiency but reducing NO_X emission at the same time. These 'goals' can be changed to suit the management objectives.

The model is set up over a period of two weeks, when the Ultramax® model receives measured parameters and generates advice for the operator. The operator makes the adjustments and then measures the changes that have occurred. This cycle is repeated about 70-100 times and results in a report that details the empirical cause-effect relationship between the boiler parameters, the improvement achieved and recommendations for the future. After this process, the model is run continuously under site licence. While operating continuously, the model updates the empirical model (achieved in the set-up cycle) after every run.

The Ultramax® model uses Bayesian Statistics and unique non-linear weighted regression algorithms. It has the ability to achieve multiple objectives, but also responds very quickly to changes, eg load changes and changes in coal quality.

Results and Benefits

The results of installing this software package for boiler operation at Longannet have included improvements in carbon-in-ash values, optimal performance at all loads and conditions, and assisting with consistent operation for various operators on different shifts.

MONITORING

Condition Monitoring

At Longannet, condition monitoring equipment is permanently installed on the turbine-alternator sets and major auxiliary plant. Hand-held condition monitoring is used for checking small auxiliaries. The reasons for condition monitoring of turbine-alternators are well known and understood, but the extension of monitoring to auxiliary plant was made specifically to increase availability and reduce repair costs.

Permanently installed condition monitoring equipment is fitted to FD fans, ID fans, primary air fans, main boiler feed pumps and auxiliary boiler feed pumps. The equipment monitors various parameters including vibration, temperature, revolutions per minute (rpm), pressures and motor current. Data are logged continuously by a proprietary software package that provides trending and analysis capabilities. The data are also routed to alarms in the control room to provide real-time warning of any parameters exceeding their set limits.

Logged data are checked daily for alarm patterns and weekly for 7-day and 60-day parameter trending. Trending is considered important in that an increase in bearing vibration may not be so severe as to cause an alarm, but will indicate that deterioration is occurring. The Production and Maintenance Departments are notified of all such occurrences to allow corrective action to be taken. This monitoring and notification system allows problems to be solved before failures occur, thus increasing availability and reducing repair costs.

The success of condition monitoring of large auxiliary plant, particularly vibration monitoring, has led to the practice being extended to smaller plant. Equipment currently being monitored includes condensate extraction pumps, condenser hydraulic pumps and deaerator lift pumps. Vibration readings from these items and their associated motors are taken every month using a hand-held collector and analysed using software supplied with the collector. The package provides trending of overall levels and spectral analysis, thus enabling diagnosis of specific faults or deterioration within the equipment. Results are discussed with the Production and Maintenance Departments and appropriate corrective action is taken. Again, routine monitoring is enabling corrective action to be taken before an unexpected failure occurs.

Results and Benefits

The major benefit from this monitoring and notification system, and indeed any condition monitoring that is implemented, is that problems can be identified and rectified before failures occur, thus increasing availability and reducing repair costs.

Emission Monitoring

Currently, UK legislation on the use of continuous emission monitors (CEM) is less stringent than elsewhere and its application is at the discretion of the individual inspectors. More recently, however, the Environment Agency has incorporated guidance notes that advocate installation of CEMs for particulates, SO_2 and NO_x for all new plant.

Most power stations in the UK have now installed CEMs for the monitoring of particulate emissions. Longannet is no exception.

Optical cross-duct CEMs are most commonly installed on power stations. In these monitors, the optical source (transmitter) and the receiver are mounted directly onto the stack or duct wall. At Longannet, the transmitter and receiver are in the same unit on the one wall and the beam of light is reflected back to the transmitter by a retro-reflector, situated on the opposite wall (see Figure 9).

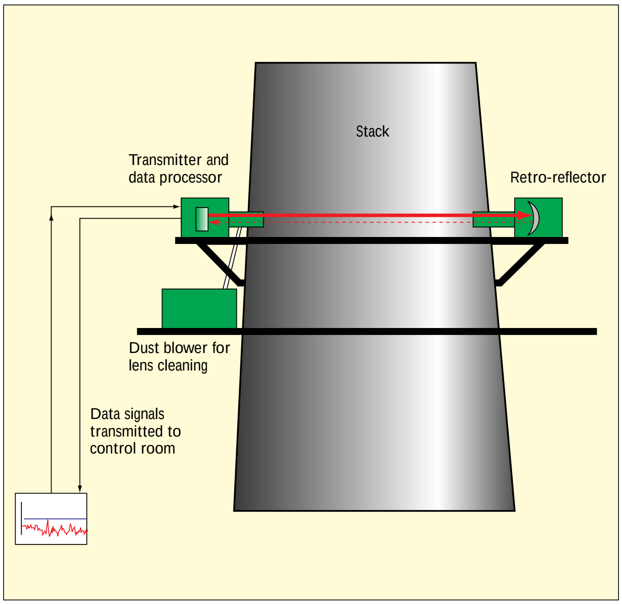

Figure 9. Principle of a cross-duct CEM

At Longannet power station, Sick RM41 cross-duct particulate emission monitors have been installed on all units since the early 1980s. The CEMS are located in the stack at the 100m level and emissions readings are linked directly to the control room. These readings are provided in percentage opacity and the limit is set for 25% opacity (~120mg Nm^3).

Since Longannet is not a new plant, management was not obliged to install CEMs for monitoring gaseous emissions. However, the decision was taken to install SO_2 and NO_x CEMs on all units and these are also directly linked to the control room software.

The gaseous emission monitor installed is of the in-situ Procal 5000, which is designed for in-stack analysis of up to six gas-phase stack emission components. This CEM is based on full ultraviolet (UV) spectrum analysis, coupled with enveloped folded beam.

HEALTH AND SAFETY

Longannet continues to be committed to the improvement of health and safety performance, promoting a positive health and safety culture and ensuring the workplace is safe for staff, contractors and visitors.

The role of the Safety Representative (SR) is continually recognised. SRs are also encouraged to be involved with safety initiatives, workplace inspections and incident investigation. The Longannet Health, Safety and Environment Committee and a number of associated sub-groups (each having SRs as members) have been set up and meet on a bi-monthly basis. All SRs have been offered the opportunity to attend a National Examination Board in Occupational Safety and Health (NEBOSH) General Certificate course organised by ScottishPower. In addition, ScottishPower continues to run joint SR training courses with the associated Trade Unions. All SRs on site, including contractors, can use the Open Learning Centre at Longannet where a number of health and safety training packages are available.

Training and development in consultation with the Safety Department have produced a health and safety training matrix that specifies a training programme for all staff, including refresher frequencies. The training matrix consists of both statutory training requirements, eg fork-lift truck operator training, and safety awareness training to ensure that the safety performance is improved through education.

The Safety Department continues to adopt the proactive approach to health and safety and has developed a safety campaign 'Safety for Me' which focuses on health and safety knowledge and not accident performance. The campaign was launched in 1997 and comprised 'toolbox' talks, workplace visits and family involvement where children were asked to take part in a safety poster campaign. The winners of the poster campaign were incorporated into a desktop calendar. The campaign continues through a number of smaller initiatives, but will be relaunched in a similar format to the 1997 campaign during the year 2000.

The Department has made a commitment to measuring the existing health and safety management system employed at each location against the Health and Safety Guidance note HSG 65 'Successful Health and Safety Management' through the Royal Society for the Prevention of Accidents (RoSPA) Quality Safety Audit. The recognition of strengths and weaknesses and the implementation of recommendations, where appropriate, in the health and safety management system currently employed at Longannet, through the use of audits, will encourage a process of continuous improvement.

In recognition of the continuous improvement in both the management of health and safety and the health and safety performance of all the staff, Longannet Power Station has been awarded four Gold Awards by RoSPA in consecutive years.

The Eagle Star Training Award is presented to RoSPA Awards entrants with the most effectively managed health and safety training programme during the entry period. The health and safety training carried out at Longannet played a major part in ScottishPower winning the Eagle Star Training Award in 1997 and being highly commended for the same award in 1999.

CONCLUSIONS

Longannet Power Station represents a valuable and well-proven asset for ScottishPower. Not only is Longannet able to meet almost half of Scotland's power requirements; it has also been successfully upgraded over the years.

The upgrading and refurbishments with modern technology have also helped with the continuing trend of reductions in running costs. Longannet has efficiency figures that are among the best of UK plant of comparable type.

The most notable achievements have been the reduction in NO_x emissions of up to 50%, due to the installation of both low-NO_x burners and gas reburn. Gas reburn has also brought other benefits in terms of reduced CO_2, SO_2 and particulate emissions, due to fuel substitution.

The introduction of automatic boiler controls, on-line data processing and the installation of software packages, eg LOMIS and Ultramax®, has shown improvements in efficiency, an excess of 0.3% has been demonstrated. More important, generation has been shown not only to be more stable and predictable, but also to be flexible and reliable, making Longannet Power Station more amenable to demands from the electricity pool.

Longannet is also very conscious of the potential impact of its activities on the environment. The continuous improvement in plant performance through the implementation of new technology and new operational procedures has been used to minimise environmental impact.

The modifications also mean that Longannet's plant life has been extended until at least the year 2020.

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