ENERGY USE IN INDUSTRY BOOKLET No. 9

REDUCING FUEL AND ELECTRICITY COSTS IN BRICKMAKING

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Department of
Minerals and Energy

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Department of Minerals and Energy
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Foreword

The wise use of energy is important to our State's prosperity.

There is a need for clear and straightforward advice on the efficient use of energy in all it forms, and this is particularly important in any drive to make our exports more competitive.

This series of booklets sets out to meet that need. Based on industrial and commercial energy studies carried out by staff of the NSW Department of Minerals and Energy, the information presented aims to reduce the energy costs of individual establishments as well as make industry and commerce as a whole more competitive.

It is the Department's objective to promote safe, responsible, effective and efficient provision and use of energy. This series of booklets will help to achieve that end.

Hon. Neil Pickard M.P.
Minister for Minerals and Energy

REDUCING FUEL & ELECTRICITY COSTS IN BRICKMAKING

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APPENDICES

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Without this assistance this booklet would not have been written.

PREFACE

Any brickmaker will say that energy, i.e. fuel and electricity, is an important part of the cost of a brick; in fact it adds between 10 and 30% to the cost. Energy management means managing fuel and electricity use to reduce this percentage. It can also result in other benefits such as improved quality, fewer rejects and reduced maintenance.

The basis of good energy management is awareness of the cost of energy and how the energy is used in the different parts of the process. The booklet is intended as a very simple aid to initiating energy management in brickmaking.

1. INTRODUCTION

The craft of working in clay is several thousand years old and the wisdom accumulated over the centuries is used today to make bricks with the required properties. This booklet is about 'energy management' and is about making the best use of fuel and electricity in the plant, thus keeping the cost down without reducing production or product quality. It is intended to help the brickmaker think more clearly about the fuel and electricity used in the process. It is intended as a stimulant, a reminder and perhaps a guide but not as a complete textbook.

The main steps in brickmaking are:

- Winning and hauling the clay.
- Crushing, mixing and forming.
- Drying the green bricks.
- Firing the bricks.
- Cooling the fired bricks.
- Packing, storing and delivering the finished product.

Fuel and/or electricity are used in every step except cooling. In many brickyards, heat from cooling the bricks is used to dry and preheat the green bricks. Figure 1.1 (overleaf) shows the usual sources of energy used at each step of the brickmaking process.

Data published by the Australian Bureau of Statistics show that the largest single item of expenditure in the Australian brick industry is wages. The next largest is energy, that is, fuel and electricity, which together account for around 25% of production cost. Energy is only one of the costs of production, but because this book is about energy use, words like 'cost reduction', 'economy', and 'cheap' in this book refer only to fuel and electricity use.

In 1986-7 the Energy Authority of NSW made a study of energy use in the Australian brick industry. This study was in three parts:

- An examination of the literature on energy use in brickmaking.
- A postal survey of Australian brickyards (see Appendix A).
- Visits to brickyards and discussions with brickmakers.

Based on this study, this booklet aims to help brickmakers become more aware of what they can do to reduce the effects of fuel and electricity costs on the price of the product.

Process	Usual source of energy
Winning and carrying	Diesel fuel
Preparation (crushing, milling, and mixing)	Electricity
Forming by pressing or extruding and cutting	Electricity
Drying in the open air, in the kiln or in a dryer	Waste heat from kiln or hot bricks, and/or direct firing with coal, gas, oil or wood
Preheating in the dryer or the kiln	As for drying
Firing in the kiln	Coal, gas, oil etc or wood
Cooling, in the kiln or open air or both	Heat given off, sometimes used elsewhere in process
Packing, storing and delivering to customers	Electricity, diesel fuel, LPG

N.B. Electricity is used in most parts of the process for fans, conveyers, compressed air etc.

Fig 1.1 - The Brickmaking Process

This booklet is meant to be read with other books on brickmaking and on energy management. Appendix B lists some of the most useful ones.

2. ENERGY MANAGEMENT SYSTEMS

2.1 Introduction

The aim of good energy management is to reduce to a minimum the cost and quantity of fuel and electricity used per thousand bricks (or per tonne of product). It does this in four ways:

- It detects deteriorations in plant performance.
- It suggests changes in operation that will reduce energy costs.
- It ensures that the plant uses the most suitable electricity tariffs.
- It enables the benefit of any change in the process or fuel used to be evaluated.

An effective energy management system has three components. Each is essential:

- Keeping records of fuel and electricity used and of changes to the equipment.
- Relating these records to production and other factors.
- Acting on what is learnt from the records.

The records should be examined and the necessary actions taken as soon as possible, for three reasons:

- The system will lose credibility unless it is seen to be used.
- It is much easier to remember and allow for outside influences such as adjustments to the plant immediately after the event.
- If repairs or changes to the plant or process are identified they should be done as soon as possible to minimise energy waste.

The first step is to prepare a table of fuel and electricity consumption and costs (from the bills) and production for the past two years. Include mobile plant. There are three reasons for this:

- To make management aware of the sums of money involved.
- To give figures for a comparison with energy use in the rest of the industry (see Appendix A, Page 30).
- To indicate the effect of production changes on the energy used.

2.2 Keeping records

Monthly bills are inadequate for routine energy management purposes because:

- Billing periods for fuel and electricity rarely coincide with each other or production periods and are too long (usually 1 month) for convenient analysis or quick response.

- The bills are received too late for quick response.
- Bills usually only give consumption figures for the whole brickyard, not for individual areas or plant items.

However, they should be recorded as they are received to provide a check on other recording systems.

To begin with, record the energy used during each production period. Get figures for electricity and mains gas from the suppliers' meters; the suppliers' meter readers are able to explain how to read the meters. For stored fuels, such as coal, oil or LPG, dip the tanks or estimate the size of the piles and allow for fuel delivered.

This information from the meters will be punctual and will be easily tied to production, but it will not show where the energy is used in the brickyard. For this reason, a system to collect more detailed data should be set up. There are five steps in setting up such a data collecting system:

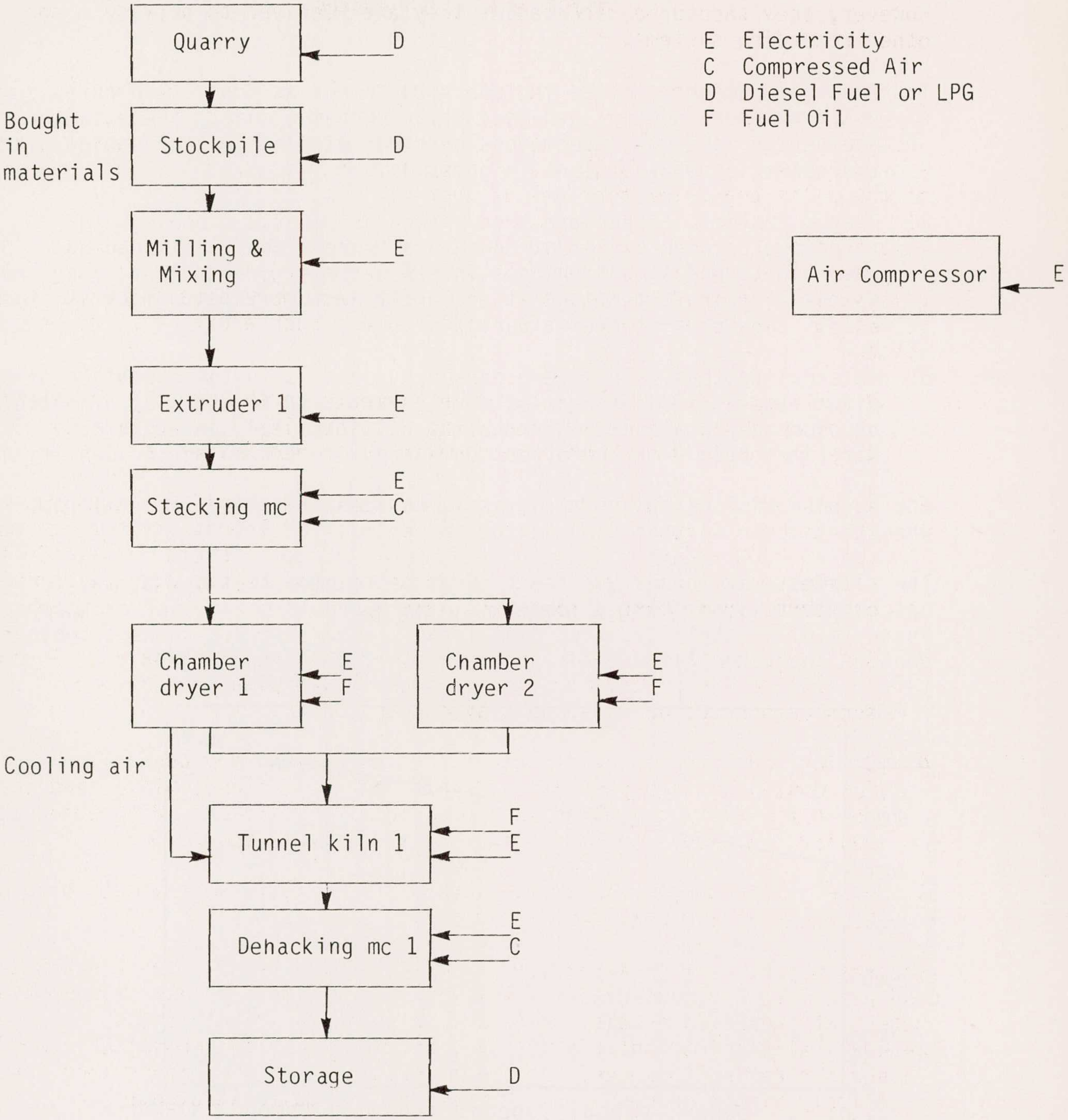
1. Prepare a diagram showing the main elements in the process and the fuel or electricity inputs to each. Fig 2.1 (overleaf) is an example of this for an imaginary brickyard making extruded bricks.
2. Assess which energy inputs are significant and should be regularly logged. As a rough criterion, a "significant" energy input costs more than $20,000/year or is more than 5% of the total energy bill. In the case of electrical equipment, use plant nameplate ratings and estimates of hours run to make a first estimate.
3. Consider measuring significant energy inputs (see Section 8). Arrange to measure and record any other factors which might affect energy use, such as production rate and clay carbon content.
4. Decide how often to record the data. As a first try use daily logging for continuous equipment such as extruders and tunnel kilns, and once per batch for batch plant such as intermittent kilns. With experience, modify the frequency to obtain more meaningful records.
5. Draw up log sheets and devise methods of analysis so that the data can be recorded and analysed immediately.

Records may be kept in a variety of ways, ranging from a simple notebook and pencil to a computerised system which automatically reads a number of meters at preset intervals, makes any calculations required and automatically prints out the results, and additionally, memorises them for future reference. However, the characteristics of a logging system for a relatively simple process like a brickyard are quite straightforward. it should include the following features:

- Be low in cost initially.
- Be simple and easy to understand.
- Calculations should be able to be made by whoever takes the readings.
- System should be readily able to be amended with experience.
- Be able to provide previous set(s) of readings for comparison.

These criteria are well met by a simple pre-printed or photocopied sheet, showing clearly where the readings are taken and how to make the calculations.

Fig 2.1 Process Diagram with Energy Flows



2.3 Routine Analysis

When figures have been collected they must be studied so any problems in the plant operation can be recognised and corrected.

Three types of factor cause changes in plant fuel or electricity consumption:

1. External factors. These include such things as production rate, green brick moisture content and type of brick being made. These factors are set by management decisions or other elements not connected with the operation of the plant in question.

2. Random factors. These are such things as minor differences in technique between different operators, errors due to misreading instruments and slight changes in raw material properties. They are essentially short term and it is rarely worth trying to identify them unless they persist over a period of time.

3. Internal factors. These are caused by changes in the operation of the plant itself, such as wear of moving parts, malfunction of a controller or blockage of a duct. Work habits of particular operators can sometimes have a marked effect on energy use and be worth identifying.

The purpose of logging and analysis is to identify these internal factors when they occur so that they can be corrected.

The simplest way to analyse the figures is to plot them day by day (or batch by batch) on 'control charts'. There should be one for each type of energy e.g. electricity, gas, diesel fuel, etc. Fig 2.2 shows a typical control chart for gas use in a tunnel kiln.

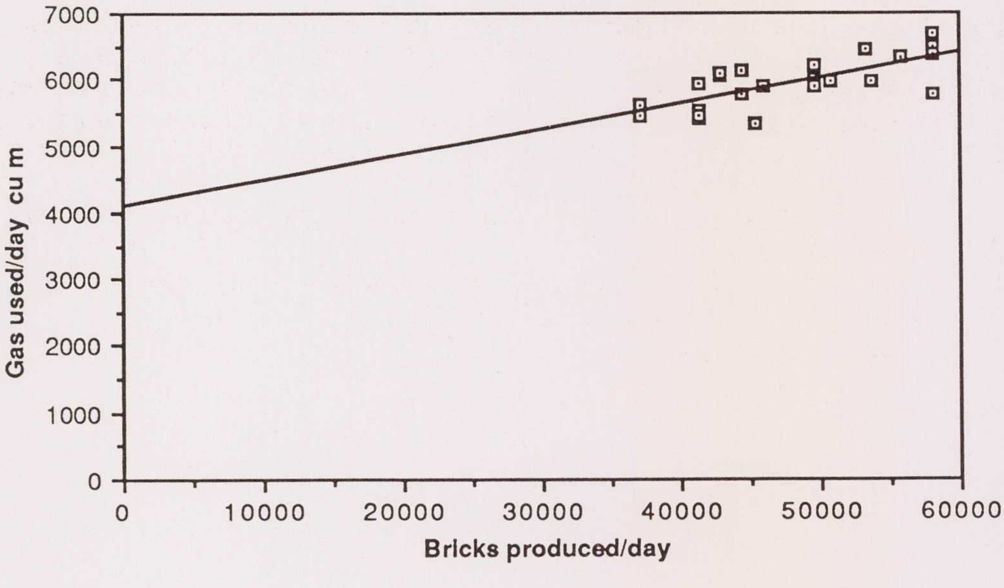


Fig 2.2 Tunnel Kiln, Gas Use Control Chart

Note that:

- Taking the readings at the same time each day makes it easier to get uniform results.
- It often takes more than one day before a significant deviation can be recognised.
- Missing a reading or making an error occasionally is not fatal.

- The points represent the daily gas use, covering kiln operation over four weeks. The line is the line of best fit to gas use in the past, the average for normal kiln operation.

- The points should be marked on the chart day by day. With practice it is easy to recognise those points where consumption is especially high or especially low. These points can then be investigated to check that there is nothing wrong with the kiln or if there is some new factor in operation that can be repeated to give continuous savings.

- The line, if extended back, crosses the vertical axis at 4000 cu m gas/day; this represents the heat lost in hot kiln cars, through the kiln insulation, to air leaks etc, all independently of the number of bricks produced.

Sometimes the performance will deteriorate slowly over a period and the deterioration cannot be noticed on a chart that only lasts a month. The gradual clogging of ducts and the slow deterioration of door seals are typical of this sort of problem. For this reason it is a good idea to calculate the average fuel or electricity used per day or per batch for each month and plot them on their own control charts.

2.4 Analysis for Change

Metering of the individual users has shown where in the brickyard the fuel and electricity go. The largest users have the greatest potential for savings so they should be tackled first.

The correct method is to study each major item of equipment in detail to find out exactly where the energy goes. For example, a downdraught kiln might use 38t of coal per cycle. If records of the different stoker settings show that 18t are used during the last 6 hours of firing, this part of the firing cycle should be investigated first. Again, then a tunnel kiln might use 15.2 GJ/thousand bricks. Measurement of the chimney flow and temperature shows that 8.6 GJ/thousand is lost up the chimney, so reduction of the chimney flow and/or temperature should have top priority.

This type of detailed analysis and the measurements needed for it do not take place continuously as the regular recording of fuel and electricity does because of the time and effort required and because the regular recording and control charting is sufficient to detect changes in performance.

Section 8 covers methods of measurement.

3. FIRING THE BRICKS

In the brick industry the cost of fuel for firing the ware is an important part of the cost of production. The fuel is usually coal, oil, gas, wood or a combination of these. Efficient use of the fuel is crucial to the economical manufacture of bricks. (Appendices D & E outline the basic theories of combustion and heat transfer).

Fig 3.1 is a simple chart to assist in diagnosis of uneconomical operation. Some points apply only to tunnel kilns but most apply to kilns of all types. The starting point is excessive fuel use per thousand bricks. This can be diagnosed by comparison of fuel use:

- Between similar kilns in the same yard.
- With industry average figures (see Appendix A).
- By monitoring (see Section 2).

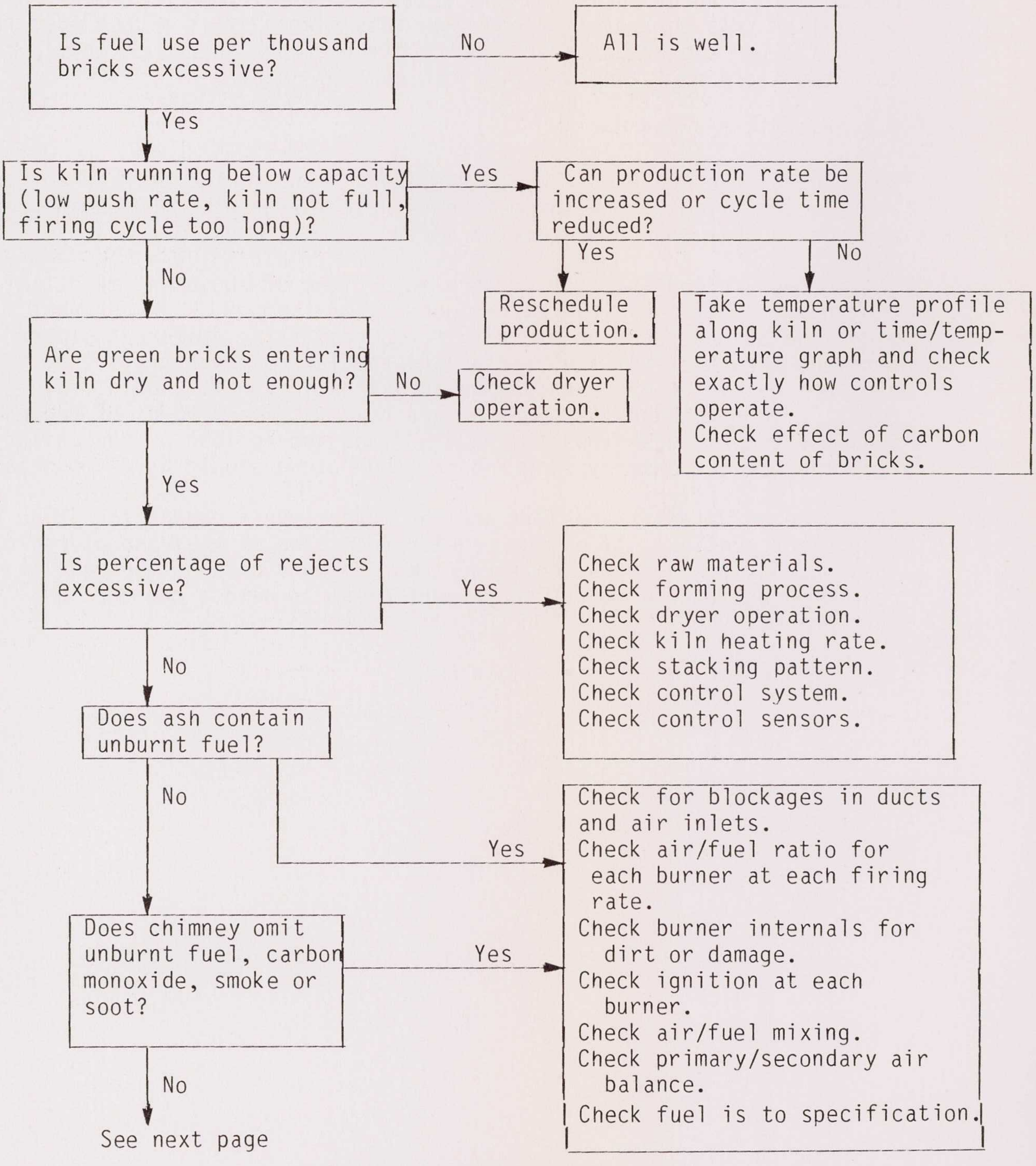


Fig 3.1 - Kiln Diagnostic Chart

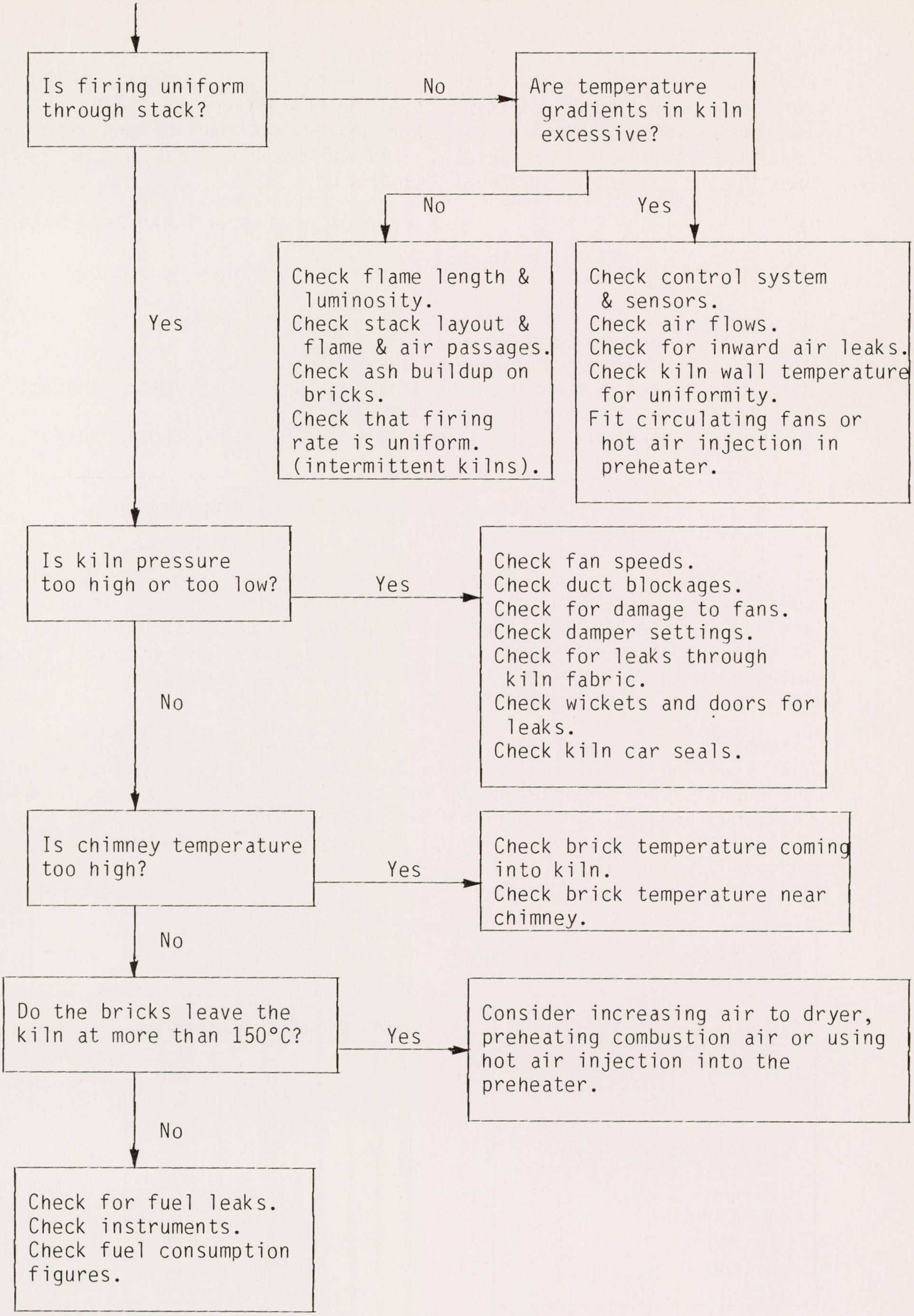


Fig 3.1 (Continuation)

Use of Fig 3.1 requires the comparison of various measurements, such as stack gas temperature and composition, with preset criteria. Kilns vary very widely in type and in methods of operation, so the criteria given (Table 3.1) must be used as for guidance rather than as precise figures.

Brick temperature leaving dryer - greater than 120°C if bricks do not need manual handling before firing.
 - 40°C if bricks need manual handling.
Carbon monoxide, in chimney gases, up to 400 ppm.
Kiln surface temperature, less than 120 °C.
Smoke in chimney, increase of 1 Ringelmann number.
Kiln pressure, depends on position in kiln, check with manufacturer.
Chimney gas temperature, maximum 150° C.
Brick stack temperature gradients, max 100 deg C top to bottom.

Table 3.1 - Criteria for Kiln Operation

Fig 3.1 suggests several possible causes for each problem. Experience suggests that uneconomical kiln operation usually has more than one cause and each has to be identified and removed. However, the various factors in kiln operation are interlinked and changing one can frequently lead to changes in the others. Kiln tuning is therefore a process of adjustment and checking and more adjustment.

In most kilns the heat lost up the chimney is a high proportion of the heat supplied by the fuel. Table 3.2 shows how this increases with both the quantity and temperature of the gases. The Table applies to a typical coal, but figures for other fuels are very similar. The excess air percentage can be found by measuring the oxygen or carbon dioxide in the gases and using Table D4 in Appendix D.

Temperature of gases, °C	100	150	200	300	400	500
Excess air supplied as %	Heat in gases as % of heat in fuel					
0	3	4	5	10	13	17
100	5	9	12	20	27	35
200	8	13	19	29	41	52
300	11	18	25	39	54	70
400	13	22	31	49	68	87
500	16	27	37	59	81	105
600	19	31	43	69	95	122
700	22	35	50	79	109	140
800	24	40	56	88	122	157

Table 3.2 - Heat Lost in Exhaust Gases (typical coal)

Another method of reducing the fuel consumption is to increase the combustible content of the green bricks. This can give cost savings because 'fuels' such as coal washery waste can be added to the clay and replace a proportion of the more expensive fuel used to actually fire the kiln. For this to succeed, six things are necessary:

- The control system must reduce the main fuel flow.
- The correct air quantity must be supplied so that combustion occurs when and as fast or as slowly as required.
- The stacking pattern must allow adequate combustion air to reach every brick.
- Adequate time must be given for complete combustion.
- The properties of the fired bricks must be satisfactory.
- Use of the different materials must not reduce the production rate.

Most of the measures suggested to improve the economy of a kiln involve negligible capital cost. Sometimes, however, it becomes apparent that the kiln will need major modifications before it can be operated economically, for example:

- Replace burners with more suitable ones.
- Reposition burners.
- Improve insulation.
- Improve seating of doors, wickets, etc.
- Increase length of preheating section.
- Increase length of cooling section.
- Improve heat recovery from cooling bricks.
- Preheat combustion air.
- Fit baffles or circulating fans for combustion gases.
- Modify or replace controllers.

If the existing fuel consumption is known, it is possible to estimate the savings resulting from these modifications and calculate the expected payback.

To remain in peak condition, all plant needs to be checked at intervals. Keeping good records of operation (see Section 2) is the first level of checking, and should provide an adequate early warning system for plant problems.

4. DRYER & PREHEATERS

Before bricks are fired they are dried. Note that there is enough heat in fired bricks at 1000°C to dry moist green bricks and preheat them to 150°C or above unless they are very moist or the dryer is very inefficient (See Appendix F). Using this heat efficiently is essential if the brickyard fuel use is to be kept down.

In yards using intermittent kilns the bricks are often dried in the kiln as the first part of the firing cycle, burning fuel to give the heat required. More modern brickyards with intermittent kilns have separate dryers using the heat given off by the fired bricks as they cool in the kiln. This has two advantages over drying in the kiln:

- It reduces the heat required.
- It reduces the turndown required on the kiln burners since very low heating rates are not required.

Installation of a separate dryer is possibly a viable alternative to installing a new kiln when yard output needs to be increased if it enables the cycle times in the kilns themselves to be reduced.

In tunnel kilns, the heat recovered from the fired bricks is ducted to the dryer to dry the green bricks. If the bricks need no manual handling between the dryer and the kiln it is possible to preheat them in the dryer, sometimes to 200°C. If the dryer requires auxiliary heating or the bricks come out too moist or too cool, the design and operation of the dryer and the kiln should be critically examined. (Fig 4.1 is designed to help in this. It is also useful if the control charts show an increase in fuel consumption or the dryer performance suddenly deteriorates).

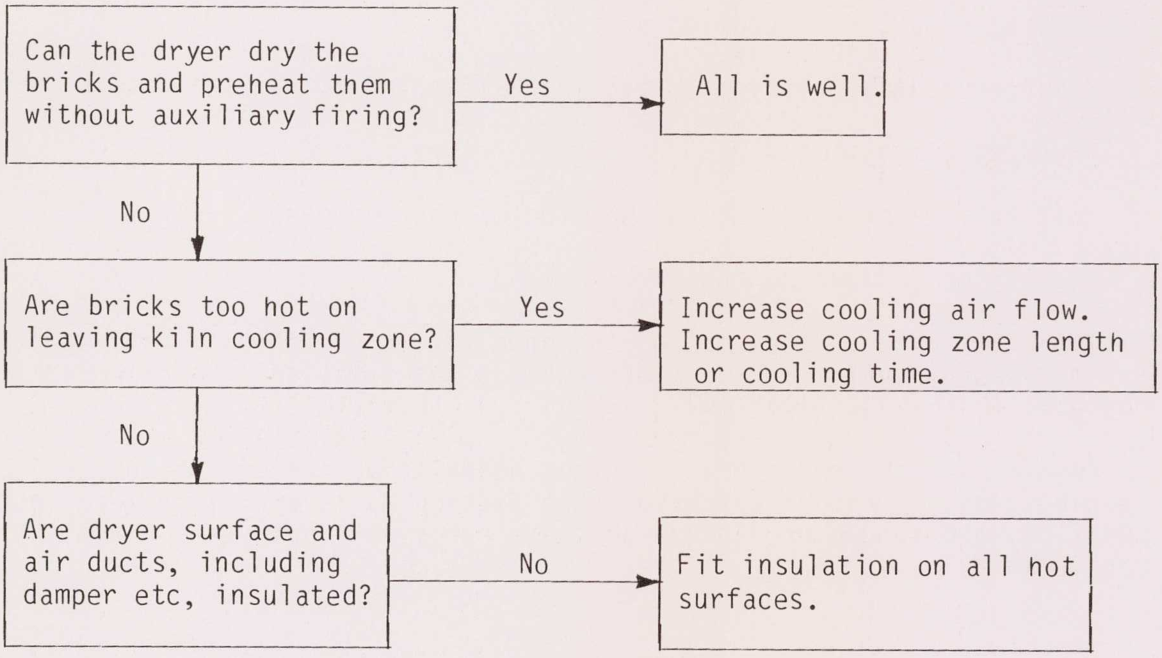


Fig 4.1 - Dryer Diagnostic Chart

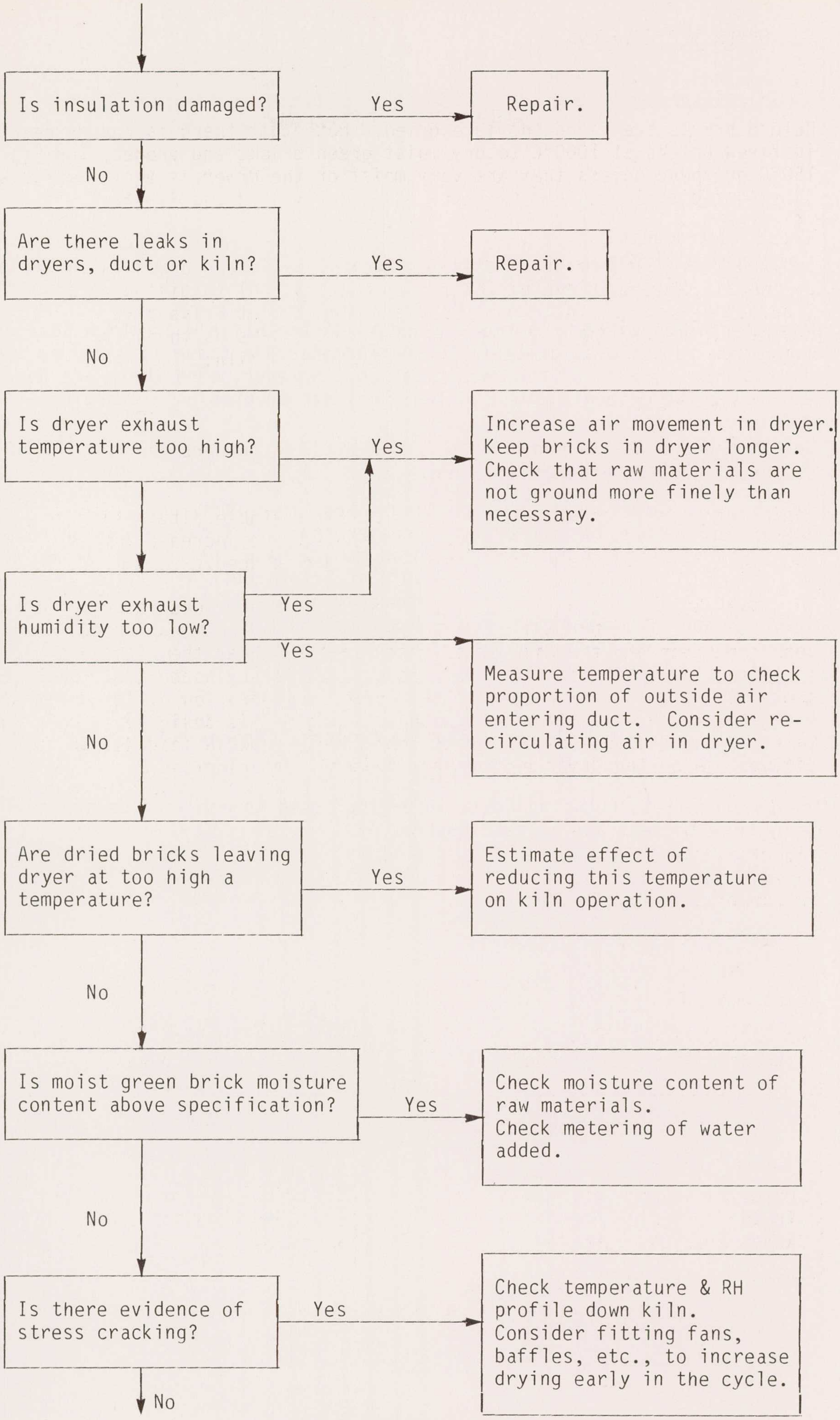
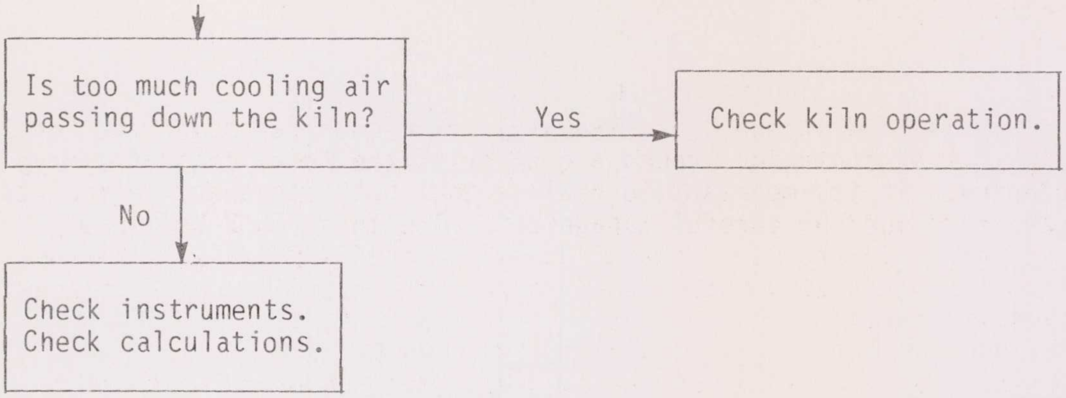


Fig 4.1 - (Continuation)



Dryer performances vary enormously and so do the kilns with which they are connected, so the best criteria for performance are those supplied by the manufacturer as part of the specification. However, when these are not available, the criteria given in Table 4.1 can be used as a starting point.

Fired brick temperature after cooling - less than 80°C
Brick temperature leaving dryer - greater than 120°C, if bricks do not need manual handling before firing
- 40°C if bricks must be handled manually before firing
Dryer exhaust temperature - less than 60°C
Dryer exhaust relative humidity - 40% at 60°C

Table 4.1 Dryer Operating Criteria (Approximate)

The EMAS booklet "Reducing Costs in Drying" (see Appendix B) describes in detail how to test and operate dryers.

5. ELECTRICITY USE

Electricity is used in the brick industry for mechanical power and for lighting. It accounts for around a quarter of the total cost of energy in the industry. It is important to realise that both its quantity and its cost can be reduced by careful management. The three EMAS booklets "Reducing your Electricity Costs" listed in Appendix B explain the fundamentals of electricity supply and the principles and practice of reducing electricity costs.

Medium and large industrial concerns in NSW have the opportunity to buy electricity under a "time of use demand tariff". This tariff has three basic features:

- Only firms with a demand of above 200kW (depending on the supply authority) are eligible.
- A charge is made for the maximum demand (in kW) during each month. This is not an instantaneous peak but is based on the maximum kWh used in any half hour period (or quarter hour period in some supply authority areas). Thus instantaneous peaks caused by starting motors hardly affect the maximum demand.
- The cost of the electrical energy used (c/kWh) depends on the time of use, being higher during the peak period (usually weekdays from 7 am - 10 pm) than at other times.

Details of these tariffs and advice as to the most economical in a particular situation are available from the supply authorities.

EMAS Booklet 4 (Appendix B) explains the principles and practice of minimising electricity use. The main considerations are:

- Turn off when not in use.
- Don't oversize motors or plant.
- Maintain plant adequately, e.g. belt tensions, gearbox oil type and level, cleanliness of motor cooling passages.
- Use high efficiency lights.
- Don't illuminate too brightly.
- Keep light fittings clean.
- Don't illuminate unoccupied areas.

One way to reduce the maximum demand is to avoid running large motors at the same time. For example, it might be economic, depending on labour costs and production facilities available, to grind the clay and store it during one shift and extrude it during another.

In the brick industry one of the biggest electricity users is often the extruder. The power used should be measured using an ammeter or kWh meter on the machine and can be minimised by:

- Using the best auger for the clay. The wrong one can increase the motor power by 50%, so the power used should be checked when the clay or the auger is changed.

- Increasing the feed moisture content. Note that this will affect the handling and shrinkage of the green bricks and increase the heat required to dry them. It will also reduce die and auger wear.

- Use a lubricant in the die.

- Reduce the number of perforations in the die, increasing the size to give the same total area of perforation. Note that this will affect the rate of drying and firing of the bricks.

- Set the cutting off knife or wire and size the die to minimise the clay returned to mixing.

Where there is a large number of fans, the power used can be considerable, especially if they run 24 hours/day, 365 days/year, as on a continuous kiln. To minimise the electricity used:

- Turn off fans whenever possible, using time switches or other controllers.

- Reduce the fan speed to reduce the air flows, rather than throttling the air with dampers.

- Check fan rotors regularly for dust build-up, corrosion, bent vanes, etc.

- Design duct work for minimum resistance, easing or removing sharp bends, etc.

- Keep ducts and inlets clear of blockages, caused either by dust or by partly closed dampers and such obstructions.

- Stop system leaks.

- Ensure belts are at the correct tensions and bearings are lubricated according to the manufacturer's instructions.

Another large user of electricity is the air compressor with the compressed air system. It is well covered in "The Energy Managers' Handbook" (see Appendix B), but three major principles can be given here:

- Lightly loaded compressors consume an inordinate amount of power. The compressor should be sized to meet the main loads, not greatly exceed them. If the load is very low for long periods, such as overnight, fitting another compressor, sized to meet the reduced load, might be economical.

- Most compressed air systems leak, but a leakage rate above 5% is excessive. To locate the leaks, run the compressor when the rest of the plant is closed down and listen around the plant for the sound of leaking air. If the compressor is a reciprocating one, timing its on-load/off-load cycles is the best way of measuring the leakage. With rotary compressors, there is no simple way of measuring the leakage. Simply plug every leak as it is detected. Repeat these tests every six months if possible, otherwise every year.

- The compressed air pipes should be sloped in the direction of air flow and fitted with automatic drains to remove the water condensing out. These should be regularly inspected and maintained. Advice on how and where to install drains and similar items is available from the suppliers.

6. CHOICE OF FUELS

In Australia many different fuels are used to fire bricks, including wood, coal, sawdust, natural gas, LPG and fuel oil. When choosing a fuel for a new brickyard or changing fuels in an existing one, consider:

- What are its cost and heating value? (See Appendix C).
- Is this cost likely to change in the foreseeable future, and if so, by how much?
- Is the supply guaranteed?
- Will the supplier offer a long term contract?
- What are the technical problems involved in using the fuel?
- What is the cost of the equipment required to handle and fire the fuel?
- What are its labour and maintenance requirements?
- Does the equipment supplier give adequate after sale service?

There are advantages and disadvantages in all fuels as shown in Table 6.1.

Fuel	Main Advantages	Main Disadvantages
Natural Gas	Low capital and operating labour costs. Low pollution. Easily transported within plant. Easily ignited. Easily controlled. Wide choice of burner types. Meter provided by supplier.	Low emissivity reduces radiant heat transfer. Flame can be blown out by excessive primary air. Not available everywhere. Supplier has monopoly. Leaks can pose a fire hazard.
LPG	Low capital and operating costs. Low pollution. Easily transported within plant. Easily ignited. Easily controlled. Wide choice of burner types. Easily metered.	Pressurised storage required. Low emissivity flame. Flame can be blown out by excessive primary air. Leaks can pose a fire hazard.
Industrial diesel fuel	Easily transported within plant. Low pollution. Easily ignited. Easily controlled. Easily metered.	Requires storage.

Table 6.1 Advantages and Disadvantages of Different Fuels

Fuel	Main Advantages	Main Disadvantages
Fuel oil		Can be messy. Storage and pumping require heating. High sulphur can give pollution problems. Possibility of smoke emissions.
Black coal	Can give unique effects on fired bricks.	High capital, operating labour and maintenance costs. Can give pollution problems. Ash removal necessary. Deteriorates in storage. Difficult to meter accurately.
Brown coal	Can give unique effects on fired bricks. Low ash.	Limited availability. Distribution & firing system is complex. Harder to ignite than gaseous or liquid fuels. Difficult to meter accurately. Requires care in storage to prevent spontaneous ignition.
Pulverised coal	Radiant flames give uniform firing. Ash on bricks can give measure of protection against thermal shock. Can be fully automated.	Crushing, distribution and firing system is complex. Ash removal facilities are required. Ash can adhere to bricks if wrong coal is used. Can give dust and soot pollution problems. Coal must be exactly to specification to give required ignition, flame and ash properties. Harder to ignite than gaseous or liquid fuels. Potential explosion hazard. Difficult to meter accurately.

Table 6.1 Advantages and disadvantages of different fuels (Continuation)

Fuel	Main Advantages	Main Disadvantages
Sawdust & planings	Radiant flames give uniform firing. Low ash. Can be fully automated.	Fuel sometimes has high moisture, requiring drying. Variation in timber can cause problems in firing. High capital, labour & maintenance cost. Few sources of supply in any one area. Planings require pulverising. Requires undercover storage to prevent deterioration. Difficult to meter accurately.
Wood billets	Low capital cost. Low ash.	Manual firing, so high labour cost.
Wood waste	Low ash.	Difficult to handle. High capital, labour and maintenance costs. Few sources of supply in any one area. Might require pulverising. Variation in timbers can cause problems in firing. Requires undercover storage to prevent deterioration. Difficult to meter accurately.

Table 6.1 Advantage & disadvantages of different fuels (continuation)

7. INSULATION & LEAKS

In a continuous kiln using fuel at the rate of 10 GJ/thousand bricks, approximately half the heat is lost by heat transmission through the kiln shell or kiln cars, by heat stored in the kiln cars or by air leaks. In an intermittent or a Hoffman kiln, heat is used to heat the kiln shell but not recovered. Table 7.1 lists where those losses occur and how they may be reduced.

Loss	How To Reduce Loss
Through walls, roof	Increase insulation thickness or quality if outside surface temperature is above 100°C. Find and repair damaged or missing insulation and refractory.
Through kiln car floor	Improve car refractory quality. Repair damaged refractory.
Through wickets	Increase thickness and/or sealing of wicket.
From hot air transfer duct surface	Insulate duct and dampers.
Heating kiln shell	Fibre line kilns. Use lightweight refractory. Recover heat from hot bricks and kiln for use in dryer.
Heating kiln car	Replace kiln car refractory with lightweight refractory.
Air leaks in or out	Seal leaks, both in shell and wickets, and round doors, peep holes etc. Maintain in good condition the seals between cars and between cars and kiln. Keep kiln pressure as close as possible to atmospheric.

Fig 7.1 Losses

8. MEASUREMENT

Accurate and reliable measurements are necessary if fuel and electricity use are to be kept to a minimum.

Fuel metering, as discussed in Section 2 is often expensive. Many brickmakers also think it is unnecessary because it is used to reduce costs rather than guarantee the quality of the bricks or increase production or reduce labour. However, it is safe to assume that in the average brickyard, fitting a meter to a large fuel users and using the readings as described in Section 2 will save about 5% of its fuel bill. If the total fuel used by the particular kiln or dryer can be estimated, either from manufacturer's data or as a proportion of the total yard consumption, the payback on the cost of the meter can be calculated.

Gas and liquid fuel quantities can most easily be measured using commercially available in-line flow meters. Taking hourly readings will give an almost continuous record of fuel consumption in, for example, an intermittent kiln. Liquid fuel use can also be calculated from dipping storage tanks and LPG from the tank level gauge, but these are less accurate and less convenient.

Solid fuels present more of a problem and high accuracy is rarely feasible. Table 8.1 shows the main metering methods.

Device	Procedure	Disadvantages
Bulk tank or hopper	1 Measure depth at intervals	Physical work involved. Must take filling into account.
	or	
	2 Weigh using load cells	Must take filling into account. High cost.
	or	
	3 Batch weighing hopper	High cost.
Screw Conveyor	Fit revolution counter or hours-run meter and calibrate.	Depends on uniform feed to conveyor. Requires calibration Low accuracy.
Belt Conveyor	1 Live belt weighing	High cost.
	or	
	2 Measure belt depth and speed and calibrate	Requires calibration. Low accuracy.
Manual handling	1 Count billets, shovel loads, etc.	Low accuracy and low realibility.

Table 8.1 Measurement of Solid Fuel Use

The supplier should know the heating value of a fuel, but failing this, the "National Association of Testing Authorities" (NATA, 688, Pacific Highway, Chatswood, NSW 2067, Tel. (02) 411 4000) can give names of suitable laboratories where fuel samples can be tested.

Electricity use is easier to monitor because large motors are, or should be, fitted with ammeters. Failing this, clamp-on ammeters (tong-testers) are suitable. The electrical current drawn by a motor does not vary with time so the power used is easily calculated from instantaneous current and hours run.

For temperature measurements and for plant control most brickyards use thermocouples. Thermocouples used for control should have a readout which can be checked against an independent thermometer. Small handheld thermocouples are available. These have interchangeable sensors for gas temperature and surface temperatures. High temperature types reading up to 1300°C are available. Bimetallic strip dial-type thermometers are also useful, but can only be read locally. The position of the sensor is crucial if readings are to be accurate. It needs to be in the main stream of the kiln gases or it will read low. The sensor also needs protection from mechanical damage when the bricks are being set and removed; taking it out and replacing it when setting is complete is often the simplest way to protect it.

It is sometimes necessary to keep a continuous record of temperature in the kiln or dryer either to check that the kiln or dryer is operating correctly or to diagnose problems with product quality, fuel consumption, omissions or similar. One option is to use a chart recorder to give a direct paper record; another is to use a data logger, which makes an electronic record and requires a computer and printer to convert it to a paper record. Both instruments are fairly complex and expensive, so for occasional use might be better hired than bought.

Portable analysers for combustion gases are of several types. In the 'Fyrite' type, a measured sample of the combustion gases is bubbled through a special chemical and the change in volume of the chemical shows the oxygen or carbon dioxide concentration in the gases. Another chemical type depends on the change in colour of special crystals. The crystals are supplied in sealed tubes which are inserted into a small hand operated suction pump, which draws the combustion gases through the crystals. Different crystals are available for measuring a wide range of gases, including carbon dioxide, carbon monoxide and hydrogen chloride. Electronic analysers are also available; they tend to be more expensive than the chemical types and require regular checking, but are quicker and simpler to use. All the analysers give results as volume percentage.

Kiln pressures are measured with a dial gauge, a U-tube manometer or an inclined manometer. The same type of manometer is also useful to measure the static pressure rise across a fan; knowing the fan head-flow characteristic (ask the manufacturer if necessary) and air temperature, air flow can be estimated.

Brick moisture content and loss on ignition are easily calculated from the comparative weights of a moist green brick, a dry green brick and a fired brick.

Instruments and measurements for dryer operation are covered in the EMAS Booklet "Reducing Costs in Drying" (See Appendix B).

Taking measurements requires pressure tapping points, holes for probes and so on. These are easily fitted during maintenance periods or when the plant is being built, but often cannot be fitted while the plant is in operation. For this reason it is recommended that connections for instrumentation be fitted at the next shut-down.

9. MOBILE PLANT

Much materials handling in brickyards is done by mobile plant, usually front end loaders and forklift trucks fuelled with automotive distillate or LPG. Fuel used in this equipment can be minimised by considering four basic principles:

- The site layout should be such as to minimise the length and number of trips made. For example it may be more economical to put a crushing mill near a stockpile and use a long conveyor to take the clay to the mixing plant than to put it near the mixing plant and make longer journeys with the front end loader.

- Mobile plant should be maintained in accordance with the manufacturers' instructions. A worn machine can use much more fuel and oil than one in good condition doing the same work. Similarly over- or under-unflated tyres can increase the fuel consumption considerably.

- Engines are often left idling for extended periods. The fuel consumption is considerable and cylinders become glazed, increasing the lubricating oil consumption and reducing the maintenance intervals. If an engine is to be out of use for 10 minutes or more it should be switched off after 5 minutes idling. (The idling allows it to cool slowly).

- Drivers should be encouraged to drive gently. Fierce acceleration and braking cause undue wear and tear on the vehicle as well as excessive fuel consumption, as well as being a safety hazard and unduly noisy.

APPENDIX A - ENERGY USE IN AUSTRALIAN BRICKYARDS

In 1985 the Energy Authority of NSW (now the Department of Minerals and Energy) conducted a survey of the brick industry throughout Australia. This covered 33 brickyards using several types of kiln and several different fuels. The questions asked covered production, kilns and forming processes as well as fuel and electricity used. The main conclusions drawn from the survey were:

1. Fuel accounts for 75% of the cost of energy, electricity for 25%.

2. 79% of the bricks produced are fired in tunnel kilns, the remainder in Hoffman or intermittent kilns.

3. Table A1 shows the fuels used.

Principal fuel used	No of yards	Total fuel used/yr		Average use per yard Million MJ/yr
		Million MJ	% of total fuel used	
Coal	12	636	9.2	53
Natural gas	14	5778	83.5	413
Wood and/or sawdust	5	378	5.4	76
Other (LPG or waste oil)	2	128	1.9	43
Total	33	6920	100.0	

Table A1 - Fuels Used - Survey Results

4. The specific fuel consumption is the heat in the fuel used per thousand bricks produced. For example, if a brickyard used 66 tonnes of coal with a heating value of 24GJ/tonne to fire 84,000 bricks, the specific fuel consumption would be $\frac{66\text{t} \times 24\text{GJ/t}}{84 \text{ thousand bricks}} = 18.9\text{GJ/thousand}$

   Table A2 shows specific fuel consumptions for different types of kiln in the survey.

Type of kiln in use	Average Specific fuel consumption	
	GJ/thousand (i)	GJ/thousand (ii)
Intermittent	17.3	21.1
Tunnel	10.0	9.9
Intermittent & Hoffman	16.8	22.1
Whole sample	11.9	17.3

(i) based on total fuel used and total production for all yards of this type
(ii) average of individual yard averages

Table A2 - Specific Fuel Consumption For Yards Using Different Types Of Kiln

5. Solid fuel fired kilns are often operated as efficiently as liquid or gas fired ones.

6. Use of reducing conditions during the firing cycle tends to increase the specific fuel consumption.

7. Table A3 shows specific electricity consumption for yards using different types of kiln. Note that most yards using tunnel kilns extrude the bricks, hence the high electricity use.

Type of kiln in use	Average specific electricity consumption	
	kWh/thousand (i)	kWh/thousand (ii)
Intermittent	92	86
Tunnel	183	222
Downdraught & Hoffman	117	181
Whole sample	167	136

(i) based on total electricity used and total production for all yards of this type
(ii) average of individual yard averages

Table A3 - Specific Electricity Consumption For Yards Using Different Types Of Kiln

8. Fuel and electricity together added (in 1984-5) between $20 and $60 to the price of 1000 bricks.

APPENDIX B - OTHER READING

1. Clay Products Manufacture

"Heavy Clay Technology" by FH Clews, published by British Ceramics Research Association and Academic Press.

"The Building Brick Industry" - No 2 in the Energy Audit Series, issued jointly by the U.K. Departments of Energy and Industry.

2. Energy Management

EMAS Booklets, published by the Energy Authority of NSW:

No 1: How to Conduct an Energy Study.
No 3: Reducing your Electricity Costs - Basic Concepts.
No 4: Reducing your Electricity Costs - By Improving the Efficiency of Energy Use.
No 5: Reducing your Electricity Costs - By Reducing the Average Purchase Price of Electricity.
No 8: Reducing Costs in Drying.

"The Energy Manager's Handbook" by GA Payne, IPC Business Press Ltd, Second edition, 1980.

"The Efficient Use of Energy", edited by IGC Dryden, IPC Science and Technology Press, Second edition, 1982.

"Steam" by EC Reid and JC Renshaw (Cole Publications, Melbourne, First metricated edition, 1977) contains several useful chapters on fuels and combustion.

"Seminar Paper on Wood - Energy Systems", available from Energy Management Centre, Hydro-Electric Commission of Tasmania (Tel 002 30 5724) discusses the use of wood as a fuel, including both combustion and fuel handling aspects.

APPENDIX C - COSTS & HEATING VALUES OF DIFFERENT FUELS

The fuels most commonly used in the brick industry are listed below, together with indicative prices (current in 1988).

Fuel	Approximate Price $/GJ (1988)
LPG	6 - 10
Automotive distillate	14
Industrial diesel fuel	14 - 16
Fuel oil - high sulphur	9
Fuel oil - low sulphur	9 - 12
Natural Gas	5 - 10
Black coal	2 - 3
Brown coal	3 - 5
Wood	
Sawdust	0 - 4
Electricity	17 - 36

Table C1 - Price Ranges Of Different Fuels (1988)

The heating value of a fuel as shown below is the heat released by complete combustion of the fuel.

Fuel	Heating Value	Notes
LPG - Propane	50.0 MJ/kg	
LPG - Butane	49.5 MJ/kg	
Automotive distillate	38.4 MJ/L	
Industrial diesel fuel	38.9 MJ/L	
Fuel oil - high sulphur	42.0 MJ/L	
Fuel oil - low sulphur	40.1 MJ/L	
Natural gas	40.0 MJ/m^3	1
Black coal	23-32 GJ/t	2
Brown coal	20-26 MJ/kg (dry)	2
Dry wood	50 GJ/Cord or 20 GJ/t	3
Dry sawdust	20 GJ/t	3
Electricity	3.6 MJ/kWh	4

1. At atmospheric pressure.
2. Exact value should be obtained from supplier or independent laboratory test.
3. Value approximate only, varies widely with timber type and moisture content. Obtain exact value by laboratory test.
4. This is not strictly a heating value but a conversion factor.

Table C2 - Heating Values Of Different Fuels

APPENDIX D - COMBUSTION

Combustion is a chemical reaction in which the combustibles in the fuel (mainly carbon, hydrogen or their compounds but sometimes some sulphur) react with the oxygen in the air, forming carbon dioxide, water or sulphur dioxide, and giving off heat.

The fuels most used in brick making and their main constituents are shown in table D1. Note that this table is meant as a guide, not a detailed analysis; fuels are often mixtures of quite complex chemicals.

Fuel	Main Constituents
Natural gas	Methane & ethane ie carbon & hydrogen
Coal (black & brown)	Carbon (mainly) Hydrogen Oxygen Sulphur Mineral matter
Wood	Carbon Hydrogen Oxygen Mineral matter
LPG	Propane ie carbon & hydrogen or butane ie carbon and hydrogen
Liquid petroleum fuels	Hydrocarbons ie carbon and hydrogen Sulphur

Table D1 - Constituents Of Fuels

Table D2 gives the main products of combustion of the various constituents. The chemistry of combustion is complicated and this table only gives the most important of the products.

Constituent of Fuel	Product of Combustion
Carbon	Carbon dioxide (Carbon monoxide if combustion is incomplete)
Hydrogen	Steam
Oxygen	-
Sulphur	Sulphur dioxide Sulphur trioxide
Mineral matter	Ash

Table D2 - Main Products Of Combustion

A certain quantity of air is required to provide the oxygen needed to completely burn the fuel. This is called the stoichiometric air quantity. If less than the stoichiometric quantity is supplied, the fuel is not fully burnt and a proportion lost as carbon monoxide or unburnt fuel. To avoid this, air in excess of the stoichiometric quantity is supplied. However, if there is too much excess air, the flame temperature is reduced and also an unnecessary quantity of heat is lost up the chimney.

The stoichiometric air to fuel ratio is determined by the composition of the fuel; table D3 gives it for various fuels. Note that different coals, woods and liquid petroleum fuels vary widely in their compositions so only ranges can be given.

Fuel	Stoichiometric air to fuel ratio
Natural gas	9.9 m^3/m^3 gas
Black coal	7 - 11 m^3/kg dry coal
Brown coal	7.5 - 8.0 m^3/kg dry coal
Wood (dry)	7 - 8 m^3/kg wood
LPG - Propane	12.4 m^3/kg gas
LPG - Butane	12.1 m^3/kg gas
Liquid petroleum fuels	10 - 12 m^3/kg fuel

Table D3 - Stoichiometric Air To Fuel Ratios

If no excess air is supplied, the combustion gases will contain no oxygen and the carbon dioxide content will depend on the fuel being burnt. As the excess air is increased, the proportion of oxygen in the combustion gases will increase and the proportion of carbon dioxide will decrease. Table D4 shows this for various fuels. Several chemical or electronic instruments are available for analysing combustion gases (See section 8), so the excess air supplied to a kiln can be measure and adjusted.

Excess air, %	0	100	200	300	400	500	600	800	1000
Oxygen, % (all fuels)	0	10.5	14.4	16.1	17.1	17.8	18.2	18.9	19.3
Carbon dioxide, %									
Fuel:									
Natural gas	12.0	5.7	3.8	2.3	2.2	1.8	1.6	1.2	1.0
Black coal (typ)	18.6	9.2	6.1	4.6	3.7	3.1	2.6	2.0	1.7
Brown coal	18.0	9.4	6.3	4.8	3.8	3.2	2.8	2.1	1.8
Wood (typ)	16.3	8.9	6.2	4.7	3.8	3.2	2.7	2.1	1.8
Liquid fuels (typ)	15.7	7.6	5.0	3.7	3.0	2.5	2.1	1.6	1.3
LPG	14.1	6.8	4.4	3.3	2.6	2.2	1.9	1.5	1.2

NB: Figures are approximate; precise values depend on the exact chemical composition of the fuel.

Table D4 - Relationship Between Excess Air And Oxygen And Carbon Dioxide Contents Of Dry Chimney Gases For Different Types Of Fuel

Many bricks are fired under 'reducing' conditions for part of the cycle, i.e. the kiln is starved of air. The resulting chemical reactions produce particular colour effects in the bricks. Reducing conditions can exist in one part of the kiln (e.g. within the flames) without the kiln as a whole having insufficient air.

To ignite and completely burn a fuel it is necessary to give close attention to the 'three T's' of combustion: Time, Temperature and Turbulence.

The fuel and oxygen must be in contact with each other for a sufficiently long **time** for the reaction to be completed. Note that if there is too much or too little excess air, the time required is increased. Thus some excess air is always required for complete combustion. However, too much excess air reduces the flame **temperature** too far, and complete combustion does not occur. The cooling effect of the surroundings can have the same result. Finally, the air and the fuel need to be intimately mixed. The best way to do this is to ensure the air and gas flows are sufficiently **turbulent.**

A burner is designed by the manufacturer to give adequate time, temperature and turbulence. However, if it gets dirty or damaged or if the fuel specification or air quantity or temperature are changed, one or more of the three T's might not be achieved and the performance will deteriorate accordingly.

The chemistry and physics of combustion are considerably more complex than appears from what is written here. Because of this, it is sometimes advantageous to supply the combustion air in two stages. Primary air is mixed with the fuel at the burner nozzle or under the grate and initiates the reactions. Secondary air supplied further from the nozzle completes the reaction and sometimes determines the shape of the flame. In some tunnel and Hoffman kilns part of the air that cools the fired bricks passes down the tunnel to the furnace section and is used as combustion air. A correct balance of primary and secondary air is essential for efficient combustion.

APPENDIX E - HEAT TRANSFER

Having burnt the fuel it is necessary to get the heat released into the bricks. Table E1 shows the principal characteristics of the three ways in which heat is transferred: conduction, convection and radiation.

	Conduction	Convection	Radiation
Takes place	Through a solid or between solids.	Within fluids or between a fluid and a solid.	Between solids or between a solid and a fluid or between a solid (or fluid) and space.
Requires	Unbroken solids or physical contact between solids.	Physcial contact.	Line of sight between hot and cold objects.
Increases with	Temperature variation in body.	Temperature difference, fluid velocity and turbulence in fluid.	Temperature of objects and temperature difference between objects.

Table E1 - Heat Transfer

Based on these characteristics, the main criteria for maximum heat transfer in a brick kiln are:

- Flames and gases should be as hot as possible.
- The gas path through the kiln should be long enough to cool gases to 50°C above the brick temperature near the exhaust.
- The gas paths through the individual stacks should be short enough to heat all the bricks at the same rate.
- The gases must contact all bricks equally.
- Uneven ash build-up on the bricks causes non-uniformity of firing.

A hot body loses heat to its cooler surroundings by convection and radiation. These losses are, together with operator safety, reasons for insulating kilns, ducts, dryers and other plant items. The rate of heat loss increases very rapidly with temperature. It is also affected by local draughts and air temperature, but to a lesser degree. Table E2 is based on air at 20°C and the air speed shown. It is accurate enough for most practical purposes.

Surface Temperature °C	Heat given off, MJ/h per square metre		
	Still air	Air speed 4 m/s	Air speed 8 m/s
50	1.1	2.8	4.0
100	3.7	9.9	14.3
150	7.6	18.9	27.2
200	12.6	31.5	45.4
250	19.1	46.7	68.7
300	27.0	67.5	97.2

Table E2 - Convection & Radiation Losses From A Hot Body

APPENDIX F - HEAT FOR DRYING AND FIRING

x

The calculation of the minimum heat required to dry and fire a brick is most easily explained by a simplified example. The key data are given in Fig F1.

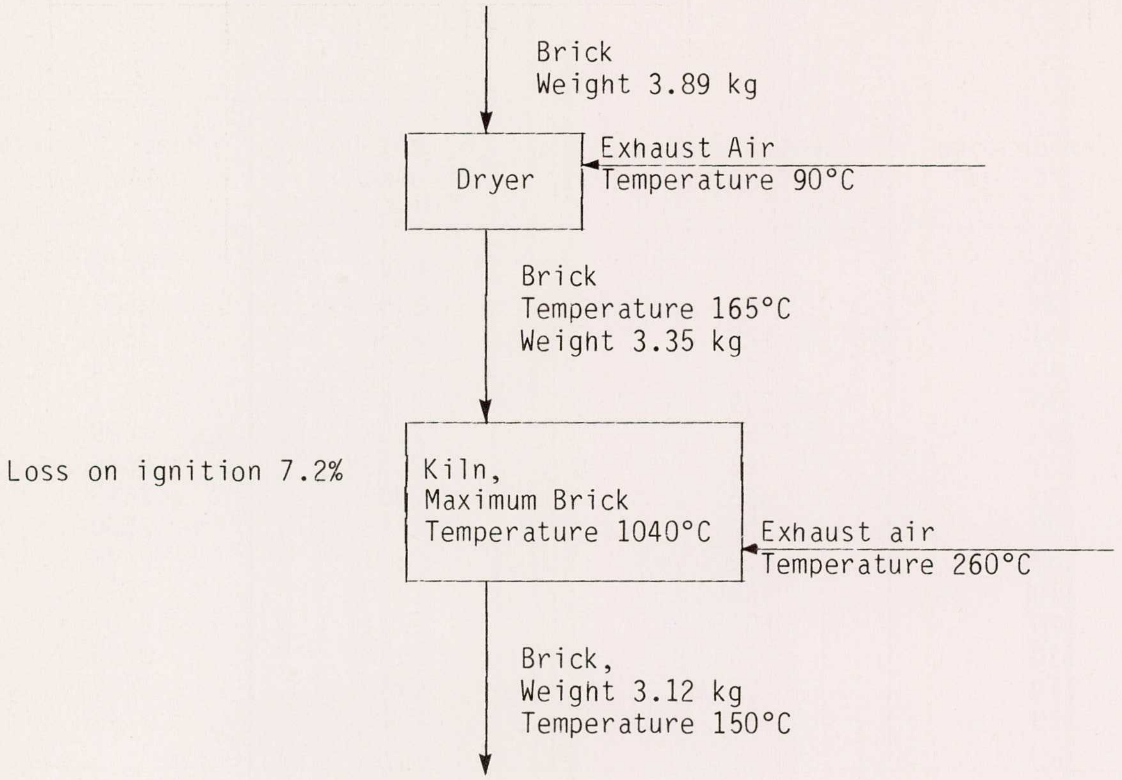


Fig F1 - Example Of Heat Balance

1. Calculate water in one moist green brick and loss on ignition

   Weight of brick entering dryer = 3.89 kg

   Mechanical water evaporated in dryer = 3.89 kg - 3.35 kg = 0.54 kg
   So moisture content of moist green bricks = 0.54kg/3.89 kg
   = 13.9%
   Loss on ignition = 3.35 kg - 3.12 kg
   = 0.23 kg
   So loss on ignition = 0.23 kg/3.12 kg
   = 7.2%

2. Calculate the heat required in the dryer for a single brick. The mechanical water comes in as water at 10°C and leaves as steam at the dryer exhaust temperature i.e. 90°C.

   From Table F1 (overleaf)

   Heat in water at 10°C = 43 kJ/kg
   Heat in steam at 90°C = 2660 kJ/kg

   So heat required = 0.54 kg x (2660 kJ/kg - 42 kJ/kg)
   = 1414 kJ

The brick is heated from 10°C to 165°C.
The specific heat is 0.85 kJ/kg°C.
So heat required = 3.35 kg x (165°C - 10°C) x 0.85 kJ/kg°C
= 441 kJ

So total heat required by dryer = 1414 kJ + 441 kJ
= 1855 kJ/brick

Temperature °C	Heat in Water kJ/kg	Latent Heat kJ/kg	Heat in Steam kJ/kg
10	42	2477	2519
20	84	2454	2538
30	126	2430	2556
40	168	2406	2574
50	209	2382	2591
60	251	2358	2609
70	293	2333	2626
80	335	2308	2643
90	377	2283	2660
100	419	2257	2676
110	461	2230	2691
120	504	2203	2707
130	546	2174	2720
140	589	2145	2734
150	632	2115	2747

NOTE:

- These figures apply at atmospheric pressure only.
- Conventional steam tables give the properties of steam at particular pressures and should be used for the properties of steam under pressure.
- These tables are based on 'Thermodynamic and Transport Properties of Fluids' by Mayhew and Rogers (Basil Blackwell, Oxford, 1980), which gives the properties of air and other gases as well as a full set of steam tables.

Table F1 - Properties Of Water And Steam

3. Calculate the heat required to heat the brick from 165°C to 1040°C.

Specific heat of brick = 0.85 kJ/kg°C
Temperature increase = 1040°C - 165°C
= 875°C

The heat required is calculated on the weight of the fired brick
Heat required = 3.12 kg x 875°C x 0.85 kJ/kg°C
= 2320 kJ/brick

4. Heat available from carbon burnout.

Note that various reactions in the kiln give up or absorb heat, but the carbon burnout is by far the most important one and the only one that needs to be considered.

Moist green brick contains 18.5% shale with a heating value of 250 kJ/kg.

Weight of shale in one brick = 3.89 kg x 18.5/100
= 0.72 kg

Heat given off = 0.72 kg x 250 kJ/kg
= 180 kJ/brick

5. Heat available from cooling fired brick.

Temperature drop = 1040°C - 150°C
= 890°C

Specific heat of brick = 0.85kJ/kg°C

So heat available = 3.12 kg x 890°C x 0.85kJ/kg°C.
= 2360 kJ/brick

Note that this is much more than the 1860 kJ required to dry and preheat the brick to 165°C.

Note: These figures are theoretical ones. The actual heat required in a kiln or dryer is always much more than these because of heat in the exhaust gases, heat loss through the kiln walls, leaks, etc.

APPENDIX G - CONVERSION FACTORS

To Convert	To	Multiply by
Btu	kJ	1.055
Btu/h	kW	0.000293
Btu/lb	kJ/kg	2.33
Btu/lb°F	kJ/kg°C	4.19
cu ft	m^3	0.028
cu ft/lb	m^3/kg	0.062
cfm	L/s	0.47
ft/s	m/s	0.305
ft/min	m/s	0.0051
kWh	MJ	3.60
HP	kW	0.746
lb	kg	0.454
lb/cu ft	kg/m^3	16.02
ton	tonne	1.016

Table G1 - Conversion factors

Prefix	Symbol	Multiple
kilo	k	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}
peta	P	10^{15}

eg 1 MW - 10^6W, 1 GJ = 10^9J = 10^6 kJ

Table G2 - Prefixes

DEPARTMENT OF MINERALS AND ENERGY

Reducing fuel and electricity costs
in brickmaking

Department of
Minerals and Energy