Cochran Chieftain Mark 4 Steam Boiler Control System Revised Design and Construction

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ABSTRACT

In this paper an attempt has been made to show how problems crea. I by imported machinery can be solved locally, and expeditiously using innovative and adaptive approaches. The technologies used were appropriate and easily understood.

A timer-control system and an electronic switch have been designed and constructed entirely from locally available materials, to replace an imported malfunctioning one.

The reliability of the locally designed and constructed one is high. It is still functioning one year after it was installed and tested. Transistors, pneumatic timers and conductors were used.

Keywords: Re-design, steam boiler, sequencer, ignition, flame detector.

INTRODUCTION

In August, 1991 the Meridian Tobacco Company, producers of 555 Cigarettes made an approach for the repair of their Thompson Cochran boiler type WEE Cochran boiler manufactured in 1975, which was malfunctioning.

First, an attempt was made to study the machine and its control panel carefully. Materials available for study included: the technical manual, a wiring diagram and a malfunctioning sequence timer-control unit.

Most machines brought into Ghana for industries became obsolete after a few years of operation due to the fast pace of technological development. These machines may then be re-conditioned or rehabilitated in order to give them a new lease of life. In a country such as Ghana a wide range of expertise with the ability for innovation is often required to restore broken down equipment back into production within a reasonable time.

Very often an attempt to obtain spare parts to repair the machines, prove futile for several reasons e.g. unavailability of the parts or that the machines are no more in production. However, if the spare parts could be obtained, it then turns out to be a big financial drain on the country's economy.

In situations like this, Ghanaian engineers are faced with finding lasting solutions to problems in order to relieve the country of some of her financial constraints.

GENERAL DESCRIPTION

The WEE Chieftain Mark 4 Boiler belongs to the latest class of boilers. It is a Tripple Pass boiler, having embodied in its design many unique features which ensure fast steam raising, great flexibility and long life. The WEE Chieftain has a fully automatic low flame start pressure jet burner, giving on/off operation on the 448kW (1122 kg/hr) boiler and high/low/off operation, ensuring a thermal efficiency in the order of 80% or above on the gross calorific value of the fuel over the operating range of the boiler. The boiler unit has only two small refractories, with low fuel consumption. It is supplied already tested and ready to put to work on site. A section of the boiler is shown in Fig. 1. [1]

The boiler is supplied with water by a feed pump (item 15). Water enters the boiler through the feed check valve (item 9). When the water reaches normal level which is about the middle of the water gauge glass (item 3) the feed pump is stopped by the dual control (item 6).

The burner (item 19) is bolted to the hinged front door (item 20) and is designed to atomise the oil fuel so that it can burn efficiently. Air required for combustion is provided by the

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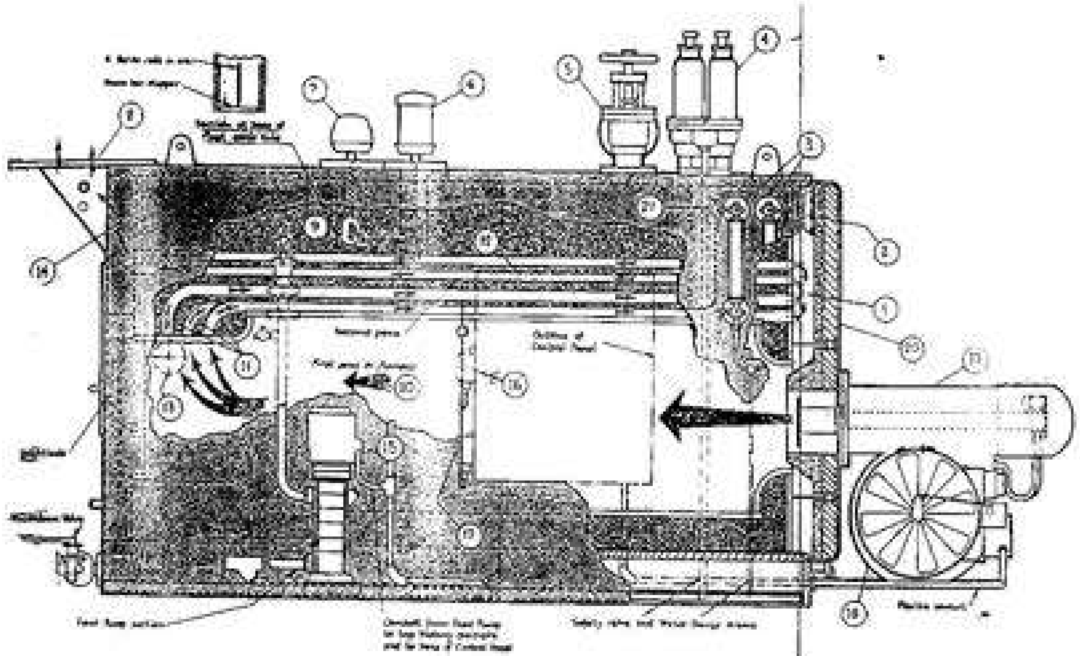

Fig.1: Cross-section Diagram of Cochran Wee Chieftain Steam Boiler.

furnace (item 10) receives radiant heat from the flame and the hot gases from the flame give up heat to the tubes in the second pass (item 11) as they travel to the front chamber (item 1). Gases turn in the front chamber and give up more heat to the tubes in the third pass (item 12) as they travel to the rear chamber (item 14). The gases leave the boiler by the chimney (item 8) at the top of the rear chamber.

As the steam pressure rises, the pressure in the boiler is shown by the pressure gauge (item 2). When the pressure is sufficiently high the main stop valve (item 5) can be opened to allow steam to pass to the process or heating system. When steam leaves the boiler the water level drops until it reaches a point (12mm) below normal level. The Dual Control will start the feed pump and more water will be fed into the boiler.

As the steam pressure falls the controlling pressure start (item 16) causes the burner to operate on the high fire. If the pressure rises the controlling pressure start will cause the burner to operate on low fire. When the boiler pressure reaches the maximum of 9.5 bar required, the limit pressure start (item 17) will stop the burner. When the boiler pressure falls to a pre-set point ie. 9 bar, the limit pressure start will cause the burner to start again. Should the limit pressure start fail to stop the burner, the safety valve (item 4) will lift and excess pressure will escape, thus preventing any further rise in boiler pressure.

If for any reason water is not supplied to the boiler and the water level falls to a point about 50mm (2") below normal level the Dual Control will stop the burner and ring an alarm bell. Provided the water level is restored quickly the alarm will stop and the burner will start automatically. If the water level continues to fall until it reaches a point about 76mm (3") below level the over riding control (item 7) will ring the bell and cause the burner to "lockout". The burner will not start again until the water level has been restored and reset switch has been operated. If it is found necessary to let water out of the boiler, this can be done by opening the blowdown valve at the back of the boiler.

THE BURNER TIMER SEQUENCE

The heart of the burner control system is a sequence timer unit. This was an LAC 3.05 sequence timer, a plug-in cam/electronic timer and flame detector device. Its operation may be divided into

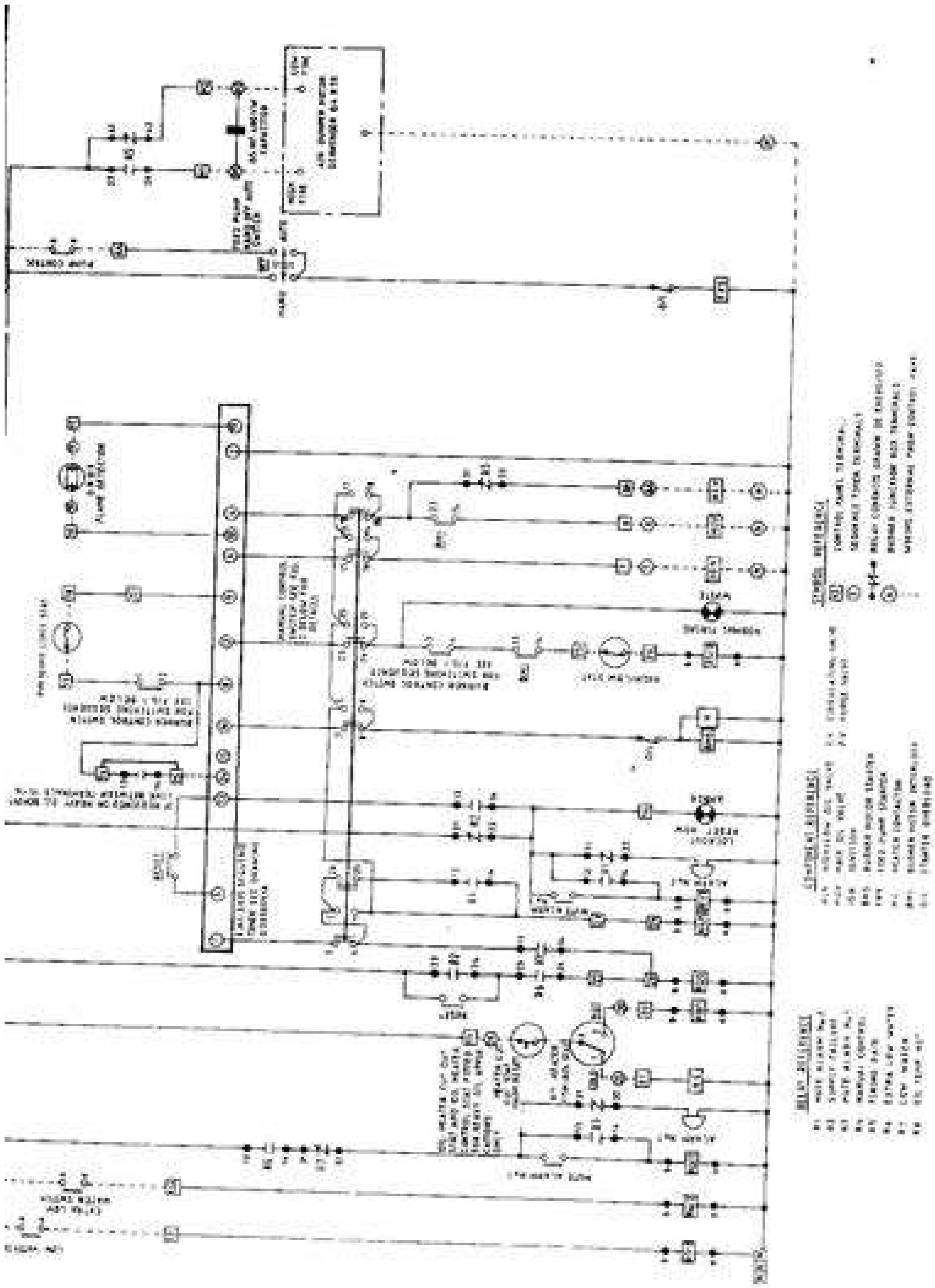

Fig. 2. *Original Control Schematic Diagram*

the following periods:-

i) a burner purge period
ii) a flame established period
iii) a flame detection and alarm period

The firing sequence can commence only after the water level float switching close their contacts to pick up relays R6 and R7 shown in Fig. 2. This makes supply voltage available to the sequence start switch. [1]

Upon starting, the sequencer starts the burner air supply motor only, and runs it for approximately 25 seconds to purge the system of any explosive air/fuel mixtures. The sequencer now enters the flame establishment period. This is a total of 25 seconds. The ignition transformer is turned on and then 5 seconds later the main oil valve is opened to allow atomized fuel into the steam. In the event that the burner is not fired and that the flame is not properly established, the flame detector, through a photo cell, switches off the system and locks it out after 15 seconds, and the system has to be manually reset. If the flame is properly established the controller locks in for a steady normal operation. The burner sequence timing is shown in table 1.

checked and replaced. It therefore became necessary to provide another solution to enable stalled production to take off.

It was decided that the new sequence timer should have the following specifications:-

i. It should copy the original timing sequence, but add a second automatic restart before lock-out in the event of flame failure.

ii. There should be no call for operator intervention.

iii. It should have identical terminals to the sequencer it is replacing.

iv. Locally sourced parts should be used.

v. It should be easily maintained. This should include a Consideration of available maintenance skills.

vi. It should be simple in construction to allow access for diagnosis when faulty.

Table 1. Sequencer Timing Table

Time in seconds	Sequencer operation
0 - 25	Burner system purge
25 - 30	Brief stop, re-start with ignition transformer energized
30 - 35	Flame established period
35 - 50	If flame is not established by the end of this time the sequencer stops and locks out. Alarm bell rings

The problem with the faulty sequencer was that after completion of the purge and flame established periods, it was unable to lock in for steady operation. It shut down and had to be reset. The indication appeared to be one of improperly functioning flame detector circuit. All attempts at repairing this circuit did not yield any fruitfull results. Identical replacement parts were not available, and it appeared these sequencer units were not intended to be repaired when faulty. Replacement units available were however not pin-identical, and a conversion drawing had to be used. However the problem persisted, even after the photo cell was thoroughly

vii. A clear schematic should be produced.

viii. All safety features should be maintained.

An examination of the control panel mounted on the side of the boiler revealed that sufficient space existed in the panel to mount any contactors and timers needed. Space also existed for the new flame detector. The original panel layout is as shown in Fig. 3.

The schematic of the modified design is shown enclosed in dotted lines in Fig. 4.

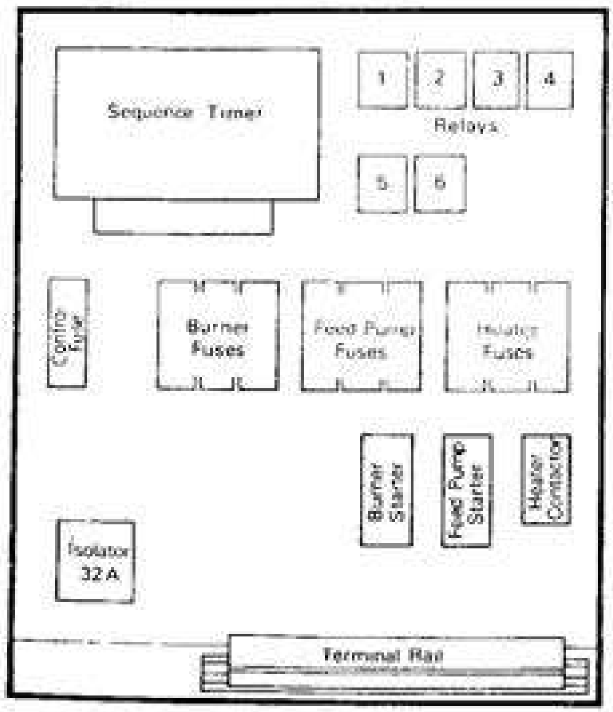

Fig. 3: Original Control Panel Layout Wee Chieftain Mark 4.

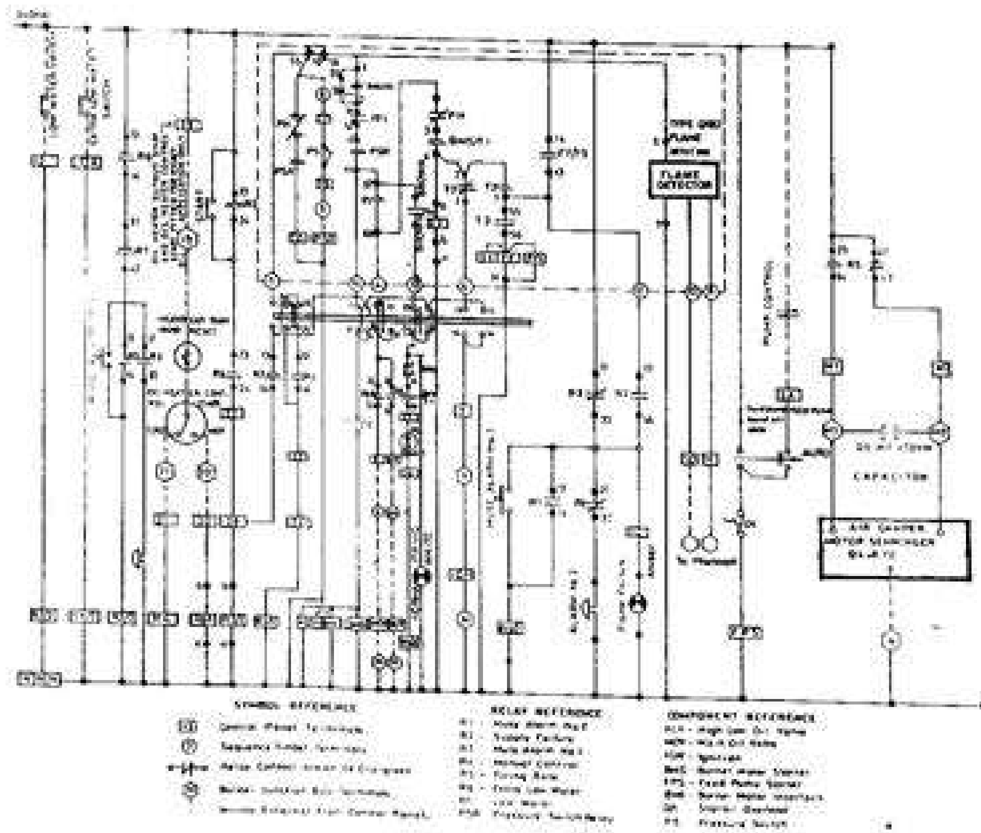

Fig. 4: Modified Control Schematic Diagram.

The following are the main features of the new sequencer:-

- **T0** is the overall cycle timer and lock-out device
- **T1** is the purge timer
- **T2** is the ignition/flame establishment timer
- **T3** is a flame failure timer and ignition cycle reset timer
- **PH** is a flame detector relay used as the lock-in device.

Table 2 shows the timing diagram for the new sequencer. Also shown in fig.4 are key relays such as the burner motor starter BMS, flame failure relay FF, ignition relay IGN, main oil valve relay MOV, fuel rate relay R5 and the high or low oil valve H/LV. The shaded areas in Table 2 indicate when a device is on. Power supply to the sequencer through terminal 1 ensures that the firing process cannot be started unless the low water level switch is closed. Again the steam pressure switch PS must be closed, indicating that the steam pressure is below its high limit before the firing sequence timer T1 can be energised. The sequence timer once started and depending on time setting as shown in Table 2, is capable of completing two firing cycles. Failure of the flame to be established by the end of the second cycle leads to stoppage of the sequence and lock out of the sequencer by the timer T0. The procedure can only be res-started manually after T0 times out.

Farther, in order to extend the life of the firing electrodes and the ignition transformer, the timer T2 ensures a definite ignition time. When the flame has been established, this circuit is disabled by a normally closed contact of the flame detector relay PH. The layout of the new sequencer and its integration in the control panel is shown in Fig. 5.

THE FLAME DETECTOR

This is a simple transistor switching device with a DPDT relay as load, designed and constructed on site. The designed parameters are as shown in

Table 2: NEW SEQUENCER TIMING.

Timing in seconds	Sequencer operation	On - operation of critical devices											
		T0	T1	T2	T3	BMS	PH	FF	IGN	MOV	RS	H/LV	
0 - 25	First Cycle System Purge	▨	▨			▨							
25 - 30	Ignition	▨		▨		▨			▨	▨			
30 - 50	Flame Failure/Reset	▨			▨	▨		▨					UNSUCCESSFUL
50 - 75	Second Cycle System Purge	▨	▨			▨		▨					FIRING
75 - 90	Ignition on	▨		▨		▨			▨	▨			
90 - 100	Flame Failure/Reset	▨			▨	▨		▨					
	Lock out	▨											
0 - 25	First Cycle System Purge	▨	▨			▨							
25 - 30	Ignition on	▨		▨		▨			▨	▨			SUCCESSFUL
30 - 50	Successful Ignition					▨				▨	▨		FIRING
	Lock in					▨	▨			▨	▨	▨	

KEY : ▨ Device on ☐ Device off

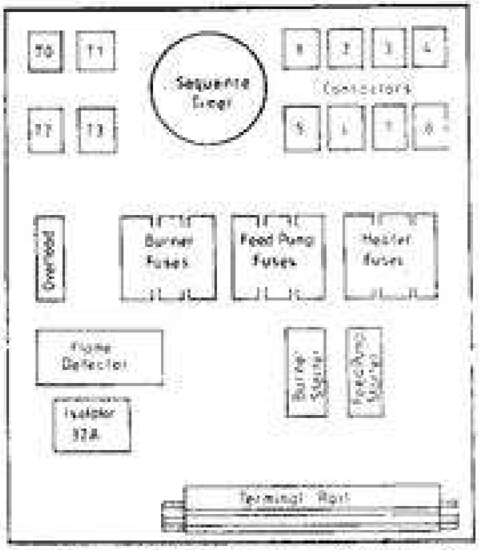

Fig. 5: Modified Control Panel Layout Wee Chieftain Mark 4

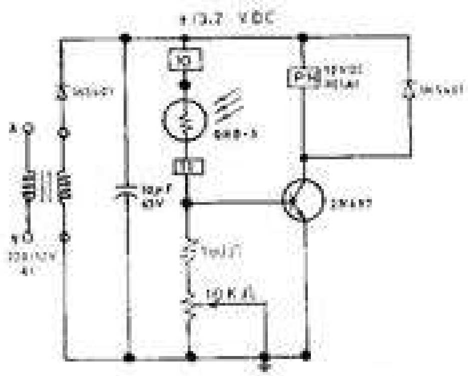

Fig. 6: New Flame Detector Circuit.

Fig.6. Although this is a well known circuit to electronic device designers, the component values shown are those particularly determined for the light dependent resistor LDR, type QRB-3 on the burner. Almost any general purpose switching transistor may be used [3]. From the manufacturers data the burner flame produces a minimum illumination level of 25 lux. However the sensitivity of the detector can be varied by use of the variable resistors, to drive the transistor into saturation and thus ensure its effective switching to pick the relay PH. This provides the lock-in contact in the burner sequencer. The entire circuit was constructed on vero-board and installed in the control panel.

THE IGNITION SYSTEM

The ignition period proceeds when timer T1 times out and closes its normally open contact. This allows the ignition period timer T2 to supply power to the ignition transformer. This transformer produces an a.c. voltage between 6-12kV which is applied to the firing electrodes, to ignite the atomized air/fuel mixture [4]. The experience of the authors elsewhere is that, this unit is a source of downtime for many electrically fired boilers. The problem is usually aggravated by the non-availability of replacement spares and the impossibility of rewinding faulty units. In a very difficult situation the ignition system may be easily replaced, at least temporarily, by the circuit shown in Fig. 7, in which components used are off-the-shelf items [3].

The duty cycle of this circuit is $D = \frac{R1}{R2}$

The charging time = 0.685 R1.C sec.

The discharging time = 0.685 R2.C sec.

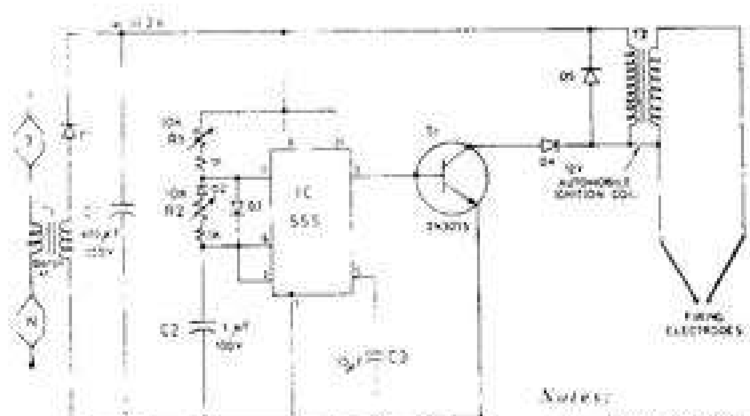

Fig. 7: Alternative Ignition Circuit.

Notes:

(1) All Resistors are half watts 10% Types.

(2) D1-D5 are 3A 100V such as 1N5401.

(3) Terminal 7 and N are in the Control Panel.

Output frequency $f = \frac{1.46}{(R1 + R2)C} Hz$

The design values for R1, R2 and C were calculated to give an ignition firing rate of about 100 sparks per second. This corresponds to an engine speed of 3000 rpm in a 4 cylinder, 4-stroke automobile spark engine. Hence the ignition coil is required only to operate within its usual range in an automobile. The component values calculated yield coil charging and discharging times of 45% and 55% respectively of a complete period. This provides sufficient time for the coil to charge up fully before discharging. The 555 timing IC is connected as an astable multi-vibrator which together with the switching transistor simulates the behaviour of the automobile engine and its distributor.

This circuit can be quickly assembled on perf-board or on printed circuit board. The Mampong Project did not require this alternative ignition system, but it was available on the eventuality that it was needed.

CONCLUSIONS

The boiler was put back into technical operation on August 20th, 1991, and shut down after 7 months for off-season maintenance in Mach 1992. Steam was produced at the rate of about 1120 kg/hr at 9.5 bar for 154 days, working 10.5 hours per day. The cyclic operation of the boiler required on the average about 2 firings per hour. This therefore called for over 3000 operations of the burner sequencer timer during the production period. Records show that there was not a single failure of the boiler during this period, and confidence in the system was firmly established. Thus, there was no loss of production due to unavailability of steam for treatment of tobacco.

Estimates of the cost of the redesign, installation and testing, including consultants fees as a percentage of the cost of lost production was only about 1.5 percent.

The design objectives stated earlier were met, including particularly the simplicity of the layout as an aid to maintenance. The resident electrician was involved in the installation and thus had the opportunity to understand the operation of the design.

ACKNOWLEDGEMENT

We acknowledge Meridian Tobacco for the opportunity given us and also providing us with logistics and material in undertaking the assignment.

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