CHAPTER 7

CONCLUSIONS, RECOMMENDATIONS AND IMPLEMENTATION OF FINDINGS

7. CONCLUSIONS, RECOMMENDATIONS AND IMPLEMENTATION OF FINDINGS

7.1 IMPLEMENTATION PHASE

In Chapter 6 it was shown how optimum combustion air flow results were obtained under test conditions (Chapter 5) and with certain special process settings (Chapter 4). The criteria were the following:

- The main aim was to determine the optimum safe air flow and flue gas oxygen content corresponding to the best appropriate thermal efficiency (Figure 6.28). This was not achieved at the lowest air flow (Figures 6.16, 6.17 and 6.18), before the production of significantly increasing CO, which conventional wisdom dictates.
- The unit as a whole was evaluated and not only the boiler in isolation.
- The tests were carried out over the anticipated loading regime of the plant (400 MW to 630 MW).
- The extremes in the possible range of supply of run of mine coal qualities, each in discreet batches of known quality type, were tested (as calculated in Chapter 4.1 and Appendices C, D and E) and as a result, distinguished by their Reactivity (Figure 6.32).
- The testing conditions were limited to steady state fixed loading (no transient conditions due to mill changes, AGC and frequency bias causing load ramps, were permitted).
- The control system was set as described in Chapters 4.6.3 and 5.1.5 (boiler master and capability range to accommodate the air/fuel correction facility range, the CV correction range and critical pressure deviation reaction rate, etc.)

- The furnace sootblowing was carried out as described in Chapter 5.1.4.
- The mill bypass damper setting produced a fully open position at 24 kg/s and fully closed at 32 kg/s PA flow (as opposed to the design of 21 and 28 kg/s respectively), as explained in Chapter 4.3.1.

These results and settings had to be evaluated under normal operational conditions prior to establishing them as future operational practice, i.e., with *blended* coal having a low to spec. quality (normal feedstock), while the unit was operating on fully automatic control (on AGC and frequency bias) and ramping load at the allowed maximum rate, etc. This was also necessary until the mining plan could be adjusted to supply batches according to the quality batch or blockburn mode required, to fully benefit from the possible efficiency gain. The minimum permissible loading of the Lethabo units had also been changed to 350 MW, since the completion of the tests. An extrapolation of the almost linear behaviour of air flow and flue gas oxygen vs load could not be accepted outright, but had to be tested first.

The results obtained confirm, amongst others, values for economiser oxygen in flue gas of below 2% for certain cases of load and coal quality, which deviates from the official Statutory Regulation(35), paragraph 4.12.7 (also see Figure 6.20). This however, in no way detracts from this Regulation, since compliance with the "minimum requirements" specified in paragraph 1.1 is considered necessary "in the absence of any supplementary information". This view is supported by an accepted international standard code[36], (mentioned in paragraph 4-5.2(b)), which contains the other relevant standard[37] (and comparative paragraph 4-2.2(b)), which recommends that the minimum and maximum values of air and fuel shall be verified by tests. This now indeed has been done for the first time at an ESKOM power station.

Sufficient confidence in the plant behaviour had been generated by the tests to apply the results for normal operation, since the values of optimum air flow and oxygen were not the extremes tested. Verification that the values determined could be proved safe and valid under transient conditions and with blended coal required practical testing on a trial unit. In order to provide an additional margin of safety, dynamic operational guides on the visual display unit (VDU) were made available to the operator (Figures 7.1 and 7.2).

In contrast with the Statutory Regulation[35], that sets the economiser outlet oxygen value alone as the limit, it was proposed that the Air Flow - Steam Flow relationship per coal quality (Figure 7.1) be the primary priority guideline. The Economiser Oxygen - Air Flow relationship (not units generated) should serve as a secondary guideline since:

- Air Flow is a primary input and oxygen a result.
- Air Flow instrumentation is more accurate, representative, stable and reliable than oxygen.

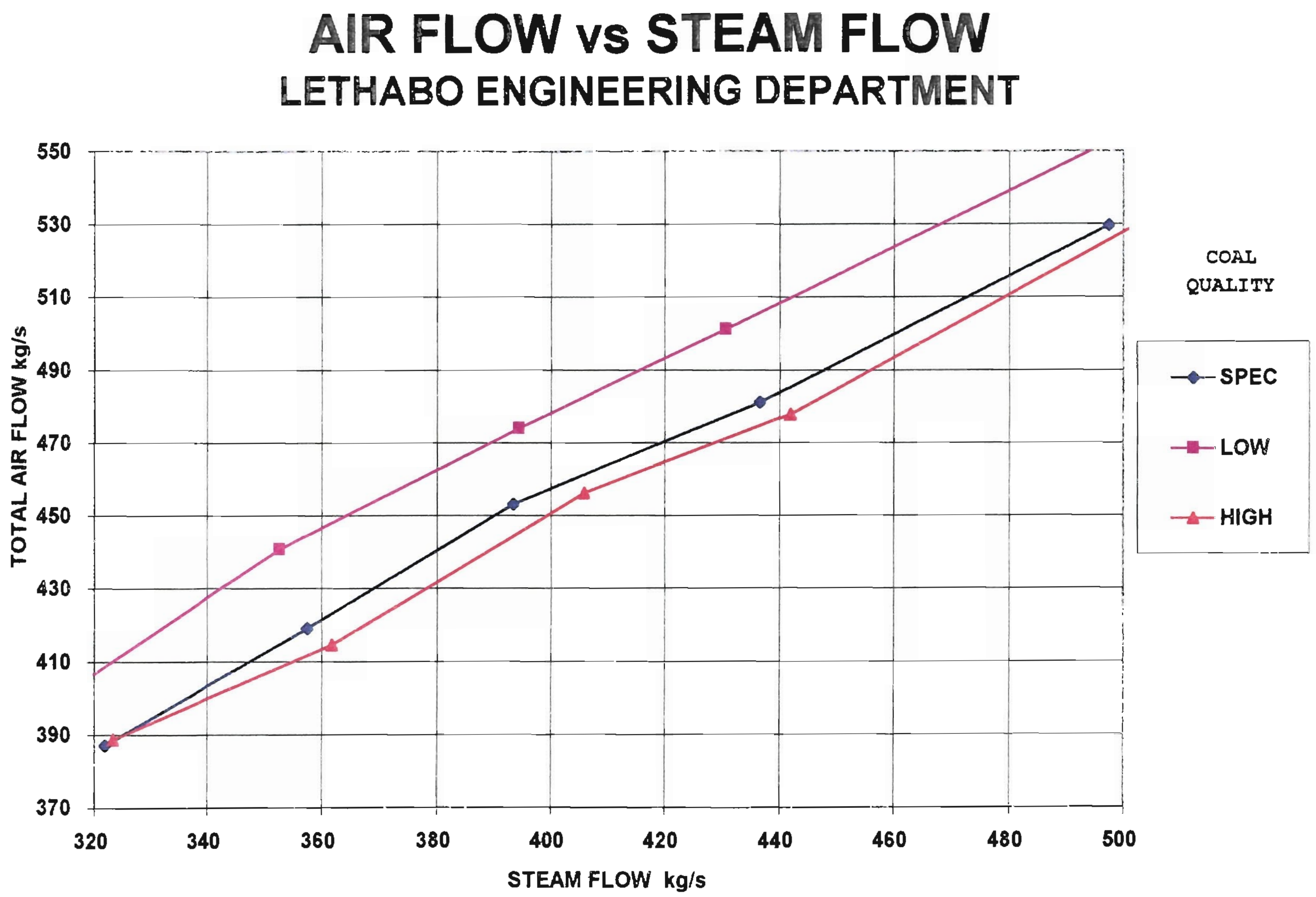

Figure 7.1: AIR FLOW - STEAM FLOW CURVE

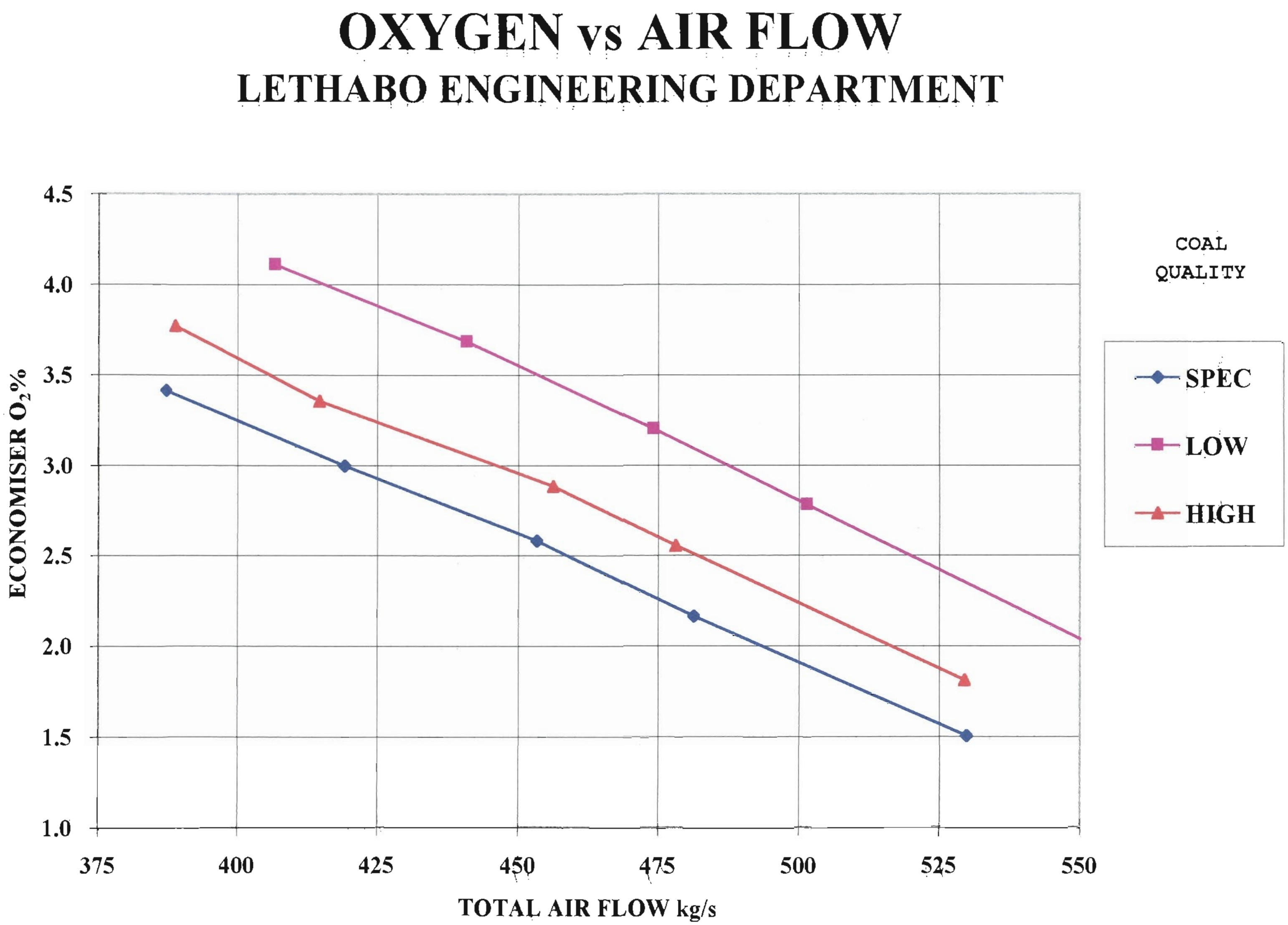

Figure 7.2: OXYGEN - AIR FLOW CURVE

- Furnace in-leakages and the oxygen content of the coal greatly effects the oxygen analyser reading.

To explain the apparent contradiction of the relative order of the oxygen lines corresponding to spec. and high grade coals (Figure 7.2), see 6.2 page 53. The two guideline screens should however be used together, since faults such as excessive air heater leakage and leaking air supply ducts affect the air flow indication. In conjunction with the desired control set-up, the air flows had to be within the control range of the Air/Fuel correction panel facility. The guideline screen information displayed on the VDU was identical to Figures 7.1 and 7.2, together with a dynamic moving operating point. The air flow target line defined for blended coal was that of the spec. grade coal, while the high grade coal line sets the minimum value. During difficult operating conditions, typically caused by Lethabo low grade coal, the air flow needs to be increased toward the low grade guideline, which should improve conditions but also serves to establish the maximum value. On the same guideline screen as the air flow - steam flow, feed flow was added as a dynamic moving point. Additional information could then be obtained such as the early warning of a tube leak, before audible detection is possible, when the two dynamic moving points (steam flow and feed flow) move apart.

The two guidelines were designed to be used by the operator to adjust the air flow to the optimum value and also serve as diagnostic tools. If conditions displayed were such that the dynamic oxygen reading (on

Figure 7.2) were *higher* than the equivalent air flow reading (on **Figure** 7.1), the following were suggested actions to identify possible process or plant deficiencies:

- Excessive furnace air in-leakage compared to the test conditions (inspection doors, faulty water seal, burner core air counter weights set differently, damaged gas-pass skin casings, etc.).
- More mills in service than the norm, introducing more seal air.
- Excessive aerofoil casing in-leakage.
- Faulty economiser oxygen instrumentation or leaking sampling matrix.
- Coal quality being different than anticipated.

If conditions were such that the dynamic oxygen reading (on **Figure** 7.2) were *lower* than the equivalent air flow reading (on **Figure** 7.1), the following were suggested actions to identify possible process or plant deficiencies:

- Excessive air heater leakage compared to the test conditions (implying the supplied air is bypassing the furnace).
- Excessive leaking air supply ducting between the fans (PA and FD) and the burners.
- Faulty economiser oxygen instrumentation.
- Coal quality being different than anticipated.

If such plant defects were eliminated, the conditions could be balanced by setting the air flow until the two related dynamic points coincided in relative position on the respective graphs. The balanced relative positions would then in turn indicate the coal quality burnt at that time. Note that other indicators such as number of mills in service and PA flows needed at that load, CV correction indication, etc., could not be used, since volatile content or reactivity, not CV, determines the optimum air flow. These diagnostic abilities had not been available previously, but were made possible by the simultaneous evaluation of the air flow and economiser oxygen guidelines.

Unit 4 was selected as trial unit, with the following requirements set for safe testing:

- The normal range of blended low and spec. grade coal had to be supplied. Coal qualities outside the limits tested fell outside the scope of these trials and should not be burnt at Lethabo at all.
- Unit and mill controls, including mill bypass damper settings, load lines and control of grinding media tonnages, were set such that the operating points fell within the range of the boiler master, CV correction and air/fuel correction functions for the coal quality range received. The unit was subjected to normal transient conditions due to AGC and frequency bias, mill changes, etc.
- Air heater leakages had not been allowed to increase to the extent where the air flow and oxygen operating points indicated inadequate air supply to the furnace.
- Sootblowing was done according to the frequency and philosophy practised during testing, as described in Chapter 5.
- The air flow and oxygen guidelines were extrapolated down to 350 MW to suit the loading minimum (as in Figures 7.1 and 7.2) and the air

flow was controlled as explained above according to the guidelines screens, utilising the VDU.

After four months of operating under the above conditions, during the latter part of 1997, the major stakeholders (Power Station Operations and Engineering as well as Corporate Engineering (custodians of the Statutory Regulation(35))), agreed upon the following conclusions based on close observations:

In general, the trial unit performed satisfactorily and safely in all respects. Any normal load change could be handled while on auto control with minor adjustments to the air/fuel correction facility necessary, while ramping load up or down. The pyrometers indicated safe operational conditions and there were no incipient metal temperature excursions, except due to other factors such as employing a top mill with problem burners, characteristic to the specific unit. Provided the control set-up was equivalent to that as explained above, the air flows were within the control range of the air/fuel correction panel facility.

The air flow - steam flow relationship was proved to be the most suitable guideline rather than oxygen - air flow. The oxygen air flow relationship is best used in combination with air flow - steam flow in tracing plant deficiencies, as a fine tuning facility or serving as a back-up to air flow. Also, oxygen should rather be evaluated against air flow rather than load as stated in the present Regulation(35).

The mill bypass damper setting as used in the 1994 tests (open at 24 and closed at 32 kg/s PA flow) contributed to the higher cycle efficiencies obtained opposed to the original setting (open at 21 and closed at 28 kg/s PA). This is clear from basic heat transfer theory, but was illustrated practically in an increased classifier exit temperature (CET) at the same boiler load for a higher PA flow, without negatively affecting the dry flue gas loss. This means that more heat was gained from the primary air heater, (known to be underdesigned in terms of surface area) into the PA without sacrificing temperature on the SA side. The ratio of the primary to secondary air flow was increased for the same total air flow. This also aided in the desired increase of drying power in the mill during the receiving of relatively wet coal.

A minor adjustment was found necessary to the mill bypass damper settings, made without sacrificing a noticeable efficiency change. Whilst the original setting proved too responsive, in occasionally causing the HP/IP bypass to open during load changes, the new setting was sluggish at times during upward load ramps from above 550 MW. The optimum bypass damper setting was explored during this period and proved to be open at 24 and closed at 30 kg/s PA flow. The safety aspects of this setting regarding air/fuel ratios in the mill and the burner pipes were found to be satisfactory, well below the stoichiometric value at the start up and shut down transient values.

During the initial on-job training, as well as the rest of the time of this practical evaluation period, positive feedback was expressed by operations staff of the additional benefits gained, especially from the dynamic operating points on the VDU. An example that occurred frequently was the prevention of superheater metal temperature excursions by means of air flow adjustment. There were occasions where temperature excursions were threatening, whilst it could clearly be seen that the oxygen value was high relative to the equivalent air flow value on the VDU guidelines. By reducing the air flow until the corresponding dynamic operating points were relatively equal, it was clear that the coal quality lay between spec. to high grade and the impending excursions were caused by too much air flow, which raised the heat release barrier (see Chapter 4.1.1).

Conversely, there were occurrences with excursions threatening with the VDU indicating that the oxygen was relatively lower than the corresponding air flow. By increasing the air flow to equalise the relative oxygen and air flow dynamic moving points, it could be seen that the coal was of the low grade type and the superheater metal temperatures improved contrary to expectation. This was due to the air flow compensating for the lack in volatiles and reducing the delayed combustion which caused the high heat release barrier. Prior to the introduction of this operating aid the prediction and visible display of the problem would have been very difficult. The general impression of the trial unit in operation was also that of smoother running and fewer problems, indicating the combustion air flow being the proper amount, hence the operating staff's positive response.

The conclusion of this exercise and validation of the results served to confirm that Lethabo Power Station will henceforth operate as per these guidelines as tested. These guidelines become the new minimum requirements with respect to air/fuel ratio as required by the Statutory Regulation(35), approved by Corporate. These guidelines do not override other normal operating standards, especially when plant and process defects are present.

7.2 CONCLUSIONS AND RETROSPECTION

The gain in overall efficiency of Lethabo Power Station, due to the optimum air flows obtained from these tests, can be expressed in monetary terms. An extremely conservative approach has been adopted, since a favourable return on investment (ROI) is not the key criterion for applying these air flows or not. It is important that the gain in efficiency and other positive advantages can be obtained without any additional capital expenditure. After the testing was completed, it only required process settings, control system adjustments and the guidelines screen implementation.

The order of magnitude of the efficiency gain can be judged against known equivalents, excluding major design modifications. A parameter that is regarded as having a significant impact on efficiency is the choice of feedpump supply. The difference in cycle efficiency between running the electric feedpumps (EFP) vs the steam turbine driven feedpump (SFP) is a loss of about 0.3 % at Lethabo. While the choice of feedpump is also not always controllable, due to the availability of the SFP, combustion air flow is the most controllable loss. The efficiency gains due to the recommended air flow ranges between 0.5 - 1.2 % on average (Figures 6.16, 6.17 and 6.18), depending on the coal quality and against which other criteria it is compared, i.e., the current practise before these tests (original design, etc.) or the Least Air Flow theory (conventional wisdom). The difference in thermal efficiency due to coal quality only can approach 2 % and due to loading 2 % as well (Figure 6.27).

Table 7.1 shows the financial gain of the Optimum Air Flows obtained from this project compared against the Current Practice for each case of Low, Spec. and High grade coal. The Current Practice values were obtained by using the current/design oxygen in flue gas values at 550 MW (± 3 - 3.3% O_2, Figure 6.20) and deriving the corresponding air flows with their tested efficiencies from Tables F.2, G.2 and H.2 (Appendices F, G and H), or graphically from Figure 6.28.

The 550 MW loading was used, since it was the load that produced the highest efficiency and was very close to the average loading of this base load station. An average of only five out of the six units were used to cater for outages, which is conservative and the cost saving is calculated per annum. The savings were divided into two sections: the Efficiency savings and the Reliability type savings (i.e. only

Table 7.1: COST BENEFIT: PROJECT OPTIMUM vs CURRENT PRACTICE

EFFICIENCY SAVINGS (ANNUAL)		LOW	SPEC	HIGH
Maximum Efficiency at Optimum Air Flow	%	35.92	36.40	38.01
Efficiency at Design/current practise Air Flow	%	35.44	36.16	37.92
C.V. of Coal fired (as received)	MJ/kg	15.54	15.36	17.89
USO	MW	550	550	550
Coal Burnt at Optimum Air Flow	kg/s	98.54	98.40	80.89
Optimum Air Flow versus Design/current practise:				
Coal Burnt saving	kg/s	1.34	.64	.19
Coal Price (marginal)	R	12.39	12.39	12.39
Coal Burnt saving (Annual for Station, 5 units @ 90% load)	R	2622064	1257619	367982
USO increase (for fixed coal supply)	MW	7.4	3.6	1.3
USO sales total profit rate	R/MWh	13.26	13.26	13.26
USO sales total nett profit	R	4292339	2076238	742114
Estimated combined saving (only one month fixed coal supply):	R	2761254	1325838	399160
EROSION AND WEAR SAVINGS (ANNUAL)				
Mill ball wear rate	g/ton	131	122	86
Mill ball price	R/ton	3200	3200	3200
Boiler Tube Leaks wear rate factor due to gas velocity		1.10	1.19	1.08
Boiler Tube Leaks wear rate factor due to less coal burnt		1.01	1.01	1.00
Total Boiler Tube Leaks wear rate, combined factor		1.11	1.19	1.09
Boiler Tube Leak history	Leaks/year	6	6	6
Average Repair cost/leak including start-up Fuel Oil	R	120000	120000	120000
Optimum Air Flow versus Design/current practise:				
Mill ball savings	R	88936	39627	8128
Projected Boiler Tube Leaks with Design/current Air Flow	Leaks/year	6.69	7.16	6.51
Cost saving on tube leaks with Optimum Air Flow	R	82780	139503	61575
Total erosion and wear saving:	R	171716	179129	69703
Optimum Air Flow versus Design/current; total annual saving:	R	2932970	1504967	468862

certain Erosion and Wear savings). A total is calculated in each category and finally a combined total is derived. In the Efficiency savings category, only the marginal price of the coal was used, which is again conservative. Should any capital expenditure in the stockyard prove necessary (additional stacker- reclaimer to accommodate blockburning, etc.), the ROI period would be longer, but then the total coal price should have been used (R29.57 per ton), which more than doubles the savings per annum. The USO profit rate used (R13.26/MWh) was also the total profit of the station and not only the generation cost profit rate, which is greater.

The Efficiency gains were calculated in two ways. Firstly the Coal Burnt saving was purely the saving in coal, due to the efficiency difference between the Optimum obtained from the tests and the Current Practice, for the three coal qualities. The second manner is one often overlooked, i.e., the additional USO due to the increased efficiency, had the coal supply rate been fixed. (This has often happened at Lethabo during peak loading, especially in winter times. Experience showed that when Lethabo ran six units above 90% load, it was only a matter of time before deloading had to take place due to inadequate coal supply rate.) This second way of calculating the efficiency gain produces figures almost double those produced by the first method (Table 7.1). The Estimated combined saving due to efficiency was calculated by weighting the two methods above at 11:1 in favor of the coal saving. This means that only a total of one month per annum is contributed to a USO gain during fixed coal supply. (In the light of the present "Trading and Bidding" scenario this may again be conservative).

Concerning the Erosion and Wear category, only savings due to reduced mill ball wear and anticipated fewer tube leaks were taken into account. The reduced mill ball wear was based on recorded figures of Lethabo grinding media consumption reduced by the amount of lower coal that has to be ground, due to the efficiency increase. The reduced number of tube leaks was based on the Lethabo tube leak history and projections. The savings were based on the experience that this erosion is proportional to gas velocity cubed (V^3) as well as less ash, due to the lower air flow and the coal saving respectively. For each tube leak the repair cost and start-up fuel oil cost is known.

The total saving, which is the combined Efficiency and Erosion/Wear saving, appears as the bottom total in Table 7.1. An identical exercise was performed by comparing the tested Optimum air flow efficiencies with those of the Least Air Flow theory. Note that the boiler tube erosion is a loss when compared to the Least Air Flow method due to the lower gas velocities, but the Efficiency and mill ball savings override that by far. The end results were savings ± 67% greater than those of the savings compared to the Current Practice (Table 7.2).

Factors and savings that were not taken into account due to not having exact figures for calculation purposes, but that would make a significant difference to the above savings are:

- Erosion of other boiler internals such as gas ducts, precipitator internals, ID fan impeller and vanes, secondary air heater pack

Table 7.2: COST BENEFIT: PROJECT OPTIMUM vs LEAST AIR FLOW

EFFICIENCY SAVINGS (ANNUAL)		LOW	SPEC	HIGH
Maximum Efficiency at Optimum Air Flow	%	35.92	36.40	38.01
Efficiency at Least Air Flow criteria	%	35.08	35.51	36.67
C.V. of Coal fired (as received)	MJ/kg	15.54	15.36	17.89
USO	MW	550	550	550
Coal Burnt at Optimum Air Flow	kg/s	98.54	98.40	80.89
Optimum versus Least Air Flow Theory:				
Coal Burnt saving	kg/s	2.36	2.48	2.95
Coal Price (marginal)	R	12.39	12.39	12.39
Coal Burnt saving (Annual for Station, 5 units @ 90% load)	R	4613614	4843696	5767838
USO increase (for fixed coal supply)	MW	12.9	13.5	19.4
USO sales total profit rate	R/MWh	13.26	13.26	13.26
USO sales total nett profit	R	7476270	7851176	11248836
Estimated combined saving (only one month fixed coal supply):	R	4852169	5094319	6224588
EROSION AND WEAR SAVINGS (ANNUAL)				
Mill ball wear rate	g/ton	131	122	86
Mill ball price	R/ton	3200	3200	3200
Boiler Tube Leaks wear rate factor due to gas velocity		.82	.90	.98
Boiler Tube Leaks wear rate factor due to less coal burnt		1.02	1.03	1.04
Total Boiler Tube Leaks wear rate, combined factor		.84	.93	1.01
Boiler Tube Leak history	Leaks/year	6	6	6
Average Repair cost/leak including start-up Fuel Oil	R	120000	120000	120000
Optimum versus Least Air Flow criterion:				
Mill ball savings	R	156486	152621	127400
Projected Boiler Tube Leaks with least Air Flow theory	Leaks/year	5.04	5.55	6.09
Cost saving on tube leaks with Optimum Air Flow	R	-115461	-53469	10590
Total erosion and wear saving:	R	41026	99152	137990
Optimum versus Least Air Flow theory; total annual saving:	R	4893194	5193471	6362578

erosion and blockages, etc.

- Savings on capital expenditure of screens, metal spraying, etc., to reduce erosion.
- Tiling of mill classifiers, burner banjo inlet core air tubes, etc.

- Mill lifting and end liner abrasion.
- Additional mill girth gear and pinion wear.
- Environmental limit excursion penalties. The opacity values also showed an improvement, compared against the Current Practice, (see Appendices F, G and H). These were only monitored to identify potential limitations of optimum air flow recommendations, which could have been overridden by opacity limitations. In the event this did not happen.

In retrospect, the following conclusions can be summarised in light of the original objectives and eventual findings of the project:

- The total combustion air flow supplies the most controllable loss and the independent variable with the highest impact in the fossil fired power generating process.
- The testing of the unit as a whole, and not just the boiler in isolation, presents higher maximum efficiencies at higher optimum air flows than the conventional "least air flow theory", thus rendering a safer operational practise.
- The best criterion to determine the optimum combustion air flow and to satisfy the most requirements i.e. financial savings, safety, global aspects and air quality emission requirements (opacity, NO_x, SO_2, CO_2, etc.), reliability aspects (boiler and gas pass erosion, indirectly turbine blade erosion, milling plant wear, etc.) is the point of maximum overall efficiency of the whole unit, as opposed to only boiler testing to satisfy e.g. just the lowest NO_x production.
- The optimum air flow is a function of load as well as coal quality.

- The indirect losses method of calculation is not adequate to calculate efficiency. It has to be reconciled with the direct side and the minimising of unaccounted losses.
- A direct side calculation method has been developed by means of a three criteria gas balance technique, which eliminated the representivity problem of coal mass flow, resulting in the calculated coal density to correlate well with coal qualities such as moisture.
- The STEP program mechanism with its sliding targets and forcing reconciliation of direct and indirect sides proved to satisfy the above requirements. A tuned model with customised targets renders it an optimising and performance monitoring tool which is more than a reporting by numbers system.
- The bomb calorimeter result fails to present CV values of coal representative of the process, which is better provided by a CV calculation method based on elemental analysis.
- The new proven mill by-pass damper setting contributed to the efficiency gain, by supplying the much needed increase in drying power of the primary air, thereby offsetting some of the primary air heater surface area deficiency.
- The frequency and philosophy of sootblowing developed for these tests proved to have operational advantages.
- This was a macroscopic, study where certain of the findings were supported by independent microscopic type studies. One such was the carbon in ash results of the different coal qualities at different air flows, which correlated with the deflagration theory of Lethabo coal ignition.

7.3 RECOMMENDATIONS

7.3.1 It is recommended that the power station formally adopts the new air flow - steam flow and oxygen - air flow guidelines, by ratifying them and ensuring that they are applied (Section 7.1).

7.3.2 It is recommended that the mining plan be investigated regarding the feasibility of the segregated coal supply. The coal contamination limits (CV) guideline proposed is according to **Figure** 7.3. This affects the heat flux to the boiler surfaces, the burner and milling limitations, etc., and should always be adhered to. The coal reactivity results (**Figure** 6.32) define the optimum combustion air flow and can be differentiated by the ratios indicated on **Figure** 7.4. The ratio of fixed carbon to total volatiles could have a segregation value of 2.2. The spec. and high grade test coal had ratios of 2.1 - 1.8 and the low grade coal 2.3 - 3.0. These values are indicated diagrammatically in **Figure** 7.5 and can be added to **Figure** 4.4, the Burner stability diagram, as an official guideline for Lethabo coal.

7.3.3 To properly implement this proposal an on-line coal analyser, which includes moisture analyses, should be employed. These produce an elemental analysis on a short time basis at a representivity of the coal which is orders greater than that of the traditional line sampler. The CV calculation from the elemental analysis for the STEP program, etc., will be readily available as well as better control during blending stockyard by-pass activities.

COAL CONTAMINATION LIMITS
CV [MJ/kg]

LEGEND: **AS FIRED**
(AIR DRIED)

	LOW		SPEC		HIGH
LIMITS	**13.5** (14.5)				**18.5** (19.3)
		15.2		**16.9**	
TESTED (BOMB)	**14.6** (15.5)		**15.0** (16.1)		**17.1** (18.4)
TESTED (CV CALC'ed)	**15.5**		**15.4**		**17.9**

Figure 7.3: COAL CONTAMINATION (CV) LIMITS

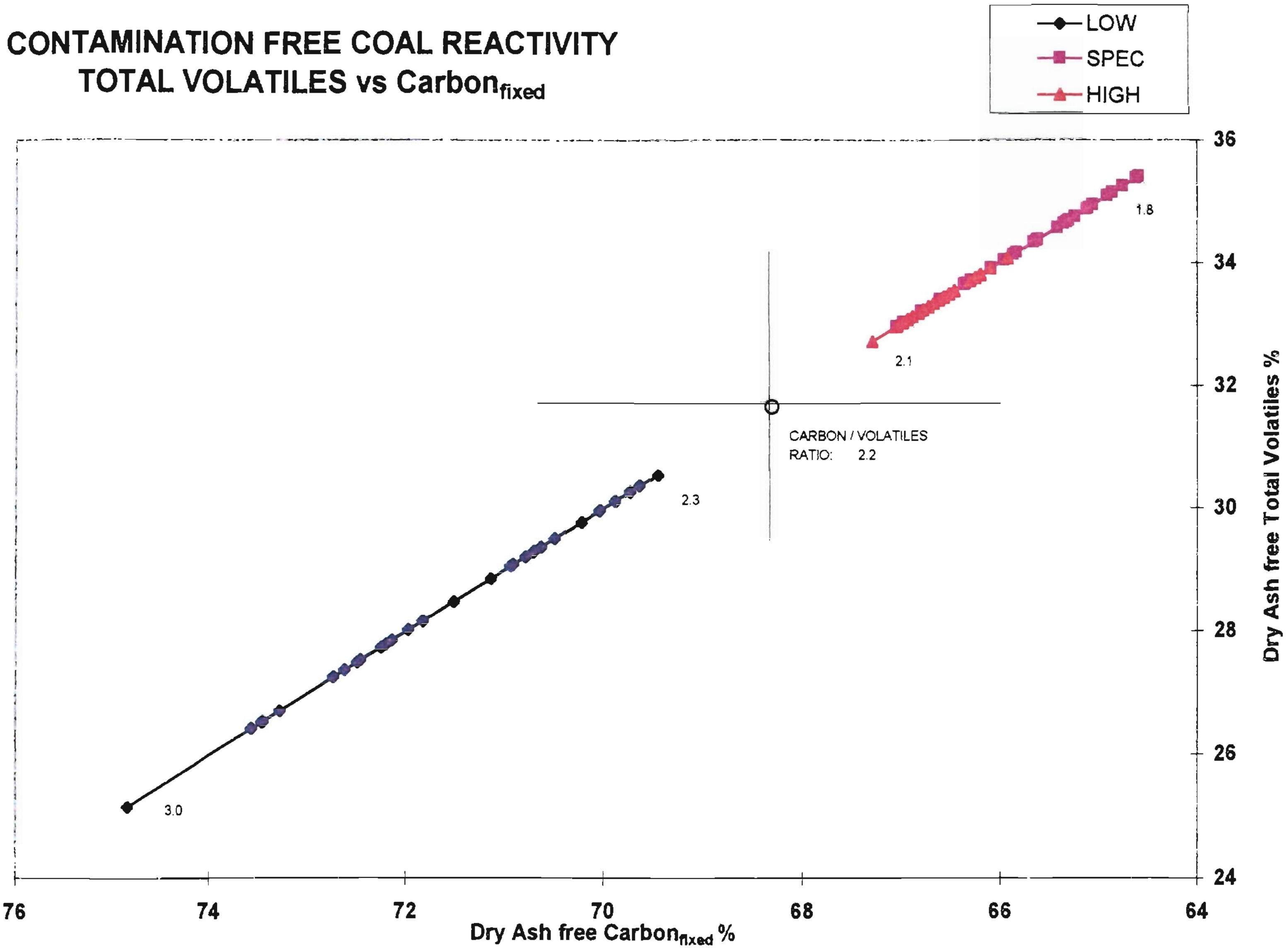

Figure 7.4: FIXED CARBON to TOTAL VOLATILES RATIO

COAL REACTIVITY LIMITS

DRY ASH FREE FIXED CARBON / TOTAL VOLATILES RATIO

	LOW		SPEC and higher	
LIMITS	3.0	2.2		NO LIMIT
TESTED	3.0	2.3	2.1	1.8

Figure 7.5: COAL REACTIVITY LIMITS

7.3.4 It is recommended that samples of Lethabo coal (Low, spec., high grade and blended qualities) be tested soon on the on-line coal analysers at present under evaluation in ESKOM.

Data for the CV calculation as well as the possible correlation of volatiles to ash trends should prove valuable in the calibration of such an instrument. These actions should provide the initial information regarding any suggested changes to the Lethabo coal contract with its bonus and penalty clauses.

Additional recommendations can be expanded to further testing and projects arising from this air flow optimisation at different coal qualities:

- A determination of the exact ratios of fly ash to bottom ash per load per coal quality. At present only the value at full load with blended spec. coal is available, and this was determined during the contractual full load precipitator acceptance test as being 92.8 : 7.2.

- The efficiency gain contribution of only the new by-pass damper setting on the mills vs the original setting, all other factors kept constant.

- In addition to the beneficial sootblowing philosophy, an attemperating spray water set-point optimisation project to enhance steam temperature and superheater metal temperature control.

- Instead of the planned acquisition of CO monitors for each unit (Lethabo already has two for the ducts of one unit), a portable CO_2/O_2 monitor can serve the purpose better and at lower cost for air in-leakage detection, after connection to the sampling matrix at the economiser. The calculation methodology in Chapter 6.1 illustrated the value of quantified air heater leakage, expressed in kg/s rather than a fraction of flue gas and furnace in-leakage. This can improve the diagnostic ability in the interpretation of the VDU graphs (Figures 7.1 and 7.2). In conjunction with an on-line coal analyser (from which a revised Ostwald diagram can be compiled) determination of furnace in-leakage can accurately be determined to evaluate the actual combustion air quantity (furnace O_2 can not be measured as explained in Chapter 6.1 and 6.2).

- To improve both STEP inputs as well as air heater leakage determination, temperature measuring points after the air heater (as in Appendix B) connected to the SICOMP data will be valuable.

- In aid of the customisation and representivity of the STEP program, an on-line STEP should be installed to eliminate the errors caused by the average of the target instead of the target of the average.

- The monitoring of tube thicknesses of the furnace walls for early detection of possible CO corrosion-erosion, since the excess air percentage is slightly lower than the design or current practice. There should be no serious problem since the optimum air flows are well above those on test that produced significant CO. The Least air flow theory could cause a greater problem in this respect.

- This project illustrated a new method of testing: The unit as a whole, rather than separate boiler and turbine acceptance testing. The testing also illustrated the potential of the application at power stations with higher CV coal. The varying oxygen content in the coal off-sets the oxygen limitations, stated in the guideline prescribed by the Statutory Regulation, that the air flow is controlled by. An investigation should be done to identify other potential power stations where the determination of the optimum air flow, especially with different coal qualities, could produce higher maximum efficiencies with financial gain and reliability improvement.