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A feasible Solution towards

Efficient & Economic Generation

Of

Steam & Utilities

In the

Valentina Industrial Zone

A study financed by Mauritius Research Council

Contents

History of the Pollution Problem at Valentina

Since the early nineties, a group of inhabitants of Valentina and Petit Camp started showing concern over what they saw as a deterioration in the environmental conditions caused by factories in the vicinity.

It is interesting to note that in October 1993 when the Ministry of Environment & Quality of life issued an EIA licence to one new factory in that zone, this group of inhabitants took the Department of Environment to Court contesting the issue of the Licence. Court proceedings started in May 1994 and lasted up to November 1994. The pollution issue was again strongly raised by the "forces vives" of that region – and eventually a Tri-partite Committee comprising Hon R. Purryag, Hon R. Peeroo, Hon S. Obeegadoo and Hon S. Lauthan (as chairman).

This committee in fact met over 20 occasions between 1996 and 1996 and several issues were discussed, namely

1. Training of boiler operators
2. Particulate Emission measurement
3. Fuel change from coal to gas
4. Use of sieved coal
5. Noise pollution
6. Water pollution
7. Health survey
8. Iron sheets & bins for the inhabitants

   Etc

I was myself associated in some of the meetings since early 1992, and with hindsight it is evident to me that the decisions implemented have not really been effective or efficient.
In fact, between Dec 1997 and Feb 1998, we wrote to a couple of Ministers to expose our views that some of the decisions taken were not in the best interests of the country and would worsen the overall situation. The title of our letter where we proposed our solution was: From a NO- WIN to a WIN - WIN situation.

We are sorry to mention that our faxes received no response at all from the Authorities!

The causes of air-pollution caused by boilers

Boilers, when properly operated, contribute significantly towards productivity in process factories – but unfortunately due to ignorance, this equipment is most often wrongly installed, poorly operated and inadequately maintained.
As a result, it causes air pollution, but even more important, it considerably affects the performance of the factory.

In 1997, we carried out a detailed survey within factories in the Valentina region to assess pertinent factors which in fact contribute towards pollution, namely :-

(1) Skills and experience of boiler operators

(2) Operational practice

(3) Fuel storage system

(4) Fuel treatment system

(5) Boiler installation

(6) Chimney

(7) Boiler maintenance practice

(8) Water treatment

(9) Steam usage

(10) Performance monitoring

Our findings revealed that most of the boilers were not being efficiently operated, and as such, problems were being encountered in areas of productivity (*which should have been a matter of concern to management of the respective factories*) and in the environmental front where the local residents strongly voiced their opinions.

Those pertinent points responsible for the sub-standard performance of boilers are described hereafter.

(1) Skills and experience of boiler operators

Most of the boiler operators simply did not have the right background and training to operate boilers to the highest efficiency and safety standards . Most of them had not followed any formal training, and they were working more or less on their own.

In at least 4 factories, boilers were operated without the attendance of any operator. Their so-called “boiler operator” would be a person (a welder or a mechanic working elsewhere) running back to the boiler only in case an alarm sounded off indicating boiler shutdown.

It must also be pointed out in other factories, the conditions inside the boiler houses were so difficult (hot, humid, noisy, dark, pungent) and the working hours so long (72 hours per week) and monitoring facilities were so lacking that the factory was “bargaining “ for inefficiency.

(2) Operational practice

Record keeping (use of log sheets) was very poor and could not be used to control and analyse performance of the boilers. Essential monitoring equipment were not available on site, and no concern at all was shown on actual boiler output/**specific** fuel consumption.

(3) Fuel storage and fuel treatment system

The heavy oil supplied to most process factories in the Valentina Region is a mixture of mainly heavy oil of viscosity 1500 Redwood seconds and small amounts of Diesel oil. This oil contains small percentages of sludge and water.

In order to give trouble free and clean combustion, it it very important to observe the following precautions in the storage and use of the fuel.

Drains

The storage oil should be provided with an appropriate drain facility to allow regular removal; condensed water and sludge which will tend to build up with time. Accumulation of such sludge will foul the quality of fuel admitted into the burners and give rise to smoke problems. In order to safely drain the storage tank without polluting the tank premises, it is essential to have properly designed separator compartments to prevent oil content escaping into the grounds or in public canals. The drainage facility must also include appropriate looking system to prevent unauthorised personnel to open the drain valve. Furthermore, the drainage activity must be carried out by a responsible person who knows what to drain, and who can provide feedback to the factory owner in case any anomaly is observed.

It must be pointed out that the drainage facilities mentioned aboved were not available in most of the storage systems in the Valentina region

Fuel Circulation

A static fuel stock tends to separate the heavier phase from the lighter phase to such extents that fuel oil admitted into the burner tends to be more viscous that the original 1000 Redwood seconds or 600 Redwood seconds fuel. As a result, heating systems designed to deal with say 1000 Redwood Seconds fuel-oil may be inadequate for 1200 Redwood Seconds or 1500 Redwood Seconds fuel, and thus give rise to smoking problems.

Hence the need to ensure proper circulation of the contents of the storage tank to prevent setting of heavier phases.

Few boiler installations had this recirculation facility in thieir fuel storage systrems

Fuel Admission System

Clean combustion inside the boiler can only be ensured if fuel is heated up to the right the right temperature and pressurized to the right pressure. All boiler operators asked the question could not give the exact temperature and exact pressure which they had to observe at the burner inlet.

In fact, in a region like Valentina, where the temperature variations between day and night and winter and summer is particularly more pronounced than elsewhere, fuel heating facilities have to be adequately rated to allow increased heating where necessary to obtain the right temperature.

Similarly, the pressure conditions also must be maintained within close range to achieve the right degree of atomization.

We have noted that fuel heating facilities and pressure control facilities were appropriate in only a couple of factories, and elsewhere there is a necessity for improving upon the existing system.

The risks of smoking will remain if the improvements suggested above are not implemented. To be able to monitor fuel quality, it is also a must to have basic measuring instruments like fuel viscosimeters. None of the factories had this meter.

All these factors can lead to an inconsistent fuel quality which can lead to smoking and unreliable operation.

(4) Boiler Installation

Few of the factories had proper boiler houses - otherwise, the boilers were housed in locations which rendered maintenance and smooth operation quite difficult. Pipe layouts and quality of pipeworks were poor, essential pipe fittings (valves, **manifolds**, gauges, samplers, etc) were missing, flooring was in a total mess, working clearances were not respected at all.

(5) Chimney

There is a misconception that a chimney is just a circular pipe of certain height to throw away the exhausts from the boiler at a height above the boiler house. In fact a chimney has to satisfy several parameters :-

(1) Emission velocity
(2) Temperature gradient
(3) Height of emission
(4) Structural constraints
(5) Exhaust gas concentration/dilution

(a) Location of boilers

Boiler houses should be located in such areas which will ensure that at least in the prevailing wind direction, the chimney height is a clear 7.5 metres above any obstacle within a distance of 90 metres.

At the time of the survey, most of the factories did not observe this criteria. As a result, due to turbulence in the wind flow, emissions did not get carried away into the atmosphere to the fullest extent.

Physical space constraints in the individual factory premises now leave only one option – raising of chimney heights.

(b) Chimney Sizes

The deterioration of chimney sizes is quite a precise exercise which takes into consideration the sulphur contents of fuel, the emission velocities of blue gases, the capacity of the boiler, the proximity of buildings and obstacles.

None of the factory owners convinced us that the chimney sizes had taken all the above factors into consideration.

In fact, the only modification carried out to most of the chimneys involve height increase-emission velocities have not been measured and adjusted where necessary. The result is therefore risks of flue gas flowing down outside of the chimney-it is suspected that this is a factor contributing to some extent to the problem of pollution in Valentina.

These factors were not really taken into serious consideration in the choice and installation of the chimneys.

(6) Boiler maintenance

Regular maintenance of the burner and regular cleaning of **tubes** and water side of tubes, of valves and traps, of exhaust chimneys are important interventions which should be carried out.

The vicious circle of poor operational practice in boiler operation dictating longer hours of operation and hence reduced or practically no maintenance is a common phenomenon in the textile and processing sector.

In most factories, little priority was given to these matters, and in fact it was more breakdown maintenance which was being practiced.

(7) Water treatment

This is perhaps the most sensitive area of boiler operation, which is responsible not only for most boiler failures but most importantly, for poor production levels as it is a form of invisible loss.

The basic in-house testing facilities and lack of instruments, coupled to the problem of inadequate design of the feed water sstem makes proper water treatment quite difficult and boiler output and boiler safety is severely jeopardised.

(8) Steam usage

The use of inappropriate steam trapping systems, steam and condensate recovery system, water heating methods and inadequate design of pumping, drain and storage sytems was also quite common in most of the factories.

(9) Performance monitoring

It was also found that in most of the factories real evaluation and analysis of energy generation, energy usage and energy alternatives have not been done, and vague figures and estimates have been used in say comparing the level of utilisation of boilers, effectiveness of steam boilers compared against thermic fluid heaters or fuel fired air dryers, etc.

This is why we consider that generating steam under the present system is equivalent to a **NO-WIN** situation in the sense that:

I. Boilers are being inefficiently used
II. Foreign exchange is being wasted
III. A chance for competitiveness is being lost
IV. Pollution problem is not tackled effectively
Etc

What then is the WIN-WIN situation??

The layout of the process factories at Valentina present an ideal site for a Centralised co-generation plant which can conveniently supply most of the plants with steam with the following advantages:

(1) CHEAPER ENERGY FROM CO-GENERATION FACILITIES

(1) CLEANER GENERATION OF STEAM

(3) SAVINGS IN FOREIGN EXCHANGE

(4) BENEFITS UNDER **KYOTO** PROTOCOL

(5) REDUCED TRANSMISSION LOSSES FROM THE NATIONAL GRID

Description of Cogeneration Plant

This cogeneration Power Plant shall consist of:

Three 10 MW medium speed Diesel Plant running on either 1500 or 3500 sec Redwood fuel oil, capable of generating 24 MW of continuous electricity, and say 12 – 15 ton/ h in the form of steam and substantial amount of hot and warm water.

The plant shall also comprise diesel powered air compressors fitted with heat recuperation facilities to also generate hot and warm water.

The steam, hot and warm water and compressed air produced by the central plant shall be supplied to the individual factories through either underground or overhead pipes, each supply being metered appropriately.

The facility could also have a centralised effluent collection farm for appropriate energy recovery, treatment, partial re-use and safe disposal.

Exhaust emissions shall be disposed by a properly designed 65m high chimney.

The plant shall be designed as a sound attenuated facility meeting the environmental standards for noise and other pollutants.

It could be owned, operated and maintained either by CEB personnel or owned by an independent Power Producer.

The plant shall not be a prototype, and shall normally be similar to plants already in proven commercial and industrial operation.

This plant could also have a dedicated fire fighting facilitiy which shall optimise on water storage and water pumping capacity.

<u>Cheaper Steam from Cogeneration facility.</u>

It is worth noting that a properly tuned boiler with strictly controlled feed water quality injecting steam into a properly conceived pipework system, with steam separators, condensate pumps, flash vessels, insulation, heating coils, pressure regulators and thermostats, blowdown tanks, etc can be expected to have a good Overall System Effectiveness (OSE) of

Combustion Eff. x Heat T.Eff. x **Utill.** Eff.

Typical values would be 0.88 x 0.85 x 0.95 = **71%,** which would be considered excellent.

On the other hand, a poorly tuned boiler with poor water treatment and poor steam pipework system will have a low Overall System Effectiveness (OSE) :

Combustion Eff. Heat T.Eff. **Utill.** Eff.

Eg 0.75 x 0.4 x 0.70 = **21%**

Unfortunately, many factories have their OSE for steam nearer to the lower side, and the tragedy is that they do not realise how much they are losing in terms of production volume, production time and production costs.

<u>Example:</u>

In any factory where there is often complaint regarding heating process to be too slow, we can assume that plant output depends on boiler availaility. In such cases, the figures below will give a clear illustration.

A 5 ton/h boiler operating at at OSE of 0.21 will generate about 500 tons of steam per month, and assuming that 1 kg of product requires 15 kg steam, the overall production output will be around 36 tons/month.

The same boiler operating at an OSE of 0.71 will generate 1,800 tons of steam per month with a production volume of nearly **120 Tons.** In other words, production volume <u>can more than treble</u> if steam is generated efficiently.

Unfortunately, our industrialists do not seem to be interested in exploring and exploiting these possibilities, and the end result is steam generated quite expensively.

COGENERATION PLANT

In a conventional electricity generating process, the most efficient power plant converts only 40% of the heat content of the fuel into electrical energy, the balance of 60% being lost as waste energy.

About 60% of this wasted energy can be recuperated from the following circuits:-

(i) Exhaust gases

(ii) Raw water and internal water circuit

(iii)Lubricating oil circuit

This recuperated heat energy can be used to generate steam and hot water. Thus a cogeneration plant converts between 75% to 80% of the heat content of the fuel compared to 40% in a conventional process.

In short,by using cogeneration technology to produce steam a competitive advantage can be given to our exporting factories and also a cost avoided to the Mauritian economy.

There are of course some basic precautions to be taken to ensure that a cogeneration performs well :-

(i) proper choice of the diesel sets required,

(ii) proper choice of auxiliary equipment used for heat recuperation

(iii) proper installation,operation and maintenance of the equipment.

In Mauritius, there is good experience and expertise in the field of diesel power generation and there is no reason why a diesel cogeneration plant cannot give reliable performance.

CLEANER GENERATION OF STEAM

A 30MW diesel power plant fitted with an exhaust chimney of height 65m and running on fuel of viscosity 380Cst having a maximum sulfur content of 4% gives off the following emanations:

Noise Levels.

Noise levels at 8 points along the periphery of the station premises are expected to be

(1) 66 dB(A)	(2) 59.5dB(A)	(3) 57.0 dB(A)	(4) 56.5 dB(A)
(5) 44.7 dB(A)	(6) 46.6 dB(A)	(7) 66.6 dB(A)	(8) 78 dB(A)

In the context of Valentina ,this means that the noise level reaching the residential zone will be less than 60dB(A) which is quite low.

Vibration levels.

The vibration levels from the power station at 3 different points along the station periphery are expected to be of the order of 0.98mm/s ,0.70mm/s and 0.40 mm/s which is well within the limits of the French standards (5mm/s for structural buildings).

Air Pollutants.

The gas emissions from a 30MW Diesel Plant in Kg/s are :-

Nitrogen	57.25
Oxygen	6.20
Steam	2.78
Carbon dioxide	4.84
Sulfur dioxide	0.12
NO_x	0.17
Particulates	0.0083
GROSS TOTAL	**71.4Kg/s**

The dispersion of these emissions will depend on the chimney height,the emission velocities at the chimney exhuast,the temperature of the exhaust and the prevailing wind condition.

In a Power Plant having an exhaust chimney of 65m,the following levels are obtained at ground level at a distance of 200m from chimney;

(i) SO_2 : 9.8 $\mu g/m^3$

(ii)NO_x 12.6$\mu g/m^3$

These levels are well within the limits set by local Authorities

SAVINGS IN FOREIGN EXCHANGE

The total annual steam consumption in all the factories of the Valentina Region (assuming that they are all fully operational) can be of the order of 180,000 tons.

Again, assuming that this steam is generated by reasonably efficient boilers, it can be estimated that total amount of fuel oil required will be around 13,000 tons per year.

Based on a fuel oil price of USD 120 per ton, it can be seen that the worth of fuel oil consumed to produce the steam requirement of all the process factories of Valentina zone will be in the order of Rs 40 million per year.

In a co-generation plant producing 30 MW of electricity, the above amount of steam (and hot water) will be generated without any further consumption of fuel oil.

This means that a co-generation plant will make possible annual savings of the equivalent of Rs 40 million in terms of foreign exchange every year

As a result of such savings, factories will be able to avail themselves of a much cheaper source of steam obtained at relatively lower cost, and this will increase the competitiveness of these factories.

It must be pointed out that another energy form used within the factories such as compressed air also offers better prospects of savings through centralised generation using the cogeneration technology.
Conventionally, the motors of air compressors use electricity which has been generated at 40% thermal efficiency in the power stations of CEB and brought to site with transmission losses of average 11%. The motors themselves have a conversion efficiency of about 85%, which means that the net heat energy transmitted to the shaft of the compressor unit gets reduced to only about 30%.

With a co-generation compressor plant, the net power transmitted to the compressor shaft will be of the order of 75% - with all the advantages described above and below.

The Kyoto Protocol

Under the above protocol, which is bound to be implemented sooner or later, the compensation figure of USD 25 per ton CO_2 not generated was quoted.

A rough calculation gives the following scenario :-

It can be deduced that the annual generation of 180,000 tons using a CO-GENERATION plant avoids the generation of the equivalent of nearly **63,000 tons of CO_2**.

This volume of reduced CO2 generation is worth a compensation/ or emissions credit of nearly **Rs 42 million per year.**

What does this mean in the practical context?

It is known that a cogeneration plant of say 30MW will definitely cost more than a conventional plant. From figures obtained by us, we find that such a cogenerated plant will cost around Rs750 million compared to about Rs500 million for a conventional plant.

It can be seen that the additional initial investment of Rs250 million can be paid back within 6 years through the system of compensation or emissions trading within the KYOTO Protocol.

This is surely an option worth investigating !!

Reducing CEB Transmission Losses

The factories in the Industrial Zone of Valentina, Pont Fer and the commercial and residential buildings in the Pont Fer, Phoenix region may be expected to consume about 25 MW of electricity which principally is transmitted and distributed from the thermal generating Power Stations in Port-Louis.

It can safely be deduced that transmission and distribution of such a power will entail energy losses of the order of 10%.

If this power were generated within the Valentina region, then such transmission losses could have been reduced from 10% to say 2%.

The avoidable energy losses corresponding to transmission of 25 MW of electricity is in the order of

0.08 x 25,000 x 24 x 365 kWh

= 17.5 GWh annually

In terms of fuel oil saved, the equivalent amount is 3,500 ton per year, which represent foreign exchange savings worth about Rs 11 million

Other cost savings include avoidable wear and tear of spare parts and consumables such as lubricants, which can be estimated to be in the order of Rs 3 million annually

Summary

Presently about Rs 50 million worth of fuel oil is being inefficiently used to generate a steam requirement of around 180,000 ton annually.

A centralised co-generation plant, on the other hand, will yield the following benefits:

Inefficiency eliminated:	Rs 10 million (*)
Worth of fuel saved:	Rs 40 million (*)
Transmission losses eliminated:	Rs 14 million (*)
Savings in Compressed air:	Rs 1 million (*)
Emissions Trading under kyoto:	Rs 42 million (**)
Total	**Rs 107 million**

(*) These figures can be proven

(**) This issue is being discussed and should be finalised in near future

The other benefits of the project include **cleaner air,**
quieter environment and
steam at much lesser cost.

<u>CONCLUSION</u>

It is quite surprising that for a country importing the bulk of its energy from abroad, this concept of cogeneration has not been implemented up to now.

This brief paper shows that not a cogeneration plant can bring net annual benefits of over **Rs 150 million** *<u>per</u>* industrial zone, besides producing a cleaner environment and boosting factory production.

If we consider that there are about <u>4 Industrial Zones</u> where this concept can be applied straight away, the potential energy savings and other benefits can be seen to be quite significant.

It is our strong recommendation that the Ministry of Energy, Industrial Development and Environment take urgent measures to review all energy development plans in order to include such genuine cogeneration proposals.