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WHAT'S WRONG WITH THERMAL PERFORMANCE ENGINEERING? [1]

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ABSTRACT

This paper discusses experiences and recommendations of six practicing thermal performance engineers with regards improving and maintaining the thermal efficiency of power plants. It discusses the authors' perceived decline over the past decade for qualified staff, and capital projects involving efficiency improvements, instrumentation and testing/monitoring projects. Such observations extend to North America and Western Europe. This paper attempts to coalesce years of observations and hands-on experience in the field into summaries useful for prudent action. It also presents several recommendations aimed at improving the consciousness towards performance engineering, which has the potential of substantially reducing emissions per electrical output, and increasing the mostly forgotten thermal efficiencies of power plants (heat rate).

INTRODUCTION

The thermal efficiency of fossil-fired power plants has direct impact on fuel costs, emission flows and the availability of the plant to achieve rated conditions. Thermal efficiency programs can be understood, leading to improved performance, by first understanding that such programs must live in two environments: engineering and political. This two-sided, but interrelated view is expounded throughout this paper. Our engineering problems cannot be addressed without addressing the political. Within the engineering environment, a viable thermal performance program must consist of three inter-related disciplines. These disciplines include real-time monitoring and/or testing, instrumentation and analysis. Like a three-legged stool, lose any one of these disciplines and the viability of a performance engineering program will fail. The consequential effect of performance engineering must be action. Such action occasionally involves equipment modifications to correct a long standing problem requiring approvals, budgeting, etc. Our observation is that performance optimization programs have suffered from a lack of continuing budgetary support. Regarding the political environment, a thermal performance program requires proper structural

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framework to survive. Such framework must support both the managerial and the regulatory aspects. What is meant is that utilities will act to benefit thermal efficiency but only if managerial philosophy includes the proper care of equipment or they are forced to do so through regulatory action or the utility believes such activity produces profit (and generally short-term profit). In this day and age, we believe it is the rare utility for which thermal efficiency is a priority regardless of regulation or immediate profits; wanting only to sufficiently protect equipment to preserve capital investments. Of course these environments overlap, one cannot expect engineers to govern utilities (as in past days), nor can we expect modern utility management, the majority being thermodynamically challenged, to understand power plants.

In this light, the following discussion delves into both the engineering and the political. From such discussion recommendations are made which, it is hoped, will provide the power industry impetus for further discussions and refined recommendations.

WAR STORIES AND THE STATE OF AFFAIRS

To provide real-world examples of problems encountered the following provides a few war stories, not for entertainment, but to illustrate the typical state-of-affairs.

· If an entry-level engineer joins a power plant staff, he/she not uncommonly is assigned to thermal performance. Although a great avenue to gain wide understanding of the plant, it also requires the greatest expertise to do well. Typically he/she will move on from that position within 3-5 years because, although the work was found challenging, it is professionally unrewarding, promotion to a plant supervisory position offering faster growth. Although attention to detail during analysis, condition of instrumentation and general follow-through is of course crucial, few have the necessary capability or conviction. Generally we observed a lack of continuity in the work force. Long range utility planning to develop thermal performance expertise is a sputtering process.

· "In the old days" the traditional path to upper management clearly ran through the power plant, through a "manager of generation" position, and from there to the top office. Traditionally these were experienced engineers. Today the route to the top lies through law and business schools (discussed below).

· The term "heat rate", when describing what performance engineers monitor and their associated improvement programs, has become worn out by being associated with lower priority reasons for spending money. Admittedly, part of the reason for this ill repute is due to poorly trained engineers utilizing overblown heat rate improvement predictions which are never achieved. But, in addition, there is a misunderstanding of the nature of heat rate improvements by thermodynamically challenged management: economic return from combustion efficiency and turbine cycle improvements can be complex and are dependent upon several factors such as capacity factor, fuel types different than design, load variations, operator vigilance, controls and weather.

· "You Cannot Improve What You Cannot Measure." A general complaint heard at many plants is the lack of instrumentation support: for testing, for calibration programs, and the supply of test gages. Performance teams in the 1980's and 1990's spent considerable time, money and energy installing accurate and well-located pressure taps and thermal-wells. A majority of the performance test groups have lost these higher quality test points to requirements of the more recently installed distributed controls systems (DCS). The good news is that much of the new instrumentation is now on-line and is being maintained. The bad news is that DCSs require only relative accuracy and thus are poorly maintained. The DCS typically store data records for the very long term, relying on many times ill-considered data compression algorithms to reduce the electronic volume. This results in removing data precision making the data useless for serious thermodynamic analysis. Finally, many plants no longer have a method for testing equipment with high accuracy instrumentation, or checking the accuracy of on-line instrumentation. This situation makes it ever more difficult to reconcile plant losses.

· The engineer's role has been blurred within the power plant environment; controls, testing and performance experience are expected be had by the same individual. In part this is due to the lack of qualified personnel … frequently an engineer will rotate through assignments to satisfy management commitments to produce a well rounded employee, and the pure necessity to assist a short-staffed facility. Controls engineers are sometimes over extended and expected to advise on everything from combustion efficiency to turbine cycle modifications. In past years, test engineers would provide critical test information that the station performance engineer would then analyze, and take action on. In the past ten years, central test teams have been dissolved (due principally to deregulation) and the test engineers have morphed into performance engineers, being spread-out to fulfill short term plant needs. This is generally a good fit as long as the test engineer has been coached by experienced performance engineers in the art of analysis and the necessity of taking action based on test results. For clarification, a performance engineer's vision should be to facilitate continuous plant performance improvements through thermodynamic understanding of unit processes and equipment. Subsequent sharing and exchange of performance knowledge with unit operators and supervisors must be used to enhance efficient operation.

· Dwindling support for performance teams has diluted their main purpose and driven their efforts into more field related activities reducing many teams into groups of "jack of all trades, masters of none". While most of this work provides a valuable service to the plants, there is no time for thermodynamic understanding at the system level.

· Many young engineers will join performance teams with great enthusiasm. However, if utility management is not "plant aware", it does not take long for the engineer to realize that a gain one year can turn into a club the next. Performance engineering is not a cumulative activity; a 1% improvement in heat rate one year does not mean one can extract 1% each year for the life of the plant.

· One author, in private conversation with the Chief Administrative Law Judge for the California Public Utilities Commission (CPUC) when asking about the then emerging deregulation program (1996), what was to be done if it did not work – what mechanisms were being put in-place to protect the public – answered that the CPUC had "some extremely bright economists working on the project". The plan called for a 10% roll-back of prices for the first year. As seen in Figure 1, by 2001 such "brilliance" brought a 30% increase in prices [CPUC, 2005; ERisk, 2001]. Note that the Los Angeles Department of Water & Power is not regulated by the CPUC, producing stable costs. Further brilliance saw the CPUC force the sale of half of California's investor-owned power plants. They are now principally owned by east-coast utilities; California utilities now own east-coast power plants. Additional madness was applied, and little noted, when the CPUC froze plant staffs for the first year after being sold. This action resulted in gross stagnation, lack of monitoring/testing, and a rapid increase in state-wide heat rate.

· Standard efficiency tests, such as ASME's Performance Test Codes, are designed for plant contractual acceptance tests. They are not designed to uncover the sources of unit efficiency degradation. They are simply designed to compute unit efficiencies, not to improve the system and assist maintenance efforts. It is not uncommon to see a plant staff analyze the data from a PTC "performance" test in days, report efficiencies (understanding nothing of the system), and do nothing.

· Emphasis on emission monitoring has typically resulted in staff transfers from performance engineering to assist with regulatory reporting, CEMS calibrations, etc. – paper pushing by any other name. Few engineers enjoy such activity. Indeed, it is ironic that if performance engineering were properly staffed and viable, that emissions would decline given improved thermal efficiencies.

· The politicos in Western Europe are pushing towards the same level of incompetence found in California. The Kyoto Protocol has been approved virtually everywhere in the world except the US and Australia. As approved by the European Union (EU), it calls for a run-back of CO_2 emissions to 1990 levels. However, the EU's CO_2 emissions from power plants has increased every year since its approval (December 1997). To meet the Protocol's requirements the EU most likely will be buying CO_2 credits from China – which will gratefully sell to underwrite its coal-fired plant construction program. Although reports vary, China is commissioning a new coal-fired power plant at a weekly rate [WSJ, 2007; Economist, 2007]. If man's impact on global warming through CO_2 emissions is real then the Kyoto Protocol as implemented by the EU is a farce.

ENGINEERING ENVIRONMENT

Overview

Instrumentation, monitoring and analysis must be at the heart of a viable performance engineering program. Each discipline feeds the other. Monitoring (including periodic testing) makes no sense if accurate data is not obtained. And no viable analysis can occur without consistent data. Analysis is impossible without quality data used for benchmarking and resolving uncertainties. No acquired data is perfectly consistent, and thus calibration programs are always a start, providing a sense of where instrumentation is fragile. Multiple sensors are always recommended at the boundary locations of the turbine cycle and at the boiler's effluent for gas temperature. Bear in mind the axiom: much sophisticated analysis has been completed (and acted on) using worthless data.

Maintaining instrumentation makes little sense if routine monitoring (either in real-time or periodic testing) is not performed. For the majority of circumstances, monitoring provides the only vehicle through which the performance engineer can resolve heat rate problems. For the badly degraded unit, testing at the "system" level (boiler and turbine cycle), with provable Calculational Closures, represents the only solution. By Calculational Closures we mean demonstrable understanding of the as-tested system through, at a minimum, a back-calculated gross generation and a computed fuel flow which satisfies working fluid demands. The typical problems of coal flow measurements obviously require coordination with fuel supply, perhaps coal sampling and engineering judgment. We believe the ASME Performance Test Codes (PTC) should be employed – but with great caution. Bear in mind the PTCs were principally written by vendors for acceptance testing and qualification of new equipment. Although their philosophies are sound and, in general, should be read, they are designed for proving warranties, not understanding to the point of improvement.

Other than maximum load testing, testing *per se* will have little value unless its data is analyzed, and analyzed quickly. The performance engineer must provide feedback to instrumentation personnel (as to the value of their work, results of instrument accuracy, etc.). They must also communicate with those in Operations who assisted with the testing (feedback regards correction to isolation procedures, etc.). Final results are only demonstrated through proven improvements in Δheat rate.

Staff Infrastructure and Long-Term Maintenance

To achieve long-term reduction of heat rate, the creation of a thermal performance engineering group is obvious. A functioning performance group, fully supported by management, is mandatory to ensure long-term maintenance of thermal efficiency and CO_2 reductions. We recommend one engineer be assigned at each power plant station, with his/her management located in the home office. A key ingredient within this recommendation is to create a "project management" focus of the performance group. This means to specify and execute deliberate thermal performance tasks: specific projects, schedules, instrumentation and operations interfaces, isolation procedures, instrument calibration schedules (where needed), testing procedures, etc.

An obvious responsibility of the performance engineer is interfacing with instrumentation and operations groups to accomplish required work tasks, including: the upgrading and routine calibration of instrumentation, and assistance with testing, its procedures, and isolations. However, the performance engineer should also be directly responsible for analysis, results presentation and seeing that his/her recommendations, once approved, are implemented. Implementation of work orders generally falls to the maintenance and/or instrumentation staffs. To this end, to meet long-term goals, it is critical that lines of authority be well-defined; a suggested method to assure necessary follow-through is to provide the performance engineer direct supervision of maintenance and instrumentation personnel for a set number of days/month/unit. Bearing in mind complex work orders, we suggest a routine 3 days/month/unit.

We believe that no distinction of manpower allocation should be made based on a unit's rating; e.g., manpower required for a 150 MWe unit should be the same as a 600 MWe unit, especially in the areas of instrumentation and maintenance, at least until the performance group becomes established and lessons are learned. Typically the smaller, older power plant requires more attention than the larger, newer units. Further, it is understood that some economy is achieved through centralization; but it is suggested that engineers need to be associated with the equipment for which they are responsible, meaning that frequent conversations with operators can be a valuable source of thermal performance information.

Performance Engineer's Job Description

With these thoughts in mind the following is a suggested Job Description for a station performance engineer; it is broken down by responsibilities, authority and qualifications.

Responsibilities:

Maintain an in-depth knowledge of each unit.
Maintain appropriate documentation on each unit (Thermal Kits, feedwater heater & condenser design details, pump head curves, P&IDs, etc.).
Walk one unit every day.
Conduct station meetings involving instrumentation, operations and maintenance (communicate!).
Establish a schedule of tests for each unit.
Discuss with other station performance engineers projects of common interest (have grid-wide meetings).
Coordinate long-term testing projects with the instrumentation staff.
Coordinate the installation and calibration schedules of all primary instrumentation.
Direct instrumentation personnel on assigned days.
Direct maintenance personnel on assigned days.
Coordinate long-term testing projects with Operations.
Write test procedures: isolation, test methods, projected outcome, safety concerns, overview of analysis to be preformed.
Be present at major tests, walk the unit, make certain test procedures and good practice are followed.
Direct analysis, or direct supervision, of all data analyses.
For major tests, conduct post-test discussions with instrumentation, operations, and maintenance.
Once per month make recommendations to management

on work orders which improve heat rate, including proof-of-outcome statements. Note that the responsibility of financial justification must not fall to the performance engineer - he/she only reports ΔkJ/kWh (ΔBtu/kWh) to be recovered, how to recover and its ultimate verification.

Implement all heat rate improvement work orders and establish monitoring to demonstrate the recovery. Note that many situations will involve small Δheat rate improvements, these must be accumulated over an extended time period.

Prepare annual report of heat rate improvement work orders, demonstrated recovery.

Authority:

The Performance Engineer shall report directly to the Manager of Performance Engineering. Either he/she should have supervisory authority over instrumentation and maintenance personnel for (say) 3 days per month for each unit assigned, or, as standing policy, any work order for heat rate improvement be given highest priority. He/she shall have managerial (not administrative) authority to see that approved heat rate improvement work orders are implemented.

Qualifications:

The Performance Engineer should be a graduate mechanical or chemical engineer having had formal training in thermodynamics; additional experience in power plant operations and hands-on testing would be highly desirable; specific knowledge of the assigned power plant would be desirable.

POLITICAL ENVIRONMENT

The political environment surrounding the generation of electricity has, of course, always been of import. However, over the past decade politicos have responded aggressively to real or perceived threats to society. We see this situation organically in which utility management, politicians and regulators feed off each other's fears, greed and ignorance. In this light, the following discusses: the managerial climate in the "typical" electric utility, i.e., taking the industry as a whole; regulatory policy towards thermal efficiency; deregulation and its impact on thermal efficiency; the green house gas issue; and US Environmental Protection Agency polices regards determining emissions.

Utility Management

Any consideration of the political environment surrounding the generation of electricity must consider who is running the shop … utility upper management, examined generically. The contention here is that basic education is, at least, one important precursor for understanding how the product being sold is created. First, allow the observation that 20 years ago, essentially all upper utility managers arrived at their positions through plant management/engineering positions. At that time and before, industry was headed by people who knew fundamentally the systems and processes of electricity generation. Today, the opposite is true. In an internet study conducted for this paper, 32 major electrical utilities in North America were researched as to the undergraduate educations of their Chairperson and/or Chief Operating Officer. Quite amazingly, but supporting the authors' broad perceptions, results indicated that less than 1/4 had engineering degrees [authors, 2007]. If the leadership of electric utilities have no knowledge of power plant systems, let alone thermodynamics, is it surprising there is no emphasis on thermal performance?

As a further environmental factor, the engineering work force is aging rapidly as has been well documented. This fact parallels our concern for qualified company leadership. Efficient electric power production, as critically important to modern societies, and as it paces developing societies, demands that the engineering student be trained both in school and during their early years on the job. Such issues of competency in leadership and a qualified work force are not new; to quote from the 1890 edition of Steam:

> "Most of the abuses connected with steam engineering have arisen from two causes – avarice and ignorance; avarice on the part of men who are imbued with the idea that cheap boilers and engines are economical, and that these can be operated by a class of men who are willing to work for the lowest wages; ignorance on the part of those who claim to be engineers, but who at the best are mere starters and stoppers."

However, in the 21st century we are faced with a monumentally more difficult political environment than found in 19th; i.e., considering global warming, population growth and incompetent leadership (both political and corporate), which, uniquely in our times, is having enormous impact.

Regulation

The political environment of the regulated electric utility is, of course, enveloped by the public utility commission (PUC), or like body. There are two issues common to all performance engineers associated with such regulatory authorities: 1) that fuel cost increases are passed-through to the rate-payer; and 2) the lack of qualified PUC staff. These are long-standing issues. These issues have been resolved through deregulation, or, ironically and more correctly stated, their consequences have encouraged deregulation. For those jurisdictions practicing regulation, it would appear that even a minimum understanding of thermal efficiency would convince regulatory engineers that higher fuel costs are either caused by degraded fuel energy content or by degraded boiler or turbine cycle efficiencies. Fuel heating values, if not tracked on-line, are certainly tracked by every power station month-over-month; this is knowable data. The issue, of course is "heat rate" (fuel energy flow per kWe produced). Instead of incentivizing utilities to degrade systems over time – resulting in ever increasing fuel and emission flows per kWe – PUCs should base-load allowable charges on original acceptance test results (if not available, then on design values), suitably modified to reflect their commercial operation, resulting in a "commercial new-plant heat rate". Fuel costs may rise with time, but the "pass-through" would apply only to that fuel which can be assigned to the commercial new-plant heat rate. To propose that equipment slowly and uniformly degrades over its 30 year design life, thus justifying an ever increasing heat rate, is ridiculous. Prime movers are typically over-hauled every 5 years; but once over-hauled, there should be no thermal or mechanical reason why the component new-plant heat rate should not be expected. If any allowance is made for wear, it would be reasonable to assess the average frequency of over-hauls and make only periodic allowances with a renewable aspect.

As to the competency of federal regulation in the United States, we quote, in part, from a recent open letter written by nine former FERC members:

> "The undersigned former Chair and Commissioners of the Federal Energy Regulatory Commission (FERC) express our support for continuing federal policies to promote open and competitive markets for electric power. This is a matter of our nation's security and economic welfare. ...Competition has improved the operating efficiency of power plants and helped lower costs. ...A number of studies confirm significant increases in generation efficiency. ...As competition has taken hold, customers have saved money. ...And in California, total wholesale energy and ancillary service cost were down 16% or $2.2 billion while total energy consumption was up 9.3% in the past year. ..."
> [FERC, 2007]

It gladdens the heart to know how well everything is going, and especially the industrial sector in California (versus Fig. 1). It is not insignificant that of nine signatories, only one has an engineering degree (the rest are attorneys), 2 have backgrounds in Texas oil, and 3 other individuals had worked for Enron.

Deregulation

Although deregulation was intended to reduce electricity costs, it has had the opposite effect in many states. As seen in Figure 2, the thermal efficiencies of independent power producers (IPPs) are not competitive with those of traditional utilities, and, as important, their efficiencies are declining [EIA, 2001-06]. Figure 2 is based only on coal-fired units. Using only this data eliminates the advantage of high efficiency gas-turbines and thus reflects the commitment of utilities and IPPs towards performance engineering – not on design advantages *per se*. There is much hype over the advantages of "competitive" markets [EPS, 2007], given the great margins associated with independently sold electricity versus the regulated. However, when buying coal for <$20/MWe-hour, selling for over $100/MWe-hour, as done during the summer of 2006, there is little financial incentive to improve power plant efficiencies. Yes, incentives abound for the consumer, but the structural framework of deregulation forces the consumer to subsidize the independent producer (ignorable by FERC commissioners). If 10% more fuel is required to produce the same power (costing $22 versus $20/MWe-hour), so what (!!), its effect on gross profit is simply not significant. However, a 10% increase in fuel flow is, at a minimum, 10% more Stack flow assuming the same excess O_2 level. However, it is most likely that such degradation will be caused by equipment neglect, poor excess O_2 level, etc. which could well affect the Air/Fuel ratio, magnifying the impact on Stack flow. A 10% increase in fuel flow is 10% more carbon effluent, which may well be taxed in the near future.

If we do not see thermal efficiency advantages associated with IPPs - they pollute more per MWe produced when burning coal (Fig. 2) and their product typically costs double that of the traditional utility - then why allow the IPP to exist? At least why allow their existence in the same market place as traditional utilities? The traditional utility could sell under long-term contracts to their ISOs, could build combustion turbines, could build co-generation facilities, etc. … only if allowed to do so. The point here is that the traditional utility has the infrastructure to maintain a performance engineering group, and although we clearly advocate an enhanced IPP and traditional utility activity, at present the traditional utility is clearly out-performing the IPP as seen in Figure

2. The data outlier seen in Fig. 2 is believed to be an artifact of the 2001 power crisis.

In fact, from early Pearl Street days through the present there has never been a workable regulatory induced incentive policy which promotes thermal efficiency. Although the incentive debate is not a new one [Phillips, 1969], historically it has always centered on "managerial" efficiencies, not thermal. It is remarkable in modern times, that though there are many different market deregulation models around the world, the placid effect on thermal efficiency has been universal. Where the pressure falls on utilities to reduce costs, it has been easier for management to cut staff and budgets than to defend good engineering standards and long-term protection of equipment. Where the focus has been on such things as availability, "sweating assets" or "asset management", it has been easier to cut efficiency related maintenance versus responsible engineering.

The hidden agenda of typical deregulation has been to break the perceived power of utilities. Commonly this has resulted in staff reductions and concomitant reductions in traditional (long term) engineering activities. Typical break-even computations used in past decades employed 5+ years for project justification, today 2 years is the norm. For a utility formerly enjoying good thermal performance, being faced with such pressures, it often will be many years before the damage becomes obvious. By then of course it is too late to attempt to recover and rebuild the lost engineering base. A perfectly viable plant is then set for closure justified that it is too late for an investment in thermal efficiency.

Green House Gases

The green house gas issue is truly an unfortunate mix of both the real and political environments. We fully expect in the near future either a carbon tax and/or cap-and-trade system in North America (the EU is presently taxing). However, as performance engineers we are increasingly concerned over the apparent ignorance of law makers and utility executives as to what the "green house gas" issue truly means. Simply put, such gases heat the upper atmosphere through absorption of the sun's radiation. There are two species emitted from power plants which do this: CO_2 and water vapor. In the upper atmosphere water is a superheated gas, at lower altitudes water is typically in a saturated or liquid droplet state. CO_2 and gaseous water absorb essentially equally throughout the infrared spectrum, often times with significant interference patterns. Transmission characteristics are not dissimilar. However, in the saturated or liquid state water is essentially opaque, it absorbs essentially all solar radiation [Shilifshteyn, 1993]. The question here is: "What, indeed, are we concerned with?" Will the earth continue to heat as politicos myopically focus on CO_2 reduction schemes?

We read that the "atmospheric water cycle" is huge, that water contributions from power plants has less than 1% influence on this cycle. Furthermore, water vapor corresponds to around 80% of the mass of green house gas found in the atmosphere (with 12.5% CO_2; 7.5% CH_4, CFC, etc.) [Beising, 2007]. Although the authors are not atmospheric scientists, we simply suggest that both CO_2 and water from power plants, in addition to direct atmospheric heating by emitted combustion products, be considered as systemic effects. We also point out that although power plants burning Powder River Basin (PRB) coal emit considerably more CO_2 per unit of calorific value versus methane, PRB contains essentially the same amount of carbon per weight of fuel as methane. More importantly, effluent water from burning PRB coal is 23% lower than produced from methane (13.6% vs 16.7% effluent water, assuming 3% excess O_2, without air leakage) [Lang & Canning, 2007].

We believe the green house gas issue is being laid at the feet of electric utilities by ill-informed politicos. We argue that if the earth is heating in-part from the power industry burning fossil fuels, that trading CO_2 credits from around the planet makes little sense. Not considering water vapor makes little sense. We argue that any solution must have a global viewpoint, that at least as engineers we should demand that our leadership make thermal efficiency a priority. The first step in emission reduction is to make systems as efficient as possible, or turn them off.

Measuring Emission Rates and Flows

There are presently a half-dozen proposed laws in the U.S. Congress which roll-back CO_2 emissions to levels believed present in prior years. For example the Kyoto Protocol attempts to roll-back to 1990 levels. However, it has been well demonstrated that US Environmental Protection Agency's (EPA) procedures can develop considerable error. When using EPA's F-Factor method (CFR 60, Appendix A, Method 19) to determine emission rates ($lb_{Pollutant}$/million-Btu_{Fuel}), without knowing the specific coal fuel chemistry, errors can exceed +10%, with common errors of +3% [Lang & Bushey, 1994a]. As to direct measurement of emission flow rates, an EPRI sponsored effort at two large power plants produced +9.8% and +18.6% higher system heat rates based on measured effluent flows [McRanie, et al, 1996]. Independent testing conducted by two of the authors at a 800 MWe coal-fired plant resulted in +20% to +30% variances between different EPA methods and results of verified heat balances [Lang, et al, 1994b]. Such results all indicate the typical US coal-fired power plant is reporting more effluent carbon than it burns.

Another area of great concern in the political environment is the apparent lack of connection between the intent of governing US law, the Clean Air Act, and its implementation. To quote from a legal summary of the Clean Air Act:

> "Compliance under [the Clean Air Act Amendments] is defined explicitly in terms of ***actual emissions***, not in terms of technology application or technology performance. Accordingly, the Administrator, other enforcement authorities and the public ***must have precise, reliable and timely information indicating the exact emissions of each unit*** in order to determine whether a source has met its emissions limitations. Utility emissions of SO_2 and NO_X are capable of verification in a cost-effective manner through use of continuous emission monitors."[Senate Report,1991]

This statement suggesting absolute measurements hardly justifies the present situation in which measured emission flows are ≈10% in error, faulty F-Factors and use of calibration programs used for CEMS instrumentation which are based on repeatability methods not absolute standards. Although such situations are not unique to the US, the US courts have substantiated such practices through case law. For example, far less than precise modeling conventions have been allowed when absolute accuracy was assumed to be not required: "Any consistent method of prediction can be adjusted in light of actual experience, and a state therefore may adjust its guidelines for future development on the basis of changes in the measured pollution levels over time. We cannot hold at this time, therefore, that lack of precision alone is a substantial objection which may be used to estimate the impact of a proposed source on actual levels of pollution" [Sierra Club, 1976].

It is not rational to establish taxing or trading systems based on carbon measurements which have gross inaccuracies, or that are based on relative standards. Both a carbon tax and/or "cap-and-trade" scheme will be placing real monies on uncertain carbon determinations, leading to unknown consequences [Schimmoller, 2007]. We do not argue for a roll-back of emissions to those of prior years unless such standards are reasonably knowable (it is possible that the US power industry is actually meeting the Protocol if comparing accurate data today with EPA-based 1990 data!). However, if global warming is truly to be addressed, we argue for sanity in regulation, accurate determinations of carbon emissions and a rational societal response which we as engineers can implement.

RECOMMENDATIONS

Given consideration of both the engineering and political environments, one solution is to foster a "self-tax" on fuel expenditures, the monies used directly to support thermal performance engineering. Such a self-tax would be imposed as follows:

> All commercial facilities burning coal for electricity generation shall establish a 1.0% self-tax on fuel expenditures. These monies shall be used only towards the betterment of thermal efficiency of generating assets, thereby reducing fuel consumption and emissions. They shall not be applied to utility administrative or governance expenditures. For the traditional utility a self-tax shall be implemented only if their regulatory authorities provide for its automatic allowance in rate cases the same year incurred. For the IPP, a self-tax shall be implemented upon allowance of appropriate tax incentives.

We believe such a self-tax has the advantage of anticipating an inevitable US carbon tax. A purposeful self-tax will greatly assist in establishing the foundations of legitimate performance engineering programs. It will under-write staffs and their training. It will under-write improved instrumentation, more frequent testing and analysis. A 1% increase in coal expenditures will not substantially affect competition between independent producers; typical fuel costs will increase by $0.20/MW-hour noting the product is sold for between $50/MW-hr to $150/MW-hr. Although in the first half of 2007 coal prices have been relatively stable; over time they can, and have, varied significantly. For example, Powder River Basin coal has varied from $20/ton in January 2006 to $10/ton in October 2006. Central Appalachian coal varied from $36/ton in October 2003 to $65/ton in June 2006. Even historically stable Illinois Basin coal varied from $30/ton in 2004 to $36/ton through most of 2006 [EIA, 2006a]. Surely, given such flux, a self-tax of 1% will not be burdensome to successful competition – and especially considering the price for which the product is sold.

For the regulated utility to be successful, a self-tax must be allowed in rate cases, it being given *a priori* justification the same year incurred. It must not be included under fuel adjustment clauses, but allowed in the rate case as a direct and automatic allowance.

Again, performance engineering can not be viewed as a cumulative activity; a 1/4% reduction in heat rate gained one year, does not mean 1/4% can be gained every year for the life of the plant. Rather, performance engineering is composed of serial activities: 1) find the low-hanging fruit; 2) maintain prior improvements; and 3) plan for long-term improvements associated with capital equipment. In addition, if a plant employs on-line performance monitoring, and it is viable, an hour-over-hour search for improvements needs to be added to the list of performance duties. For the regulated utility, these funds must not be used for general administrative or governance burdens, but expended directly towards thermal performance improvement. Indeed, this is the proposed pact: if the monies are spent on performance engineering, it is then either an immediate pass-through for the regulated utility or a realized tax incentive for the independent power producer.

Another recommendation is to reconstitute the function of independent versus traditional power producers. As they compete, electricity prices to residential users rise given the great disparity between fuel costs and selling price. The scenario being played out by opportunistic merchant plants is to drive peak prices in all sectors, the traditional utility being hamstrung by short-term fixed, regulated rates. In addition to driving a system which has little spinning reserves, and, perhaps concomitantly, merchant plants have no incentive to be thermally efficient (Fig. 2). It is recommended that regulation address the strengths of both: federally regulate independent power producers to sell only to industry; while traditional generators to supply the residential market but also allowed to make long-term industrial contracts. If the independents cannot provide a reasonably priced product, industry will build its own generation and/or contract elsewhere.

A recommendation for regulated utilities is to revise procedures for allowing fuel cost pass-through. Such revision must consider reasonable equipment wear, but also that proper maintenance can significantly restore equipment efficiencies.

FINAL COMMENTS

The authors write this article neither with the expectation nor promise of wholesale change, but rather to promote debate and to evolve solutions. Because electric power is of critical importance to all societies, we find the political and financial tampering which has occurred over the past decade to be reprehensible; it has been blind at best, destructive at worst.

We believe that performance engineering in the western world requires re-vitalization through both managerial and political re-structuring. Such re-structuring should begin with a self-tax on fuel, could occur through a carbon tax, and especially through electric utility leadership who understands how the product is produced. We believe independent and traditional power producers cannot occupy the same space; separation of markets must be established. The generation of power should be a boring business; it should simply provide safe and reliable power for a reasonable rate of return.

We can not accept an engineering community, upon which society relies for dependable power, be composed of "starters and stoppers".

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Figure 1: California Average Retail Electricity Prices

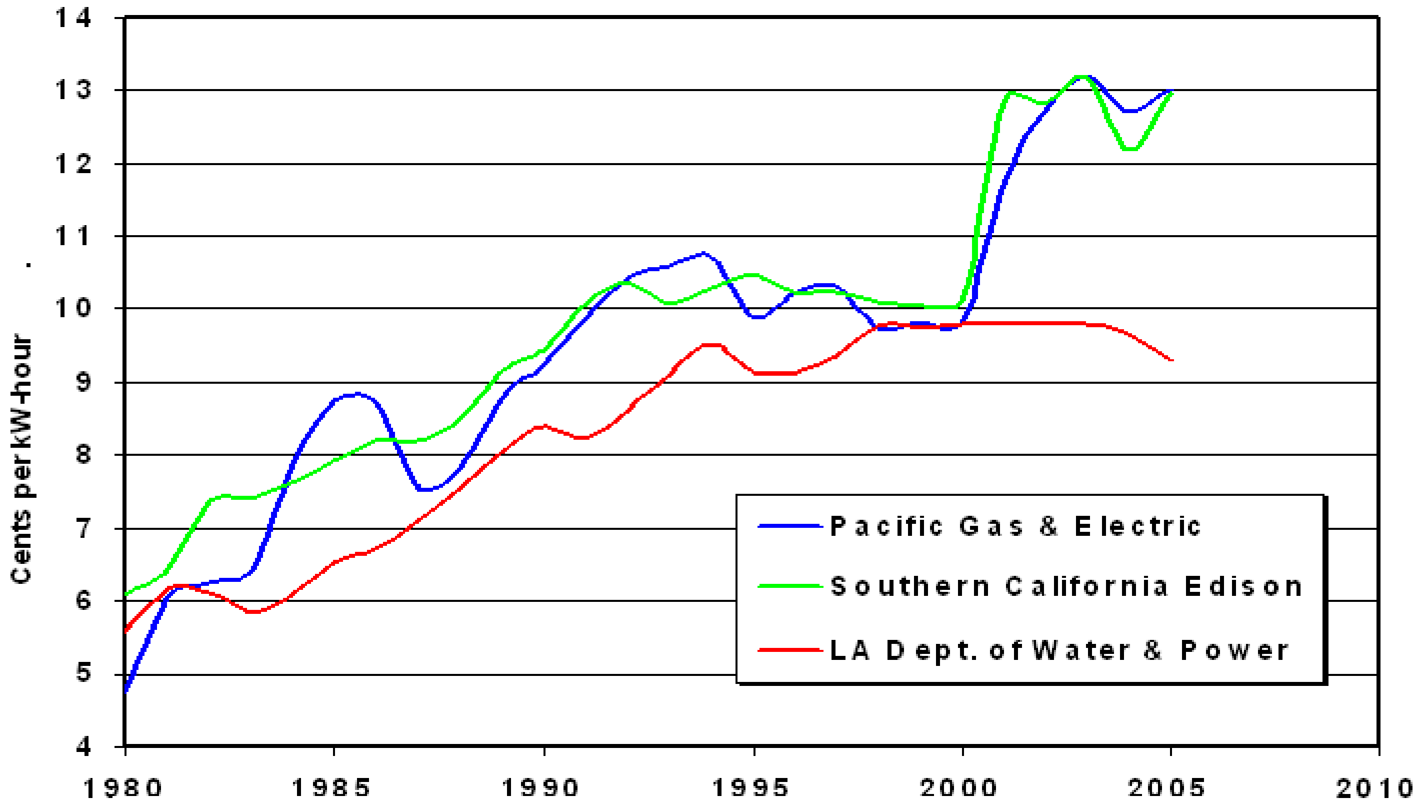

Figure 2: Coal-Fired Thermal Efficiencies, Traditional vs IPP