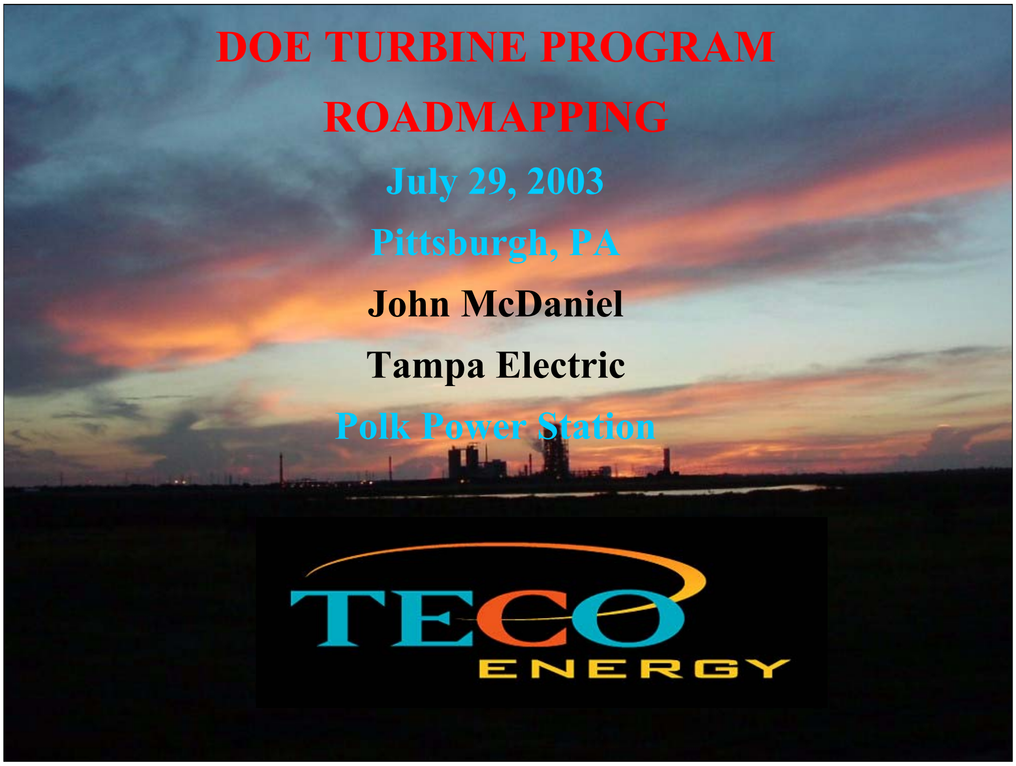

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Polk Power Station IGCC

DISCLAIMER:

The following presentation is intended to stimulate thought and discussion. It reflects some views and opinions of the presenter. These views and opinions do not necessarily reflect those of Tampa Electric Company.

INTRODUCTION:

One of the most appealing features of IGCC is its tremendous improvement potential. Tampa Electric very much appreciates the continuing efforts of the US Department of Energy in striving to reach that potential through various programs including the Clean Coal Technology program, without which the Polk Power Station IGCC would not exist.

When the concept of IGCC was first studied in the 1970's, it quickly became apparent that turbine improvements could do more to enhance IGCC systems than developments in any other area. This remains true today, so DOE's refocused Turbine Program has the opportunity to make a big difference. Consequently, I'm very grateful to have an opportunity to share some thoughts with this group today

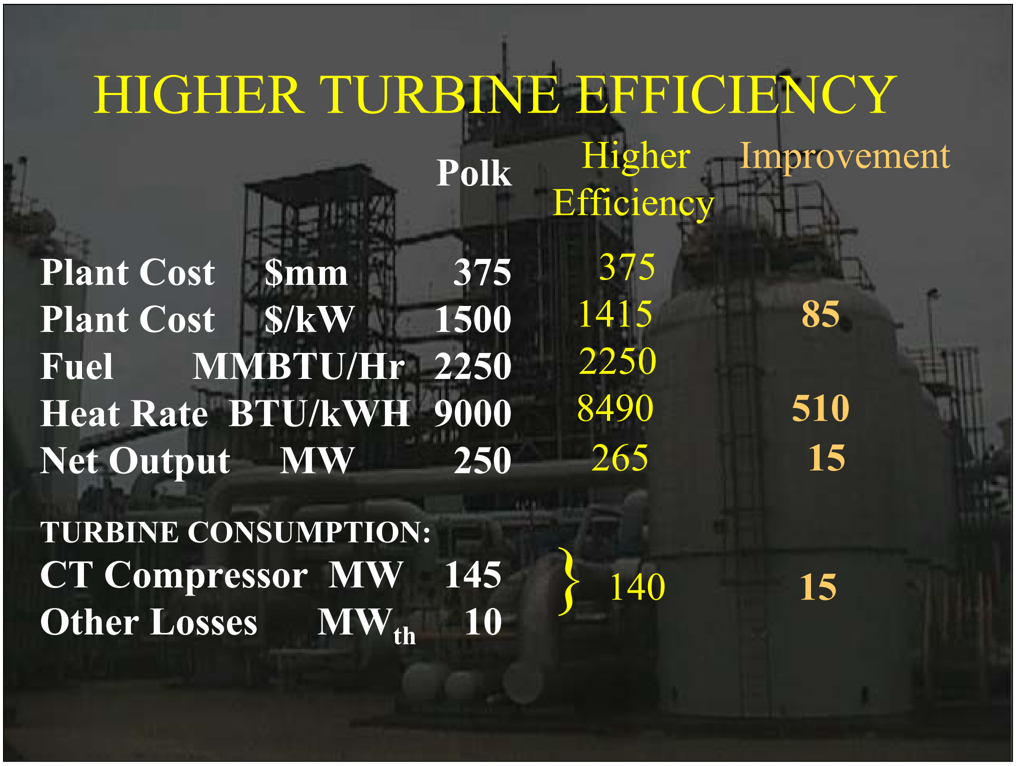
The previous speakers, Neil Richter and Gordon Sims, concentrated on gasification system improvements and the needs of IGCC systems, especially as potential end-users perceive them. I will try to address a few issues very directly related to the turbine technology.

The first two items I'll discuss, higher turbine efficiency and low NO_x combustors for syngas, already are key elements of the DOE Turbine program. They are extremely important and deserve be highest on everyone's agenda.

The third item on my list, saturation, isn't widely discussed, but its proper application can lead to higher efficiency, lower cost IGCC systems. We recently placed a syngas saturator in service at Polk.

My items 4 and 5, properly functioning isolation valves and backup distillate systems, are extremely important for safe reliable IGCC operation. They continue to be problematic even though they are not particularly "high-tech".

Improvements on the final two items, trace metal and sulfur removal, are likely to be in the hands of gasification system developers instead of turbine groups such as this. However, success in these areas can have significant positive effect on the turbine and combined cycle.



Higher turbine efficiency is the single most important improvement that can be made to enhance IGCC technology. The first column in the above example reflects Polk's cost and performance. At full load on syngas fuel, the combustion turbine's compressor consumes shaft horsepower capable of generating 145 MWe and heat balances indicate other losses (bearing losses, etc) are equivalent to 10 MWth. If only 10% of the compressor parasitic load and losses could be transformed into net output without any significant capital cost increase, the results would be as shown in the second column. The efficiency improvement would be a reduction of over 500 BTU/kWH in heat rate, giving IGCC a much clearer efficiency advantage over conventional coal-fired generation technology. More importantly, the overall IGCC plant cost would be reduced by about $85/kW since the same sized plant would produce more net power. This $85/kW is about half the difference most people believe separates IGCC plant costs from those of conventional coal plants.

IGCC is already recognized to be environmentally superior to conventional coal fired plants. The 500 BTU/kWH heat rate improvement for IGCC would clearly establish its higher efficiency. These factors together with the $85/kW cost reduction would make it very difficult to select conventional technology over IGCC for coal-based power production.

Such improvements are achievable, and this audience is much more familiar than I am with the most potentially fruitful avenues of development. The following are some examples of which I am aware:

Turbine compressors are already highly efficient, but there may be some potential since every 1% compressor efficiency gain means a lot to the cycle.

Lowering the required air flow has much promise. This can be done either through operating at higher firing temperature or by finding a source of supplemental mass flow at a low energy cost such as from a saturator.

It is also possible to reduce mechanical losses. For example, Polk once had a magnetic bearing system on one of our boiler feedwater pumps. Its major drawback was that it required a few minutes to start which was unacceptable for the pump application. But it might be very useful for a turbine if some enhancements were made.

We must always keep our eyes open for promising advanced or improved cycles. Unfortunately these are almost always much longer term, more difficult developments. Also, advanced cycles usually end up costing more and being more complex which will not enhance IGCC's marketability. This often applies to more highly integrated IGCC configurations. We must always keep in mind that adding any equipment item, process step, or level of integration whose operation is required for the overall system to run will reduce the overall system availability.

Polk's main method of NO_x abatement is diluent nitrogen (DGAN) injection. This "process" uses the plant's primary product, electricity, the highest and most valuable form of energy, to generate a pressurized stream of nitrogen. This gas dilutes the syngas, lowering its adiabatic flame temperature to reduce thermal NO_x. However, nitrogen's heat capacity is relatively low, so its NO_x abatement capability is significantly lower than that of other common gases such as water vapor or CO_2. It does result in additional mass flow through the combustion turbine, so we can expect that about half the electricity used to produce the DGAN is recovered in the cycle <u>if</u> the turbine can accommodate the extra flow efficiently. The penalty to the cycle for this process during normal operation is probably about 8 MW, half of the 16 MW net compression requirement. However, the overall penalty is greater than this since the entire 16 MW is consumed during all IGCC system startups.

The capital cost of this system is also significant, about $10 million, for the compressors, piping, and control systems. Furthermore, the DGAN system as configured at Polk is an integration step required for IGCC operation. Consequently, it does reduce system availability, though the effect has been relatively minor at Polk.

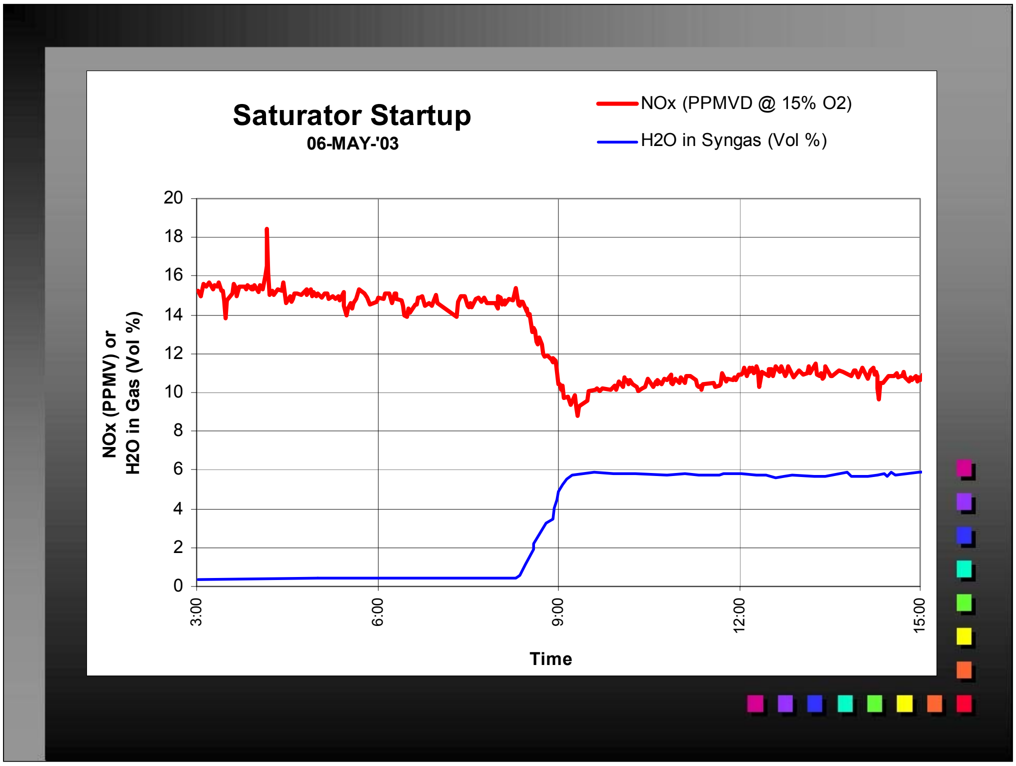
All in all, it would certainly seem that a less expensive, more efficient IGCC system could be designed if a low NO_x syngas combustor were available.

At least the DGAN system does enable us to meet current NO_x limits. However, this will probably not always be the case for two reasons.

First, CO_2 in the syngas is a significant NO_x suppression agent, but we can expect less CO_2 to be available in future systems. CO_2 typically reflects gasification inefficiencies, and we can expect lower CO_2 concentration in syngas from more efficient gasifiers in the future. Also, CO_2 is typically removed from syngas along with sulfur. As we strive for deeper sulfur removal, we can expect CO_2 in the product gas to decrease. Tail gas recompression and reinjection will mitigate this effect, though. Finally, the quest to reduce greenhouse gases will encourage CO_2 removal and recovery from syngas. Note, however, that by shifting CO to CO_2, IGCC systems can still achieve high levels of CO_2 removal and recovery while leaving significant amounts of CO_2 in the syngas to the turbine. But despite mitigating steps, we can expect less CO_2 in the syngas long term.

Second, no matter how low IGCC emissions are, it seems the targets always continue to move. We can expect continued pressure for lower NO_x emissions, at least until IGCC reaches parity with the cleanest natural gas combined cycles.

Because of these longer term trends, low NO_x syngas combustors will probably be essential. However, saturation can help, certainly to meet current NO_x emission limits, and possibly in the future to supplement low NO_x syngas combustions systems instead of post combustion treatment (SCR).

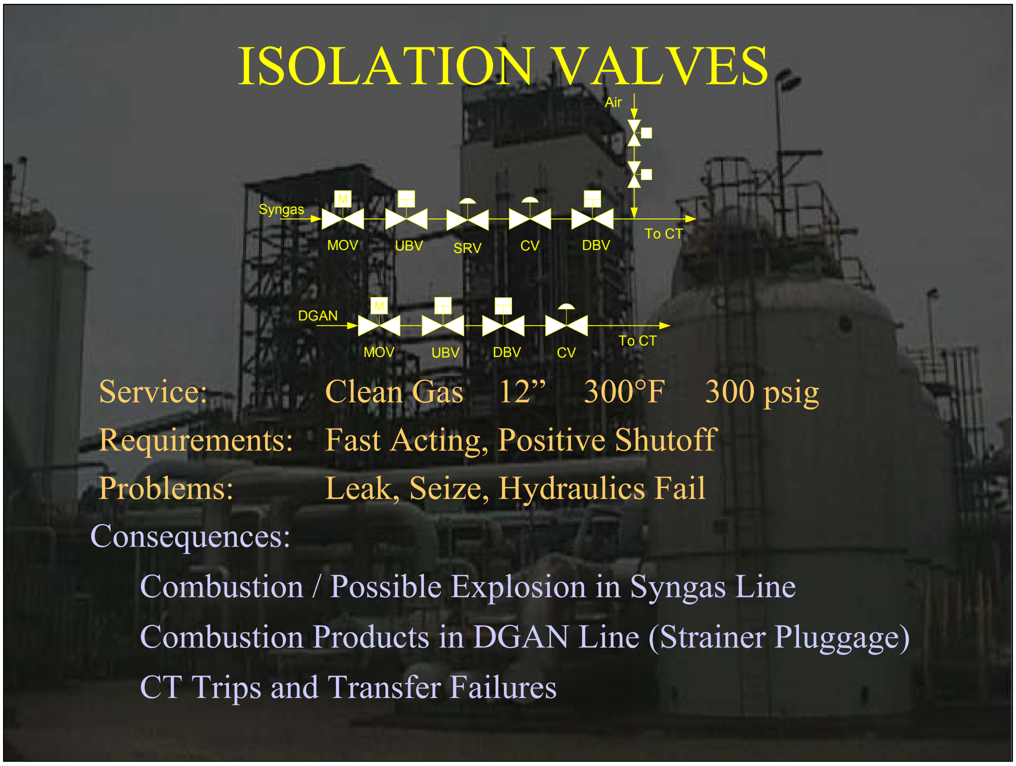


During Polk's permitting phase, the technology was new and NO_x emission levels were somewhat uncertain. So the permit was written to require a temporary emission limit of 25 ppmvd (15% O_2) and a reassessment (BACT) after 5 years of operation. This BACT resulted in lowering the permitted emissions to 15 ppmvd (15% O_2). Polk's DGAN system could meet this new limit under certain very specific conditions, but not always. So we decided to add a syngas saturation system which used low level waste heat to add 6% water vapor as diluent to the syngas.

The saturator was started on May 6, 2003, and has operated as designed and trouble-free ever since. Polk's NO_x emissions now average 10 ppm ± 1 ppm with our current fuel blend of 50% coal and 50% petroleum coke. The saturator startup is shown on this graph.

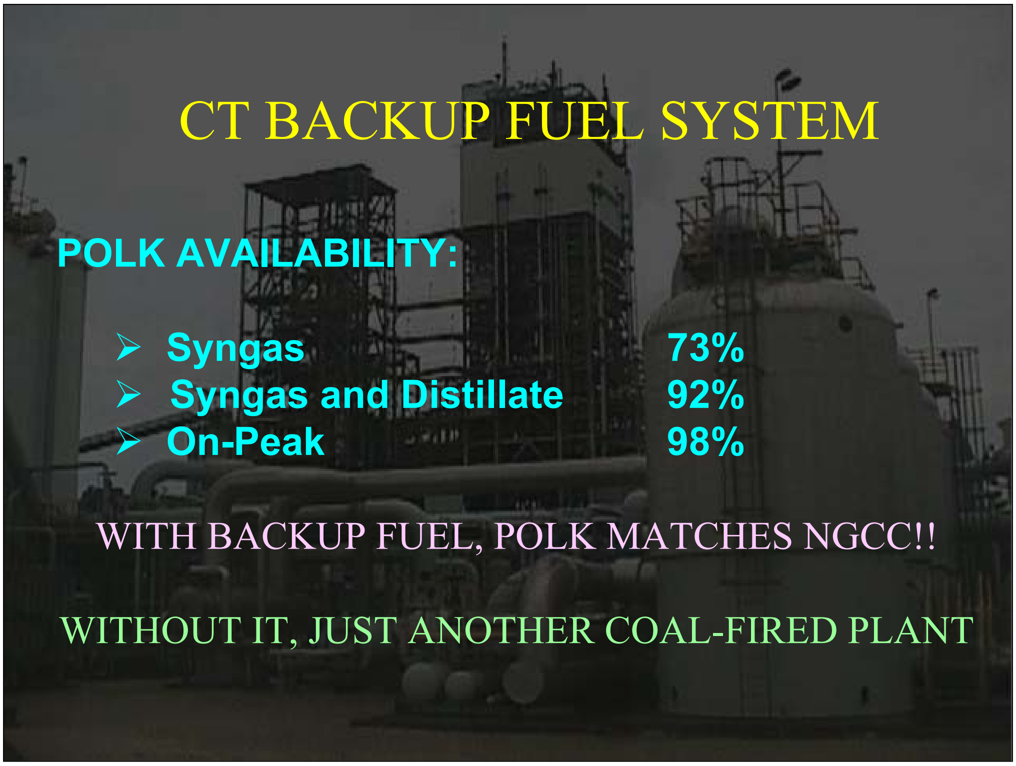
Saturation systems use low level waste heat and very simple hardware to generate diluent and produce mass flow through the turbine for power augmentation. This is in dramatic contrast to DGAN systems which use the highest form of energy, electricity, in large rotating equipment to do the same thing. Saturation is used in virtually all IGCC systems, but it's not widely discussed, probably because it's so relatively simple that it's not "owned" or licensed by any organization. It is a very stable system with no significant startup and integration issues, especially if it is a supplemental system as it is at Polk. And we can certainly hope and expect that saturation will boost the performance of future low NO_x syngas combustion systems as it does for the current DGAN systems.

Saturation is best used to recover low level and otherwise relatively useless waste heat. This imposes somewhat of a limitation since such heat is limited in a well designed cycle. There will probably be more such heat available for additional saturation in future cycles as we design the systems for deeper sulfur removal. This is because all residual sulfur in the syngas elevates the dew point of the HRSG stack gas. Polk's stack gas dew point is typically between 240°F to 250°F. Deep sulfur removal would lower this dew point to the 200°F range. Each degree that the stack temperature can be lowered represents about 1 million BTU/Hr available to the cycle.



I now will change focus from broader cycle issues to some hardware issues.

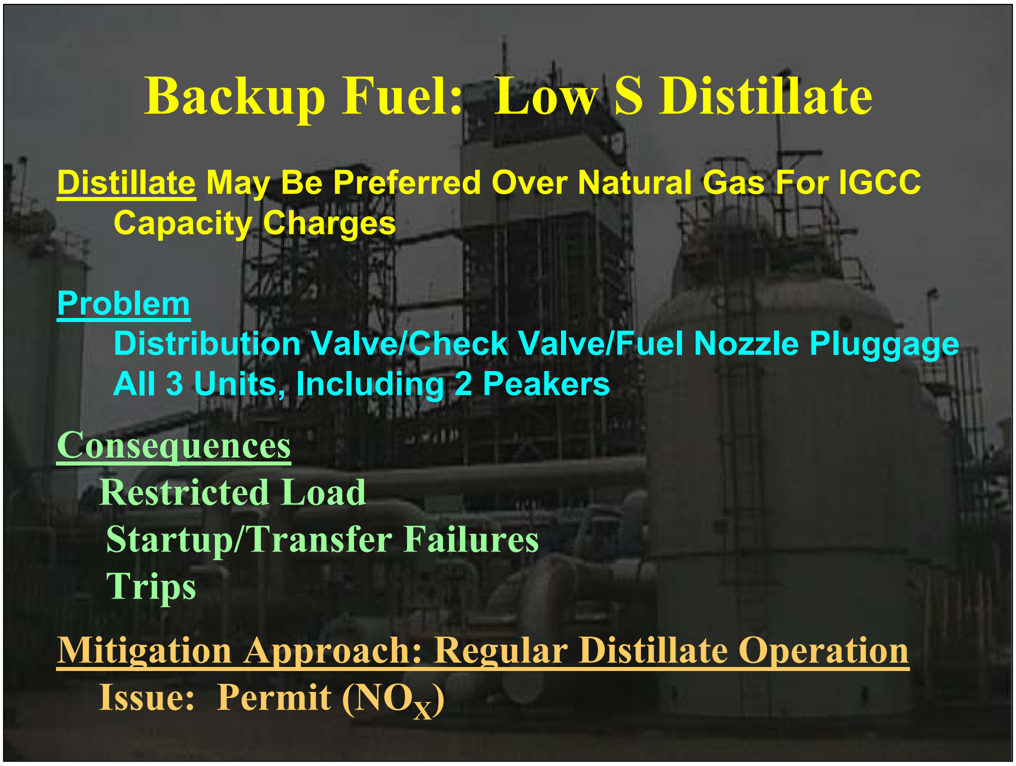
The slide shows the control and isolation valve trains for syngas and DGAN into the turbine. Each train has two very expensive hydraulic actuated isolation valves intended to provide fast positive shutoff. Although the service is not particularly severe, these valves have repeatedly failed to operate properly. The valves themselves have several failure modes and the hydraulic servos are also very prone to failure. We have tried different valve types and modifications. We eventually added motor operated valves to each train which usually provide positive isolation, but they don’t stroke quickly enough to satisfy the system requirements. These valve failures have been very costly in terms of startup delays, trips, and transfer failures. They could be dangerous as well. We have solved similar problems with the gasifier’s oxygen and slurry isolation valves where the service is more severe, particularly for the slurry. But the solution for these syngas and DGAN valves has eluded us to date.



The backup fuel system for the turbine is extremely valuable but it poses another set of hardware issues.

It does not seem that potential IGCC users generally recognize the importance of a highly reliable backup fuel system. Polk's availability on syngas fuel has averaged 73% for the last 4 years, but the combined cycle's overall availability has been 92% and on-peak availability has been 98% recently. When the backup fuel is considered, Polk's availability can match that of many natural gas combined cycles even though our backup fuel system has had some problems. Without the backup fuel system, Polk's statistics look more like those of any coal-fired power plant.

The incremental availability provided by the backup fuel system is extremely valuable. For one thing, it has a significant impact on IGCC design decisions regarding spare gasification equipment. It's more difficult to justify incremental investment to improve gasifier reliability if the benefit is only lower fuel cost for a short period of time rather than complete unavailability.



Polk's backup fuel is low sulfur distillate for the IGCC turbine and our two natural gas fired peaking turbines. Maintaining distillate fuel backup capability for IGCC systems is particularly important. Even though natural gas can be used as a backup, there are increasing availability and price concerns about it. More important are the capacity charges for gas. When a gasifier trips, a significant amount of backup fuel is needed very quickly, and it is needed until the gasifier can be returned to service or until an alternate source of electricity can be found. Distillate fuel can be purchased ahead of time and stored, but natural gas must be nominated daily and the capacity charges paid if it is the backup, whether or not it's used. These capacity charges can be devastating.

Polk's distillate fuel problems have mostly involved plugging of fuel system components with coke formed in the distillate fuel lines during extended operation on the base fuel. Improvements have been made to the syngas turbine so its starting and transfer reliability are much improved, although there are still occasional problems. The peaking turbines don't transfer to distillate reliably without manual intervention. We believe cofiring the syngas machine periodically with distillate fuel would further improve the distillate system reliability, but our permit does not provide for this mode of operation.

High-technology component development is very important to the future of IGCC turbines, but significant enhancements to they system can also be made by paying more careful attention to lower-tech components like isolation valves and distillate fuel backup systems.

The previous topics I've discussed relate directly to the turbine. I'll now touch on two areas of gasification system development which have implications for the power block.

The first is trace metal removal. Mercury has received much attention lately, and it is clear that mercury can be removed economically from syngas. However, there are other problematic trace metals. For example, we've found ppm levels of some trace metals such as arsenic in small turbine and HRSG deposits. Even these very low concentrations in small deposits necessitate using personnel protective equipment whenever maintenance is performed. This is costly and time consuming. These trace concentrations also can render water used for cleaning turbine parts hazardous, significantly increasing disposal costs. Also, emission reduction of some of the other trace metals besides mercury may be mandated, and they do pose problems for SCR systems if SCR is needed sometime in the future. Consequently, there are several reasons to at least consider removing them. As we study mercury removal with Chevron/Texaco at Polk, we are also looking at simultaneous removal of some of these other metals that we have found troublesome. It would be helpful if others studying mercury removal would do the same, if they are not doing so already.

The second point for consideration by gasification system developers is deep sulfur removal. Proven technologies for deep sulfur removal from syngas are documented. Consequently, I believe we can expect mounting pressure to incorporate it into future IGCC systems to bring IGCC into SO_2 emission parity with natural gas fired combined cycles. Deep sulfur removal is also a requirement for successful operation of SCR in IGCC systems if SCR is needed in the future.

The available technologies for deep sulfur removal are more capital intensive and less efficient than the systems currently in use at IGCC plants. However, some advantages would accrue if deep sulfur removal became the IGCC standard. I've observed that much time and money is wasted in the project development phase to "optimize" sulfur removal and recovery. This is particularly true for IGCC plants which co-produce chemicals where some very bizarre (and probably inoperable) configurations have been suggested. Deep sulfur removal would also be more compatible with CO_2 removal and recovery in the future. Also, there would be some cost offsets. Deep sulfur removal would make more stack heat available for gas saturation as discussed previously, and it would eliminate troublesome HRSG sulfur deposits which we are experiencing at Polk such as those shown on the next slide.

This is an elemental sulfur deposit which formed in Polk's HRSG economizer, although they form in some higher temperature zones as well. Note the corroded tubes and fins in the background.

I believe IGCC technology would be well served if we were more proactive in addressing deep sulfur removal. Items on my "wish list" might be:

- Definitive information on SCR operating issues including elemental sulfur deposition data at various stack SO_2/SO_3 concentrations
- Comparative cost and efficiency studies for various gasification technologies operating at different pressure levels that can be used in project scope development and permitting. The studies should document the real incremental cost of deep sulfur removal for typical integrated and optimized systems.
- Data supporting the assumptions made for the above studies. For example, data would be useful that supports the hypothesis presented in a relatively recent paper that Rectisol™ would also remove mercury.
- A continuing effort to develop deep sulfur removal systems. These efforts should be accompanied every step of the way by good engineering studies to assure that the proposed system will indeed be lower cost, more efficient, and no more complex than the existing technology.

In conclusion, I believe:

- Higher efficiency turbines still hold the greatest promise for significant IGCC improvement
- Development of low NO_x syngas combustors is extremely important
- Syngas saturation deserves more attention since it is a low capital cost system that can help meet efficiency and emission reduction goals
- High-tech materials development programs are extremely important, but attention must also be paid to lower-tech nuts and bolts hardware like valves and backup fuel systems.
- Work that the gasification process developers do on removal of trace metals besides mercury and on deep sulfur removal will also pay dividends for the turbine and combined cycle.