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RESTRICTED

June 1989
ENGLISH

17611

DEVELOPMENT OF EXPERTISE IN FERTILIZER PLANT OPERATIONS

DP/IND/85/006/11-01

REPUBLIC OF INDIA

Report on Energy Conservation Assignment in India*

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of E. P. Wells
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UNIDO
REPORT ON ENERGY CONSERVATION ASSIGNMENT IN INDIA
MARCH 4 THROUGH APRIL 15, 1989

SECTION I - INTRODUCTION

In conducting this assignment I spent time for evaluation at the following plants:

IFFCO	Phulpur
GNFC	Bharuch
NFL	Vijaipur

and also time at NFL Panipat for participating in an energy seminar arranged jointly by Dr. G. B. Purohit and NFL.

I would like to express my appreciation for the kind reception and helpful cooperation given to me by personnel at all of the plants.

My experience on this assignment has reinforced my previously held opinion concerning the individual competence of Indian fertilizer industry personnel. Man for man they are at least as good and generally better than comparable personnel at similar fertilizer plants elsewhere in the world. Translating this expertise into superior performance requires disciplined systems, training, and availability of an industrial infrastructure. Some aspects are pertinent to my energy assignment and are covered in this report.

It was a pleasure for me to return to India, renew old friendships and establish new ones.

SECTION II - GENERAL COMMENTS APPLICABLE TO ALL PLANTS

Energy conservation in a fertilizer plant is of primary importance. Energy is the major cost in producing the product, and conservation provides the biggest scope for reducing those costs.

Energy conservation is a broad field. It includes everything that affects factory performance. As you all know shut downs are a major energy waste. The subsequent start up requires use of fuel and venting of process gas for hours and sometimes days until production is resumed. Anything that reduces the number of shutdowns will improve energy consumption per tonne of product and comes within the scope of the energy conservation program.

Having established the importance and broad base of energy conservation lets review what an effective program requires. The first and most important requirement is the commitment of top management to the program. This commitment must include making sure that the organizational structure and the manpower assignments are compatible with the program, that the program responsibilities are clearly defined, and that authority for carrying out the program is clearly delegated. Without top management commitment and action no program can succeed!

Energy conservation work can be broken down into the following categories:

1. Data collection and data analysis.
2. Identification of projects.
3. Setting priorities, assignment of responsibilities and setting schedules.
4. Progress reporting.

The arrangement I have found to be best is to have energy conservation data collection and analysis done by a Technical Service Department staffed adequately to perform this function. Technical Service and Production personnel must cooperate. The Production Department is responsible for operating the plant on a minute to minute, day to day basis. Their priority is to keep it running and making product. The Technical Service Department does not have the burden of present and immediate operating responsibilities. Their task is to review operations with a longer term view to detect long term problems, evaluate energy consumption, assess catalyst life, evaluate potential capital improvement changes etc.

A basic tool that Technical Services must use is performance testing of the plant. This should be done once every three to six months depending on circumstances. Conducting a performance test requires the cooperation of Production, Maintenance and Mechanical Engineering personnel. A date for the test should be scheduled ahead of time and needed instrument calibration and standardized pressure gauges made ready. Plant production rate should not be changed to accommodate the test, but a time should be picked when the rate is expected to be above 100% and at or near the maximum normal rate. Data should be collected on flag sheets developed for the purpose. The flag sheet data should be issued to appropriate personnel in Production, General Engineering and Maintenance Departments.

In addition to performance testing of the entire plant, testing of individual sections or equipment items should be done as frequently as necessary to identify problems and assess whether performance in critical areas is changing. These special tests may be requested by production personnel if they notice changes and need them to be analyzed, or by engineering department or maintenance personnel to check out mechanical equipment (turbine and compressors for example) about which there is reason for concern. These individual tests require the same careful planning and instrument calibration as the performance test of the entire plant.

It is of course, not enough to just take performance test data. That data must be compared with data from previous tests (including the guarantee test run for the plant) and with design figures. Differences must be evaluated. This evaluation should normally be done by Technical Services Personnel, but will frequently require consulting Production, General Engineering and Maintenance Personnel. Evaluation must include reasons for deviations from design performance and the significance of changes from previous reports. Copies of the final reports with evaluation should be issued to all concerned.

In addition to performance testing, Technical Services must also report on monthly production, specific energy consumption per tonne of product, etc. This report must include a list of each shutdown (or partial shutdown) that occurred, the production and energy effects of each shutdown and its cause. Any other factors that affected production or energy consumption without necessarily causing shutdowns should also be listed.

II- IDENTIFICATION OF PROJECTS

The reports that I have just described provide a sound basis for identifying energy conservation projects. Each deviation from design energy conservation and the cause of each shutdown is a potential project. Some will be worth pursuing and some will not. Much of the information needed for evaluation (magnitude of energy loss etc.) is included in the reports.

Although the Technical Service Reports are a major source for identifying projects they are by no means the only source. Part of a good energy conservation program consists of getting the enthusiastic support of all plant personnel. This is important and will lead to identification of some good projects as well as improved energy conservation by people in the course of their normal duties.

Other sources of potential projects are reports from contractors, other plants, catalyst suppliers, equipment suppliers, technical publications, and technical meetings. The type of projects from these sources usually (but not always) involve spending capital money for a plant modification of some kind. They should be given consideration. It is important for any plant to keep technically up to date with developments in the field and use what is applicable.

Potential projects can be identified by anyone, and projects can be of many types. There are almost always more projects than can be implemented at any given time. It is necessary that potential projects be listed and kept track of systematically. This is a function that should be performed by Technical Services, and all potential projects should be reported to them so this can be done. The project list should include a brief description of the project and a rough estimate of the potential benefits.

It is necessary to have a system as I have outlined, but the system must not be allowed to interfere with quick action when quick action is needed. In some cases (i.e. rapid fouling of heat exchangers etc.) immediate action may be necessary and should be taken without identifying a project, reporting it to Technical Services etc. Such action should be reported by Technical Services retroactively.

SETTING PRIORITIES AND SCHEDULES AND ASSIGNING RESPONSIBILITY

As I said earlier there are almost always more energy conservation projects then can be worked on at once. In this situation, setting priorities is vital. The projects with the best prospects for improvement should be worked on first. The Technical Service Project list provides theavailable information for setting priorities. On any particular project the first work required will be different. Simple projects may be implemented as soon as approved. Some may require a shutdown. Some may require process and engineering design as well as capital investment. Some may require more investigation to determine whether or not work should proceed.

The decisions must be made by top management. In India this should be the General Manager of the factory and should preferably not be delegated. The decisions should be made in a meeting attended by appropriate Production, Technical Service, General Engineering and Maintenance personnel. Each item on the list should be discussed, priorities should be set and responsibility assigned for doing the work. Approximate schedules should be discussed and agreed on. Technical Services should keep notes of the meeting and re-issue the project list to include the decisions made.

Such meetings should be repeated at appropriate intervals (perhaps monthly) to consider any new projects, review progress on old projects and make any changes indicated by circumstances.

PROGRESS REPORTS

I have just mentioned that one of the things that will be done in the regular meetings with the General Manager is review progress.

Technical Service as the keeper of the list must update it monthly to include a brief report on the progress for each item as well as to include any new items. The writeups on each item should be kept short, but include the pertinent facts. A good report will provide the basis for a good meeting. A badly written rambling report will cause time to be wasted in the meeting.

In addition to the reporting of progress on each individual item overall progress on energy consumption should be reported-monthly and yearly. The reports should be made by Technical Service in consultation with Production personnel and others as needed. There should not be separate reports by Production and Technical Services providing duplicate information in different form or calculated differently.

At the end of the year it could be of interest to list the improvements made as a result of the projects implemented during the year.

Progress reporting should be kept simple, brief and pertinent. A report that includes too much is as bad or worse than one that includes too little.

Each project that is completed should have a post project evaluation by Technical Services to briefly determine if it has accomplished what was expected.

This completes my brief review of the basic system that should be used for handling energy conservation. Technical Services plays a key role as the record keeper. I have mentioned Technical Services more frequently in this writeup than other groups but that does not mean that they control energy conservation or are more important to achieving goals than Production, General Engineering or Maintenance personnel. Production personnel play a vital role in conservation in keeping operations tuned to maximum efficiency, skillfully avoiding shutdowns where possible etc. It is important that <u>everyone</u> in the factory is energy conscious and does his job with the view of doing it the best he can to be energy efficient. This starts with top management, and motivating others is one of top management's key roles.

The system I have described should be kept simple. It is intended to provide discipline not red tape. It should speed and facilitate implementation not delay it, and it should ensure doing the most important things first. I have devoted a high percentage of my report to this subject because in India system and discipline are needed. Individually, personnel in the factories in India are as well are better qualified than anywhere in the world. Together, as an organization, the results achieved in India are not as good. There are many reasons, but one is the system used to achieve results. Some plants have very rudimentary organizational systems and results are achieved by individual effort. This is inefficient and results in delays and sometimes inadequate priorities. In other plants the systems are much too developed. There is too much red tape and so <u>many levels of supervision</u> that decisions and actions are delayed. Information passes through so many levels from originator to top management that it is sometimes distorted and often delayed. The right degree of streamlined systems and organizations are an urgent need.

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There are a number of specific items that need attention to a greater or lesser degree in almost all fertilizer plants in India. These are listed below:

1. Plant Trip System
2. Time Required for Start Up
3. Maximum Production Rate
4. Turnaround Frequency
5. Excess Air in Furnaces and Boilers
6. Vents to Atmosphere
7. Relief Valves
8. Compressor Anti Surge Valves

9. Steam System Balancing
10. Steam Leaks
11. Steam Trap Performance
12. CONDENSATE Recovery
13. Cooling Water System
14. Surface Condenser Vacuum
15. Insulation

Each topic warrants a brief description with suggestions covering what should be done.

1. PLANT TRIP SYSTEM

Shutdowns are big energy wasters as I mentioned earlier. Anything that can be done to reduce them has a big payoff. The automatic trips cause shutdowns each year in almost every plant. If the trip saved a disastrous equipment failure or averted other serious problems it was necessary and the shutdown was unavoidable. However this is frequently not the case. False trips occur, as do trips which, though not false, did not avert a dangerous situation-an alarm would have worked just as well.

Trips are generally provided for individual equipment items and for the plant as a whole based on the recommendations of the equipment supplier and the plant design contractor. The equipment supplier is familiar only with his item of equipment, and understandably wants it protected regardless of the effect on the overall plant. Some trips on individual equipment items are necessary-(low lube oil pressure on turbines and compressors, overspeed trips on turbines etc.) but some are not (radial vibration trips etc.) because the risk they protect against isn't great enough to warrant the risk of a shutdown. The equipment supplier is not in position to evaluate these risks-only the plant owner can.

The design contractor who provides the plant trips is better equipped to evaluate them than the equipment supplier, but he is a designer-not a plant owner/operator and his judgement should be considered but not blindly accepted by the plant owner.

Basic trip systems come in two types-normally de-energized, energize to trip, or normally energized, de-energize to trip. For plants already built it is difficult, if not impossible to change; for plants being designed I have a strong preference for the first system-normally de-energized, energize to trip. Spurious trips due to local power interruptions are less likely and back up power for tripping can be supplied to make the chance of not having tripping power when something needs to trip so unlikely that it is not of concern. Many contractors call the de-energize to trip system "fail safe". In my mind it is not fail safe, but fail unsafe. It represents a plant shutdown on a crash basis and a subsequent startup. Each such cycle reduces equipment life (in case of primary reformer tubes significantly) and adds the risks of problems during the subsequent startup. I cannot call this "fail safe".

What should be done?

Each plant should carefully examine each trip and decide what should be done with it. The evaluation must consider the following:

1. How likely is a spurious trip?
2. What are the consequences of a spurious trip?
3. What is the likelihood of operators understanding the situation and having time to take corrective action if the trip is converted to an alarm?
4. How much time would normally elapse from the trip alarm point until damage occurred?
5. How serious would that damage be?

Sometimes, particularly in the case of flame alarms and some vibration analyzers, the trip requires more than one sensing device to reach the set point before the trip is actuated. This at least minimizes the likelihood of a spurious trip.

Item three above requires consideration of the operator training program (both initial and refresher) and the adequacy of emergency procedures. Because the subject is important to good performance and thus energy conservation I will digress briefly to consider operator training more fully. For new operators there should be a formal program consisting of both classroom and field training every day, with a short, well designed daily test. The test provides feed back not only on the individual being tested but also on the adequacy of the teaching. The training course should be in two parts-first a general course on operating fundamentals and then a specific course on the unit the personnel will be assigned to.

Startup, shutdown and emergency procedures must be kept up to date and must be thoroughly covered in training. Periodic dry runs should be held on emergencies to make sure all operators know what to do, and periodic refresher training , (again with daily testing) should be given to old operators.

With well trained operators more responsibility can safely be assigned to them and less left to the automatic trip.

After completing the systematic review of all trips, decisions should be made and issued on which to leave as trips and which to eliminate. The action to be taken should be thoroughly communicated to all concerned ahead of time. In some plants it is the practice to regularly bypass certain trips at times when it is felt the trip might be activated. Sometimes this may be necessary, but trips that are frequently bypassed should probably be converted to alarms.

2. TIME REQUIRED FOR STARTUP

Much has been written and talked about recently on fast, low energy startups for reforming plants. The concept was originated by Hays Mayo (a copy of his article is attached) and adopted by a number of plants.

Mr. Mayo has carefully considered the effect of faster startups on reformer tubes, catalyst, and refractory and emphasizes the need for good planning and well trained operators.

I agree that money can be saved following Mr. Mayo's concepts. I think the most important need in starting up faster is training, and the need to have a top ammonia plant supervisor (not shift engineer) in charge of the startup and on the unit at all times during the startup.

At any plant, startup should be speeded up a little bit at a time. Each startup should be conducted just a little faster than the previous one, until finally either the target set by Mr. Mayo is reached, or some other limit is reached which it is decided not to exceed. Changing a little bit at each startup does not require a major adaptation by the operators at one time and minimizes the chance of operator error. It must be remembered during fast startups that things are changing more quickly than normal and if something unusual occurs, such as a stuck valve that delays introduction of feed to the reformer, action must be taken quickly.

3. MAXIMUM PRODUCTION RATE

The incremental tonne of product is usually made at a lower energy consumption than the average tonne, and it is certainly more profitable than the average tonne. It is desirable for every plant to run at the maximum rate possible without jeopardizing safety or equipment integrity. On a new plant or an existing plant in which changes have been made to increase capacity, production rates above the previous maximum should be made in small increments and allowed to stabilize for a day at the new condition before increasing rate the next increment. This prevents having severe problems in some of the systems which have a time lag. One example is the CO_2 removal system which for a short period can handle an increased load until the absorbing solution gradually gets saturated and stripping capacity is exceeded. Also cooling water temperature might slowly increase to an unacceptable level. Allowing a full day to stabilize at the new rate minimizes the chance of nasty surprises.

4. TURNAROUND FREQUENCY

According to the last AICHE report on Causes of Ammonia Plant Shutdowns turnaround frequency in North American Plants is 24 months, in Europe it is 20.5 months and in the rest of the world it is 13.5 months. There are real differences that make it more difficult to run a plant for two years in India than it is in America but it can be done, and minimizing turnarounds can be a big money saver. It requires careful planning, good preventive maintenance, thorough nondestructive testing while on line (signature analysis of rotating equipment, infra red surveys etc.) and good luck. It also requires good equipment history records. It is probably impossible with a new plant where the idiosyncrasies of individual equipment items have not become known. However on each plant, time between turnarounds should be increased at least a little bit each time.

5. EXCESS AIR TO FURNACES AND BOILERS

This is an interesting item. High excess air is a well known energy waster. All plants know this, but almost all have problems achieving their own goals. In some cases oxygen analyzers aren't working (analyzers with zirconium oxide cells should be used), in some cases burners are faulty and can't be adjusted, in some cases fuel quality (usually coal) is bad and requires more excess air.

This is an item that needs continuous attention in all plants. There is no easy fix. It requires close monitoring, and time consuming, difficult burner adjustments. The rewards are not huge, but they are real and it is good practice to require well tuned combustion systems. The people doing the adjusting must always be alert to avoiding a fuel rich situation which might not be seen on the oxygen analyzer if there are leaks allowing air to enter where it should not. Air in-leakage should be checked regularly and especially just before starting a concentrated program of burner adjustment to reduce excess air.

6. VENTS TO ATMOSPHERE

There are process vents to atmosphere (or flare) and steam vents to atmosphere. Normally these should be closed except perhaps a slight vent of steam at the lowest pressure level if there is no constructive use for it. Each operator should check the vents in his area each shift to verify that they are closed and not passing material through a closed valve. The shift engineer should also check them each shift, take action if possible and report any passing valves that he cannot stop. There is more loss from vents than reported by supervision at most plants.

7. RELIEF VALVES

Relief valves leaking through is another source of loss. Operators should check each shift and report any leakage. Steam system relief valves can be particularly troublesome. If certain relief valves give repeated difficulty consideration should be given to installing block valves to isolate them where there are multiple relief valves (most steam systems). These valves can then be removed, repaired and reinstalled without requiring a shutdown.

8. COMPRESSOR ANTI SURGE VALVES

Open or passing anti surge valves are significant energy wasters. All plants I have been in have had some open or passing anti surge valves. Operators need to check them each shift and report any problems. At some plants I was told they were all closed with no passing, but on checking in the field several were hot and obviously passing-another instance of the actual field situation being different from management's perception.

9. STEAM SYSTEM BALANCING

All plants have steam systems at multiple pressure levels. Design basis provides for lower pressure level makeup extraction from steam turbines at the desired pressure level. The quantity to be extracted to vary with the requirement. Some turbines are provided with induction capability to balance requirements. Frequently, for various reasons, conditions are not as designed and steam must be let down through control valves from one pressure level to the next. In existing plants, projects for providing increased flexibility warrant consideration and in new plants extra flexibility is a worthwhile feature.

10. STEAM LEAKS

Steam leaks need attention at all plants-some worse than others. Many of the leaks were at small valve bonnets and packing glands. If a stream leak starts it is important to stop it quickly. If not it will erode the surfaces and cannot be stopped without "furmaniting". To catch leaks quickly operators should survey their area every shift-going to all platforms at all levels and being alert for leaks as well as any other significant conditions. It is most helpful if operators can be given small wrenches to tighten packing glands themselves without having to call maintenance people. This can make the difference between stopping a leak or not stopping it.

11. STEAM TRAP PERFORMANCE

Steam traps need continued attention in all plants. I have found bucket traps to be the best. In open systems it is easy to spot plugged or leaking traps. In closed systems it is more difficult. An acoustic leak detector is best, but requires skill for proper use. In plants with a closed system a small group of people should be trained in use of the detector and should be assigned regularly to steam trap work.

In the main superheated steam headers, traps can be shut off during normal operation, but they must not be forgotten and must be opened when shutting down and starting up.

Some reforming plants have a big dead leg in the emergency process steam connection to the process air line to the secondary reformer. It is essential that this dead leg be adequately drained at all times. A slug of water into the process air line in case of emergency could cause severe damage. Necessary precautions need to be developed on a plant by plant basis.

12. CONDENSATE RECOVERY

Recovering condensate from steam traps in a closed system, flashing to recover low pressure steam and using the remaining condensate as boiler feed water can be an energy saver if:

A. Steam traps are maintained in good condition.
B. Corrosion/erosion is prevented in the collecting system.

A steam trap program with acoustic tester as out lined earlier is essential. Corrosivity of condensate should be checked and steam additives used if necessary. The various water treating companies will provide free service if their chemicals are purchased, and I recommend consulting them and selecting one for providing monitoring services and advice.

13. COOLING WATER SYSTEM

Fertilizer plants-especially ammonia plants-like cold weather. The turbines and compressors are more efficient and the plants produce more. A major reason is the lower cooling water temperature. Recognizing this, it is obviously important to have the cooling water as cool as possible at all times, but especially in hot weather. This means maintenance on cooling water fans, cell distribution valves, etc. that might require taking a cell out of service should be scheduled and done in the winter.

At all times flow distribution in the cooling tower should be monitored and adjusted so all cells get the same amount of water. The operator responsible should make regular trips to the cooling tower top to monitor distribution, and supervisors should also periodically check conditions. All of the plants I visited could improve water distribution in their cooling towers.

Cooling water flow distribution through the plant exchangers is also important. Frequently the water flows are wide open to all exchangers. This results in increased total water flow and a lower water return temperature. Water flow through each exchanger should be adjusted to optimum. Some should have the flow reduced where there is no penalty. Others such as surface condensers and other critical services probably need full flow. Reducing overall water flow will help cooling tower performance.

During turn arounds the cooling tower fill should be checked and repaired to ensure good internal distribution and contact with the air. Fan housings must be maintained to avoid excessive clearances and loss of efficiency.

In addition to cooling tower performance, the cooling water treatment system also needs close attention. The difference between good treatment and poor treatment can make a tremendous difference in energy usage. If treatment is inadequate there will be fouling problems causing loss of compressor and turbine efficiency, corrosion problems requiring periodic equipment replacement and perhaps shutdowns.

The best way to get good cooling water treatment is to employ one of the major water treating companies. They will provide regular monitoring and advice along with the chemicals. At any given plant the company that will provide the best and most competent service is the best one to use. The chemicals that each provide are about the same.

I am convinced that water treating service by an expert specialized company is the only way to get good water treatment. The same company should also be used for boiler water treatment and condensate treatment if necessary.

14. SURFACE CONDENSER VACUUM

Surface condenser vacuum that is less than design (pressure higher than design) is another factor frequently leading to high steam usage in condensing turbines. There can be several reasons:

A. Excessive Air In Leakage-This should always be checked when the vacuum deteriorates and corrected as quickly as possible.

B. Poor Ejector Operation-Ejectors require a minimum pressure to perform. If the steam pressure is too low it will lower performance drastically, however steam pressure above design will not improve performance.

   Check ejector nozzles for erosion. Long term nozzle wear is a problem, and when the nozzles wear, ejector performance drops off.

C. Cooling Water Temperature-This was discussed in the previous section.

15. INSULATION

It is almost possible to judge the age of a plant by the condition of the insulation. In the old plants insulation is unsatisfactory and requires extensive work. It is obvious that insulation maintenance has not been done on a regular basis. In the old plants an insulation survey should be made to determine extent of replacement required. The type of insulation and thickness should be determined by present standards. The original insulation may have been inadequate. In locations where insulation must be frequently removed for maintenance, removable jackets should be used.

In new plants a program of replacing and repairing insulation after each turnaround should be followed.

E P Wells

E. P. Wells

SECTION III - IFFCO PHULPUR PLANT

Time at this plant was limited to 3 1/2 days (3:00PM March 7 to 10:00AM March 11) and the IFFCO list of items they wanted to discuss was not received from UNIDO in time for preparing information on specific items of special interest to Phulpur.

My comments on IFFCO's list are given below with paragraph numbers the same as in their list.

MAJOR CONSULTING WORKS OF IFFCO'S INTEREST

1. BENFIELD SYSTEM MODIFICATIONS

   IFFCO is interested in converting the existing Benfield CO2 removal system to a multi-ejector type low-heat Benfield System. They would like to get process design and detailed engineering. The desired system is similar to that at NFL Vijaipur and I suggest that appropriate IFFCO personnel visit Vijaipur for a review of the system to assess feasibility of modifications. The only alternate is to get information direct from the process licensor.

2. Stripping of H_2S from the naphtha with hydrogen is feasible but requires detailed design calculations to check tower size flow rates etc. Time is not provided in my present contract to permit making these calculations.

DISCUSSION ON NEW ENERGY SAVING CONCEPTS

A. AMMONIA PLANT

1. Synthesis gas molecular sieve purification is a viable retrofit option and has worked well at several plants. It is important to design the system with a regeneration cycle shorter than the on stream cycle to provide time for any necessary maintenance work on the regenerated bed without shutting the unit down.

Kellogg, Casale, and Topsoe all have developed converter basket retrofit designs for use in existing converter shells. Casale has the most in service in the USA and have generally been able to quote the lowest prices and best efficiency. Performance of Casale retrofits installed has been very good.

2. I have no experience with the use of a mechanical steam compressor. For the amount of very low pressure vent steam available I doubt that it would be economical.

3. I have had no experience with the grooved Korodense tubes made by Wolverine Tube, Inc. I doubt that it would be worthwhile to retube before making a thorough check of possible cooling water fouling and cooling water treatment, ejector performance etc.

4. Slow rolling of all turbines except the condensing turbines have been stopped. Stopping slow rolling of condensing turbines is possible but requires more elaborate preparation.

5. Suction chillers for the syntheris gas compressors have been used to add capacity when the compressor was the plant bottleneck. It does not save overall energy. I prefer a booster blower for the air compressor suction rather than a chiller if additional air compressor capacity is needed.

6. The only really satisfactory way to optimize the synthesis loop parameters for optimum performance is to use a computer program. Kellogg have one for their units and claim good results.

7. Some plants have gone to blanket insulation with a hard surface spray to minimize erosion. Performance has generally been satisfactory.

8. Use of the 201-C exchanger appears feasible as proposed by IFFCO. Calculating exchangers with vaporizing and condensing streams such as naphtha requires vaporization and condensation curves for the specific naptha composition at the operating pressure of the exchanger.

9. It is not feasible to convert the three temperature level refrigeration system at IFFCO to a four level system. The compressor is not designed for the four level system and the

modification costs would exceed the value of the benefits.

10. For surface condenser use, vacuum pumps are rarely used. Vacuum pumps are economical only in very low volume systems.

11. Plant optimization by use of critical ratio controllers is generally done by computer control. Benefits of computer control have been estimated at 1-2% reduction in energy costs.

12. On-line cleaning of surface condensers is not feasible with standard surface condensers. The special exchangers designed for on line cleaning have built in brushes and a brush catcher at each end. Valves are provided to switch flow from one end to the other and this forces the brushes through the tubes to the other end. I would prefer to reduce water side fouling by improving water treatment and use of dispersants.

13. Temperature of flue gas out of the reformer is 190°C vs a design of 157°C. Before deciding to add an additional steam superheating coil in the convection section I would check the furnace carefully for air leaks, excess air, and fouling of the convection coils. If fouling occurs regular use of soot blowers should be investigated.

    Adding a steam superheat coil is, of course, feasible provided the space is available.

14. I consider recovery of seal gas losses from the synthesis compressor of questionable value. Great care would be required to avoid safety and catalyst problems with possible air contamination.

B. UREA PLANT

1. Operating experience on the L. P. Steam injection type turbine envisaged for the CO2 compressor would have to come by finding out from the turbine suppliers where similar machines have been used and getting information direct from that user. Information on performance from vendors should always be checked with the user. Vendors sometimes don't get complete feed back, and sometimes paint a rosier picture because they want to sell equipment.

2. I did not have time to look at the details of possible recovery of heat from the CO_2 compressor intercoolers.

3. I have no additional information on this item. I would suggest getting a list of users from Snam Progetti and checking directly with them.

4. NFL Vijaipur has a deep hydrolyzer but has not been able to use it as designed because of high pressure water pump problems. I understand there is also one working property at the Indo Gulf Plant. Information should be available from them.

5. Urea and Carbamate deposits can be washed off with water. If cyanuric acid deposits are formed they are glass like and require special procedures which are usually recommended by the plant designer. This is a problem in some Toyo plants.

6. I don't think it is economically feasible to convert L. P. steam to higher pressure steam with ejectors.

C. POWER PLANT

1. Unburned carbon in the ash indicates inadequate contact of fuel with air. Smaller pulverized coal particle size and better mixing of fuel and air at the burner might help. For detailed analysis and recommendations the boiler manufacturer (BHEL) should be urgently requested to give specific recommendations.

D. OFFSITES

1. The cooling tower should first be balanced to give equal flow throughout the tower. At the time of my visit flow was uneven, and the other steps described in the general section on cooling water should be followed. When all adjustments are made a performance test should be conducted on the cooling tower. Based on the test results a decision can be made on retrofitting or adding cells. Usually adding cells requires less down time than a retro fit.

DISCUSSION ON MAJOR PLANT OPERATING PROBLEMS

1. Sometimes back blowing the catalyst beds has been tried, but it gives little and very short term improvement. The best method is to vacuum

off the top section of the catalyst creating the high pressure drop. To avoid pressure drop build up the distributors should be inspected to make sure they are in good condition and all liquid carry over such as to the methanator must be prevented.

2. Turbines frequently use more than design steam. The reasons are many and could be caused by either bad turbine performance or bad compressor performance or both. A performance test is needed to pinpoint the cause so corrective action can be taken.

3. Air leakage into furnaces must be sealed, burners adjusted (time consuming) as discussed in the general section of this report.

   Dampers often give some problems and need adjustment at each TAR. If replacement is required I have found the double butterfly type damper to be good.

4. Soot blowers are the recognized methods for cleaning convection coils in operation. Requires a hole in the convection section (sealed) for inserting a steam lance. Care must be taken not to cause erosion of the convection tubes.

5. Startup time is discussed in the general section of this report.

6. Seal leakage in the major centrifugal compressors in an ammonia plant is sometimes a problem. Obtaining improvement requires working closely with the compressor supplier to suggest changes. (It is too late in existing plants, but seal performance is an item that should be checked before purchasing a compressor from a specific supplier) Measurement of leakage depends on the installation of the specific system. Prevention is the best course of action.

7. Reduction of drainage time in shutting down the refrigeration system requires considerable care, attention and skill during the shutdown. The liquids should be almost completely eliminated prior to shutting down the compressor. This can be done and is the only good way to minimize the problem. After the liquid is gone ammonia vapors should be purged to the flare using nitrogen.

8. The reformer penthouse is very hot and working there is a problem. Some plants (I haven't seen it on Kellogg Plants) do take FD fan suction from hot areas, but I've not seen it as far away as the reformer penthouse. The duct work would be large, expensive, and would add

pressure drop in the fan suction. These are the major problems and can be evaluated. I expect the cost might be prohibitive.

E. P. Wells

SECTION IV - GNFC BHARUCH PLANT

I spent five days at this plant including my oral report to plant management and plant tecnical staff.

My comments resulting from the plant visit are given below:

1. Knock Out Drum For Synthesis Gas Waste Heat Boiler

   The internals of the Borsig waste heat boiler in the synthesis system are not adequate to prevent liquid carryover into the steam. Such carryover can contribute significantly to fouling of blading in the steam turbines and increase stream consumption. It also adds to the erosion /corrosion problem in the condensate system. I strongly recommend installation of an external knock out drum in the steam line exiting the Borsig boiler.

   I have had an opportunity to discuss this subject briefly with Topsoe Engineers and they indicated agreement with this recommendation. The Borsig boilers have had the same carry over problem at other plants.

2. K. O. Drum In Fuel Line To Superheater Furnace

   It is important to have positive provisions for making sure that liquid cannot be carried with the fuel gas into any gas fired furnace. Many days of downtime and resulting energy losses have occured in plants where knock out drums have been omitted to save money with the thought that normally there would be no liquid in the fuel gas. It is the upset condition that causes problems and it is then that the protection of the knockout drum is needed.

   I realize this item is being considered by GNFC personnel and I encourage installation of a knockout drum.

3. Guard Vessel Upstream Of First Shift Converter

   Many plants have used guard vessels upstream of shift converters to catch material that would otherwise cause pressure drop buildups in the shift converter and lead to frequent shutdowns (a major energy waster) to remove the top catalyst layer by vacuuming. (Back blowing without opening the vessel has rarely been successful for more than a few days).

Such a knockout drum should have block valves and a by pass permitting removal from service for cleaning without interfering with plant operation.

The decision on whether or not to install the drum should be made on economic grounds by offsetting the cost against the savings resulting from fewer shutdowns. GNFC personnel are well qualified to make the evaluation.

4. Expander Turbines in Rectisol System

In modern plants the energy in the pressure let down of CO_2 absorbing solutions from absorbing to regeneration pressures is recovered in expander turbines and used to supply much of the pumping energy for the solution. Such turbines have been in use for many years and if obtained from experienced suppliers are reliable.

Retrofitting to add expander turbines is not as advantageous as having them included as part of the original design but should be carefully considered. I recognize that the Rectisol licensor has not used them and is reluctant to recommend them but this attitude is not consistent with present day plant design technology.

5. Eliminate Steam Leaks

Steam leaks are a major problem at the GNFC Bharuch Plant. The leakage is excessive and is a significant cause of energy inefficiency. Steam leakage of the magnitude experienced at Bharuch can be due to a number of causes that require attention. Flanges in high pressure steam systems should be minimized and eliminated wherever possible. If certain flanges leak regularly piping alignment should be checked, and flange gasket surfaces should be inspected. The type of gaskets used should also be reviewed. If raised face flanges are supplied, flexitallic type spiral wound gaskets should be used. The gaskets must be obtained from qualified manufacturers and inspected to make sure quality is satisfactory. Over the years I have had problems with spiral wound gaskets made in the United States and also in India due to two major causes.

- Inadequate spot welding which allows the gasket to unwind in service.
- Poorly designed spirals which are too easily deformed and don't provide adequate sealing against the flange sealing surfaces.

Both problems are correctable but require working with the gasket manufacturer.

Leaks at valve bonnets and packing glands can be due to poorly designed valves. Special care must be given to valve designs in high pressure steam systems and if repetitive leaks occur in certain valve types, that style valve should be replaced with a better design.

In addition to problems with equipment , excessive steam losses can also be due at least in part to lack of proper attention on the part of plant personnel. Steam leaks progress rapidly and the only hope of stopping them by tightening is to do so almost as soon as the leak starts. Operating personnel should make careful rounds of the plant each shift to all platform levels and all locations. This should be a normal part of their duties - not just to check for steam leaks. However if they observe steam leaks they should immediately attempt to tighten them if it is a relatively small flange, bonnet, or packing leak (operators should have wrenches for this purpose) or if it is a large flange they should report the situation and maintenance personnel should attempt the tightening. Inadequate attention is a major source of excessive leaks at many plants.

Leaks frequently develop in steam system flanges after shutdowns when the system is heated up and pressurized. Some plants have found it helpful to tighten critical flanges during the heating up period to prevent leaks from starting.

Eliminating steam leaks should be given high priority at GNFC Bharuch. I feel sure that if this is done the problem can be solved.

6. Steam Trap Performance

Steam traps and the condensate collecting system are major problems at GNFC Bharuch. Several things should be done that will help.

A. Eliminate carry-over from the Borsig boiler. This contributes excess condensate to the system which causes overloading of the traps and excessive velocity in the condensate system leading to erosion and leaks

B. Establish a steam trap leak detection team using an acoustic detection system are discussed in the general section. NFL have established such a team and are willing to assist.

C. Work with an established water treating company to obtain steam additives that will reduce condensate corrosion. Select the company that will provide the best service and advice at the Bharuch Plant. Nalco is doing a good job for NFL at Vijaipur and might be considered but I've found that because a company gives good service in one location does not mean they can or will do the same in another location.

7. Insulation

This is another problem area at the GNFC Bharuch Plant. It has been recognized and lists have been prepared detailing the insulation needing repair or replacement, but insulation condition is still bad. Urgent attention should be given to getting the necessary work done. Consideration should be given to replacing the damaged insulation with insulation that is thicker than that originally provided.

Much of the damage to the insulation was done during maintenance and some areas may need removable jackets.

8. Cooling Water Treatment

Cooling water treatment can be improved and will help energy conservation at the Bharuch Plant. I strongly recommend that GNFC use the services of a professional water treating company who will provide technical advice and monitoring of the system in addition to the necessary chemicals. NFL at Vijaipur is using Nalco and their cooling water treatment is very good. Vijaipur has the same Urea plant design with the water cooled exchanger operating at about 60°C on the cooling water side. They have had no trouble with fouling which they attribute to good cooling water treatment. They use a chromate treatment and this is not possible at Bharuch because of pollution problems but there are more up to date alternative treatments available than are being used at GNFC and they can give much improved performance in the cooling water system. This will significantly help energy consumption.

water system. This will significantly help energy consumption.

9. Cooling Tower Performance

The cooling tower at Bharuch as at most plants needs continued attention. During my visit the fan in one cell was taken out of service but it was not possible to shut off the water in that cell because of a problem with the shutoff valve. This is inefficient and raises the cooling water temperature. The steps listed in the general section of this report should be closely followed.

E. P. Wells

SECTION V - NFL VIJAIPUR PLANT

I spent sixteen days at the Vijaipur plant. My comments resulting from the plant were presented orally to the plant staff in a meeting prior to my departure and are given below:

1. Plant Organization

The first five pages of the general section of this report are specially applicable to the Vijaipur plant. The plant is relatively new and the organization for:

1. Data collection and data analysis
2. Identification of projects
3. Setting priorities, assignment of responsibilities and setting schedule
4. Progress reportinghas not been established. It needs to be done quickly and urgently.

Plant performance to date has been reasonably good due to the individual efforts of the Vijaipur personnel, who are well qualified and knowledgeable. However the lack of organization and disciplined systems for training and the items listed above will make continued good performance more difficult as time goes by.

2. Plant Trips

The general section of the report is applicable to the Vijaipur plant. A trip system review should be made soon and appropriate action taken. Major trips that I found to be redundant on a quick review during my visit are listed below:

1. Low natural gas flow to primary reformer
2. Low process steam flow to primary reformer
3. Low process air flow to secondary reformer
4. High flue gas pressure in primary reformer
5. High flue gas pressure in steam superheat furnace

6. Low natural gas to process air ratio

Item five above caused an unnecessary shutdown during my visit and others had caused unnecessary shutdowns in the past.

During my visit I was given the opportunity to review my comments jointly with Topsoe representatives and NFL Vijaipur personnel. Topsoe agreed that trips could be reduced as I have suggested provided operator training was done well and refresher training maintained on a continuing basis.

3. Increase Production Rate

(See item three in the general section) Maximum rate at Vijaipur was limited at the time of my visit by the fouled condition of the synthesis gas steam turbine driver. This was scheduled for cleaning in late April. I suggested that after this was done, the plant production rate be increased systematically as discussed in Item III of the General Section of the report. Rate should be increased in this fashion until a limit is found. The limit may be different depending on the outside temperature. Ammonia plants do better in cold weather.

4. Motor Driven Automatically Started Pumps

It is standard practice to have some of the critical spare pumps (boiler feed water, lean CO_2 absorbing solution, etc.) equipped to start automatically if the main pump fails. This is the case at NFL Vijaipur and the critical spares are motor driven. However, the motor drivers at Vijaipur are not sized for the maximum horsepower requirement of the pump at full flow. This is a design error and has caused problems because when the spare pump is needed due to failure of the main pump, control valves will already have opened nearly to maximum condition and the motor will be subject to maximum horsepower requirements. Because the motors are undersized they have tripped due to overload thus making a bad situation worse. This problem should be corrected as soon as possible. Topsoe was made aware of this situation in our joint discussions and agreed to investigate. They should have some responsibility to see that the problem is corrected.

5. Synthesis Gas Waste Heat Boiler (Borsig) Carryover

There has periodically been carryover of liquid boiler feed water into the high pressure steam leaving the Borsig waste heat boiler in the synthesis loop. The level has been very hard to control which contributes to the problem. The Vijaipur operators have become quite skilled at preventing carry over during normal operation and recent analysis has shown no carry over under steady state conditions. However the level is still unstable during upsets or rate changes. Carry over from this boiler has caused fouling of steam turbine drivers which at the time of my visit was limiting plant production and causing excessive steam usage—both very costly items.

I strongly recommend installation of an external separator to eliminate the boiler feed water carry over and the severe problems it causes. In our discussions Topsoe agreed that the Borsig design had inadequate internals to prevent carry over.

6. CO_2 Shortage

At full production rate of the ammonia plant there is not enough CO_2 feed for the urea plant to process all of the ammonia produced. To offset this, excess feed gas is used in the front end of the ammonia plant to produce more CO_2. The excess gas at the suction of the synthesis compressor is returned to the primary reformer as fuel. This is wasteful of energy and will get worse when the gas company removes the heavy ends from the gas as they are planning.

The simplest solution is to have more rather than less heavy ends in the gas. This possibility should be explored with the gas company and both Topsoe and the primary reformer catalyst supplier should be consulted to make sure the heavy ends are kept low enough to avoid coking in the reformer.

7. Energy Recovery From Natural Gas Letdown To Fuel

Vijaipur Tech Service personnel are evaluating use of an expansion turbine to recover this energy. It is a good project. Use of expansion turbines for this purpose is a standard technique which has been considered for many plants in the United States. It requires proper drying of the gas upstream of the turbine and the turbine should be obtained only from an experienced supplier who has furnished similar machines that are working well in other locations.

8. Carryover From Benfield CO_2 Absorber Tower

There have been some problems with carry over of Benfield solution from the top of the CO_2 Absorber Tower. At times this has passed through the knock out drum and appears to have fouled E-1311 exchanger. This has put an increased load on E-1312. E-1312 has so far been able to pick up the extra load but in hot weather and higher throughput this may become a problem.

The main cause of carry over is foaming of the Benfield solution. To minimize foaming tendency it is important to keep the solution clean by keeping the solution filter in operation and changing the cartridges quickly when they become fouled.

Regular addition of anti foam solution will help. (This is being done)

When carry over starts it usually starts slowly and then builds up exponentially. If it is detected immediately corrective action (anti foam addition, change in circulation rate, etc.) can be taken to prevent solution going beyond the knock out drum. For early detection the high level alarm in the knock out drum should be as low as possible. This change was made at my suggestion during my visit.

9. Energy Recovery From Stripped Process Condensate

Ammonia Plant engineers have written up a plan for adding exchangers to accomplish this. Several alternates were considered. It appears to be a good project. My preference of the alternates is to put the exchanger only upstream of E-1322. Pressure drop requires close checking and it must be assured that the low pressure steam saved at the CPP will reduce letdown from the 40K system. This project should be taken over by Technical Service and General Engineering Departments.

10. Desuperheater For Stream Superheat Coil In The HRU

At high loads the steam temperature out of the HRU steam superheat coil exceeds the 500°C limit even after installation of a brick shield wall to reduce heat transfer. This project would include adding a desuperheating station and removing the shield wall. The result would be increased steam generation with no increased fuel usage and thus increased HRU efficiency. CPP management were planning to take the matter up with JGC who handled the original HRU installation. This is a good project which should be handled by Technical Services and General Engineering.

11. Excess Air In Boilers And Furnaces

In addition to the discussion in Item V in the General Section of this report, the Vijaipur plant needs maintenance work on the bad burners in the steam superheat furnace and on the auxiliary boiler burners. When this work is done and oxygen analyzers are installed and operating, some improvements can be obtained.

Adjustment of the primary reformer excess air is difficult and very time consuming because of the very large number of burners (500 +).

12. Non Return Valve In CO_2 Line To Urea Plant

Many plants don't have a non return valve in the CO_2 line from the ammonia plant to the urea plant. Consideration should be given to removing it to reduce pressure drop in this line and thus reduce CO_2 compression horsepower at the urea plant.

13. Excess Steam Usage By The Urea Plant CO_2 Compressor Turbine

This is a serious problem at Vijaipur and is due to deficiencies in both the compressor and turbine. Increased pressure must be put on the supplier (BHEL) to help with solutions to the problem. At present the Urea Plant operating personnel are handling this. Such matters should not be an operating department function. Operating personnel have a full time job running the plant as it is, and do not have time to effectively negotiate with vendors on deficiencies and needed improvements. Such negotiations should be handled by a General Engineering Department staffed with people capable of effectively carrying out such work. This item highlights my concern that performance at Vijaipur will deteriorate unless the organization is improved to assist the capable individuals to perform effectively.

14. Urea Plant Exchangers E-18 And E-19

These exchangers have two pass shells which are bypassing and causing significant energy losses. Two pass shells are rarely satisfactory, and the Vijaipur experience is typical. For this service plate exchangers are a much better choice and replacement should be considered.

15. Control Valve In Steam Line To Vacuum Ejectors

At present it is difficult to optimize steam flow to the ejectors. A control valve in the steam line would permit making these adjustments much more quickly and easily and would increase efficiency.

16. Urea Leaks At Carbamate Separator

During my visit there were several leaks which were contributing to urea deposits building up on the outside of piping, valves, and equipment. Care must be taken to prevent urea from corroding carbon steel materials (bolting materials are especially susceptible) and causing future failures.

17. Steam Leaks

For a relatively new plant, steam leaks at Vijaipur are excessive. Most of the Vijaipur leaks are at packing glands on small valves. Either the valves are basically unsatisfactory for the service they are in or the Vijaipur personnel are not taking immediate action when leaks develop. Operators should go to every section and every platform level of the plant several times each shift. They should have small wrenches and should tighten any leaking packing glands they find. This may help. If certain type valves continue to have excessive leaks they should be replaced with a better design.

18. Steam Traps

Some are leaking through and the recommendations in Section 11 of the General Section of this report should be followed.

19. Recover Condensate From Steam Trap Outlets And Boiler Drum Blowdown

If a good steam trap maintenance program is installed and is keeping traps in good condition. Collection of the condensate and flashing to the 3.5K system for steam recovery and using the condensate for boiler feed water could be attractive. The system should be discussed with Nalco to get their recommendations on use of an additive to prevent condensate corrosion.

20. GAIL Gas Metering Station

The GAIL gas metering station is an elaborate installation that looks very good with only one exception. There is no meter prover installation to provide for checking the turbine meters. The GAIL representative said that they planned to install a prover further upstream on the line, but this would include gas for other plants as well as NFL.

21. DEKA Air Preheater

From the data I saw and discussion held it appears that the DEKA Air Preheater is undersized and has never performed as it should, and never will unless changes are made. This is an original plant guarantee item which should be vigorously pursued by Technical Services and General Engineering. The organization needs to be set up so there are people in General Engineering and Technical Services to do this work without requiring significant time by operating personnel who must devote their attention to good day to day operation of the plant.

22. Primary Reformer

I was asked to look specifically at tube #13 which has a rapidly changing sheen. I have seen similar surface appearances on other reformer tubes and they have not caused problems. I think it is O. K.

I was also asked about the heat at the top platform level of the reformer. I made a number of trips to the top platform on different days with different wind conditions. I agree that the temperature is excessive. I tried to subjectively detect any areas of internal refractory damage that could be causing the excessive heat but could find none. The up wind side was always significantly cooler and it appears to me that the enclosure design could have permitted much greater air circulation which might solve the problem. More study would be required to determine if this is a reasonable retrofit option and it should be taken up with the furnace supplier.

Overall the primary reformer furnace looks good except as previously noted.

23. Possible Major Future Addition

A. Computer Control Of Critical Variables

Both Topsoe and Kellogg have programs that they claim are effective. Topsoe claims energy consumption improvement of 0.3 G Cal/MT and Kellogg claim about half that much.

I'm sure improvement is possible but I would not recommend immediately considering such a project. Hardware problems could offset the benefits and should be carefully considered.

B. Molecular Sieve Dryers For Synthesis Gas

This is one of the standard techniques for reducing energy consumption and has been used successfully in a number of plants. Care must be used in specifying the design and the regeneration cycle should allow for enough "free" time to be able to accomplish minor repairs without interfering with operation. Some valve types used in switching beds from on stream to regeneration and vice versa have caused problems and some have been trouble free. It is important to get good ones.

Topsoe claims energy reduction of between .05 and .15 G Cal per MT for this addition.

I would not recommend that NFL Vijaipur give serious thought to this addition until plant limitations have been fully identified and evaluated. There may be better projects.

C. Synthesis Gas Compressor Suction Chiller

If synthesis gas compression is a long term production limitation at Vijaipur a suction chiller could be considered as a possible debottlenecking step. It would not reduce overall energy consumption but would permit increased ammonia production.

E. P. Wells

Low-Energy Accelerated Start-Up of Ammonia Units

Approximately 50 ammonia units use these low-energy start-up procedures, which typically take 12 hours and 12 million std ft^3 (0.34 = 10^6 m^3) of natural gas. The procedure is also used for naphtha feed units with similar savings.

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The panel members who participated in the discussion of this paper are:
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In the early 1980's, due to the high cost of energy, the cost of starting an ammonia plant had become very high. During 1981 work was started on revised start-up procedures to reduce the cost. The revised start-up procedures were used in early 1982.

After retirement in February, 1983, I set up Hays Mayo Enterprises, Inc. (HME) and offered engineering and operational consultation to industry.

Since that time HME has 23 plants who operate 34 ammonia units as customers for Low Energy Accelerated Start-up Procedures. At this time 40 or more ammonia units are using Low Energy Accelerated Start-up Procedures.

HME customers report no failures or accidents due to the procedures. They also report that the increased planning required reduces delays and increases safety.

HME customers report an average natural gas use for a cold start-up using catalysts that have previously been in service and do not require reduction of 12 billion BTU (12 million SCF) including import steam, and time from lighting of first reformer burner to ammonia production and the start-up heater off of 12 hours. This compares with their prior experience using conventional start-up procedures of about 30 billion BTU (30 million SCF) of natural gas and 30 hours time.

The savings in energy are due to a reduction in the rate of use of energy and to a reduction in time.

Due to the lower rate of use of energy, delays increase the savings. The more the delay, the greater the savings.

The procedures are also applicable to and have been used on naphtha feed units. Here the savings are greater because of the increased time required to put naphtha reforming catalyst into service and because the energy cost of naphtha is higher.

At this time in the United States and Canada most units with capacities of 600 TPD and larger are using HME's Low Energy Accelerated Start-up Procedures and the "old conventional" procedure is obsolete.

LOW ENERGY ACCELERATED START-UP OF AMMONIA UNITS

Low Energy Accelerated Start-up of Ammonia Units using either natural gas or naphtha as feed result in very large energy and time savings.

Hays Mayo is President of Hays Mayo Enterprises, Inc., an engineering and operational consulting firm located in Lawrence, Kansas. Mr. Mayo pioneered "Low Energy Accelerated Start-up of Ammonia Units."

As an average, gas fed 1000 TPD units on restarts using catalyst that does not require reduction are using 12 billion BTU, including import steam, (12 million SCF of natural gas) and taking 12 hours for start-up.

Gas use and time are measured from lighting of the first reformer burner until ammonia is being produced and the start-up heater is off. By comparison similar units using conventional procedures are using 30 to 35 billion BTU (30 to 35 million SCF of natural gas) and taking 30 to 35 hours for start-up.

The savings for naphtha feed units are greater because reforming catalyst require longer activation times. The expected naphtha consumption for a restart of a 1000 TPD naphtha feed unit using new reforming catalyst and other catalyst that do not require reduction is 15 billion BTU (about 360 metric tons) and 22 hours time. By comparison, similar units using conventional procedures require approximately 30 billion BTU (about 720 metric tons of naphtha) and about 50 to 65 hours for start-up.

Simplified start-up schedules for natural gas and naphtha feed and for accelerated and conventional start-up are shown in Figure 1 to Figure 4.

A process study of start-up conditions has been made and start-up conditions have been optimized. As a result, feed, fuel and steam use have been reduced. Compressor and pump speed and power have been reduced. The result is a large savings in the rate of use of energy.

Time required to heat the reformer and the various catalyst beds has also been studied. The results are faster and less damaging procedures and less damage due to start-up.

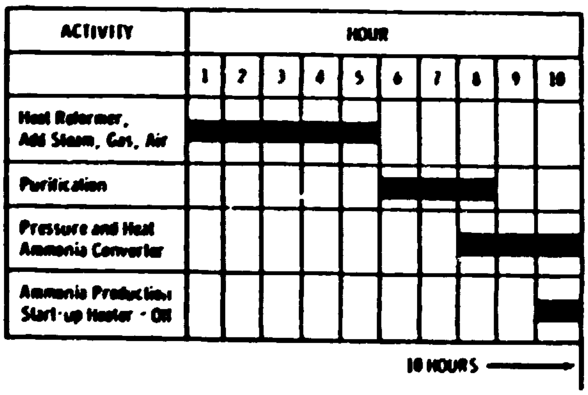

Figure 1. Low-energy accelerated start-up: natural gas feed.

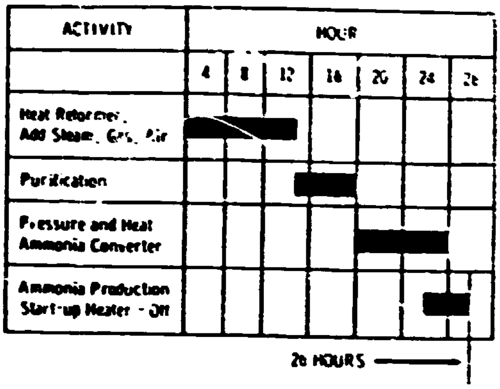

Figure 2. Conventional start-up: natural gas feed.

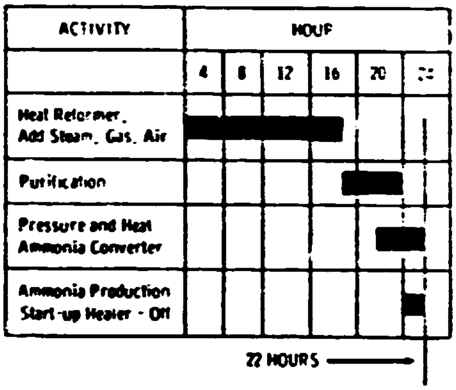

Figure 3. Naphtha feed new reforming catalyst: low-energy accelerated start-up.

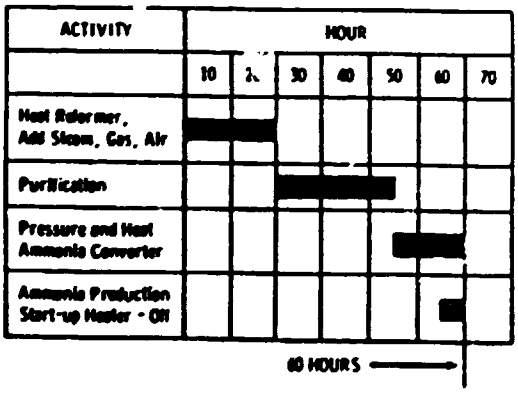

Figure 4. Naphtha feed new reforming catalyst: conventional start-up.

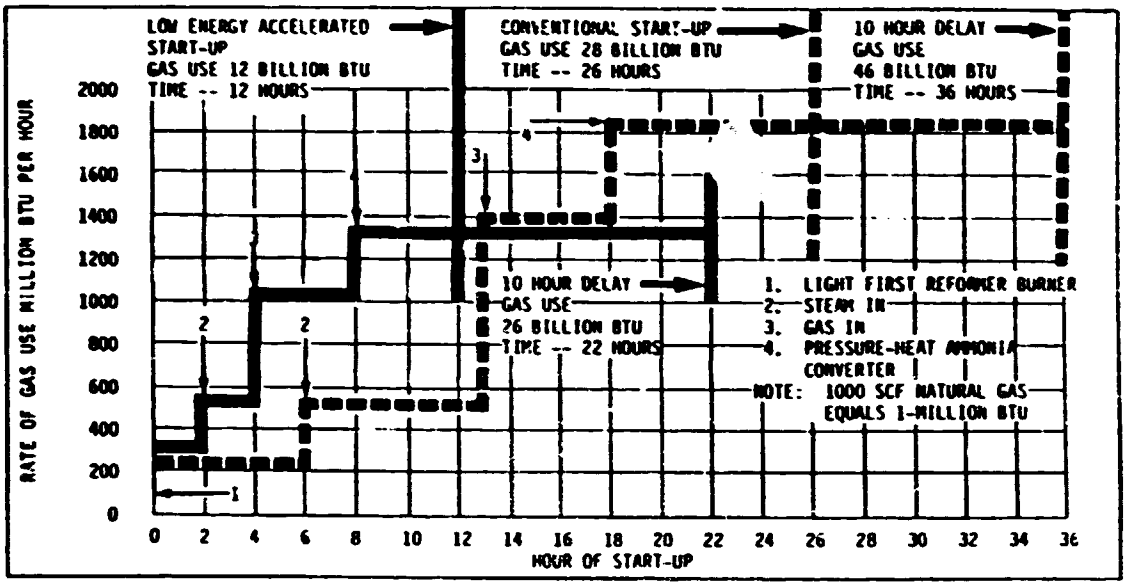

Figure 5. Energy use of natural gas feed unit: low-energy accelerated vs. conventional start-up.

An indirect and important benefit of the reduced times required is that planning must be more complete. Equipment must be ready when needed. This means more pre start-up work, specific assignment of work and operators must completely understand the start-up plan.

If time is required to reduce catalyst, or if trouble occurs on start-up, the energy savings due to the lower rate of energy use become larger. In other words, the more start-up delay you have, the larger the savings.

The start-up delay of 10 hours shown in Figure 5 increases gas consumption of a Low Energy Accelerated Start-up to 26 billion BTU and a conventional start-up to 46 billion BTU. The savings for the Low Energy Accelerated Start-up is 20 billion BTU. At a cost of $3 per billion BTU, this is $60,000 savings in gas cost.

In an actual start-up during 1985, one customer experienced severe delays resulting in a start-up time of 6 days. The customer's comparison of start-up cost of the Low Energy procedures used with the conventional procedures used in the past showed a savings of $225,000.

In their review of Ammonia Plant Shutdowns Survey IV, C.P. Williams and W.W. Hoehing indicate a world wide average of 9 shutdowns per year.* Of these, 5 are for major equipment failures and probably require a complete start-up. Assuming some delay occurs a world wide average savings in natural gas cost per start-up using Low Energy Accelerated Start-up procedures is about 20 billion BTU which at $3 per million BTU is $60,000 and the world wide average annual start-up savings $300,000.

There are additional savings in electricity, chemicals, operating labor and maintenance. There is also one or more days extra production.

For naphtha feed units, without delay, there is an energy saving of 15 billion BTU per start-up. At a cost of $6 per million BTU, this is $90,000 per start-up. On a world wide average of 5 start-ups per year this is $450,000 energy savings per plant per year. Again, there are additional savings in electricity, chemicals, operating and maintenance labor and several days of extra production.

REFORMER TUBE LIFE

Experimental and theoretical work shows that thermal cycling is damaging to tubes,

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*C.P. Williams and W.W. Hoehing, "Causes of Ammonia Plant Shutdowns--Survey IV," AIChE Ammonia Safety Symposium, November, 1982.

but that the rate of heating and cooling has little effect on tube life. The theoretical work is a result of a computer program that has been developed to predict the life of tubes under typical operating conditions.* This program predicts the creep damage due to pressure and thermal stresses and also accounts for the damaging effects of cycling from heat up and cool down.

Table 1 gives typical conditions for reformer tubes during normal operation and for start-up conditions. Stresses due to the thermal gradient through the wall of a tube during normal operation can be up to ten times the stress due to internal pressure (e.g. 1200 psi). On the other hand, these thermal stresses relax during periods of steady operation and over a relatively short period of time the thermal stresses become less than the pressure stress. However, cyclic operation results in a temporary and substantial reduction of the thermal gradient, and the tensile stress at the inside of the tube wall becomes compressive during these periods of time. Plastic deformation from compressive stresses is predicted to occur whenever cycling occurs. The net result from each cycle is a restoration of the thermal gradient stress once steady operating conditions are again achieved.

The cyclic thermal stresses are predicted to be the major source of creep damage in reformer tubes. The level of these cyclic stresses is proportional to the thermal gradient across the wall of the tube. Under steady process conditions in a top fired, box type reformer this temperature difference is about 115°F. During start-up an additional thermal gradient results from the heat up rate. This temperature difference can be estimated as $\Delta T = kL^2 / 2\kappa$ where k is the heat up rate in °F per hour, κ is the thermal diffusivity (about 0.2 ft^2 per hour for HK-40 alloy) and l is the wall thickness of the tube. For an extreme heat up rate of 1000°F per hour and a typical wall thickness of 0.6 inch, the predicted temperature difference is only about 6°F. Table 1 gives calculated temperature differences for a 300°F per hour heat up.

It is seen that the temperature difference from heat up will always be small relative to the through wall temperature difference from normal process conditions for the reformer tube. Thus enhanced stresses from accelerated start-up should not reduce the creep rupture life of tubes.

temperature differences for a 300°F per hour heat up.

It is seen that the temperature difference from heat up will always be small relative to the through wall temperature difference from normal process conditions for the

Cyclic creep rupture tests have been performed at Battelle Columbus Laboratories. The stress was held constant but the temperature was cycled from test temperature down to room temperature at one week intervals. These temperature excursions were found to reduce the specimen life by a factor of 60 to 70%. However, changing the heat up rate from 35 to 300°F per hour had little effect on the life of the specimen.

There are other data from the Battelle Columbus study that show that reformer tube materials become less ductile after exposure to service temperatures. Tensile elongations are reduced from about 25% to about 5%. However, this loss of ductility occurs within the first few thousand hours of service when the tube is still relatively new. Thus there is little reason to impose different start-up requirements on an old reformer relative to a newer reformer.

In summary, the results of tube life predictions show that cyclic operation gives a substantial reduction in tube life. The reduction in life is due mainly to a decrease in the through-wall temperature difference as the process conditions change during start-up, shut-down, and process upsets. On the other hand, the rate of heating and cooling has little effect on the through-wall temperature difference and the thermal stresses due to this temperature difference. Consequently accelerated start-up rates are believed to have little impact on tube life.

LIGHTING OF REFORMER BURNERS

Conventional start-up procedures call for a slow heat-up rate on the primary reformer as indicated by average flue gas or average reformer tube outlet temperatures. This means that a small number of burners are lighted. Obviously, the tubes nearest the burner are heated faster and to higher temperatures than tubes farthest from the burners. With more burners lit, the heating rate of the tubes nearest the burners stays

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*Jaske, C.E., Simonen, F.A., and Roach, D.B., "Predicting Reformer Furnace Tube Life," Hydrocarbon Processing, pp. 63-68, January, 1983.

Table 1. Operating conditions for reformer tubes

(a) Normal Operating Conditions - 378 Tube Reformer, Top Fired	
Temperature of outside tube wall	1655°F
Temperature of inside tube wall	1540°F
Through-wall temperature difference	115°F
Maximum heat flux	33000 BTU/ft^2
Pressure at hottest spot	475 PSIG
(b) Start-up Conditions - 378 Tube Reformer, Top Fired	
Heat up rate	300°F/Hour
Steam 40,000#/HR. - 600°F in - 1200°F out	
Maximum heat flux to heat steam	2800 BTU/ft^2
Through-wall temperature difference for 2800 BTU/ft^2	9°F
Through-wall temperature difference to heat tube metal	2°F
Total through-wall temperature difference to heat tube metal and steam	11°F
Pressure at hottest spot	150 PSIG

about the same, but the average heating rate is increased by increasing the temperature of the colder tubes and the reformer is heated more uniformly.

In a 1000 TPD unit with a 9 row, 378 tube top fired box type reformer with ten rows of burners and 200 burners, light 2 burners per row in the outside row and 4 burners per row in the inside row for a total of 40 lit burners. The lit burners should be equally spaced and there should be the same number on each side of the riser. The burners should be fired at minimum pressure and as more heat is needed more burners are lit.

Steam is normally added at 600°F and at this time approximately 100 burners will be lit. It should be noted that at the time steam is added that the same number of burners will be lit regardless of the heating rate. At 100°F per hour it takes longer to get there, but once there, the number and location of lit burners is the same. This is also true at the time process gas is added.

It is expected that 150 or more burners will be lit at the time gas is added.

This procedure assures that the average tube temperature on each side of the riser is the same and minimizes riser bending.

In a side fired reformer, establish a minimum burner pressure. Light every fifth burner in the bottom row. Lit burners should be opposite each other in order to provide more even heat to each tube. The burner pressure should be held as low as possible and more burners should be lit as more heat is needed. After all burners in the bottom row are lit, and more heat is needed, start lighting burners in the next row.

This procedure insures that the heat added to a tube is the same all around the tube which minimizes tube bowing.

INSULATION

Brick Lined Radiant Box Primary Reformer. Insulating firebrick used for the box lining have been cured as part of the manufacturing process and are dry. The brick are light weight and porous. The mortar is porous and is in thin sections and water in the mortar is largely absorbed by the brick.

All manufacturers report that an installation using their material that has previously been in service can be safely heated at a rate of 300°F (167°C) per hour.

Some manufacturers are now saying that because their insulating fire brick as manufactured are dry and porous, and mortar is thin and porous, that new installations using their material can also be heated up the first time at 300°F (167°C) per hour.

CONVECTION SECTION--CASTABLE INSULATION

All United States insulation manufacturers say that castable insulation that has previously been in service can safely be heated up at the rate of 300°F (167°F) per hour.

Many say that if castable manufactured with rapid heat up technology is employed it can be heated up initially at 300°F (167°C) per hour. Following is a quotation from A.P. Green. "A plus castable could be fired at 300°F per hour on its initial start-up with little risk of explosive spalling or serious thermal spalling."

BLANKET TYPE INSULATION

Blanket type insulation can be heated at any practical rate.

BURNER BLOCKS

Conventional burner blocks have been heated to high temperatures in manufacture and are dry. They can be heated at the rate of 300°F per hour.

Some manufacturers are offering a light weight block that is fibrous in texture and almost totally free of thermal shock cracking.

CATALYST

All catalyst manufacturers are in agreement that the rate of heating of catalyst does not hurt the catalyst. Procedures used in Low Energy Accelerated Start-up have been reviewed by UCI, ICI, Katalco, BASF, Topsoe and all have agreed that these procedures will not hurt their catalyst.

OPERATING PERSONNEL

It is conventional to have two shifts (8 to 10 operators and two supervisors) available for a Low Energy Accelerated Start-up.

	Gas Use Billion BTU	Time Hours
Low Energy Accelerated	12	12
Conventional	30	30

Figure 6. Energy and time used for start-up.

	Million BTU Per Hour	
	Low Energy Accelerated	Conventional
Heat Reformer	350	250
Steam In	550	550
Gas In	1050	1400
Heat NH_3 Converter	1350	1950

Figure 7. Rate of energy use at start-up.

Operators like the procedures because the start-up is usually over in 12 hours and they do not get as tired.

Many times the comment has been made that the procedure requires that moves are planned ahead of time which saves time and reduces errors.

Many plant managers have made the comment that the shorter start-up reduces fatigue and the operating crew is more alert and makes less errors.

HISTORY OF DEVELOPMENT

Because of the high cost of natural gas and the resulting high cost of ammonia unit start-up, I began working on reducing the start-up time and energy cost in 1980. The revised procedures were being used in 1982. (See Figures 6 and 7)

On retirement in 1983 I set up a consulting company and offered the technology to industry.

To date there are 29 plants operating 40 ammonia units, with more than 100 start-ups using Low Energy Accelerated Start-up Procedures. (Figure 8)

24 Customers

41 Ammonia Units

More Than 100 Start-ups

February 1983 to July 1985

Figure 8. Users of low-energy accelerated start-up procedures.

A partial list of customers, plants and start-up data are shown in Table 2 and Table 3.

At the Gulf Coast Ammonia Producers meeting held in Baton Rouge, April 9-10, 1985, my customers reported an average use per start-up of 12 million SCF of natural gas (about 12 billion BTU) and about 12 hours time. One plant using the procedures since early 1982 reported 10 start-ups with an average of 12 million SCF of natural gas and 12 hours time. This plant also reported no reformer tube or riser failures.

There have been no reported cases of failures due to the use of Low Energy Accelerated Start-up Procedures. The large number of units using the procedures (42) and the large number of start-ups (more than 100) give statistical support to theoretical studies which directiorally indicate less damage by using these procedures.

Hays Mayo

Table 2. Partial list of customers

Agrico Chemical Company, Blythville, Arkansas
Agrico Chemical Company, Catoosa, Oklahoma
Agrico Chemical Company, Donaldsonville, Louisiana
Arcadian Chemical, Geismar, Louisiana
Allied Fibers & Plastics, Hopewell, Virginia
American Cyanamid Co., Fortier Plant, Westwego, Louisiana
Canadian Fertilizers, Ltd., Medicine Hat, Alberta, Canada
Canadian Industries, Ltd., Sarnia, Ontario
Carbochimique SA, Tertre, Belgium
Columbia Nitrogen Corporation and Nipro, Inc., Augusta, Georgia
Cominco American, Borger, Texas
Cominco, Ltd., Carswell, Alberta, Canada
Esso Chemical, B.V., Rosenburg, The Netherlands
Esso Chemical, Edmonton, Alberta, Canada
Namhae Chemical Corp., Yeosu, Korea
Fertilizers of Trinidad & Tobago, Ltd., Trinidad, West Indies
Imperial Chemical Industries PLC, Billingham, England
Imperial Chemical Industries, Severnside, England
Imperial Chemical Industries, Immingham, England
Sherrit Gordon Mines, Ltd., Fort Saskatchewan, Alberta, Canada
Sohio Chemical Company, Lima, Ohio
Triad Chemical, Donaldsonville, Louisiana
Union Oil, Brea, California

To date more than 100 Low Energy Accelerated Start-ups have been made.

Table 3. Ammonia unit low energy accelerated start-ups to date

			LOW ENERGY ACCELERATED START-UPS				
Plant			Year	Number	Start-up	Natural Gas Use	
	Rating		Start	Start-ups	Time Hours	Best One Time	
Number	STPD	Builder	Using	To Date	Best[1]	MM SCF	1000 NM[3]
1	1000	MWK	1983	3	12	8	214
2	1000	MWK	1983	10	12	13	348
3	1150	MWK	1983	1	--	--	
4	1000	MWK	1983	4	8	5	134
5	1000	MWK	1983	3	17	9.2	241
6	600	Girdler	1983	1	--	--	
7	1150	MWK	1983	2	11	9.8	263
8	1150	MWK	1983	2	11	12	322
9	1500	Braun	1983	1	--	--	
10	1500	Bechtel	1984	3	26	19	509
11	1150	MWK	1984	2	12	12	322
12	1150	MWK	1983	2	12	12	322
13	1000	MWK	1984	3	14½	14	375
14	1150	MWK	1984	1	12	9	241
15	1150	MWK	1984	--	--	--	
16	1000	Bechtel	--	--	--	--	
17	1000	MWK	1984	3	11	12	322
18	600	Pritchard	1984	1	18	7½	201
19	1650	Bechtel	1983	4	16	21	563
20	600	Bechtel	1983	3	30	16	429
21	1000	MWK	1984	1	--	--	
22	1000	MWK	1984	1	39	36	979
23	1500	Braun	1985	0	--	--	
24	1000	MWK	1984	1	--	--	
25	1150	MWK	1984	1	20	14	375
26	1000	ICI	1985	0			
27	1000	MWK	1985	0			
28	1000	MWK	1985	0			
29	1000	MWK	1985	0			
30	600	Bechtel	1985	0			
31	1500	Bechtel	1985	0			
32	1000	MWK	1984	1	41	Naphtha Feed	
33	1000	MWK	1984	0		Naphtha Feed	
34	750	Braun	--	0			

QUESTIONS FOR F. A. SIMONEN OF BATTELLE PACIFIC NORTHWEST LABORATORIES

1. Please review Battelle's experience in life determination of reformer tubes.

2. Please describe in your own way the things that happen to a reformer tube and that eventually lead to its failure.

3. What are the two major sources of stress in thick wall reformer tubes?

4. In a thick wall reformer tube, such as above, what is the generalized ratio of thermal to pressure stress?

5. Does the rate of heating and cooling affect reformer tube life?

6. Would a heat up rate of 300°F per hour cause more damage than a heat up rate of 100°F per hour?

7. In a reformer using blanket type insula-

tion, a fuel gas trip may result in very fast cooling of tubes. Would, in your opinion, an extreme cooling rate of say 1000°F per hour cause damage to the tube metal because of the cooling rate only?

8. In shutting down the reformer would a fast cool down rate from operating conditions of 1650°F, OD, 1550°F, ID, to 1200°F in a few minutes, say 15 minutes, which results in a cooling rate of about 1200°F per hour do more or less damage to the tube than cooling at the rate of 100°F per hour.

9. The statement has been made that in heating up of a reformer tube that time must be allowed for the molecules to rearrange themselves and, if not, damage to the tube will result. Please comment.

10. The statement has been made that any heating rate higher than 75°F per hour will increase the damage to a reformer tube. Please comment.

11. Should the heat up rate of a tube that has been in service for 100,000 hours be different than a new tube in order to decrease possibility of tube failure during heat up?

REMARKS BY F.A. SIMONEN

My background is in area stress analysis and structural integrity, and I would like to address some of the factors that affect reformer tube life. I will discuss the impact of rapid heating rates on tube life. Much of the concern with rapid heat-ups is with the effect of excessive heat-up rates and with the associated excessive stresses in the tubes. The reason for the excessive stresses is that the rapid heat-up brings on additional through-wall thermal gradients that will damage the tube and shorten tube life. There are also questions of metallurgical damage, apart from the stresses. Are there microstructural or metallurgical effects that may shorten tube lives if they are heated or cooled too rapidly? If adjacent tubes expand at different rates can one get into situations of unacceptable stresses? Our understanding of this question is that it is primarily a matter of properly controlling burners and relative heat-up rates of adjacent tubes rather than being an issue of the actual time to bring the plant on-line. Finally, should one treat older tubes differently than newer ones?

We have done some work at Battelle with a computer program called TUBE that is used to do stress analyses of reformer tubes and predict creep damage. One of the important effects that the calculations show are the significant thermal stresses in tubes due to through-wall thermal gradients. The damage from these stresses is primarily due to the cycling of the stresses as the unit goes on-line or off-line, is heated-up or cooled down, and goes through upset cycles. We have done a number of computer simulations of tube stresses and damage. These simulations have shown that heating and cooling rates do not seem to have much effect on tube life. Nevertheless, the fact that the tube goes through an upset or a shutdown seems to have a big effect on reducing tube life.

We have looked at the design of replacement tubes for older reformers and have seen that tube wall thickness can, in fact, be optimized. We can identify a certain optimum wall thickness such that adding additional metal to the wall simply buys little or no additional tube life. Thermal stresses associated with a thicker wall result in a reduction of life that exceeds the expected increase in life due to the thicker wall and reduced pressure stresses. There is perhaps a 3:1 increase in tube life just from changing to alloys other than the HK-40, ie. the HP type alloys and similar proprietary type materials. Finally, I would like to emphasize that overheating is a very important factor in tube life, regardless of thermal stresses and heat-up rates.

The major issue is the thermal gradient induced by a rapid heat-up. This gradient can be predicted from a rather simple equation that predicts the temperature difference from the inside to the outside wall of the tube. The equation shows that the stress is proportional to the heat-up rate in degrees Fahrenheit per hour and inversely proportional to the thermal diffusivity of the material which is essentially the same for all stainless heat resistant cast alloys. Finally, the wall thickness enters in through a term where it is proportional to the square of the wall thickness. If one applies typical numbers for reformer tubes at an extreme heat-up rate, 1,000°F per hour, the stress associated with the heat input to the metal tube shows a temperature difference of only 6°F per hour. Compare this with the temperature difference during normal operation of the tube which is in the range of 100°F per hour. Therefore, the most important thermal gradient is the normal operating condition rather than the gradients during the transient heat-up of the metal in the tube.

Compare typical conditions during steady state operation versus start-up conditions. Through-wall temperature differences can be in the range of 115°F during the steady operation of a tube. The pressures will be in the neighborhood of 500 psig. During start-up we mentioned that a 6°F per hour temperature difference was typical of a 1,000° F per hour heat-up. This is probably three times faster than the rapid start-up rates that we are addressing here. The estimated thermal gradient is about 2°F from the thermal shock associated with heating the metal of a tube. There are also other thermal gradients across the tube wall due to the process conditions. There is about a 9F temperature difference through the wall.

There are also questions about metallurgical effects or tube damage due to heat-up rates. The following are results from laboratory creep tests, performed at 1600°F, at Battelle Memorial's Institute in Columbus, Ohio. The load on the creep specimen was held constant in the base line condition. The time to fail the specimen was about 2,000 hours when the test was run under steady conditions. The other test variable simulated a start-up and shutdown of a unit. The test was interrupted once each week; it ran steady for six days, and then cooled down and held at room temperature for one day. It was found that this cycling between room temperature and operating conditions reduced the life of the metal by a factor of three. I consider this to be a significant metallurgical effect. However, we found that the rate of heating and cooling during the shutdown of the experiment and the subsequent heat-up had essentially no effect at all on the life of the specimen. The rate was varied in the experiment from about 100°F per hour up to 300°F per hour, and essentially the same life was achieved. This is further evidence that a more rapid heat-up rate does not have a detrimental effect on reformer tube life.

Finally, there is a question of tubes in older plants. Older material may have lower elongation and may be more sensitive to thermal expansion type stresses during heat-up and cool down. As expected, the tests on the material show a sharp reduction in elongation as the material is exposed to operating temperatures. The important thing to note is that this effect seems to saturate very early in the life of a tube, and after 1,000 hours the resultant ductility has reached its lower limit. In practical terms 1,000 hours is essentially a new tube. For the particular concern with loss in ductility, the difference between a new unit and an old unit is really not an important matter.

In conclusion, the rapid heat-up associated with a low energy start-up of an ammonia unit should not damage tubes or cause premature tube failures.

QUESTIONS
ANSWERS BY JOE P. CAGNOLATTI

Please cover the following in your presentation.

1. When did your ammonia unit start using Low Energy Accelerated Start-up Procedures?

   Faustina, March 28, 1984
   Verdigris, January 13, 1984.

2. Are you still using these procedures?

   Yes.

3. How many start-ups have you had to date using these procedures?

   Faustina. Eight total start-ups. Five partial "backend" type start-ups.

   Verdigris. Nine total start-ups, three of which were partially hot start-ups.

4. Using these procedures, what is your shortest, longest and average time from lighting of the first reformer burner until ammonia production?

   Faustina. Shortest was 14 hours. Longest was 23 hours. Average was 16 hours.

   Verdigris. Shortest 12-1/2 hours, longest approximately 32 hours (with delays). Average approximately 16 hours.

5. What is your lowest, highest and average natural gas use per start-up?

   Faustina. About 12,000, 20,000 and 14,000 mmbtu, respectively.

   Verdigris. 11,200, 35,000 (hold up due to 103-JHC thrust bearing problems) and 16,000 mmbtu, respectively.

6. Before using the procedures, what was your average natural gas use per

start-up?

About 35,000 mmbtu to 45,000 mmbtu.

7. Have you had any reformer tube or riser failures since using the procedures and if so, were they due to the procedures?

Faustina. Yes, there were riser failures after the procedures and no, they were not due to the procedures. Analyses by our metallurgist on risers that had failed previous to the procedures when compared to those that had failed after the procedures indicated no difference in the failure or the mechanism.

Verdigris. Some catalyst tubes were replaced as a result of NDT inspecting. Some riser liners have collapsed, but this was also occurring before we adopted rapid start. One riser transition weld (inconel to C.S.) has failed but we cannot attribute it to rapid start.

8. Give a short description of the sequence and times involved in start-up.

0 hour -- 70F on tunnels
1st hour -- 36 total arch burners lit.
2 total auxiliaries.
400 F on tunnels.
Superheater vent open.
2nd hour -- 81 total arch burners lit.
3 total auxiliaries.
1500# LD valves unblocked.
Superheater vent closed.
3rd hour -- 108 Total arch burners lit.
660 F on tunnels.
60,000 LBH steam to Primary (Min. FRCa-2).
Venting at inlet of HTS.
Air machine in slow roll.
MEA system on circulation.
4th hour -- 135 total arch burners lit.
950 F on tube bottoms.
4 total auxiliaries.
Steam into air coil.
Switching vent from inlet to exit HTS.
250,000 SCFH warm-up gas to LTS Guards.
Refrigeration machine on slow roll.
5th hour -- All 180 arch burners lit.
1100 F on tube bottoms.
Inlet HTS vent totally closed.
Air machine at minimum speed.
6th hour -- 1400 F on tube bottoms.
250,000 SCFH of process gas to primary.
Air loaded up and air to secondary (about 530,000 SCFH).
7th hour -- Pressuring to inlet absorber.
Opening by-pass around LTS guard and main.
By the end of the hour venting at inlet of absorber and closing vent exit HTS.
8th hour -- Refrigeration machine to minimum speed.
Switching LTS guard warm-up to LTS main.
Pressuring up on and then bringing flow through LTS guards.
9th hour -- Syn gas machine on slow roll.
Coming through MEA system and stabilizing.
10 hour -- Pressuring into methanator.
Venting at suction of syn gas machine.
Closing vent inlet absorber.
Syn gas machine to minimum speed.
11th hour -- Pressuring into the syn gas loop.
Syn gas machine at 10,000 RPM, 250 psig suction pressure, and heat-up begins when discharge pressure at 1100 psig.
12th hour -- MOV-5 syn gas loop recycle valve open, opening on MOV-4 recycle to syn gas machine, and firing on start-ups heater to maintain between 900 and 1000F inlet converter.
13th hour -- Raising front end rates to 50%.
Still heating converter.
14th hour -- Front end rates to 90%.
Converter on during middle to end of hour, usually 2.5 hours.
Start-up heater quenched.

9. Describe your procedure for heating up the reformer. Please cover the heating rate, fluid in the tube, and at what temperatures steam and gas are introduced.

300°F per hour. Steam in at 600°F at 25% rate. Gas in at 1400°F at 25% rate.

10. What process rate do you use before starting of the synthesis gas and refrigeration compressor.

About 25%.

11. What process rate do you use after starting of the synthesis gas and refrigeration compressors?

Faustina. 25% till hour 13.

Verdigris. 25% till converter is active.

12. What determines the process rate?

The amount of capacity the start-up heater can handle and the anticipation of converter light off. Also at reduced pressure, 103-J horsepower is minimized. 1500 lb. steam requirement must be closely monitored to save energy. Minimum flow trips also sets minimum rate.

14. What steam to carbon ratio do you use on start-up?

Initially 5:1, then as steam pressure builds and the minimum on FRC a-2 increases, it probably goes to about 6.5:1.

15. How do you heat the high temperature shift converter, the LTS converter?

When flow is established through vent before the inlet HTS with hot steam, we open to HTS and heat through to its exit vent with hot steam.

We heat the LTS guards with natural gas from the process stream when the temperature exceeds 350°F from the zinc bed and then return the gas back to fuel and burn it. It takes less time to heat the lower volume of the LTS guards with the low process (to fuel) rate. This heat up rate increases when actual process gas (and therefore fuel rate) is brought into the primary. When all temperatures exceed 350°F we go through the bed.

After the LTS guards are warmed up, we heat up the LTS main and it is usually up to temperature right before the rates are raised in heating up the syn converter.

Verdigris. HTS done the same way. LTS is heated with natural gas exit the 108-D (zinc bed) via a watercooled exchanger for temperature control. The gas is recycled through the feed gas compressor. LTS is heated to 350°F.

16. How long does it take to heat the ammonia converter?

About 2.5 hours. Also see temp recorder charts. Two for "hot start" and two for cold start.

17. What personnel do you bring in for start-up?

1 or 2 members of management - i.e., production manager, area manager, ammonia superintendent, or area engineer - to act as an "offensive coordinator." This person(s) continually reviews the start-up plan and modifies accordingly if there are any delays. Also this person keeps a running log of sequence of data and events on start-up for a critique afterward. One or two shift supervisors and one day supervisor. They receive instructions for the next hour or two from the coordinator. One and one-half to two full operating shifts - 7 to 10 operators.

18. How do operating people like the Low Energy Accelerated Start-up?

An overwhelming majority like the procedure. They feel it is a little harder, but it is worth it to get the plant up and back to a normal routine more quickly.

19. Do you think there is more, less or no difference in damage to the unit on start-up with these procedures as compared with conventional procedures?

I believe there is less damage.

20. Have these procedures saved you money and have they made it possible to make more ammonia?

Yes and yes.

21. Does use of the procedure result in more planning for start-up?

Yes, from both an operating and maintenance perspective. Operations does not start-up the unit until maintenance can assure them all work is completed before the start-up path, which they have been advised of the quicker time frame.

The start-up schedule and sequence of events has been put on an event diagram for the latest Verdigris start-up. Done with a MacIntosh Apple computer and a CPM software program, Mac Project.

Additional Comment:

One of the most significant results of the rapid startup becomes evident when NH_3

efficiencies are compared historically. Figure A-1 shows how the yields have levelled off after January, 1984. The 1983 peaks are indicative of plant shutdowns and startups with equipment problems and TA. In fact, low onstream factors now have a much diminished adverse impact on plant efficiencies.

Namhae Chemical Co., Korea, saves 30 hours per startup in Naptha feed NH_3 units. And energy savings per startup is 1,000 kiloliters.

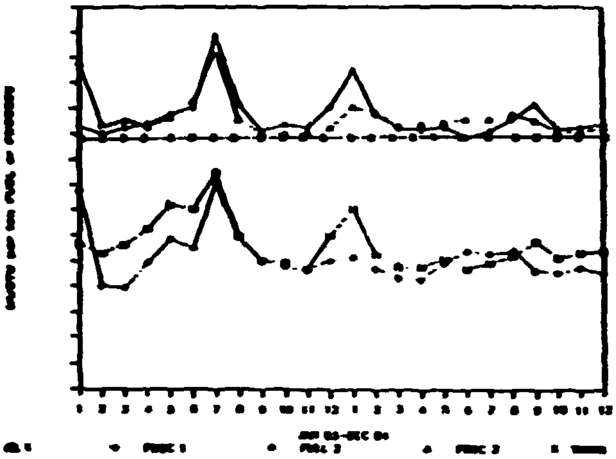

Figure A-1. Ammonia plant efficiency: two-year plot.

REMARKS BY JOE P. CAGNOLATTI

Agrico was first approached by Mr. Mayo in mid-1983, and it was not until December that we decided all our questions were adequately answered and felt like it was something we wanted to pursue. Those questions were ones that might be expected. If start-up actually could be done this fast without any damage to the equipment, then why was the original procedure not written that way?

We undertook an engineering study and found several things. The original procedures were established based on heat-up rates dictated by the catalyst and by what we felt was conservatism based on the price of gas ten to fifteen years ago when the plants were constructed. We explored this with the catalyst manufacturers and found that faster heat-up rates could be tolerated. This may be, in part, due to some improvements in the catalysts themselves.

Refractory was another concern. Once refractory is cured after the initial dry-out, it can then withstand a 300°F per hour heat-up rate. And as Mr. Simonen pointed out, reformer tube stresses and creep rupture considerations are not much different when you consider the heat-up rate, because the main stress comes from the higher thermal gradient subjected to the tube during reforming in normal operation.

Management from all of Agrico's plants reviewed the rapid start-up procedure. Then, after we decided to do it, we had training meetings with Mr. Mayo for our supervisors and eventually our operators.

We started using the rapid start-up procedure at Verdigris in January, 1984. We took a very conservative approach at first and used a modified rapid start-up procedure using higher gas rates and slower thermal heat-up rates than were specified in the procedure. Now we have fully adopted the rapid start-up procedure. The Donaldsonville plant first used the rapid start-up in March, 1984, and the three Kellogg plants are still using the rapid start-up procedures. There are some equipment modifications which must be installed at our Arkansas unit, so they are not using the procedures yet. The plant in Donaldsonville has had 8 total start-ups, five of those were back-end type start-ups where the front end of the plant was still hot to some degree. The plant in Oklahoma has had 9 start-ups and 3 of these were "hot" start-ups. Our number one unit in Oklahoma has experienced most of these start-up cycles. 1984 was not a good year for that unit because of some mechanical problems. This plant had previously had eight or nine cold cycles in its 9 year history. It had enjoyed a very good on-stream factor and as a result of these start-ups we have seen absolutely no equipment damage or degradation.

Some numbers on start-up natural gas usages for the Donaldsonville and Olkahoma plants: our lowest usage ranged from 11.2 to 12.0 MMBTU, our highest is between 20 and 35 MMBTU, and our average is between 14 and 16 MMBTU. Before that our average was between 35 and 45 MMBTU. We have had some riser failures at the Louisiana plant, but the same failure mode was experienced before adopting these rapid start-up procedures and metallurgical examinations have concluded that the failure mechanisms were the same and not related to the rapid start-up procedures.

Some catalyst tubes have been replaced in our Oklahoma plant since rapid start-up procedures began. However, this is a normal turnaround procedure as a result of nondestructive testing methods where some tubes with flaws were located and changed out. Allowing for the fact that the reformer is almost 11 years old, this type of failure is expected. We also had a failure between the carbon steel and inconel weld at the top of the riser in one of the Oklahoma units, but this failure mode also occurred previously to adoption of the rapid start-up procedures and was attributed to lack of weld penetration during original construction.

We use a 300°F per hour heat-up on the reformer and steam is put in at 600°F at a 25% rate. Gas is put in at 1,400°F at a 25% rate. We have the luxury of offsite steam generators, so the amount of steam that we use may tend to be higher than the 25% from time to time to maintain sufficient flow through our flow meters. Flow indications at these low rates, even at reduced pressure, are somewhat unreliable at the low end of the square root scale, and we want to stay safely away from any possibility of running into a zone where we might make carbon.

In determining the process rate in order to save the energy, the process gas and steam rates have to be left at as low a rate as possible. That needs to be determined by the people in control of the plant.

Guard against the natural tendency to return to the area of operation where the operators feel most comfortable, such as starting-up at a higher pressure and using more steam on the synthesis gas compressor than required by the procedures. A large amount of the energy saved is from reduced horsepower on the syngas compressor.

The ammonia converter can be heated-up in about 2.5 hours. We have paid particular attention to thermal gradients in heavy walled vessels. We used the manual temperature indicators on the converter shell on the first two start-ups and satisfied ourselves that there was no problem of exceeding the manufacturer's thermal gradient recommendations.

As for employees at the plants liking the rapid start-up procedures, it is key to get them onboard early in the game; and everyone likes the procedures, because they save money for the company without added risk. In today's market that is very important.

There is essentially no more damage and there could actually be less damage to the equipment using these procedures. One of the benefits of planning for the start-up is that it brings to light the amount of planning that really needs to be done to avoid unnecessary delays. Often those tend to be mechanical in nature, and now a fire is not lit until everything is ready.

Our most recent start-up was put on a bar chart event diagram with the use of a personal computer. This allows flexibility and gives one a chance to customize start-ups. This is helpful especially for planned start-ups, like after a turnaround.

One of the most significant results is on the bottom line. We looked at our ammonia plant operation over a two year period, 1983-1984, and plotted efficiencies on a monthly average basis. In 1983, everytime we shutdown and started up a plant, a tall peak was plotted on our graph. In 1984, even though we cycled the number one unit many times, the plot lines were relatively flat.

REMARKS BY JOHN EMRICH

Hays Mayo approached CIL with a proposal for an accelerated low energy start-up for our TPD Kellogg ammonia plant. At that time an average start-up took 20 to 24 hours and required 28 to 30 MM scf of natural gas. The proposal that Hays presented would reduce the time to 12 hours and the gas consumption to 10 MM scf. With the ever increasing gas prices, there was an obvious incentive to further investigate this new start-up procedure. After many review meetings, discussions, and detailed examinations, we satisfied ourselves that there would be no metallurgical, mechanical, or safety problems as a result of using the new accelerated low energy procedure.

The first opportunity to use this plan occurred in January, 1983. Although not totally prepared with all the check lists and operator training, the new start-up procedure was attempted. The results were encouraging: start-up time was reduced to approximately 14 hours with a gas consumption of 14 MM scf. Spurred on by this success, a detailed check list was prepared and all the operators were trained on the technique. In the next startup in the second quarter of 1983, we used all that we had learned in the first start-up and were able to start the plant in 12 hours using approximately 10 MM scf of gas. This startup went exceptionally well with only one delay of 2 hours due to a start-up heater problem.

We have used the accelerated low energy start-up 14 times to date. Start-up times have averaged 12 to 13 hours and the average gas consumption is 12 to 14 MM scf. We start by putting a nitrogen flow through the reformer tubes and lighting 4 burners per row at a gas pressure of 7 psig. Approximately one hour later when the middle tunnel temperatures are at 400°F, we introduce steam into the tubes at a rate of 50,000 lb/hr. Additional burners are started to maintain an average tube temperature rise of 300°F per hour. When the reformer outlet temperature reaches 1,400°F, the natural gas feed is introduced at a rate of 20 to 25% and the steam to gas ratio is maintained at 4.5:1 to 5.0:1. The air machine is brought on line and run at approximately 6,400 rpm with valves set at minimum flow conditions. If required, we preheat the high temperature shift catalyst using steam and the low temperature shift catalyst using hot gas. When proceeding forward through our CO_2 removal system, we have to increase the feed gas rate to approximately 35 to 40%. This is done to satisfy the need for CO_2 in the downstream urea plants. Going through the Sulfinol system at a 25% rate did not yield sufficient CO_2 at constant pressure to enable the urea plants to start-up.

We continue with this 35% rate until we are making ammonia. We also have a limitation on our start-up heater, and it takes us 3 hours to bring the ammonia converter on line.

The key to the success of the program is planning and preparation. Since many of the activities and equipment are required to be ready almost twice as fast as previously, we have doubled our operating crew when starting the plant. This includes bringing in additional supervisory personnel. We feel that this eases the pressure of the fast paced activities somewhat, and hence, reduces the risk of making a mistake or falling behind schedule.

Crucial import.

In addition, a pre-start-up check list has to be completed before the start-up commences. We have also developed a bar chart for the start-up which identifies at what time after the start each specific piece of equipment is required. This allows for better coordination of work between maintenance and production and also identifies the priority items for the operators.

Some mechanical problems were experienced after the third and fourth start-ups. During these start-ups we discovered two leaking pigtails and a weld crack in the top weld of a catalyst tube. The first question asked was, are these failures due to the use of accelerated start-up? We did detailed metallurgical examinations of the failures and found that the failures were due to inclusions and welding techniques employed during fabrication which had no connection to the accelerated start-up procedure.

Going from a 24 hour start to a 12 hour start, reducing gas consumption by 50%, and doing it all in a safe manner, is a significant accomplishment.

DISCUSSION

Richard Pocock, *ICI, Billingham, England*: We would like to thank you for the lead you have taken showing us how to do faster plant start-ups. Your technique on fast start-ups and gas conservation is going to help us greatly. In fact, would you be prepared to award a trophy at the next meeting in Boston to the operator that you think does the fastest and best start-up this year?

Mayo: Thank you for the kind words. The trophy is a good idea, and Hays Mayo Enterprises will underwrite it. However, some rules will need to be established.

Max Appl, *BASF, Ludwigshafen, West Germany*: I would like to get the opinion of some of the major ammonia contractors on the fast and energy-saving start-up.

S. Madhavan, *M. W. Kellogg, Houston, TX*: Kellogg recognized that the start-up could be done faster than the conventional procedure and presented a paper in the Kellogg ammonia club meeting last year. The paper emphasized the risks taken in doing a faster start-up, and it highlighted problem areas and precautions that plant people should be taking.

Mayo: I have Kellogg's written approval of a heat up rate for the primary reformer of 300 °F (167 °C) per hour for subsequent start-ups after initial operation. The Kellogg letter states, "This (approval) ~~is~~ based upon our checking with both refractory suppliers and catalyst tube suppliers, who both confirm that heat up rates of 300 °F are acceptable for their products."

Mr. George Kratsioss of Foster-Wheeler has given verbal agreement to the 300 °F (167 °C) heat up rate for subsequent start-ups after initial operation.

Exxon Chemical Central Engineering Division states that heat up rates for existing linings that are dry should be limited to 500 °F (260 °C) per hour.

Ken Wright, *Cominco American, Borger, TX*: Our plant was one of the first in this country to try the Mayo madness. The plant was started up after it had been down for four months, and everything was either glued or stuck together. The start-up time was about 24 hours; 14 hours was spent trying to set an air compressor overspeed trip assembly. About $80,000 was saved in that start-up in the middle of a raging blizzard, and the insight we received from this process is appreciated. Hays Mayo is careful to protect the critical parts of any plant process, such as the steam drum heating procedures. This is a situation where there is a definite process that has to be done on a timely and well-practiced basis, and these precautions are taken care of very carefully.

S. Quraidis, *Saudi Arabian Fertilizer Co., Dammon, Saudi Arabia*: Has there been any feedback from the rotating equipment manufacturers?

Cagnoletti: The major consideration here is to have overspeed trip checks done and have the machines warmed up and on slow roll when they are needed. The rate of acceleration and rotating speed of the machinery is really no factor. However, special care needs to be taken with the topping turbine in the Kellogg Unit because there have been instances where the out board bearing was wiped because of alignment problems and heat conduction problems related to the rate of acceleration.

Mayo: The equipment manufacturer's procedures are used for starting and stopping the machines. The low energy accelerated procedures call for the machines to be ready to come to speed when they are needed. This means overspeed trips, safety trips and slow roll needs to be done before the machines are needed. In the case of the synthesis gas compressor, slow roll should be done with the case pressured with nitrogen. The procedures have been discussed with two manufacturers, who both commented that they comply with their recommendations.

Cagnoletti: Sometimes overspeed trips cannot be checked, for instance, if an off-site steam is not available.

John Livingstone, *Consultant, Cleveland, England*: Congratulations to Hays for his prodding people about how they start-up these plants, the instructions and restrictions that have been talked about were written 15 or 16 years ago. He was right to turn them over and see if they could be improved.

In the new procedures are the points of sensitivity highlighted for the operator? Take reverse circulation in boilers for instance. If the start-up rate of the plant is speeded up, then the rate at which the boilers start to circulate is speeded up. Therefore, if a boiler is in reverse, the operator must be very careful to stop the plant to adjust for that. Do instructions go to the sensitivities of the particular operator and give him further warning of the sort of problems that can arise?

The catalyst is never reduced in the top of the reformer tube, because it never gets hot enough. In fact, more heterogeneous and homogeneous carbon formation is there, so there is carbon on the top of the tube at any time, and if the plant goes to steaming at higher temperatures quickly, that carbon is removed faster. Are the catalyst manufacturers happy that that is not going to affect the overall catalyst life?

Emrich: Reverse circulation has not been experienced in our 101-C waste heat boilers, but as part of the start-up procedure, critical areas are identified that cannot be exceeded, be it flow or the low limit settings. There is a point identified for the operator that should not be exceeded.

Mayo: The procedures to determine reverse circulation in Bayonet type boilers are determined by the customer and are not changed in the low energy accelerated start-up procedure. Rules for pressuring thick wall vessels such as the ammonia converter and rules for testing of relief valves are compared with the requirements of the ASME code and the discrepancies pointed out to the customer. Decisions on rules are made by the customer. More planning is required for both low energy and accelerated start-up. This increased planning reduces the risk and results in safer, lower cost, faster start-ups.

Livingstone: Some long-term effects could be a problem; these must be looked at and need to be watched, and boiler circulation is one of them. I commend this procedure change from the panel and from Mr. Mayo. Operators occasionally need to rethink procedures, but caution is needed for both short-term and long-term effects.

Mayo: Many HME customers have been using accelerated start-up procedures for more than one charge of reforming catalyst. Many of my customers say they see no difference in catalyst performance. All major manufacturers have given written approval or HME accelerated start-up procedures for their catalyst.

Max Appl, *BASF, Ludwigshafen, West Germany*: Are more people needed for this accelerated start-up? Are there figures available?

Cagnolatti: Essentially twice the normal number of people are on hand for the accelerated start-up. One of the most important areas is the reformer itself. At initial firing and low firing rate, the tube temperatures cannot be monitored by the flue temperatures. The radiant section outlet temperatures do not give a good indication of what is happening inside the box. Two people do nothing but look through the peepholes and communicate with other operators who are controlling the firing.

Madhavan: Has there been any problem in accomplishing the converter start-up in two hours with the start-up heater capacity, considering there is a temperature limitation on the transfer line?

Mayo: The limits of the heater, which are very well documented in the operating manual, are at no time exceeded. The pressure of the ammonia converter is held down in the interest of saving power and steam. At a pressure of 1,200 psig (8.4 MPa), your rating would permit a temperature of at least 1,000 °F (538 °C). In no case would that 1,000 °F be exceeded. The start-up heater is fired at the maximum burner pressure which can be attained without afterburning in the stack of the heater. Under those conditions, no published limit has been exceeded on the heater.

Madhavan: What is the start-up duration for the auxiliary boiler, and is that duration included in the total start-up duration of ten or twelve hours that shows on the schedule?

Mayo: The normal procedure for start-up would require that the plant is getting steam at a high enough pressure to let down from the 1,500 psig (10.3 MPa) system to the normal 550 psig (3.8 MPa) system in two hours. Even problems such as water hammer seem to be less at the accelerated start-up condition than what had been previously encountered with the conventional procedure.