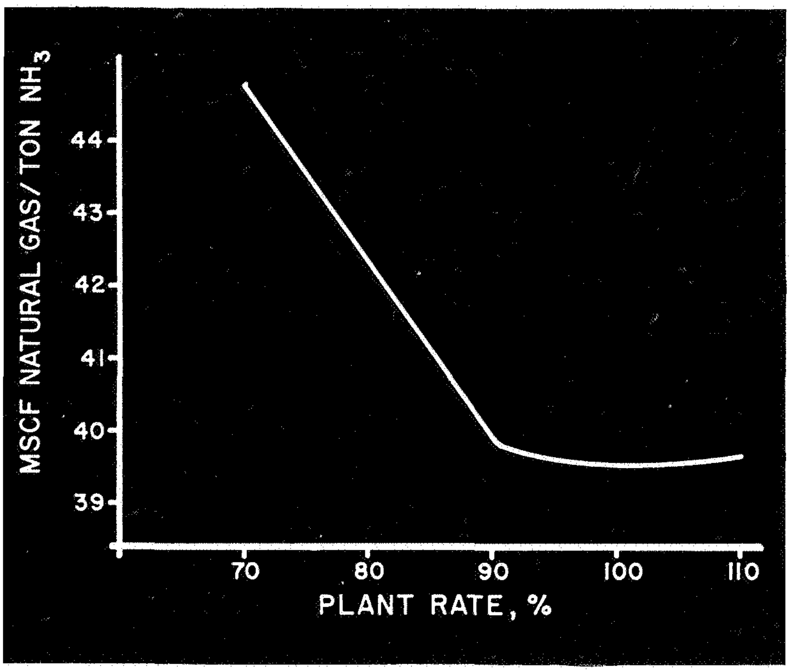

Figure 1. Overall plant efficiency.

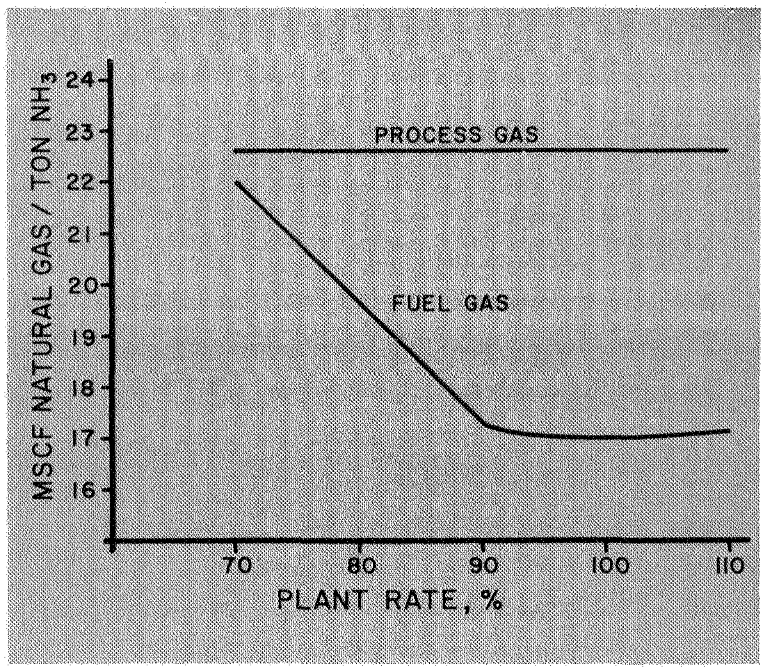

Figure 2. Fuel and process gas consumption.

AMMONIA PLANT OPERATIONS:

Turndown Efficiency of a Single-Trair

Tests on a 1,000 ton/day single-train unit show that changing from natural gas fuel to light fuel oil can be accomplished with overall plant efficiency remaining essentially constant.

J. G. Sawyer, Allied Chemical Corp., Hopewell, Va.

G. P. Williams, Cooperative Farm Chemicals Association, Lawrence, Kan.

An ammonia plant—facing today's energy shortages—can maintain its overall efficiency if it is compelled to switch fuels, say from natural gas to No. 2 fuel oil. Results in a commercial scale plant in Virginia, have shown that the primary problem is instability in reformer operations when the fuel changeover is made while the unit is onstream.

The well publicized "energy crunch" is having varying degrees of economic meaning across the United States. At present, Gulf Coast ammonia producers still enjoy "close to the source" availability and a reasonable price for natural gas, whereas more remote producers suffer both curtailed gas supply and higher prices.

Even though natural gas is still the cheapest ammonia plant feedstock and fuel, its favorable economic value as a fuel is diminishing. This is evidenced by the dramatic price increases during the past few years which have narrowed the price differential between it and other fuels. However, at present, restricted natural gas availability provides the main incentive for a producer to evaluate the economics of alternate fuels.

Without a backup fuel, an ammonia plant suffering mild gas curtailment, i.e., 20% to 30%, would incur the economic penalties of a production loss and higher unit consumptions. With an alternate fuel source, the plant has the option of either operating at full capacity or at some economically efficient rate. A backup fuel can also permit a plant to remain onstream during a severe gas curtailment when it might otherwise be forced to shut down, thereby avoiding significant shutdown and startup expense, plus possible equipment damage.

The ammonia production facilities of Allied Chemical Corp. in Hopewell, Va., have been subjected to periodic winter months gas curtailments since 1953. Until 1967, these curtailments were not of sufficient magnitude and frequency to affect the manufacturing cost of ammonia significantly. In 1967, the multi-train unit was replaced with a 1,000 ton/day, single-train, centrifugal plant. Since that time Allied Chemical has experienced an annual increase in the frequency and magnitude of gas curtailments. These curtailments now play a significant role in the economic operation of the unit and have prompted a detailed study of the plant turndown efficiencies so that the economics of burning supplemental No. 2 fuel oil could be accurately determined.

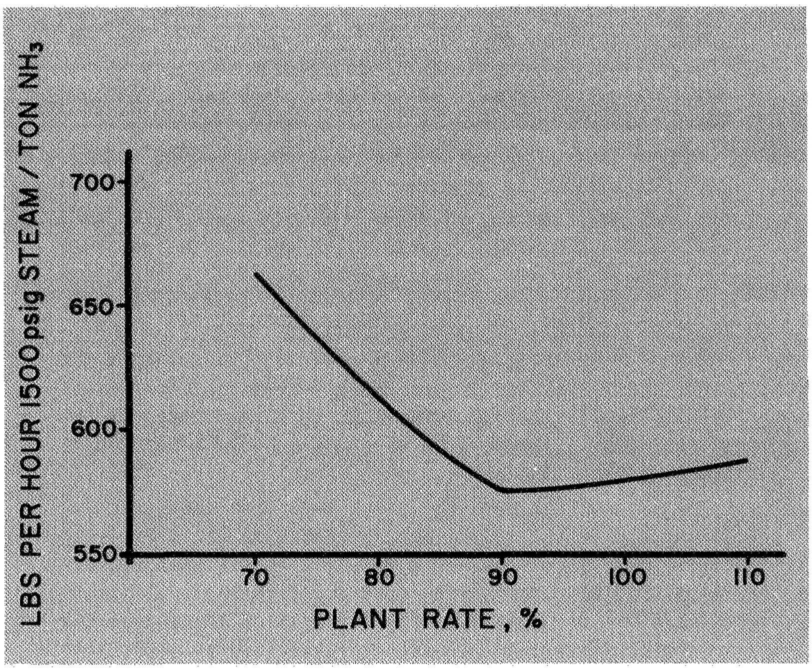

Figure 3. Unit steam consumption.

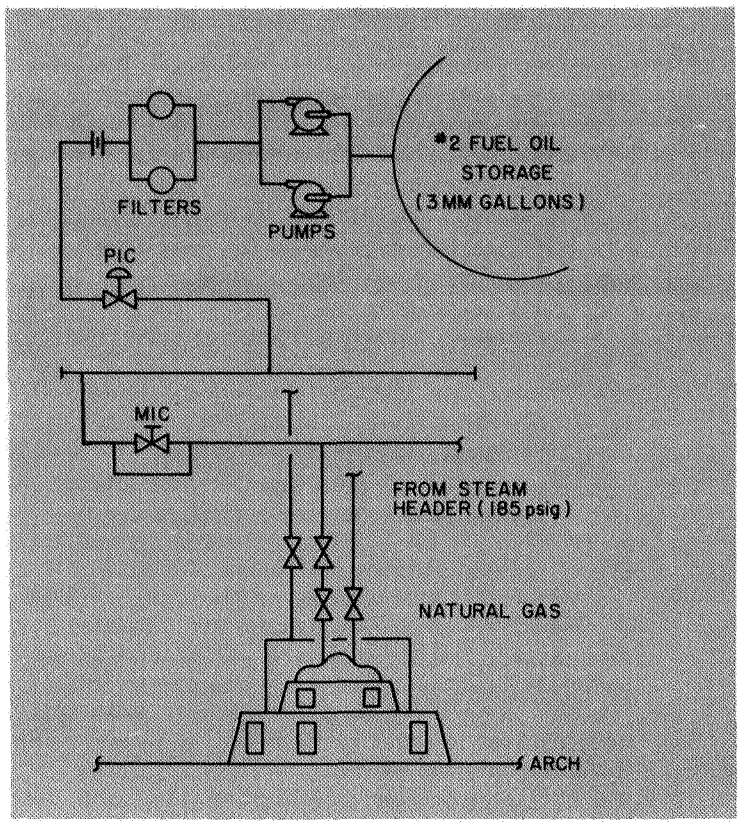

Figure 4. Fuel oil system.

Plant

This article presents the results of the turndown efficiency study, along with some comments regarding the safety aspects of burning a liquid fuel in the primary reformer.

Optimum efficiency between 95% and 105% rate

The Hopewell ammonia facility is a single-train, 1,000 ton/day, centrifugal-type of M. W. Kellogg design, equipped with combination gas-oil, down-shot burners in the primary reformer arch. The oil burners are designed to burn No. 2 fuel oil.

Several series of tests were conducted at plant rates ranging from 71% to 108% to determine the effect of plant rate on the unit consumption of natural gas and/or fuel oil per ton of ammonia production. Figure 1 shows the overall efficiency, expressed as unit consumption of natural gas, which is essentially constant at rates between 90% and 110% of design rate.

There appears to be an optimum efficiency point between 95% and 105% rate. Below 90% rate, the overall efficiency rapidly deteriorates and the overall unit consumption of natural gas increases 12% when the rate is reduced to 70%. At the 700 ton/day rate, this efficiency loss is equivalent to 3.4 million std. cu. ft./day natural gas, or $1,360/day based on $0.40/thousand std. cu. ft. gas.

No distinction was made between heat input from natural gas and fuel oil because fuel type did not materially affect the efficiency. No. 2 fuel oil requires about 5% additional air, plus about 6,000 lb./hr. additional steam consumption. Unit energy consumption is shown as 1,000 std. cu. ft. natural gas (1,000 B.t.u./std. cu. ft., 60°F., 14.7 lb./sq. in. abs., dry basis). It should be noted that the overall energy consumption is a net value because the energy derived from burning purge gas is excluded. The original energy consumption curve constructed from the initial test data was believed to be accurate with ±500 std. cu. ft./ton ammonia. Refinement of the original data was necessary when it became apparent that data from the short 12-hr. test runs, which were generally begun 6 hr. after a rate change, indicated abnormally high consumption rates. Subsequent data obtained from 2 to 3 day test runs were more reliable and allowed us to refine the overall consumption curve to ±200 std. cu. ft./ton.

Figure 2 shows the breakdown of the overall efficiency curve into process and fuel gas consumption. The process gas consumption remains constant, while the loss in efficiency at lower rates is entirely due to the higher consumption of fuel gas. This is somewhat surprising, because some deviation in the process gas consumption might be expected in view of the wide range of space velocities encountered and their subsequent effect on conversion efficiency. However, within the accuracy of the tests, a change was not detected.

The fuel gas consumption curve follows the shape of the overall efficiency curve. Below 90% rate, the fuel consumption increases by 22% when the rate is reduced to 70%. Virtually all of this additional energy goes into the production of 1,500 lb./sq. in. gauge steam, as shown in Figure 3.

Below 90% rate the anti-surge, or kickback, valves on the three major centrifugal compressors begin to open. At minimum governor speed and minimum flow, the total energy requirement for the major compressors remains essentially constant between 70% and 90% rates.

The following comments summarize the major observations and results of the test runs:

First: at reduction of plant rate from 110% to 90%:

- 1,500 lb./sq. in. gauge steam production decreased proportionately to the rate.
- Steam-to-gas ratio was constant.
- Compressor speeds were reduced without opening the kickback valves.
- Process, fuel gas, and overall efficiency remained essentially constant.

Second: at reduction of plant rate from 90% to 70%:

- The steam-to-gas ratio was increased slightly (about 10%) at lower rates to maintain satisfactory flow distribution through the primary reformer tubes; however, tube "spotting" still occurred below 80% rate.
- The three major compressors (i.e., the synthesis gas, refrigeration, and air compressor) were operated at minimum speed, and the kickback valves were increasingly opened to maintain minimum flow requirements.
- The 1,500 lb./sq. in. gauge steam pressure was gradually reduced to about 1,350 lb./sq. in. gauge to improve the steam balance.
- Process gas unit consumption remained constant while the fuel gas unit consumption increased about 27%.

Plant performance remained good

During the efficiency tests, the plant was in relatively good mechanical condition and the activity of the various catalyst beds was from good to excellent. Typical plant performance during the test runs is as follows:

1. Methane leakage exit the primary reformer was 8% to 10%.
2. Methane leakage exit the secondary reformer was 0.2% to 0.3%.
3. CO leakage exit the high-temperature and low-temperature shift converters was, respectively, 2.0% and 0.15%.
4. Ammonia loop inerts were 10% to 15%.
5. Steam-to-gas ratio was 3.7 above the 80% rate.

The Hopewell ammonia plant is one of the few large tonnage plants in the country that has the capability to burn No. 2 fuel oil. An interest has been expressed in the industry to relate some of our experience in this field; especially since many synthetic natural gas plants are considering fuel oil firing.

Hopewell originally fired No. 6 fuel oil in the multi-train reformers. It took several tube ruptures, plus their associated shutdowns, and considerable research to determine that the cause was trace metals in these heavier fuel oils. We then switched to No. 2 fuel oil, and subsequently designed the new 1,000 ton/day reformer to fire No. 2 fuel oil.

The burners were designed to fire natural gas, purge gas mixture, and/or No. 2 fuel oil at the same time. Fuel oil pressure is controlled at 155 lb./sq. in. gauge and atomizing steam at 185 lb./sq. in. gauge. Flows to individual oil and gas headers are manually controlled from the control board. (See Figure 4.)

The switch from one fuel to another is done one row at a time. Usually when the oil system has not been in service for a while, considerable pluggage is experienced in the internal oil orifice. The operators will then remove and clean the burners in-run. More attention has to be given the reformer when firing oil because of the pluggage problem and the different burner air louver settings. When firing gas and oil at the same time, a major rate change will upset the burner firing, and additional work will have to be done to straighten out the firing.

There has been no appreciable decrease in overall plant efficiency by burning No. 2 fuel oil in place of natural gas. The main problem with firing alternate fuels is the reformer instabilities incurred when switching from one fuel to another during operation. As has been discussed, temperature cycling of reformer tubes ultimately reduces tube life. When switching from one fuel to another, it is almost impossible not to temperature-cycle the furnace to some extent. Therefore, we continue to operate with a base load of oil even when additional natural gas is available on a short term basis in order to minimize the number of thermal cycles.

As a result of the efficiency tests, the economics of firing No. 2 fuel oil in the Hopewell plant have been clarified and are somewhat different than originally anticipated. Even though the cost of No. 2 fuel is still considerably more than that of natural gas, its impact on the manufacturing cost is significantly reduced by permitting plant operation at an improved efficiency rate. Presently, we can fire up to 65,000 gal./day of No. 2 fuel oil, and this has allowed the plant to operate at 90% to 100% rates when it would otherwise be curtailed to a 70% rate.

In anticipation of further gas curtailments, plans are presently under consideration to convert other natural gas fired burners to combination oil-gas burners; thereby increasing the oil firing capacity to about 100,000 gal. /day.

Useful points for improving efficiency

For an existing single-train centrifugal plant considering efficiency improvements and/or alternate fuel sources, the following facts may be worthwhile pursuing:

1. When operating at reduced rates, compressor turndown and minimum flow points become very important from an energy conservation standpoint. Improved kickback, or anti-surge, control systems should be studied carefully. It may be possible to reduce the kickback flows significantly if minimum flow points are known with greater accuracy, or if the control system is more sophisticated.

2. Capacity of auxiliary, or offsite, boilers should be taken into consideration when designing or modifying the system because the quantity of steam required in trim or offsite boilers increases below 90% rate.

3. At reduced rates the optimum inert level in the loop appears to be somewhat higher than design. An inert level 10% to 15% above design gave somewhat better control of the converter and a slight improvement in ammonia production.

The safety and accident prevention aspects of firing an alternate fuel along with natural gas requires considerable thought and care. Hopewell experienced a severe fire in the reformer penthouse while firing fuel oil. Many structural members, burners, insulation, piping, etc., had to be replaced, and the arch in this area of the reformer has an 8-to-12-in. sag. A fire alarm system was installed after the fire.

The main problem is simply due to the added complexity of a dual firing system. Because of the extra threaded unions, valves, piping, controls and steam piping in the dual system, much greater care must be exhibited in both design, operation, and maintenance. #

DISCUSSION

W.J. NEWLAND, Consolidated Fertilizers, Ltd., Australia: We operate a 600 ton/day naphtha plant and at plant rates of 70% design and less we have a naphtha consumption of 1.2 tons of naphtha/ton of ammonia. You say that when you change from oil to gas and from gas to oil firing you do so by rows. Does that mean you isolate each particular row and change a whole row at a time or do you do the burners individually?

SAWYER: We basically switch each burner individually, but you work one row at a time. We isolate the row, open the burners up, turn the steam on, and then the operator can control the oil valve, the header valve, from the board. The board operator starts monitoring it after the operators have opened up the burner valves on each row.

NEWLAND: Do you use the same burner guns for gas and oil or do you change guns as well?

SAWYER: Well, the way the burner is designed, it is an internal gun, with two gas burners, one on each side of the oil burner. The oil burner is a totally separate gun from the gas.

JOHN CROMEANS, Catalyst Consulting Services: When you turn down to 70 per cent rate, do you consider that you could run steady at 70 per cent for an extended period of time?

SAWYER: If we had to, John. Yes, we could. But the economics clearly comes out that it's a lot better the other way.

WILLIAMS: That's right. At least back up to 90 percent, you can justify burning your fuel oil, if the differential is not too great.

SAWYER: East Coast—or Gulf Coast producers would have a problem, but in our position, with our high cost of natural gas it is economically favorable to run at 90 per cent rate; above that you have to justify the increased production on what you're selling your ammonia for.

We feel a minimum point we can run the plant at is about 65 per cent.

JERRY WILLIAMS, CFCA, (formerly Allied Chemical): The gentleman makes a valid point on reduction of process gas pressures at reduced rates. We haven't pursued that. I do think there are some savings there, particularly if you run lower pressures on the air machine and gas machine; I think you'd find you're better off from a standpoint of your surge controls. In other words you would have less power consumption on these.

But I think most of the times the limitations in Hopewell have been of such short duration in terms of maybe one, two, three days for the most part, there have been some longer ones, that we really haven't pursued this and you really should if you're seriously considering running extended lengths of time at reduced rates.

O.B. ROWLAND, Commercial Solvents Corp.: We have received considerable favorable comment from visitors. And I don't know that we were the first ones to use it.

On our fire alarm system which has been very effective in our furnace penthouse. It's no more than a black piece of plastic tubing (Creascent type P Polyethylene tubing 1/4" X .040) that comes in 500 ft. rolls and we have it run down each walkway hung on wires between tube rows in penthouse, I'd say about 7 ft. high. Instrument air is supplied through an orifice at 15 psi and the tubing is connected to a pressure switch. If the tubing heats to 170–180 degrees, it melts, thus releasing the air pressure and tripping the pressure switch and triggers a panel alarm in the control house. This has proven to be instant notification of even minor fires in the penthouse.