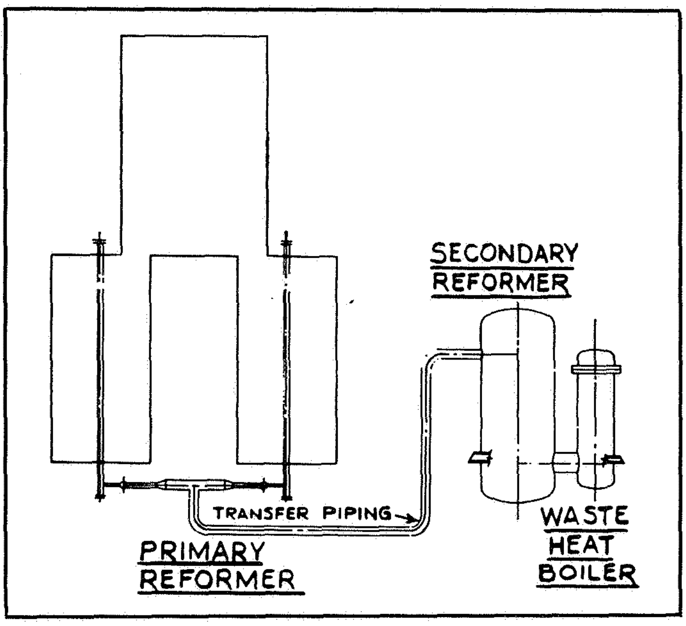

Figure 1. A typical reforming arrangement used in industry.

The Module Concept Of Reformer Design

A new approach to primary-secondary reformer design in ammonia plants is expected to minimize, if not eliminate, recurring design problems.

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Although ammonia plant capacity has increased rapidly during this decade, the basic concept of the gas reform section has remained essentially unchanged. Design changes due to increased reforming pressures have helped reduce equipment dimensions below those that would otherwise have resulted from a simple expansion of earlier designs. But, in spite of this, equipment size has increased considerably. Often it has been necessary to install duplicate half capacity units, because of difficulties in manufacturing, transporting, or erecting single large capacity vessels or reactors.

This problem has been compounded by a general deterioration of quality control in the fabricated equipment. Our experience has shown the need for a major improvement in quality control procedures including: a superior level of inspection at the vendor's shops; specific detailed instructions for field erection, assembly, and testing; and a trend toward simplification of basic mechanical designs.

A great deal of attention has been given to the problem of failure in transfer lines between the primary and secondary reformers because of the extended shutdowns and tremendous production losses that accompany such a mishap. This problem was discussed in detail at Chemico and, after a cursory review, B. Walton and J. Connor, who are now co-authors of the reformer module patent, concluded that the surest way to eliminate transfer line problems was to eliminate the transfer line.

Reformer module concept

The typical reforming arrangement used in industry is shown in Figure 1. The features of the new concept (see Figure 2) are:

1. A primary reformer
2. A transfer arrangement between the primary and secondary reformers
3. A secondary reformer
4. A transfer arrangement between the secondary reformer and the reform gas waste heat boiler
5. A reform gas waste heat boiler

In the reformer module the equipment has been arranged to eliminate the transfer lines between the primary and secondary reformers and the line between the secondary reformer and the reform boiler. Any conventional primary reforming furnace with a bottom collecting manifold can be used with this design.

Product gas from the catalyst tubes is collected in the bottom manifold. A connection stub at the center of the manifold permits the collected gas to enter a mixing chamber, at which point the process air is added. The mixed high temperature gas enters the secondary reformer, flows up through the catalyst bed and into the waste heat boiler within the same shell. As you will note, all equipment is close coupled, or integral, and a transfer line is not required.

The reformer module design may be adapted to any capacity and to most commercially available primary reformers. To meet industry needs, standard module units of 500, 750, and 1,000 tons/day capacity have been developed by Chemico. The modules may be combined to give double capacity, i.e., 500 tons/day modules can be duplicated with a common convection section to form a 1,000 tons/day unit. In the same manner, 750 and 1,000 tons/day modules can be combined to form 1,500 and 2,000 tons/day units.

In addition to eliminating transfer line problems, the module also permits a reduction of stress in the collecting manifolds and pigtails of the primary reformer. The Battelle Memorial Institute is presently conducting an extensive research and development program with regard to steam reforming furnaces. One of the items to be investigated is the effect of temperature cycling combined with external imposed forces on the collection manifolds, pigtails and catalyst tubes. Results to date tend to indicate that temperature cycling combined with the resultant thermal movements are detrimental to the primary reformer internals. By the elimination of the transfer line, the thermal movements are kept to a minimum, thus tending to prolong the expectant life of the collection manifolds, pigtails, and catalyst tubes.

In the case of a twin module installation, slight modifications can be incorporated so as to make it practical to completely isolate one module train (primary, secondary and waste heat boiler). This would be advantageous if one wished to continue plant operation while making repairs to the isolated train or, for economy reasons, operate at reduced plant capacity.

In addition, results of a detailed cost analysis clearly indicate that the module concept compares favorably with the conventional design using transfer lines.

Process considerations

By the simplest definition of process considerations, it makes no difference whether the process gas flows up or down through a reactor, or whether there is one reactor or many. Equilibrium considerations, reaction rate effects and pressure drop—shape relationships remain unchanged. Upon more detailed examination, however, some differences are revealed, but these are related more to the dynamics of the system than to its chemistry, and are more concerned with upset conditions than design rates.

The most obvious change in the new system is downflow to upflow; the most obvious potential problem is catalyst fluidization or bumping. As there is no change in the dimensions of the catalyst bed, the dead load of the catalyst, on its support, amounts to between two and three times the pressure drop through the catalyst bed. Therefore, there is little chance of disturbing the catalyst either during normal operation of the plant or even as a result of a surge which might accidentally occur during a startup or shutdown.

A severe piping or equipment fracture downstream of the reformer would result in a rapid depressurization of the system and the high flow rate and pressure drop which would occur could be great enough to lift the catalyst. As this is a very rare occurrence, it seems reasonable to accept this risk. It is probably no greater than the chance of lifting the catalyst in a downflow

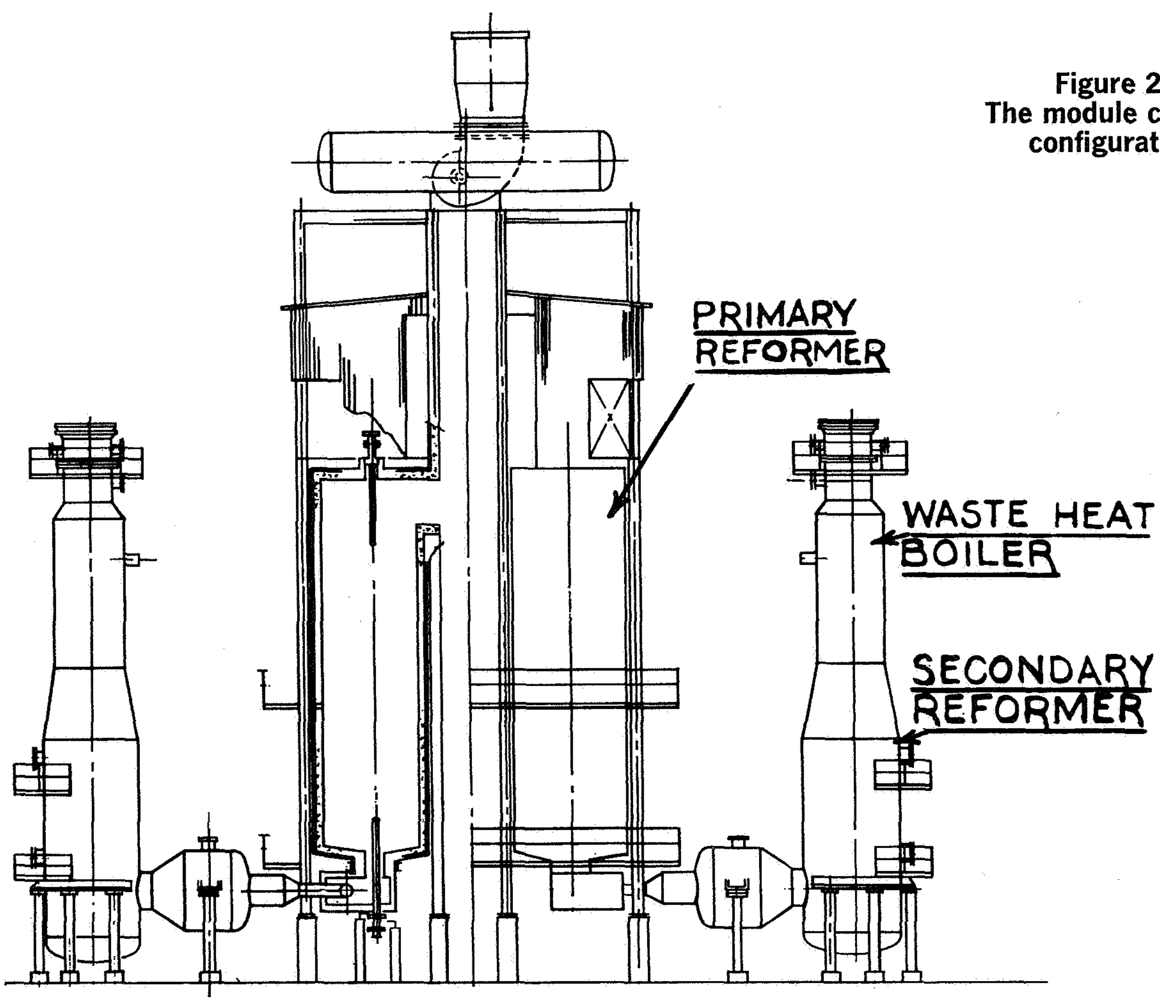

Figure 2. The module concept configuration.

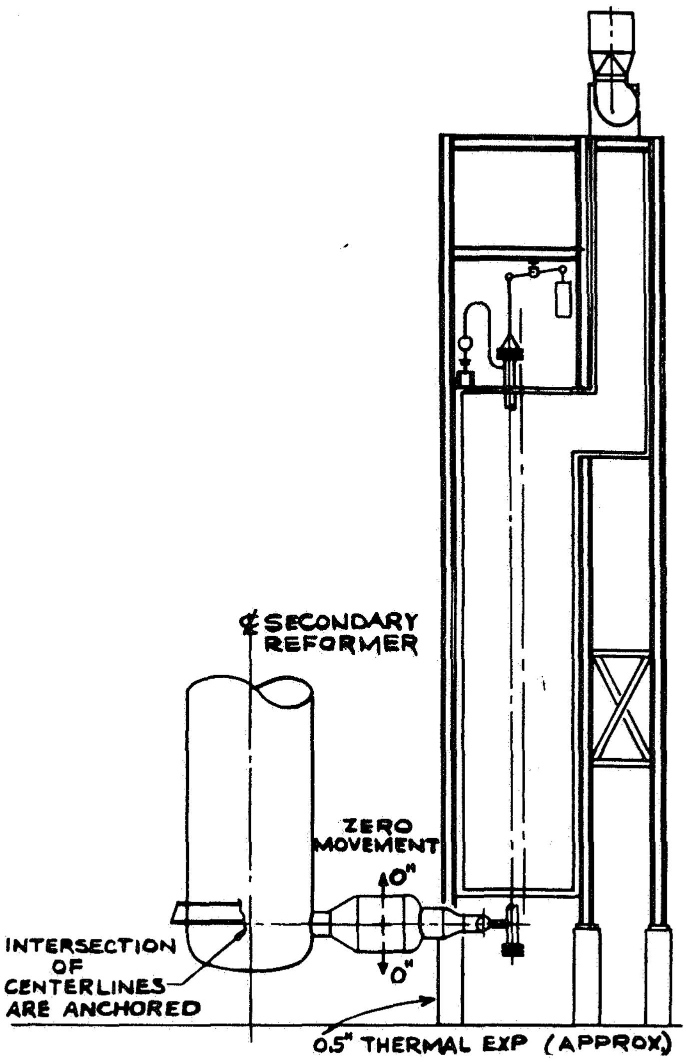

Figure 3. Thermal expansion movements in module concept equipment.

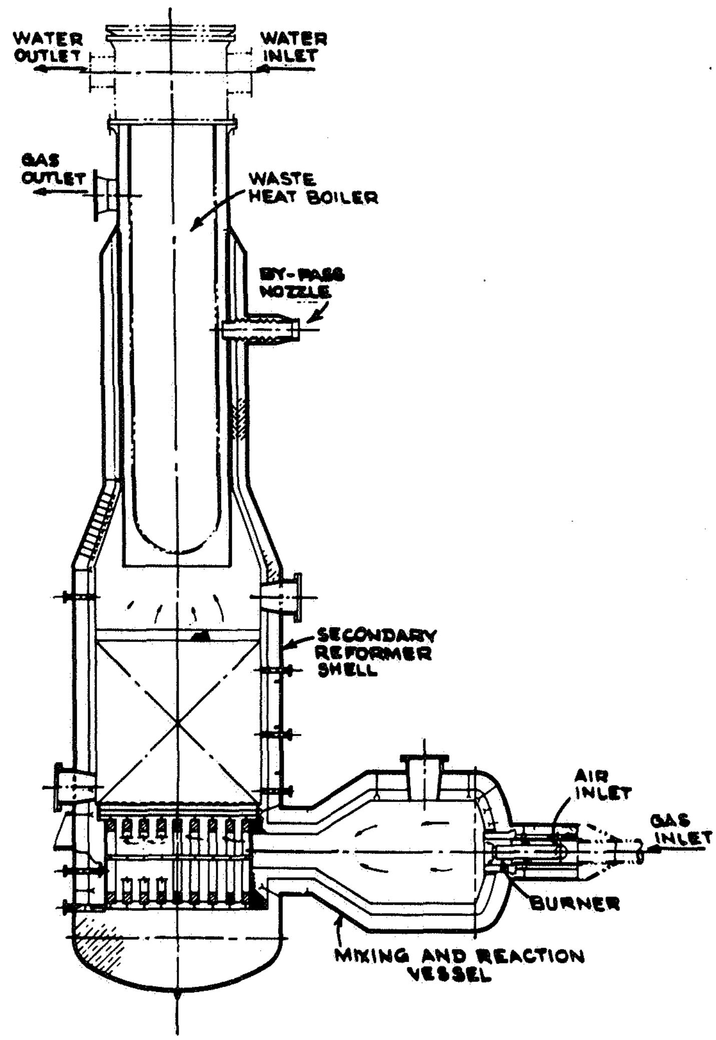

Figure 4. Diagram showing the waste heat boiler in a common shell with the secondary reformer.

reformer as a result of a severe failure between the primary and secondary.

Chemico had used upflow secondary reformers on two ammonia plants, both of which have been working continuously and satisfactorily for several years. The main features of these successful units have been incorporated in our new module design. Although there has been no reported trouble with catalyst disturbance in these plants, the ratio of catalyst dead load to pressure drop has been increased in our new designs primarily as a result of vessel geometry.

The main difference between the earlier design and the present one is the addition of a separate combustion chamber. In the former version, the air burner was located in the gas inlet nozzle of the secondary reformer and the gas distribution tunnel also served as the combustion chamber. The availability of refactory shapes, of satisfactory mechanical strength, limits the diameter of this tunnel so that the combustion volume available in it increases proportionally to the diameter of the vessel. The catalyst quantity and, therefore, plant capacity increases as the square of this diameter.

Thus, on the larger plant capacities, the combustion space available would be inadequate and a separate combustion chamber is the obvious solution. It has the incidental advantage of protecting the catalyst support refractories from the high temperature differentials associated with high intensity combustion and allowing the reform reaction to moderate the temperature before the gas enters the supporting and distributing refractories in the base of the reformer. The air injection nozzle used is a proven design which has been applied to various secondary reformers in recent years.

The goal of any new or modified reform plant design in the front is essentially to provide an improved system that will provide a more efficient reaction and a simpler mechanical design. The specific merits of the module concept are:

1. Process air and primary reformer effluent streams are completely mixed prior to the admission of the process gas into the secondary catalyst bed. This results in the passage of a gas stream of constant composition into the catalyst bed.

2. Close coupling of the secondary reformer, reaction chamber and furnace outlet, all on a defined axis, eliminates excessive deformation and stress due to relative differential expansion.

3. A combined secondary reformer and waste heat boiler eliminates relative differential expansion and resultant stress.

4. The metal skin temperatures are low and the resultant thermal expansion is relatively small because the hot gas connection between the primary and

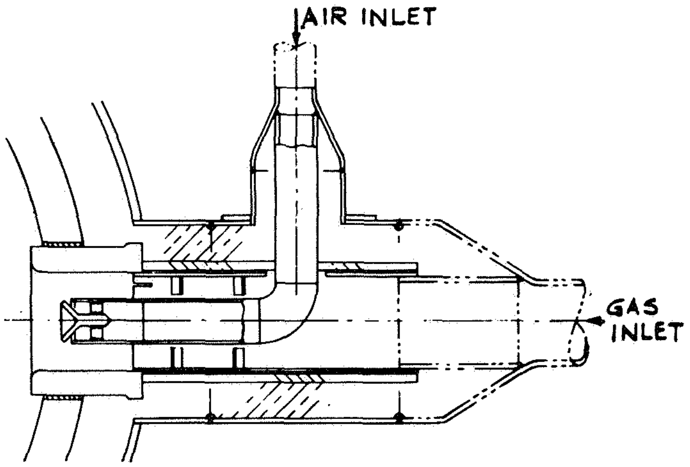

Figure 5. A conical burner to insure complete mixing of air and hydrogen prior to entrance into the catalyst.

secondary reformers is very short, and the entire combination is lined with refractory material.

Thermal expansion movements

The secondary reformer vessel is the fixed anchor terminal point. As shown in Figure 3, a direct connection is made between the furnace outlet manifold and the secondary reformer through the reaction chamber.

By placing a directional restraint at the center of the collecting manifold, thermal expansion is limited only to the horizontal plane. Movement in the vertical plane is restricted so as to avoid bending stresses on the high temperature manifold. A common horizontal center line with no vertical motion is established for the secondary reformer, mixing chamber, and collecting manifold. To reduce thermal expansion in the horizontal plane, the junction of the secondary reformer is refractory lined. The entire equipment combination expands horizontally toward the primary reformer outlet manifold. The primary reformer tubes are connected by individual pigtails or other means that readily absorb or transmit the small horizontal thermal expansion. The waste heat boiler is in a common shell with the secondary reformer and therefore has no relative differential movement. (See Figure 4.)

Gas entering the mixing chamber, Figure 4, reacts with the air and enters the secondary reformer below the catalyst bed through a refractory tunnel. This tunnel has openings which permit the gas to disperse uniformly into a brick checkered catalyst support grid. A uniform gas distribution and pressure drop through the bed is assured.

Product gas exits from the top of the catalyst bed and passes over the "U" tube bundle of the waste heat boiler which is suspended in the top of the secondary reformer. Thermal expansion of the tube bundle is downward and unrestricted. The common shell of the boiler and secondary reformer eliminates differential expansion and reduces cost. A forced circulation system is utilized on the water side of the boiler. Provisions are made in the upper section of the shell for the gas outlet and gas by-pass connections. A stainless steel shroud is suspended from the upper section of the shell and prevents gas by-pass behind the refractory, Figure 4.

A refractory lining consisting of a durable, erosion-resistant, hard facing of high alumina backed by a thermal insulating refractory is used in all high temperature areas. Detailed procedures define application, curing, and dry-out to insure a stable lining. The integrity of the lining is a function of the care in installation and final curing and dry-out.

The design of the waste heat boiler considers the need for a positive non-destructive examination of the materials and fabricated components. Stringent quality control is maintained during fabrication, and testing of all materials and welds is mandatory. All necessary steps are taken to insure that possible failure during operation is minimized.

The Chemico high velocity venturi burner is used to insure complete mixing of air and hydrogen in the mixing chamber. A conical burner, in successful operation in similar service, was utilized to insure this mix prior to its entrance into the catalyst bed, Figure 5.

A catalyst may be installed in the secondary reformer prior to the assembly of the secondary reformer and waste heat boiler or through a manway above the catalyst bed. Any section of the system may be examined during a shutdown. The boiler is flanged and bolted to the secondary reformer to permit ease of removal and installation.

In summary

Reduction or elimination of piping thermal expansion substantially reduces resultant induced stresses. Reduction of the stress level reduces or eliminates mechanical failure of components in the critical service.

To insure reliability, design features and components used in this module concept are presently in service and have a successful history of operation. The composite arrangement is new but each component or separate piece of apparatus is in use in various plants. #

S. J. Bongiorno is chief engineer at Chemical Construction Corp. He is responsible for maintaining the efficiency, technical competence and general engineering work for Chemico projects. In addition, he is in charge of assigning personnel to project teams and periodically reviews department work loads and organization. Bongiorno is a registered professional engineer and a graduate of Brooklyn Polytechnic Institute.

J. M. Connor graduated in chemistry in 1943 and obtained his Ph.D. degree in chemical engineering from Imperial College London. He spent several years on the research staff at Imperial College. Connor joined Chemico's London office in 1951 and later became manager of process engineering. He was transferred to the New York office in 1966 where he works as senior consultant.

B. C. Walton is a graduate mechanical and professional engineer licensed in the state of New Jersey. He is currently chief design engineer of Chemical Construction Corp. Walton has extensive industrial experience in the design of petrochemical plants with specific emphasis in the areas of high temperature and high pressure technology, mechanical equipment, piping, vessels, metallurgy, furnace design and code application. His knowledge of the design and procurement of pressure equipment spans many areas of the world, notably Europe and the Far East.