POWER RECOVERY SYSTEMS AND HOT GAS EXPANDERS

by
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John P. Balfoort was born of Dutch parents in the East Indies. He was educated in Holland and graduated from the Maritime Academy in Amsterdam in 1940. During World War II, he served as an Engineering officer on board troop ships in the Atlantic and Pacific theaters. After the war, he was employed by the Shell Oil Company and was assigned as an Equipment Engineer at the Shell-Houston Refinery. In 1949, he became an American citizen.

He has been intimately involved in the design, application, selection, construction, inspection, initial start-up and maintenance of all mechanical equipment, especially in the early states of high speed, high pressure centrifugal barrel type compressors in hydrogen recycle service in catalytic reformers. He has also been involved in large gas turbine installations and power recovery systems in fluid catalytic cracking units.

Mr. Balfoort was promoted to Senior Engineer and then to Staff Engineer in 1966. He has been on loan to all other Shell Refineries in the United States to check out and start up mechanical equipment in new process units. In 1967, he was assigned to the Expansion-Construction Department and became Group Leader for the Mechanical Equipment Group. After construction was completed, he was reassigned in 1971 to the Engineering Services Department where he is presently in charge of the Mechanical Equipment Section.

In 1972, Mr. Balfoort was promoted to Senior Staff Engineer.

INTRODUCTION

As the cost of energy has always been a substantial factor in the overall cost of oil refining, engineers have devoted a great deal of attention to recovering the available energy in the high temperature flue gas of Catalytic Cracking Units.

The generally accepted method to recover the heat has been to channel the flue gas through a CO burning boiler or process furnace.

In this method, however, a large amount of the available energy is wasted because of required throttling of the flue gas (40 - 70 BTU/#).

A more efficient design, therefore, required the replacement of the throttling devices but also necessitated the development of two major system components.

1. A turbine to allow the gas to expand thereby converting energy into mechanical power. The turbine design premise was set to allow continuous operation at 1200°F and sustain rapid temperature increases to higher temperature levels for short periods of time during unit upsets.
2. A separator to protect the turbine from highly erosive catalyst particles present in the flue gas stream. The separator design necessarily called for very high efficiencies in removing the catalyst particles, and at the same time retain high resistance to erosion for long periods of time.

Since 1963, the Shell Oil Company of the United States and Shell Canada Ltd. have installed 4 power recovery systems in their manufacturing facilities employing separators and hot gas expanders to generate the required power for the Catalytic Cracker main air blowers. In 1970, Shell Berre installed a power recovery system in the Pauillac Refinery in France. In addition, three CCU power recovery systems have been licensed to other oil companies.

DISCUSSION

Figure 1 illustrates schematically the power recovery train integrated into a new Catalytic Cracker Unit in Shell's Martinez Refinery in 1966.

The regenerator flue gas, after passing through two internal stages of conventional type cyclone separators is channeled through duct work into the third stage separator where all, but a fractional minimum, of the catalyst particles left in the flue gas are separated. The clean gas is then expanded through a turbine where energy is converted into mechanical power. The gas leaving the expander at a temperature of 950°F and containing about 8% CO is then channeled into CO burning boilers where the remaining heat is utilized to generate steam for plant use. As the expander acts as a fixed orifice, the regenerator pressure is maintained by a full size 60″ butterfly type control valve located between the separator and expander. The expander with an inlet pressure of about 20 PSIG and inlet temperature of 1200°F develops 15,500 horsepower.

Other equipment in the train includes a 130,000 SCFM axial air blower, a 10,000 HP steam turbine, and a 4,000 HP motor-generator. The steam turbine is used to start the entire train; the motor is activated later in the startup procedure when a higher speed is required. During the initial stages of startup the expander absorbs energy but as the flue gas pressure and temperature are increased, the expander begins to develop power. The steam turbine output is automatically reduced and eventually will cease to supply power altogether. The steam turbine will then continue to windmill. The electric motor converts to a generator when the operating speed of 3,600