be used to vaporize the feed stream and less cooling water is required to condense the overhead vapor of the ethylbenzene/styrene splitter

The mass steam to oil ratio, i.e., the ratio of steam to ethylbenzene contained in a feedstream("oil") on a weight basis, is an important factor in the dehydrogenation of ethylbenzene. In the past, styrene production plants operated at overall steam/oil weight ratios of 1.3 to 1.7. Improved catalysts have allowed the process to operate at steam/oil weight ratios of about 1.0 with acceptable reductions in yield or ethylbenzene conversion.

To supply the proper amount of heat to the system at an overall steam/oil weight ratio of 1.0 or lower, the temperature at the outlet of the steam superheater would have to be increased to 950°C or even higher. However, superheater temperatures above 927°C require the use of special and costly metallurgy. It would be advantageous to have a system which operates at both low steam/oil ratios and lower temperatures.

## SUMMARY

In an ~~embodiment~~aspect of the present ~~invention~~disclosure a method is provided herein for providing heat to a chemical conversion process stream containing at least one chemical reactant. The method includes the steps of
(a) superheating a heat transfer fluid; (b) transferring heat from the superheated heat transfer fluid to the process stream; (c) dividing at least some of the heat transfer fluid into a first portion and a second portion; (d) pressurizing the first portion of heat transfer fluid; (e) recycling the pressurized first portion of heat transfer fluid to superheating step (a); and, (f) introducing the second portion of the heat transfer fluid into the process stream.

In another embodiment a process is provided herein for the production of an olefin by the catalytic dehydrogenation of a feedstream which contains a hydrocarbon having at least a

portion of the molecule capable of undergoing dehydrogenation such as, for example, alkyl compounds (e.g., ethane, propane, butane, etc.) and alkylaromatic compounds (e.g., ethylbenzene, n-propylbenzene, cermene, etc). The process comprises transferring heat from superheated steam, which may already have been heated by indirect heat exchange, to a process stream containing diluent steam and the hydrocarbon capable of being dehydrogenated, the additional heat from the superheated steam being sufficient to effect catalytic dehydrogenation of at least a portion of the hydrocarbon capable of being dehydrogenated in a reaction zone, wherein after transferring the heat the superheated steam becomes spent steam. The spent steam is split into two streams: a recycle steam and a process steam. The recycle steam is pressurized through the use of a thermocompressor. It is then combined with motive steam and heated to a predetermined temperature in the steam superheater. The process steam is reheated to generate superheated steam and is combined with the feedstream which contains the hydrocarbon capable of being dehydrogenated before entering the dehydrogeneration reactor. The net result is more superheated steam available for heat transfer compared to the steam required to satisfy the steam/oil ratio in the reactor.

In another aspect, there is provided a process for the production of olefins by the catalytic dehydrogenation of a hydrocarbon, comprising:

a) superheating a steam feed stream in a heater comprising a plurality of heating zones;

b) transferring heat from superheated steam to a process stream comprising diluent steam and the hydrocarbon, the heat being sufficient to effect catalytic dehydrogenation of at least a portion of the hydrocarbon in a reaction zone, wherein after transferring the heat the superheated steam becomes spent steam;

c) splitting said spent stream into a first portion and a second portion;

d) pressurizing the first portion of said spent steam;

e) recycling the pressurized first portion of the spent steam to a first heating zone in the heater;

f) recycling the second portion to a different section of the heater to a second heating zone in the heater;

g) heating the second portion of the spent steam to regenerate superheated steam in the second heating zone; and

h) combining at least a portion of the superheated steam with the process stream.

In another aspect, there is provided a process for the production of styrene in a reaction zone by contacting a mixture of steam and ethylbenzene having a mass steam/oil ratio with a dehydrogenation catalyst at a dehydrogenation reaction temperature, the improvement comprising:

combining sufficient diluent steam with ethylbenzene to reduce the mass steam/oil ratio to no more than 1.0;

wherein superheated steam at a temperature of less than 815°C is used to transfer sufficient heat to raise the ethylbenzene and diluent steam to the reaction temperature, and wherein at least a portion of said superheated steam is combined with the ethylbenzene to provide at least a portion of the diluent steam.

In yet another aspect, there is provided a process for the production of styrene by the catalytic dehydrogenation of ethylbenzene, said process comprising:

a) providing at least first and second reaction zones, each reaction zone having associated therewith a catalytically effective amount of a dehydrogenation catalyst;

b) providing a furnace having a plurality of heating zones;

c) providing a feed stream containing a vaporized mixture of water and ethylbenzene having a steam/oil weight ratio of no more than 0.5;

d) combining the feed stream with a first stream of superheated steam to provide a fluid stream having a steam/oil weight ratio of no more than 1.0;

e) contacting the fluid stream with the dehydrogenation catalyst in the first reaction zone under dehydrogenation reaction conditions to provide a first effluent;

f) transferring heat from a second stream of superheated steam to the first effluent in a heat transfer zone associated with the second reaction zone, the second stream of superheated steam becoming a stream of spent steam after transfer of its heat to the first effluent;

g) contacting the heated first effluent with dehydrogenation catalyst in the second reaction zone under dehydrogenation reaction conditions to provide a product stream containing styrene;

h) dividing the stream of spent steam into first and second portions;

i) pressurizing the first portion of spent steam;

j) heating the pressurized first portion of spent steam in a first heating zone in the furnace to provide the second stream of superheated steam which is recycled upstream to the heat transfer zone associated with the second reaction zone;

k) heating the second portion of the spent steam in a second heating zone in the furnace to provide the first stream of superheated steam.

Also provided is a system for the production of styrene by the catalytic dehydrogenation of ethylbenzene.

The process and system described herein advantageously can be operated at a steam/oil ratio of 1.0 or below while requiring a superheated steam temperature low enough to avoid the need for specialized metallurgy for the steam superheater furnace and transfer lines (i.e., the piping connections for transferring superheated steam from the steam superheater furnace to the heat exchangers and reactors and back to the steam superheater). This scheme could also be used at higher mass steam/oil ratios.