Fondamenti dell’ingegneria di processo

anno accademico 2021-2022

Tracing Chemicals

Tracing Chemicals through the Process Flow Diagram

- ✓ In a continuous chemical process, there are reactants, products, and inerts
- ✓ These components enter, leave, are formed, or are consumed in the process
- ✓ Each component can be followed through the process

Each step in tracing the flow paths increases our understanding of the process

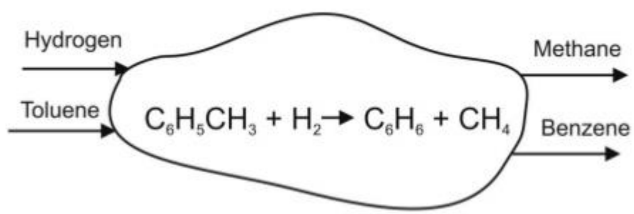
- Chemical species identified in the overall block flow process diagram - those **associated with chemical reactions** - are termed **primary chemicals**.
- The paths followed by primary chemicals between the reactor and the boundaries of the process are termed **primary flow paths**

Only in reactors are feed chemicals transformed into product chemicals

Tracing Chemicals

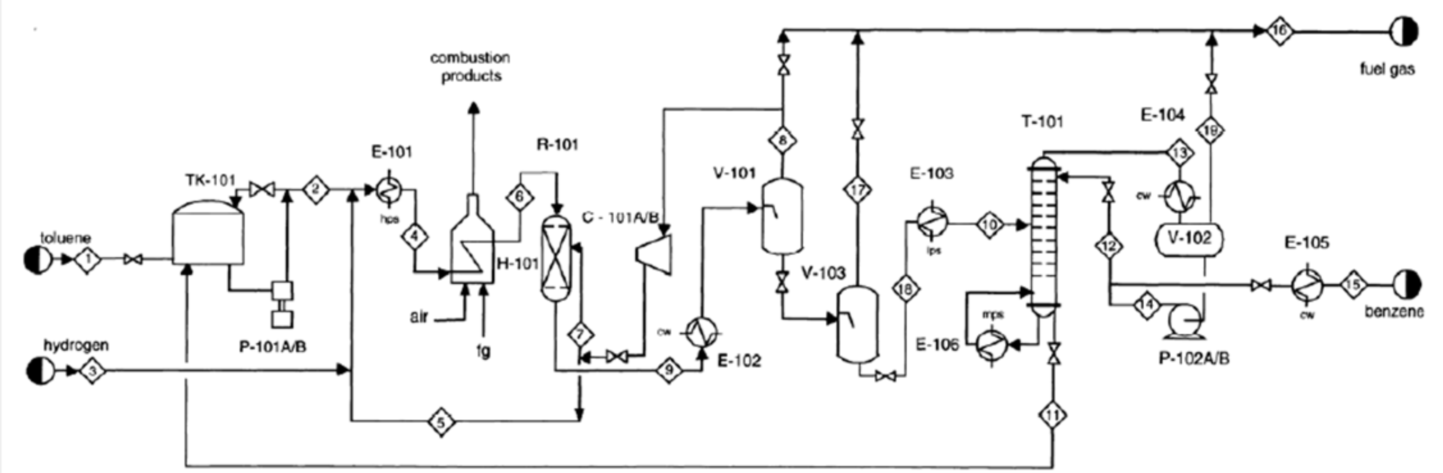
Tracing Chemicals through the Process Flow Diagram

Toluene Hydrodealkylation Process



Two general guidelines should be followed when tracing these **primary chemicals**:

- **Reactants**: Start with the feed (left-hand side of the PFD) and trace chemicals forward toward the reactor.
- **Products**: Start with the product (right-hand side of the PFD) and trace chemicals backwar d toward the reactor



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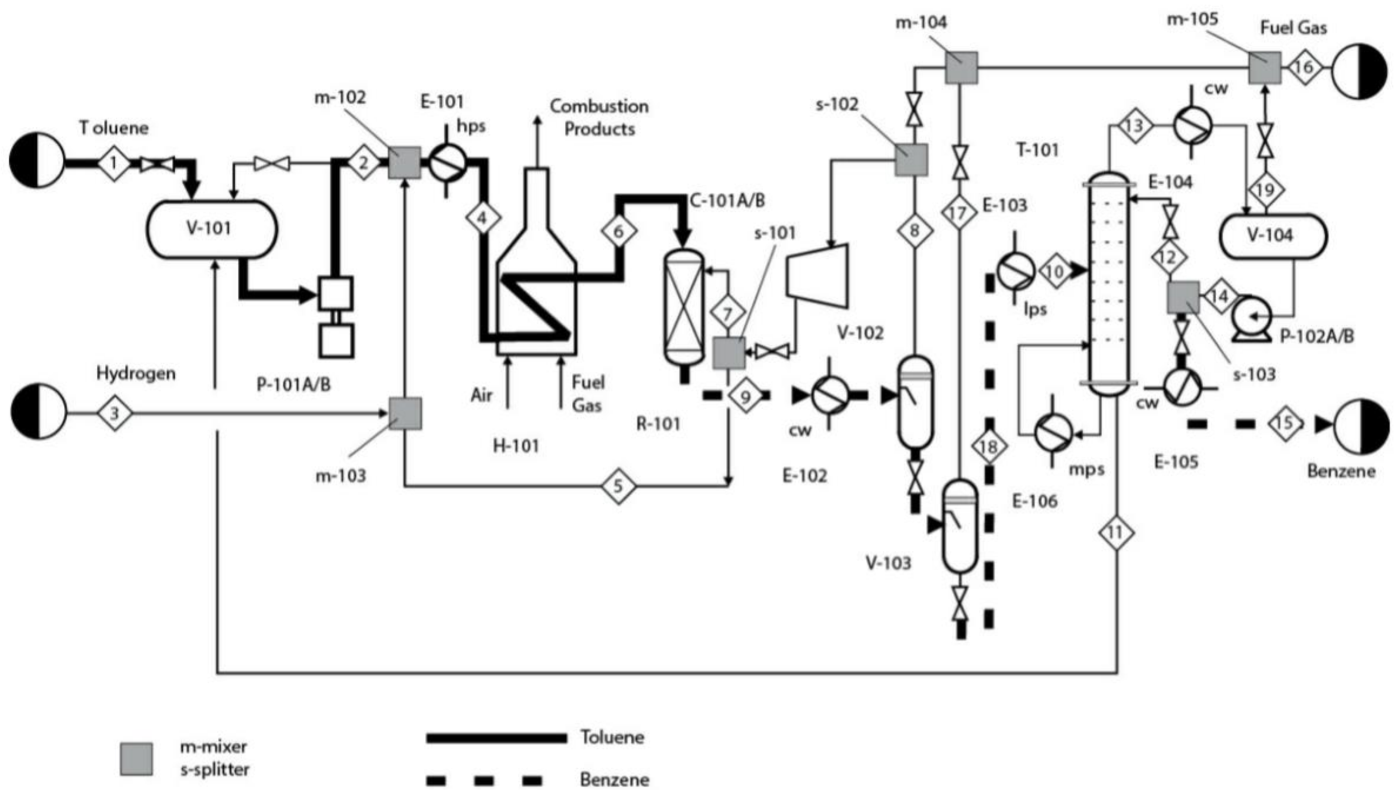

Primary Chemical Pathways for Benzene and Toluene

Tracing Chemicals

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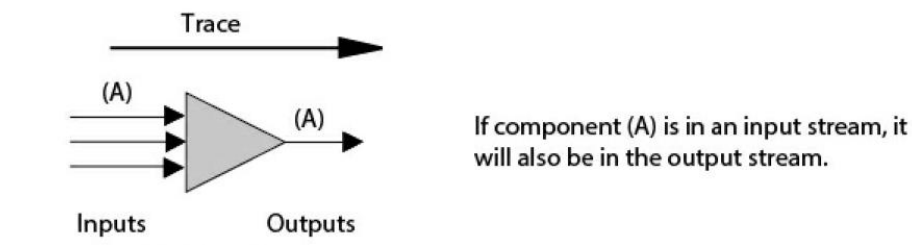
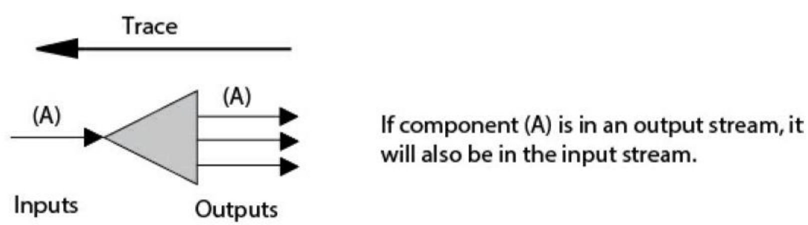
The following tactics for tracing chemicals apply to all unit operations *except for chemical reactors:*

- **Tactic 1**: Any unit operation, or group of operations, that has a single or multiple input streams and a single output stream is traced in a forward direction. If chemical A is present in any input stream, it must appear in the single output stream



- **Tactic 2**: Any unit operation, or group of operations, that has a single input stream and single or multiple output streams is traced in a backward direction. If chemical A is present in any output stream, it must appear in the single input stream



- **Tactic 3**: Systems such as distillation columns are composed of multiple unit operations with a single input or output stream. It is sometimes necessary to consider such equipment combinations as blocks before implementing Tactics 1 and 2.

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RECYCLE AND BYPASS STREAMS

It is important to be able to recognize recycle and bypass streams in chemical processes. When identifying recycle and bypass streams, we look for **flow loops** in the PFD. Any time we can identify a flow loop, we have either a recycle or a bypass stream. The direction of the streams, as indicated by the direction of the arrow heads, determines whether the loop contains a recycle or a bypass:

- ✓ If the streams in a loop flow so that the flow path forms a complete circuit back to the point of origin, then it is a **recycle loop**.
- ✓ If the streams in a loop flow so that the flow path does not form a complete circuit back to the place of origin, then it is a **bypass stream**.

It is worth noting that certain pieces of equipment normally contain recycle streams. In particular, distillation columns very often have top and bottoms product reflux streams, which are essentially recycle loops.

Tracing Chemicals

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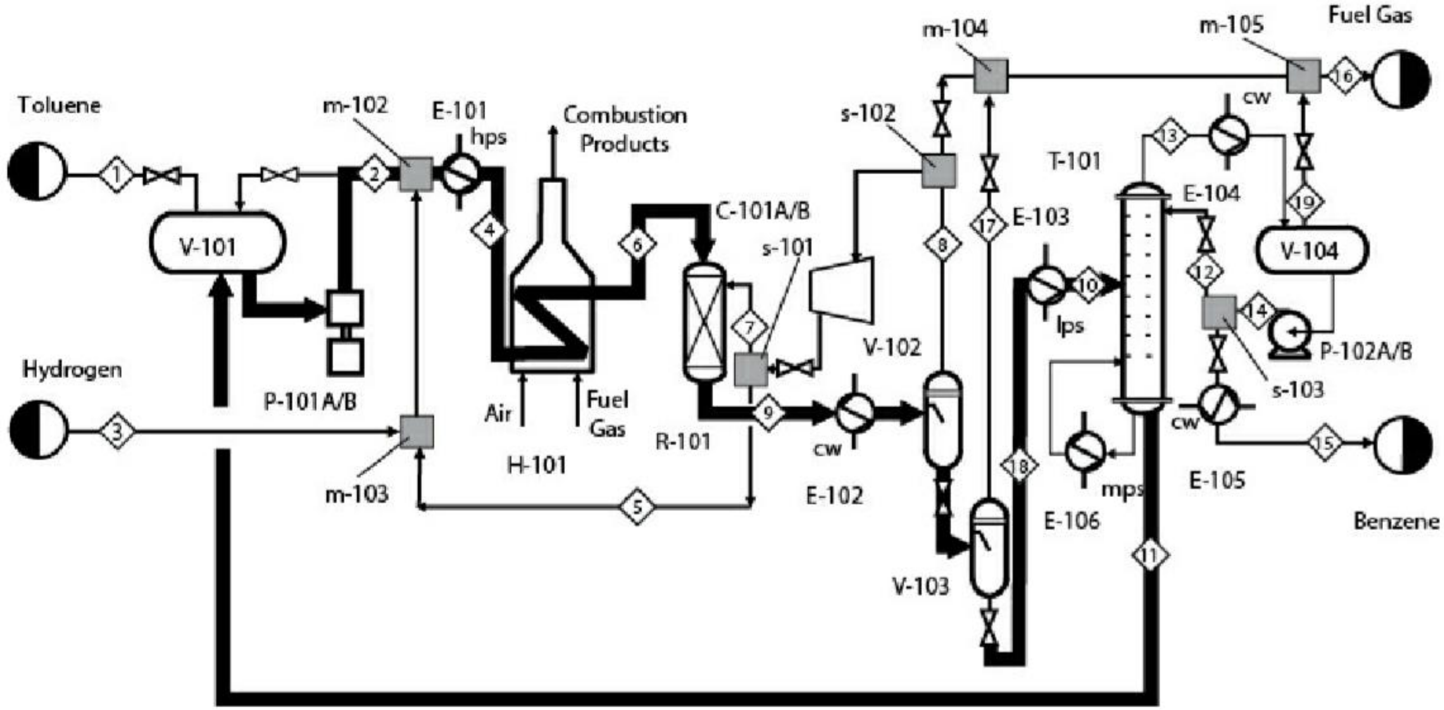
RECYCLE AND BYPASS STREAMS



Toluene Recycle Loop

Tracing Chemicals

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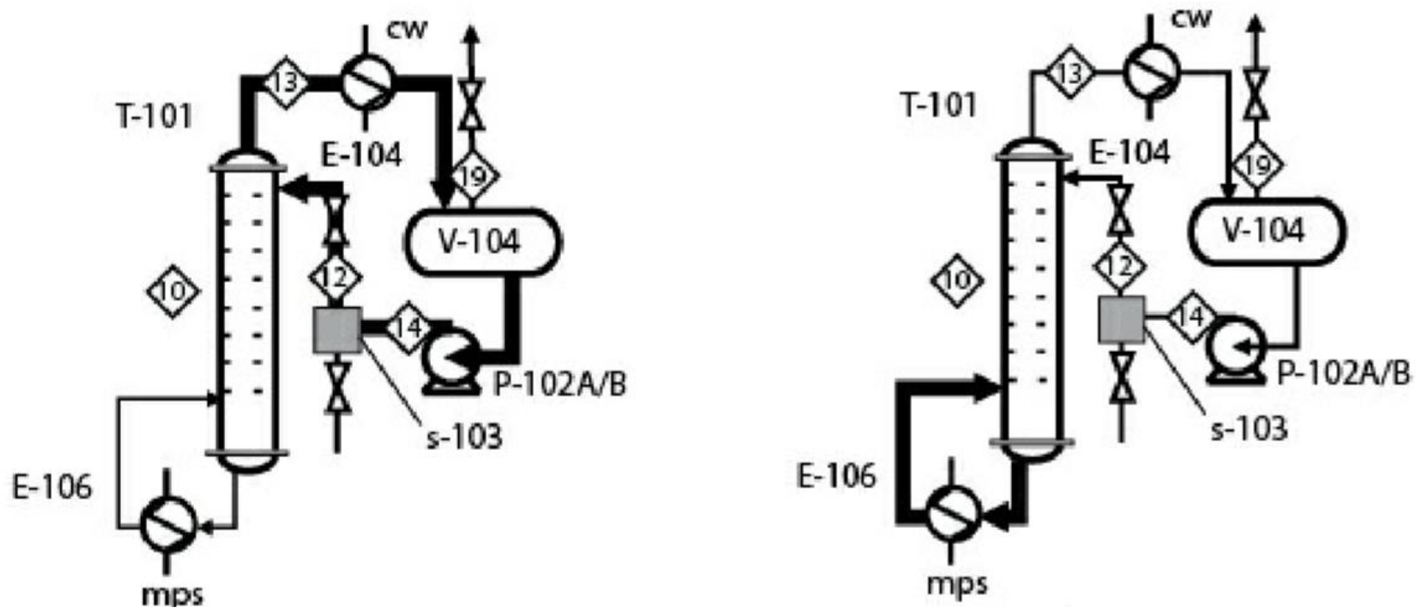
RECYCLE AND BYPASS STREAMS



Other Recycle Loops in Toluene Hydrodealkylation PFD

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Production of Benzene via the Hydrodealkylation of Toluene (HDA process)

Fresh toluene, Stream 1, is combined with recycled toluene, Stream 11, in the storage tank, V-101. Toluene from the storage tank is pumped, via P-101, up to a pressure of 25.8 bar and combined with the recycled and fresh hydrogen streams, Streams 3 and 5. This two-phase mixture is then fed through the feed preheater exchanger, E-101, where its temperature is raised to 225°C, and the toluene is completely vaporized. Further heating is accomplished in the heater H-101, where the temperature of the stream is raised to 600°C. The stream leaving the heater, Stream 6, enters the reactor, R-101, at 600°C and 25.0 bar. The reactor consists of a vertical packed bed of catalyst, down through which the hot gas stream flows. The hydrogen and toluene react catalytically to produce benzene and methane according to the following exothermic reaction:

$$\text{Reaction: } C_7H_8 + H_2 \rightarrow C_6H_6 + CH_4$$

The reactor effluent, Stream 9, consisting of benzene and methane produced from the reaction, along with the unreacted toluene and hydrogen, is quenched in exchanger E-102, where the temperature is reduced to 38°C using cooling water. Most of the benzene and toluene condenses in E-102, and the two-phase mixture leaving this exchanger is then fed to the high-pressure phase separator, V-102, where the liquid and vapor streams are allowed to disengage.

The liquid stream leaving V-102 is flashed to a pressure of 2.8 bar and is then fed to the low-pressure phase separator, V-103. The liquid leaving V-103, Stream 18, contains toluene and benzene with only trace amounts of dissolved methane and hydrogen. This stream is heated in exchanger E-103 to a temperature of 90°C prior to being fed to the benzene purification column, T-101. The benzene column, T-101, contains 42 sieve trays and operates at approximately 2.5 bar. The overhead vapor, Stream 13, from the column is condensed using cooling water in E-104, and the condensate is collected in the reflux drum, V-104. Any methane and hydrogen in the column feed accumulates in V-104, and these noncondensables, Stream 19, are sent to fuel gas. The condensed overhead vapor stream is fed from V-104 to the reflux pump P-102.

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The liquid stream leaving P-102, Stream 14, is split into two, one portion of which, Stream 12, is returned to the column to provide reflux. The other portion of the condensed liquid is cooled to 38°C in E-105, prior to being sent to storage as benzene product, Stream 15. The bottoms product from T-101, Stream 11, contains virtually all of the toluene fed to the column and is recycled back to V-101 for further processing.

The vapor stream leaving V-102 contains most of the methane and hydrogen in the reactor effluent stream plus small quantities of benzene and toluene. This stream is split into two, with one portion being fed to the recycle gas compressor, C-101. The stream leaving C-101 is again split into two. The major portion is contained in Stream 5, which is recycled back to the front end of the process, where it is combined with fresh hydrogen feed, Stream 3, prior to being mixed with the toluene feed upstream of E-101. The remaining gas leaving C-101, Stream 7, is used for temperature control in the reactor, R-101. The second portion of the vapor leaving V-102 constitutes the major portion of the fuel gas stream.

This stream is first reduced in pressure and then combined with the flashed vapor from V-103, Stream 17, and with the noncondensables from the overhead reflux drum, Stream 19. The combination of these three streams is the total fuel gas product from the process, Stream 16.