

The Right and the Wrong – Two Process Design Optimization Examples

What case study story would be complete
without spraying diesel out on the unit?

James Turner
Fluor Enterprises, Inc.

STS AIChE

Oct. 4, 2012



FLUOR[®]

Safety Moment



NEWSFLASH – On November 8, 1999, a refinery storage tank near Catlettsburg, KY ruptured, spilling ~285,230 gallons of petroleum distillate (gas oil) into a tributary of the Big Sandy river. Some of the gas oil was entrained with steam escaping the tank and “rained” down on the surrounding community.

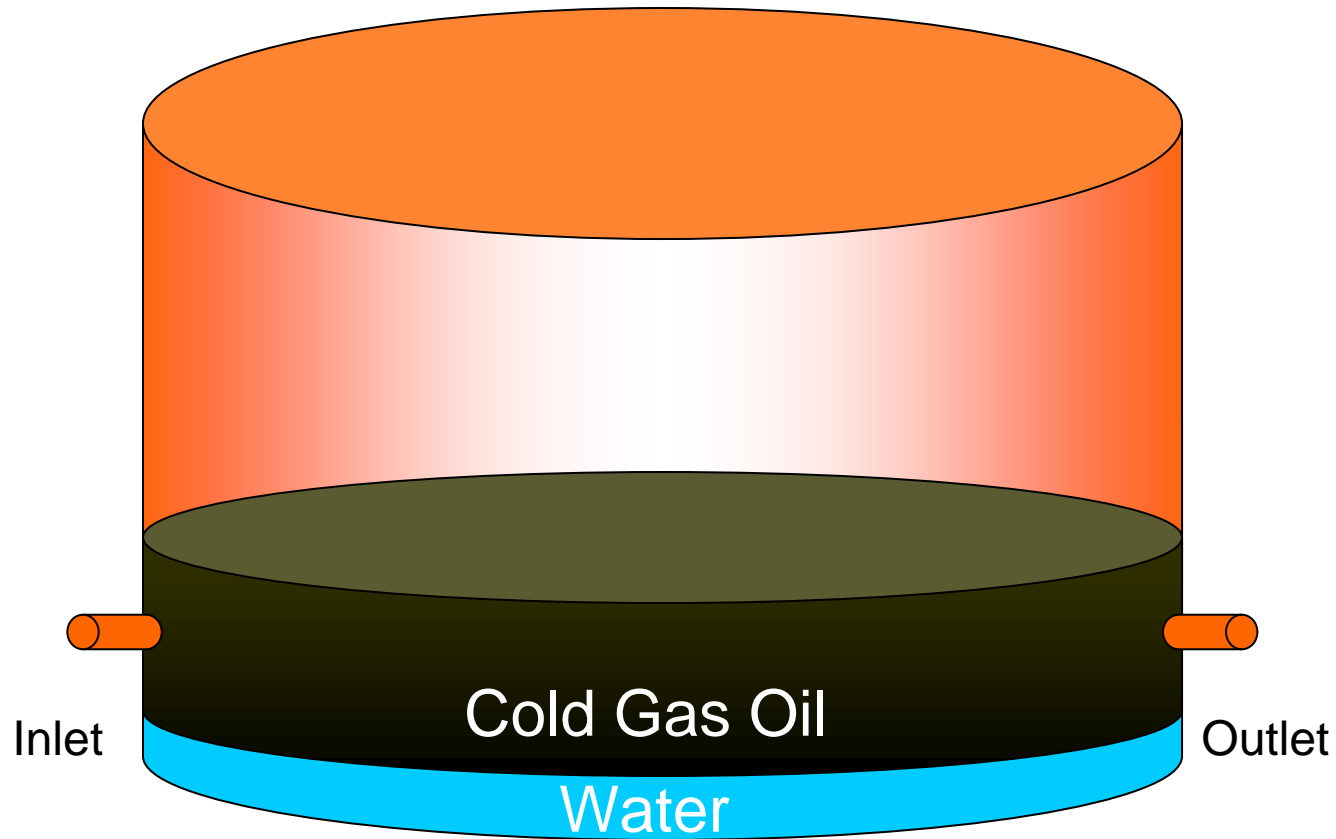


Why did this happen?

What made the situation worse?

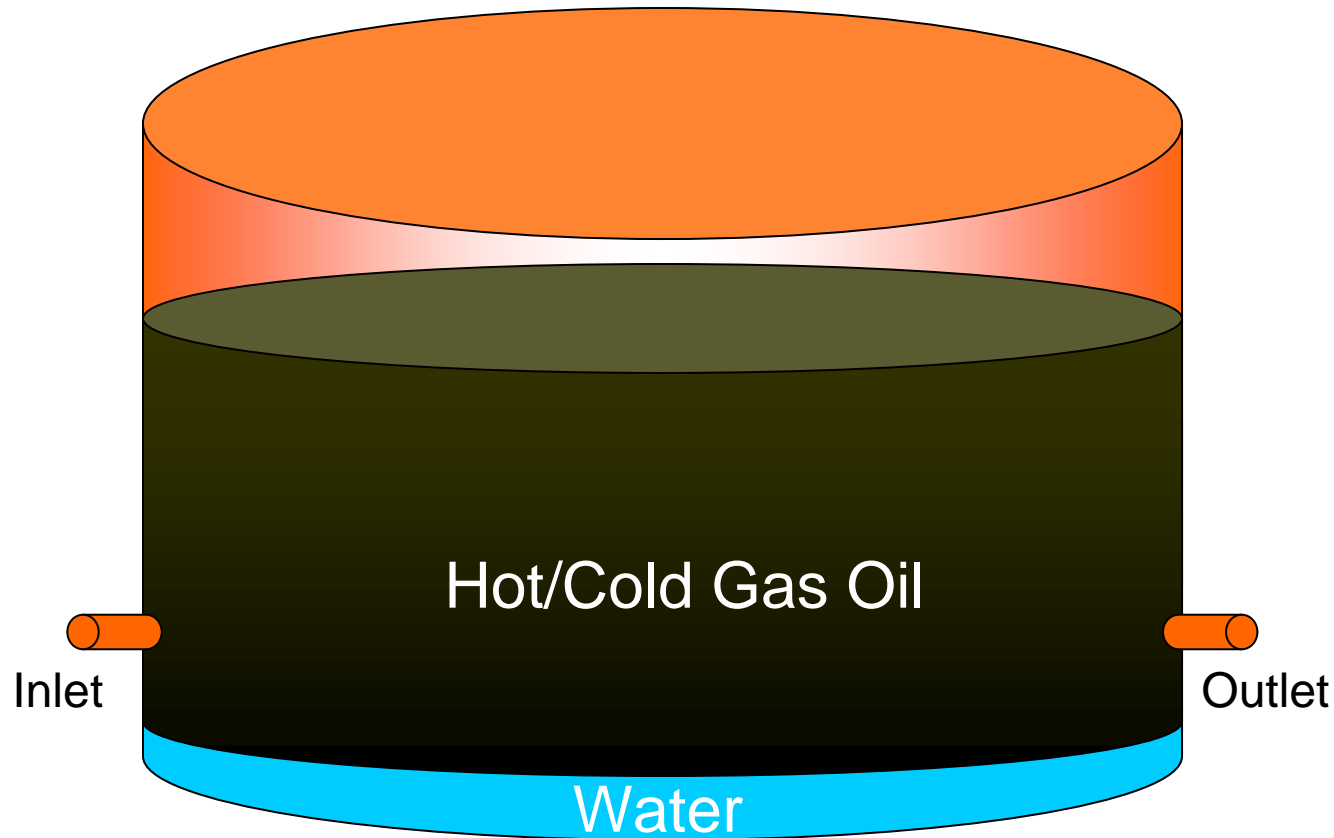
How could it have been prevented?

Safety Moment



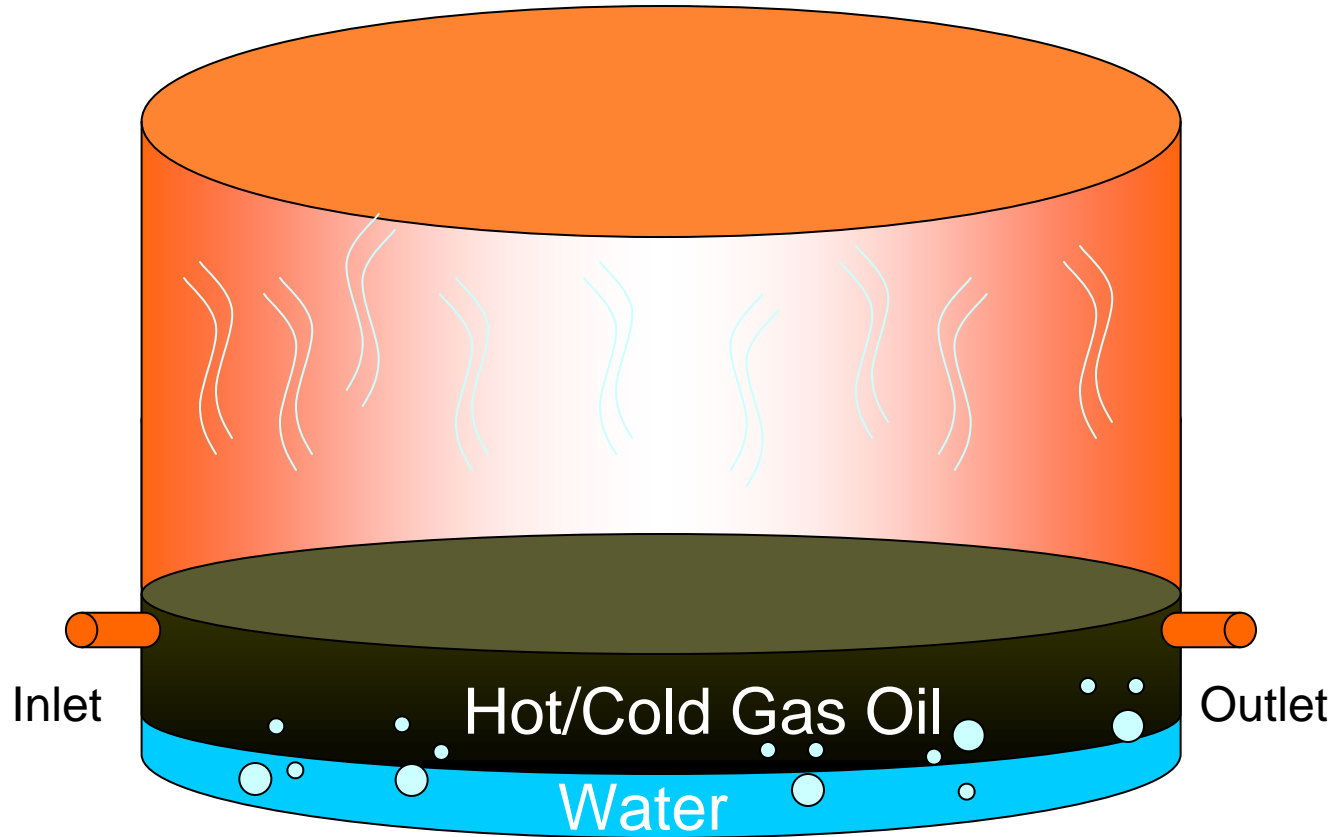
Normal Operation – 150-180°F Gas Oil

Safety Moment



Operations ran down hot gas oil from unit to tank, which mixed with cold gas oil – combined temp ~ 215-230°F

Safety Moment



As gas oil was pumped out, hot gas oil caused water to vaporize, raising pressure in tank, causing the side of the tank to rupture.

Safety Moment



Summary – Hot oil and water do not mix well!

Takeaways –

Good understanding and proper execution of operating procedures is required for safe operation.

Additional instrumentation and interlocks could be used to provide more layers of protection.

Sometimes what “makes sense” to do is the opposite of what should be done.

Refinery ARDS Licensor Selection

- ◆ Middle East NOC plans to build a major new refinery
- ◆ Late November 2005 – Fluor hired as PMC for this project



FLUOR[®]

Refinery ARDS Licensor Selection



ARDS – Atmospheric Resid Desulfurization

- ◆ In a planned new refinery, the ARDS units are the centerpiece of the refinery
 - Primary refinery product is desulfurized fuel oil
 - It has been said that all other units are pre-treatment or post-treatment of the ARDS unit feed and products
- ◆ Catalyst volume, and therefore \$\$, are huge!
- ◆ This project is by a factor of 8 the largest single ARDS commitment in history, and will represent over 20% of the world ARDS capacity since the beginning of time.

Refinery ARDS Licensor Selection



- ◆ All licensors are major corporations, that have well connected representatives in the client country, and all of them really wanted this business
 - One licensor fairly dominant in last 25 years – this project would put any of the other three “on the map”
- ◆ This was the first award in the overall project program, which includes over 600 MBPD capacity of other licensed units

In summary – this was a big deal!

Refinery ARDS Licensor Selection



- ◆ Late November 2005 – Fluor hired as PMC for this project
- ◆ James Turner appointed as ARDS Licensing Manager



ARDS Licensor Selection Activities



- ◆ ITB Issued by Client (before Fluor is hired)
- ◆ Developed Licensor Selection Plan, including licensor scoring table (reviewed with and issued to client)
- ◆ Met with Licensors and Client
- ◆ Client ARDS Licensor Selection Committee formed
- ◆ Responded to Licensor Questions (sent answers to all)
- ◆ Finalized Unit Feed Basis
- ◆ Planned visit to Licensee Operating Units
- ◆ Prepared Questions for Licensees

ARDS Licensor Selection Activities



- ◆ Received Licensor Bids
- ◆ Prepared questions/requests for clarifications
- ◆ Licensors allowed to adjust proposals based on issues raised in discussions
- ◆ Prepared “normalized” equipment lists
- ◆ +/-40% estimates prepared for each licensee
- ◆ Economics (NPV) of each design estimated
- ◆ Prepared preliminary Licensor Scoring Tables

ARDS Licensor Selection Activities



- ◆ Visited licensees and reviewed Q&A
- ◆ Scoring tables reviewed by Licensor Selection Committee
- ◆ Proposed contract terms reviewed and discussed with Licensors and Client Attorneys
- ◆ ARDS Licensor Selection Team agreed on recommendation & prepared presentation for Board
- ◆ Client began final negotiations with selected licensor

ARDS Licensor Technology



Licensor Technology Highlights

L1	L2	L3	L4
“Permutable” Guard Bed Reactors	1 st Reactor is Upflow Reactor “CUT” Unloading Technology	Graded Bed Experience “Drill & Drop” Unloading Technology	By-passable Guard Bed

ARDS Licensor Technology



Licensor Optimization Required

L1	L2	L3	L4
None attempted (design not competitive)	Original proposal was one “mega-unit”	Original proposal would not meet product specifications	Original proposal had very large reactors – not competitive

* Licensors not in same order as previous slide

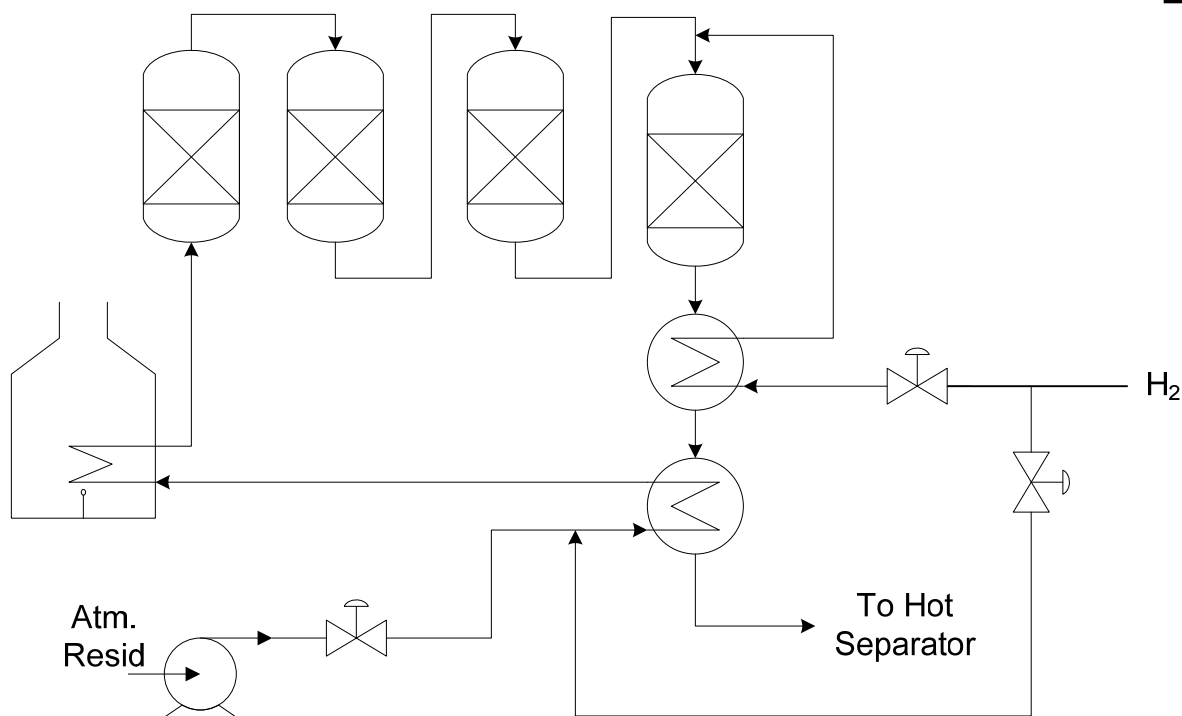


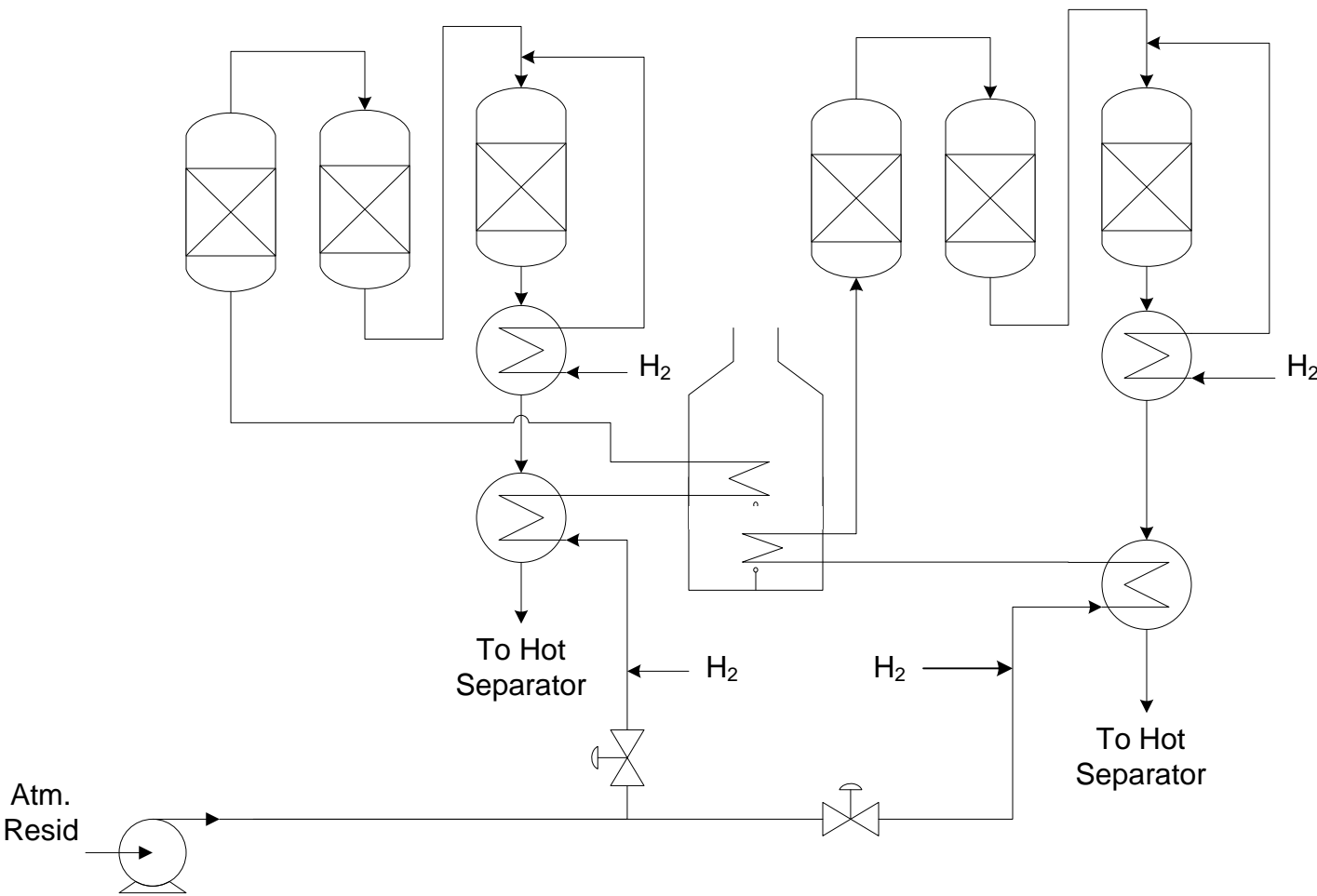
ORIGINAL CONFIGURATION

One of six 55,000 BPD Trains

Reactor Size (meters)

<u>Diameter</u>	<u>Height</u>
6.0	16.2
5.5	19.1
5.5	19.1
5.5	19.1





**Two parallel trains of 3
Reactors in series**

Reactor Size (meters)

<u>Diameter</u>	<u>Height</u>
4.5	14.9
4.5	19.8
4.5	23.0

**REVISED
CONFIGURATION**

FLUOR®

ARDS Licensor Selection

- ◆ After much internal discussion, Client decided to evaluate based on optimized design and one licensor scored the highest and was selected.



Comments/Lessons Learned



- ◆ All licensors needed “help” to optimize their design to meet project requirements in best way
 - While they are experts in their process, they may not truly understand project requirements or equipment economics
- ◆ Political and relationship issues may be as important than technical issues in managing licensor selection
- ◆ After any game where a winner is selected, someone will be unhappy

Comments/Lessons Learned



- ◆ All licensors needed “help” to optimize their design to meet project requirements in best way
 - While they are experts in their process, they may not truly understand project requirements
- ◆ Political and relationship issues may be as important than technical issues in managing licensor selection
- ◆ After any game where a winner is selected, someone will be unhappy

This is not a reason to not play the game!

Diesel Hydrotreater Revamp

A Diesel Hydrotreater was revamped for higher capacity

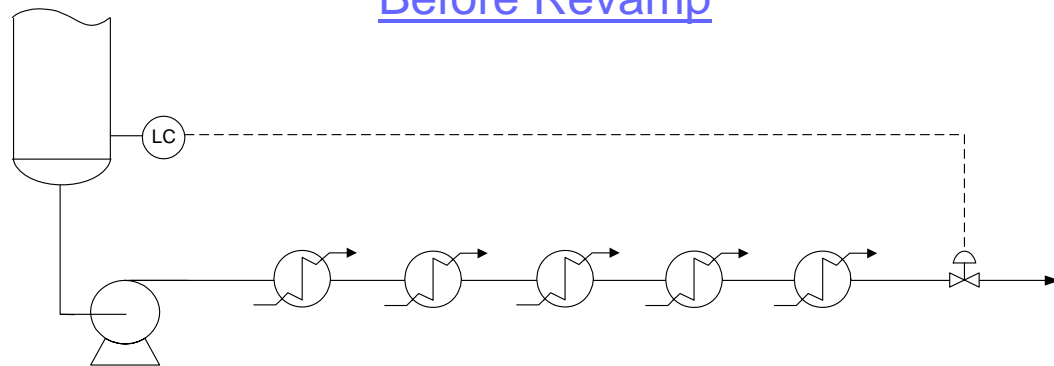
The product rundown circuit was modified with the ability to isolate one train for cleaning

The original design intent apparently was that the exchangers were designed for pump “shut-in” – there were no PSVs in the circuit

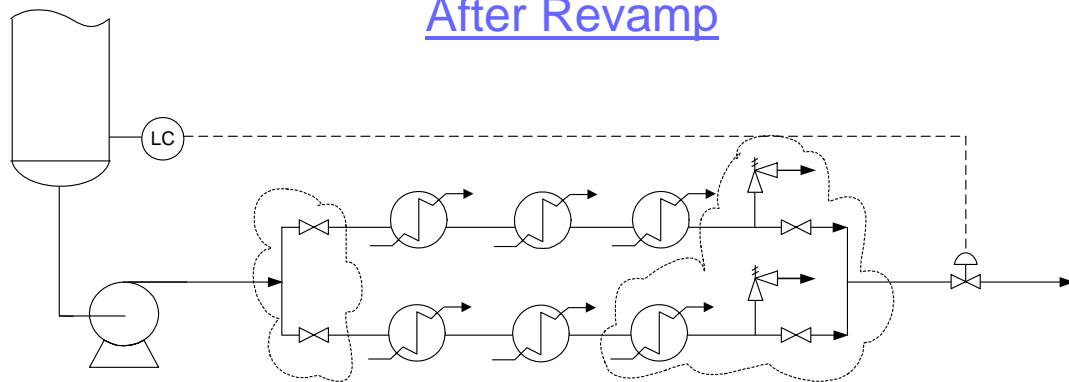
New PSVs to the flare were added to protect against a fire scenario while one train is blocked in for cleaning

FLUOR

Before Revamp



After Revamp



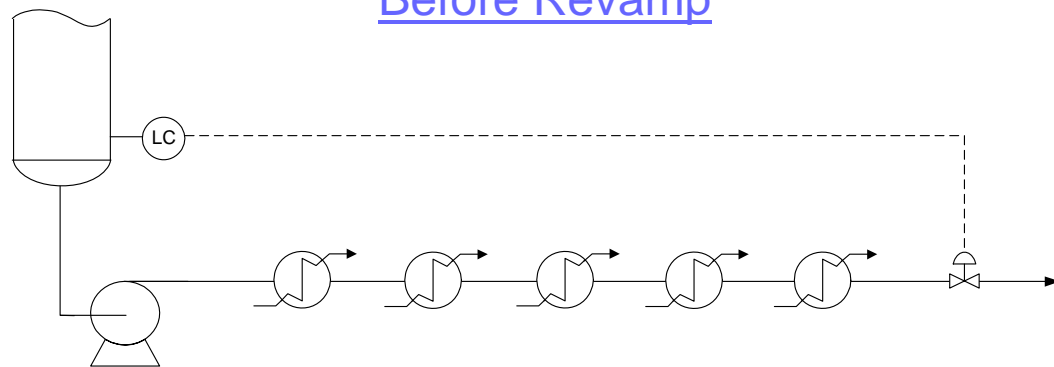
Diesel Hydrotreater Revamp



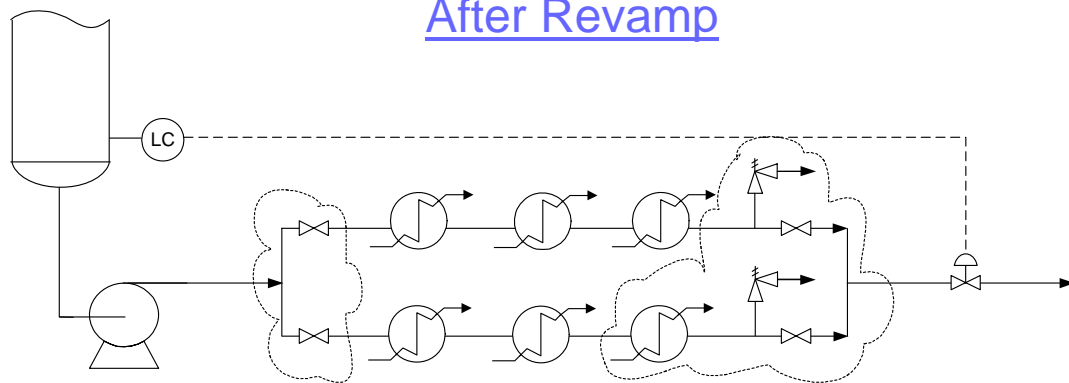
During start-up, the PSVs lifted. The relief valves chattered and the piping ruptured, spraying diesel across the unit

The startup was aborted, and there was no major damage or injuries

Before Revamp



After Revamp



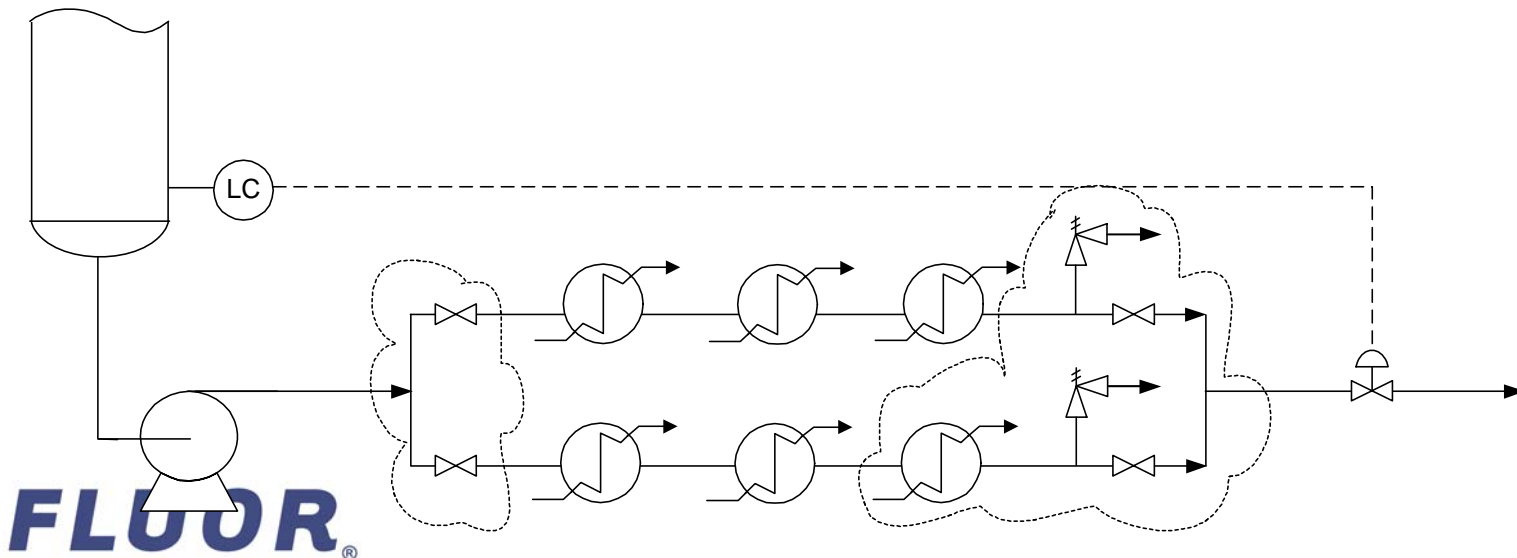
Diesel Hydrotreater Revamp



- The system was designed for “shut-in pressure” with a diesel specific gravity of 0.65
- At startup, cold diesel is circulated, and the actual specific gravity is 0.81

Normal Pump Discharge Pressure: 180 psig
Normal Shut-in Pressure: 220 psig
Exchanger Design Pressure: 225 psig

Pump Discharge Pressure with Cold Diesel: 249 psig

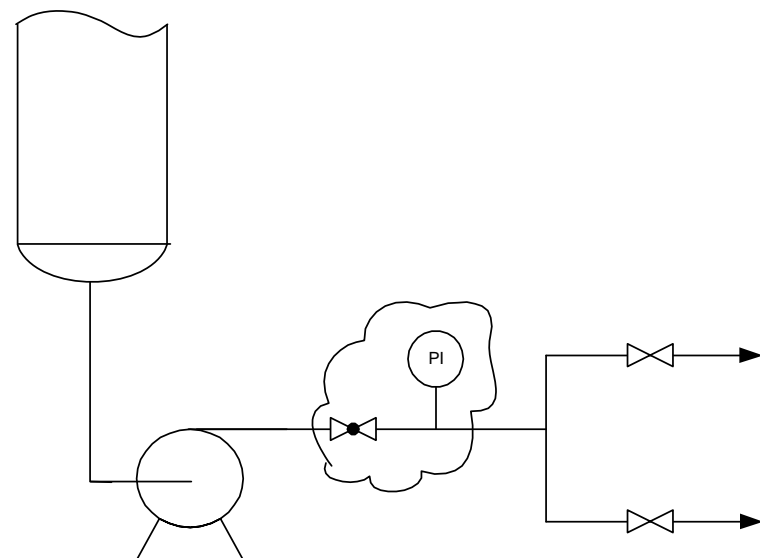


Diesel Hydrotreater Revamp



Engineering Solution:

Add a globe valve followed by a PI, to be used to manually throttle the pressure before the exchangers during start-up



Lessons Learned:

- Revamps often encounter situations where the existing design did not properly consider all operating scenarios.
- Pumps and downstream equipment should be checked for cold flow and high density cases.
- PSVs and associated piping should be designed for a liquid relief case if the normal service is liquid, even if a liquid relief case is not readily identified.

Conclusion

One engineer – Many stories



I bet a lot of you have interesting stories as well

Questions / Comments



H2S Stripper that didn't Strip H2S

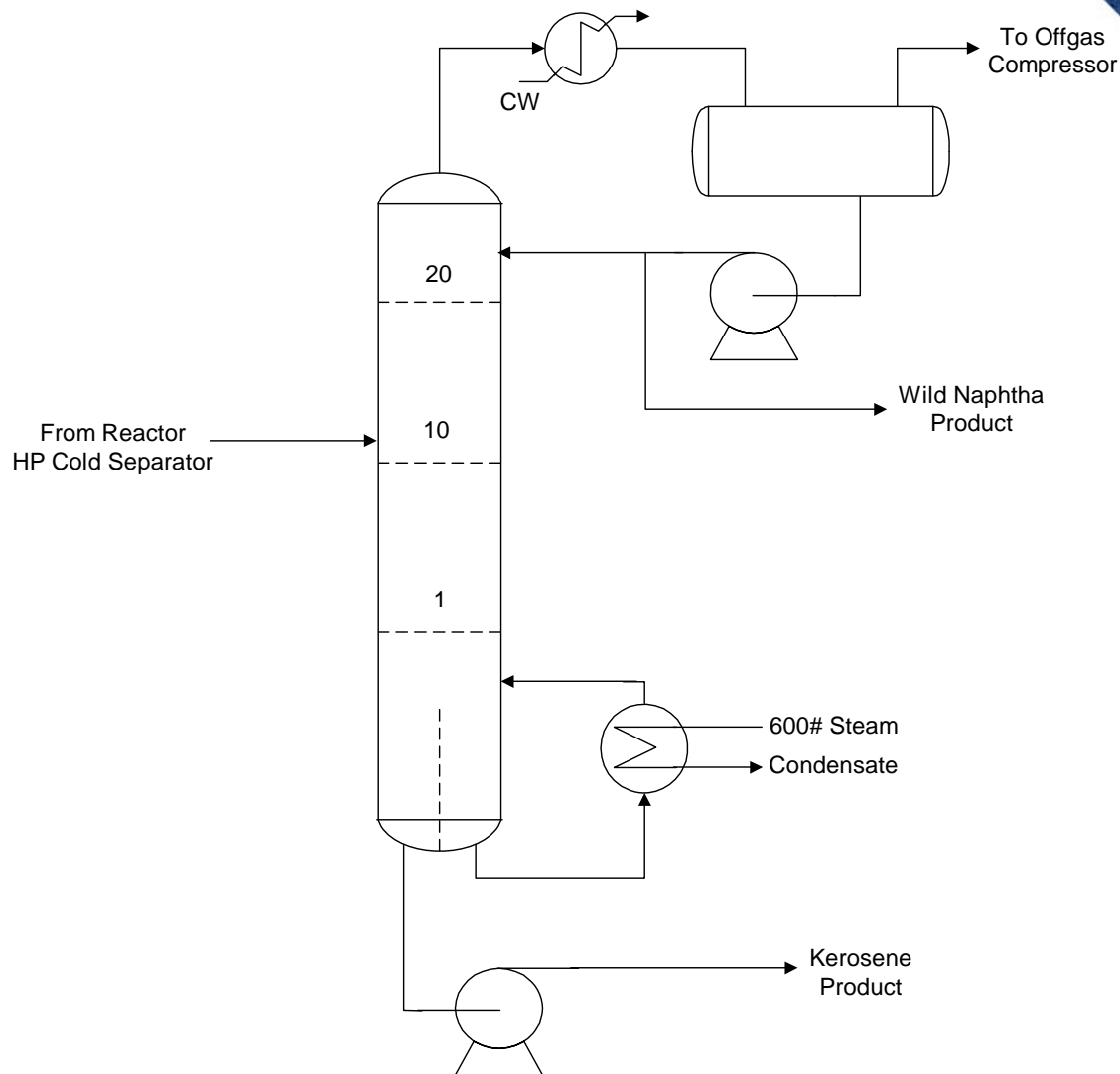


- ◆ In 1990, I was Lead Process Engineer on two hydrotreater revamps for a midwest refinery, as part of an overall refinery re-configuration
- ◆ One hydrotreater revamp was converting a 3 MBPD Naphtha Hydrotreater to a 7 MBPD Kerosene Hydrotreater
- ◆ After startup, the product H2S Stripper was not successfully removing all of the H2S

H2S Stripper that didn't Strip H2S



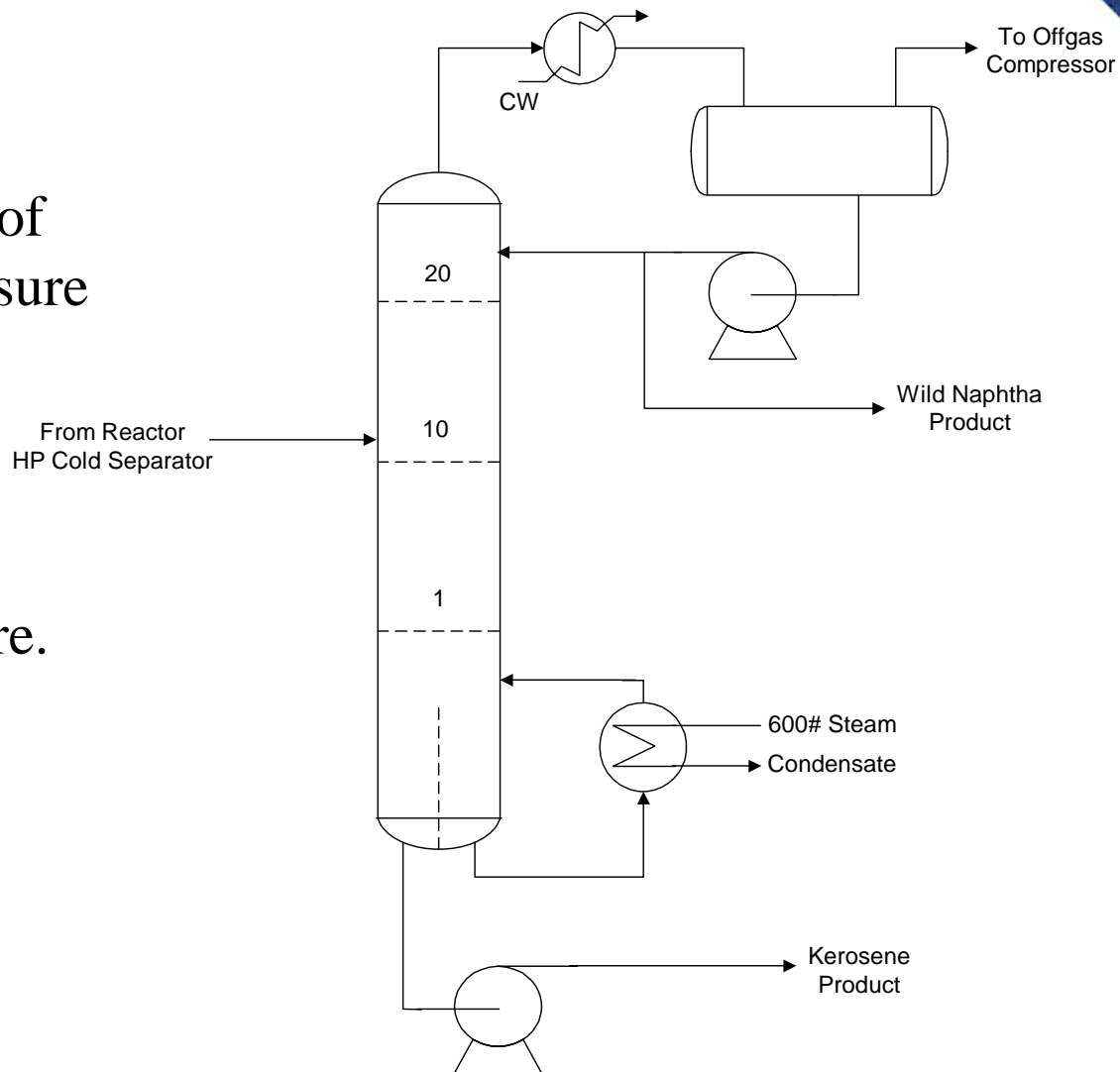
- At start-up, the Stripper was not removing all the H₂S.
- With Fluor assistance the stripper could meet the specifications at reduced rate “most of the time” - but was very sensitive to operational upsets.



H2S Stripper that didn't Strip H2S



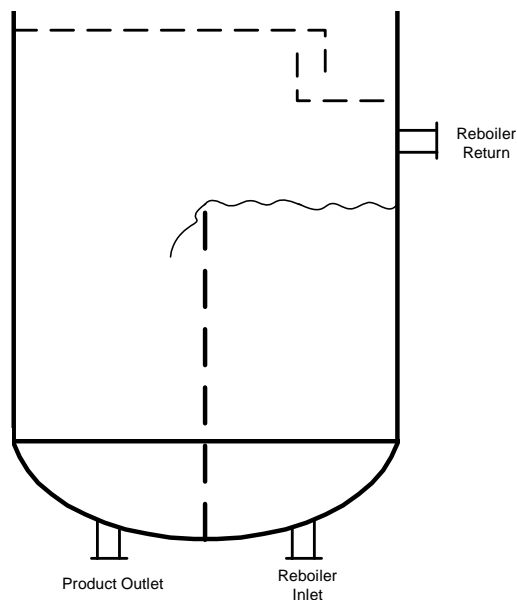
- Design Basis had a minimum steam pressure of 600 psig – but actual pressure was 585 psig.
- Tower overhead pressure drop was slightly higher than predicted, raising the reboiler operating pressure.



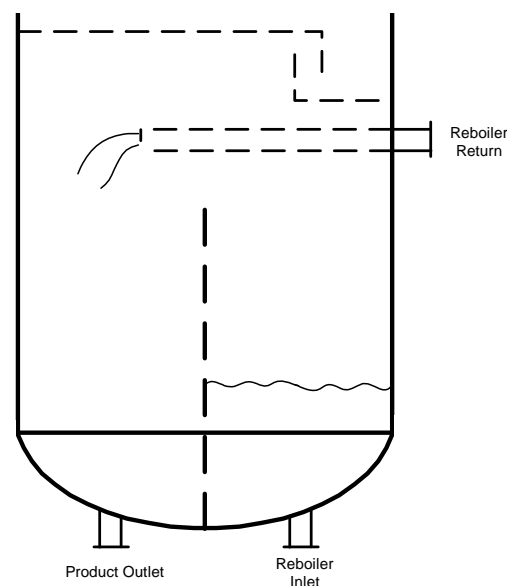
H2S Stripper that didn't Strip H2S



Recirculating
Thermosiphon



Once-through
Thermosiphon



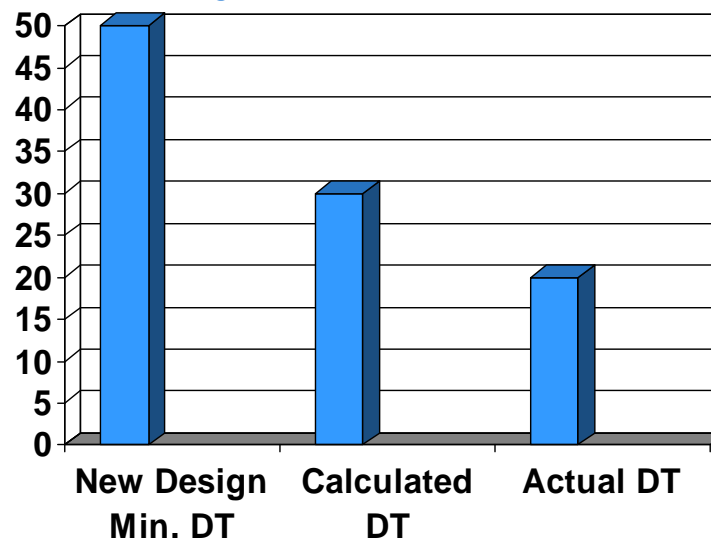
Existing Tower/Reboiler design was a recirculating thermosiphon – this means that the reboiler is at a higher pressure than the tower due to the liquid static head.

H2S Stripper that didn't Strip H2S



The three factors caused a “pinch” on exchanger temperatures, making the available exchanger surface area inadequate

Reboiler Temperature
Driving Force, °F



The existing trays were checked during design by the vendor, and considered OK, but in reality, they were very sensitive to vapor rate, and would weep at rates just below the design rate.

H2S Stripper that didn't Strip H2S



Possible Solutions:

- ◆ Scrap the exchanger and install a new fired heater
 - Costly – and would take a long time to implement.
- ◆ Stick with exchanger, but consider the following:
 - Replace trays
 - Modify baffle to convert reboiler to once-through (lower reboiler pressure)
 - Replace reboiler bundle with finned bundle to improve heat transfer

H2S Stripper that didn't Strip H2S

- ◆ Client decided to stick with exchanger and implement all three proposed modifications.
- ◆ Stripper worked fine after modifications installed.



“Lessons Learned”



- ◆ Sometimes, everything that can go wrong, will go wrong.
- ◆ Sometimes little things can make a big difference. Details matter.
- ◆ Need to properly document possible design issues during Design Phase. The tightness of the reboiler design was known in advance by Fluor, but not documented in writing to client – we could have pulled the client into the design decisions in advance.
- ◆ Hydraulics on thermosiphon reboiler designs on low pressure columns should be checked for impact to equilibrium flash, not just for hydraulic driving force.

Hydrotreater Hot Separator Problem Solved

James Turner



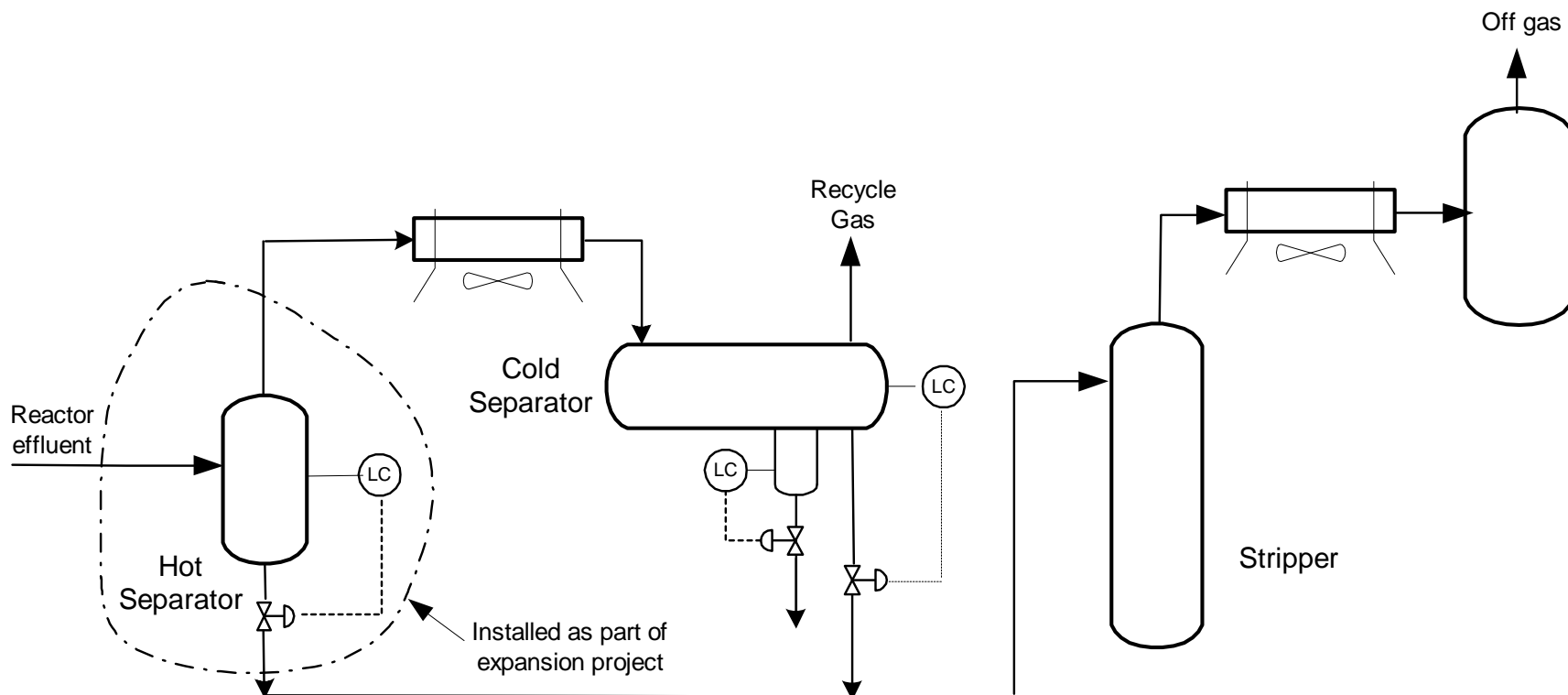
FLUOR®

Hot Separator Problem - 1998

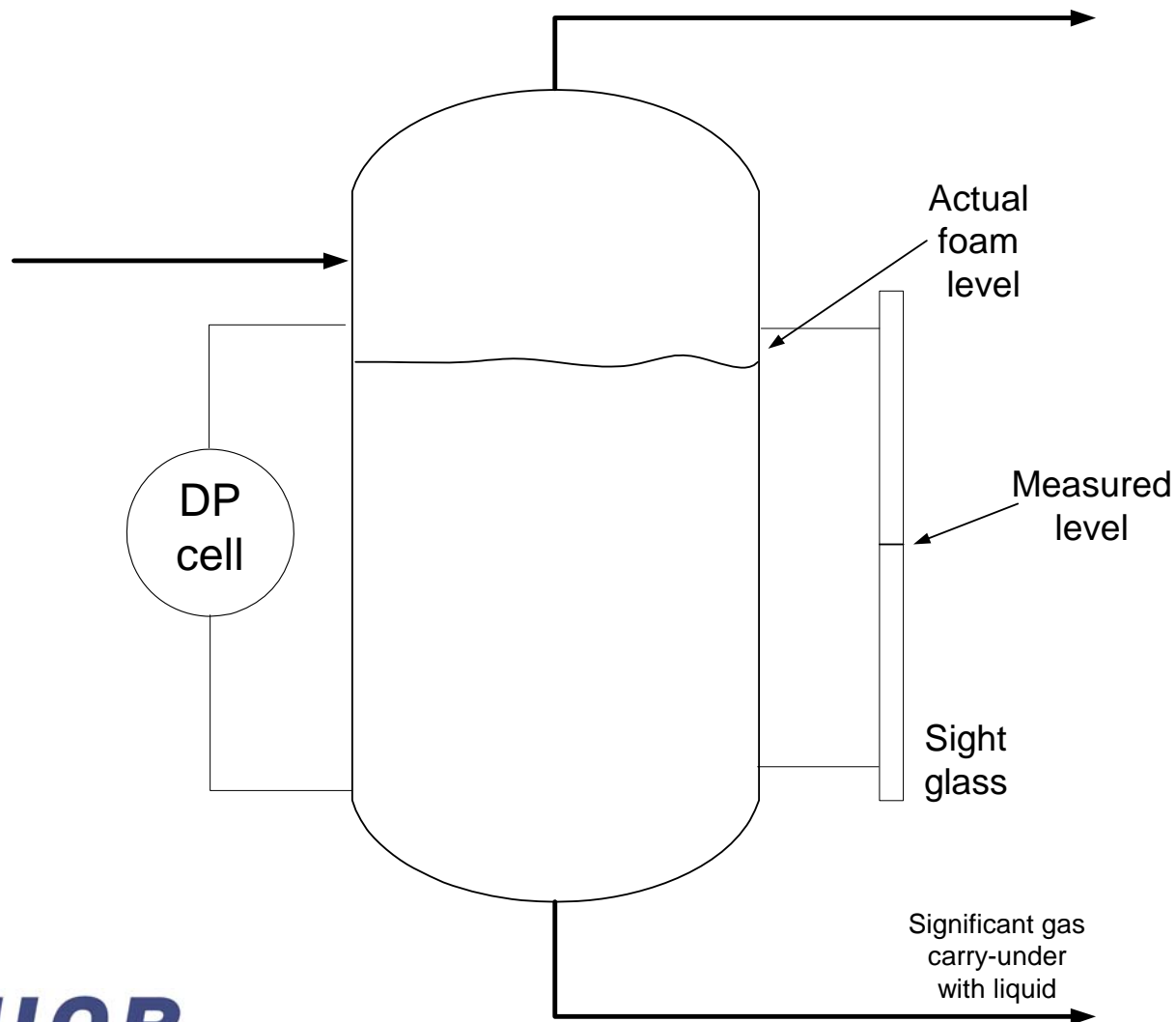


- ◆ Designed a gas oil hydrotreater Hot Separator for a major unit Gulf Coast refinery
- ◆ Unfortunately, it didn't separate!
 - Major hydrogen carry-under out the bottom with the liquid
 - Vessel was full of dense foam – therefore level guage was incorrect
 - Operations didn't know it, raised the level above the vessel inlet, causing massive carry-over
 - Operations failed to respond to the rising level in the downstream vessel, leading to a “series of unfortunate events” culminating in shutting the whole refinery down
- ◆ On top of unplanned refinery shutdown, problem was costing refiner ~\$0.5 MM/month in lost profits

Hot Separator Problem



Hot Separator Problem



Hot Separator Problem



- ◆ This led to a high level collaboration between Fluor and Client Management, resulting in my relocation to the refinery “until an agreeable path forward could be determined”
- ◆ This was a “high profile” opportunity, so I was motivated to perform
- ◆ I led a three pronged study to determine:
 - Impact of Process Variables on Separator Performance
 - Survey of Other Refineries with Similar Units
 - Potential Alternative Vessel Designs/Modifications

Data Correlation “solutions”



Remove resid material in feed	Not economic to remove
Lower liquid velocity	Would require significant throughput reduction
Increase operating temperature	Small improvement – higher increase not practical for heat integration and metallurgy impacts
Remove trace impurities	Trace impurities not present in unusual levels
Lower piping velocity	No improvement observed – not economical

Hot Separator Problem



- ◆ Result of data gathering – no practical solution by manipulating process conditions
- ◆ Industry survey found no problems with refiners that have horizontal separators
- ◆ one refiner that had solved a similar problem by install vendor inlet internals
- ◆ My recommendation was to install vendor internals to improve the separation
 - Industry experts that were consulted said it wouldn't work

“Vortex Cluster”



FLUOR®

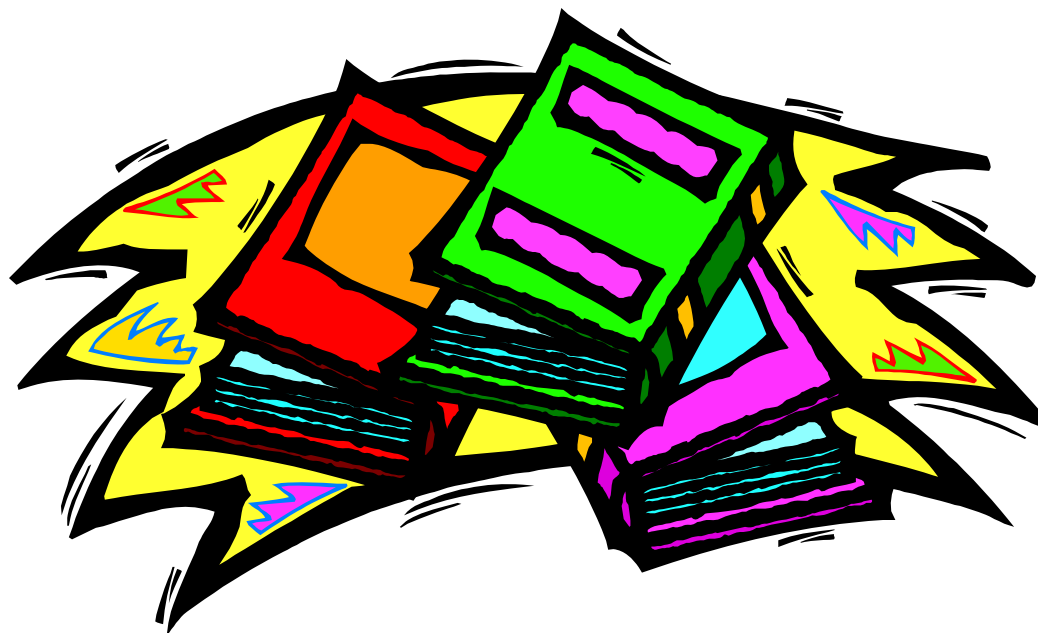
Hot Separator Problem



- ◆ This was the first time that Fluor had tried this type of internals in this service -
 - Fortunately, it worked very well!
- ◆ Fluor has done many other projects with this client since (including more than one multi billion project)
- ◆ These internals have been subsequently used in several similar situations, all with good success
- ◆ Recently, these internals were used for the first time in a Crude Unit Preflash Column
 - They also worked very well in this application.

Reference Article

“Stop foaming on hydrotreater hot separator”,
J. Turner, J. Asquith, R. Atkinson, Hydrocarbon
Processing, June 1999



Lessons Learned



- ◆ Hydrogen and Heavy Oil can cause difficult foaming issues
- ◆ “Experts” may not know all there is to know
- ◆ By surveying other operations, good solutions may be found
- ◆ Vendor systems typically used in one industry may be very useful in other industries
- ◆ “crisis” = dangerous opportunity