KLM Technology Group

Practical Engineering Guidelines for Processing Plant Solutions

Design Guidelines for Distillation Revamps

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C. Process Simulation

D. Rate the Existing Equipment

E. Equipment Design

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Introduction

Successful revamps generally have several key steps.

1. **The first step is a high load test to accurately determine the existing distillation equipment's available capacity.**

2. **The second step is to reconcile the data gathered in the high load test by a heat and material balance. This normally utilizes distillation software such as PROII.**

Introduction

3. The third step is with the reconciled data, rate the existing equipment verses it's designed and target values.

4. The fourth step is to select the key items to be upgraded with the maximum return on investment.

Introduction

5. The fifth step is to design and manufacture the key items selected.

6. The sixth step is to inspect the installation of the key items to be upgraded.

7. The seventh step is to safety commission the key equipment.

New Plant Cost Benchmark

Keep in mind that operational plants have an original capital value per yearly production.

For example, a new ethylene plant ISBL (inside the battery limit not including utilities and tank farms) might have a cost of US$ 400.00 per KTA (thousand metric tonnes per annum).

A new 300 KTA ethylene plant would then cost US$ 120,000,000.

To be cost effective, a revamp should have less cost, than the cost per tonne of a new plant.

With the proper selection of key items this can easily be accomplished, while also improving the life cycle cost.

Life cycle cost includes original capital, energy, operation, and maintenance costs over a typical life span of 10 years.

Step No. 1 – High Load Test

Planning and executing a high load test is a critical part of any successful revamp.

It can identify and / or eliminate key equipment to be replaced or retained.

Completion of an accurate high load test can simplify the steps which follow, with the ultimate result – a successful revamp.

High Load Test Objectives

There are many reasons to revise a distillation system. Capacity could certainly be one of them. However – It is important to identify the most important objectives:

- **Operability?**
- **Improved reliability?**
- **Reducing and or eliminating an environmental impact?**
- **Improved system safety?**
- **Better product purities or the need for new products?**

Objectives

The most common reason cited is to increase capacity. The incremental cost of producing a unit of product goes down with higher throughput and profits increase significantly.

Return on investment is usually quite high for capacity increases and typically exceeds the ROI of any other objective.

High Load Test Team

The success of most endeavors is based upon the quality of the team of individuals that are assembled for the project.

A multidiscipline team needs to be established to plan and executed the high load test.

The team should include people from operations, maintenance, laboratory, safety, process and distillation engineers.

It is important with the team that you listen carefully. The operations and maintenance personnel have the most experience with the equipment and the most information about the unit.

You must learn the art of extracting details from these vital sources. They will be truthful and helpful, even thought they speak a different technical language.

High Load Test Preparation

- Do a Quick Review of the current operating data.
- Check this data against original Design and find out why things are different
- Do a P&ID walk down – look for changes in the field and check accessibility of instruments.

Work up a list of Available Measurements

Item Tag Number: DIB Tower T-421

Date: ____________________

Time: ____________________

Description	Measurement	Tag No.	Units	Value
Feed From Butamer	Liquid Flow	FV-4621	BBL/D	
	Temperature	TE-4521	°F	
	Pressure**	PI-4685	PSIG	
	Composition	Analyzer	Mole %	
Feed From Depropanizer	Liquid Flow	FE-4428	BBL/D	
	Temperature	TE-4527	°F	
	Pressure	PI-4477	PSIG	
	Composition	Sample	Mole %	
135 psi Steam	Flow	FE-4429	LB/Hr	
	Temperature	Local	°F	
	Condensate Temp	Local	°F	
Tower	Top Temperature	TE-4510	°F	
	Top Pressure	PIC 4483	PSIG	
	Bottom Temperature	TI-4517	°F	
	Bottom Pressure	PI-4481	PSIG	
	Delta-P	None	PSI	
	Sight Glass		%	
Reflux	Drum Pressure	PI-4479	PSIG	
	Temperature	TI-4511*	°F	
	Temperature	Local at tower	°F	
	Flow	FE-4430	BBL/D	
i-Butane Product	Flow	FE-4431	BBL/D	
	Temp	TE-4513	°F	
	Composition	Analyzer	Mole %	
n-Butane Product	Flow	FE-4001	BBL/D	
	Temp	TE-4517	°F	
	Composition	Sample***	Mole %	

This is to establish a Heat and Material Balance around the Distillation unit

Data Collection

The largest source of error on most distillation columns is with the pressure.

Where possible install a pressure gage at the pressure transmitter for verification.

For vacuum systems utilize a mercury manometer.

Data Collection

When possible always double check the data.

Temperature can be confirmed with a pyrometer gun.

Pressure can be confirmed with separate pressure gauges.

On-stream analyzers can be checked with extra lab samples.

Data Collection - Samples

Samples of the products should be taken where the process stream is sure to be one phase.

Samples should be taken in the well mixed part of the process:

For liquids, samples should be taken following pumps, control valves, or in bends.

Vapor samples from a distillation column need to be taken where there is little chance of entrained liquid.

The High Load Test

The 2nd most important thing to remember for a high load test is what is your objective:

If you are looking for improved capacity? This test had better be at your maximum documented throughput.

If you are looking for improved reliability, better purities, improved safety or other reasons then this test should not be "pushing" the capacity limit.

Step No. 2 - Preliminary Data Analysis

To obtain a heat and material balance on the column is not a simple task.

In most cases commercial columns are not instrumented well enough to check the heat and material balance by independent measurements on all streams, sometimes even the major streams are not measured.

In other cases it will be necessary to use a "reasonableness" test.

If the overall flow rates and component balances match within 10%, this data can be utilized.

Process simulation is a powerful chemical engineering tool that has wide spread use in the chemical processing industry.

Utilized correctly it can help design, optimize and troubleshoot process units, when you follow guidelines developed from the fundamental basics of chemical engineering.

It is important to remember that machine calculations are for the purpose of improving only the speed of the calculation.

Despite rapid progress in computational speed and user friendly interfaces, understanding the rules and limitations of simulation tools is still a prerequisite to obtain simulated results close to those measured in the field.

The engineer needs to supply the correct input data, interpret errors that occurred and make critical judgment on the results.

Mastering these techniques often requires substantial field experience and practice.

Data Analysis - Hydraulics

Check the capacity calculations in PRO-II.
They can give you an idea that you are close to or far from maximum capacity.

Also check the internal loads you get from your simulation against the original design rating sheet for the tower.

Finally – if this does not satisfy you (i.e. the column is near flood but all the above says the tower is way oversized) get in touch with the original vendor (or whoever owns them today). Check their software visit their website etc.

Choose what needs changing

Use economics to decide what units need changing, upgrading, replacement or additions.

Let us look at a case example.

An Ethylene Unit in Malaysia wished to convert a Gasoline Hydrotreater Stabilizer Column to a DePentanizer Column operation.

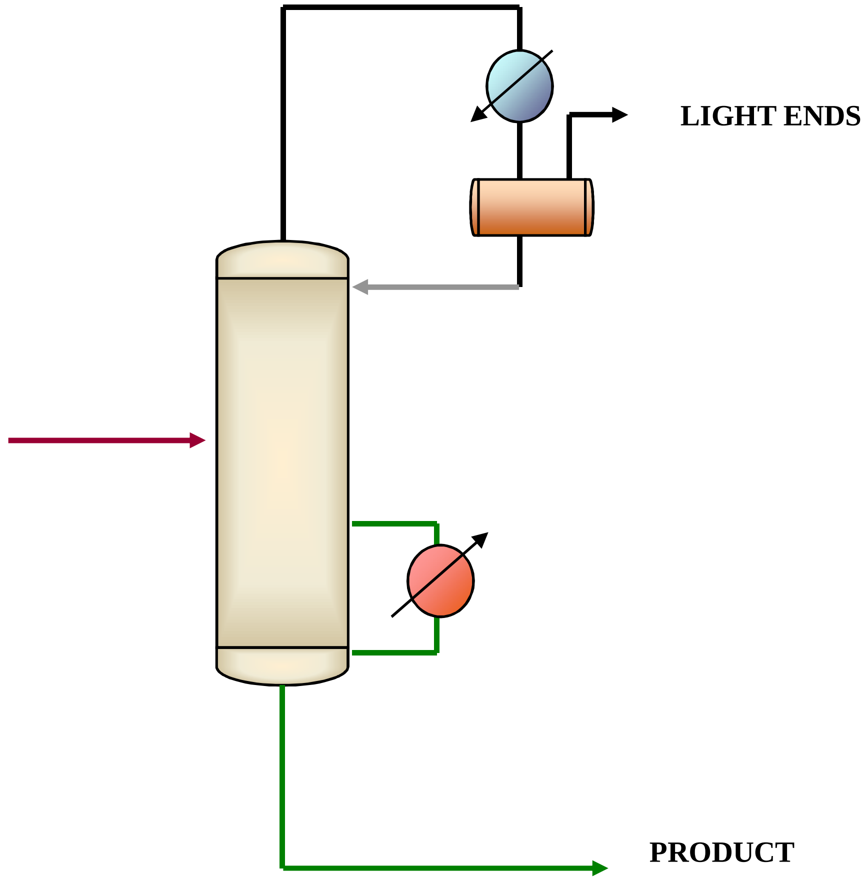
The Stabilizer was designed to remove C4s and lighter hydrocarbons.

They now wished to remove C5s and lighter hydrocarbons, while minimizing benzene loss in the overhead.

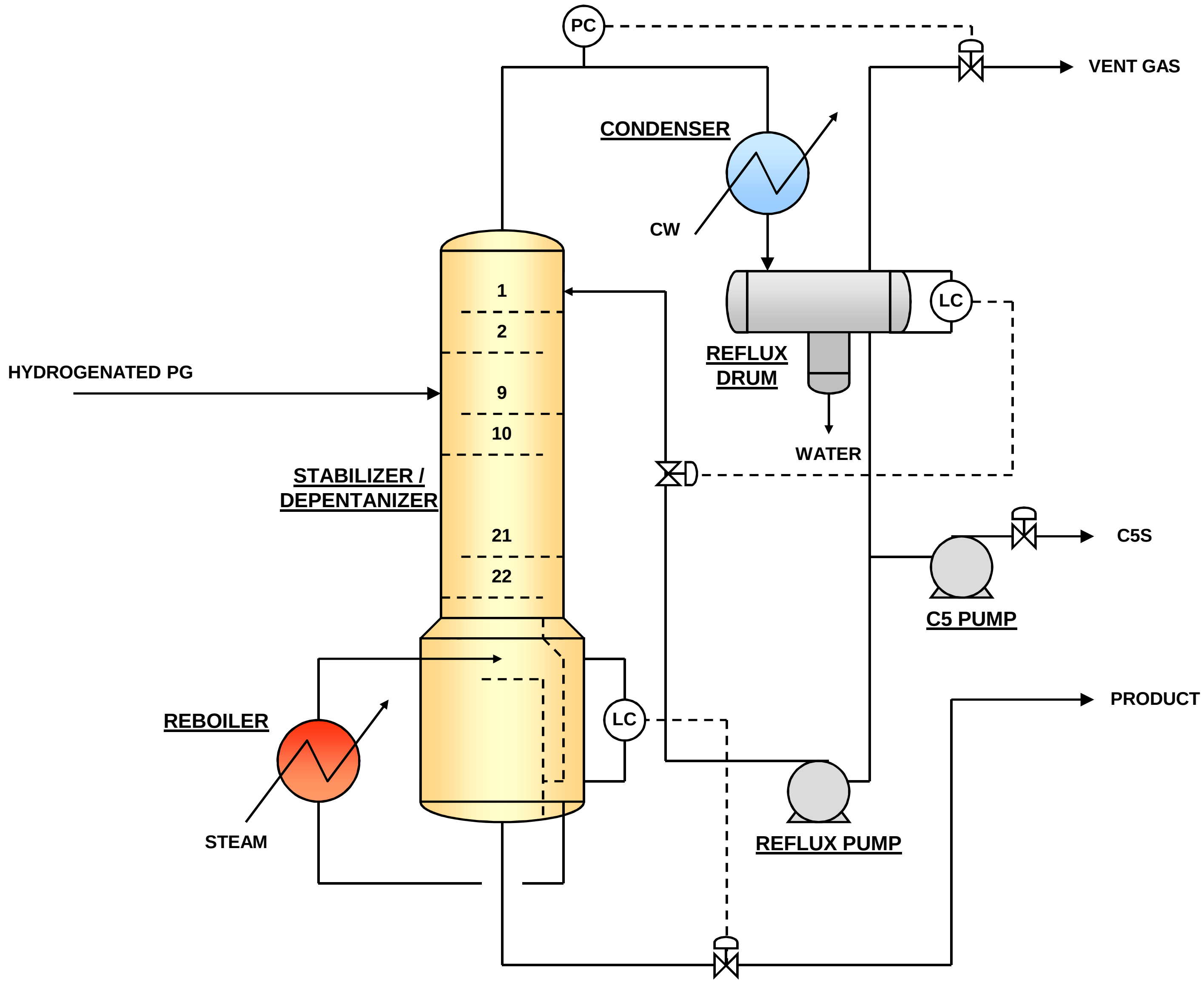
Case One – Ethylene DePentanizer

Original Column had 28 sieve deck trays, with a bottom diameter of 1.8 meters, and a top diameter of 1.0 meters.

The original design feed rate was 16,155 tons/hr with a bottoms specification of 1.0% C4s and lighter.



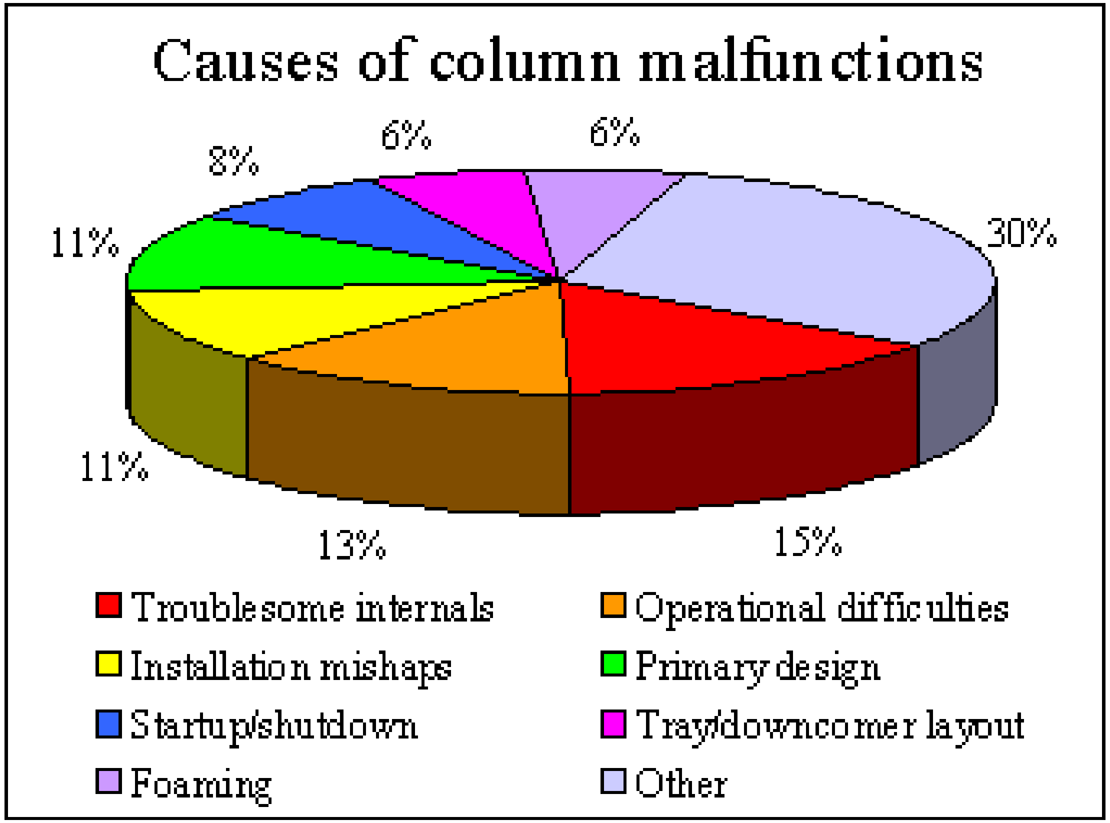
Case One – Ethylene DePentanizer



A good place to start in a revamp would be to go research what has been successful and not successful in the proposed revamp unit operation.

Case One – Ethylene DePentanizer

There are over 900 published cases of unsuccessful distillation operations.



Source: Henry Kister, Trans. IChemE, Vol. 75

It is a very good idea to have a ball park range of what the correct answer should be before you began to simulate to prevent the 901st case.

Many successful DePentanizers have about 38 - 45 trays. Average tray efficiency has been about 75 - 85%. For our design case we utilized 70%.

There are many short cut methods to establish number of trays and reflux ratios based on relative volatilities of the light and heavy keys.

Step one is to perform a high load test with the guidelines previously mentioned.

The current unit operation may need a test run with data analysis to develop an accurate current heat and material balance. Most flow meter accuracy is only +/- 2.0%.

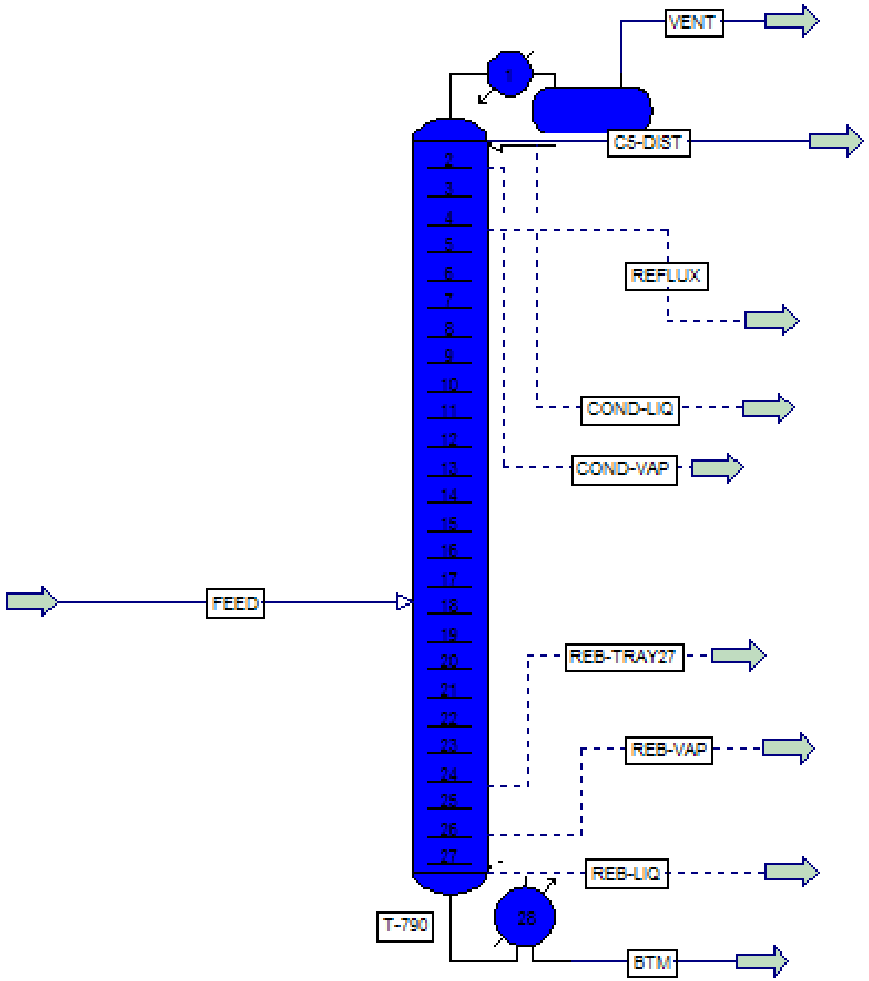
A next step in a revamp might be to simulate the original heat and material balance provided by the licensor, and the then the current unit operation.

If these two cases can be matched then one can utilize that tuned model to project the future cases.

Without accurate models that match the original heat and material balance and current unit operation future projections are a risky adventure.

Step three would be to utilize the tuned model to verify if the existing tower could be utilized, possibility by raising the reflux ratio, adjusting the pressure or other simple modifications.

Case One – Ethylene DePentanizer



Step three is really has two parts. Part one would be to modify the tuned model, and then rate the tray hydraulics.

In this case the client desired increased capacity and increased separation ability, which is difficult to achieve in an existing column.

The existing column could not provide the increased capacity and separation.

A design was developed utilizing the tuned Pro II model which met the desired capacity and separation.

The proposed new tower design had 40 stages.

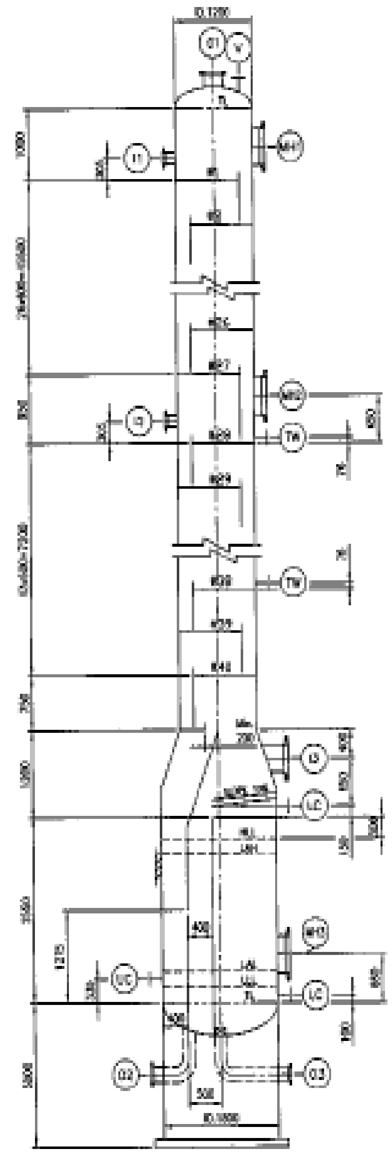
This required a 1.8 meter bottom diameter and a 1.2 meter top diameter due to the increase capacity and separation requirements.

Depentanizer Column (T-790)

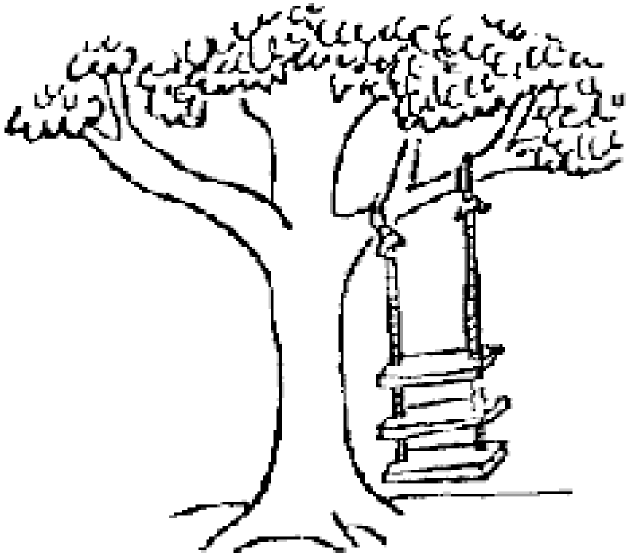
	Old	New
Feed capacity	16,155 kg/hr	19,840 kg/hr
Distillate	C4+ Max 1.0%	Benzene Max. 0.1 wt.%
Bottom Product	N/A	C5+ Max. 1.0 wt%

Case One – Ethylene DePentanizer

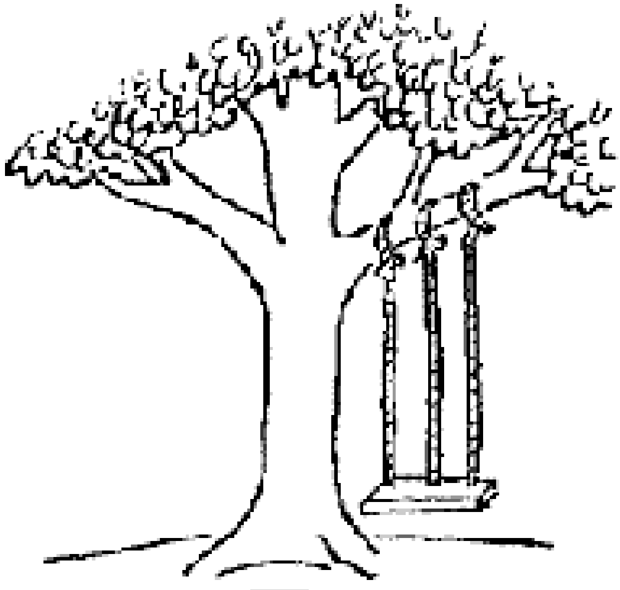
Design of New 40 Tray Column



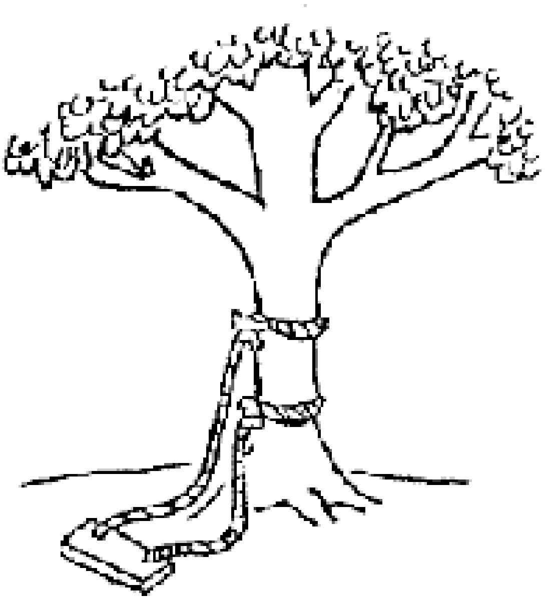
The Equipment inspection is the a very important part of a distillation revamp as well as any project due to the following scenario, which you may have been on a project like this in the past.



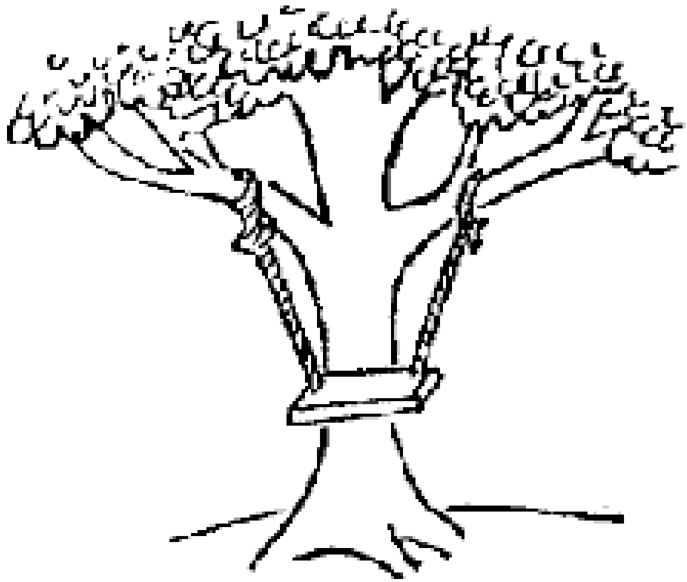
What Marketing Requested



What Sales Ordered

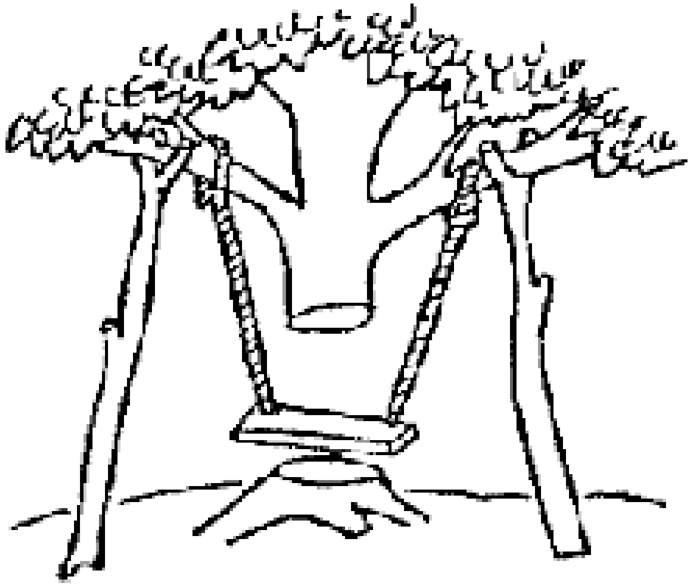


What Engineering Designed

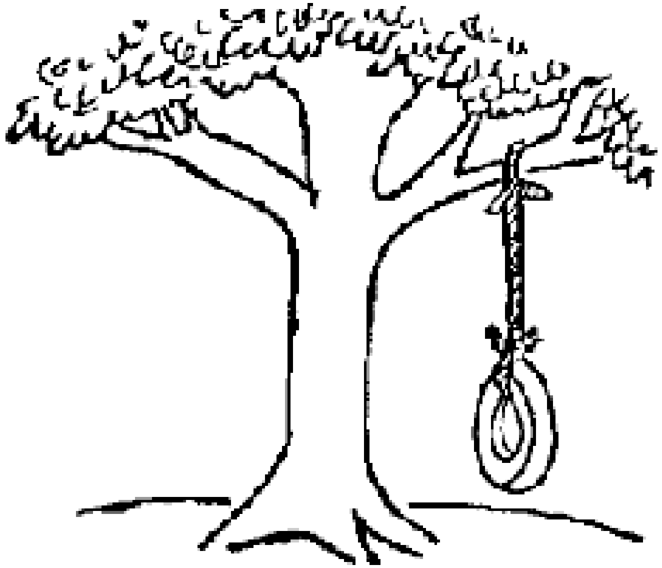


What was Manufactured

Equipment Inspection



What was Installed



What the Customer Wanted

Challenges

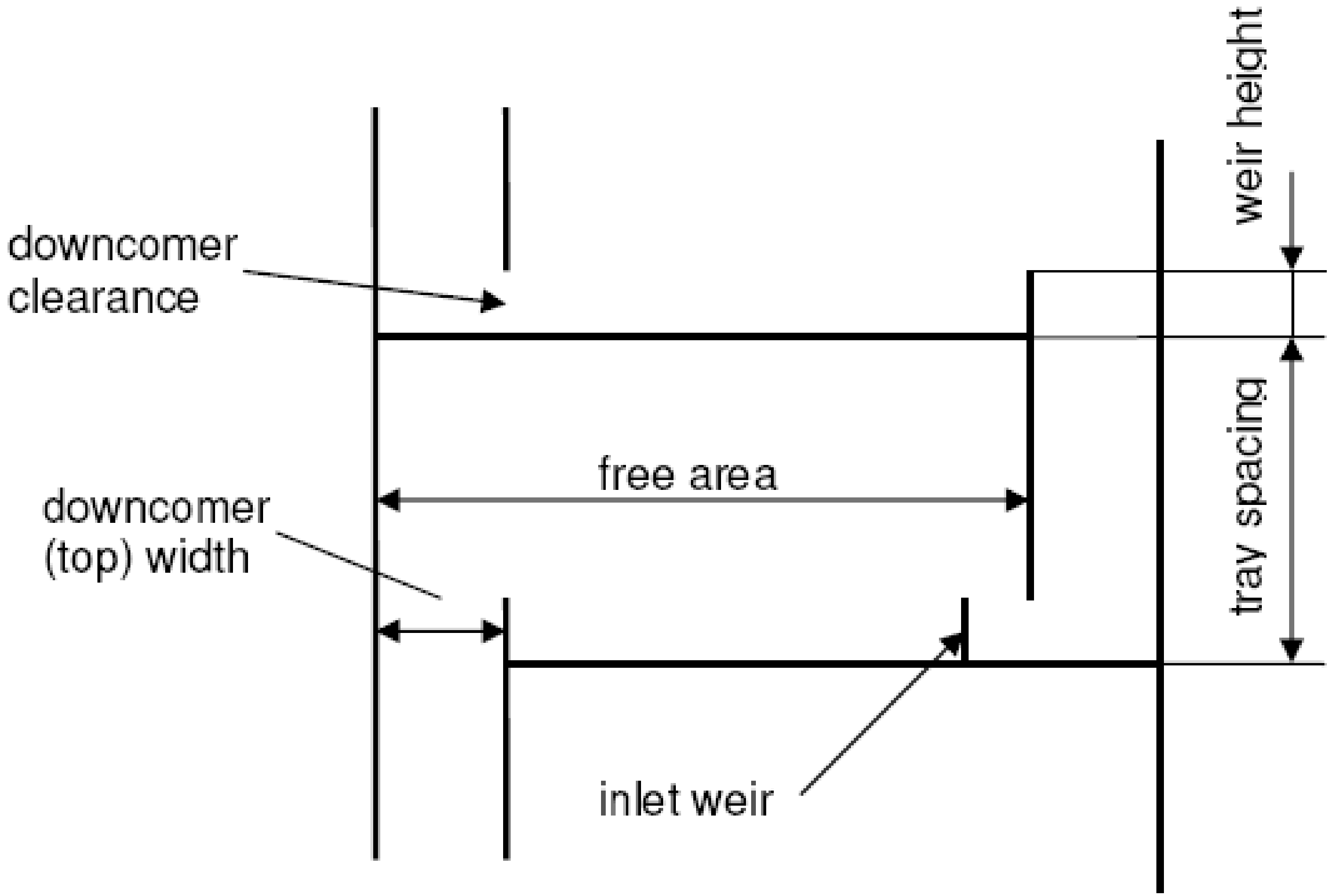
1. One engineer runs a simulation.
2. A second engineer runs hydraulics.
3. A third engineer designs the trays.

Each assumes the other engineer has adequate safety margin in his design. They can be employed by two different companies in three locations. It is very important that there is adequate communication among the designers.

Equipment Inspection

Equipment Inspection is very important part of a distillation revamp to insure what was intended is what is installed. Items to check include;

1. Levelness
2. Down comer clearance
3. Weir heights
4. Inlet weir clearance
5. Bolt tightness
6. Feed and reflux piping
7. Fabrication Errors



weir height
downcomer
clearance
free area
tray spacing
downcomer
(top) width
inlet weir

Correct Down Comer Clearance

Equipment Inspection

Incorrect Down Comer Clearance

Correct Inlet Weir Clearance

Incorrect Inlet Weir Clearance

Equipment Inspection

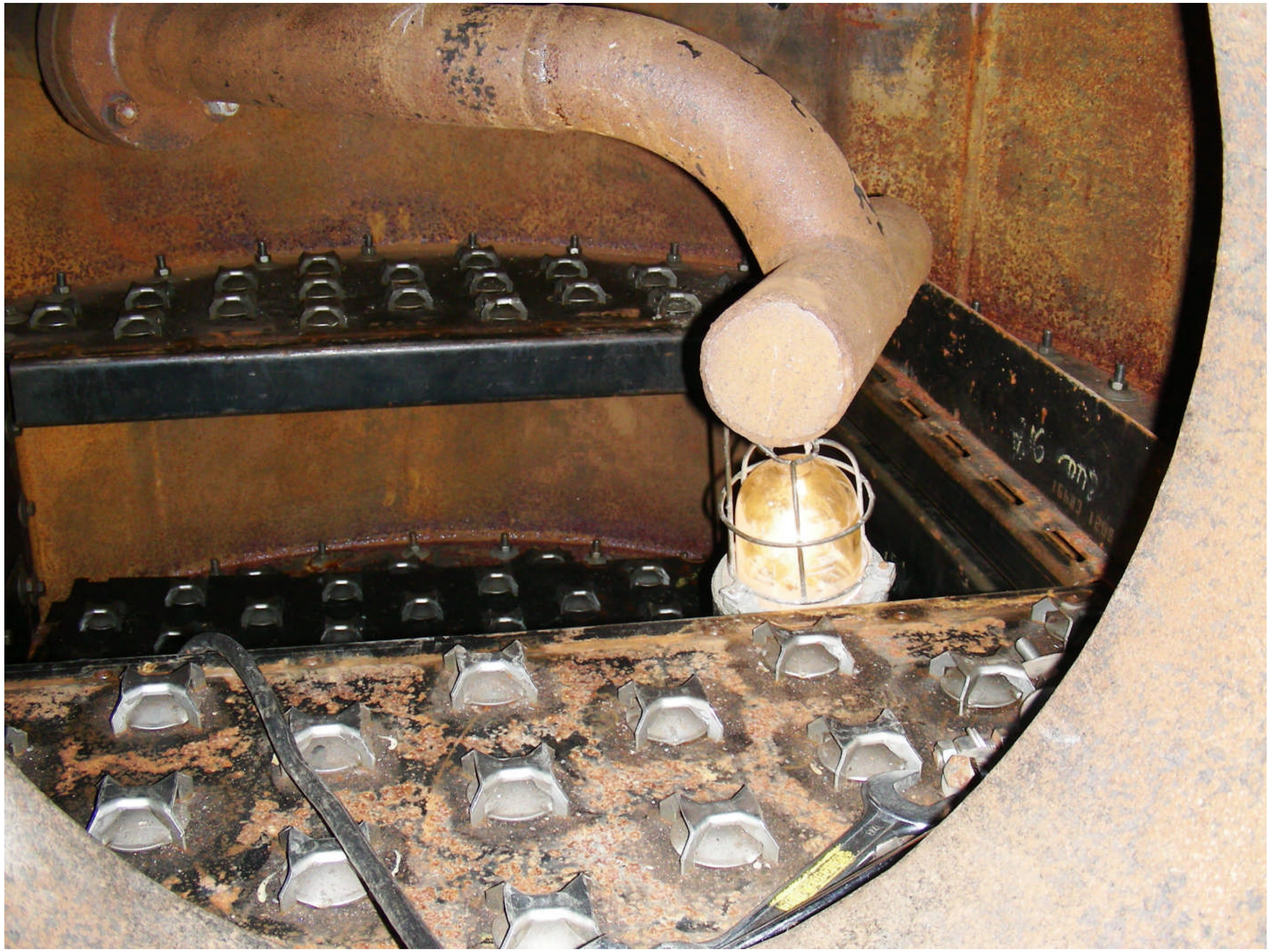
Nuts and Bolts installed correctly

Equipment Inspection

Nuts and Bolts not installed correctly

Reflux piping installed correctly

Equipment Inspection



Reflux piping not installed correctly

Fabrication Errors

Fabrication Errors

Commissioning

Commissioning of a revamp is an important step that must be done properly for the revamp to be a success. Items to consider in commission include;

1. Line Clearing of debris
2. Tightness of unit
3. Dryness of unit
4. Safe introduction of hydrocarbon

Conclusions

A Success Distillation Revamp involves many aspects. The team must;

1. **Gather data,**
2. **Analyze the data,**
3. **Rate equipment,**
4. **Design new equipment**
5. **Inspect the fabrication and installation**
6. **Commission the new equipment**

Thank You