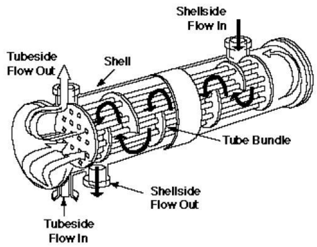
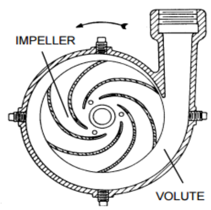
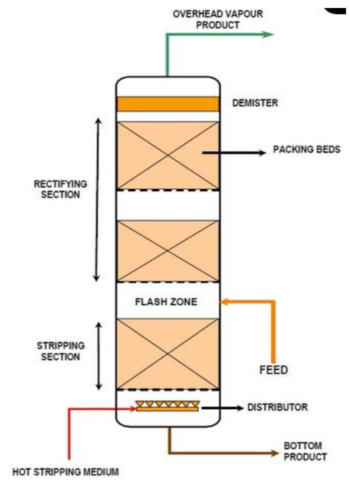
IICHE-FAI SEMINAR ON

Materials of Construction
for Chemical Process Plants
21-22 August, 2015
IIChE(NRC), C-27, Qutab Institutional Area
New Delhi







CONSIDERATIONS IN MATERIAL SELECTION

By

A.K.Lahiri

CHEMICAL PROCESS INDUSTRY IS ONE OF THE PILLER OF MODERN INDUSTRIAL GROWTH

OIL & GAS PRODUCTION
REFINERY
ORGANIC & INORGANIC FERTILISER
PETROCHEMICAL
ORGANIC & INORGANIC ACIDS & SALTS
PULP & PAPERS
SOAPS & DETERGENTS
ETC.

BATCH VS CONTINUOUS PROCESS

- MANY CHEMICAL PROCESSES WERE DEVELOPED FROM EARLY DAYS OF CIVILISATION BUT BECAUSE OF LIMITED DEMAND THESE WERE OPERATED MANUALLY IN BATCHES.
- MOC OF REACTION VESSELS AND PIPING WERE LIMITED TO COPPER' IRON, WOOD AND GLASS.
- WITH INCREASING DEMAND IT BECAME NECESSARY TO INTRODUCE CONTINUOUS PROCESSES WHERE ALL FUNCTIONS STARTING FROM INLET OF FEED (REACTANTS) TO OUTLET OF PRODUCTS RUN UNINTERRUPTED.
- THESE IN TURN REQUIRED DEVELOPMENT & UPGRADATION OF DIFFERENT EQUIPMENT & MATERIALS LIKE REACTORS, VESSELS, EXCHANGERS, PIPING, PUMPS COMPRESSOR , ETC NEEDED TO RUN THE PLANT.

FOUNDATION OF MODERN CHEMICAL PROCESS INDUSERY STARTED WITH REFINING INDUSTRY

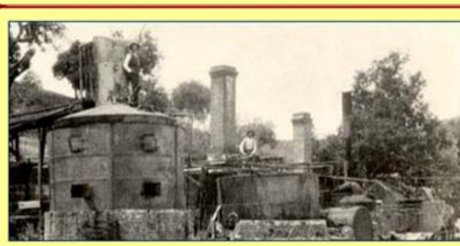
- THE OIL REFINING GOT A STATUS OF INDUSTRY AFTER INVENTION OF KEROSENE LAMP IN 1857 LEADING TO LARGE DEMAND OF KEROSENE.

* FURTHER RAPID GROWTH STARTED AFTER 1867 WITH THE INVENTION OF 4-STROKE ENGINE AND SUBSEQUENT INTRODUCTION OF GASOLINE POWERED AUTOMOBILES IN EUROPE BY KARL BENZ AND WILHELM DAIMLER AND HENRY FORD IN USA.

- THIS FORMED BASIS OF MODERN OIL REFINERY

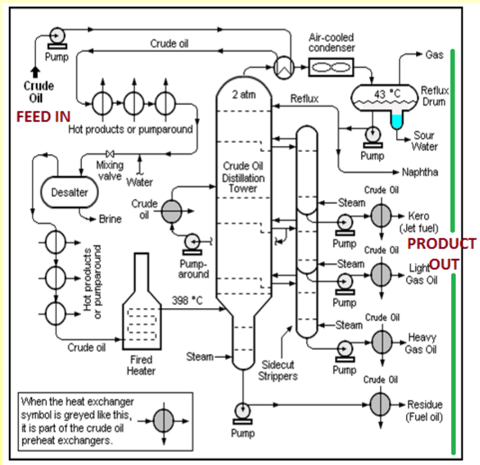
EARLY BATCH REFINERY

1876 California Oil Refinery



Distillation Still At Digboi
1905

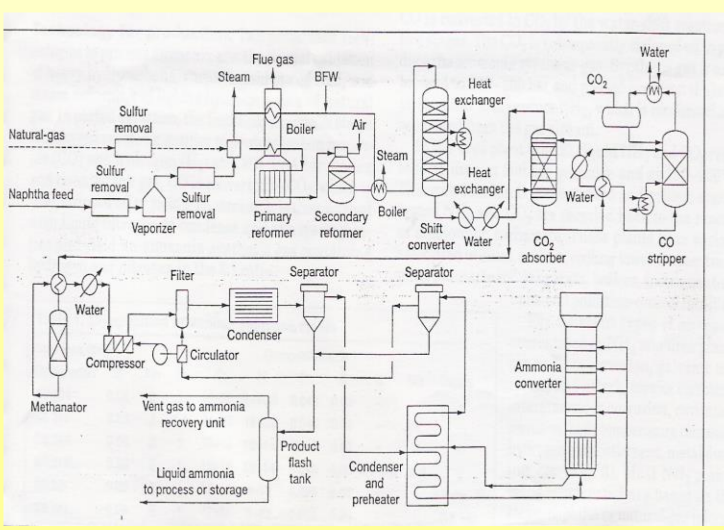
MODERN REFINERY PROCESS UNIT



PROCESS FLOW DIAGRAM

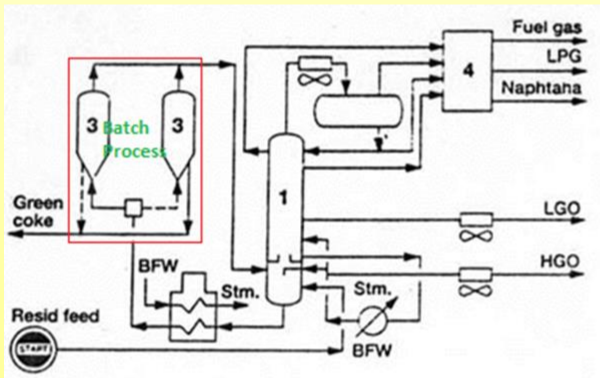
VIEW OF OPERATION AREA

MODERN CONTINUOUS PROCESS PLANT PRODUCING HYDROGEN & AMMONIA



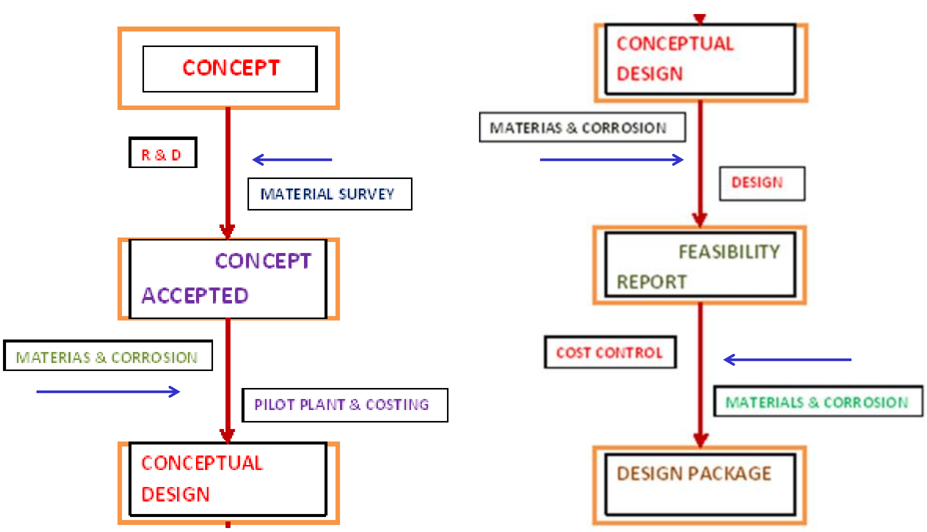
OPERATING BATCH PROCESS AS CONTINUOUS PROCESS

IN CASE OF BATCH PROCESS LIKE POLYMER PRODUCTION, COKER, ETC CONTINUOUS OPERATION IS ACHIEVED BY PROVIDING TWO TRAINS OF CONCERNED SECTION OF UNIT. SWITCHING FROM ONE TO OTHER & VICE VERSA DOES NOT REQUIRE SHUTDOWN OF OTHER SECTION OF PLANT



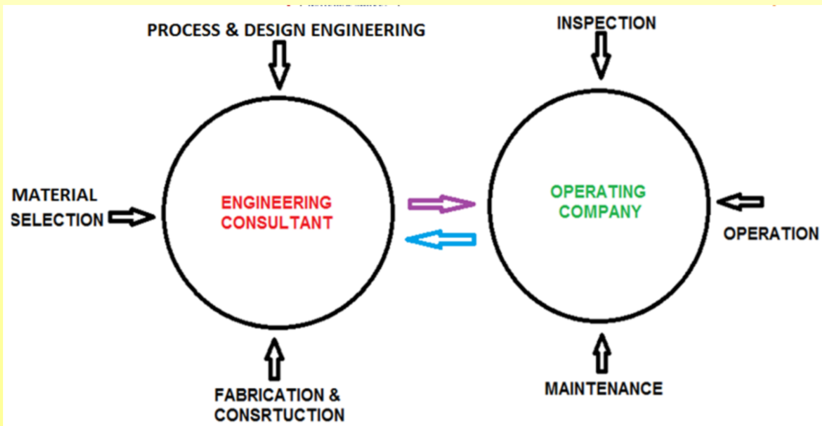
COKING UNIT – BATCH PROCESS

SELECTION OF MOC IS FIRST AND MOST IMPORTANT STEP IN COMMERCIALISATION OF ANY PROCESS WHICH STARTS FROM INITIAL STAGE OF PROJECT DEVELOPMENT



INTERACTION OF VARIOUS DISCIPLINES IN SETTING UP OF A PROCESS PLANT

- HANDING OVER OF PROCESS PACKAGE BY PROCESS LICENSOR TO THE OWNER IS FOLLOWED BY DETAIL ENGINEERING, FABRICATION & CONSTRUCTION



CONSIDERATIONS IN MATERIAL SELECTION

I COMPATIBILITY WITH ENVIRONMENT RELATED TO

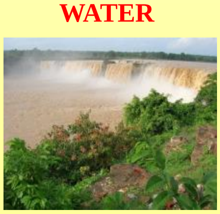
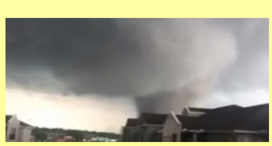
Medium;
Temperature;
Pressure;

TYPES OF ENGINEERING MATERIALS

ENGINEERING MATERIALS

- **METALS**
  - **FERROUS**
    - STEEL
    - ALLOY STEELS
    - STAINLESS STEELS
    - CAST IRONS
  - **NON FERROUS**
- **NON-METALS**
  - CERAMICS
  - GRAPHITE
  - PLASTICS
  - ELASTOMERS
- **COMPOSITS**
  - CARBON/RESIN
  - FRP

MATERIAL/ENVIRONMENT INTERACTION CAN BE COMPARED TO FOUR CLASSICAL ELEMENTS (TATWA) OF INDIAN PHILOSIPHY

WATER	AIR	FIRE	EARTH
			
AQUEOUS CORROSION	ATMOSPHERIC CORROSION	HIGH TEMPERATURE ATTACK	SOIL CORROSION

AQUEOUS CORROSION

- **MILD CORROSIVE ENVIRONMENT**
- *CARBON STEEL + CA*
- *CARBON STEEL + CA + INHIBITION*
- *CARBON STEEL + COATING (ORGANIC; METALLIC)*
- **HIGH CORROSION ENVIRONMENT**
- *CONVENTIONAL STAINLESS STEELS (304; 316; 317, 401)*
- *HIGH ALLOY STEELS (SUPER AUSTENITIC STEELS; DUPLEX, SUPER DUPLEX, HYPER DUPLEX STAINLESS STEELS)*
- *NICKEL; MONEL*
- **EXTREMELY HIGH CORROSION ENVIRONMENT**
- *Ni-Cr; Ni-Cr-Mo; ZIRCONIUM; TANATLUM*

HIGH TEMPERATURE DRY CORROSION

-- OXIDATION

* Cr (1-9%)-Mo (0.5-1Mo) Alloy Steels;
* 300 Series (321;347;310) Stainless Steels;
- Heat Resistant Cast Steels (HH; HT; HK; HP, Etc)
- High Nickel Stainless Steels (Alloy 800H & 800 HT;

-- SULFIDATION

* Cr (5-9%)-Mo (0.5-1%) Alloy Steels; 410, 321, 347 Stainless Steels

-- HYDROGEN DAMAGE

* Cr (1-3%)-Mo (0.5-1%) Alloy Steels

-- NITRIDING

* 300 Series (321;347;) Stainless Steels; Nickel Base Alloys Inconels

-- METAL DUSTING

* INCONEL 693; Alloy 800

II METALLURGICAL DEGRADATION

- **Phase Precipitation**

*** Carbide Spherodisation / Coarsening; Sigma; Chi; G , etc.**

- **Hydrogen Embrittlement**
- **Temper Embrittlement**

III MECHANICAL & PHYSICAL PROPERTIES

- **Strength**
- *Tensile / Yield / % Elongation / % RA*
- **Ductility / Toughness**
- *Charpy / DBT*
- **Creep Strength & Creep Ductility**
- **Workability / Formability**
- **Weldability / Maintainability**
- **Thermal Conductivity**
- **Coefficient Of Expansion**

IV TYPES OF EQUIPMENT

- **COLUMN/VESSEL**
- *CARBON STEEL CAN BE USED WITH HIGHER CA; CRA CLADDING;*
- **FURNACE INTERNALS**
- *HT RSISTANT ALLOY AS EXPOSED DIRECTLY TO FLUE GAS TEMP.*
- **HEATER TUBES**
- *LOWER RESISTANT MATERIAL CAN BE USED BECAUSE OF COOLING EFFECT OF FLUID BEING HEATED*
- **EXCHANGER**
- *MATERIAL COMPATIBLE WITH FLUIDS*
- **PIPING**
- *LOWER RESISTANT POSSIBLE BECAUSE OF EASE IN REPLACEMENT*
- **REACTORS**
- *DEPENDING ON CRITICALITY (NOMALLY BETTER MATERIAL)*
- **PUMP/COMPRESSOR**
- *CRITICALITY; SIZE; AVAILIBILITY OF STANDBY; FLUID*

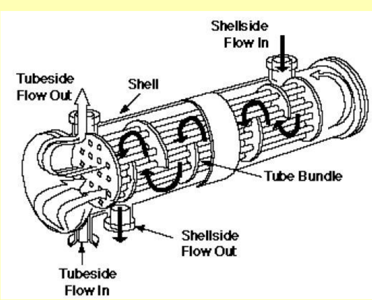
V MATERIAL MAINTENANCE

- INSPECTION / CONDITION MONITORING
- RISK BASED INSPECTION
- MAINTENANCE PRACTICES

* Period In-between Major Shut Downs
* Maintainability

- FAILURE & SUCCESS ANALYSIS
- RECORDING SYSTEM
- KNOWLEDGE BASE OF LATEST DEVELOPMENTS

SHELL & TUBE MOC UNDER FOUR CASES
1 More corrosive fluid – A
Less corrosive fluid – B
2 High pressure fluid – X
Low pressure fluid – Y
3 Viscous fluid – V
Light fluid – L
4 Fresh water cooling media – F
Sea water cooling media - S



CASE 1: A on tube side; B on shell side

CASE 2: X on tube side; Y on tube side

CASE 3: V on tube side; L on shell side

CASE 4: F on tube or shell side; S on shell side

VI OPERATIONAL & OTHER CONSIDERATIONS

- SAFETY
- ENVIRONMENT
- SYSTEM DEPRESSURISATION EFFECT
- OPERATIONAL UPSETS
- START UP SHUTDOWN PROCDURE
- PLANT LOCATION
- PRODUCT PURITY & CLEANLINESS
- HUMAN CONSIDERATIONS

VII DESIGN PHILOSOPHY

***HIGH MAINTENANCE LOW CAPITAL COST**

*** LOW MAINTENANCE HIGH CAPITAL COST**

*** OPTIMUM MAINTENANCE AND OPTIMAL COST**

STEPS INVOLVED IN MATERIAL SELECTION

PROJECT IMPLEMENTATION

1. **Preparation of material balance sheet**
2. **Development of PFD along with identification of various stationary equipment like vessels, distillation columns, reactors, piping, tankages etc. and rotating equipment like pumps, compressors, etc.**
3. **Selection of material of construction (MOC) and specifying additionally corrosion preventive measures.**
4. **Preparing MSD & Material Selection Report**
5. **Finalising material specification including service related additional requirement during procurement and construction.**
6. **Detail engineering**
7. **Fabrication / procurement as per applicable Codes**
8. **Construction**
9. **Commissioning, operating and maintenance of plant**.

WHAT MATERIAL TO SELECT?

For new projects where the number of equipment and investments are large, the materials with proven experience should only be specified within the basic requirements enumerated earlier. Use of unproven or material/treatment with limited experience should be avoided.

WHAT MATERIAL TO SELECT?

* For a running plant, the approach can be different. Though due weightage is to be given to proven materials or protective systems, one has got the option to try new or not widely used or even costlier alternatives for special situations / problems experienced during the operation of plant.
* If proven experience is available, replacement can be directly made.
* If not trial runs using limited amount can be used to assess its suitability before replacement.

TYPICAL PROCESS DATA SHEET FOR OIL & GAS PRODUCTION SYSTEM

Stream No	Governing case	Pressure (Bar A) Operating	Pressure (Bar A) Design	Temperature (Deg C) Operating	Temperature (Deg C) Design	PP of CO2 (Bar A)	wt % of water in liquid	vol % of water in liquid
1301	CASE-II (MAX WATER CASE) INLET @ 110 REV A.HSC	19.00	438.00	110.00	-21 & 110	0.68	80.06	75.01
	CASE-I (MAX OIL CASE) INLET @ 57 REV A.HSC	19.00	438.00	57.00	-21 & 110	0.89	46.52	39.28
1302	CASE-I (MAX OIL CASE) INLET @ 57 REV A.HSC	16.00	24.00	56.45	-17 & 110	0.74	46.77	39.65
	CASE-II (MAX WATER CASE) INLET @ 110 REV A.HSC	16.00	24.00	109.61	-17 & 110	0.56	80.30	75.43
1303	CASE-I (MAX OIL CASE) INLET @ 57 REV A.HSC	19.00	438.00	37.00	-21 & 110	0.92	-	-
	CASE-II (MAX WATER CASE) INLET @ 110 REV A.HSC	19.00	438.00	110.00	-21 & 110	0.65	91.93	89.49
1304	CASE-I (MAX OIL CASE) INLET @ 57 REV A.HSC	16.50	24.00	35.85	-17 & 110	0.80	-	-
	CASE-II (MAX WATER CASE) INLET @ 110 REV A.HSC	16.50	24.00	109.90	-17 & 110	0.55	92.03	89.67
1305	CASE-I (MAX OIL CASE) INLET @ 57 REV A.HSC	53.00	66.00	80.00	-6 & 110	0.00	0.30	0.26
1306	CASE-I (MAX OIL CASE) INLET @ 57 REV A.HSC	411.00	438.00	80.00	-6 & 110	0.00	0.34	0.27
2001	CASE-I (MAX OIL CASE) INLET @ 57 REV A.HSC	16.00	24.00	56.45	-17 & 110	0.00	12.69	9.80
	CASE-II (MAX WATER CASE) INLET @ 110 REV A.HSC	16.00	24.00	109.61	-17 & 110	0.00	12.34	9.59
2002	CASE-I (MAX OIL CASE) INLET @ 57 REV A.HSC	12.50	18.00	56.04	-13 & 110	0.61	12.74	9.87
	CASE-II (MAX WATER CASE) INLET @ 110 REV A.HSC	12.50	18.00	108.98	-13 & 110	0.41	12.38	9.65

MOC REPORT

PROJECT NAME: xxxxxxx

Report by : ***Dr. A. K. LAHIRI***
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A) **INTRODUCTION**

A study was conducted to recommend MOC for various topsides process systems of xxxxxxxx.

The present report gives recommended MOC of different, lines, exchangers and vessels. It has been ensured that recommended materials are covered under xxxxxxxx

MOC STUDY GUIDELINES

PROCESS SYSTEMS

I. MOC FOR SYSTEM RELATED TO XX CORROSION

A. In case of oil / gas / water multi phase

1. First corrosion rate in presence of XX was calculated xxxxxxx
2. Design life was considered as XX years for piping & vessel.
3. If the corrosion rate arrived XXX then carbon steel will be MOC. In case corrosion rate was found to be high then material was upgraded to CRA.
4. CRA selection would then be assessed step by step
5. High pressure oil & gas are handled in off shore platforms under number of constraints; these include high maintenance cost, lack of adequate working space, hazardous working conditions, safety of personnel & equipment and environmental hazards. Material selection requires balancing of above constraints. In selection of material these points were kept in view along with avoiding too many different materials which is likely to increase the inventory and also investment and operational costs

MOC OF LINES

(Drawing No: . X – X – P – XA – 26 – 0001 – 01)

* Lines 2022/2004/2601 Gas from Test & 1st Stage Separator to 1st Stage HP Suction Cooler 26 – HE – 001 A/B	22 Cr DSS /NACE	Higher Gr ade DSS recommended taking care of possible carryover of chloride. TO BE DELETED
* Line 2603 to HP Suction Scrubber 26 – VG – 001 A/B	22 Cr DSS /NACE	
*Line 2607 to 1st Stage HP Compressor 26 – KA – 001 A/B	22 Cr DSS /NACE	
* Line 2609 to 2nd stage HP suction Cooler 26 – HE – 002 A/B	22 CR DSS /NACE **CS?**	**No condensation shall take place and CS can be used. Better to hav 22 Cr DSS for continuity**
*Line 2611 to Glycol Contactor Inlet Scrubber 24 – VG - 001.	22 Cr DSS /NACE	.
* Line 2401 to Glycol Contactor 24 – VB – 001	22 Cr DSS /NACE	
* Line 2402 to Scrubber 26 – VG – 002 A/B to associated Cooler 26 – HE – 003 A/B to Final Export.	LTCS + 3 mm CA	
* Line 2617 to 3rd Stage Compressors and Associated Coolers and Scrubbers and further to 2626 to Final Export	CS + 3 mm CA **TO DELET**	CS used shall be of LTCS grade △1
* Line 2007/2008 Gas from 2nd Stage separator to LP Suction Cooler 23 – HB – 001 △1	22 Cr DSS/NACE	Possible chloride carry over

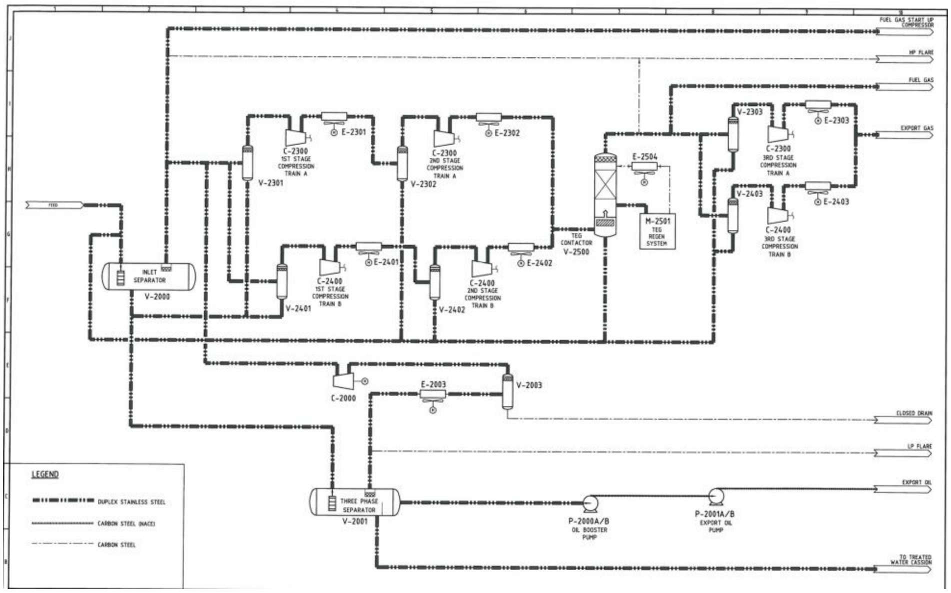
MOC OF HEAT EXCHANGERS
LP & HP Compression System
(x – x – P – XA – 26 – 0001 – 01)

Equipment No	MOC Shell / Tube	Comments
26 – HE - 001 A/B	For printed Circuit Heat Exchanger: 22 Cr DSS 1	Chances of Chloride Carry Over NACE
26 – HE - 002 A/B	For printed Circuit Heat Exchanger: SS 316 / 22 Cr DSS	NACE
26 – HE - 003 A/B	For printed Circuit Heat Exchanger: SS316	
26 – HE – 004 A/B	For printed Circuit Heat Exchanger: SS316	**TO DELET**
23 – HB - 001 1	For Printed Cir cuit or Plate Heat Exchanger: SS 316 / 22 Cr DSS	NACE

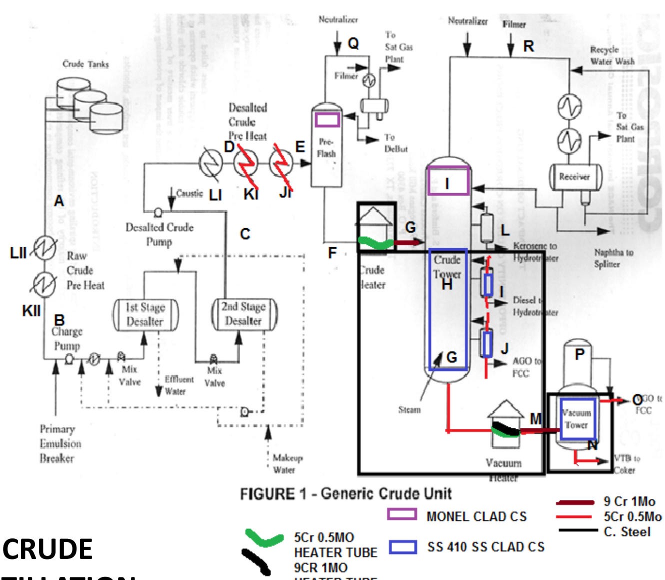
MOC OF VESSELS

LP & HP Compression System
(x – x – P – XA – 26 – 0001 – 01)

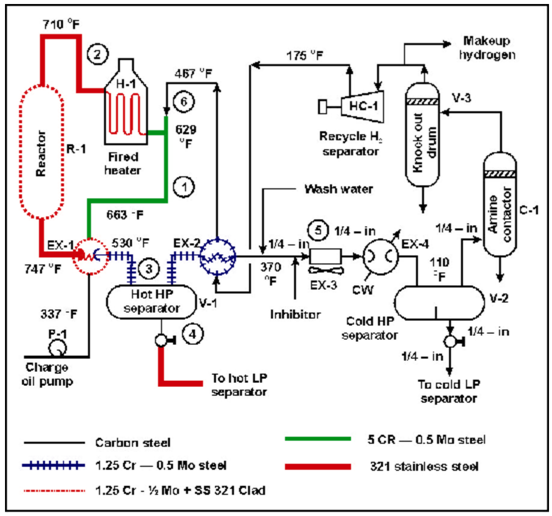
Equipment No	MOC	Comments
26 – VG - 001 A/B	CS + 3 mm CA + Lining or 22 Cr DSS Clad + NACE	In case of lining pr ovide i mpingement plate on shell opposite inlet nozzle
24 – VG - 001	CS + 3 mm CA + Lining or 31 6L Clad + NACE	In case of lining provide i mpingement plate on shell opposite inlet nozzle
24 – VB - 001	CS + 3 mm CA. Bottom lined with SS 316L. Internals 316L + NACE	
26 – VB – 002 A/B	CS + 3 mm CA	
26 – VG – 003 A/B	CS + 3 mm CA	
23 – VG - 001	CS + 3 mm CA + Lining or 316L Clad / NACE	



MATERIL SELECTION DIAGRAM **(MSD)** OF GAS SEPRATION UNIT



CRUDE DISTILLATION MOC



Reactor R-1
Shell - 1.25 Cr - 0. Mo + SS 321 Clad
Internals - SS 321

Fired Heater H-1
Heater Tube SS 321

EX-1
Shell : 1.25 Cr - 0.5 Mo + SS 321
Tubes : SS 321

EX-2
Shell : 1.25 Cr - 0.5 Mo
Tubes : 1.25 Cr - 0.5 Mo

Simplified material selection diagram for the high pressure portion of a gas oil desulfurizer

STEPS AFTER MATERIAL SELECTION HAS BEEN FINALISED

SPECIFICATION OF METALS & ALLOYS

FOR USE IN DESIGN & PROCUREMENT

* DEFINES THE USE
- FORM OF MATERIAL, SUCH AS,

  PLATES, RODS, PIPES, FORGING, CASTING, ETC
- SETS RANGE IN WHICH VARIATIONS IN CONTENTS OF ALLOYING ELEMENTS AND IMPURITIES ARE PERMITTED
- NORMALLY MAX. CONTENTS ARE SPECIFIED
- GIVES METHODS OF PRODUCTION & HEAT TREATMENT
- SPECIFIES MINIMUM MECHANICL PROPERTIES FOR DIFFERENT ALLOYS
- GIVES SPECIAL SUPPLIMENTARY REQUIRMENTS WHERE NECESSARY
- FIXES TOLERENCE IN DIMENSIONS, THICKNESS
- OTHER SPECIFIC REQUIREMENTS WHERE NECESSARY

ADDITIONAL REQUIREMENTS

SERVICE SPECIFIC REQUIREMENTS TO BE SPECIFIED BY USER

- GIVE ADDITIONAL REQUIREMENTS / LIMITS WITH RESPECT TO COMPOSITION, STRENGTH, TOUGHNESS, ETC TO MEET DEMAND OF SPECIFIC SERVICE.
- FOR EXAMPLE:

  - FOR SOUR SERVICE ASK FOR HARDNESS CONTROL, LOW SULFUR SHAPE CONTROLLED STEEL AS PER STANDARDS
  - FOR GOOD WELDEBILITY & HARDNESS CONTROL SPECIFY STEEL WITH LOW CARBON EQUIVALENT AND LOW RESIDUAL ELEMENTS LIKE Cr, Ni, Cu, Mo, ETC AND ASK TO REPORT THEIR CONTENTS
  - FOR P22 / P3 HYDROCRACKER MATERIAL ASK TO LIMIT J FACTOR
  - SPECIFY WHERE REQUIRED PWHT DURING FABRICATION & CONSTRUCTION INDEPENDENT OF CODE REQUIREMENT
  - TAKE SERVICES OF THIRD PARTY INSPECTION AGENCIES TO CERTIFY COMPLIANCE WITH SPECIFIED REQUIREMENTS

ALL FABRICATION SHALL BE AS PER PV CODE WHICH MAY BE ASME, EU OR COUNTRY CODE

ROLE OF CODES IN EQUIPMENT INTEGRITY

R.B. Grover Shoe Company. March 20, 1905, after boiler explosion

(Prior To Introduction Of ASME Boiler Code)

- **FOR PRESSURISED COMPONENTS MECHANICAL DESIGN HAS A MAJOR ROLE IN ENSURING INTEGRITY**
- **PV CODES (NATIONAL OR INTERNATIONAL) COVER THIS**
- **AS OF NOW USA (ASME) PV CODES ARE MORE POPULAR**

Type of Structure	Failure rate
Boiler (explosion), USA, c.1900	Approx. 400 per year (rate per vessel, year not stated)
Boiler (explosion), USA, c.1970	Approx. 20 per year (rate per vessel, year not stated)
Onshore gas pipeline, Western Europe	0.6 per 1000 km/year
Petroleum products pipeline, USA	0.55 per 1000 km/year
Pressure vessels (catastrophic failure), UK	2×10^{-6} per vessel year

PRESSURE VESSEL CODE – WHAT IS ITS OBJECTIVE?

- **CODE GIVES MINIMUM REQUIREMENTS FOR RELIABILITYAND SAFETY CONSIDERING NORMAL DAMAGE AND MAINTAINENCE**
- **EXTERNAL JOINTS ARE MOST CRITICAL AS FAILURES CAN RESULT IN LEAKAGE OR RUPTURE**
- **CODES ARE BASED ON ENSURING MECHANICAL INTEGRITY**
- **IN MANY INSTANCES RELIABILITY DEPENDS ON SERVICE & REQUIREMENTS OF WHICH ARE NOT COVERED IN CODES**
- **IN SUCH CASES USER SPECIFIES ADDITIONAL REQUIREMENTS TO BE DURING DURING FABRICATION, CONSTRUCTION AND REPAIR.**

Allowable Stress Basis For Ferritic Steels

Design Code	Allowable Stress
ASME Section VIII Division 1 (Pre 1999)*	$\frac{UTS}{4}$ and $\frac{YS_{0.2}}{1.5}$ whichever is less
VIII Division 1 (1999)	$\frac{UTS}{3.5}$ and $\frac{YS_{0.2}}{1.5}$ whichever is less
ASME Section VIII Division 2 (Pre 2007)	$\frac{UTS}{3}$ and $\frac{YS_{0.2}}{1.5}$ which ever is less
VIII Division 2 (2007)*	$\frac{UTS}{2.4}$ and $\frac{YS_{0.2}}{1.5}$ which ever is less
EN 13445	$\frac{UTS_{20}}{2.4}$ and $\frac{YS_{0.2}}{1.5}$ which ever is less

where,
UTS = Minimum ultimate tensile stress at design temperature
$YS_{0.2}$ = Minimum0.2% off set yield stress at design temperature
UTS_{20} = Minimum ultimate tensile stress at 20^{0}C (68^{0}F)

UNLESS PROPERLY IMPLEMENTED FAILURES WOULD OCCURE FOR NUMBER OF REASONS WHICH ARE RELATED TO

DEFICIENCIES IN

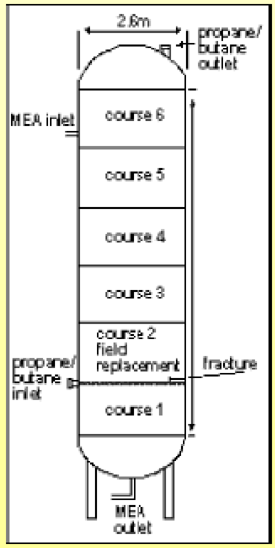
***MATERIAL SELECTION,**
***DESIGN,**
***CONSTRUCTION,**
***OPERATION &**
***MAINTENANCE**

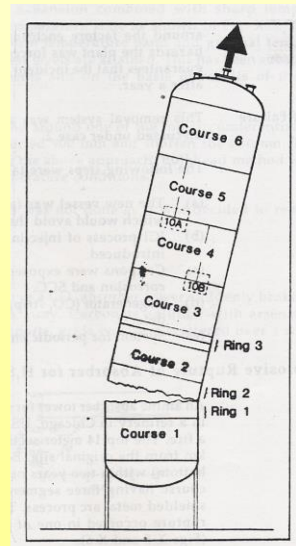
CASE OF CORRECT SELECTION BUT WRONG SPECIFICATION

CRACKING OF AMINE ABSORBER FOR SOUR GAS SWEETENING AS A RESULT OF HIC

15 METER OF TOP SECTION BLEW UP

HIC RESISTENCE NOT SPECIFED AS SPECIAL REQUIREMENT





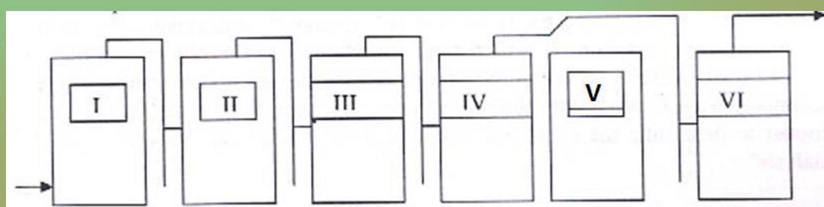
FLIXBOROUGHO DISASTER

CORROSION NOT ONLY LEADS TO EQUIPMENT DAMAGE BUT CAN CAUSE CATASTROPHIC ACCIDENTS.

- **Flixborough (UK) Accident**

  Company produced highly explosive caprolactum from cyclohexane,

- **Reactor 5 out of six developed leak.**
- **It was isolated by joining 4th to 6th reactor**



SOON AFTER RE CONNECTING PIPE CRACKED RESULTING IN RELEASE OF CYCLOHEXANE

RESULTED IN FORMATION OF VAPOUR CLOUD FOLLOWED BY EXPLOSION EQUIVALENT TO 15 TONS OF TNT

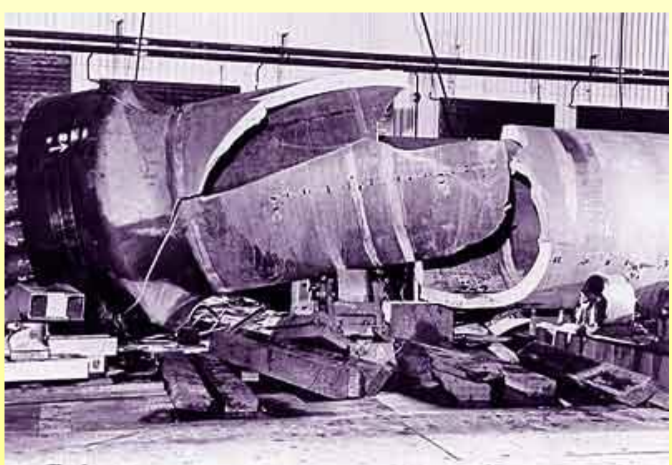

Overall view of plant after the incident

A CASE OF POOR PIPING STRESS ANALYSIS

ROOT CAUSE – CORROSION & STRESS

- PRIOR TO LEAKAGE, REACTOR 5, WAS BEING SPRAYED WITH RIVER WATER BECAUSE OF A LEAKY FLANGE. RIVER WATER CONTAINED HIGH NITRITE WHICH CAUSED SCC.
- NO STRESS ANALYSIS WAS DONE OF PIPING CONNECTEING 4^{TH} AND 5^{TH} REACTOR
- EXPANSION BELLOW GAVE AWAY BECAUSE OF EXCESSIVE STRESS.

RUPTURE OF AMMONIA CONVERTOR DURING HYDROTESTING



CASE OF IMPROPER WELDING DURING FABRICATION– LEFT SMALL H2 INDUCED CRACK OF CRITICAL SIZE

MFL - SELECTION OF VALVE OF WRONG DESIGN

INHIBITEDCARBONATE / BI-CARBONATE SOLUTION IS USED TO REMOVE CO2 FROM REFORMED GAS.

SOLUTION CAUSES ACCELERATED CORROSION BEYOND CERTAIN CRITICAL VELOCITY

REPLACEMENT WITH A VALVE OF NEW DESIGN LED TO TURBULANCE DOWN STREAM OF VALVE

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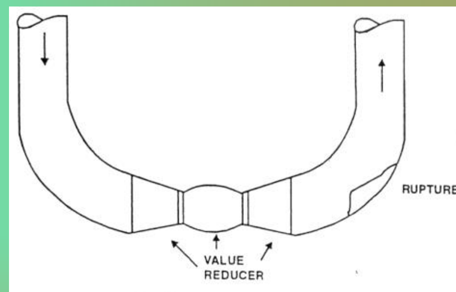
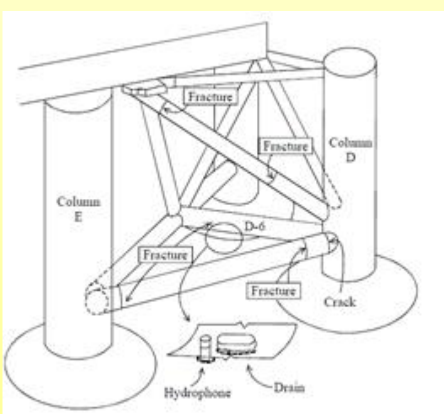


Details of the elbow in 16" line

RESULTANT EROSION CORROSION RUPTURED PIPE.

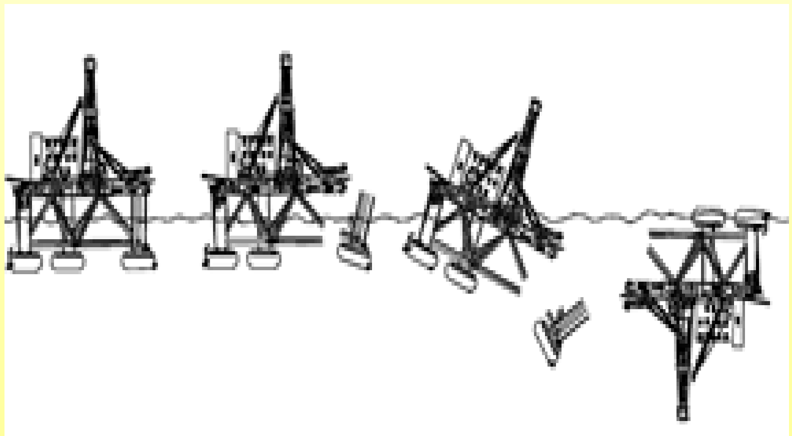
STREAM OF HOT SOLUTION ENTERED CONTROL ROOM CAUSING TWELVE FATALITIES OF OPERATORS TAKING LUNCH

Alexander L. Kielland Disaster Led to Death of More Than 100 People - A Case of Poor Workmanship



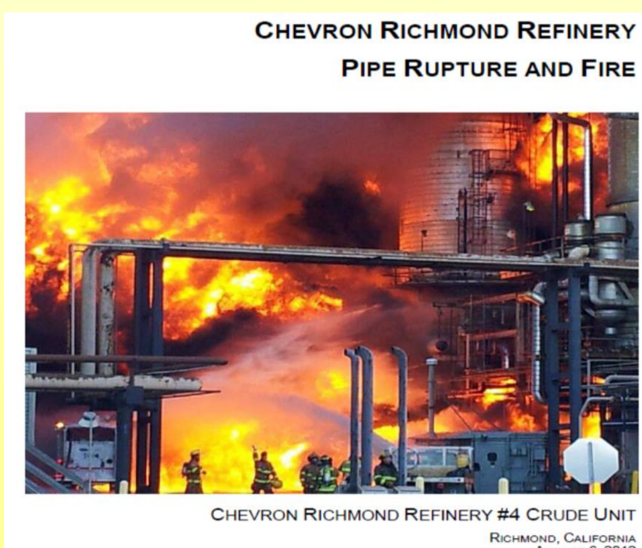
- TWO ATTACHMENTS WERE FITTED ON BRACING D6
- WELDING OF DRAIN TO BRACING WAS DONE AS PER DESIGN RULES
- FOR HYDROPHONE CIRCULAR HOLE WAS FLAME CUT & DOUBLE FILLET WELDED WITHOUT EDGE GRINDING
- POOR JOB RESULTED IN GROWTH OF FATIGUE CRACK & BREAKING OF COLUMN D

Process of capsize of Alexander L. Kielland
A Semi-Submersible Off Shore Platform



CASE OF POOR JOB PLAN & SUPERVISION

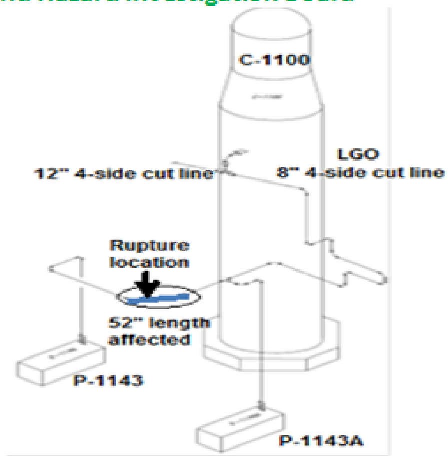
Case of Unknown Corrosion Property of Steel At Time of Refinery Construction & Poor Management



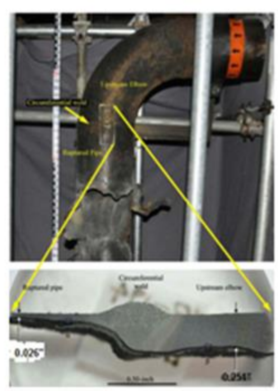
RICHMOND REFINERY FIRE ON 6^{TH} AUGUST 2012

U.S. Chemical Safety And Hazard Investigation Board

Rupture in a 1250 mm (50") long section of light gas oil (LGO) draw off-line caused formation of vapor cloud followed by fire. The MOC of 200 mm diameter 8.18 mm thick carbon steel pipe section operated at 343^0C ruptured as a result of thinning due to sulfidation attack. No substantial thinning at different corrosion monitoring locations (CML) on the line and the bends were recorded. As no CML was located in the short length of ruptured section the thinning during service went un noticed.

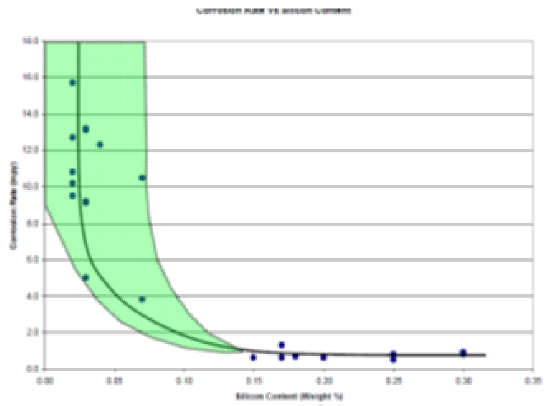


The affected portion had silicon content of 0.01 wt. % against 0.16 wt. % in case of rest of unaffected line. The importance of silicon content in steel against sulphidation was known only since 1974 and refiners are specifying this only since 1980s. Normally, A 53 or A 106 piping is used of which the former does not specify silicon content against minimum 0.1% in case of the latter. Thus piping used where sulphidation is possible should conform to A 106.

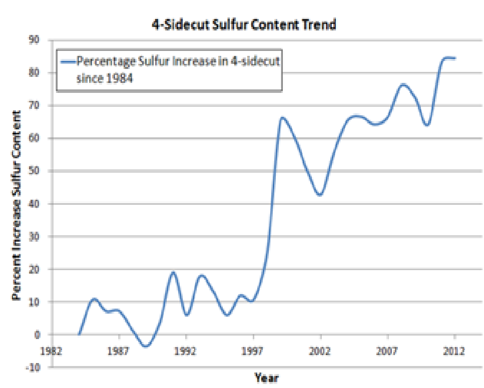


SUBSEQUENT TO FIRE THE MOC OF WHOLE LGO DRAW OFF LINE WAS UPGRADED TO 9CR-1MO

Role Of Silicon Content On Sulfidation Resistance Of Steel



SULFUR IN THE STREAM INCREASED FROM 0.8 TO 1.6 WT% WITH CORROSPONDING INCREASE OF SULFUR IN CRUDE BY 85% BETWEEN 1984 AND 2012 INCLUDING A SIGNIFICANT JUMP OF 32% FROM 1998 TO 1999. THIS INCREASE CORRESPONDED WITH A SIMULTANEOUS INCREASE IN THE USAGE OF NON-DOMESTIC HIGH SULFUR CRUDE.



Adverse Remark By Federal Invesigatar

U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD REPORT HIGHLIGTS FOLLOWING CONCLUSIONS

- STRIKING LACK OF ATTENTION ON THE PART OF THE RICHMOND CHEVRON REFINERY TO MAINTENANCE AND METALLURGY UPGRADES
- CHEVRON RICHMOND REFINERY'S FAILURE TO IMPLEMENT A RECOMMENDED 100% COMPONENT INSPECTION PROGRAM FOR HIGH-RISK PIPING.
- CHEVRON DID NOT CONDUCT AN MOC ANALYZING IMPACT AND CHANGE ITS CORROSION MONITORING PROGRAMS DUE TO THE INCREASED SULFUR CONTENT
- THERMO SCIENTIFIC NITON XL3T XRF ANALYSER GIVES SILICON CONTENT