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Pancevo Petrochemical Modernization Feasibility Study

Final Report

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ABB Lummus Global

PANCEVO PETROCHEMICAL COMPLEX MODERNIZATION FEASIBILITY STUDY

FINAL REPORT

Job No. 12227
February 2003

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PANCEVO PETROCHEMICAL COMPLEX MODERNIZATION FEASIBILITY STUDY

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1.0 EXECUTIVE SUMMARY AND RECOMMENDATIONS

1.1 Overall Summary

Hemijska Industrija Pancevo (HIP) Petrochemija contracted with ABB Lummus Global Inc. for this feasibility study, which was paid for jointly by the United States Trade and Development Agency and Lummus. The purpose of the study was to examine the technical and economic means available for the future survival and development of HIP's petrochemical complex at Pancevo, near Belgrade in Serbia.

The complex is centered around a 200,000 metric tons per year ethylene plant built in 1977 to supply ethylene for the manufacture of high density polyethylene (HDPE), low density polyethylene (LDPE), and vinyl chloride monomer (VCM), with the VCM converted to polyvinyl chloride (PVC). No propylene upgrading was included, though the mixed C_4s were provided with added value by processing in the FSK complex at Elemir 50 kilometers away. The forced shutdown of the VCM unit in 1999 has limited the ethylene plant to operation at only 56% of its design capacity, resulting in essentially no net revenue. It is critical that HIP install additional facilities in order to obtain good profitability. These new facilities need to obtain full utilization of the capacity of the ethylene plant, with good value for its products. For additional benefit, expansion of the ethylene plant has also been considered, together with installation of additional or enlarged associated downstream facilities.

Many variations and possible configurations of a future HIP complex, including the interactions between Pancevo and the FSK C_4 complex, were studied. As part of the study, a linear program (LP) model created for the NIS refineries at Pancevo and Novi Sad was adapted to cover the HIP petrochemical complex and its future options, so that the supply of feedstock from the refineries to HIP could also be studied. The details and results of this LP screening work are included in Section 4.0, and the economic evaluations of each of the process units are included in Section 6.0.

Four overall processing schemes were selected for detailed study, whose features and results are presented in Section 1.2. As seen in Table 1.2-1, completion of the largest project considered (Scheme 2, with inclusion of the ethylene plant expansion) would have a very good return on investment (with an estimated simple payout of 2.2 years) and generate nearly US $400 million of annual net revenue, but require a very large investment of about US $800 million. To facilitate the acquisition of financing, it has been subdivided into a series of phases for consideration.

Special focus is on completing the attainment of full utilization of the existing ethylene plant capacity (through Phase 4 of Scheme 2) and deferring the expansion (Phase 5). Scheme 1 is the same as Scheme 2 through Phase 4, except that it does not incorporate certain preinvestments included in Scheme 2. Its return on investment is even better (about 1.7 years simple payout) with the required investment reduced to about US $400 million (and generating annual net revenue of about US $227 million).

Schemes 3 and 4 are alternative approaches to achieve full utilization of the ethylene plant for still lower investment than Scheme 1 (< US $200 million for both these schemes, i.e., less than half that of Scheme 1, <25% of the investment of Scheme 2). Scheme 3 shows the best economics (generation of > US $150 million annual net revenue for a simple payout of about 1.1 year), while Scheme 4 is unattractive (generation of only about US $50 million with simple payout of about 4 years) unless a polypropylene plant would be added to it (for significant extra investment but also generation of substantial additional net revenue).

Our recommendation is to defer the expansion of the ethylene plant (Phase 5 of Scheme 2) for consideration as a future project and, as the immediate goal, to attain full utilization of the existing plant, plus initiate operating efficiency improvements. For the immediate goal of full utilization of the existing plant, our recommendation is to complete Scheme 3 through Phase 5. It is the preferred modernization route in many ways:

- The capital investment needed (< US $200 million) is the least for achieving full utilization of the ethylene plant (to obtain substantial increase in net revenue: > US $150 million/year)
- The payout is the fastest (1.2 years)
- The schedule is short (2006 completion feasible)
- Polystyrene and new HDPE can be considered for the future, especially if/when additional ethylene plant capacity is installed (e.g., completing Scheme 2 subsequent to Scheme 3)

The key features of Scheme 3 are as follows:

- Polypropylene as primary source of new revenue, representing major value addition from current chemical grade propylene
- Maximization of propylene for polypropylene by
  - Operating ethylene plant in maximum propylene mode*
  - Inclusion of FCC propylene from Pancevo refinery
  - OCT (olefins conversion technology) unit to convert ethylene and butylenes to propylene*
- Production of impact grade polypropylene
  - Increases market price
  - Consumes some ethylene*

The features marked with asterisk (*) enable the ethylene plant to reach full utilization. Scheme 3 also includes expansion of the existing HDPE plant, further helping the ethylene plant to reach full utilization. Capacities of new or expanded units are:

- Expansion of existing HDPE to 75 KTA
- 149 KTA C_3 splitter
- 84 KTA OCT unit
- 225 KTA polypropylene unit
- Debottleneck ethylene plant C_3/C_4 fractionation

Other features include:

- Continue operating existing LDPE unit at 50 KTA
- Upgrade 58 KTA propylene from NIS refinery to polypropylene
- Operate FSK with imported C_4s to produce 17 KTA MTBE, 36 KTA SBR

The ways in which Scheme 3 can be optimized to increase revenues are described in Section 6.0. To proceed with the project, it is recommended that HIP study the Scheme 3 variations presented in Sections 4.0 and 6.0 in order to determine how many phases to carry out on what schedule, and how to accomplish the financing. In addition, future plans should be taken into account and the new facilities should be sized to be compatible with both the near term goal of completing Scheme 3 and the potential for future upgrading project possibilities, e.g., to subsequently complete Scheme 1, 2 or 4.

It is also recommended that HIP review the utilities (especially energy) and Fixed Costs (especially manpower requirements) for the existing facilities. There appears to be significant potential for increasing net revenue even further through cost savings in these areas.

Further discussion is provided in Sections 1.5 – 1.11 for each of the process plants that were studied, summarizing the more detailed results found in Sections 4.0 and 6.0.

1.2 Overall Schemes and Results

The overall schemes are summarized below. Further details are provided in Section 4.0, where phases are also defined so that the capital investment required could be spread over several years in order to make the repayment of financing debt easier.

Scheme 1:
- Full ethylene plant utilization with C_3/C_4 debottlenecking but no expansion of cracking furnaces or cracked gas compressor
- Revamp existing HDPE unit to 75 KTA
- New carbon black unit 15 KTA
- New OCT unit 67 KTA
- New C3 splitter 129 KTA
- New polypropylene unit 225 KTA
- Increase benzene by dealkylation
- New polystyrene train 124 KTA

Scheme 2:
- Expand ethylene plant to 351 KTA (gross from cracking furnaces)
- Revamp existing HDPE unit to 75 KTA
- New carbon black unit 15 KTA
- New OCT unit 112 KTA
- New C3 splitter 216 KTA
- New polypropylene units 345 KTA
- New HDPE unit 118 KTA (or larger if shut down existing LDPE and/or HDPE)
- Increase benzene by dealkylation
- New polystyrene train 178 KTA

Scheme 3: Minimum investment for full ethylene plant utilization with C_3/C_4 debottlenecking but no expansion of cracking furnaces or cracked gas compressor
Maximum propylene mode
Revamp existing HDPE unit to 75 KTA
New OCT unit 84 KTA
New C3 splitter 149 KTA
New polypropylene unit 225 KTA

Scheme 4: Minimum investment for full ethylene plant utilization with C_3/C_4 debottlenecking but no expansion of cracking furnaces or cracked gas compressor
New HDPE unit 147 KTA
Shut down existing LDPE unit

These schemes are compared in Table 1.2-1.

The full completion of Scheme 3 according to Section 6.0 (adding Phase 5) would result in economics even superior to that listed in Table 1.2-1 by adding a second reactor to the polypropylene plant so that it can produce impact copolymer as well as homopolymer. That additional stage would augment Scheme 3's net revenue by approximately US $50 million for an extra investment of only about US $25 million.

Our recommendation is to defer the expansion of the ethylene plant (Phase 5 of Scheme 2) for consideration as a future project and, as the immediate goal, to attain full utilization of the existing plant, plus initiate operating efficiency improvements. For the immediate goal of full utilization of the existing plant, our recommendation is to complete Scheme 3 through Phase 5.

Table 1.2-1
Comparison of HIP Modernization Schemes

	Scheme			
	1	2	3	4
Number of Phases	4	5	4 (Phase 5 not included in this table)	1
Brief Description	Revamp HDPE + Add Carbon Black; Add P/P Splitter + PP; Add OCT unit; Add PS train + Upgrade PP + Debottleneck Eth. Plant Fractionation	Revamp HDPE + Add Carbon Black; Add P/P Splitter + PP; Add OCT unit; Add PS train + Upgrade PP + Debottleneck Eth. Plant Fractionation; Expand Ethylene Plant + Add New HDPE + Expand PP + PS	Run in max. propylene mode + Add P/P Splitter + Debottleneck Eth. Plant Fractionation; Revamp HDPE; Add OCT unit; Add PP	Add New HDPE + Shut Down LDPE+ Debottleneck Eth. Plant Fractionation
Ethylene Plant C2= Gross Production, KTA	112>127 > 127 > 144> 200	112>127 > 127 > 144>200 > 351	112>112 > 127 >150> 150	112>200
Net Revenue Relative to Base Case Net Revenue, MMUS$/Year	227.18	371.85	137.49	44.63
Total Installed Cost, MMUS$	394.60	806.50	168.80	180.00
Simple Payout, Years (TIC/Net Revenue)	1.74	2.17	1.23	4.03
%IRR (Complete Scheme, Phased Construction)	74.23	67.84	92.81	28.52
Major Products, KTA:				
Propylene (Chemical Grade)	0	0	0	93
Propylene (Polymer Grade)	0	0	34	0
Polypropylene	207	316	180	0
LDPE	50	50	50	0
HDPE	75	193	75	196
Polystyrene	124	178	0	0
Carbon Black	15	15	0	0
Year of Completion	2009	2012	2006	2006

1.3 Financing Plan

The financing structure is based on HIP's current ability to produce and export petrochemical products. However, it is recommended that grants, equity and concessional financing be sought from all available government and industry sources.

The loans to HIP are anticipated to be secured by export revenues that accumulate in an offshore bank account. The amount of export revenues that flow through the account must be 50 percent more in a six-month period than the amount needed to be paid to the lender of the loans. This protects the lender against price changes in products. Surplus funds after payment to the lender go to HIP.

Details of possible loan and payment arrangements are given in Appendix A.

1.4 Environmental Effects

The water effluents and atmospheric emissions from the HIP complex at Pancevo have been estimated for the future based on the modernization according to Scheme 3. These effluents and emissions are compared in Table 1.4-1 with those generated in 2001.

Table 1.4-1
Comparison of Base Case and Future Effluents and Emissions for Scheme 3 at HIP

		2001	2007	% Change
1.	Wastewater Effluents, m^3/yr			
	Pancevo	653,387	923,350	+41
	FSK	1,599,054	1,517,215	-5
2.	Atmospheric Emissions, MT/yr			
	Pancevo			
	NOx	772	1,000	+30
	SOx	1,109	1,629	+47
	Particulates	94	136	+45
	CO_2	518,000	642,084	+24
	FSK			
	NOx	23	21	-8
	SOx	1.7	1.5	-8
	Particulates	0.4	0.4	-8
	CO_2	20,492	18,852	-8

The increases at Pancevo are as a result of the increase in throughput of the existing and new units. At FSK there is projected to be a reduction in atmospheric emissions as a result of lower steam generation rate.

2.0 INTRODUCTION AND BACKGROUND

In May 2002, ABB Lummus Global Inc. began work on the present master plan for the modernization of the HIP Petrohemija Petrochemical Complex at Pancevo in Serbia. This complex consists of the following process units.

	Capacity MTA
Ethylene Plant	
1. Ethylene Plant	200,000
2. Propylene, chemical grade 95%	85,000
3. C_4 fraction (up to 60% butadiene)	45,000
4. Pyrolysis Oil	38,000
5. Pyrolysis Gasoline	138,000
SBR Plant (at Elemir)	
1. Styrene Butadiene Rubber (SBR)	40,000
2. MTBE, Methyl Tertiary Butyl Ether	35,000
3. 1,3 Butadiene	45,000
4. Raffinate #2	22,000
Electrolysis Plant	
1. Chlorine	88,800
2. Sodium Hydroxide (100%)	100,000
3. Sodium Hypochlorite	8,000
VCM Plant	
1. Vinyl Chloride Monomer, VCM	100,000
2. Ethylene Dichloride, EDC	15,000
3. Hydrochloric Acid (min. 33%)	18,000
Polymer Plants	
1. Low Density Polyethylene, LDPE	45,000
2. High Density Polyethylene, HDPE	60,000
3. PVC Plant	
Polyvinyl Chloride, (PVC powder)	34,000
Polyvinyl Chloride, (PVC pellets)	16,000

Polymer Processing (not part of the Master Plan)

1. Polyethylene Pipes
2. Electrofusion fittings
3. Corrugated Electro – insulating pipes (PVC, PP, PE)
4. PVC and HDPE black and colored granulate

The scope of the master plan is to examine the following issues, with priority being given to those of greater economic consequence.

- Expansion of the ethylene unit from 200,000 MTA to 320,000 MTA.
- New cracking furnaces and new recovery section.
- Enhance design of cracking furnaces to accommodate greater feedstock flexibility.
- Increase yields of ethylene and propylene.
- Reduction of energy consumption; the original ethylene plant design requires 9,600 kcal/kg of ethylene, while operating at today's 60-75% capacity the energy consumption is 12,000 kcal/kg of ethylene.
- Improve plant operability; i.e. DCS control throughout, eliminate and minimize fouling in recovery systems, e.g. green oils, polymers, etc., reduce maintenance requirements and enhance plant reliability with modern facilities and systems; eliminate and minimize corrosion and coke formation.
- Upgrading of ethylene derivative units, polyethylene (LDPE and HDPE).
- Increase propylene production from the ethylene plant and optimize the production of chemical grade and polymer grade propylene.
- Evaluate the disposition of pyrolysis gasoline in coordination with the refinery.
- New plant for the production of polypropylene with a possible capacity of 135,000 MTA; combining propylene production from the expanded ethylene plant with that recovered from refinery production (from the FCC unit), 40-50,000 MTA, the possible capacity could be 180,000 MTA.
- Discontinue manufacture of methyl tertiary butyl ether (MTBE) and convert the unit to isooctane production.
- Alternative use of raffinate #2 from the synthetic rubber (SBR) plant.
- LLDPE production in addition to LDPE; the issue is the market (data to be supplied by HIP), and the source for butene-1 or hexene-1 (produce or purchase); currently the plant purchases hexane for HDPE production.
- Caustic/chorine, VCM and PVC facilities: study the investment cost, the market (data to be supplied by HIP), and analyze the economics and environmental risks to determine if future domestic and export markets warrant continuation of this business program or if investment should be dedicated to the polyethylene and polypropylene markets.

The capacity of the units in the complex is more than sufficient to provide for the needs of Serbia for those products manufactured by HIP, and so exports are necessary for economical operation. The population of Serbia and Montenegro is about ten million people, rather small for a petrochemical complex built around a steam cracker producing 200,000 metric tons per year of ethylene.

The complex is built adjacent to the oil refinery of the national oil company of Serbia, NIS, from which the ethylene plant receives some of its naphtha feedstock. The balance of the feedstock is imported. The mixed C_4s from the ethylene cracker go by rail to Elemir where the butadiene is extracted to make synthetic butadiene rubber and the raffinate reacts with methanol to make methyl tertiary butyl ether (MTBE).

It is to be expected that Serbia will join the European Union. At that time there will be a free market for imports and exports of polymers and petrochemicals and the Pancevo complex must therefore be made efficient and cost competitive in order to remain in production.

3.0 PETROCHEMICAL COMPLEX EVALUATION

3.1 Ethylene Unit

3.1.1 Capacity Expansion to 320,000 MTA

3.1.1.1 Basis of Study

Scope of Study

The purpose of the study is to determine the major modifications needed to expand the capacity of HIP's Ethylene Plant from 200,000 MTA to 320,000 MTA (net) of ethylene.

The ISBL sections of the ethylene plant included in this study are:

- Feed Preheat and Cracking Heaters
- Gasoline Fractionator, Quench and Dilution Steam System
- Compression, Acid Gas Removal and Drying
- Chilling, Demethanization and H_2 Purification
- Ethylene Product Recovery
- Propylene Product Recovery
- C_4 Product Recovery
- Propylene Refrigeration
- Ethylene Refrigeration
- GHU Unit

Definition of Study

The expanded capacity for this study is 320,000 MTA (net) ethylene.

The feedstocks for the expansion are NIS refinery naphtha and import naphtha as defined in the feedstock specifications section. The feedstock slate for design capacity calculation is summarized below:

Table 3.1.1
Feedstock Slate

Feed	MTA
NIS Refinery Naphtha	298,984
Import Naphtha	778,472

All ethane and propane produced in the plant are recycled and cracked to extinction. Raffinate C_4s are recycled as a feed to pyrolysis furnace from the Olefins Conversion Unit (OCU). Propane is co-cracked with ethane and C_4 is co-cracked with naphtha.

In addition, following internal and external streams are also processed in the recovery section.

- HP Offgas from GHU
- LP Offgas from GHU
- Offgas from PP plant
- Offgas from PE plants
- Offgas from OCU Unit
- Propylene rich stream from NIS refinery

Operating Hours

Operating hours will be 8000 hours per calendar year.

<u>Feedstock Specifications</u>

NIS Refinery Naphtha

Specific Gravity			0.714
Total Sulfur content		ppm wt.	430
Distillation (% vol.)	IBP	°C	67
	50	°C	94
	EBP	°C	128
PNA Analysis	Paraffins	% wt.	74.0
	Naphthenes	% wt.	18.1
	Aromatics	% wt.	7.9

Import Naphtha

Specific Gravity			0.745
Total Sulfur content		ppm wt.	800
PNA Analysis	Paraffins	% wt.	58
	Naphthenes	% wt.	32.5
	Aromatics	% wt.	9.5
Distillation (% vol.)	IBP	°C	108
	50	°C	133
	EBP	°C	180

Product Specifications

Polymer Grade Ethylene

Characteristics	Units	Value
Ethylene	% (v/v)	min 99.9
Inerts (CH_4, C_2, C_2H_6, N_2)	% (v/v)	max. 0.1
C_3 and heavier	ppm (v/v)	max. 25
Acetylene	ppm (v/v)	max. 10
Carbon Monoxide	ppm (v/v)	max. 1
Carbon Dioxide	ppm (v/v)	max. 6
Hydrogen	ppm (v/v)	max.10
Oxygen	ppm (v/v)	max. 5
Total Sulfur	ppm (m/m)	max. 1
Carbonyls	ppm (m/m)	max. 1
Alcohol (as Methanol)	ppm (m/m)	max. 1
Ammonia	ppm (m/m)	max. 1
Water	ppm (v/v)	max. 5

Polymer Grade Propylene

Component	Unit	Specification
Propylene	mol %	99.5 min
Propane	mol %	0.5 max
Acetylene	mol ppm	1 max
Ethylene	mol ppm	50 max
Ethane	mol ppm	100 max
Methylacetylene	mol ppm	1 max
Propadiene	mol ppm	2 max
Butenes + Butadiene	mol ppm	1 max
Cyclopropane + Butanes	mol ppm	1 max
Carbon Monoxide	mol ppm	0.2 max
Carbon Dioxide	mol ppm	2 max
Oxygen	mol ppm	2 max
Water	mol ppm	5 max
Sulfur as Hydrogen Sulfide	mol ppm	1 max
Total Oxygenated Hydrocarbons	mol ppm	1 max
incl. Alcohols (as MEOH)		
Chlorides	wt ppm	1 max
Total Combined Nitrogen	mol ppm	1 max
Arsine	wt ppm	0.15 max

C_4 Fraction

Characteristics	**Units**	**Value**
1,3 Butadiene	% (m/m)	min 43 max. 60
Iso-butene and butene 1	% (m/m)	min. 25 max. 42
C_3s	% (m/m)	max. 0.7
C_5s	% (m/m)	max. 0.3

Pyrolysis Treated Gasoline

Characteristics	**Units**	**Value**
ASTM Distillation Initial boiling point	°C	min 40
ASTM Distillation Initial End Point	°C	max. 205
Density	kg/m^3	840 ± 30
	kg/m^3	max. 0.03
Total Sulfur	ppm (m/m)	max. 500
pH	µg/l	max. 30
	min.	min. 360
Aromatics	% (m/m)	min. 70

Hydrogen Product

Hydrogen	mol %	94.93
Methane	mol %	Balance
Nitrogen	mol %	0.10 max.
CO and CO_2	ppm mol	5.0 max

Methane Rich Gas

Methane	mol %	86.6
Hydrogen	mol %	12.93
CO	mol %	0.46
C_2s	mol %	0.01
Total		100.00
LHV, Btu/lb		21896 (est.)

Fuel Oil

Characteristics	Units	Value
Density (16°C)	°C	1050 ± 10
ASTM Distillation Initial Point 50%	°C	min. 180 max. 290
Coke	% (m/m)	max. 15
Total Sulfur	% (m/m)	max. 0.05
Water	% (m/m)	max. 0.5
BMCI (from distillation)	min.	min. 125
Flash point (open cup)	°C	min. 80
Ash	% (m/m)	max. 0.02

Battery Limit Conditions

	State	Pressure		Temperature	
		kg/cm^2g	psi (g)	°C	°F
Products					
Hydrogen Product	Vapor	24.5	348	Ambient	
Polymer Grade Ethylene	Vapor	55.9	795	22.8	73
	Liquid	3.5	50	-98	-144
Polymer Grade Propylene	Liquid	23.9	340	43.9	111
Raw C_4 Product	Liquid	7.2	103	37.8	100
Pyrolysis Treated Gasoline	Liquid	7.3	104	37.8	100
Fuel Gas	Vapor	3.7	53	37.8	100
Fuel Oil	Liquid	7.7	110	50-80	122-176
Feedstocks					
Import Naphtha	Liquid	11.3	161	Ambient	
NIS Refinery Naphtha	Liquid	11.3	161	26.7	80
NIS Refinery Propylene	Liquid	20.4	290	51	124
HDPE Offgas	Vapor	12.7	180	44.4	112
LDPE Offgas	Vapor	31.3	445	23.9	75
PP Offgas	Vapor	2.5	35	10-41	50-105

Utilities Specifications

Steam

		Normal Operating Conditions			
		Pressure		Temperature	
		kg/cm^2g	psi (g)	°C	°F
Saturated Steam (High Pressure)	SH	107.6	1530	315.6	600
Superheated Steam (High Pressure)	SSH	105.5	1500	440.6	825
Medium Pressure Steam	SM	19.0	270	293.3	560
Low Pressure Steam	SL	3.5	50	232.2	450

Cooling Water

	Pressure		Temperature	
	kg/cm^2g	psi (g)	°C	°F
Supply	4.1	58	28.3	83
Return	-	-	43.3	110

5.0 COST ESTIMATES

5.1 Overview

Cost estimates for each of the alternate upgrade configurations for the HIP petrochemical complex at Pancevo as described in Section 4.0 were prepared. These cost estimates were prepared using curve-type estimates based on data in ABB Lummus Global's historical files, as well as from licensor-provided cost estimates for various units. These data are based on United States Gulf Coast (USGC) locations. A location factor to convert estimates from USGC to Serbian location costs was developed. Cost estimates for Pancevo are presented in U.S. dollars to minimize the effects of currency changes.

Cost estimates for facilities outside battery limits were also developed, using a factored approach based on the experience of ABB Lummus Global.

Both onshore and offshore component costs were considered, and an estimate of the overall breakdown of onshore and offshore costs is provided.

This section of the report describes the methodology for preparing the cost estimates.

5.2 Capital Cost Estimating Methodology

Capital cost estimates for the facilities at Pancevo petrochemical complex are described and detailed in this section. A review of the terms and the methodology used in developing the capital costs is given below.

5.2.1 Definitions Used In Describing the Cost Estimate

The following definitions are used in describing the estimate:

- ISBL – Inside Battery Limits – It applies to the equipment and materials associated with the process units and are confined to the battery limits line around the physical definition of a process unit.
- USGC – United States Gulf Coast – Refers to costs in the United States Gulf Coast. It is a reference point from which factors are applied to estimate costs in Serbia.
- OSBL – Outside Battery Limits – It applies to those utility and support facilities such as storage and buildings required by the process units.
- Offshore – Material and services provided by Western firms and businesses located outside of Serbia.
- Onshore – Material and services provided by firms and businesses located within Serbia.

- ISBL Cost Estimate – A cost estimate developed for each process unit on a USGC 2Q 2003 basis. The costs were obtained primarily from factored estimates, process licensors, and ABB Lummus Global cost files, which include data from completed projects.

- OSBL Cost Estimate - The OSBL costs were based on factors developed from the experience of ABB Lummus Global.

5.2.2 Location factors and Estimation of Onshore / Offshore split of costs

Table 5.2.2-1 presents the Ratio of Estimated Dollar/Dinars Split of Investment Expenditures (Offshore/Onshore) for five major cost components. The table was developed on the basis of the chosen technologies and the corresponding requirements of appropriate construction and installation materials.

USGC costs were factored for US dollar expenditure to integrate the project location (Serbia) and the proposed project schedule. The factoring has been applied to equipment, commodities, engineering, construction supervision, and subcontractor components of the USGC cost estimates. The resulting overall cost factor to convert USGC costs to Serbian location is 1.03. This factor is applied to the total ISBL and OSBL costs.

The split of costs between offshore and onshore components for ISBL and OSBL facilities at Pancevo is estimated to be:

	Offshore Costs	Onshore Costs
ISBL	60%	40%
OSBL	10%	90%

5.2.3 ISBL Costs

The development of site-specific costs is based upon establishing the United States Gulf Coast cost estimate for each process unit. Most of the units are obtained from factored cost estimates and ABB Lummus Global files. Estimating the cost of a new unit requires knowledge of unit performance requirements (e.g., feed rate, yield, quality, etc.).

Additionally, ABB Lummus Global has contacted various vendors and licensors to obtain budgetary costs for units being considered for the Pancevo petrochemical complex modernization. These include costs obtained for:

- Ethylene unit revamp (See Section 3.1 for further details)
- New HDPE unit and revamping existing HDPE unit (Section 3.3)
- New polypropylene unit (Section 3.2)
- New EB/SM and polystyrene unit (Section 3.8)
- MTBE unit conversion (Section 3.5)
- Toluene dealkylation unit (Section 3.7)

Table 5.2.2-1

Ratio Of Estimated Dollar / Dinars Split Of Investment Expenditures (Offshore/Onshore)

COST COMPONENT	OFFSHORE DOLLAR AMOUNT	ONSHORE DINAR AMOUNT
EQUIPMENT MATERIALS	RANGES FROM 50% TO 80%	RANGES FROM 20% TO 50%
COMMODITY MATERIALS	RANGES FROM 40% TO 50%	RANGES FROM 50% TO 60%
CONSTRUCTION	0	100%
ENGINEERING	RANGES FROM 70% TO 100%	RANGES FROM 0% TO 30%
CONSTRUCTION SUPERVISION	RANGES FROM 0% TO 10%	RANGES FROM 90% TO 100%

Costs are given on a Pancevo basis. Included in the estimates are:

- License fee
- Basic engineering
- Detailed engineering
- Equipment (vessels, pumps, heat exchangers, etc.)
- Commodities (structural steel, concrete, instrumentation, etc.)
- Construction
- Construction management
- Catalyst first charge
- Contingency of 12.5%

5.2.4 Cost Estimate Considerations

The estimates are for budgetary purposes to support the economics and the investment analysis of the Pancevo petrochemical complex.

The accuracy of the estimates is +/- 30%.

The following items have been excluded from the development of the cost estimates for the complex:

- Spare parts for two years
- Training
- Start-up Costs

- Performance payment bonds.
- Risk assessments for contractual, currency, schedule and process considerations.
- Forward cost escalation.
- Owner's cost (e.g. development of organization, engineering and project development, site preparation and demolition of existing equipment, permitting, etc.).
- Product pipelines.
- Social infrastructure costs that might be required outside the battery limits of the complex such as schools, roads, housing, etc.
- Financing fees

OSBL cost estimates vary between 30% of ISBL costs for new units, to 5% for simple revamps and make allowance for the fact that there is considerable infrastructure already in place.

5.2.5 Summary of Capital Cost Estimates

Table 5.2.5-1 summarizes the capital cost estimates used in the HIP master plan.

Table 5.2.5-1
Summary of Capital Cost Estimates
$ million

Basis: mid-2003, Pancevo site

Unit	Capacity, KTA	Timeline	ISBL	OSBL	Total
HDPE Revamp	75	Scheme 1, Phase 1	7.5	0.3	7.8
		Scheme 2, Phase 1			
New	118	Scheme 2, Phase 5	106.5	27.5	134.0
Carabon Black	15	Scheme 1, Phase 1	22.3	6.2	28.5
		Scheme 2, Phase 1			
C_3 Splitter	148	Scheme 1, Phase 2	19.4	5.8	25.2
	215	Scheme 2, Phase 1	24.8	7.4	32.2
Polypropylene	180	Scheme 1, Phase 2	77.5	19.9	97.4
		Scheme 2, Phase 2			
	+45	Scheme 1, Phase 4	14.2	3.4	17.6
	225				
	+120	Scheme 2, Pphase 5	58.5	15.3	73.8
	345				
C_4 Selective Hydrogenation	60	Scheme 1, Phase 3			
	106	Scheme 2, Phase 3			
Olefins Conversion Unit + Debutanizer	67	Scheme 1, Phase 3	14.6	3.8	18.4
	112	Scheme 2, Phase 3	21.0	5.3	26.3
Pygas Hydrogenation Revamp	146	Scheme 1, Phase 4	1.0	1.0	1.0
	256	Scheme 2, Phase 4	1.0	1.0	1.0
Toluene Dealkylation	39	Scheme 1, Phase 4	17.0	4.6	21.6
	55	Scheme 2, Phase 4	21.5	5.7	27.2
Ethylbenzene/Styrene Monomer	122	Scheme 1, Phase 4	70.2	19.7	89.9
	172	Scheme 2, Phase 4	88.3	24.6	112.9
Polystyrene	124	Scheme 1, Phase 4	53.2	14.0	67.2
		Scheme 2, Phase 4			
	+54	Scheme 2, Phase 5	30.1	8.2	38.3
	178				
Ethylene					
Heater Revamp	200		27.4		
Expansion	+150	Scheme 2, Phase 5	94.4	27.9	122.3
	350				

7.0 ENVIRONMENTAL EFFECTS

The objectives of this study were to (1) define an upgrade strategy which to allow the existing ethylene plant to operate at its original design capacity (200 KTA ethylene), and then (2) evaluate the economic viability of revamping the ethylene plant to 351 KTA (ethylene production exclusive of the Olefins Conversion Unit or other ethylene consumers). To meet these objectives, new process units as described in Sections 3.0 and 4.0 of this report were proposed.

This section describes the major environmental effects of the new process units compared to the base case HIP operation.

7.1 Overview

HIP is subject to the environmental regulations of the Federal Republic of Yugoslavia and the Republic of Serbia. Yugoslavia plans to seek full membership in the European Union and this will require that the HIP Petrochemical Complex meet EU standards in the future. New and revamped process units would include design features as discussed in Section 3.0 designed to meet the EU environmental performance standards.

As defined in Section 4.0, the base case for comparisons is the assumed operation, at full capacity, of the complex as it was in 2001 without any investment in new plants or upgrades with throughputs.

7.2 Atmospheric Emissions

The main sources of atmospheric emissions in the Petrochemical Complex are:
- combustion flue gases from fired heaters
- fugitive emissions from tankage and equipment leaks
- process gas emissions to atmosphere from vents

Table 7.2-1 provides a summary of the fuel burned in the HIP process units. For Scheme 1 and Scheme 2, a greater part of the energy is provided by cleaner-burning fuel gas than in the Base Case.

Table 7.2-2 presents a summary of emissions from Combustion at the HIP facilities. The following observations are made:

For the Pancevo site, from the Base Case to Scheme 1 (after stage 4), the fired duty increases approximately 20% from 26100 GJ/d to 31300 GJ/d. The fuel oil consumption decreases slightly and fuel gas firing increases. This leads to
- a 16% decrease in SO_2 emissions from 3326 kg/d to 2794 kg/d due to the substitution of cleaner burning fuel gas for fuel oil
- a 5% decrease in particulate emissions from 281 kg/d to 272 kg/d due to the substitution of cleaner burning fuel gas for fuel oil
- a 3% increase in NO_x emissions from 2315 kg/d to 2388 kg/d due to the overall increased fuel consumption

- a 11% increase in CO_2 emissions from 1554000 kg/d to 1719800 kg/d due to the overall increased fuel consumption

For the Pancevo site, from the Base Case to Scheme 2 (after stage 5), the fired duty increases approximately 58% from 26100 GJ/d to 41100 GJ/d. The fuel oil consumption decreases by nearly 64% and fuel gas firing is more than double from 349 MT/d in the Base Case to 738 MT/d in Scheme 2. This leads to

- a 60% decrease in SO_2 emissions from 3326 kg/d to 1316 kg/d due to the substitution of cleaner burning fuel gas for fuel oil
- a 73% decrease in particulate emissions from 281 kg/d to 75 kg/d due to the substitution of cleaner burning fuel gas for fuel oil
- a 1% increase in NO_x emissions from 2315 kg/d to 2388 kg/d due to the overall increased fuel consumption coupled with the substitution of cleaner burning fuel gas for fuel oil
- a 33% increase in CO_2 emissions from 1554000 kg/d to 2064300 kg/d due to the overall increased fuel consumption

For the FSK site, from the Base Case to Scheme 1 or Scheme 2 there is a small reduction (8%) in the fired duty with an equivalent reduction in emissions from combustion sources.

The fugitive emissions are primarily from storage tank losses, spills of volatile organics and leaks from valves and equipment. All new tankage will be selected based upon the regulatory criteria of the vapor pressure of the stored material. A leak detection and repair program should be established to monitor for leaks and perform required maintenance in a timely manner. Preventative maintenance programs have been demonstrated to be effective for reducing fugitive emissions from equipment leaks by up to 95%.

New process units will not discharge any process vent streams directly to atmosphere. All process vent streams will be recovered or combusted in the flare or fired heaters as appropriate to control hydrocarbon emissions.

The Scheme 1 and Scheme 2 will incorporate significant increases in production of polymer products and the addition of Carbon Black manufacture. These plants rely upon pneumatic systems to convey materials through the process and into the packaging/shipping systems. Particulate emissions from conveying system discharges will be controlled through application of bag filters to control emissions to the Best Available Technology limit of 20 mg/Nm3.

7.3 Liquid Wastes

The wastewater from HIP Petrochemical units will continue to be collected and treated through the existing wastewater treatment plant. A summary of the expected wastewater flows from each process unit in the Base Case, Scheme 1 and Scheme 2 is provided in Table 7.3-1.

In the Base case, the WWT plant will be operating with spare capacity. This is due to the reduced capacity operation on the Ethylene plant and the available capacity formerly used to treat the electrolysis and VCM plant wastewaters. In Scheme 1, the flow of wastewater is nearly twice the Base Case wastewater flow. The increased flow is primarily from the Ethylene plant (approximately

45%) which is operated at the design capacity for Scheme 1, and the Carbon Black Unit (approximately 33% of the flow increase). This volume of flow from the ethylene plant is consistent with the unit design and sufficient WWT capacity should be available. In Scheme 2, the flow to the WWT plant from HIP Petrohemija is nearly three times the base case flow rate. This volume of flow is greater than the historical contribution from the HIP Petrohemija wastewater. With additional wastewater that is expected from Pancevo Refinery and Power Plant, it is expected that the WWT plant will require expansion to process the Scheme 2 wastewater flow.

The wastewater treatment plant is reported to have a capacity of 16,280 m3/day. The wastewater treatment plant processes the wastewater from HIP Petrohemija, the Pancevo oil refinery and the power plant. Water received at the wastewater treatment plant is pretreated at the individual process units as required to meet the following specification:

Parameter	Unit	Limit
pH	Std units	6.5 – 9.0
Sulfides	mg/l	<1
Phenols	mg/l	<20
Cyanides	mg/l	<0.03
Oils	mg/l	<350
Mercaptans	mg/l	0
Suspended solids	mg/l	<150

New and revamped process units will include pretreatment as required to meet these limits for discharge to the wastewater treatment plant. A thorough review of the facility water and wastewater requirements should be undertaken to identify opportunities for reuse or recycle. The loss of electrolysis plant will provide some spare capacity at the WWT. Improved operation of the revamped API separator in Pancevo refinery is also expected to reduce the load to the WWT plant. With the proposed expansion of Pancevo Refinery, HIP Petrohemija and the power plant, WWT plant capacity may not be adequate to handle all increased loads.

Potentially contaminated storm water from the additional plot area that is developed during the planned expansion must be collected for analysis before discharge. An additional storm water holding tank must be included in Scheme 1 or Scheme 2 for this purpose. If clean, the collected storm water can be discharged direct to the canal, when contamination is detected, the contaminated storm water must be treated in the wastewater treatment plant prior to discharge.

7.4 Solid Waste

New solid wastes that will be introduced following construction of Scheme 1 or Scheme 2. The characteristics of these solid wastes are included in Table 7.4-1.

Table 7.2-1: Fuel Consumed in Fired Heaters, MT/D
Basis: LP Outputs

	Wt% S	Base Case	Scheme 1 (after Ph 4)	Scheme 2 (after Ph 5)
Fuel Consumption HIP				
Fuel Oil	0.73%	223		
Fuel Oil	0.86%		185	
Fuel Oil	0.09%			80
Fuel Gas	0.01%	349	466	738
Fuel Consumption FSK				
Fuel Gas	0.01%	1,295	1,200	1,200

Table 7.2-2: HIP Emissions from Combustion Sources

Unit	HDPE Plant	New HDPE	New Toluene Dealk	New PS Plant	Olefins Conversion	New Carbon Black	Steam Cracker	Pygas HT1	Stm Generation-HIP	HIP Plant	% Change from Base Case Oper.
Base Case											
Capacity	180						339	248	1854		
Fuel Oil, GJ/d							4313		4482	8795	
Fuel Gas, GJ/d	38						17183	58	0	17279	
Fuel Fired, GJ/d	38						21496	58	4482	26074	
Fuel Oil, MT/D							109.35748		113.64252	223	
Fuel Gas, MT/D	0.8						347.08109	1.1715476	0	349	
SO2, kg/d	0.2						1666.0	0.2	1659.2	3326	
NOx, kg/d	2.1						1628.0	3.3	681.9	2315	
CO2, kg/d	1887.4						1194667.7	2880.8	354564.7	1554001	
Particulates, kg/d	0.0						146.7	0.1	134.4	281.3	
Scheme 1 (after Ph 4)											
Capacity, MT/d	225		123	322	201	45	606	441	1946		
Fuel Oil, GJ/d							2771		4503	7274	-17.3
Fuel Gas, GJ/d	47		85	196	69	1228	22288	107	0	24020	39.0
Fuel Fired, GJ/d	47		85	196	69	1228	25059	107	4503	31294	20.0
Fuel Oil, MT/D							70.5	0	114.5	185	
Fuel Gas, MT/D	0.9		1.6	3.8		23.8	432.4	2.1	0.0	465	
SO2, kg/d	0.2		0.3	0.8		4.8	1115.4	0.4	1672.1	2794	-16.0
NOx, kg/d	2.6		3.3	7.6		47.6	1633.6	5.8	687.2	2388	3.1
CO2, kg/d	2242.2		4055.0	9350.3		58582.8	1283149.4	5104.5	357318.1	1719802	10.7
Particulates, kg/d	1.0		1.0	1.1		2.1	115.1	0.1	151.9	272	-3.2
Scheme 2 (after Ph 5)											
Capacity, MT/d	225	394	124	363	335	45	1054	763	3877		
Fuel Oil, GJ/d									3194	3194	-63.7
Fuel Gas, GJ/d	47	74	120	281	116	1228	31533	188	4342	37929	119.5

Table 7.2-2: HIP Emissions from Combustion Sources

Unit	HDPE Plant	New HDPE	New Toluene Dealk	New PS Plant	Olefins Conversion	New Carbon Black	Steam Cracker	Pygas HT1	Stm Generation-HIP	HIP Plant	% Change from Base Case Oper.
Fuel Fired, GJ/d	47	74	120	281	116	1228	31533	188	7536	41123	57.7
Fuel Oil, MT/D	0	0	0	0	0	0	0	0	80	80	
Fuel Gas, MT/D	0.9	1.4	2.3	5.5	2.3	23.9	613.6	3.7	84.5	738	
SO2, kg/d	0.2	0.3	0.5	1.1	0.5	4.8	122.7	0.7	1184.9	1316	-60.4
NOx, kg/d	2.6	2.9	4.7	10.9	4.5	47.8	1535.3	10.2	716.6	2335	0.9
CO2, kg/d	2248.8	3540.6	5741.5	13444.7	5550.1	58754.6	1508720.5	8995.0	457346.3	2064342	32.8
Particulates, kg/d	0.0	0.1	0.1	0.3	0.1	1.2	30.7	0.2	42.5	75	-73.3

Table 7.2-2: FSK Emissions from Combustion Sources

Unit	Stm Generation FSK	FSK Plant	% Change from Base Case Oper.
Base Case			
Capacity	1101		
Fuel Oil, GJ/d			
Fuel Gas, GJ/d	1295	1295	
Fuel Fired, GJ/d	1295	1295	
Fuel Oil, MT/D			
Fuel Gas, MT/D	25.0	25.0	
SO2, kg/d	5.0	5.0	
NOx, kg/d	70.0	70.0	
CO2, kg/d	61475.0	61475.0	
Particulates, kg/d	2.1	2.1	
Scheme 1 (after Ph 4)			
Capacity, MT/d	1020		
Fuel Oil, GJ/d			-100.0
Fuel Gas, GJ/d	1200	1200	-93.1
Fuel Fired, GJ/d	1200	1200	-95.4
Fuel Oil, MT/D			
Fuel Gas, MT/D	23.0	23.0	
SO2, kg/d	4.6	4.6	-99.9
NOx, kg/d	64.4	64.4	-97.2
CO2, kg/d	56557.0	56557.0	-96.4
Particulates, kg/d	2.0	2.0	-98.1
Scheme 2 (after Ph 5)			
Capacity, MT/d	1020		
Fuel Oil, GJ/d			-100.0
Fuel Gas, GJ/d	1200	1200	-93.1
Fuel Fired, GJ/d	1200	1200	-95.4
Fuel Oil, MT/D			
Fuel Gas, MT/D	23.0	23.0	
SO2, kg/d	4.6	4.6	-99.9
NOx, kg/d	64.4	64.4	-97.2
CO2, kg/d	56557.0	56557.0	-96.4
Particulates, kg/d	2.0	2.0	-98.1

Table 7.3-1: HIP Wastewater Effluent

	Wastewater Effluent, m3/yr			% Change from Base Case	
Unit	**Base Case**	Scheme 1 (after Ph 4)	Scheme 2 (after Ph 5)	Scheme 1 (after Ph 4)	Scheme 2 (after Ph 5)
FSK Stm Generation	3670	3400	3400	-7.4	-7.4
FSK BD Extraction	392663	414829	414829	5.6	5.6
FSK SBR Plant	1199988	1199988	1199988	0.0	0.0
FSK MTBE Plant	2733	3267	3267	19.5	19.5
FSK Plant	1599054	1621483	1621483	1.4	1.4
HDPE Plant	229160	286450	286450	9.6	5.1
New HDPE	0	0	55159	0.0	4.9
New PP 1st Train	0	14744	22471	2.5	2.0
New PP 2nd Train	0	14744	22471	2.5	2.0
New EB/SM Plant	0	29354	32853	4.9	2.9
New Toluene Dealk	0	1107	1116	0.2	0.1
New PS Plant	0	12880	14520	2.2	1.3
C4 Sel HT	0	1638	2871	0.3	0.3
Olefins Conversion	0	0	0	0.0	0.0
C4 Full HT	0	0	0	0.0	0.0
New Carbon Black	0	194248	194248	32.7	17.2
C3/C3= Split	0	0	0	0.0	0.0
Steam Cracker	337831	603910	1050365	44.8	63.2
Pygas HT1	2232	3969	6867	0.3	0.4
Stm Generation-HIP	6180	6487	12923	0.1	0.6
Actyln/Prpdiene HT	135	279	513	0.0	0.0
Stm Crckr Recycle	0	0	0	0.0	0.0
CD DeIsobutanizer	0	0	0	0.0	0.0
LDPE Plant	23450	23450	23450	0.0	0.0
PVC Plant	54399	54399	54399	0.0	0.0
HIP Plant	653387	1247658	1780676	91.0	172.5

Table 7.4-1: Solid Waste Summary

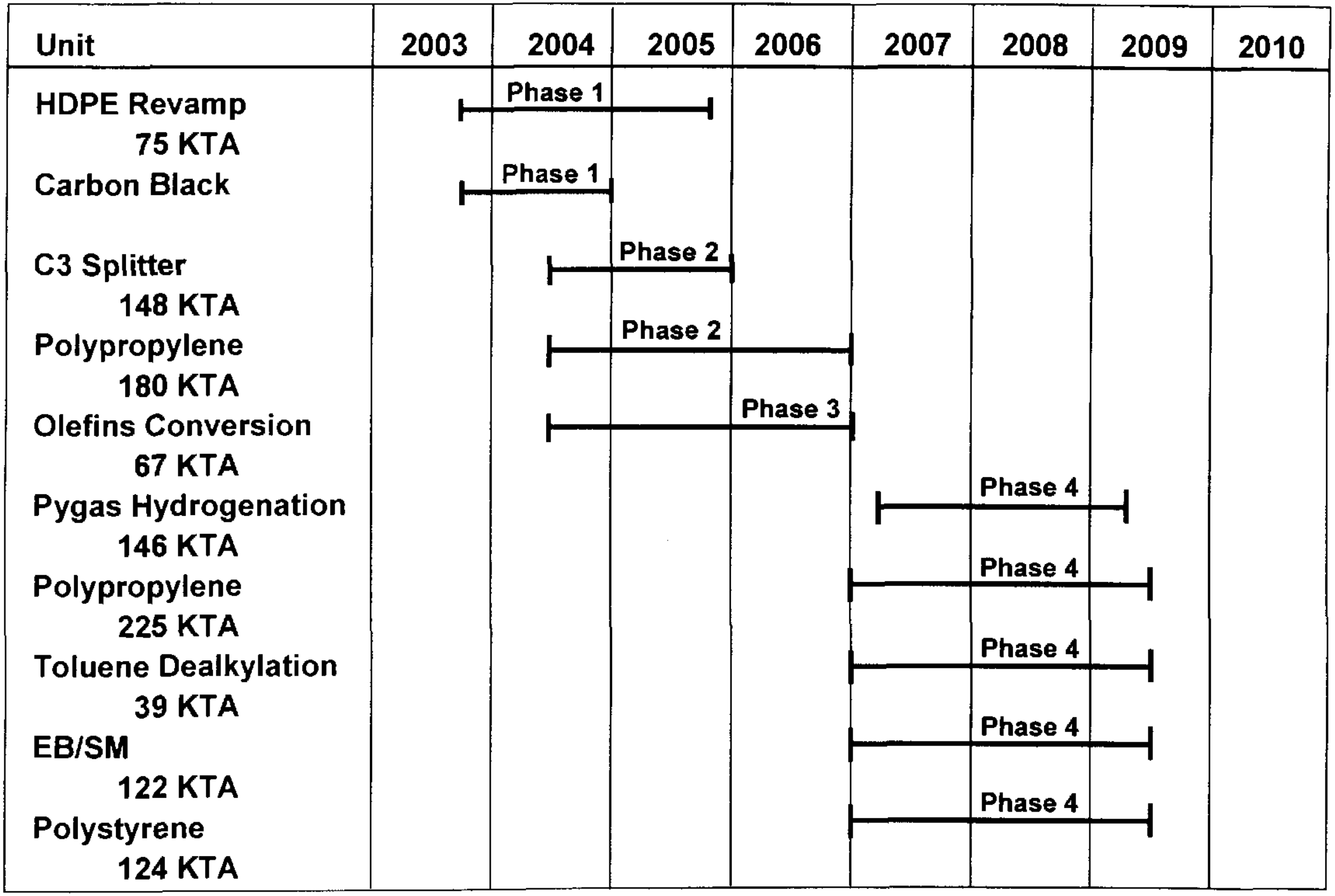
Unit	Waste description	*Disposal Options*
HDPE Plant	Fines and polymer from start-up, shutdown, and wastewater pretreatment	Incineration, landfill or sale as off spec product
	Silica gel from dryers	Landfill
New HDPE	Fines and polymer from start-up, shutdown, and wastewater pretreatment	Incineration, landfill or sale as off spec product
	Silica gel from dryers	Landfill
New PP 1st Train	Fines and polymer from start-up, shutdown, and wastewater pretreatment	Incineration, landfill or sale as off spec product
New PP 2nd Train	Fines and polymer from start-up, shutdown, and wastewater pretreatment	Incineration, landfill or sale as off spec product
New EB/SM Plant	Spent Zeolite Catalyst from Alkylator and transalkylator	Landfill after hydrocarbon is stripped
	Spent clay	Landfill after hydrocarbon is stripped
	Spent iron oxide catalyst from Dehydrogenation reactor	Landfill after hydrocarbon is stripped
New Toluene Dealk	Spent Catalyst	Reclaim for metal content or Hazardous waste disposal
	Spent Clay	Landfill after hydrocarbon is stripped
New PS Plant	Fines and polymer from start-up, shutdown, and wastewater pretreatment	Incineration, landfill or sale as off spec product
C4 Sel HT	Spent catalyst	Return to vendor or landfill
Olefins Conversion		
C4 Full HT	Spent catalyst	Return to vendor or landfill
New Carbon Black	Fines and contaminated debis	Landfill
Steam Cracker	Spent Catalysts	returned to vendors for reclaim
	Dryer Adsorbents	Landfill
	Coke from TLE Cleaning;	landfill or incineration
CD DeIsobutanizer	Spent catalyst	Landfill
LDPE Plant	No change from Existing unit	
PVC Plant	No change from Existing unit	

8.0 IMPLEMENTATION SCHEDULE

The implementation schedules for Schemes 1, 2, 3 and 4 are given on the following four pages. Although it is technically possible for each Scheme to be built all at once, the requirement for financing and debt repayment requires the phase construction shown. The actual phase timing will depend on the terms of the financing secured by HIP.

Fig. 8.0-1

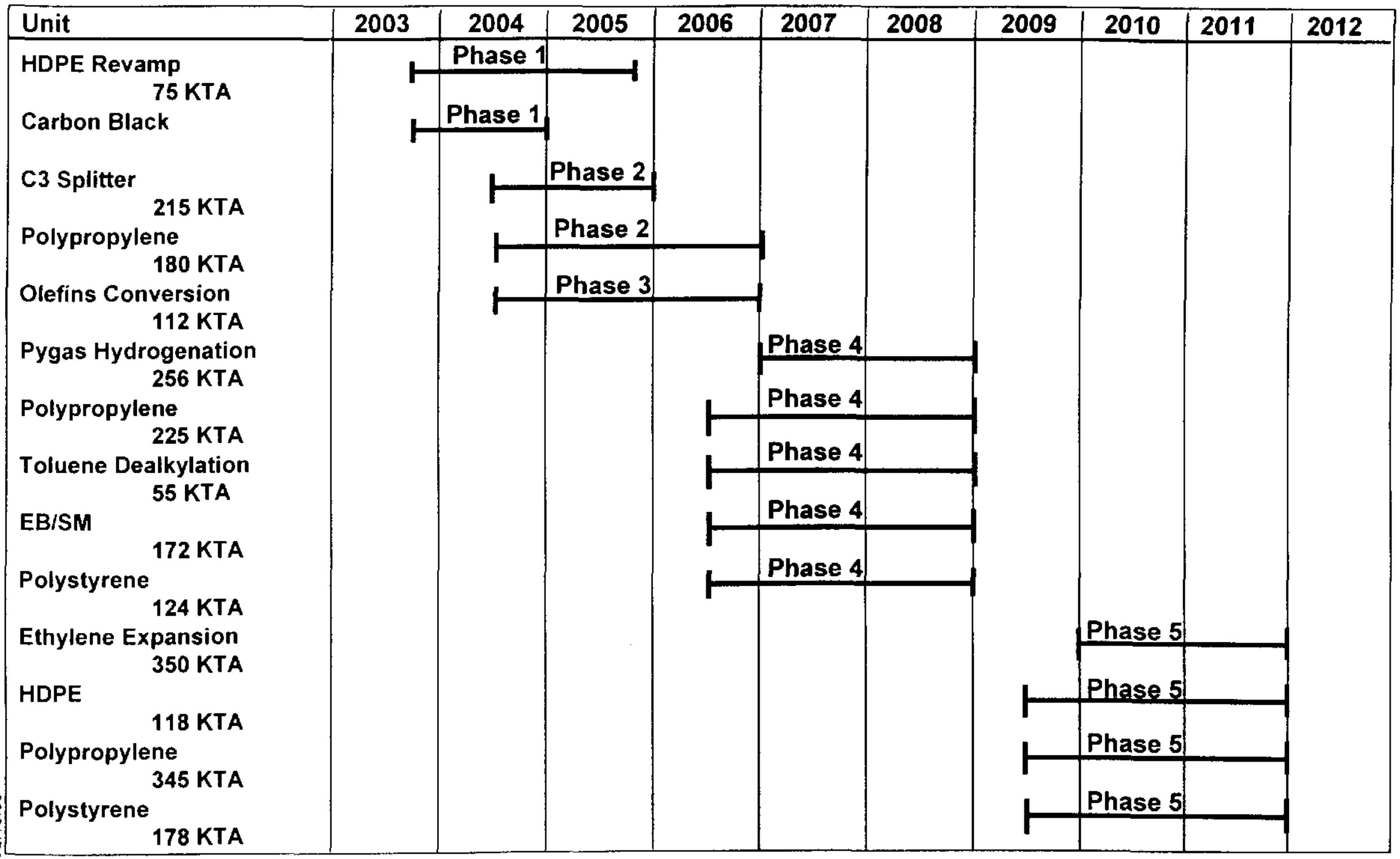
HIP Implementation schedule - scheme 1



ABB

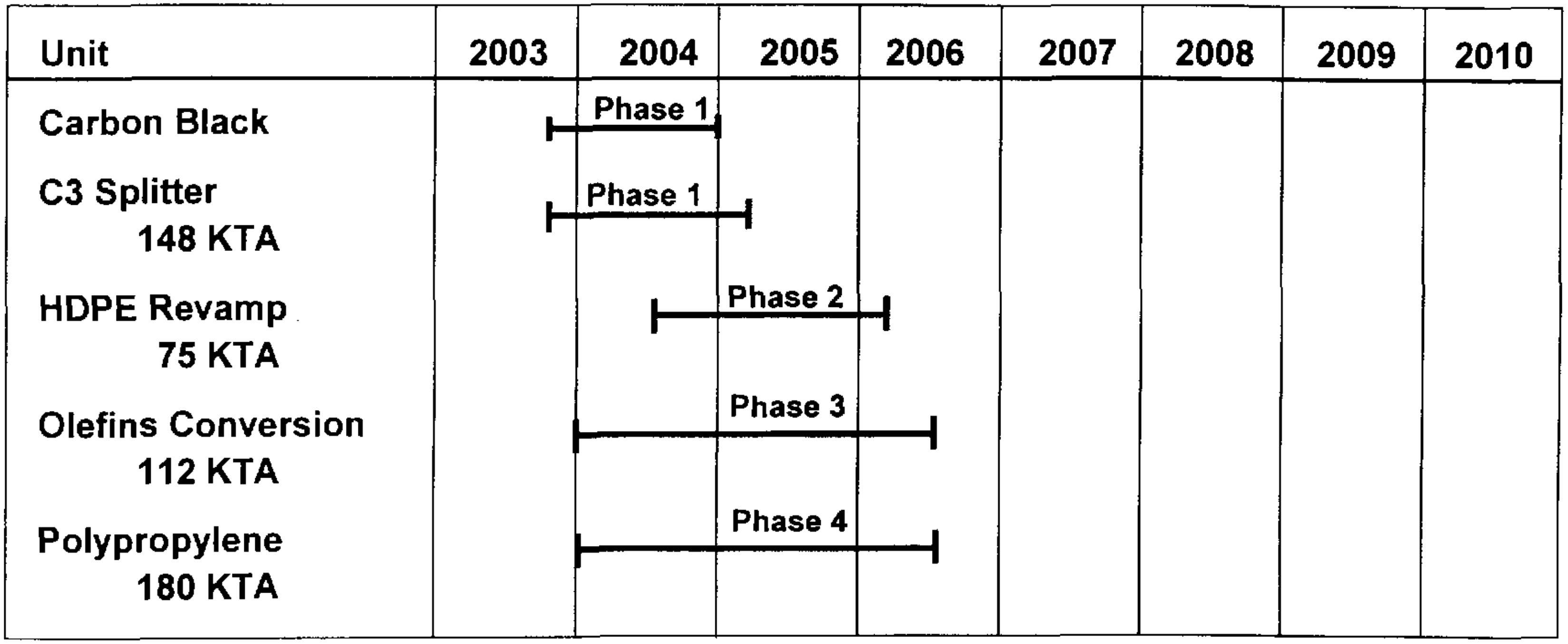
HIP Implementation schedule – scheme 2

Fig. 8.0-2



HIP Implementation schedule - scheme 3

Fig. 8.0-3



HIP Implementation schedule - scheme 4

Unit	2003	2004	2005	2006	2007	2008	2009	2010
HDPE 147 KTA								

9.0 FINANCING PLAN SUMMARY

ABB Lummus Global's financial advisory partner has investigated the options for financing the upgrade and modernization projects for the HIP petrochemicals facility and constructed a financial model to evaluate the effects of the financing on the internal rate of return for each of the cases.

Several phases for each of the four project schemes are evaluated both on their own and for the cases where each one is implemented on a simultaneous basis and over a longer period of time.

For each of the five cases, the following six tables are produced.

Table 1 – Project Cost Estimate
Table 2 – Sources of Financing and Disbursement Schedule
Table 3 – Fees and Interest Rate Assumptions
Table 4 – Loan Schematic
Table 5 – Payment Schedule
Table 6 – Cash Flow Analysis

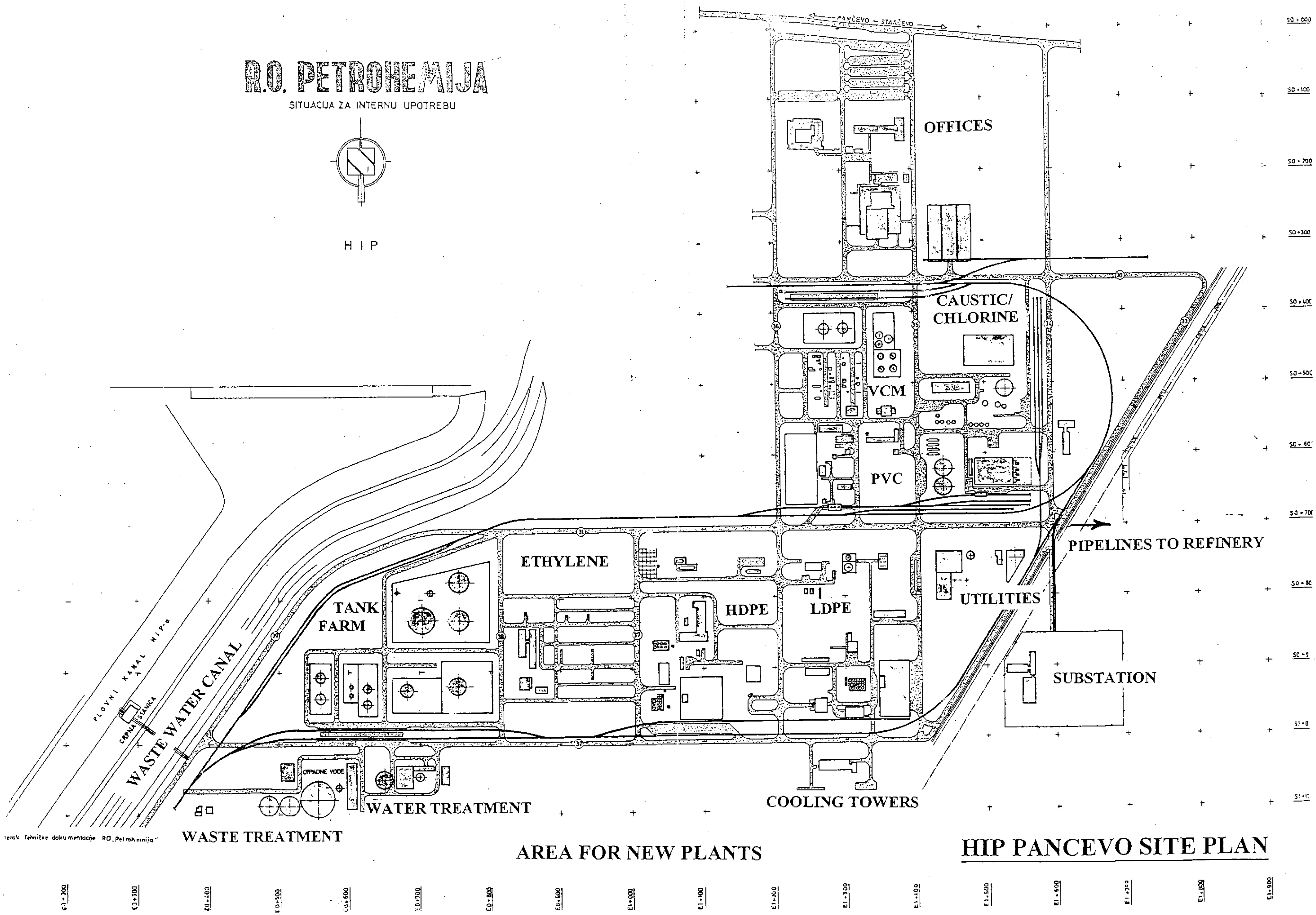
Given market conditions, the financing structure is based on HIP's current ability to produce and export petrochemical products. The structure relies on the involvement of one or more export credit agencies (ECA) such as U.S. Eximbank, Hermes (Germany) and SACE (Italy) and one or more multilateral financial institutions (MFI) such as the European Bank for Reconstruction and Development or European Investment Bank to provide the maximum amount of financing and maximum repayment tenor under its policies for both offshore and onshore goods and services.

The financial model assumes that the ECA and MFI will co-finance and provide 100% financing for the projects. However, it is recommended that grants, equity and concessional financing be sought from all available government and private sources. The effect of involving any of these sources will be to reduce the amount of debt financing required and is modeled in the sensitivity analysis as changes in the debt/equity ratio.

Because of the export cash flow from HIP, financing could be secured by the exports of petrochemical products. The amount of exports required (Assigned Product Sales) on an annual basis if shown in the Cash Flow Analysis table for each case. Details are presented in Appendix A – Financing Plan, by ABB Structured Finance.

10.0 SITE PLAN

The following page shows the site plan for HIP at Pancevo. The area for new plants is to the south of the existing facilities. This is a large area which is near to the road, rail connection, flares and utilities, waste treatment and ethylene unit (for feedstocks).



HIP PANCEVO SITE PLAN

APPENDIX B

Ethylene Plant Turnaround Survey – vol. 6, 9th Ethylene Producers' Conference 1997, American Institute of Chemical Engineers

ETHYLENE PLANT TURNAROUND SURVEY

HERMIE L. BUNDICK, HUNTSMAN PETROCHEMICAL CORP.
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Introduction

The AIChE Ethylene Producers Committee sponsors an Operations Subcommittee to promote the sharing of non-confidential operating practices, maintenance practices, quality issues, operator training, and operating problems. The purpose of this activity is the better utilization of resources and the enhancement of the environment and safety of our plant operations for both plant personnel and the surrounding communities in which we operate. The committee has endeavored to adhere to these basic guidelines by promoting a series of surveys among olefin producers to identify and share good operational and maintenance practices in a confidential, anonymous manner. As a continuation of the series, the subcommittee commissioned a survey on the general turnaround practices of olefins plants. A condensed version of this survey, which included North American plants only, was presented at the 1996 AIChE Spring National Meeting held in New Orleans, Louisiana.

The survey presented in this paper represents the more detailed survey commissioned by the Ethylene Producers Committee and provides a more thorough examination of the philosophy and administration of the maintenance work performed during and in preparation for an olefin plant turnaround. Over the years, environmental regulations have increased the complexity and length of plant turnarounds. This survey presents the industry experience with complying with these regulations in general and specifically in the quench system. Additionally, a series of questions probe the safety issues surrounding an olefin plant turnaround.

The actual survey consisted of nineteen pages of general and specific questions which was mailed to plants around the world. The paper presents the results of this world wide survey response from 41 plant sites.

BACKGROUND INFORMATION

A total of 41 plants responded to the survey. The majority of the plant are from North America. However, 17% are from Europe, 12% from the Far East and 7% from other parts of the world. The Far East and the other regions of the world are combined into one geographic region for the remainder of the survey. This is done to keep the identity of the plants in other regions of the world confidential.

There is a good balance of feedstock types represented in the survey results. Natural gas liquids (NGL) and ethane crackers are 46% of the survey. Mixed feed crackers are 34% and naphtha crackers are 20% of the survey. Mixed feed crackers for this survey are plants cracking gas oil only or a liquid feed and gas feed together.

Plant capacity in the survey reflects the ever increasing size of ethylene plants. The average ethylene capacity in the study is about 1.2 billion pounds annually. Plants with a capacity greater than 1.5 billion pounds are 22% of the survey. Thirty-two percent have a capacity of 1 to 1.5 billion pounds. Plants with a capacity less than 1 billion pounds are 46% of the survey. The average capacity varies with the type feedstock cracked. Mixed feed crackers average 1.5 billion pounds, ethane crackers 1.2 billion and naphtha and NGL crackers are 1.0 billion each.

Most of the plants in the survey have been in operation for many years. Plants built before 1980 are 80% of the survey. Nearly 90% of the plants have been modernization since their original design. About 60% of the modernization occurred this decade.

Ethylene units have a lot of equipment. The average plant in this survey has 484 major pieces of equipment. Broken down, the average plant has 12 cracking furnaces, 8 compressors, 22 towers, 189 exchangers, 173 pumps, 6 reactors, 4 boilers or superheaters and 70 other major pieces of equipment. Of course, the amount of equipment varies with feedstock. Ethane only crackers have an average of 245 pieces of equipment, NGL 300, Naphtha 565 and mixed feed 597.

A turnaround of an ethylene unit usually means there is a turnaround in an auxiliary or support unit. Seventy-three percent of the survey have a turnaround in conjunction with the ethylene plant turnaround in at least one auxiliary or support unit. The most common is 46% have a first stage gasoline hydrogenation turnaround and 39% take a utility plant turnaround. Other support and auxiliary unit turnarounds taken in conjunction with the ethylene plant are 27% a second stage gasoline hydrogenation turnaround, 24% butadiene recovery unit turnaround, 20% C_4 hydrogenation and 22% other units.

TURNAROUND DEFINITION

Run Length Between Turnaround

One of the major questions for plants is how long should they run before taking a turnaround. The average length of time between turnarounds for the survey is 4.3 years. There is a wide range in the survey from as short as 2 years to greater than 6 years. However, almost half of the survey have run times of 5 years or greater.

There are differences geographically in the time between turnarounds. Both North American and European plants average about 4.7 years between turnaround. The Far East/ Other is significantly shorter at 2.5 years. All units with a run time of greater than 5 years are in North America.

There is some variation in run length based on feedstock type. Mixed feed, NGL and ethane crackers are all around the average. Mixed feed units are a little longer averaging 5.1 years. Ethane units are a little shorter averaging 3.8 years between turnarounds. However, naphtha crackers average 2.8 years. This may be due to the large number of the Far East/ Other plants that are naphtha crackers. The only plants in the survey running longer than 5 years between turnarounds are mixed feed and NGL crackers. Mixed feed plants are 53% of the plants running longer than 5 years and NGL plants are 47%. No mixed feed unit has a run length of less than 4 years.

Turnaround Reason

The primary reason plants take a turnaround is for mechanical integrity and inspections with 60% of the plants reporting this reason. The next most reported reason is government regulation with 14% of the plants reporting this reason. Unit efficiency and predictive maintenance are also important reasons with 12% reporting unit efficiency and 9% reporting predictive maintenance.

Geographic location influences the reason for taking a turnaround. Government regulation is the reason 60% of the European plants and 50% of the Far East/ Other plants. However, no North American plant takes a turnaround because of government regulation.

Turnaround Duration

Turnaround duration for the survey is the time from feed out until feed in. The average duration is 32 days. Duration varies from less than 15 days to about 65 days. Turnaround duration does not vary significantly with geographic location.

Feedstock type, as one would expect, affects turnaround duration. The more pieces of equipment a plant has, the longer the turnaround duration. The average duration for mixed feed plants is 40 days, naphtha is 33 days, NGL is 24 days and ethane is 29 days. No mixed feed nor naphtha crackers have a turnaround less than 15 days.

The length of time a plant runs between turnarounds impacts the turnaround duration. However, it is not as significant as would be expected. Plants with longer than a 5 year run have an average turnaround duration of 41 days. However, one such plant has a turnaround duration of less than 15 days and one is less than 25 days. Plants with a run length of less than 5 years have an average duration of 27 days. None of these plants have a duration greater than 45 days.

Turnaround Critical Path

The charge gas compressor is the critical path for setting the duration of the turnaround for about half of the plants. Refrigeration compressors and towers are next each being the critical path for 13% of the plants. Capital projects are the critical path for only 11% of the plants. This is interesting since 50% of the plants have modernized since 1990. Geographic location does not effect the critical path.

Feedstock type does not effect critical path except for ethane crackers. The critical path for ethane crackers splits evenly between exchangers, charge gas machine, towers, capital projects and refrigeration compressors.

The critical path for plants running longer than 5 years is different from the average. Capital projects are the critical path for 40% of the plants. However, the charge gas compressor is the critical path in another 40% of the plants.

Plants with a turnaround duration of less than 15 days also differ somewhat in the critical path from average. The charge gas compressor is the critical path for 33% of the plants. But, for another 33% it is other equipment. Towers and exchangers are evenly split for the remaining third.

Scheduled Mini-Outages

One method thought to extend run time or to shorten turnaround duration is to schedule planned mini-outages during the run. This method happens in 22% of the survey. The average duration of the outage is 4 days.

Mini-outages play a minor role for plants running longer than 5 years. These plants use mini-outages no more frequently than the average for the survey.

Mini-outages do appear to help reduce the turnaround duration. Mini-outages are used in about 40% of plants having a turnaround duration of less than 15 days. However, they are not a guarantee to decrease turnaround duration. Mini-outages are used in 20% of plants with a turnaround duration longer than 45 days.

Plant Restart Time

The survey considers two steps to restart a unit. The first is the time from the first hydrocarbon inventory until feed to the charge gas compressor. The second is the time from feed to the charge gas compressor until the plant produces specification ethylene.

There is a wide variation is the amount of time to inventory the unit until feed is in the charge gas compressor. Times ranged from less than 4 hours to greater than 5 days. The average is 26 hours. However, this variation may not impact the total downtime of the unit. That is because some plants may inventory the flare system while mechanical work is still on-going. This may give a long inventory time but not impact the overall downtime. There is also a definition problem with this question in that some plants may not classify starting the flare as inventorying the unit. Therefore, information about this question is subjective.

The time from feed into the charge gas compressor until producing specification ethylene is a good measure for the restart time on all plants. Time to do this step ranged from less than 4 hours to greater than 24. The average is 15 hours. There is not a significant difference based on geographic location or type feedstock used.

Start-up procedure flexibility is one item that may impact start-up time. Some plants use flexible procedures with fewer details, allowing for operator experience to react to the varying startup situations. Other plants use less flexible procedures that are very detailed and limit operator deviation from the procedure as the startup situations vary. An average of 32% of the survey use the less flexible procedures.

The philosophy used varies by geographic location. The Far East/ Other use less flexible procedures in 50% of the plants. North America and Europe use them in about 28% of the plants.

Feedstock type also impacts the philosophy used. The heavier the feed, thus the more complex the unit, the more likely the plant uses less flexible procedures. Ethane plants use them 20% of the time. This increases to 28% for NGL plants and 39% for naphtha and mixed feed plants.

The time from feed into the charge gas compressor until specification ethylene favors the less flexible procedures. Plants using the less flexible procedures averaged 11 hours, while flexible procedure plants average 17 hours.

Flare Reduction

Higher demands on the environment and by the public have increased the interest in methods to reduce flaring, especially on startup.

One method used is to recycle ethylene or propylene back to the furnaces. Twenty-nine percent of the survey use this method. The overseas plants use this method more frequently. Forty-three percent of plants in European, 38% of plants in the Far East/ Other use this method. Only 23% of plants in North America use it.

Another method to reduce flaring is off-spec storage. Forty percent of the survey have off-spec ethylene storage. Sixty-eight percent have off-spec propylene storage.

SAFETY ISSUES

Unit Safing

<u>Construction Personnel On Unit</u>

Since the earlier the maintenance work begins the sooner the turnaround ends, two questions considered the introduction of maintenance and/or construction crews onto the unit to begin turnaround work. A majority of the respondents, 56%, do not allow maintenance or construction crews onto the unit while shutting the unit down and clearing of hydrocarbons. Conversely, 82% of the plant sites in the survey do permit maintenance/construction crews onto the parts of the unit that have been cleared while still safing the remainder of the unit.

<u>Geographic Preferences</u>

There appeared to be two distinct groupings regarding the introduction of maintenance crews onto the unit during shut down and safing. In North America, 54% of the respondents do not allow maintenance and/or construction personnel onto the unit to begin work. In Europe, Far East, Pacific Rim and Other world locations, 71% of the plant sites do not allow maintenance and/or construction crews onto the unit during this time period. In all cases, a minority of plant sites permitted crews other than operations onto the unit while safing. However, in North America, 60% more sites were disposed to permit crews onto the unit to speedup the turnaround work.

All locations favored allowing maintenance to begin on parts of the unit that were free of hydrocarbons while the balance of the unit was still undergoing safing. In Europe all sites permitted crews to begin work. While in North America and in the Far East/Pacific Rim/Others plant sites permitted work to commence on parts of the unit which were safe in 81% and 62% of the responses, respectively.

<u>Turnaround Length</u>

Of those plant sites with short duration turnarounds, 25 days or less, 71% permitted maintenance and/or construction crews onto the unit during initial hydrocarbon clearing. 92% of these same plant sites allowed work crews onto the parts of the unit that were hydrocarbon free. For plants with long duration shutdowns, 46 to 65 days, none permitted crews onto the unit during this initial clearing and only 50% of these plant sites would even allow crews to commence work before all the unit was safe. Perhaps this philosophy led in part to the longer shutdowns.

Fire Retardant Clothing

A majority, 69%, required fire retardant clothing for employees during normal operations, but that requirement dropped to 47% during turnarounds after the unit was free of hydrocarbons. During normal operations, North American plants were the strongest proponents of fire retardant clothing at 80% of respondents followed closely by Europe at 57%. A minority, 43%, of the Far East, Pacific Rim and other world sites required fire retardant clothing.

Once the unit was free of hydrocarbons, North American plants dropped their requirement for fire retardant clothing to 52% of plant sites versus the 80% during normal operations. In Europe the requirements did not change. Plants which required fire retardant clothing during normal operations also required the same during turnarounds. We guess they assume the old adage that a gun is always loaded. The Far East, Pacific Rim and other world sites essentially dropped their requirements during turnarounds with 83% not requiring fire retardant clothing.

Safety Monitoring

Inspectors

In response to the use of plant personnel other than safety personnel to perform safety inspections during turnarounds, 76% of the plants sites responded positively. The average number of safety inspectors per 100 workers was 2.3. The Far East, Pacific Rim and Other world locations dropped below this average at 1.4.

Audits

The average number of safety audits conducted per day per 100 workers was 4.6. European plants performed the fewest safety audits at an average of 3.8 versus North America and the Other world sites at 4.7 and 4.8, respectively.

Safety Meetings

The majority of plants conducted safety meetings each shift, 53%, with daily meetings used at 32% of the plants. North American plants far and away conduct safety meetings on a shift basis. Whereas, European plants never do and Other world locations are almost evenly split between per shift and daily. The typical length of a safety meeting was 5 to 15 minutes. However, the length of a safety meeting was diverse from plant to plant considering 41% held safety meeting for 10-15 minutes, 26% for 5-10 minutes, and 21% for 15-30 minutes. Typically, the more frequent the safety meeting the shorter the meeting. That surely comes as no surprise.

Training

The average for total hours, general training hours, and site specific hours of safety training required of contractor personnel prior to working on the plant site are 7.5, 4.7, and 3.0 hours, respectively. Europe required the fewest total hours, 3.9. The Far East, Pacific Rim and Other world sites required the highest total hours of safety training at 9.9. North American plants were in the middle at 7.6 hours of total safety training. The split in general and site specific were as follows:

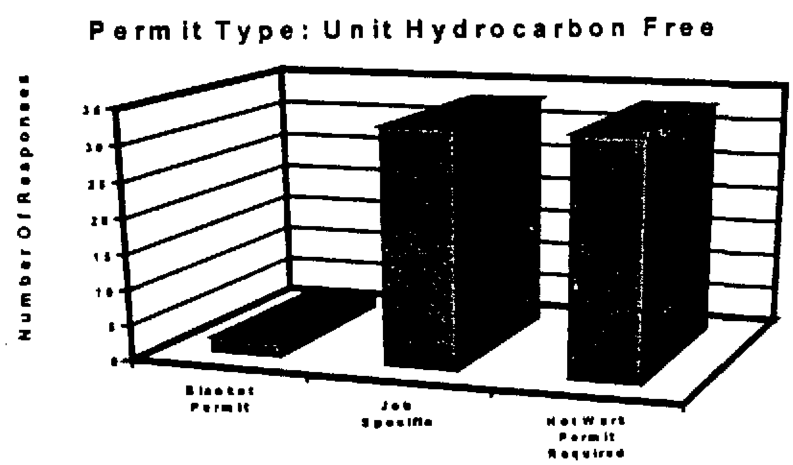
Safety Training Hours

Geographic Location		Hours	Percent Of Total
North America			
	General	5.1	65%
	Site Specific	2.7	35%
Europe			
	General	1.6	44%
	Site Specific	2.0	56%
Far East, Pacific Rim, Others			
	General	5.6	53%
	Site Specific	5	37%

Permit Philosophy

Once the unit is free of hydrocarbons, most plants continue to use permits that are job specific and still require hot work permits. This is illustrated in the Figure 1, below.

FIGURE 1



Responsibility for writing, approving, and closing out permits is universally the responsibility of the operations personnel. However, a majority, 57%, of the European plants assign maintenance the responsibility for closing out permits.

Lockout/Tagout Philosophy

Basically, the lockout/tagout procedures adopted by most plant sites were independent of whether the unit was hydrocarbon free or not. From the data, it would appear universally accepted that once personnel have been trained in the use of a lockout/tagout philosophy, that philosophy is not changed just because the unit is down and hydrocarbon free.

Responsibility
Primary lockout responsibility both before and after the unit is hydrocarbon free reside with the operating personnel as illustrated in Figures 2 and 3.

FIGURE 2

Primary Responsibility For Lockout Before Hydrocarbon Free

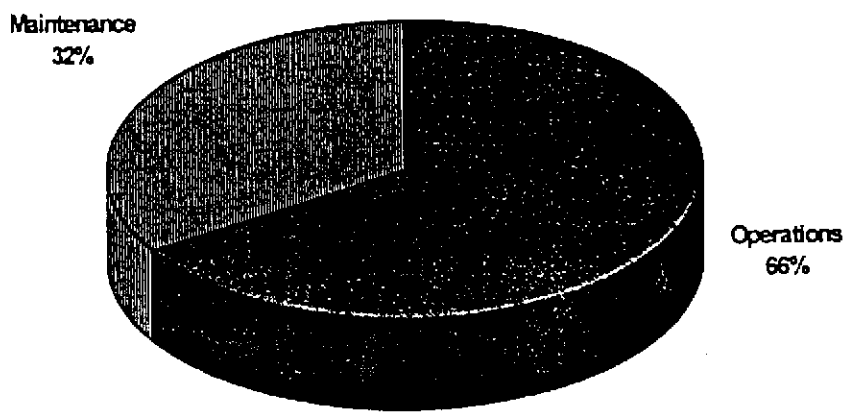
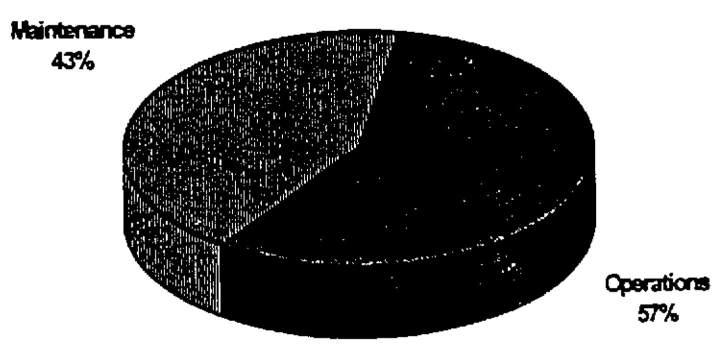


FIGURE 3

Primary Responsibility For Lockout After Hydrocarbon Free



System/Type
Since lockout/tagouts can occur in difference systems such as process, electrical, or mechanical systems, respondents were asked to indicate who has responsibility for

lockouts/tagouts in each system and by type of lockout/tagout procedure. The responses are provided in the flowing two Figures 4 and 5.

FIGURE 4

Primary Lock Out Responsibility During Hydrocarbon Freeing

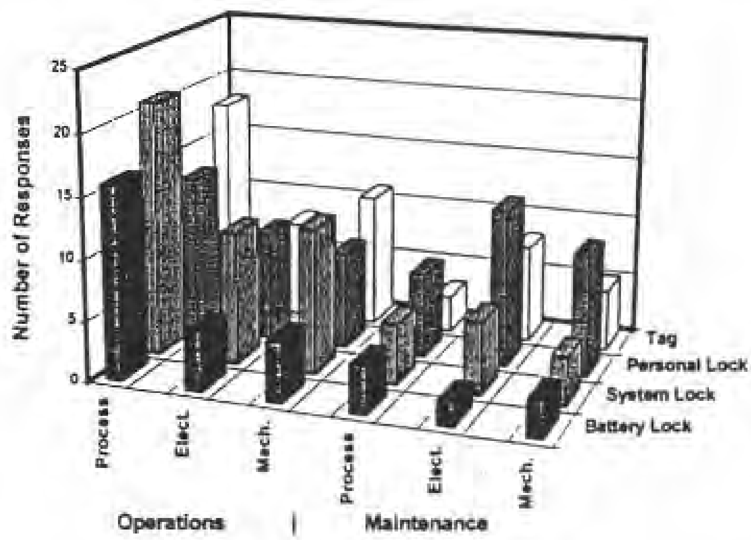
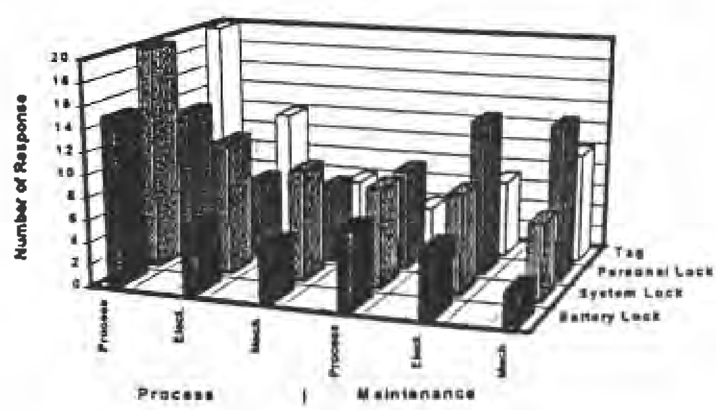


FIGURE 5

Primary Lockout Responsibility After Hydrocarbon Free



From these figures, maintenance assumes considerably more responsibility in the electrical and mechanical systems using system locks and personal locks. The process systems remain the domain of operations primarily using battery and system locks. However, a considerable number of plants are using tags for lockout and the use increased after the unit is hydrocarbon free.

Blind Installation

Since blinds are an important part of ensuring the isolation of systems and because so many are used during a turnaround, the responsibility for tracking these blinds was an important question in the survey. Basis responses to this question, the tracking of blind installations is the primary responsibility of operations in 82% of the cases.

Work Schedules

Maintenance work for turnarounds are scheduled for 6 to 7 days per week with the majority of plants scheduling turnaround work 7 days per week. This comes as no surprise. However, there are distinct geographic differences. In North American, Far East, Pacific Rim, and Others plants schedule turnarounds for 7 days per week 84 - 88% of the time, 12-16% schedule for 6 days per week, and none at 5 days per week. In Europe, on the other hand, 86% of the plants schedule turnarounds for 6 days per week, 14% for five days per week, and none for 7 days per week.

Employee work schedules for days per week, shifts per day and hours per shift are provided in Attachments A through D for operating , maintenance, and technical personnel. Typically, operating personnel are working 7 days per week, 2 shifts per day, and 12 hours per shift. Maintenance personnel are scheduled to work 6/7 days/week (35%/60%), 2 shifts per day, and 10/12 hours per shift (29%/58%). Technical personnel are scheduled to cover the turnaround for 6/7 days per week (34%/60%), 1/2 shifts per day (29%/68%), and 10/12 hours per shift (23%/67%). Regarding employee time off during the turnaround, North American plants tend to make no provisions while all other locations tend to arrange for some form of employee time off.

Recorded Injuries

The survey requested respondents provide recordable injuries per 200,000 man-hours worked for plant personnel and contractor personnel during normal operations and during turnarounds. The average injuries per 200,000 man-hours for plant personnel during normal operations and turnarounds are 1.81 and 1.49, respectively. For contractors, the average injuries per 200,000 man-hours during normal operations and turnarounds are 1.49 and 3.25, respectively. Both North America and Europe showed similar injury rates. The Far East, Pacific Rim and Others showed higher injury rates.

The key question is what factors set apart the plant sites with the lowest injury rates during turnarounds. The table below summaries the various factors evaluated from the survey results.

Factors Affecting Turnaround Injuries

	Normal Operations			Turnaround		
	Plant	Contractor	Total	Plant	Contractor	Total
Geographic Region						
North America	1.8	1.9	3.6	1.4	2.9	4.4
Europe	1.5	1.7	3.2	1.4	3.4	4.8
Others	2.7	0.8	3.5	2.2	4.5	6.6
Audits/Day/100 Workers						
Less Then 3	2.2	1.4	3.6	1.8	2.4	4.2
More Then 4	1.3	2.6	3.8	0.9	5.0	5.9
Inspectors/100 Workers						
Less Than 3	1.8	1.6	3.3	1.6	2.8	4.3
More Than 4	2.0	2.1	4.1	1.2	5.0	6.2
Plant Safety						
Less Than 3	1.5	1.4	2.9	1.5	2.2	3.6
More Than 4	2.7	2.6	5.28	1.7	5.4	7.1
Safety Training						
Avg. 3.9 Total Hr.	1.5	1.7	3.2	1.4	3.4	4.8
Avg. 8.1 Total Hr.	1.9	1.7	3.6	1.5	3.2	4.7
Safety Meetings						
Per Shift	1.9	1.8	3.7	1.1	3.6	4.7
Daily Plus	1.5	1.6	3.1	1.6	2.8	4.4
Turnaround Length						
25 Days or Less	1.9	1.8	3.7	1.3	4.7	6.0
46-65 Days	1.2	1.6	2.8	2.4	1.3	3.7
Work Schedule						
5-6 Days & 8-12 Hr./Shft	1.8	1.9	3.7	1.3	4.4	5.7
7 Days & 12Hrs/Shft	1.9	1.6	3.5	1.8	2.0	3.8

Of all the factors evaluated, only the plant safety record during normal operations showed any correlation. Those plants with low injury rates during normal operations also had low injury rates during plant turnarounds even though they did not appear to be differentiated by any other factor. The data suggest that safety is a matter of corporate culture not just an issue of safety programs. We must not only train and prod the employees involved, but we need to establish a mind set for safety.

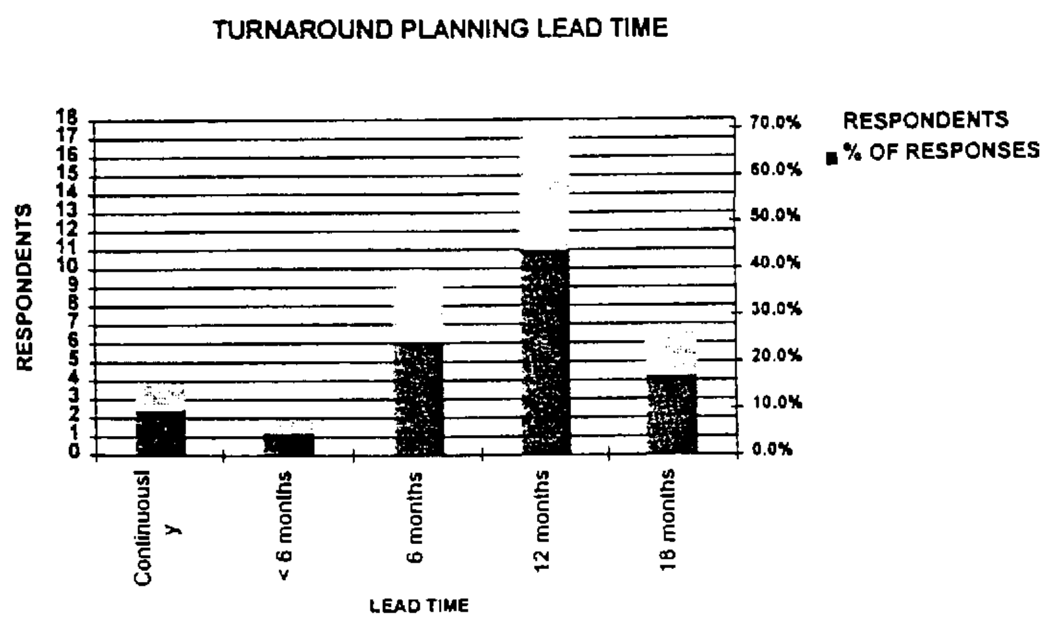
Turnaround preplanning is one of the most important jobs associated with a turnaround. This importance is indicated by the survey. The respondents to the survey assigned the task of coordinating the turnaround to plant personnel almost 90% of the time. About 56% had a plant person permanently assigned to this job, 32% reassigned a plant person to this job and 2% used a retiree. A minority hired a regular contractor 7% of the time or a temporary contractor 5% of the time to do this job. The actual preplanning work was still weighted toward plant personnel with 70% of the respondents using permanent personnel, 49% reassigned personnel and 14.6% retirees. A larger percentage of the companies used contractors. Thirty-four percent used regular contractors and 19% used temporary personnel.

Primivera is the most used tool for planning a work with 34% of the respondents selecting this method followed by the Open Plan with 19% usage, and the 12% scheduling manually. Eleven other methods were also being used. Ninety percent of the survey respondents use plant personnel to maintain the schedule.

Turnaround Lead Time

As shown in Figure 6, 44% of the responses had a 12 month planning lead time, 24% had a lead time of 6 months, 17% had a lead time of 18 months, 5% had a lead time of less than 6 months. On the other end of spectrum, 10% said they were always ready for the turnaround and continually planned for it.

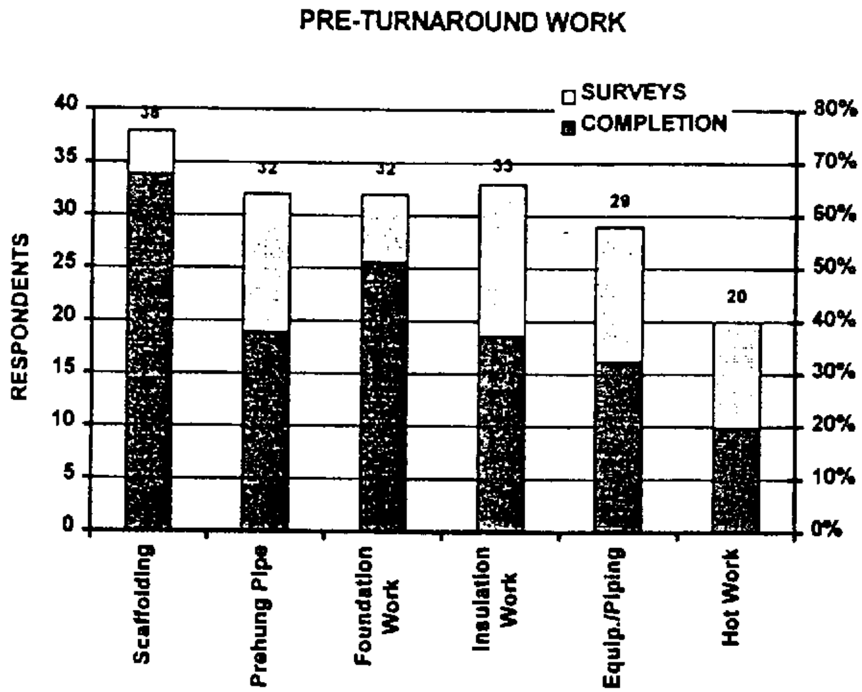
Figure 6



Turnaround Prework

Overall 68% of the scaffolding is completed before a turnaround, 51% of the foundation work is completed, 38% of the pipe is prehung, 37% of the insulation work is completed, 32% of the equipment/piping inspections are completed and 20% of the hot work is completed.

Figure 7



<u>Scaffolding</u>
Thirty-nine respondents allow scaffolding to be erected during plant operation. Eighteen limit the work because of safety and 26 limit the work because of operations. Twenty-five respondents complete 75% of their scaffolding before the turnaround. Six respondents complete 100% of their scaffolding and 5 complete 50%.

<u>Prehung Piping</u>
Thirty-five respondents allow piping to be prehung during plant operation. Twenty-one limit the work because of safety and 18 limit the work because of operations. Eleven respondents complete 75% of their piping before the turnaround. One respondent completes 100% of the piping and 8 complete 50%.

<u>Foundation Work</u>
Thirty-six respondents allow foundation work during plant operation. Twenty limit the work because of safety and twenty-two limit the work because of operations. Ten respondents complete 50% of their foundation work before the turnaround. Nine respondents complete 100% and 8 complete 75%.

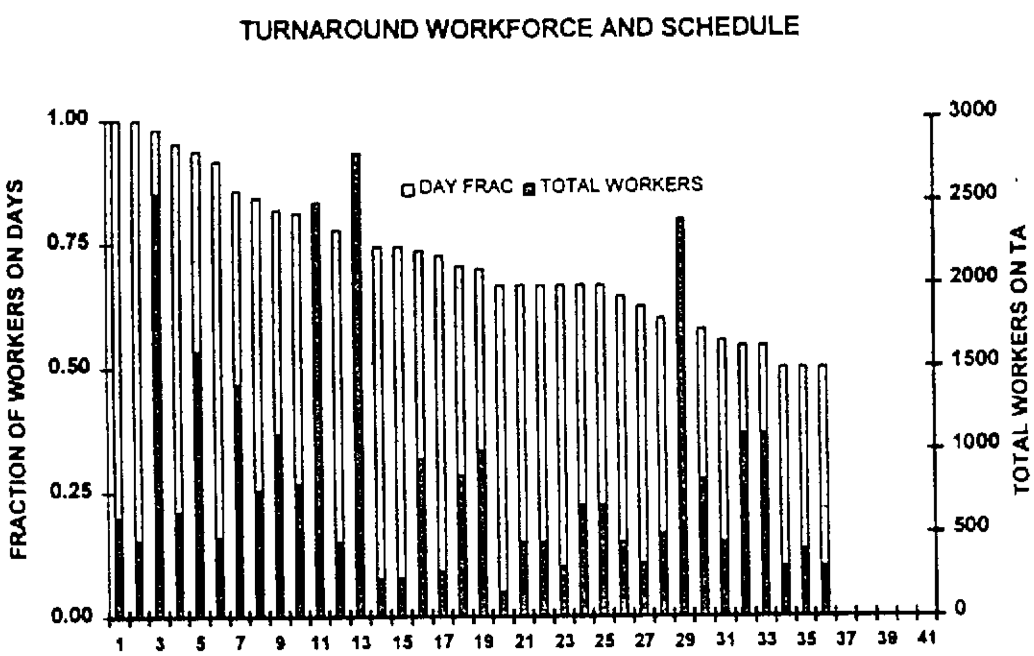
Insulation Work

Thirty-seven respondents allow insulation work during plant operation. Sixteen limit the work because of safety and 27 limit the work because of operations. Fourteen respondents complete 50% of their insulation work before the turnaround. Seven respondents complete 75% and 6 complete 25%.

Work Schedules

In the survey, the fraction of workers working on days varied between 50 and 100 percent with the average being 75%. On average there are 674 day workers and 224 night workers. The peak work load ranged from 150 to 2800 workers for a turnaround with the average work load being about 900. Eighty-five percent of the European respondents had greater than 85% of their workers on days.

Figure 8



Equipment/Piping Inspections

Thirty-four respondents allow inspections during plant operation. Eighteen limit the work because of safety and 25 limit the work because of operations. Ten respondents complete 50% of the inspections before the turnaround. Seven respondents complete 75% and 6 complete 25%.

Hot Work

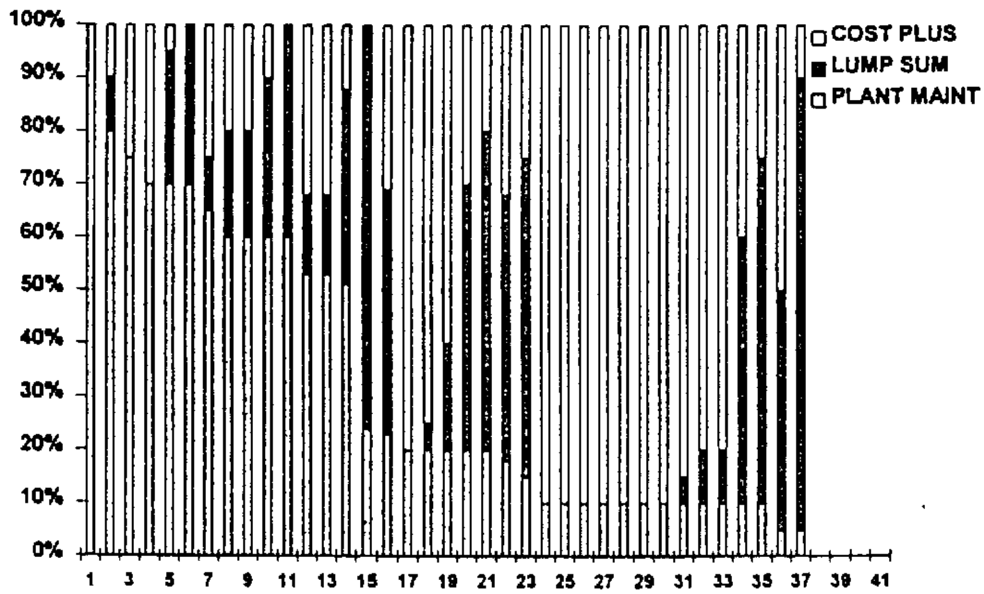
Twenty-eight respondents allow hot work during plant operation. Twenty-five limit the work because of safety and fifteen limit the work because of operations. Nine respondents completed 10% of the hot work before the turnaround. Six complete 75% of the hot work, and 3 complete 50%. One respondent completes 100% of the hot work before the turnaround.

Plant Maintenance, Lump Sum or Cost Plus

This question examined how the work is divided between plant maintenance, lump sum and cost plus. As would be expected, the results ranged from one survey where all of the work was done by plant personnel to the two surveys where 95% of the work was done with contractors. About 35 % of the respondents do at least 50% the shutdown work themselves while 65% do less than 25% percent themselves. Thirty percent of the respondents have more than 80% of their work done with cost plus, and 49% do less than 32%. Seventy percent of the respondents used lump sum for some of the work and of these 80% used lump sum for 50% or less. Sixty percent use lump sum less than 20% of the time.

Figure 9

SPLIT OF TURNAROUND WORK
(Plt. Maint., Lump Sum or Cost Plus)



Maintenance during the turnaround is an important issue for all plants. Many questions in the survey deal with the maintenance practice of the plants during turnaround.

Plant versus Contract Personnel

One issue concerning maintenance is who supervises and who does the work. The plants were asked whom they use to supervise and whom they use for craftsman, plant personnel or contract personnel.

In most categories, the supervisors are plant personnel. The areas where plants typically rely on contractors to provide 45 to 55% of the supervision are painting and insulation, scaffold building, hydroblasting and civil work. Plants typically supply over 90% of the supervision for Inspection, Inst. & Elec., Quality Assurance and Safety. In the safety area 95% of the plants use their own personnel. However, for other crafts, plants used both plant and contract personnel to supervise the work.

This picture changes when it comes to the craftsman. Most plants use contract labor. This is not unexpected with the large labor force needed to do the work. For the actual work, contractors were used for between 40 and 90% of the work. Again Inst. & Elec., Quality Assurance, Inspections, machinists crafts and Safety were the areas retained by the plants for their own workers with only 40 to 50% of this work being contracted. At the other end of the spectrum are scaffolding, painting & insulation, hydroblasting, tower and exchangers work with over 85% of this work being contracted. Plants also widely use contract craftsmen for compressor work. Eighty percent of the plants use contract craftsman for the compressor work.

There are some significant variations in philosophy when the surveys are sorted by geographical locations. As shown in Figure 10, the Far East is much more likely to use plant supervision and almost no contract supervision. Europe is more likely than the total group to use contractor supervision. As shown in Figure 11, Europe is much more likely to use contract workers than either North America or the Far East especially in the furnace and the I&E areas. Plants in North America are much more likely to use their own craftsman for I&E work than the rest of the world. Plants in the Far East/ Other rely almost entirely on their own personnel for supervision with almost no contract supervision. These plants rely heavily on contract and their own personnel for craftsman. Plants in Europe rely equally on plant and contract supervision. Europe relies almost entirely on contract craftsman to do the work. Almost no European plant uses its own personnel for craft work except in the area of safety and quality assurance.

Figure 10

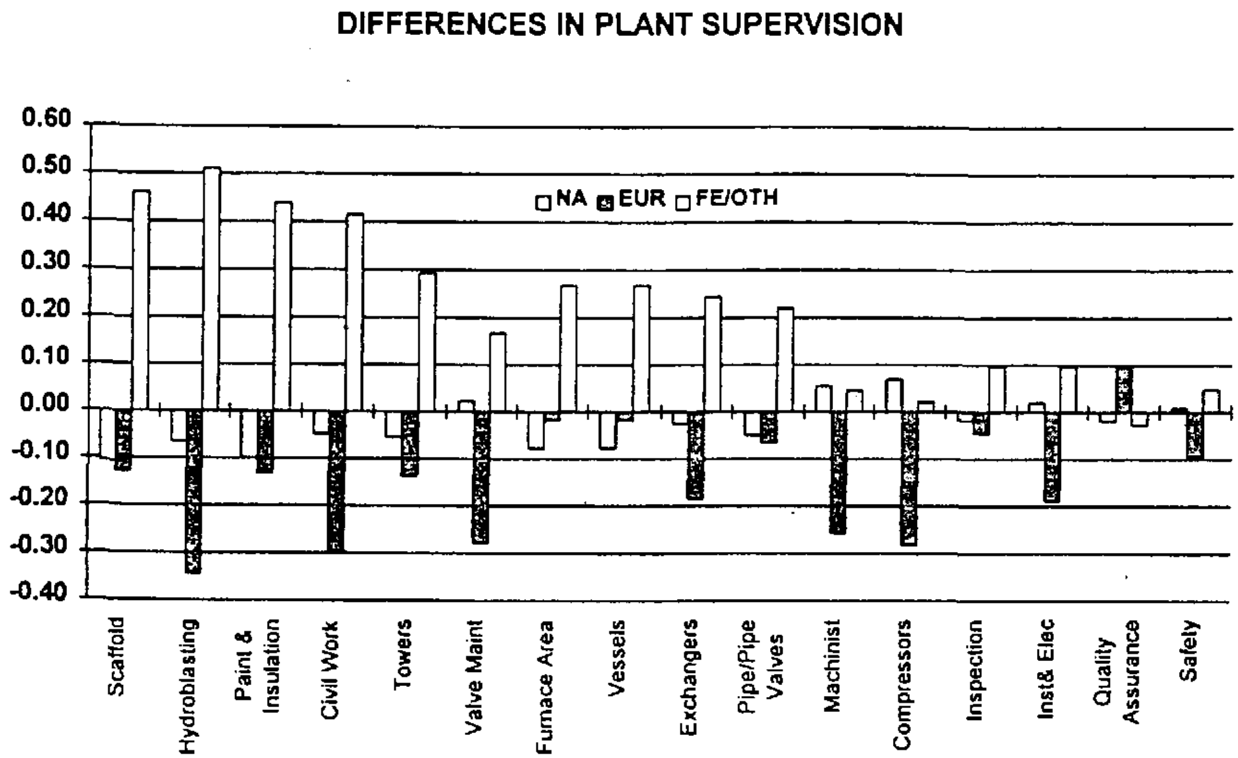
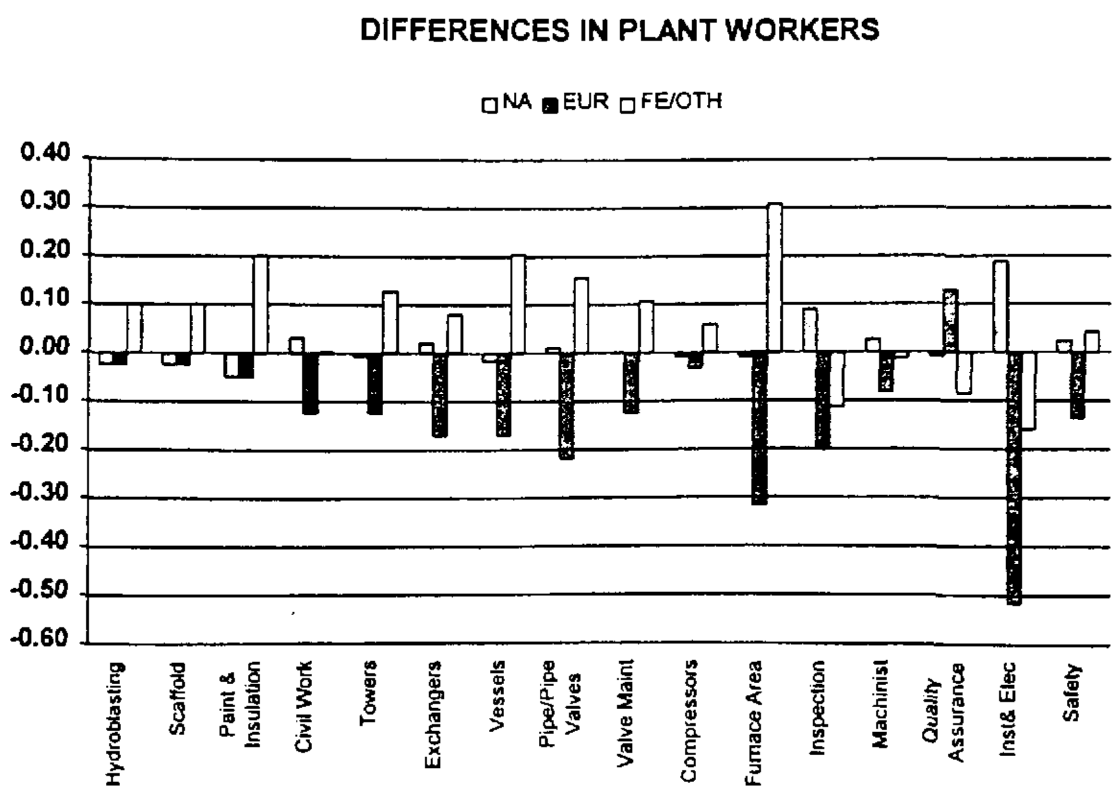


Figure 11



Compressors

Charge Gas Compressor

Every turnaround, 73% of the plants open the charge gas compressor. Only 17% of the plants open it every other turnaround and 10% open it every third turnaround.

Feedstock affects how often plants open the compressor. Naphtha crackers are the least likely to open the compressor every turnaround. Naphtha plants open the machine 60% of the time every turnaround and 25% every other turnaround. Ethane and mixed feed plants are the most likely to open the machine every turnaround, with 80% of the plants reporting this.

Another method to evaluate opening the machine is to look at the number of years it is in operation between openings. This is determined by looking at the frequency of turnarounds it is opened and the time the plant runs between turnarounds. The average time between opening the compressor is 6 years. The feedstock results change when this method is considered. Mixed feed and NGL plants open the machine on average only every 6.6 years. Ethane crackers average 5.6 years. Naphtha crackers, because of their shorter run between turnarounds, open the machine on average every 4.4 years.

The length of time between turnarounds does not increase the percentage of plants opening the compressor every turnaround. Plants running longer than 5 years open the compressor every turnaround 70% of the time with the other 30% being every other turnaround. This gives an average time between opening the machine of 8 years for plants with a run length of greater than 5 years..

Refrigeration Compressors

Plants open the refrigeration compressors less frequently than the charge gas compressor. Only 28% of the plants open the propylene and ethylene refrigeration compressors every turnaround. Opening the propylene refrigeration compressor usually occurs every other turnaround with 40% of the plant doing this. However, 33% of the plants open it every third turnaround or longer. Some plants have never opened the machine!

The ethylene refrigeration compressor is opened every other turnaround by 35% of the plants. However, 38% open it every third turnaround or longer.

Methane compressors are opened every turnaround by 37% of the plants using them. Sixteen percent of the plants open the machines every other turnaround. Nearly one-half of the plants using methane compressors can go to every third turnaround or longer without opening the machine.

The average time between opening the refrigeration compressors is 11 years for each of the machines.

Compressor Drivers

Steam Turbines

All of the plants in the survey have steam turbines. Plants open these drivers fairly frequently. Every turnaround, 50% of the plants open the case and every other turnaround 31% open it. Twelve percent of the plants are able to run longer than every third turnaround before opening.

North American plants are the most likely to open every turnaround with 64% doing so. Another 24% open the case every other turnaround. Europe and Far East/ Other are the least likely to open every turnaround. Every turnaround, 38% of European plants and by 22% of the Far East/ Other plants open the case. Fifty percent of European plants open the case every other turnaround. In the Far East/ Other, 33% of the plants open it every other turnaround, 22% every third and 23% longer than every third turnaround. This frequency gives Europe the longest time between opening the case at 9 years, followed by North America at 8 years and the Far East/ Other at 6 years.

Gas Turbine

Twenty-seven percent of the survey plants use gas turbines. Not surprisingly, plants open these cases frequently. Seventy-three percent of the plants open the case every turnaround, 18% every other turnaround and 9% beyond the third turnaround. Gas turbines have a time between opening of 6 years.

Motor Drivers

Motors are used by 51% of the survey plants. The plants do not open the motors frequently. Motors are opened every turnaround by 24%, every other by 14%, every third by 24% and beyond every third by 38%. This gives a run life of greater than 12 years.

Feed Chilling

Plants infrequently open equipment in the feed chilling section. This is because opening the equipment requires significant commissioning to return to service and it is not a fouling service. Feed chilling equipment has never been opened by 56% of the survey. Some units (21%) open the system every turnaround, with 18% every other.

Age of the plant does not increase the number of plants that have opened the feed chilling equipment. Plants built before 1980 also have 56% that have never opened the feed chilling system.

Geographically, 46% of North America plants do not open feed chilling. In Europe and the Far East/ Other, about 75% each have never opened it.

Feedstock does not affect the likelihood of opening the feed chilling system. Naphtha and mixed feed plants can be more likely to open because of refinery feedstock contamination. However, the data does not support this. Naphtha plants report that 75% have never opened and 50% of mixed feed plants report the same.

Plants opening the feed chilling system do so mainly for operation or maintenance reasons. Plants opening the equipment do so 31% for operability, 25% maintenance, 22% safety inspections, and 11% NO_x cleaning.

Feedstock and geography have an impact on NO_x cleaning. No ethane cracker nor naphtha cracker report doing NO_x cleaning. NO_x cleaning occurs in 14% of NGL and 15% of mixed feed crackers. Only plants located in North America report NO_x cleaning.

The mechanical history of the cold box has been good. Sixty percent of the plants report no mechanical problems. Twelve plants report having a failure of the cold box. Nine of these failures had no corrosion associated with the failure. Two other plants report having corrosion but no failures. All failures reported occurred in plants built before 1980. Mixed feed plants report the most failures with 36%, followed by NGL at 28%. All feedstock types report at least one failure. All regions also report at least one failure.

Turnaround duration clearly impacts opening the feed chilling system. Eighty percent of plants with a turnaround duration of less than 15 days never open the feed chilling system. Seventy percent of plants with 25 day turnarounds do not open. However, 40% of plants with a duration greater than 45 days open it every turnaround.

Exchanger Work

Another area with substantial work during a turnaround is heat exchangers. The survey asked plants what routine work they do to various heat exchangers during a turnaround.

Quench Area

The exchangers in this area include the quench oil and quench water exchangers that do not use cooling water. The work in this area reflects the dirty service of these exchangers.

Cleaning the quench oil exchangers is done by most plants. Seventy-eight percent of the plants having a quench oil system clean the process side, 43% clean the utility side and 22% do no work.

Cleaning quench water exchangers occurs less than in quench oil exchangers. Cleaning the process side occurs in 54% of the plants and 49% report cleaning the utility side. Inspections happen in 59% of the plants. Twelve percent of the plants do no work.

Feedstock affects the cleaning of the quench water exchangers. Eighty percent of ethane crackers report cleaning the exchangers. Mixed feed follows with 64% and naphtha with 38%. Interesting, only 29% of NGL plants clean these exchangers.

Cooling Water Exchangers
The exchangers in this group include all the main cooling water exchangers in the quench, charge gas compressor, surface condensers, propylene, and refrigeration compressor systems. The majority of the work on cooling water exchangers is to clean the utility side of the exchanger. Cleaning the cooling water side ranged from 56% for ethylene refrigeration up to 85% for the charge gas coolers.

A large percentage of the plants also clean the process side of dirty service exchangers. Cleaning the quench exchanger process side occurs in 46% of the plants. Cleaning the process side of the charge gas compressor exchangers happens in 61% of the plants. Fifteen percent of the plants clean the process side of clean service exchangers.

A large number of plants report doing other work on cooling water exchangers. Tube repairs happen in 34% of the plants on the charge gas compressor exchangers and in 29% on the surface condensers. On average, 18% of the plants do cathodic protection work. Inspection occurs in about 60% of the plants for these exchangers.

Cold Exchangers
This group includes refrigeration, feed chilling and brazed aluminum exchangers. Predominately, the work is inspection with 40% of the plants inspecting the standard exchangers and 27% the brazed aluminum exchangers. However, a significant number of plants do no work. No work occurs on the brazed aluminum exchangers in 41% of the plants. Another 32% report no work for the feed chilling exchangers. Twenty-seven percent report no work for refrigeration exchangers.

Some plants report cleaning the exchangers in feed chilling and refrigeration service. A small number of plants also clean the brazed aluminum exchangers. Other work includes tube repairs, VOC repairs and insulation repairs.

Furnace Area Exchangers
Exchangers included in this group are the furnace quench exchanger, secondary TLE and the dilution steam generator. The main work on these exchangers is cleaning, as one would expect. Cleaning occurs in 30% to 50% of the plants. Inspection work happens in 25% to 35% of the plants.

Spare Exchangers
Many plants have spare exchangers. Most plants do not work on these exchangers during a turnaround. However, 27% of the plants do work on them during the turnaround.

Duration And Run Length Impact
Exchanger work in plants having a turnaround duration of less than 15 days differs some from the average. The amount of cleaning of the dirty service exchanges varies some but there is still a large amount of cleaning done. The only dirty service exchangers not being cleaned are those in dilution steam service. The main difference is the cold

exchangers. No work occurs on the cold exchangers. Also, limited inspection work occurs. No spare exchangers have work done during the turnaround.

Plants running greater than five years have some differences in exchanger work as compared to the average. The percentage cleaning exchangers in dirty service is about the same as the average. The exception is the furnace area. Plants running more than 5 years report no work on these exchangers. There is also no work reported to clean cold service exchangers. There is an increase in tube repairs and VOC repairs. The amount of cathodic protection work also is higher than the average.

Towers

Quench Area

Towers in this area are the quench oil tower, quench water tower, the gasoline stripper and the fuel oil stripper. Since this is a dirty service about 70% of the plants report opening these towers every turnaround. Twenty percent to thirty percent of the plants report opening only as required.

Opening the towers every turnaround varies geographically. Plants in Europe open the towers every turnaround except for the quench oil tower. For this tower, 86% of the European plants report opening every turnaround. In the Far East/ Other, 70% to 90% of the plants open the towers ever turnaround. North America is the least likely to open the towers every turnaround. Between 50% and 70% of the North American plants open the towers every turnaround.

Plants operating longer than 5 years between turnarounds open the quench oil tower and fuel oil stripper every turnaround. The gasoline stripper is opened by 75% of the plants every turnaround. Opening the quench water tower every turnaround occurs in 67% of the plants.

On average, plants open the quench oil and quench water towers every 6.7 years. Plants open the gasoline stripper and the fuel oil stripper every 6.4 years.

The majority of the work done on these towers is cleaning and inspection. Cleaning is reported by 80% to 100% of the plants. Inspection is reported by 70% to 80% of the plants.

Clean Distillation Towers

The towers in this group are the demethanizer, ethylene fractionator and the propylene fractionator. Because this service is clean, plants do not open these towers frequently. In fact, the majority (50% to 70%) only open these towers as required. The remaining plants are about evenly split between opening every turnaround and every other turnaround. North America and Europe are the most likely to open the towers. About 20% of the plants open every turnaround and another 20% every other turnaround. The Far East/ Other predominately (90%) open only as required. Plants open the demethanizer and ethylene fractionator about every 13 years. Opening the propylene fractionator occurs about every 11 years.

Plants with less than a 15 day turnaround only open these towers as required. Plants running longer than 5 years are more likely to open these towers. About a third of the plants running longer than 5 years open the demethanizer and the ethylene fractionator every turnaround. Another one-third open the towers ever other turnaround. The final third opens only as required. The amounts change for the propylene fractionator to half every turnaround and one-quarter each for every other and as required.

Work performed is primarily inspection. However, some plants clean the towers. About 20% of the plants doing work clean the demethanizer and the ethylene fractionator. Another 30% of the plants doing work clean the propylene fractionator.

Dirty Distillation Towers

The deethanizer, depropanizer and debutanizer are in this group.

Plants are least likely to open the deethanizer. Every turnaround, 40% of the plants open the tower. Every other turnaround, 15% open it. Forty percent open it as required. This gives the tower an average of 10 years between being opened. The survey can not determine the number of plants in which the deethanizer is not a dirty service tower. The deethanizer in plants with a front end depropanizer is not as subject to fouling and these plants may not open it as frequently as other plants.

Plants open the depropanizer and debutanizer mainly every turnaround. About 80% open these towers every turnaround. This gives an average run time of about 6 years.

Feedstock affects the frequency of opening the tower. Plants cracking ethane are the most likely to open the deethanizer. All plants cracking ethane report opening the deethanizer every turnaround. Ethane crackers are the least likely to open the depropanizer and the debutanizer.. Every turnaround two-thirds of the plants open the depropanizer and half open the debutanizer. The remainder opened these towers only as required.

NGL crackers are the least likely to open the deethanizer. Only 15% open it every turnaround, 30% every other turnaround and 45% as required. Opening the depropanizer or debutanizer did not vary significantly from the average.

Naphtha crackers split on the deethanizer opening. Half open every turnaround and half open as required. Opening the depropanizer or debutanizer did not vary significantly from the average.

Mixed feed crackers are also split on opening the deethanizer. Forty percent open every turnaround and forty percent open as required. Also, opening the depropanizer or debutanizer did not vary significantly from the average.

The work performed on the depropanizer and debutanizer is primarily cleaning. About 90% of the plants report cleaning. Deethanizer cleaning occurs in 45% of the plants. Feedstock affects tower cleaning. Less than half of the ethane crackers clean the depropanizer and debutanizer during the turnaround. Only about 30% of the NGL crackers clean the deethanizer. Inspection work is done by 70% to 80% on the towers.

Miscellaneous Towers

The caustic tower, amine tower, process condensate stripper and the process water stripper are in this group. Plants usually perform work every turnaround on these towers. Every turnaround, 80% of the plants having a process condensate stripper or caustic tower open them. Every turnaround, 70% of the plants with an amine or process water stripper open them. The rest open the towers mainly as required.

Most plants clean and inspect these towers. About 80% of the plants clean and inspect the caustic tower. About 70% clean and inspect the process condensate stripper and the process water stripper. About 60% clean and 30% inspect the amine tower.

Miscellaneous Work

Demister & Vane Separators.
The survey questioned plants about the work done on demisters and vane separators in dirty service. The primary work is cleaning. Forty-five percent of the plants responding clean the charge gas compressor demisters, 52% clean the caustic tower demisters and 65% clean the quench tower demisters. A large number replace rather than clean the demisters. Twenty-five percent do this for the change gas compressor, 30% for the caustic tower, and 12% for the quench tower. Plants almost exclusively clean the vane separators. However, about 15% report they do no work.

Plants with less than a 15 day turnaround duration report no difference from the survey average. The frequency of work and the work done is the same as average.

Sieves and Catalyst
Another area of miscellaneous work is to see if plants take advantage of turnaround to change charge gas dryer sieve or the acetylene converter catalyst. Predominantly, plants do not change this material during turnaround. Thirty-five percent change the charge gas dryer sieves during turnaround. Twenty-two percent change the acetylene converter catalyst during turnaround. Interestingly, plants with less than a 15 day turnaround duration are just as likely to change sieves during turnaround as the average of the survey. However, these plants do not change reactor catalyst during turnaround. All plants with greater than 5 year run time change both the sieves and catalyst outside turnaround.

Relief Valves

One key safety system evaluated in the survey is relief valve maintenance practices.

One issue questioned is plant practices of inspecting relief valves prior to turnaround while the plant is in operation. An average of 70% inspect at least some of the relief valves prior to turnaround. North America is most likely to do this with 81% doing at least some. Europe and Far East/ Other are less likely. In Europe, 57% inspect prior to turnaround. In the Far East/ Other, 43% inspect prior to turnaround. Inspection prior to turnaround happens in 86% of plants running longer than 5 years. All of the plants with less than 15 day turnaround inspect the relief valves prior to turnaround.

All plants report using shop testing for inspections. In addition, 12% do on-line inspection. The average inspection time varies based upon the valve service. The time varies between one and five years.

Some plants have on line spare relief valves. Fifty-three percent use spare relief valves. Another 10% have at least some spare relief valves. Geographically, 100 % of Europe plants have spare relief valves, 62% of North American, and 38% for Far East/ Other. Interestingly, only 40% of plants with less than a 15 day turnaround duration and only 14% with runs longer than five 5 years have spare relief valves.

Plant practices with relief valve isolation valves was also questioned. About 90% of the plants use an isolation valve under at least some relief valves. Seventy-five percent of the plants have discharge isolation valves. Plants do not use three way valves for isolation as a rule. Only 40% of the plants allow them on at least some valves. Geographically, the results vary some. All European plants report having isolation valves under relief valves. Also, Europe is the most likely to use three way valves with 75% reporting they use them on at least some relief valves. The Far East/ Other has no three way valves in use. All plants with less than a 15 day turnaround duration or greater than a five year run report having isolation on at least some valves.

Plants use many methods to ensure relief valves are not isolated. In plants using isolation valves, 50% use administrative procedures, 40% lock and chain, 25% keyed valves, 10% special blinds, and 35% have other methods. The preferred method varies geographically. In North America, 70% of the plants use administrative procedures and 50% other methods. In Europe, 100% use keyed valves and 60% use lock and chain. In the Far East/ Other 60% use lock and chain and 45% keyed valves.

Whom do plants use for field inspection of relief valves after maintenance and reinstallation? Maintenance personnel are used by 65% of the plants and production personnel by 58%. The only geographic note is that European plants mainly use maintenance for the inspection.

Flares

Flare maintenance practices were also questioned. In the survey, 76% of the plants use an elevated flare, 22% both elevated and ground flares, and 2% a ground flare only. Ground flare use is more frequent in Europe and Far East/ Other. North America has one plant reporting a ground with an elevated flare and one with a ground flare only.

The work frequency is primarily every turnaround. About 60% of plant report doing work every turnaround. The other 40% do work only as required.

Few plants have planned maintenance on elevated flares. About 68% do only what is required. About 15% of plants replace the tip with a new tip and 7% replace it with a spare tip. Ten percent refurbish the existing tip. The run length between turnarounds affects the work performed. Forty percent of plants running greater than five years replace the tip with a new tip every turnaround. Plants having a turnaround duration of less than 15 days only do flare work as required.

One common elevated flare repair is pilot thermocouples. Plants in the survey have an average of 4.4 thermocouples. Plants replace nearly all of the thermowells during turnaround. Failure is the reason for replacing about half. Preventive maintenance is why plants replace the other half.

Plants make more repairs on the ground flares. For plants reporting work on the ground flare, 50% replace insulation, 80% replace burners, and 70% replace pilots.

Mechanical Integrity

Mandated Hydrotest

Government regulations mandate some plants to periodically hydrotest equipment to demonstrate mechanical integrity. Plants mandated to perform hydrotests make up 32% of the survey. However, this is strictly are regional issue.

No North American plants are mandated by the government to periodically hydrotest equipment to demonstrate mechanical integrity. This excludes plants that have loading lines that fall under Coast Guard hydrotest regulations. In Europe, 86% of the reporting plants must hydrotest. In the Far East/ Other group, 62% must hydrotest.

The equipment that must be hydrotested varies regionally. In Europe, 83% of the plants must hydrotest hot service equipment. Hydrotests occur in cold service equipment in 50% of the European plants. In the Far East/ Other, 40% do hot service pressure vessels, 20% hot service pipe, 20% cold service pressure vessels and 20% other. The average frequency reported for doing the hydrotest is about 6 years for hot service pressure vessels and pipe. Cold service pressure vessels are 7.5 years and cold service pipe is 7 years. Other equipment is hydrotested every 3.5 years.

Other Mechanical Integrity Inspections

Most of the plants in the survey do not use periodic hydrotests to prove mechanical integrity. The survey asked plants what other inspections methods they use to check for mechanical integrity.

Most plants use several methods. Most of the plants doing mandated hydrotests also use other methods to check for mechanical integrity. The most common method used is visual inspections. This is used by 21% of the plants. X-ray and ultra sonic inspections are done by 18% of the plants each. Pneumatic testing is also done. It is not clear how many plants do a full pressure pneumatic test and how many use it only for a low pressure leak check. Both were reported, however, most of the plants did not indicate which they were doing. Dye penetrant and wet mag. particle tests are done in 10% of the plants each. Other less used methods are acoustical testing, on-line corrosion meter, metalography and comparative service analysis.

Pipe Mechanical Inspection

Pipe in sweating, caustic and amine service are subject to corrosion. Plants were asked about their inspection practices for pipe in this service.

About half of the plants inspect pipes in these services between turnaround. The other half inspect during turnaround. As few inspect as needed. The average time between inspects is about 5 years.

ENVIRONMENTAL ISSUES

Effects Of Environmental Regulations

Increased Manpower

Respondents indicated that turnaround manpower increased up to 10% in 77% of the plants in the survey due to environmental regulations. 16% of the plants reported no increase in manpower requirements. Europe reported the highest incident of increased manpower due to environmental regulations. On average, North America reported the lowest increase, although two North American plants reported the highest increase in manpower anywhere.

Increased Turnaround Time

Environmental regulations increased turnaround times for 79% of the plant sites by 1-5 days. Europe again reported the highest incident of increased time at 1-2 days, and Far East/Pacific Rim/Others had the highest incident at 3-5 days, but a North America plant site had the longest increase at up to 10 days.

Increased Turnaround Costs

All plants experienced some increase in turnaround costs due to environmental regulations. The majority at 54% estimated an increase in costs of 5-15%. The next largest group at 43% estimated less than 5% increase in costs. North American plants indicated the largest increases followed by the Far East/Pacific Rim/Others.

Quench System Entry

Time Required

The additional time required to comply with the environmental regulations for entry into the quench system during a turnaround was 3-4 days for 47% of the plants, 5-7 days for 27%, and 1-2 days for 18%. All plants reported some increase in time required. On average, Europe had the largest increase in time and North America had the lowest.

Benzene

The average benzene exposure level for employee entry into the quench system was 1.5 ppm. North America had the lowest permissible level at 0.8 ppm average. Europe averaged 2.4 ppm, and the Far East/Pacific Rim/Others averaged 3.8 ppm.

Methods For Clearing Quench System

The preferred method for clearing the quench system for entry was steaming purge to flare, steaming/hot water, and solvent wash in that order. There was no changes in methods for clearing the quench system anticipated from last turnaround to the next turnaround.

Emissions Monitoring

While Freeing Unit Of Air

While freeing the unit of air, 60% of the plants in the survey check for leaks using the bubble test. 30% of the respondents reported that this question does not apply.

Valve Repairs

After valves have been repaired in the shop, 53% of the plants use a bubble test to check the valve for leaks prior to installing back in the field. 21% of the plants do not confirm the valves in the shop after repair.

New Valves

When purchasing new valves for installation in emission regulated service, plants depend upon a manufacturer certificate in 40% of the responses, require valves be 100% tested in 30% of the responses, do not require any monitoring in 22% of the responses, and perform random testing in 8% of the responses.

CONCLUSION

The AIChE Ethylene Producers Committee's Operation Subcommittee conducted an olefin plant turnaround survey. Anonymous and Confidential responses representing 41 plant sites from North America, Europe, Far East, Pacific Rim and Other world locations were received and the results are presented in this paper. The results are shared with the industry with the intention of meeting the subcommittee's objective for improving the performance of the industry in the maintenance, environmental, and safety practices during an olefin unit turnaround.

We wish to thank the companies and individuals who chose to participate in the survey for their time and effort. With their input we have a data base with which to compare and improve each of our respective operations in regards to turnaround practices..

Olefins Plant Background Data						
1. Plant geographic location						
North America	28					
Europe	7					
Far East/Pacific Rim	5					
Other	3					
total	41					
2. Major Feedstocks						
Ethane	5					
NGL	14					
Naphtha	8					
Mixed Feed	14					
total	41					
3. Plant Capacity		Average Size				
A. Based on Current Ethylene Capacity		1172	MM lbs			
< 500MMLb	3					
<1000MMLb	16					
<1500MMLb	13					
> 1500MMLb	9					
	41					
B. Operating hours per year for current ethylene capacity	0					
<8000	12					
8000 - 8400	29					
>8400	0					
	41					
4. Plant Vintage						
A. Original Design						
Earlier than 1965	8					
1966 - 1970	12					
1971 to 1980	15					
1981 to 1990	8					
1990 +	2					
	41					
B. Latest Modernization						
1970-1979	2					
1980-1989	13					
1990+	21					
None/ No Response	6					
5. Number of Major Pieces of Equipment				AVERAGE	AVERAGE	AVERAGE
Major Equipment	Major Pieces Per Unit Equipme	Opened for Maint Reasons	Opened for Safety Reasons	Major Pieces Per Unit Equipme	Opened for Maint Reasons	Opened for Safety Reasons
Furnaces	406	240	12	12	8	4
Compressors	335	173	4	8	6	1
Towers	912	338	42	22	9	6
Exchangers	7737	2609	132	186	75	15
Pumps	7049	817	32	173	30	4
Reactors	256	34	0	8	1	0
Equipment Total	11413	3156	95	394	143	12
Boilers/Superheaters	138	40	8	4	2	1
Other Equipment	1620	877	38	70	38	7
Total	11587	3071	92	483	171	18
6. Other facilities associated with Olefin Plant turnaround						
A. Auxiliary Units		% of Total Survey				
Butadiene Recovery Plant	10	24%				
Cogeneration Plant	2	5%				
Utility Plant	16	39%				
Other	9	22%				
B. Supporting Units		% of Total Survey				
C4 Hydrogenation	8	20%				
C5 Hydrogenation	2	5%				
First Stage Gasoline Hydrogenation	18	44%				
Second Stage Gasoline Hydrogenation	11	27%				

Turnaround Definition					
	2 Years	3 Years	4 Years	5 Years	Other
1. INTERVAL BETWEEN TURNAROUNDS	5	9	10	13	7
2. MAJOR REASON(s) FOR TURNAROUND INTERVAL (SELECT ONE)		Average Time Between TAR	4.3		
Mechanical Integrity & Inspections	25				
Business Climate	0				
Safety System Inspection	1				
Predictive Maintenance	4				
Regulatory	6				
Unit Efficiency	5				
Other Facilities	0				
Other	1				
	42				
3. TYPICAL LENGTH OF TURNAROUND DEFINED AS FEED OUT TO FEED IN.		Average Days Down	33		
14 Days or Less	6				
16 - 25 days	9				
26 - 35 days	12				
36 - 45 days	10				
46 - 55 days	3				
56 - 65 days	2				
65+ days	0				
4. ITEMS WHICH TYPICALLY DETERMINE CRITICAL PATH OF TURNAROUND. (SELECT ONE)					
Exchangers	4				
Charge Gas Compressor	21				
Towers	6				
Furnaces	0				
Capital Projects	5				
Refrigeration Compressor	6				
Other	3				
	45				
5. MINI-OUTAGES BETWEEN TURNAROUNDS					
A. Scheduled between Outages					
Yes	9				
No	32				
b. If YES Length of Mini-outage					
1-2 days	6				
3-4 days	6				
6-7 days	4				
>8 days	3				
Plant Re-Start					
1 Typical length of time from introduction of hydrocarbon inventory until cracked gas feed in the charge gas compressor?		Average	18		
<4 hours	9				
4-8 hours	6				
8 hours to 1day	17				

Attachment A: 1997 Turnaround Survey: World

>1 to 2 days	6	
>2 to 3 days	5	
>3 to 4 days	1	
>4 to 5 days	2	
>5 days	0	
	41	
2 Typical length of time from cracked gas feed to the charge gas compressor to ethylene product on test?		Average 18
<4 hours	1	
>4 to 8 hours	7	
>8 to 12 hours	8	
>12 to 18hours	8	
>18 to 24 hours	12	
>24 hours	5	
	41	
3 Do you practice minimal flaring startups by recycling ethylene and/or propylene to the furnaces?		
Yes	12	
No	29	
4 Do you have storage for off test product?		
Ethylene	Ethylene	Propylene
Yes	16	27
No	25	13
Propylene		
Yes	27	
No	13	
5 Would you describe your startup procedures from cold start to ethylene product on test as		
Limited operator flexibility	13	
Operator flexibility	28	

WORK PRIOR TO TURNAROUND

1 INTERVAL BETWEEN TURNAROUNDS	Implemented	Primary Coordination
i Permanent Staff	20	23
ii Reassigned Staff	20	13
iii Temporary Staff (Retirees)	6	1
iv Regular Contractor	14	3
v Temporary Contractor	4	3

2 SCHEDULING METHODOLOGY
A Please list method Used to Plan Turnaround (such as Premvera or Manual)

	Plant	Contractor
B Who runs and maintains the turnaround schedule?	37	4

3 TIMING TO PERFORM DETAILED TURNAROUND PLANNING AS CALLED BY YOUR STANDARD PROCEDURES	
i Continuously	4
ii Less than 6 months	2
iii 6 months	10
iv 12 months	18
v 18 months	7
vi Greater than 18 months	0

4 WHAT TURNAROUND PREWORK IS ALLOWED DURING UNIT OPERATION

	[illegible]	Limited by		[illegible]				
	Do Not Allow	Safety	Operations	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Scaffolding	39	18	26	6	25	5	2	0
Prehung Pipe	35	21	18	1	12	8	7	5
Foundation Work	36	20	22	9	6	10	3	2

Insulation Work	37	16	27	1	7	14	6	5
Equip /Piping	34	18	25	1	7	10	6	5
Inspection	9	9	6	0	1	3	0	3
Hot Work	28	25	15	1	8	3	1	9
Other	2	1	2	0	1	1	0	0

5 What is you peak loading, plant plus contractor, during	Average	Maximum	Minimum	Lowest Quartile	Second Quartile	Third Quartile	Highest Quartile
Day shift workers	617	2500	100	237.5	455	662.5	2500
Night shift workers	212	1000	0	93.75	150	231.25	1000
6 What percent of the turnaround plant maintenance cost is:							
Plant Maintenance	33.19	100	5	10	20	60	100
Contractor Lump Sum	32.67	85	0	12.5	30	50	85
Contractor Cost Plus	47.64	90	5	25	32	80	90

Maintenance Survey Summary Numeric Results

1 Rotating Equipment: Do You open the ca	TA	2nd TA	3rd TA	Other	Number of Respo	Frequency Years
Cracked Gas	30	7	0	4	41	8 05
Propylene	11	16	2	11	40	10 55
Ethylene	11	14	4	11	40	10 78
Methane	7	3	1	8	19	10 74
Steam Turbine	21	13	3	6	42	7 79
Gas Turbine	8	2	0	1	11	8 27
Motor	5	3	5	8	21	12 38

1. Rotating Equ (% Responding)	TA	2nd TA	3rd TA	Other
Cracked Gas	73%	17%	0%	10%
Propylene	28%	40%	5%	28%
Ethylene	28%	35%	10%	28%
Methane	37%	16%	5%	42%
Steam Turbine	50%	31%	7%	12%
Gas Turbine	73%	18%	0%	9%
Motor	24%	14%	24%	38%

2 Feed Chilling

A Frequency Opened	TA	2nd TA	3rd TA	Never
	8	7	2	22

B Reason	Yes	% who said yes
Maintenance	10	59%
Preventive/Operability	12	71%
Safety Inspection	12	71%
NOx Cleaning	4	24%

	Average # Years
C Cold Box NOx Cleaning Frequency	8

D History of Cold Box	Yes	No
Corrosion	6	33
Failure	12	27

3 Exchangers: Routine Work	Clean Process Side	Clean Utility Side	Tube Repair	VOC Repair	Insulation Work	Inspection	Cathodic Protection	None
Quench Oil	18	10	5	0	6	15	0	5
Quench Water	22	20	8	0	5	24	2	5
Cooling Water - Quench System	19	25	8	0	4	24	6	7
Cooling Water - CGC Train	25	36	14	5	4	31	10	1
Cooling Water - Surface Condensers	7	30	12	2	5	24	9	2
Cooling Water - Propylene System	6	24	9	5	4	24	6	5
Cooling Water - C3E System	6	24	8	7	5	21	7	7
Cooling Water - C2E System	6	23	7	8	5	20	7	6
Refrigeration	2	7	6	3	5	16	1	11
Feed Chilling	4	4	4	4	4	17	1	13
Brazed Aluminum	1	0	0	0	2	11	0	17
Dilution Steam Generation	16	7	6	0	3	11	0	14
Furnace Quench	20	4	4	1	3	15	0	10
Furnace Secondary TLE	13	4	3	0	4	10	0	13

3 Exchangers (%)	Clean Process Side	Clean Utility Side	Tube Repair	VOC Repair	Insulation Work	Inspection	Cathodic Protection	None
Quench Oil	78%	43%	22%	0%	22%	65%	0%	22%
Quench Water	84%	49%	20%	0%	12%	59%	5%	12%
Cooling Water - Quench System	46%	61%	20%	0%	10%	59%	15%	17%
Cooling Water - CGC Train	61%	88%	34%	12%	10%	76%	24%	2%
Cooling Water - Surface Condensers	17%	73%	29%	5%	12%	59%	22%	5%
Cooling Water - Propylene System	15%	59%	22%	12%	10%	59%	15%	12%
Cooling Water - C3E System	15%	59%	20%	17%	12%	51%	17%	17%
Cooling Water - C2E System	17%	56%	17%	20%	12%	49%	17%	15%
Refrigeration	5%	17%	15%	7%	12%	39%	2%	27%
Feed Chilling	10%	10%	10%	10%	10%	41%	2%	32%
Brazed Aluminum	2%	0%	0%	0%	5%	27%	0%	41%
Dilution Steam Generation	39%	17%	15%	0%	7%	27%	0%	34%
Furnace Quench	49%	10%	10%	2%	7%	37%	0%	24%
Furnace Secondary TLE	32%	10%	7%	0%	10%	24%	0%	32%

	Yes	No
4 Are spare exchangers scheduled for wor	11	30

5 Maintenance on Towers	Frequency Entered				Work Performed			No Response
	Every TA	Every 2 TAs	Every 3 TAs	As Required	Tower Inspection	Tower Cleaning	Other Tower Work	
Demethanizer	5	7	2	22	23	6	9	5
Deethanizer	15	6	2	15	26	16	8	3
C2 Splitter	5	8	2	22	22	7	0	4
Depropanizer	29	3	0	4	25	32	4	5

5 Maintenance on Towers	% responses: Frequency Entered				% doing work: Work Performed			Frequenc
	Every TA	Every 2 TAs	Every 3 TAs	As Required	Inspection	Cleaning	Other Work	Years
Demethanizer	14%	19%	6%	61%	64%	17%	26%	12 78
Deethanizer	39%	16%	5%	39%	68%	42%	21%	10 05
C2 Splitter	14%	22%	5%	59%	59%	19%	24%	12 88
Depropanizer	81%	8%	0%	11%	69%	89%	11%	8 08

Attachment A: 1997 Turnaround Survey: World

C3 Splitter	7	7	2	15	25	10	6	10	28%	23%	4%	48%	61%	32%	10%	11.16
Debutanizer	25	2	1	6	25	28	8	8	79%	8%	3%	10%	79%	84%	18%	8.58
Quench Oil Tower	17	1	1	4	18	22	3	18	74%	4%	4%	17%	79%	89%	12%	8.70
Quench Water Tower	28	1	2	6	27	29	2	4	76%	3%	6%	16%	73%	78%	6%	8.78
Caustic Tower	29	2	0	5	28	30	5	5	81%	8%	8%	14%	78%	83%	14%	8.31
Amine Tower	6	1	0	2	8	6	1	32	67%	11%	9%	22%	67%	84%	11%	8.44
Process Condensate Stripper	17	1	0	4	15	14	6	19	77%	4%	9%	10%	88%	64%	23%	8.64
Gasoline Stripper	17	1	0	3	16	18	1	20	81%	6%	0%	14%	71%	84%	6%	8.43
Fuel Oil Stripper	13	1	0	3	11	14	2	24	78%	6%	9%	18%	65%	82%	12%	8.29
Process Water Stripper	17	0	0	8	18	17	3	16	88%	9%	8%	82%	84%	68%	18%	8.84

6 Safety Systems

A Relief Valves	Yes	Yes, Some	No										
Are valves inspected & tested prior	26	3	12										
valves under	14	24	3										
valves on discharge	8	23	10					% of yes and yes some					
iv How do you ensure isolation is open	Administrative	Lock & Chain	Keyed Valve	Special Blind	Other			Administrative	Lock & Chain	Keyed Valve	Special Blind	Other	
	18	15	10	4	13			47%	39%	26%	11%	34%	
	Yes	Yes, Some	No										
v Do you allow three way valves	3	14	23										
vi Do you have spare relief valves	22	4	15										
	Average												
vii What is test frequency	119	Data Meaningless use 1 to 5 years		% total Survey									
viii What type of RV testing is done	Shop Testing	on-line Testing		Shop Testing	on-line Testing				% of Total Survey				
	41	5		100%	12%								
								Production	Maintenance	Technical	Contractor	Safety	Other
ix Who performs field inspection	Production	Maintenance	Technical	Contractor	Safety	Other		66%	56%	7%	5%	2%	2%
	27	23	3	2	1	1							
x Do you maintain spare pool	Yes	No											
	27	14											

B Flare System Maintenance

i Type of Flare	Elevated	Ground	Both						
	31	1	9						
						% Using			
ii Elevated Flare Work						Every TA	2nd TA	3rd TA	As Required
a Timing for work on flare tip	Every TA	2nd TA	3rd TA	As Required	Elevated	56%	3%	3%	38%
	23	1	1	15	Ground	55%	0%	0%	45%
b Work performed	Replace w/ New T	Replace w/Spare	Refurbish	As Required		Replace w/ New T	Replace w/Spar	Refurbish	As Required
	6	3	4	28		15%	7%	10%	68%
iii Ground Flare									
a Timing for work on ground flare	Every TA	2nd TA	3rd TA	As Required					
	6	0	0	6	% of Number with Ground Flare				
b Work Performed	Replace Insulation	Replace Burner	Replace Pilot		Replace Insulation	Replace Burner	Replace Pilot		
	5	6	7		60%	66%	70%		
iv Flare Line Seal Drum Work									
a Timing for work on Seal Drum	Every TA	Every 2nd TA	3rd TA	As Required					
	19	3	0	11					
b Work Performed	Inspect/Repair	Replace							
	34	0							
	Average								
v Pilot Thermocouples									
Number Available	4.4								
Number Replaced	3.8								
Replaced Due to Failure	2.1								
Replaced as Preventive Maintenance	1.7								

7 Mechanical Integrity	Yes	No									
A Are you mandated to hydrostatic test	12	29					% Mandated to Hydro				
B What equipment must have hydrotest	Pressure Vessel H	Piping Hot	Pressure Vessel C	Piping Cold	Other		Pressure Vessel	Piping Hot	Pressure Ves	Piping Cold	Other
	7	6	4	3	2		58%	50%	33%	25%	17%
minimum or maximum temp	Can't some the data it is too meaningless										
C Frequency of Hydrotest yrs AVERAGE	6.14	6.00	7.50	6.67	3.50	Inspection Methods Sorted by Hand					
D What method is used to evaluate mecha	Have to sort by hand					Visual	17				
						X ray	15				
d Miscellaneous Maintenance Work						Ultra Sonic	15				
A Charge Gas Dryer Desiccant			Average			[illegible]	[illegible]				

Attachment A Page 5 of 8

1. Change Out	Between TA	During TA	Frequency			Dye Penetrant	8
	29	15	4.0			Mag Particle	7
						Eddy Current	4
2 Reason for Changeout	Performance	Scheduled				Acoustical	3
	32	8				On-line Corosome	1
						Metalography	1
B Acetylene Reactor Catalyst			Average			Comparative Serv	1
1 Change Out	Between TA	During TA	Frequency				
	24	7	8.8		Between TA	During TA	Frequency
				Charge Gas Dryer	86%	34%	4.0
2 Reason for Changeout	Performance	Scheduled		Acetylene Reactor	80%	20%	8.8
	36	0					

C Demister Pad or Vane Separator Work Performed	Demister			Vane Separator		
	Clean	Replace	No Work	Clean	Replace	No Work
CGC Drums	22	10	7	11	0	2
Caustic Tower	16	9	8	8	0	2
Quench Tower	11	2	4	4	0	1

D Inspect piping in following areas	Between TA	During TA	Frequency	As Required
Sweating service	20	19	6.0	2
Caustic service	20	18	4.6	1
Amine service	12	8	4.7	0
Other				

9 Personnel used for turnaround maintenance work	Supervising Personnel		Work Performed by		% of Total Survey	Supervising Personnel		Work Performed by	
	Plant Personnel	Contractor	Plant Personnel	Contractor		Plant Personnel	Contractor	Plant Personnel	Contractor
Quality Assurance	37	8	24	20	Quality Assurance	90%	20%	59%	49%
Safety	39	11	29	17	Safety	95%	27%	71%	41%
Furnace Area	30	6	13	26	Furnace Area	73%	15%	32%	63%
Compressors	35	10	13	33	Compressors	85%	24%	32%	80%
Towers	29	10	5	36	Towers	71%	24%	12%	88%
Exchangers	31	9	7	36	Exchangers	76%	22%	17%	88%
Vessels	30	8	7	34	Vessels	73%	20%	17%	83%
Inst & Elect	37	4	27	21	Inst & Elect	90%	10%	66%	51%
Inspection	37	2	20	25	Inspection	90%	5%	49%	61%
Pipe/Pipe Valves	32	9	9	32	Pipe/Pipe Valves	78%	22%	22%	78%
Paint & Insulation	23	19	2	36	Paint & Insulation	56%	46%	5%	88%
Scaffold	17	23	1	37	Scaffold	41%	56%	2%	90%
Hydroblasting	20	21	1	36	Hydroblasting	49%	51%	2%	88%
Civil Work	24	12	5	33	Civil Work	59%	29%	12%	80%
Valve Maint	29	12	11	33	Valve Maint	71%	29%	27%	80%
Machinist	34	9	21	26	Machinist	83%	22%	51%	83%

SAFETY

	Yes	No	
1. DO YOU ALLOW MAINTENANCE AND/OR CONSTRUCTION PERSONNEL ON THE UNIT DURING THE INITIAL UNIT HYDROCARBON CLEANING	16	24	
	Yes	No	
2. DO YOU ALLOW MAINTENANCE AND/OR CONSTRUCTION PERSONNEL ON SECTIONS OF THE UNIT THAT HAVE BEEN CLEARED OF HYDROCARBONS WHILE STILL CLEARING THE BALANCE OF THE UNIT	33	8	
	Yes	No	Specific Locations Only
3. DO YOU REQUIRE FIRE RETARDANT CLOTHING ON THE UNIT DURING NORMAL OPERATIONS?	27	12	
	Yes	No	Specific locations only
4. DO YOU REQUIRE FIRE RETARDANT CLOTHING ON THE UNIT AFTER HYDROCARBON FREE?	17	19	

5. HOW MANY SAFETY AUDITS ARE PERFORMED DURING THE TURNAROUND?	Average
Number Audits/day/100 workers	4.85

6. WHAT IS THE RATIO OF SAFETY INSPECTORS (COMBINED PLANT AND CONTRACTOR) TO 100 WORKERS	Ratio - Average
	2.3

7. DO YOU USE PLANT PERSONNEL OTHER THAN SAFETY PERSONNEL TO PERFORM SAFETY INSPECTIONS DURING TURNAROUNDS?	Yes	No
	31	10

8. HOW MANY HOURS OF SAFETY TRAINING ARE REQUIRED FOR CONTRACTORS PRIOR TO WORKING ON THE UNIT	AVERAGE
Total Hours	7.53
General Training Hours	4.72
Site Specific Training Hours	2.96

9. HOW OFTEN ARE SAFETY MEETINGS CONDUCTED?	Once/ Shift	Daily	Weekly	Other
	23	14	3	3

10. THE LENGTH OF THE SAFETY MEETI	5-10 minutes	10-15 minutes	15-30 minutes	Longer
	11	18	9	5

11. PERMITTING AFTER THE UNIT IS HYDROCARBON FREE.	
Blanket Permit	2
Job Specific	33
Hot Work Permit Required	33

12. RESPONSIBILITY FOR ISSUING THE PERMITS.	Write	Approve	Close
Maintenance, In House	11	11	14
Contractor	10	10	8
Operations	29	41	28

13. LOCKOUT/TAGOUT PROCEDURES:	During Hydrocarbon Freeing Yes		After Hydrocarbon Freeing Yes	
LOCK PHILOSOPHY	Yes	No	Yes	No
Battery Lock	15	23	1	0
System Lock	17	21	0	1
Personal Lock	18	20	1	0
Tag	23	16	1	0

DURING HYDROCARBON FREEING	Operations			Maintenance			
Primary Responsibility							
Area to be Locked:	Process	Elect.	Mech.	Process	Elect.	Mech.	
Battery Lock	16	5	5	4	2	3	
System Lock	21	11	12	5	6	4	
Personal Lock	13	9	8	7	13	10	
Tag	18	8	11	3	8	6	
	68	33	35	19	29	22	
		Operations	117			Maintenance	70

AFTER HYDROCARBON FREEING	Operations	Maintenance
Primary Responsibility		

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Area to be Locked:	Process		Elect	Mech		Process	Elect.	Mech.	
Battery Lock	15		8	6		7	6	3	
System Lock	20		12	10		9	9	7	
Personal Lock	13		7	7		9	14	14	
Tag	20		12	8	Operations	4	7	10	Maintenance
	68		37	28	133	29	36	34	99
14. WHO TRACKS THE BLIND INSTALLATION AND REMOVAL DURING THE UNIT TURNAROUND?									
Plant Operations	38	62%							
Plant Maintenance	6	11%							
Contractor	3	7%							
	44								
15. SCHEDULES									
A. TURNAROUND SCHEDULE	4		6	6		7			
Days/Week	0		1	11		28			
B. PERSONAL SCHEDULES FOR TURNAROUND WORK									
OPERATIONS PERSONNEL	4		6	6		7			
Days/Week	0		1	9		29			
	1		2	3					
Shifts/day	6		2	33					
	8		10	12					
Hours/Shift	0		0	0					
MAINTENANCE PERSONNEL	4		4	4		7			
Days/Week	0		2	14		24			
	1		2	3					
Shifts/day	5		12	24					
	8		10	12					
Hours/Shift	0		0	0					
TECHNICAL PERSONNEL	4		4	4		7			
Days/Week	0		2	13		23			
	1		2	3					
Shifts/day	4		9	26					
	8		10	12					
Hours/Shift	0		0	0					
17. WHAT IS THE RECORDABLE INJURIES PER 200,000 MAN-HOURS DURING:	NORMAL OPERATIONS			TURNAROUND					
Operating Company	1.81			1.49					
Contractor	1.71			3.25					
18. WHAT PROVISIONS ARE MADE FOR EMPLOYEE DAYS OFF?	See Geographic Summaries								

Environmental

1. To comply with government environmental regulations pertaining to volatile organic compounds (VOC), naturally occurring radioactive materials (NORM) such as radon, carcinogenic chemicals such as benzene and butadiene and asbestos exposure or other local regulations requires A. Increase in Turnaround Manpower	None	5% or Less	6-10%	11-15%	>15%
	6	13	10	1	1
	None	1-2 Days	3-5 Days	6-10 Days	>10 Days

B. Increase in Turnaround Time	10	13	13	2	0		
	None	<5%	5-10%	11-15%	>15%		
C. Increase in Turnaround Costs (Excluding Lost Production)	0	16	13	7	1		
2 To comply with regulations and internal standards for safe entry of the quench system:	1-2 Days	3-4 Days	5-7 Days	8-10 Days	> 10 Days		
A. Time Required to Comply	7	19	11	3	0		
	AVERAGE PPM	Does Not Apply					
B What benzene exposure level is allowed by government regulation or internal standard?	1.52	1					
	Steaming	Steaming/Hot Water	Surfactant Wash	Solvent Wash	Purge to Flare	Purge to Atm	Other
C. Methods tried to clear Quench system during last turnaround	27	14	7	10	19	5	3
	Steaming	Steaming/Hot Water	Surfactant Wash	Solvent Wash	Purge to Flare	Purge to Atm	Other
D Method(s) Selected for use at next Turnaround	27	13	7	12	19	6	3
3 Regulations limiting fugitive hydrocarbon emissions from valves and							
	Bubble Test	Tracer Gas	Other	Does Not Apply			
A. How do you monitor for potential emissions while freeing unit of air?	22	2	2	11			
	Don't Confirm	Bubble Test	Tracer Gas	Other	Does Not Apply		
B How do you shop confirm valve repairs made to meet emission regulations?	8	20	0	7	3		
	Operating Pressur	AVERAGE Nominal Pressure, psig					
C If you shop test valve repairs, at what pressure?	18	43.8					
	Not Required	Manufacturer Certificate	100% Tested	Random Tested			
D What monitoring is used for new valves prior to installation in emission regulated service?	8	15	11	3			

Olefins Plant Background Data						
1 Plant geographic location:						
North America	26					
Europe	0					
Far East/Pacific Rim	0					
Other	0					
total	26					
2 Major Feedstocks						
Ethane	3					
NGL	14					
Naphtha	0					
Mixed Feed	9					
total	26					
3 Plant Capacity						
A. Based on Current Ethylene Capacity		Average Size				
< 500MMlb	2	1212				
<1000MMLb	9					
<1500MMLb	8					
> 1500MMLb	7					
	26					
B. Operating hours per year for current ethylene capacity						
<8000	0					
8000 - 8400	1					
>8400	25					
	0					
4 Plant Vintage	26					
A Original Design						
Earlier than 1965	6					
1966 - 1970	10					
1971 to 1980	8					
1981 to 1990	2					
1990 +	1					
	26					
B Latest Modernization						
1970-1979	2					
1980-1989	13					
1990+	9					
	24					
5 Number of Major Pieces of Equipment						
Major Equipment	Major Pieces Per Unit Equipment	Opened for Maint Reasons	Opened for Safety Reasons	AVERAGE Major Pieces Per Unit Equipment	AVERAGE Opened for Maint Reasons	AVERAGE Opened for Safety Reasons
Furnaces	314	167	12	12	7	4
Compressors	186	129	2	7	5	0
Towers	510	188	20	20	8	3
Exchangers	4190	1260	103	161	67	15
Pumps	3743	436	14	144	27	2
Reactors	133	13	0	6	1	0
Equipment Total	8453	1611	61	340	115	10
Boilers/Superheaters	109	28	4	5	2	1
Other Equipment	848	242	32	46	20	8
Total	8424	1891	58	428	145	15
6 Other facilities associated with Olefin Plant turnaround						
A Auxiliary Units		% of Total Survey				
Butadiene Recovery Plant	5	19%				
Cogeneration Plant	2	8%				
Utility Plant	12	46%				
Other	5	19%				
B Supporting Units		% of Total Survey				
C4 Hydrogenation	2	8%				
C5 Hydrogenation	0	0%				
First Stage Gasoline Hydrogenation Unit	6	23%				
Second Stage Gasoline Hydrogenation Unit	5	19%				

Turnaround Definition

	2 Years	3 Years	4 Years	5 Years	Other
1 INTERVAL BETWEEN TURNAROUNDS	0	4	7	8	7
2 MAJOR REASON(s)FOR TURNAROUND INTERVAL (SELECT ONE)		Average Time Between TAR	4.7		
Mechanical Integrity & Inspections	18				
Business Climate	0				
Safety System Inspection	0				
Predictive Maintenance	4				
Regulatory	0				
Unit Efficiency	5				
Other Facilities	0				
Other	0				
	27				
3 TYPICAL LENGTH OF TURNAROUND DEFINED AS FEED OUT TO FEED IN		Average Days Down	32		
15 Days or Less	4				
16 - 25 days	6				
26 - 35 days	8				
36 - 45 days	5				
46 - 55 days	3				
56 - 65 days	2				
65+ days	0				
4. ITEMS WHICH TYPICALLY DETERMINE CRITICAL PATH OF TURNAROUND. (SELECT ONE)					
Exchangers	1				
Charge Gas Compressor	13				
Towers	3				
Furnaces	0				
Capital Projects	5				
Refrigeration Compressor	5				
Other	2				
	29				
5 MINI-OUTAGES BETWEEN TURNAROUNDS					
A. Scheduled Between Outages					
Yes	8				
No	20				
B If YES Length of Mini-outage					
1-2 days	5				
3-4 days	4				
5-7 days	2				
>8 days	3				

Plant Re-Start

1 Typical length of time from introduction of hydrocarbon inventory until cracked gas feed in the charge gas compressor?		Average	22
<4 hours	4		
4-8 hours	4		

Attachment B Page 2 of 9

8 hours to 1day	9	
>1 to 2 days	5	
>2 to 3 days	4	
> 3 to 4 days	0	
>4 to 5 days	0	
>5 days	0	
	26	
2 Typical length of time from cracked gas feed to the charge gas compressor to ethylene product on test?		Average [illegible]
<4 hours	1	
>4 to 8 hours	3	
>8 to 12 hours	3	
>12 to 16hours	7	
>16 to 24 hours	9	
> 24 hours	3	
	26	
3 Do you practice minimal flaring startups by recycling ethylene and/or propylene to the furnaces?		
Yes	6	
No	20	
4 Do you have storage for off test product?		
Ethylene	Ethylene	Propylene
Yes	9	15
No	17	11
Propylene		
Yes	15	
No	11	
5 Would you describe your startup procedures from cold start to ethylene product on test as:		
Limited operator flexibility	7	
Operator flexibility	19	

WORK PRIOR TO TURNAROUND

1. PLANNING PERSONNEL	Preplanning	Primary Coordination
i. Permanent Staff	16	18
ii. Reassigned Staff	17	10
iii. Temporary Staff (Retirees)	5	0
iv. Regular Contractor	11	1
v. Temporary Contractor	5	0

2. SCHEDULING METHODOLOGY										
A. Please list method Used to Plan Turnaround (such as Premivera or Manual)	Open Plan	[illegible]	MS Projects	2	Timeline	1	Premivera	10	TASK/MASK	1
	CASP	2	PS5	1	Manual	2	Kurtz & Steele	1	ProPlan	1

	Plant	Contractor
B. Who runs and maintains the turnaround schedule?	24	2

3. TIMING TO PERFORM DETAILED TURNAROUND PLANNING AS CALLED BY YOUR STANDARD PROCEDURES	
i. Continuously	1
ii. Less than 6 months	0
iii. 6 months	6
iv. 12 months	12
v. 18 months	6
vi. Greater than 18 months	0

4. WHAT TURNAROUND PREMISE IS ALLOWED DURING UNIT OPERATION	Do You Allow	Limited by: Safety	Limited by: Operations	Percent Complete Prior to Unit Shutdown, %: 100	75	50	25	10

Scaffolding	28	13	18	4	17	2	2	0
Prebung Pipe	24	13	12	0	10	4	8	3
Foundation Work	22	13	14	4	8	8	2	1
Insulation Work	25	10	17	0	5	9	5	4
Equip./Piping	23	12	15	0	5	9	4	3
Inspection	8	7	8	0	1	2	0	2
Hot Work	18	14	10	0	8	2	1	5
Other	1	0	1	0	1	1	0	

5. What is you peak loading, plant plus contractor, during	Average	Maximum	Minimum	Lowest Quartile	Second Quartile	Third Quartile	Highest Quartile
Day shift workers	464	2100	100	200	300	600	2100
Night shift workers	253	1000	50	115	200	262.5	1000

6. What percent of the turnaround plant maintenance cost is:							
Plant Maintenance	30.92	100	5	10	19	54.75	100
Contractor Lump Sum	27.56	65	0	10	20	47	65
Contractor Cost Plus	52.91	90	5	25	40	87.5	90

Maintenance Work During Turnaround

1. Rotating Equipment Do You open the case every	TA	2nd TA	3rd TA	Other	Number of Responses	Frequency Years
Cracked Gas	19	8	0	2	26	6.65
Propylene	7	10	0	9	26	11.98
Ethylene	7	9	1	9	26	12.12
Methane	4	2	0	6	12	12.66
Steam Turbine	16	6	1	2	25	7.88
Gas Turbine	5	1	0	1	7	6.14
Motor	4	2	2	4	12	13.66

% Responding

1. Rotating Equipment Do You open the case every	TA	2nd TA	3rd TA	Other
Cracked Gas	73%	19%	0%	8%
Propylene	27%	38%	0%	35%
Ethylene	27%	35%	4%	35%
Methane	33%	17%	0%	50%
Steam Turbine	64%	24%	4%	8%
Gas Turbine	71%	14%	0%	14%
Motor	33%	17%	17%	33%

2. Feed Chilling A. Frequency Opened	TA	2nd TA	3rd TA	Never
	8	8	2	11

B. Reason	Yes	% who said yes
Maintenance	10	77%
Preventive/Operability	7	54%
Safety Inspection	7	54%
NOx Cleaning	4	31%

	Average # Years
C. Cold Box NOx Cleaning Frequency	6.38

D. History of Cold Box	Yes	No
Corrosion	5	19
Failure	9	15

3. Exchangers Routine Work	Clean Process Side	Clean Utility Side	Tube Repair	VOC Repair	Insulation Work	Inspection	Cathodic Protection	None
Quench Oil	6	3	3	0	2	4	0	7
Quench Water	13	12	8	0	2	13	2	3
Cooling Water - Quench System	14	18	8	0	2	14	8	5
Cooling Water - CGC Train	15	22	10	4	3	18	8	0
Cooling Water - Surface Condensers	6	20	8	2	3	15	7	1
Cooling Water - Propylene System	3	14	8	5	3	13	4	4
Cooling Water - C3E System	8	14	6	7	3	12	8	6
Cooling Water - C2E System	4	13	4	7	3	11	6	6
Refrigeration	0	1	4	3	4	9	0	8
Feed Chilling	3	1	3	3	2	11	0	8
Brazied Aluminum	1	0	0	0	1	8	0	10
Dilution Steam Generation	7	4	3	0	1	5	0	12
Furnace Quench	11	3	4	0	2	7	0	9
Furnace Secondary TLE	8	3	3	0	3	6	0	11

3. Exchangers Routine Work	Clean Process Side	Clean Utility Side	Tube Repair	VOC Repair	Insulation Work	Inspection	Cathodic Protection	None
Quench Oil	23%	12%	12%	0%	8%	16%	0%	27%
Quench Water	50%	46%	33%	0%	8%	50%	8%	12%
Cooling Water - Quench System	54%	62%	73%	0%	8%	54%	31%	19%
Cooling Water - CGC Train	58%	69%	38%	15%	12%	69%	31%	0%
Cooling Water - Surface Condensers	23%	77%	81%	8%	12%	58%	27%	4%
Cooling Water - Propylene System	12%	54%	31%	19%	12%	50%	15%	15%
Cooling Water - C3E System	31%	54%	31%	27%	12%	46%	31%	19%
Cooling Water - C2E System	15%	50%	19%	27%	12%	42%	19%	19%
Refrigeration	0%	4%	15%	12%	10%	34%	0%	23%
Feed Chilling	12%	4%	12%	12%	8%	42%	0%	31%
Brazied Aluminum	4%	0%	0%	0%	4%	31%	0%	38%
Dilution Steam Generation	27%	15%	12%	0%	4%	19%	0%	46%
Furnace Quench	42%	12%	15%	0%	8%	27%	0%	35%
Furnace Secondary TLE	31%	12%	12%	0%	12%	23%	0%	42%

% responses

% doing work

4. Are spare exchangers scheduled for work during TA	Yes	No
	6	20

5 Maintenance on Towers	Frequency Entered: Every TA	Every 2 TAs	Every 3 TAs	As Required	Work Performed: Tower Inspection	Tower Cleaning	Other Tower Work	No Response
Demethanizer	4	5	1	12	14	3	7	4
Deethanizer	8	6	1	8	18	10	8	2
C2 Splitter	8	6	1	12	12	4	7	3
Depropanizer	17	3	0	2	14	18	4	4
C3 Splitter	4	4	1	8	12	5	6	9
Debutanizer	16	2	0	2	15	18	5	6
Quench Oil Tower	6	1	1	1	6	9	2	17
Quench Water Tower	17	1	2	4	17	18	2	2
Caustic Tower	16	2	0	3	16	17	4	5
Amine Tower	2	1	0	1	3	1	1	22
Process Condensate Stripper	6	1	0	3	7	6	3	16
Gasoline Stripper	4	1	0	2	4	4	1	19
Fuel Oil Stripper	3	1	0	2	4	3	2	20
Process Water Stripper	7	0	0	8	7	7	3	13

5 Maintenance on Towers	Frequency Entered: Every TA	Every 2 TAs	Every 3 T	As Requir	Work Performed: Inspectio	Cleaning	Other Work	Frequenc Years
Demethanizer	19%	23%	5%	55%	64%	14%	32%	13.41
Deethanizer	38%	29%	4%	33%	47%	48%	38%	10.17
C2 Splitter	32%	23%	4%	52%	57%	17%	30%	13.04
Depropanizer	77%	14%	0%	9%	64%	82%	19%	8.73
C3 Splitter	34%	24%	4%	47%	71%	29%	36%	12.53
Debutanizer	80%	10%	0%	10%	79%	90%	26%	6.70
Quench Oil Tower	67%	11%	11%	11%	67%	100%	33%	8.22
Quench Water Tower	71%	4%	8%	17%	71%	78%	9%	8.04
Caustic Tower	76%	10%	0%	14%	76%	81%	19%	7.29
Amine Tower	60%	20%	0%	24%	71%	29%	29%	9.00
Process Condensate Stripper	60%	10%	0%	30%	70%	60%	30%	9.70
Gasoline Stripper	67%	14%	0%	29%	57%	57%	14%	10.86
Fuel Oil Stripper	60%	17%	0%	33%	67%	60%	33%	10.33
Process Water Stripper	54%	0%	8%	46%	54%	54%	23%	12.00

6 Safety Systems A Relief Valves	Yes	Yes, Some	No
Are valves inspected & tested prior	18	3	5
valves under	9	15	2
valves on discharge	5	14	7

iv How do you ensure isolation valve under relief valve is open	Administrative	Lock & Chain	Keyed Valve	Special Blind	Other
Count	16	7	0	3	11
% of yes are yes some	87%	29%	0%	13%	46%

	Yes	Yes, Some	No
v Do you allow three way valves	2	10	13
vi Do you have spare relief valves	12	4	10

	Average	
vii What is test frequency	79.5	Data Meaningless use 1 to 5 years

viii What type of RV testing is done	Shop Testing	on-line Testing
Count	26	3
% total Survey	100%	12%

ix Who performs field inspection	Production	Maintenance	Technical	Contractor	Safety	Other
Count	20	14	2	0	0	0
% of Total Survey	77%	54%	8%	0%	0%	0%

x Do you maintain spare pool	Yes	No
Count	21	6

8 Flare System Maintenance i Type of Flare	Elevated	Ground	Both
Count	24	1	1

ii Elevated Flare Work				
a Timing for work on flare tip	Every TA	2nd TA	3rd TA	As Required
	12	0	0	13
b. Work performed	Replace w/ New T	Replace w/Spare	Refurbish	As Required
	8	2	3	16

% Using	Every TA	2nd TA	3rd TA	As Required
Elevated	48%	0%	0%	52%
Ground	67%	0%	0%	33%
	Replace w/ New T	Replace w/Spar	Refurbish	As Required
	23%	6%	12%	68%

iii Ground Flare				
a Timing for work on ground flare	Every TA	2nd TA	3rd TA	As Required
	2	0	0	1
b. Work Performed	Replace Insulation	Replace Burner	Replace Pilot	
	0	1	1	

% of Number with Ground Flare	Replace Insulation	Replace Burner	Replace Pilot
	0%	50%	50%

iv. Flare Line Seal Drum Work				
a Timing for work on Seal Drum	Every TA	Every 2nd TA	3rd TA	As Required
	10	3	0	6
b Work Performed	Inspect/Repair	Replace		
	20	0		

v Pilot Thermocouples	Average
Number Available	4.1
Number Replaced	3.7
Replaced Due to Failure	2.8
Replaced as Preventive Maintenance	0.9

7 Mechanical Integrity	Yes	No
A Are you mandated to hydrostatic test	1	25

B What equipment must have hydrotest	Pressure Vessel I	Piping Hot	Pressure Vessel C	Piping Cold	Other
	0	0	0	0	1
minimum or maximum temp	Can't some the data it is too meaningless				

% Mandated to Hydro	Pressure Vesse	Piping Hot	Pressure	Piping Cold	Other
	0%	0%	0%	0%	100%

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C Frequency of Hydrotest yrs AVERAGE					1.00

D What method is used to evaluate mecha Have to sort by hand

Inspection Methods Sorted by Hand	
Visual	17
x-ray	15
Ultra-Sonic	15
Pneumatic	10
Die Penetrant	8
Mag. Particle	7
Eddy Current	4
Acoustical	3
On-line Corosome	1
Metalography	1
Comparative Servi	1

8 Miscellaneous Maintenance Work			
A. Charge Gas Dryer Desiccant			
1 Change Out	Between TA	During TA	Average Frequency
	21	7	4.1
2. Reason for Changeout	Performance	Scheduled	
	20	7	
B Acetylene Reactor Catalyst			
1 Change Out	Between TA	During TA	Average Frequency
	17	4	9.3
2 Reason for Changeout	Performance	Scheduled	
	22	0	

	Between TA	During TA	Frequency
Charge Gas Dryer	75%	25%	4.1
Acetylene Reactor	81%	19%	9.3

C Demister Pad or Vane Separator Work Performed	Demister			Vane Separator		
	Clean	Replace	No Work	Clean	Replace	No Work
CGC Drums	12	7	5	7	0	1
Caustic Tower	8	6	5	1	0	2
Quench Tower	7	1	3	1	0	1

D Inspect piping in following areas	Between TA	During TA	Frequency	As Required
Sweating service	12	13	5.1	1
Caustic service	15	11	6.0	1
Amine service	10	2	4.7	0
Other				

9 Personnel used for turnaround maintenance work	Supervising Personnel		Work Performed by	
	Plant Personnel	Contractor	Plant Personnel	Contractor
Quality Assurance	23	6	15	12
Safety	25	8	19	8
Furnace Area	17	3	8	16
Compressors	24	3	8	19
Towers	17	5	3	22
Exchangers	19	5	8	23
Vessels	17	6	4	22
Inst. & Elect.	24	1	22	8
Inspection	23	0	15	13
Pipe/Pipe Valves	19	6	6	20
Paint & Insulation	12	13	0	23
Scaffold	8	16	0	24
Hydroblasting	11	16	0	24
Civil Work	14	6	4	20
Valve Maint	19	7	7	21
Machinist	23	3	14	15

% of Total Survey

	Supervising Personnel		Work Performed by	
	Plant Personnel	Contractor	Plant Personnel	Contractor
Quality Assurance	88%	23%	58%	46%
Safety	96%	31%	73%	31%
Furnace Area	65%	12%	31%	68%
Compressors	92%	12%	31%	73%
Towers	65%	19%	12%	85%
Exchangers	73%	19%	19%	88%
Vessels	66%	19%	15%	85%
Inst. & Elect.	92%	4%	85%	31%
Inspection	88%	0%	58%	50%
Pipe/Pipe Valves	73%	23%	23%	77%
Paint & Insulation	46%	50%	0%	88%
Scaffold	31%	62%	0%	92%
Hydroblasting	42%	62%	0%	92%
Civil Work	54%	31%	15%	77%
Valve Maint	73%	27%	27%	81%
Machinist	88%	12%	54%	58%

SAFETY

	Yes	No
1. DO YOU ALLOW MAINTENANCE AND/OR CONSTRUCTION PERSONNEL ON THE UNIT DURING THE INITIAL UNIT HYDROCARBON CLEARING	12	14
2. DO YOU ALLOW MAINTENANCE AND/OR CONSTRUCTION PERSONNEL ON SECTIONS OF THE UNIT THAT HAVE BEEN CLEARED OF HYDROCARBONS WHILE STILL CLEARING THE BALANCE OF THE UNIT	21	5
3. DO YOU REQUIRE FIRE RETARDANT CLOTHING ON THE UNIT DURING NORMAL OPERATIONS?	20	5

Specific Locations Only

	Yes	No	Specific Locations Only			
4. DO YOU REQUIRE FIRE RETARDANT CLOTHING ON THE UNIT AFTER HYDROCARBON FREE?	12	11				
5. HOW MANY SAFETY AUDITS ARE PERFORMED DURING THE TURNAROUND?	Average					
Number Audits/day/100 workers	4.82					
	Ratio - Average					
6. WHAT IS THE RATIO OF SAFETY INSPECTORS (COMBINED PLANT AND CONTRACTOR) TO 100 WORKERS	2.44					
	Yes	No				
7. DO YOU USE PLANT PERSONNEL OTHER THAN SAFETY PERSONNEL TO PERFORM SAFETY INSPECTIONS DURING TURNAROUNDS?	19	7				
8. HOW MANY HOURS OF SAFETY TRAINING ARE REQUIRED FOR CONTRACTORS PRIOR TO WORKING ON THE UNIT	AVERAGE					
Total Hours	7.81					
General Training Hours:	5.13					
Site Specific Training Hours:	2.69					
	Once/ Shift	Daily	Weekly	Other		
9. HOW OFTEN ARE SAFETY MEETINGS CONDUCTED?	20	6	1	1		
	5-10 minutes	10-15 minutes	15-30 minutes	Longer		
10. THE LENGTH OF THE SAFETY MEETING?	11	9	7	1		
11. PERMITTING AFTER THE UNIT IS HYDROCARBON FREE.						
Blanket Permit	1					
Job Specific	22					
Hot Work Permit Required	20					
12. RESPONSIBILITY FOR ISSUING THE PERMITS.						
	Write	Approve	Close			
Maintenance, In House	5	10	7			
Contractor	6	10	7			
Operations	22	26	19			
13. LOCKOUT/TAGOUT PROCEDURES:	During Hydrocarbon Freeing Yes		After Hydrocarbon Freeing Yes			
LOCK PHILOSOPHY	Yes	No	Yes	No		
Battery Lock	7	18	1	0		
System Lock	11	14	0	1		
Personal Lock	10	18	1	0		
Tag	18	10	1	0		
DURING HYDROCARBON FREEING						
Primary Responsibility	Operations			Maintenance		
Area to be Locked:	Process	Elect.	Mech.	Process	Elect.	Mech.
Battery Lock	6	3	2	1	1	2
System Lock	13	7	7	3	5	3
Personal Lock	5	5	3	3	7	6
Tag	11	5	6	1	6	3

	37		20		20	77	9	19	14	41
AFTER HYDROCARBON FREEING										
Primary Responsibility	Operations						Maintenance			
Area to be Locked:	Process		Elect.		Mech.		Process	Elect.	Mech.	
Battery Lock	8		5		4		2	4	1	
System Lock	14		9		7		5	7	5	
Personal Lock	6		4		4		3	9	8	
Tag	14		9		3	Operations	2	6	8	Maintenance
	42		27		18	87	12	26	22	59
14. WHO TRACKS THE BLIND INSTALLATION AND REMOVAL DURING THE UNIT TURNAROUND?										
Plant Operations	23	79%								
Plant Maintenance	4	14%								
Contractor	2	7%								
	29									
15. SCHEDULES										
A. TURNAROUND SCHEDULE	4		5		6		7			
Days/Week	0		0		4		21			
B. PERSONAL SCHEDULES FOR TURNAROUND WORK										
OPERATIONS PERSONNEL	4		5		6		7			
Days/Week	0		1		4		19			
	1		2		3					
Shifts/day	0		0		26					
	8		10		12					
Hours/Shift	0		0		0					
MAINTENANCE PERSONNEL	4		6		6		7			
Days/Week	0		0		7		18			
	1		2		3					
Shifts/day	2		8		18					
	8		10		12					
Hours/Shift	0		0		0					
TECHNICAL PERSONNEL	4		6		6		7			
Days/Week	0		0		6		19			
	1		2		3					
Shifts/day	1		2		23					
	8		10		12					
Hours/Shift	0		0		0					
17. WHAT IS THE RECORDABLE INJURIES PER 200,000 MAN HOURS DURING:	NORMAL OPERATIONS				TURNAROUND					
Operating Company	1.76				1.41					
Contractor	1.89				2.94					
18. WHAT PROVISIONS ARE MADE FOR EMPLOYEE DAYS OFF?	As schedule Allows	1	Emergency Days off only	1	Staggered Work schedules	1				
	No Provisions, Work Straight thru	8	60 Hour Work Week	1						
	Schedule 1 Day per Week	7	One Day Every 14 Days	2						
Environmental										

1. To comply with government environmental regulations pertaining to volatile organic compounds (VOC), naturally occurring radioactive materials (NORM) such as radon, carcinogenic chemicals such as benzene and butadiene, and asbestos exposure or other local regulations requires:	None	5% or Less	6-10%	11-15%	>15%		
A. Increase in Turnaround Manpower	4	9	10	1	1		
	None	1-2 Days	3-5 Days	6-10 Days	>10 Days		
B. Increase in Turnaround Time	9	7	8	2	0		
	None	<5%	5-10%	11-15%	>15%		
C. Increase in Turnaround Costs (Excluding Lost Production)	0	11	7	7	1		
2. To comply with regulations and internal standards for safe entry of the quench system:	1-2 Days	3-4 Days	5-7 Days	8-10 Days	> 10 Days		
A. Time Required to Comply	5	16	6	0	0		
	AVERAGE PPM	Does Not Apply					
B. What benzene exposure level is allowed by government regulation or internal standard?	0.81	0					
	Steaming	Steaming/Hot Water	Surfactant Wash	Solvent Wash	Purge to Flare	Purge to Atm	Other
C. Methods tried to clear Quench system during last turnaround	12	11	7	7	11	3	0
	Steaming	Steaming/Hot Water	Surfactant Wash	Solvent Wash	Purge to Flare	Purge to Atm	Other
D. Method(s) Selected for use at next Turnaround	13	10	7	8	11	4	0
3. Regulations limiting fugitive hydrocarbon emissions from valves and	Bubble Test	Tracer Gas	Other	Does Not Apply			
A. How do you monitor for potential emissions while freeing unit of air?	12	0	2	8			
	Don't Confirm	Bubble Test	Tracer Gas	Other	Does Not Apply		
B. How do you shop confirm valve repairs made to meet emission regulations?	7	11	0	6	0		
	Operating Pressur	AVERAGE Nominal Pressure, psig					
C. If you shop test valve repairs, at what pressure?	11	40.5					
	Not Required	Manufacturer Certificate	100% Tested	Random Tested			
D. What monitoring is used for new valves prior to installation in emission regulated service?	7	7	7	1			

Olefins Plant Background Data						
1 Plant geographic location:						
North America	0					
Europe	7					
Far East/Pacific Rim	0					
Other	0					
total	7					
2 Major Feedstocks						
Ethane	0					
NGL	0					
Naphtha	2					
Mixed Feed	5					
total	7					
3 Plant Capacity:						
A Based on Current Ethylene Capacity		Average Size				
< 500MMlb	1	1107				
<1000MMLb	2					
<1500MMLb	3					
> 1500MMLb	1					
	7					
B Operating hours per year for current ethylene capacity						
<8000	0					
8000 - 8400	4					
>8400	3					
	0					
4 Plant Vintage	7					
A Original Design						
Earlier than 1965	1					
1966 - 1970	1					
1971 to 1980	5					
1981 to 1990	0					
1990 +	0					
	7					
B Latest Modernization						
1970-1979	0					
1980-1989	0					
1990+	7					
	7					
5 Number of Major Pieces of Equipment						
Major Equipment	Major Pieces Per Unit Equipment	Opened for Maint Reasons	Opened for Safety Reasons	AVERAGE Major Pieces Per Unit Equipment	AVERAGE Opened for Maint Reasons	AVERAGE Opened for Safety Reasons
Furnaces	96	38	0	14	8	
Compressors	98	23	2	14	3	2
Towers	254	87	21	36	12	21
Exchangers	2106	803	14	301	115	14
Pumps	2312	100	0	330	20	
Reactors	58	13	0	8	2	
Equipment Total	2483	838	0	621	210	
Boilers/Superheaters	18	7	1	3	1	1
Other Equipment	610	395	4	102	66	4
Total	2347	871	0	587	218	
6 Other facilities associated with Olefin Plant turnaround						
A Auxiliary Units		% of Total Survey				
Butadiene Recovery Plant	2	29%				
Cogeneration Plant	0	0%				
Utility Plant	1	14%				
Other	3	43%				
B Supporting Units		% of Total Survey				
C4 Hydrogenator	2	29%				
C5 Hydrogenator	1	14%				
First Stage Gasoline Hydrogenation Unit	7	100%				
Second Stage Gasoline Hydrogenator Unit	2	29%				

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Turnaround Definition

	2 Years	3 Years	4 Years	5 Years	Other
1 INTERVAL BETWEEN TURNAROUNDS	0	0	2	5	0
2 MAJOR REASON(s)FOR TURNAROUND INTERVAL (SELECT ONE)		Average Time Between TAR	4.7		
Mechanical Integrity & Inspections	3				
Business Climate	0				
Safety System Inspection	0				
Predictive Maintenance	0				
Regulatory	4				
Unit Efficiency	0				
Other Facilities	0				
Other	0				
	7				
3 TYPICAL LENGTH OF TURNAROUND DEFINED AS FEED OUT TO FEED IN.		Average Days Down	33		
15 Days or Less	0				
16 - 25 days	3				
26 - 35 days	1				
36 - 45 days	3				
46 - 55 days	0				
56 - 65 days	0				
65+ days	0				
4 ITEMS WHICH TYPICALLY DETERMINE CRITICAL PATH OF TURNAROUND. (SELECT ONE)					
Exchangers	1				
Charge Gas Compressor	4				
Towers	2				
Furnaces	0				
Capital Projects	0				
Refrigeration Compressor	0				
Other	1				
	8				
5 MINI-OUTAGES BETWEEN TURNAROUNDS					
A. Scheduled Between Outages					
Yes	1				
No	6				
B If YES Length of Mini-outage					
1-2 days	0				
3-4 days	2				
5-7 days	1				
>8 days	0				

Plant Re-Start

1 Typical length of time from introduction of hydrocarbon inventory until cracked gas feed in the charge gas compressor?		Average	20		
<4 hours	3				
4-8 hours	0				
8 hours to 1day	2				

>1 to 2 days	1		
>2 to 3 days	1		
> 3 to 4 days	0		
>4 to 5 days	0		
>5 days	0		
	7		
2 Typical length of time from cracked gas feed to the charge gas compressor to ethylene product on test?		Average	18
<4 hours	0		
>4 to 8 hours	1		
>8 to 12 hours	3		
>12 to 16hours	0		
>16 to 24 hours	2		
> 24 hours	1		
	7		
3. Do you practice minimal flaring startups by recycling ethylene and/or propylene to the furnaces?			
Yes	3		
No	4		
4. Do you have storage for off test product?			
Ethylene	Ethylene	Propylene	
Yes	2	6	
No	5	1	
Propylene			
Yes	6		
No	1		
5 Would you describe your startup procedures from cold start to ethylene product on test as:			
Limited operator flexibility	2		
Operator flexibility	5		

WORK PRIOR TO TURNAROUND

1 PLANNING PERSONNEL	Preplanning	Primary Coordination
i Permanent Staff	5	4
ii Reassigned Staff	2	2
iii Temporary Staff (Retirees)	1	0
iv Regular Contractor	3	0
v Temporary Contractor	2	1

2 SCHEDULING METHODOLOGY

A Please list method Used to Plan Turnaround (such as Premvera or Manual)				
	Premivera	3	CMMS	1
	Manual	1	HLK Plan	1

	Plant	Contractor
B Who runs and maintains the turnaround schedule?	5	2

3 TIMING TO PERFORM DETAILED TURNAROUND PLANNING AS CALLED BY YOUR STANDARD PROCEDURES	
i. Continuously	1
ii Less than 6 months	0
iii 6 months	1
iv. 12 months	4
v 18 months	1
vi Greater than 18 months	0

4 WHAT TURNAROUND PREWORK IS ALLOWED DURING UNIT OPERATION		Limited by		Percent Complete Prior to Unit Shutdown, %				
	Do You Allow	Safety	Operations	100	75	50	25	10
Scaffolding	7	3	6	1	5	1	0	0
Prehung Pipe	6	4	3	0	0	4	0	2
Foundation Work	7	4	4	2	[illegible]	2	0	1

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Insulation Work	7	4	5	0	2	4	1	0
Equip /Piping	7	2	4	1	2	1	1	1
Inspection	1	2	0	0	0	0	0	1
Hot Work	8	8	3	0	1	1	0	3
Other	1	1	1	0	0	0	0	0

5 What is you peak loading, plant plus contractor, during	Average	Maximum	Minimum	Lowest Quartile	Second Quartile	Third Quartile	Highest Quartile
Day shift workers	1050	2800	440	530	650	1350	2500
Night shift workers	91.43	200	0	35	50	125	200
6 What percent of the turnaround plant maintenance cost is							
Plant Maintenance	15.67	24	5	11.25	17.5	20	24
Contractor Lump Sum	50.17	85	10	27.5	55	72	85
Contractor Cost Plus	41	80	10	25	30	60	80

Maintenance Work During Turnaround

1 Rotating Equipment. Do You open the ca	TA	2nd TA	3rd TA	Other	Number of Respo	Frequency Years	1. Rotating Equ	% Responding TA	2nd TA	3rd TA	Other
Cracked Gas	7	0	0	0	7	4.71	Cracked Gas	100%	0%	0%	0%
Propylene	2	3	1	1	7	10.14	Propylene	29%	43%	14%	14%
Ethylene	2	2	2	1	7	10.86	Ethylene	29%	29%	29%	14%
Methane	1	0	0	1	2	12.50	Methane	50%	0%	0%	50%
Steam Turbine	3	4	0	1	8	9.25	Steam Turbine	38%	50%	0%	13%
Gas Turbine	1	0	0	0	1	4.00	Gas Turbine	100%	0%	0%	0%
Motor	0	0	1	2	3	18.33	Motor	0%	0%	33%	67%

2 Feed Chilling

A Frequency Opened	TA	2nd TA	3rd TA	Never
	1	1	0	5

B Reason	Yes	% who said yes
Maintenance	0	0%
Preventive/Operability	2	100%
Safety Inspection	2	100%
NOx Cleaning	0	0%

	Average # Years
C Cold Box NOx Cleaning Frequency	4.5

D History of Cold Box	Yes	No
Corrosion	0	7
Failure	1	6

3 Exchangers: Routine Work	Clean Process Side	Clean Utility Side	Tube Repair	VOC Repair	Insulation Work	Inspection	Cathodic Protection	None
Quench Oil	5	3	0	0	0	6	0	2
Quench Water	3	3	0	0	0	6	0	1
Cooling Water - Quench System	2	2	0	0	0	4	0	2
Cooling Water - CGC Train	5	6	1	1	0	7	1	1
Cooling Water - Surface Condensers	0	4	1	0	1	4	0	1
Cooling Water - Propylene System	3	4	0	0	0	6	0	1
Cooling Water - C3E System	1	5	0	0	0	5	0	1
Cooling Water - C2E System	1	5	1	1	0	5	1	0
Refrigeration	1	5	0	0	0	3	0	4
Feed Chilling	1	1	0	1	1	3	0	3
Brazed Aluminum	0	0	0	0	1	3	0	3
Dilution Steam Generation	3	0	0	0	0	3	0	2
Furnace Quench	4	1	0	1	0	4	0	1
Furnace Secondary TLE	2	1	0	0	0	2	0	2

% responses

Clean Process Side	Clean Utility Side	Tube Repair	VOC Repair	Insulation Work	Inspection	Cathodic Protection	None
71%	43%	0%	0%	0%	71%	0%	29%
43%	43%	0%	0%	0%	71%	0%	14%
29%	29%	0%	0%	0%	57%	0%	29%
71%	86%	14%	14%	0%	100%	14%	14%
0%	57%	14%	0%	14%	57%	0%	14%
43%	57%	0%	0%	0%	86%	0%	14%
14%	71%	0%	0%	0%	71%	0%	14%
14%	71%	14%	14%	0%	71%	14%	0%
14%	71%	0%	0%	0%	43%	0%	57%
14%	14%	0%	14%	14%	43%	0%	43%
0%	0%	0%	0%	14%	43%	0%	43%
43%	0%	0%	0%	0%	43%	0%	29%
57%	14%	0%	14%	0%	57%	0%	14%
29%	14%	0%	0%	0%	29%	0%	29%

4 Are spare exchangers scheduled for wo	Yes	No
	3	4

5 Maintenance on Towers	Frequency Entered: Every TA	Every 2 TAs	Every 3 TAs	As Required	Work Performed: Tower Inspection	Tower Cleaning	Other Tower Work	No Response
Demethanizer	1	1	1	4	4	1	2	0
Deethanizer	2	0	1	4	4	2	2	0
C2 Splitter	0	2	1	4	4	1	2	0
Depropanizer	6	0	0	1	7	7	0	0
C3 Splitter	2	2	1	2	7	3	0	0
Debutanizer	5	0	[illegible]	1	7	6	0	0

% doing work

Frequency Entered: Every TA	Every 2 TAs	Every 3 T	As Requir	Work Performed: Inspectio	Cleaning	Other Work	Frequency Years
14%	14%	14%	57%	57%	14%	29%	15.00
29%	0%	14%	57%	57%	29%	29%	14.29
0%	29%	14%	57%	57%	14%	29%	15.57
86%	0%	0%	14%	100%	100%	0%	8.43
29%	29%	14%	29%	100%	43%	0%	11.29
71%	0%	14%	14%	100%	86%	0%	7.86

Quench Oil Tower	6	0	0	1	7	7	1	0	86%	0%	0%	14%	100%	100%	14%		6.86
Quench Water Tower	5	0	0	0	5	5	0	2	100%	0%	0%	0%	100%	100%	0%		4.80
Caustic Tower	6	0	0	1	7	7	1	0	86%	0%	0%	14%	100%	100%	14%		6.43
Amine Tower	2	0	0	0	2	2	0	5	100%	0%	0%	0%	100%	100%	0%		5.00
Process Condensate Stripper	5	0	0	0	4	4	1	2	100%	0%	0%	0%	80%	80%	20%		4.80
Gasoline Stripper	7	0	0	0	7	7	0	0	100%	0%	0%	0%	100%	100%	0%		4.71
Fuel Oil Stripper	4	0	0	0	3	4	0	3	100%	0%	0%	0%	71%	100%	0%		4.75
Process Water Stripper	4	0	0	1	4	4	0	2	80%	0%	0%	20%	80%	80%	0%		7.80

6 Safety Systems

A Relief Valves	Yes	Yes, Some	No			
Are valves inspected & tested prior	4	0	3			
valves under	3	4	0			
valves on discharge	2	4	1			
iv. How do you ensure isolation valve on relief valve is open	Administrative	Lock & Chain	Keyed Valve	Special Blind	Other	
	0	4	7	1	1	
	Yes	Yes, Some	No			
v. Do you allow three way valves	1	4	2			
vi Do you have spare relief valves	7	0	0			
	Average					
vii What is test frequency	19.6	Data Meaningless use 1 to 5 years				
viii What type of RV testing is done	Shop Testing	on-line Testing				
	7	1				
ix. Who performs field inspection	Production	Maintenance	Technical	Contractor	Safety	Other
	1	4	1	1	1	0
x Do you maintain spare pool	Yes	No				
	2	5				

% of yes and yes some

Administrative	Lock & Chain	Keyed Va	Special Blind	Other
0%	57%	100%	14%	14%

% total Survey

Shop Testing	on-line Testing
100%	14%

% of Total Survey

Production	Maintena	Technical	Contractor	Safety	Other
14%	57%	14%	14%	14%	0%

B Flare System Maintenance				
i Type of Flare	Elevated	Ground	Both	
	3	0	4	
ii Elevated Flare Work				
a Timing for work on flare tip	Every TA	2nd TA	3rd TA	As Required
	5	1	0	1
b Work performed	Replace w/ New T	Replace w/Spare	Refurbish	As Required
	0	1	1	6
iii Ground Flare				
a Timing for work on ground flare	Every TA	2nd TA	3rd TA	As Required
	2	0	0	2
b Work Performed	Replace Insulation	Replace Burner	Replace Pilot	
	4	3	3	
iv Flare Line Seal Drum Work				
a Timing for work on Seal Drum	Every TA	Every 2nd TA	3rd TA	As Required
	3	0	0	3
b Work Performed	Inspect/Repair	Replace		
	6	0		
	Average			
v Pilot Thermocouples				
Number Available	4.8			
Number Replaced	4.0			
Replaced Due to Failure	2.0			
Replaced as Preventive Maintenance	2.0			

% Using

	Every TA	2nd TA	3rd TA	As Required
Elevated	71%	14%	0%	14%
Ground	50%	0%	0%	50%
	Replace w/ New Tip	Replace w/Spare	Refurbish	As Required
	0%	13%	13%	75%

% of Number with Ground Flare

Replace Insulation	Replace Burner	Replace Pilot
100%	75%	75%

7 Mechanical Integrity	Yes	No			
A Are you mandated to hydrostatic test	6	1			
B What equipment must have hydrotest	Pressure Vessel H	Piping Hot	Pressure Vessel	Piping Cold	Other
	5	6	3	3	0
minimum or maximum temp	Can't some the data it is too meaningless				
C Frequency of Hydrotest yrs AVERAGE	7.8	8.25	10.00	7.60	
D What method is used to evaluate mecha	Have to sort by hand				

% Mandated to Hydro

Pressure Vesse	Piping Hot	Pressure	Piping Cold	Other
83%	83%	60%	60%	0%

Inspection Methods Sorted by Hand

Visual	17
x ray	15
Ultra Sonic	15
Pneumatic	10
Dye Penetrant	[illegible]

8 Miscellaneous Maintenance Work			
A Charge Gas Dryer Desiccant			Average
1 Change Out	Between TA	During TA	Frequency

	5	3	4.1		Mag Particle	7			
					Eddy Current	4			
2 Reason for Changeout	Performance	Scheduled			Acoustical	3			
	6	1			On-line Corosome	1			
					Metalography	1			
B Acetylene Reactor Catalyst			Average		Comparative Serv	1			
1 Change Out	Between TA	During TA	Frequency						
	4	1	7.6		Between TA	During TA	Frequency		
				Charge Gas Dryer	63%	34%	4.1		
2 Reason for Changeout	Performance	Scheduled		Acetylene Reactor	80%	20%	7.8		
	8	0							
C Demister Pad or Vane Separator Work P	Demister			Vane Separator					
	Clean	Replace	No Work	Clean	Replace	No Work			
CGC Drums	5	2	1	3	0	0			
Caustic Tower	6	0	0	3	0	0			
Quench Tower	3	0	0	1	0	0			
D Inspect piping in following areas	Between TA	During TA	Frequency	As Required					
Sweating service	4	4	5.0	0					
Caustic service	3	4	6.0	0					
Amine service	0	2		0					
Other									
						% of Total Survey			
9 Personnel used for turnaround maintenance work	Supervising Personnel		Work Performed by			Supervising Personnel		Work Performed by	
	Plant Personnel	Contractor	Plant Personnel	Contractor		Plant Personnel	Contractor	Plant Personnel	Contractor
Quality Assurance	7	1	5	4	Quality Assurance	100%	14%	71%	57%
Safety	6	2	4	6	Safety	86%	29%	57%	86%
Furnace Area	5	3	0	7	Furnace Area	71%	43%	0%	100%
Compressors	4	5	2	7	Compressors	57%	71%	29%	100%
Towers	4	5	0	7	Towers	57%	71%	0%	100%
Exchangers	4	4	0	7	Exchangers	57%	57%	0%	100%
Vessels	5	3	0	7	Vessels	71%	43%	0%	100%
Inst & Elect	5	3	1	7	Inst & Elect	71%	43%	14%	100%
Inspection	6	2	2	7	Inspection	86%	29%	29%	100%
Pipe/Pipe Valves	5	3	0	7	Pipe/Pipe Valves	71%	43%	0%	100%
Paint & Insulation	3	6	0	7	Paint & Insulation	43%	86%	0%	100%
Scaffold	2	6	0	6	Scaffold	29%	86%	0%	86%
Hydroblasting	1	5	0	5	Hydroblasting	14%	71%	0%	71%
Civil Work	2	4	0	6	Civil Work	29%	57%	0%	86%
Valve Maint	3	5	1	7	Valve Maint	43%	71%	14%	100%
Machinist	4	5	3	6	Machinist	57%	71%	43%	86%
SAFETY	Yes		No						
1. DO YOU ALLOW MAINTENANCE AND/OR CONSTRUCTION PERSONNEL ON THE UNIT DURING THE INITIAL UNIT HYDROCARBON CLEARING	2		5						
	Yes		No						
2 DO YOU ALLOW MAINTENANCE AND/OR CONSTRUCTION PERSONNEL ON SECTIONS OF THE UNIT THAT HAVE BEEN CLEARED OF HYDROCARBONS WHILE STILL CLEARING THE BALANCE OF THE UNIT	7		0						
	Yes		No		Specific Locations Only				
3. DO YOU REQUIRE FIRE RETARDANT CLOTHING ON THE UNIT DURING NORMAL OPERATIONS?	4		3						
	Yes		No		Specific Locations Only				
4 DO YOU REQUIRE FIRE RETARDANT CLOTHING ON THE UNIT AFTER HYDROCARBON FREE?	4		3						

5. HOW MANY SAFETY AUDITS ARE PERFORMED DURING THE TURNAROUND?	Average											
Number Audits/day/100 workers	3.83											
	Ratio - Average											
6. WHAT IS THE RATIO OF SAFETY INSPECTORS (COMBINED PLANT AND CONTRACTOR) TO 100 WORKERS	2.83											
	Yes		No									
7. DO YOU USE PLANT PERSONNEL OTHER THAN SAFETY PERSONNEL TO PERFORM SAFETY INSPECTIONS DURING TURNAROUNDS?	6		1									
8. HOW MANY HOURS OF SAFETY TRAINING ARE REQUIRED FOR CONTRACTORS PRIOR TO WORKING ON THE UNIT	AVERAGE											
Total Hours	3.9											
General Training Hours	1.65											
Site Specific Training Hours	2.04											
	Once/ Shift		Daily		Weekly		Other					
9. HOW OFTEN ARE SAFETY MEETINGS CONDUCTED?	0		4		1		2					
	5-10 minutes		10-15 minutes		15-30 minutes		Longer					
10. THE LENGTH OF THE SAFETY MEETI	0		3		1		3					
11. PERMITTING AFTER THE UNIT IS HYDROCARBON FREE.												
Blanket Permit	0											
Job Specific	7											
Hot Work Permit Required	7											
12. RESPONSIBILITY FOR ISSUING THE PERMITS.	Write		Approve		Close							
Maintenance, In House	2		0		4							
Contractor	2		0		1							
Operations	3		7		2							
13. LOCKOUT/TAGOUT PROCEDURES.	During Hydrocarbon Freeing Yes				After Hydrocarbon Freeing Yes							
LOCK PHILOSOPHY	Yes		No		Yes		No					
Battery Lock	3		2		#REF!		#REF!					
System Lock	1		4		#REF!		#REF!					
Personal Lock	2		3		#REF!		#REF!					
Tag	1		4		#REF!		#REF!					
DURING HYDROCARBON FREEING												
Primary Responsibility	Operations						Maintenance					
Area to be Locked:	Process		Elect.		Mech.		Process		Elect.		Mech.	
Battery Lock	3		1		1		1		0		0	
System Lock	3		2		2		0		0		0	
Personal Lock	3		2		2		1		2		2	
Tag	2		1		1	Operations	0		1		1	Maintenance
	11		6		6	2	3		1		3	9
AFTER HYDROCARBON FREEING												
Primary Responsibility	Operations						Maintenance					
Area to be Locked:	Process		Elect		Mech		Process		Elect		Mech	
Battery Lock	2		0		0		2		1		1	

System Lock	2		1		1		1		1		1	
Personal Lock	2		1		1		2		3		3	
Tag	1		1		1	Operations	0		1		1	Maintenance
	7		1		2	17	6		6		6	17
14 WHO TRACKS THE BLIND INSTALLATION AND REMOVAL DURING THE UNIT TURNAROUND?												
Plant Operations	5	83										
Plant Maintenance	0	0										
Contractor	1	17										
	6											
15 SCHEDULES												
A TURNAROUND SCHEDULE	4		5		6		7					
Days/Week	0		1		6		0					
B PERSONAL SCHEDULES FOR TURNAROUND WORK												
OPERATIONS PERSONNEL	4		5		6		7					
Days/Week	0		0		2		5					
	1		2		3							
Shifts/day	3		2		3							
	8		10		12							
Hours/Shift	0		0		0							
MAINTENANCE PERSONNEL	4		5		6		7					
Days/Week	0		2		6		0					
	1		2		3							
Shifts/day	2		5		1							
	8		10		12							
Hours/Shift	0		0		0							
TECHNICAL PERSONNEL	4		5		6		7					
Days/Week	0		2		4		0					
	1		2		3							
Shifts/day	2		5		0							
	8		10		12							
Hours/Shift	0		0		0							
17 WHAT IS THE RECORDABLE INJURIES PER 200,000 MAN-HOURS DURING:												
	NORMAL OPERATIONS				TURNAROUND							
Operating Company	1 49				1 43							
Contractor	1.66				3 37							
18 WHAT PROVISIONS ARE MADE FOR EMPLOYEE DAYS OFF?	Scheduled One Day Per Week	1	None	1								
	Scheduled Days Off	3	Balance Days or Equivalent Pay	1								
Environmental												
1 To comply with government environmental regulations pertaining to volatile organic compounds (VOC), naturally occurring radioactive materials (NORM) such as radon, carcinogenic chemicals such as benzene and butadiene, and asbestos exposure or other local regulations requires	None	5% or Less	6 10%	11 15%	>15%							
A Increase in Turnaround Manpower	0	4	3	0	0							
	None	1-2 Days	3-5 Days	6 10 Days	>10 Days							
B Increase in Turnaround Time	0	[illegible]	2	0	[illegible]							

	None	<5%	5-10%	11-15%	>15%		
C. Increase in Turnaround Costs (Excluding Lost Production)	0	4	3	0	0		
2. To comply with regulations and internal standards for safe entry of the quench system.	1-2 Days	3-4 Days	5-7 Days	8-10 Days	> 10 Days		
A. Time Required to Comply	1	2	1	3	0		
	AVERAGE PPM	Does Not Apply					
B. What benzene exposure level is allowed by government regulation or internal standard?	2.43	0					
	Steaming	Steaming/Hot Water	Surfactant Wash	Solvent Wash	Purge to Flare	Purge to Atm	Other
C. Methods tried to clear Quench system during last turnaround	7	2	0	2	6	2	0
	Steaming	Steaming/Hot Water	Surfactant Wash	Solvent Wash	Purge to Flare	Purge to Atm	Other
D. Method(s) Selected for use at next Turn	8	2	0	3	5	2	0
3. Regulations limiting fugitive hydrocarbon emissions from valves and	Bubble Test	Tracer Gas	Other	Does Not Apply			
A. How do you monitor for potential emissions while freeing unit of air?	6	1	0	1			
	Don't Confirm	Bubble Test	Tracer Gas	Other	Does Not Apply		
B. How do you shop confirm valve repairs made to meet emission regulations?	1	4	0	1	1		
	Operating Pressur	AVERAGE Nominal Pressure, psig					
C. If you shop test valve repairs, at what pressure?	3	45.67					
	Not Required	Manufacturer Certificate	100% Tested	Random Tested			
D. What monitoring is used for new valves prior to installation in emission regulated service?	0	4	2	2			

Olefins Plant Background Data

1 Plant geographic location		
North America	0	
Europe	0	
Far East/Pacific Rim	5	
Other	3	
total	8	
2 Major Feedstocks		
Ethane	2	
NGL	0	
Naphtha	6	
Mixed Feed	0	
total	8	
3 Plant Capacity		
A. Based on Current Ethylene Capacity		Average Size
< 500MMlb	0	1100
<1000MMLb	4	
<1500MMLb	2	
> 1500MMLb	1	
	8	
B Operating hours per year for current ethylene capacity		
<8000	0	
8000 - 8400	7	
>8400	1	
	0	
4 Plant Vintage	8	
A Original Design		
Earlier than 1965	0	
1966 - 1970	1	
1971 to 1980	2	
1981 to 1990	4	
1990 +	1	
	8	
B Latest Modernization		
1970-1979	0	
1980-1989	0	
1990+	5	
	5	

5 Number of Major Pieces of Equipment

Major Equipment	Major Pieces Per Unit Equipment	Opened for Maint Reasons	Opened for Safety Reasons	AVERAGE Major Pieces Per Unit Equipment	AVERAGE Opened for Maint Reasons	AVERAGE Opened for Safety Reasons
Furnaces	86	47	0	11	12	
Compressors	62	21	0	7	4	
Towers	148	81	1	19	10	1
Exchangers	1441	544	15	180	91	15
Pumps	1034	281	18	129	47	9
Reactors	66	8	0	8	3	
Equipment Total	2477	708	34	413	177	17
Boilers/Superheaters	9	5	1	2	2	1
Other Equipment	382	40	0	121	40	
Total	2818	809	34	563	203	34

6 Other facilities associated with Olefin Plant turnaround

A Auxiliary Units		% of Total Survey
Butadiene Recovery Plant	3	38%
Cogeneration Plant	0	0%
Utility Plant	3	38%
Other	1	13%
B Supporting Units		% of Total Survey
C4 Hydrogenation	4	50%
C5 Hydrogenation	1	13%
First Stage Gasoline Hydrogenation Unit	5	63%
Second Stage Gasoline Hydrogenation Unit	4	50%

Turnaround Definition

	2	3	4	5	Other
1. INTERVAL BETWEEN TURNAROUNDS	5	2	1	0	0
2. MAJOR REASON(s) FOR TURNAROUND INTERVAL (SELECT ONE)		Average Time Between TAR	21		
Mechanical Integrity & Inspections	4				
Business Climate	0				
Safety System Inspection	1				
Predictive Maintenance	0				
Regulatory	2				
Unit Efficiency	0				
Other Facilities	0				
Other	1				
	8				
3. TYPICAL LENGTH OF TURNAROUND DEFINED AS FEED OUT TO FEED IN.		Average Days Down	31		
15 Days or Less	1				
16 - 25 days	0				
26 - 35 days	5				
36 - 45 days	2				
46 - 55 days	0				
56 - 65 days	0				
66+ days	0				
4. ITEMS WHICH TYPICALLY DETERMINE CRITICAL PATH OF TURNAROUND. (SELECT ONE)					
Exchangers	2				
Charge Gas Compressor	4				
Towers	1				
Furnaces	0				
Capital Projects	0				
Refrigeration Compressor	1				
Other	0				
	8				
5. MINI-OUTAGES BETWEEN TURNAROUNDS					
A. Scheduled Between Outages					
Yes	2				
No	6				
B. If YES Length of Mini-outage					
1-2 days	1				
3-4 days	2				
5-7 days	1				
>8 days	0				

Plant Re-Start

	2	3	4	5	Other
1. Typical length of time from introduction of hydrocarbon inventory until cracked gas feed in the charge gas compressor?		Average	42		
<4 hours	2				

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4-8 hours	2	
8 hours to 1day	1	
>1 to 2 days	0	
>2 to 3 days	0	
> 3 to 4 days	1	
>4 to 5 days	2	
>5 days	0	
	8	
2 Typical length of time from cracked gas feed to the charge gas compressor to ethylene product on test?		Average 18
<4 hours	0	
>4 to 8 hours	3	
>8 to 12 hours	2	
>12 to 18hours	1	
>18 to 24 hours	1	
> 24 hours	1	
	8	
3 Do you practice minimal flaring startups by recycling ethylene and/or propylene to the furnaces?		
Yes	3	
No	6	
4 Do you have storage for off test product?		
Ethylene	Ethylene	Propylene
Yes	5	8
No	3	1
Propylene		
Yes	8	
No	1	
5 Would you describe your startup procedures from cold start to ethylene product on test as:		
Limited operator flexibility	4	
Operator flexibility	4	

WORK PRIOR TO TURNAROUND

1 PLANNING PERSONNEL	Preplanning	Primary Coordination		
i Permanent Staff	8	3		
ii Reassigned Staff	1	1		
iii Temporary Staff (Retirees)	0	1		
iv Regular Contractor	0	2		
v Temporary Contractor	1	1		
2 SCHEDULING METHODOLOGY				
A Please list method Used to Plan Turnaround (such as Premivera or Manual)	Premivera	3	CMMS	1
	Manual	1	K&H Plan	1
	Plant	Contractor		
B Who runs and maintains the turnaround schedule?	8	0		
3 TIMING TO PERFORM DETAILED TURNAROUND PLANNING AS CALLED BY YOUR STANDARD PROCEDURES				
i. Continuously	2			
ii Less than 6 months	2			
iii 6 months	1			
iv. 12 months	2			
v. 18 months	1			
vi Greater than 18 months	0			

4 WHAT TURNAROUND PREWORK IS ALLOWED DURING UNIT OPERATION		Limited by		Percent Complete Prior to Unit Shutdown, %				
	Do You Allow	Safety	Operations	100	75	50	25	0
Scaffolding	6	2	4	1	3	2	0	0

Prehung Pipe	5	4	3	1	2	0	1	0
Foundation Work	7	3	4	2	1	0	1	0
Insulation Work	6	2	6	1	0	1	0	1
Equip /Piping	4	4	8	0	0	0	1	1
Inspection	0	0	0	0	0	1	0	0
Hot Work	4	5	2	1	0	0	0	1
Other	0	0	0	0	0	0	0	0

5. What is you peak loading, plant plus contractor, during	Average	Maximum	Minimum	Lowest Quartile	Second Quartile	Third Quartile	Highest Quartile
Day shift workers	887.4	2000	290	600	647	900	2000
Night shift workers	196	600	0	120	160	200	500

6. What percent of the turnaround plant maintenance cost is:							
Plant Maintenance	56	90	10	51	60	70	80
Contractor Lump Sum	28	40	10	30	30	30	40
Contractor Cost Plus	30	90	10	10	10	30	90

Maintenance Work During Turnaround

% Responding

1. Rotating Equipment Do You open the ca	TA	2nd TA	3rd TA	Other	Number of Responses	Frequency Years	1. Rotating Equipment Do You open the case every	TA	2nd TA	3rd TA	Other
Cracked Gas	4	2	0	2	8	5.25	Cracked Gas	50%	25%	0%	25%
Propylene	2	3	1	1	7	5.71	Propylene	29%	43%	14%	14%
Ethylene	2	3	1	1	7	5.71	Ethylene	29%	43%	14%	14%
Methane	2	1	1	1	5	5.80	Methane	40%	20%	20%	20%
Steam Turbine	2	3	2	2	9	8.22	Steam Turbine	22%	33%	22%	22%
Gas Turbine	2	1	0	0	3	2.67	Gas Turbine	67%	33%	0%	0%
Motor	1	1	2	2	6	7.00	Motor	17%	17%	33%	33%

2. Feed Chilling

A. Frequency Opened	TA	2nd TA	3rd TA	Never
	2	0	0	6

B. Reason	Yes	% who said yes
Maintenance	0	0%
Preventive/Operability	3	100%
Safety Inspection	3	100%
NOx Cleaning	0	0%

	Average # Years
C. Cold Box NOx Cleaning Frequency	#DIV/0!

D. History of Cold Box	Yes	No
Corrosion	0	7
Failure	2	6

3. Exchangers: Routine Work	Clean Process Side	Clean Utility Side	Tube Repair	VOC Repair	Insulation Work	Inspection	Cathodic Protection	None
Quench Oil	7	4	2	0	3	8	0	0
Quench Water	6	5	2	0	3	8	0	1
Cooling Water - Quench System	3	7	2	0	2	8	0	0
Cooling Water - CGC Train	5	7	3	0	1	6	1	0
Cooling Water - Surface Condensers	1	6	3	0	1	6	2	0
Cooling Water - Propylene System	0	6	3	0	1	5	2	0
Cooling Water - C3E System	0	5	2	0	2	4	1	1
Cooling Water - C2E System	0	5	2	0	2	4	1	1
Refrigeration	1	4	2	0	1	4	1	1
Feed Chilling	0	2	1	0	1	3	1	2
Brazed Aluminum	0	0	0	0	0	1	0	4
Dilution Steam Generation	6	3	3	0	2	3	0	0
Furnace Quench	6	0	0	0	1	4	0	0
Furnace Secondary TLE	3	0	0	0	1	2	0	0

3. Exchangers: Routine Work	Clean Process Side	Clean Utility Side	Tube Repair	VOC Repair	Insulation Work	Inspection	Cathodic Protection	None
Quench Oil	64%	50%	25%	0%	38%	73%	0%	0%
Quench Water	76%	88%	25%	0%	88%	76%	0%	11%
Cooling Water - Quench System	38%	88%	25%	0%	25%	78%	0%	0%
Cooling Water - CGC Train	63%	63%	38%	0%	13%	75%	13%	0%
Cooling Water - Surface Condensers	13%	75%	38%	0%	13%	63%	38%	0%
Cooling Water - Propylene System	0%	78%	38%	0%	13%	63%	25%	0%
Cooling Water - C3E System	0%	63%	25%	0%	25%	50%	13%	13%
Cooling Water - C2E System	0%	63%	25%	0%	25%	50%	13%	13%
Refrigeration	13%	50%	25%	0%	13%	50%	13%	13%
Feed Chilling	0%	25%	13%	0%	13%	38%	13%	25%
Brazed Aluminum	0%	0%	0%	0%	0%	13%	0%	50%
Dilution Steam Generation	75%	38%	38%	0%	25%	38%	0%	0%
Furnace Quench	83%	0%	0%	0%	13%	50%	0%	0%
Furnace Secondary TLE	38%	0%	0%	0%	13%	25%	0%	0%

% responses — Frequency Entered; % doing work — Work Performed

4. Are spare exchangers scheduled for work during TA	Yes	No
	2	6

5. Maintenance on Towers — Frequency Entered | Work Performed | No Response | Frequenc

	Every TA	Every 2 TAs	Every 3 TAs	As Required	Tower Inspection	Tower Cleaning	Other Tower Work			Every TA	Every 2 TAs	Every 3 TAs	As Required	Inspection	Cleaning	Other Work	Years
Demethanizer	0	1	0	6	5	2	0	1		0%	14%	0%	86%	71%	29%	0%	8.57
Deethanizer	4	0	0	3	6	4	0	1		57%	0%	0%	43%	86%	57%	0%	5.43
C2 Splitter	0	1	0	6	6	2	0	1		0%	14%	0%	86%	86%	29%	0%	8.57
Depropanizer	6	0	0	1	4	7	0	1		86%	0%	0%	14%	57%	100%	0%	3.71
C3 Splitter	1	1	0	5	6	2	0	1		14%	14%	0%	71%	86%	29%	0%	7.71
Debutanizer	4	0	0	2	3	6	0	2		67%	0%	0%	33%	50%	100%	0%	4.67
Quench Oil Tower	5	0	0	2	5	6	0	1		71%	0%	0%	29%	71%	86%	0%	4.57
Quench Water Tower	6	0	0	2	5	6	0	0		75%	0%	0%	25%	63%	75%	0%	4.38
Caustic Tower	7	0	0	1	5	6	0	0		88%	0%	0%	13%	63%	75%	0%	3.63
Amine Tower	2	0	0	1	1	2	0	5		67%	0%	0%	33%	33%	67%	0%	4.00
Process Condensate Stripper	6	0	0	1	4	4	1	1		86%	0%	0%	14%	57%	57%	14%	3.71
Gasoline Stripper	6	0	0	1	4	7	0	1		86%	0%	0%	14%	57%	100%	0%	3.71
Fuel Oil Stripper	6	0	0	1	4	7	0	1		86%	0%	0%	14%	57%	100%	0%	3.71
Process Water Stripper	6	0	0	1	5	6	0	1		86%	0%	0%	14%	71%	86%	0%	3.71
6 Safety Systems																	
A Relief Valves	Yes	Yes, Some	No														
Are valves inspected & tested prior	3	0	4														
valves under	2	5	1														
valves on discharge	1	5	2														
							% of yes and yes some										
iv How do you ensure isolation valve on relief valve is open	Administrative	Lock & Chain	Keyed Valve	Special Blind	Other		Administrative	Lock & Chain	Keyed Va	Special Blind	Other						
	2	4	3	0	1		29%	57%	43%	0%	14%						
	Yes	Yes, Some	No														
v Do you allow three way valves	0	0	8														
vi Do you have spare relief valves	3	0	5														
	Average																
vii What is test frequency	20	Data Meaningless use 1 to 5 years															
				% total Survey													
viii What type of RV testing is done	Shop Testing	on-line Testing		Shop Testing	on-line Testing												
	8	1		100%	13%												
								% of Total Survey									
ix Who performs field inspection	Production	Maintenance	Technical	Contractor	Safety	Other		Production	Maintena	Technical	Contractor	Safety	Other				
	6	5	0	1	0	1		75%	63%	0%	13%	0%	13%				
x Do you maintain spare pool	Yes	No															
	4	4															
8 Flare System Maintenance																	
i Type of Flare	Elevated	Ground	Both														
	4	0	4														
ii Elevated Flare Work						% Using											
a Timing for work on flare tip	Every TA	2nd TA	3rd TA	As Required		Every TA	2nd TA	3rd TA	As Required								
	6	0	1	1	Elevated	75%	0%	13%	13%								
					Ground	50%	0%	0%	50%								
b Work performed	Replace w/ New T	Replace w/Spare	Refurbish	As Required		Replace w/ New T	Replace w/Spar	Refurbish	As Required								
	0	0	0	7		0%	0%	0%	100%								
iii Ground Flare																	
a Timing for work on ground flare	Every TA	2nd TA	3rd TA	As Required													
	2	0	0	2													
					% of Number with Ground Flare												
b Work Performed	Replace Insulation	Replace Burner	Replace Pilot		Replace Insulation	Replace Burner	Replace Pilot										
	1	4	3		25%	100%	75%										
iv Flare Line Seal Drum Work																	
a Timing for work on Seal Drum	Every TA	Every 2nd TA	3rd TA	As Required													
	6	0	0	0													
b Work Performed	Inspect/Repair	Replace															
	8	0															
	Average																
v Pilot Thermocouples																	
Number Available	4.6																
Number Replaced	3.7																
Replaced Due to Failure	0.4																
Replaced as Preventive Maintenance	3.3																
7 Mechanical Integrity	Yes	No															
A Are you mandated to hydrostatic test	5	3															
							% Mandated to Hydro										
B What equipment must have hydrotest	Pressure Vessel Hot	Piping Hot	Pressure Vessel Cold	Piping Cold	Other		Pressure Vessel	Piping Hot	Pressure	Piping Cold	Other						
	2	1	1	0	1		40%	20%	20%	0%	20%						

minimum or maximum temp	Can't some the data it is too meaningless								
C. Frequency of Hydrotest yrs AVERAGE	4.333333333	5.00	5.00	5.00	6.00				
						Inspection Methods Sorted by Hand			
D What method is used to evaluate mechanical integ	Have to sort by hand					Visual	17		
						x-ray	15		
8 Miscellaneous Maintenance Work						Ultra-Sonic	15		
A Charge Gas Dryer Desiccant			Average			Pneumatic	10		
1. Change Out	Between TA	During TA	Frequency			Die Penetrant	8		
	3	5	3.7			Mag. Particle	7		
						Eddy Current	4		
2 Reason for Changeout	Performance	Scheduled				Acoustical	3		
	6	1				On-line Corosome	1		
						Metalography	1		
B Acetylene Reactor Catalyst			Average			Comparative Serv	1		
1. Change Out	Between TA	During TA	Frequency						
	7	2	6.2		Between TA	During TA	Frequency		
				Charge Gas Dryer	38%	63%	3.7		
2. Reason for Changeout	Performance	Scheduled		Acetylene Reactor	78%	22%	8.2		
	8	0							
C Demister Pad or Vane Separator Work P	Demister			Vane Separator					
	Clean	Replace	No Work	Clean	Replace	No Work			
CGC Drums	5	1	1	1	0	1			
Caustic Tower	3	3	1	2	0	0			
Quench Tower	1	1	1	2	0	0			
D Inspect piping in following areas	Between TA	During TA	Frequency	As Required					
Sweating service	4	2	4.7	1					
Caustic service	2	3	1.5	0					
Amine service	2	1		0					
Other									
						% of Total Survey			
9 Personnel used for turnaround maintenance work	Supervising Personnel		Work Performed by			Supervising Personnel		Work Performed by	
	Plant Personnel	Contractor	Plant Personnel	Contractor		Plant Personnel	Contractor	Plant Personnel	Contractor
Quality Assurance	7	1	4	4	Quality Assurance	88%	13%	50%	50%
Safety	8	1	6	3	Safety	100%	13%	75%	38%
Furnace Area	8	0	5	4	Furnace Area	100%	0%	63%	50%
Compressors	7	2	3	7	Compressors	88%	25%	38%	88%
Towers	8	0	2	7	Towers	100%	0%	25%	88%
Exchangers	8	0	2	6	Exchangers	100%	0%	25%	75%
Vessels	8	0	3	5	Vessels	100%	0%	38%	63%
Inst. & Elect	8	0	4	6	Inst. & Elect	100%	0%	50%	75%
Inspection	8	0	3	5	Inspection	100%	0%	38%	63%
Pipe/Pipe Valves	8	0	3	5	Pipe/Pipe Valves	100%	0%	38%	63%
Paint & Insulation	8	0	2	6	Paint & Insulation	100%	0%	25%	75%
Scaffold	7	1	1	7	Scaffold	88%	13%	13%	88%
Hydroblasting	8	0	1	7	Hydroblasting	100%	0%	13%	88%
Civil Work	8	0	1	7	Civil Work	100%	0%	13%	88%
Valve Maint	7	0	3	5	Valve Maint	88%	0%	38%	63%
Machinist	7	1	4	5	Machinist	88%	13%	50%	63%
SAFETY	Yes		No						
1. DO YOU ALLOW MAINTENANCE AND/OR CONSTRUCTION PERSONNEL ON THE UNIT DURING THE INITIAL UNIT HYDROCARBON CLEARING	2		5						
	Yes		No						
2. DO YOU ALLOW MAINTENANCE AND/OR CONSTRUCTION PERSONNEL ON SECTIONS OF THE UNIT THAT HAVE BEEN CLEARED OF HYDROCARBONS WHILE STILL CLEARING THE BALANCE OF THE UNIT	5		3						
	Yes		No		Specific Locations Only				
3. DO YOU REQUIRE FIRE RETARDANT CLOTHING ON THE UNIT DURING NORMAL OPERATIONS?	3		4						

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	Yes		No		Specific Locations Only
4. DO YOU REQUIRE FIRE RETARDANT CLOTHING ON THE UNIT AFTER HYDROCARBON FREE?	1		5		

5. HOW MANY SAFETY AUDITS ARE PERFORMED DURING THE TURNAROUND?	Average
Number Audits/day/100 workers	4.83

	Ratio - Average
6. WHAT IS THE RATIO OF SAFETY INSPECTORS (COMBINED PLANT AND CONTRACTOR) TO 100 WORKERS	1.38

	Yes		No
7. DO YOU USE PLANT PERSONNEL OTHER THAN SAFETY PERSONNEL TO PERFORM SAFETY INSPECTIONS DURING TURNAROUNDS?	8		2

8. HOW MANY HOURS OF SAFETY TRAINING ARE REQUIRED FOR CONTRACTORS PRIOR TO WORKING ON THE UNIT	AVERAGE
Total Hours	9.86
General Training Hours:	6.57
Site Specific Training Hours:	6.00

	Once/ Shift		Daily		Weekly		Other
9. HOW OFTEN ARE SAFETY MEETINGS CONDUCTED?	3		4		1		0

	5-10 minutes		10-15 minutes		15-30 minutes		Longer
10. THE LENGTH OF THE SAFETY MEETING?	0		6		1		1

11. PERMITTING AFTER THE UNIT IS HYDROCARBON FREE.	
Blanket Permit	1
Job Specific	4
Hot Work Permit Required	6

12. RESPONSIBILITY FOR ISSUING THE PERMITS.	Write		Approve		Close
Maintenance, In House	4		1		3
Contractor	2		0		0
Operations	4		8		7

13. LOCKOUT/TAGOUT PROCEDURES:	During Hydrocarbon Freeing Yes			After Hydrocarbon Freeing Yes		
LOCK PHILOSOPHY	Yes		No	Yes		No
Battery Lock	5		3			
System Lock	5		3			
Personal Lock	6		2			
Tag	7		1			

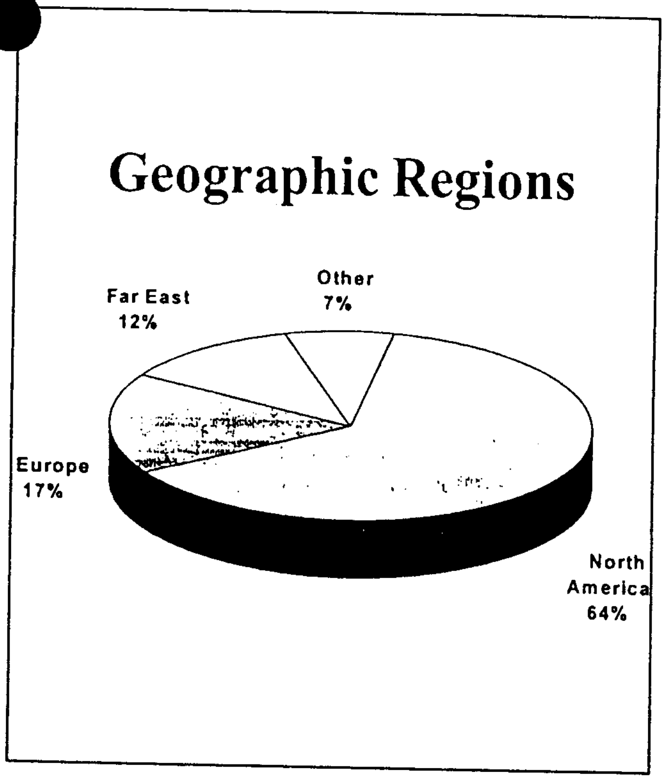
DURING HYDROCARBON FREEING						
Primary Responsibility	Operations			Maintenance		
Area to be Locked	Process	Elect	Mech	Process	Elect	Mech
Battery Lock	5	1	2	2	1	1
System Lock	5	2	3	2	1	1
Personal Lock	5	2	3	3	4	2
Tag	5	2	2	2	[illegible]	1

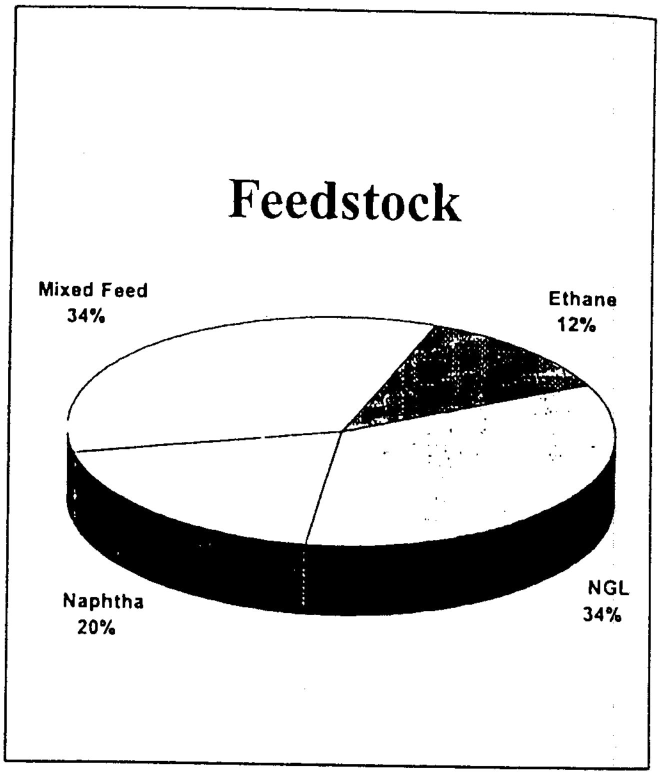
	Operations: Process		Operations: Elect.	Operations: Mech.		Maintenance: Process	Maintenance: Elect.	Maintenance: Mech.	
	20		7	10	37	9	7	5	21
AFTER HYDROCARBON FREEING									
Primary Responsibility	Operations					Maintenance			
Area to be Locked:	Process		Elect.	Mech.		Process	Elect.	Mech.	
Battery Lock	5		1	1		3	1	1	
System Lock	4		2	2		3	1	1	
Personal Lock	5		2	2		4	2	3	
Tag	5		2	2	Operations	2	1	1	Maintenance
	19		7	7	33	12	5	6	23
14. WHO TRACKS THE BLIND INSTALLATION AND REMOVAL DURING THE UNIT TURNAROUND?									
Plant Operations	8	89%							
Plant Maintenance	1	11%							
Contractor	0	0%							
	9								
15. SCHEDULES									
A. TURNAROUND SCHEDULE	4		6	6		7			
Days/Week	0		0	1		7			
B. PERSONAL SCHEDULES FOR TURNAROUND WORK									
OPERATIONS PERSONNEL	4		5	6		7			
Days/Week	0		0	3		5			
	1		2	3					
Shifts/day	3		0	5					
	8		10	12					
Hours/Shift	0		0	0					
MAINTENANCE PERSONNEL	4		5	6		7			
Days/Week	0		0	2		6			
	1		2	3					
Shifts/day	1		2	4					
	8		10	12					
Hours/Shift	0		0	0					
TECHNICAL PERSONNEL	4		5	6		7			
Days/Week	0		0	3		4			
	1		2	3					
Shifts/day	1		2	3					
	8		10	12					
Hours/Shift	0		0	0					
17. WHAT IS THE RECORDABLE INJURIES PER 200,000 MAN HOURS DURING:	NORMAL OPERATIONS			TURNAROUND					
Operating Company	2.70			2.15					
Contractor	0.78			4.45					
18. WHAT PROVISIONS ARE MADE FOR EMPLOYEE DAYS-OFF?	One Day Per Week	1							
	Not Scheduled	1							
	Scheduled	2							
Environmental									

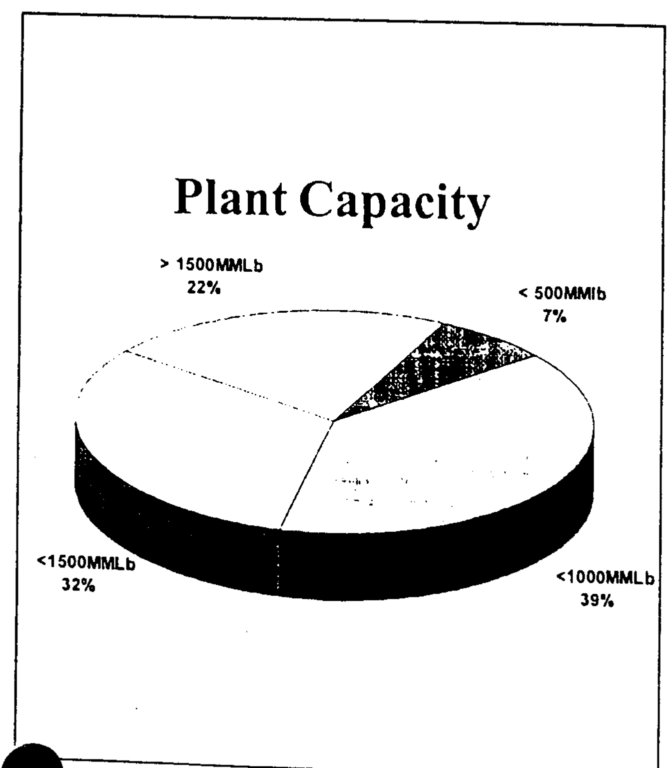
Attachment D Page 8 of 9

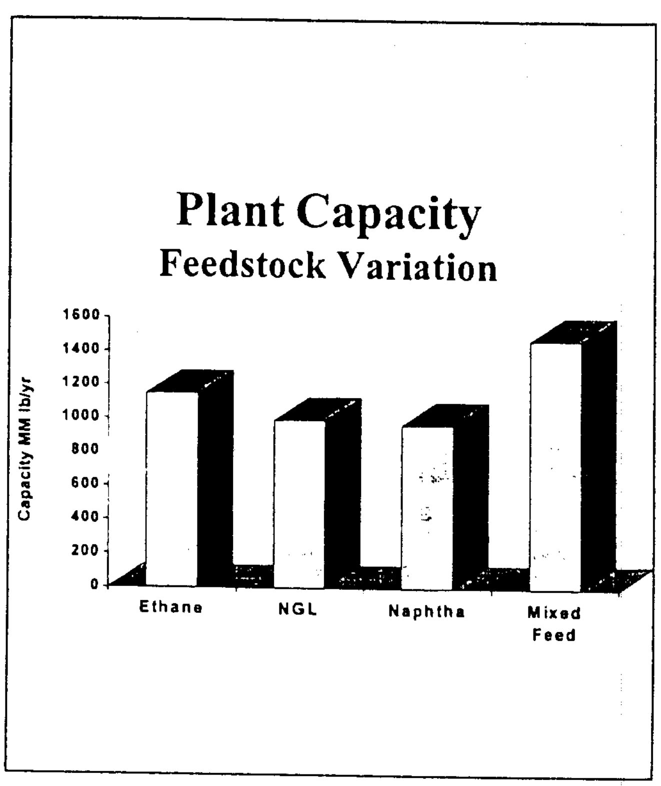
Attachment D: 1997 Turnaround Survey: *Far East, Pacific Rim, Others*

1. To comply with government environmental regulations pertaining to volatile organic compounds (VOC), naturally occurring radioactive materials (NORM) such as radon, carcinogenic chemicals such as benzene and butadiene and asbestos exposure or other local regulations requires	None	5% or Less	8-10%	11-15%	>15%		
A Increase in Turnaround Manpower	2	0	3	0	0		
	None	1-2 Days	3-5 Days	6-10 Days	>10 Days		
B Increase in Turnaround Time	1	1	3	0	0		
	None	<5%	5-10%	11-15%	>15%		
C Increase in Turnaround Costs (Excluding Lost Production)	0	1	3	0	0		
2 To comply with regulations and internal standards for safe entry of the quench system	1-2 Days	3-4 Days	5-7 Days	8-10 Days	> 10 Days		
A Time Required to Comply	1	2	4	0	0		
	AVERAGE PPM	Does Not Apply					
B What benzene exposure level is allowed by government regulation or internal standard?	3.8	1					
	Steaming	Steaming/Hot Water	Surfactant Wash	Solvent Wash	Purge to Flare	Purge to Atm	Other
C Methods tried to clear Quench system during last turnaround	8	1	0	1	3	0	3
	Steaming	Steaming/Hot Water	Surfactant Wash	Solvent Wash	Purge to Flare	Purge to Atm	Other
D Method(s) Selected for use at next Turnaround	8	1	0	1	3	0	3
3 Regulations limiting fugitive hydrocarbon emissions from valves and	Bubble Test	Tracer Gas	Other	Does Not Apply			
A How do you monitor for potential emissions while freeing unit of air?	4	1	0	2			
	Don't Confirm	Bubble Test	Tracer Gas	Other	Does Not Apply		
B How do you shop confirm valve repairs made to meet emission regulations?	0	5	0	0	2		
	AVERAGE Operating Pressur	Nominal Pressure, psig					
C If you shop test valve repairs, at what pressure?	4	#DIV/0!					
	Not Required	Manufacturer Certificate	100% Tested	Random Tested			
D What monitoring is used for new valves prior to installation in emission regulated service?	1	4	2	0			

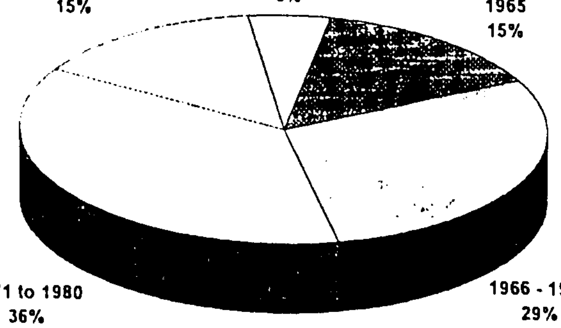

Geographic Regions
Other
7%
Far East
12%
Europe
17%
North
America
64%


Feedstock
Mixed Feed
34%
Ethane
12%
Naphtha
20%
NGL
34%

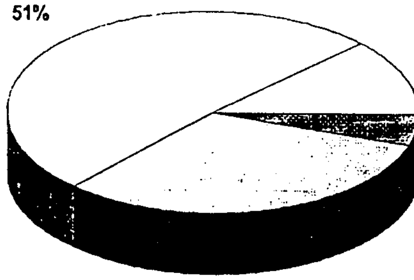

Plant Capacity
> 1500MMLb
22%
< 500MMlb
7%
<1500MMLb
32%
<1000MMLb
39%


Plant Capacity
Feedstock Variation
Capacity MM lb/yr
1600
1400
1200
1000
800
600
400
200
0
Ethane
NGL
Naphtha
Mixed
Feed

Plant Original Design



Plant Modernization



Equipment Quantity

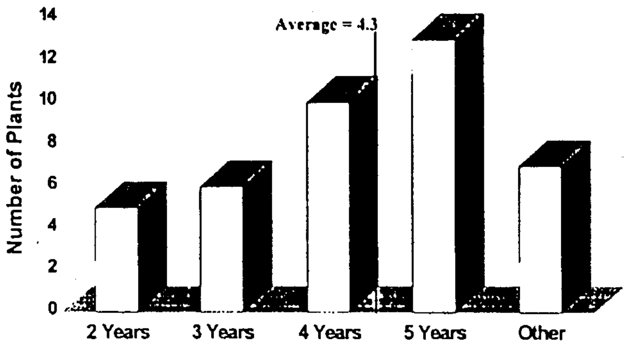
✦ Furnaces	12	✦ Exchangers	189
✦ Compressors	8	✦ Pumps	173
✦ Towers	22	✦ Boilers/ Superheaters	4
✦ Reactors	6	✦ Other	70

Total 484

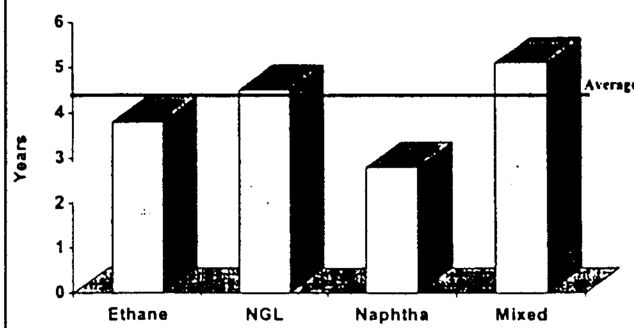
Total Equipment
by Feedstock

✦ Ethane	245
✦ Natural Gas Liquid	300
✦ Naphtha	565
✦ Mixed Feed	597

Time Between Turnarounds



Time Between Turnarounds
Feedstock Comparison



Reason for Turnaround

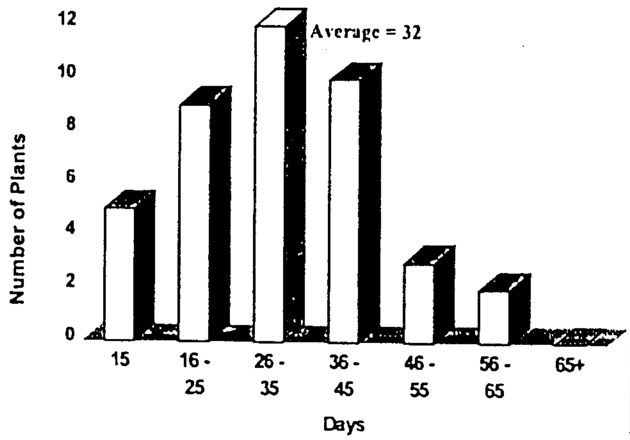
✦ Mechanical Integrity Inspection	57%
✦ Government Regulation	20%
✦ Unit Efficiency	12%
✦ Preventative Maintenance	9%

Reason for Turnaround
Government Regulation

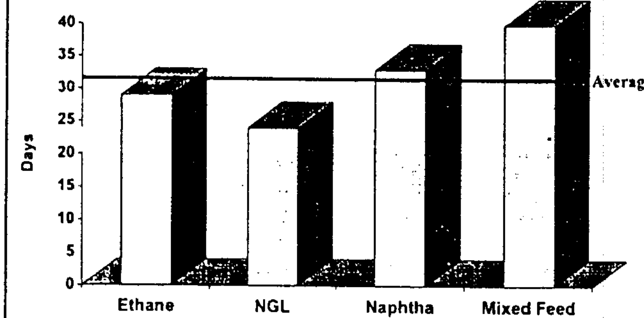
<u>It is a Regional Issue</u>

✦ Far East/ Other	25%$^{+}$
✦ Europe	60%
✦ North America	None

Turnaround Duration



Turnaround Duration
Feedstock Impact



Turnaround Duration
Run Length Impact

✦ Longer than 5 Years	41 Days
✦ Less than 5 Years	27 Days

✦ One Plant Runs Longer than 5 Years with less than a 15 Day Turnaround Duration

Turnaround Critical Path

✦ Charge Gas Compressor	47%
✦ Refrigeration Compressor	13%
✦ Towers	13%
✦ Capital Projects	11%

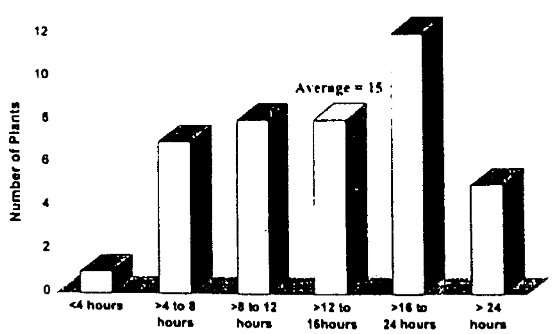
Turnaround Critical Path
Items that Impact

- ✦ Longer than 5 Year Run
  - Capital Projects 40%
  - Charge Gas Compressor 40%
- ✦ Less than 15 Day Duration
  - Charge Gas Compressor 33%
  - Towers or Exchangers 33%
  - Other 33%

Scheduled Mini-Outage

- ✦ 22% Of the Survey Uses
- ✦ Average Duration - 4 Days
- ✦ Longer than 5 Year Run - No Increased Use
- ✦ < 15 Day Duration - 40% Use

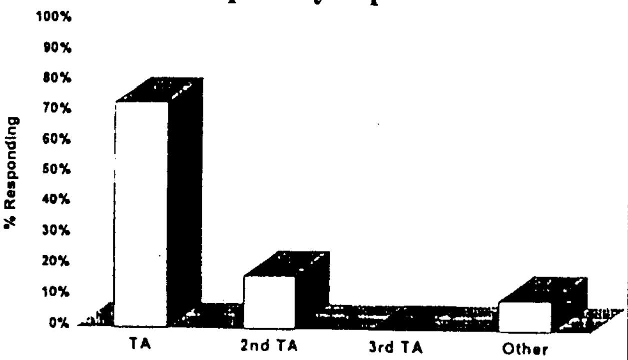
Plant Re-Start Time



Summary

- ✦ Survey has Good Cross Section of Plants
- ✦ Run Time Average - 4.3 Years
- ✦ Turnaround Reason - Mechanical Integrity
- ✦ Average Duration - 32 Days

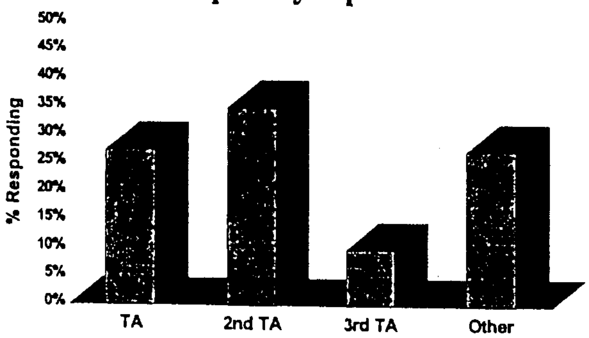
Charge Gas Compressor
Frequency Opened



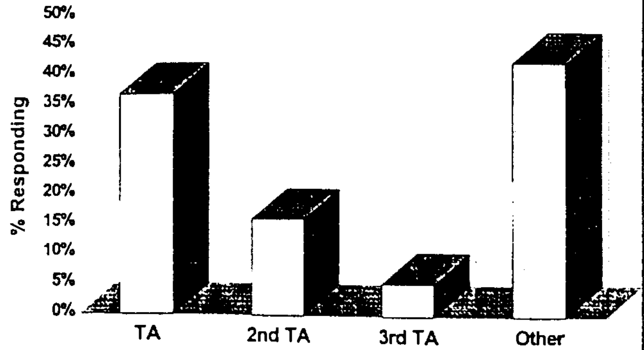
Charge Gas Compressor
Observations

- ✦ No Major Regional Differences
- ✦ No Major Feedstock Differences
- ✦ No Difference in Plants Run Time
- ✦ Average Time Between Opening 6 Years

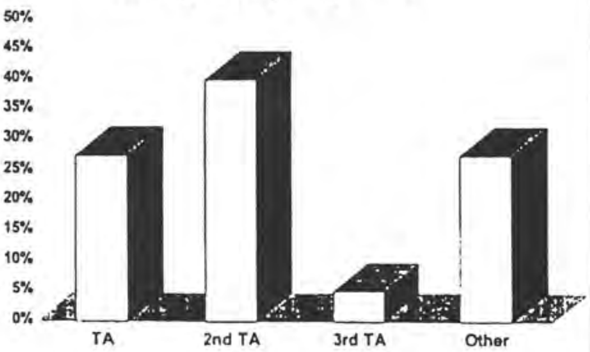
Ethylene Compressor
Frequency Opened



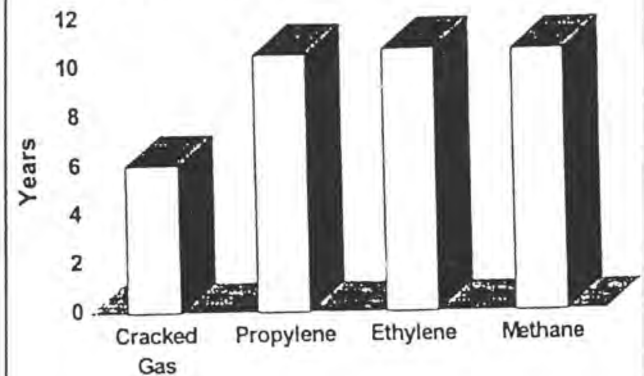
Methane Compressor
Frequency Opened



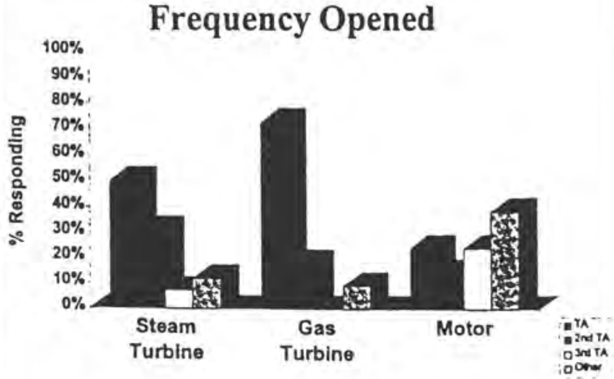
Propylene Compressor
Frequency Opened



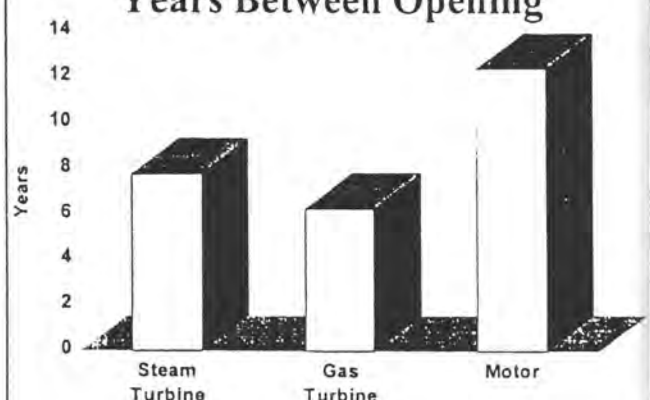
Refrigeration Compressors
Years Between Opening



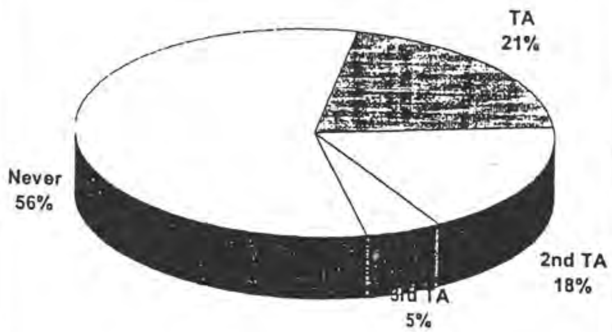
Compressor Driver
Frequency Opened



Compressor Driver
Years Between Opening



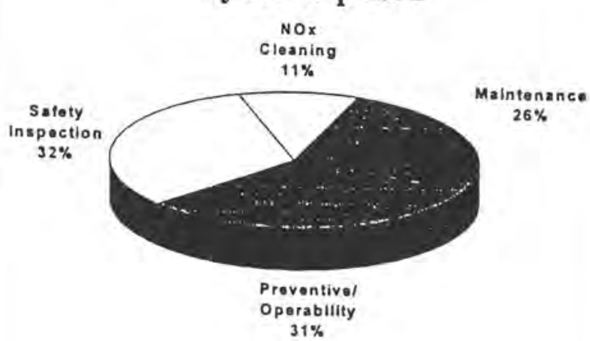
Feed Chilling
Frequency Opened



Feed Chilling
Observations

- ✦ Europe and Far East/ Other Open The Least
- ✦ Feedstock Does Not Affect Opening
- ✦ Age Does Not Affect Opening
- ✦ <15 Day Turnaround Duration - Don't Open

Feed Chilling
Why it is Opened



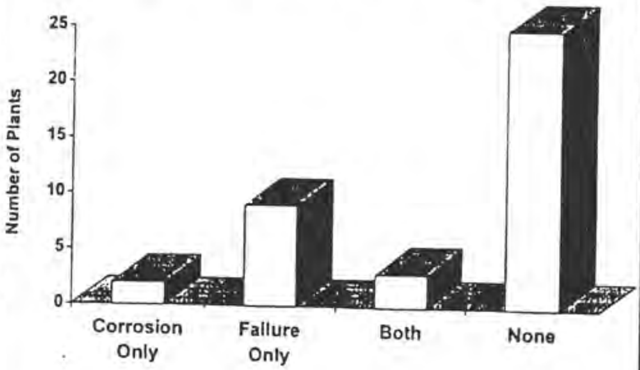
Feed Chilling
NO_x Issues

✦ Cleaning Increases with Heavier Feed

* Ethane	None
* NGL	33%
* Naphtha	None
* Mixed Feed	33%

✦ Only North American Plants Clean

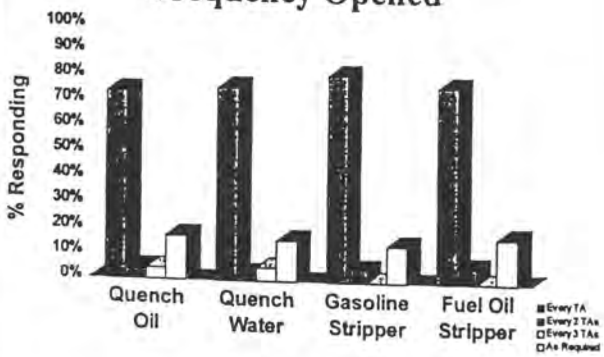
Feed Chilling
Mechanical History



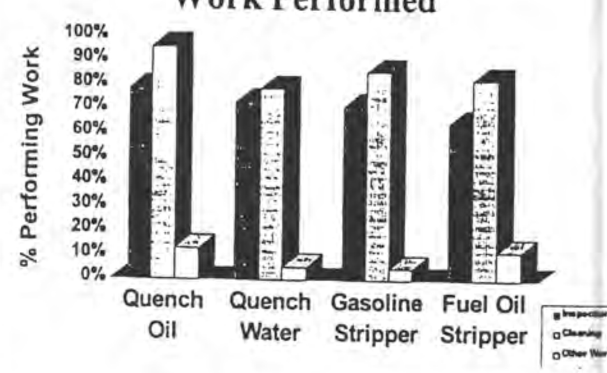
Feed Chilling
Mechanical History

- All Failures in Pre - 1980 Plants
- More Failures in Mixed Feed and NGL Plants
- All Feed Types Report at Least One Failure
- All Regions Report at Least One Failure

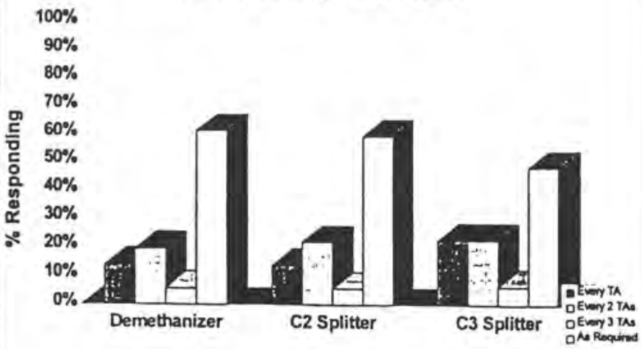
Quench Area Towers
Frequency Opened



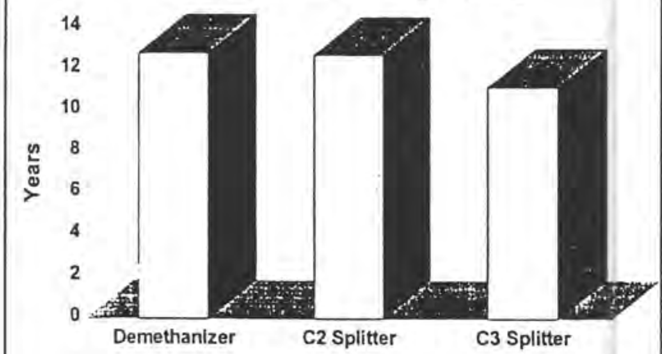
Quench Area Towers
Work Performed



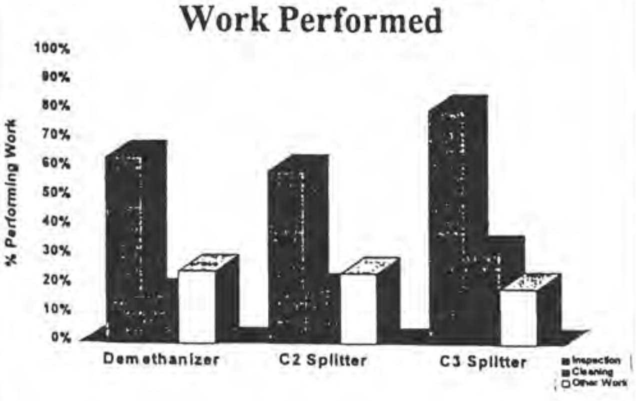
Clean Distillation Towers
Frequency Opened



Clean Distillation Towers
Years Between Opening



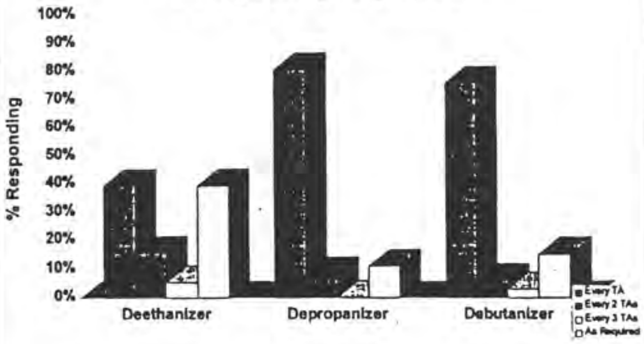
Clean Distillation Towers
Work Performed



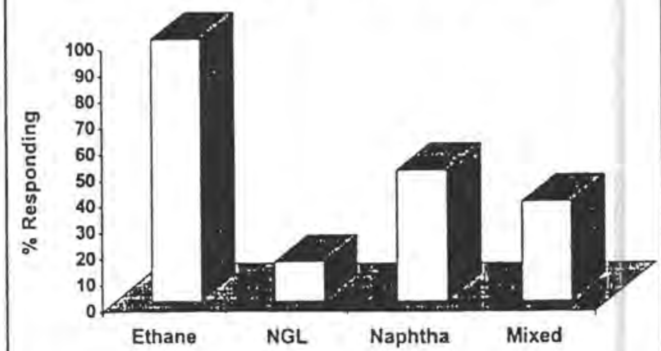
Clean Distillation Towers
Observations

- Far East/ Other Open Only As Needed
- <15 Day Duration Open Only As Needed
- >5 Year Run More Likely to Open Every Turnaround

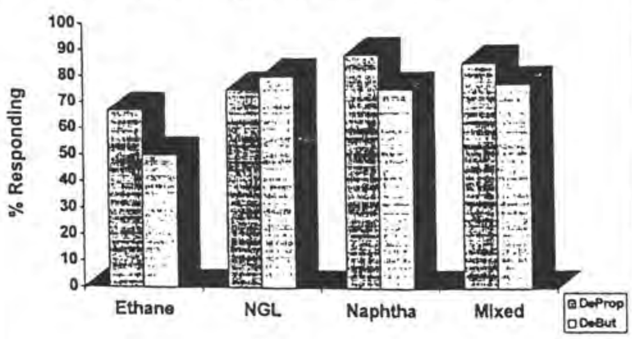
Dirty Distillation Towers
Frequency Opened



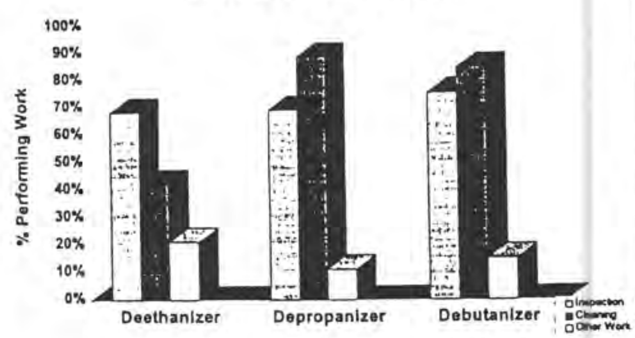
Deethanizer Tower
Frequency Opened by Feed



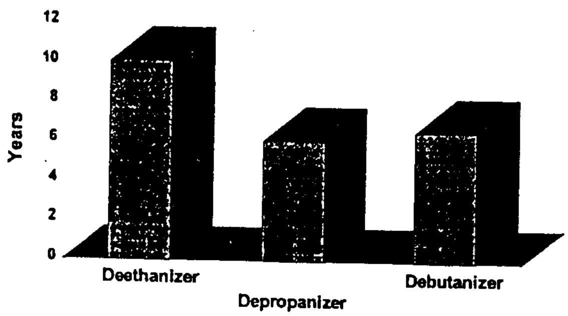
Depropanizer & Debutanizer
Frequency Opened by Feed



Dirty Distillation Towers
Work Performed



Dirty Distillation Towers
Years Between Opening



Quench Area Exchangers

- ✦ Process Side Cleaning
  - –Quench Oil - 78%
  - –Quench Water - 54%
- ✦ Utility Side Cleaning - 50%
- ✦ Inspection - 60%
- ✦ No Work
  - –Quench Oil - 22%
  - –Quench Water - 12%

Cooling Water Exchangers

- ✦ Quench Exchangers
- ✦ Charge Gas Coolers
- ✦ Surface Condensers
- ✦ Propylene Coolers
- ✦ Refrigeration Desuperheaters

Cooling Water Exchangers
Cleaning

- ✦ Most Plants Clean Cooling Water Side
  - –85% for Charge Gas Cooler
  - –73% for Surface Condensers
  - –60% for the Rest
- ✦ Most Plants Clean Dirty Service Process Side
  - –46% for Quench Exchangers
  - –61% for Charge Gas Coolers
  - –15% or Less for the Rest

Cooling Water Exchangers
Other Maintenance

- Tube Repairs
  - Charge Gas Exchangers 34%
  - Surface Condensers 29%
- Cathodic Protection 18%
- Inspection 60%

Cold Service Exchangers

- Refrigeration Exchangers
- Feed Chilling Exchangers
- Brazed Aluminum Exchangers

Cold Service Exchangers
Work Performed

- No Work
  - Shell & Tube Exchangers 25%
  - Brazed Aluminum 40%
- Inspection
  - Shell & Tube Exchangers 40%
  - Brazed Aluminum 25%
- Clean Utility Side of S&T Exchangers 20%
- Tube Repairs 15%

Spare Exchanger Work

73% Do Not Work Spare Exchangers During Turnaround

Exchanger Work
Turnaround Duration <15 Days

- Clean Dirty Exchangers
- Clean Cooling Water Exchangers
- No Cold Exchanger Work
- Limited Inspections
- No Spare Exchanger Work

Exchanger Work
Run Time > 5 Years

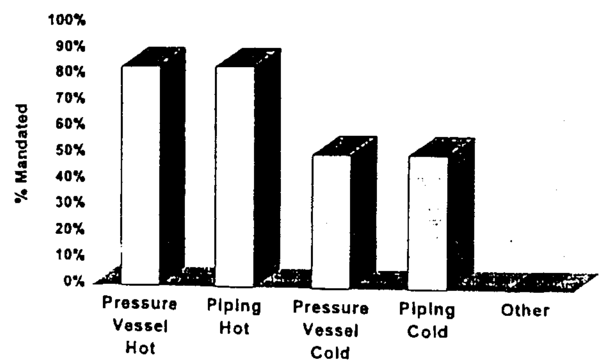
- Clean Dirty Service Exchangers
- Clean Cooling Water Exchangers
- Increase in Tube Repairs
- Increase in VOC Repairs
- Increase in Cathodic Protection

Government Mandated Hydrotest

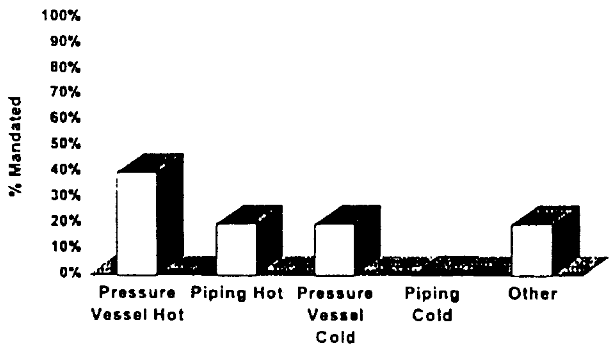
<u>Required by Region</u>

✦ Europe	86%
✦ Far East/ Other	62%
✦ North America	None

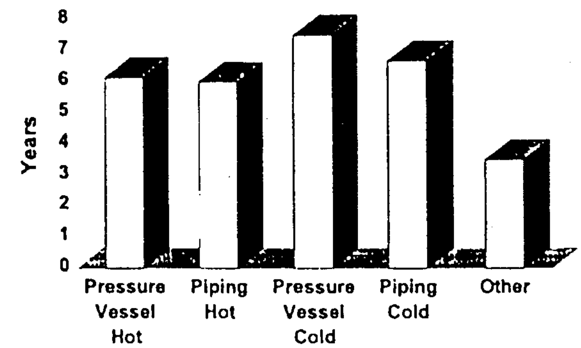
Government Mandated Hydrotest
Europe Requirements



Government Mandated Hydrotest
Far East/ Other Requirements



Government Mandated Hydrotest
Frequency



Mechanical Integrity
Other Inspection Methods Used

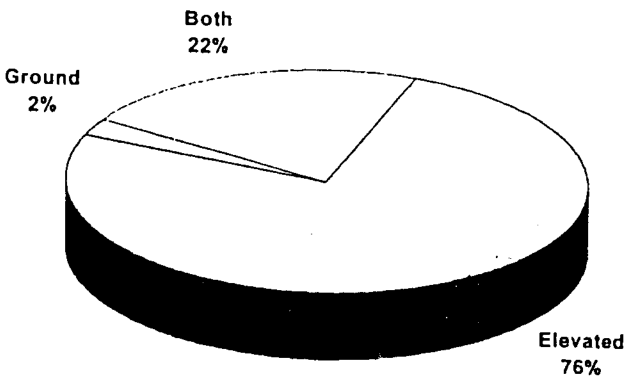
✦ Visual	21%
✦ x - ray	18%
✦ Ultra Sonic	18%
✦ Pneumatic	12%
✦ Dye Penetrant	10%

Mechanical Integrity
Pipe Inspection

Sweating, Caustic & Amine Pipe Considered

- Half Inspect Between Turnaround
- Half Inspect During Turnaround
- Average Frequency - Every Five Years

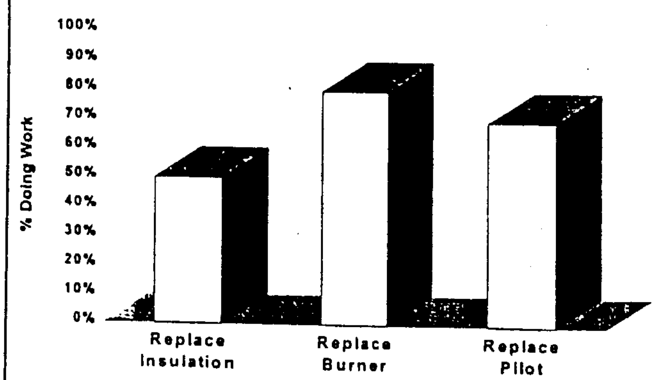
Flare Types Used



Elevated Flare Maintenance

- Most Plants Repair Only As Required
- Some Install a New Tip Every Turnaround
  - Highest for Plants with >5 Year Run
- Most Pilot Thermocouples Replaced
  - 1/2 Burned Out
  - 1/2 Preventative Maintenance

Ground Flare Maintenance



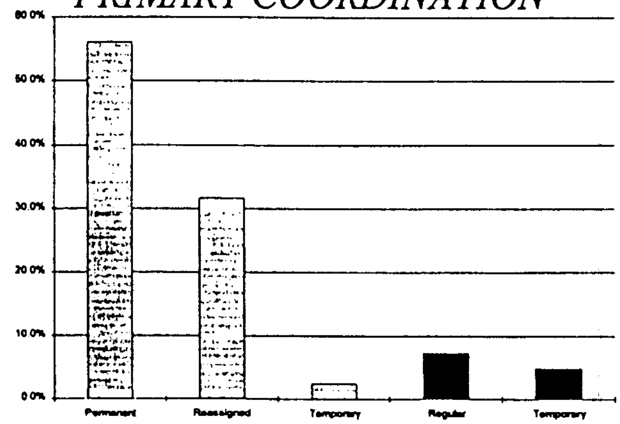
Maintenance Summary

- Dirty Service Equipment
  - Opened Frequently 6 Years
  - Cleaning and Inspection
- Clean Service Equipment
  - Opened Infrequently 12^{+} Years
  - Inspection
- Feed Chilling
  - Most Don't Open
  - Some Failures in Older Plants

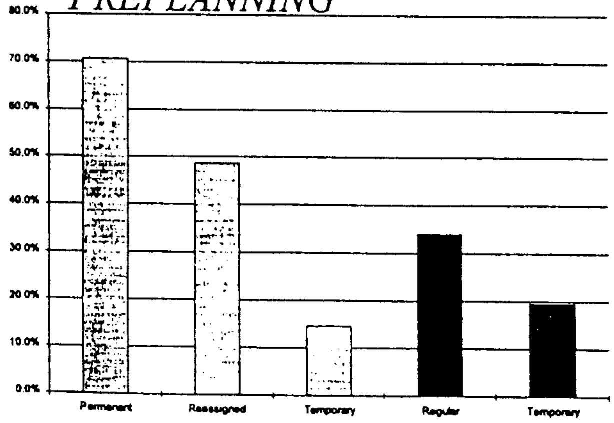
Maintenance Summary

- Longer than 5 Year Run
  - More Equipment Opened Every Turnaround
  - Dirty Service Work Same as Average
  - More Repairs
- Less than 15 Day Duration
  - Dirty Service Work Same as Average
  - Very Little Cold Service Work

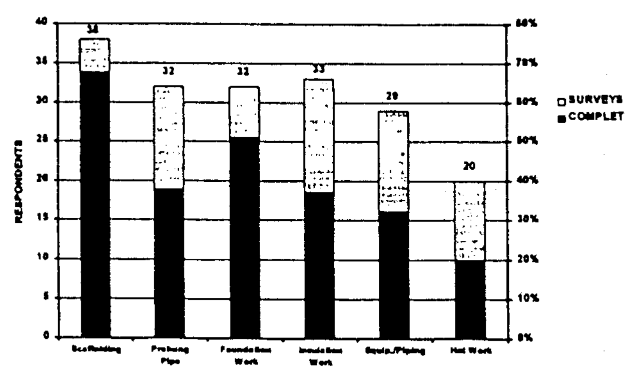
PRIMARY COORDINATION



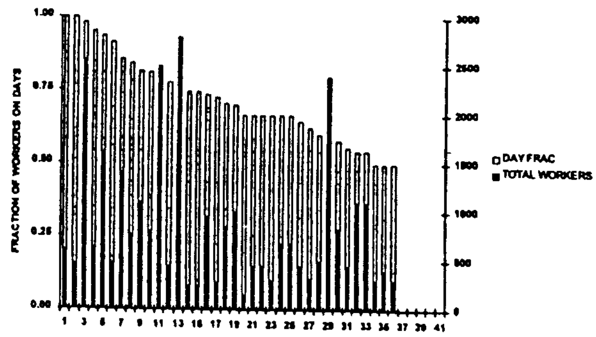
PREPLANNING



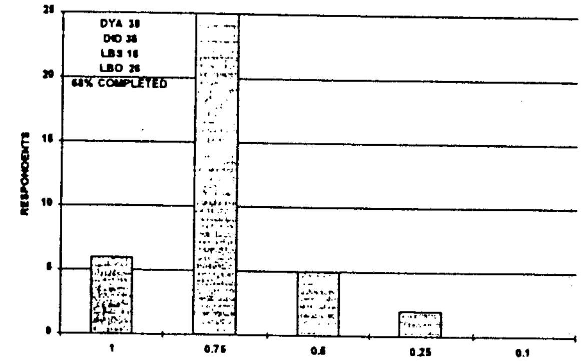
PRE-TURNAROUND WORK



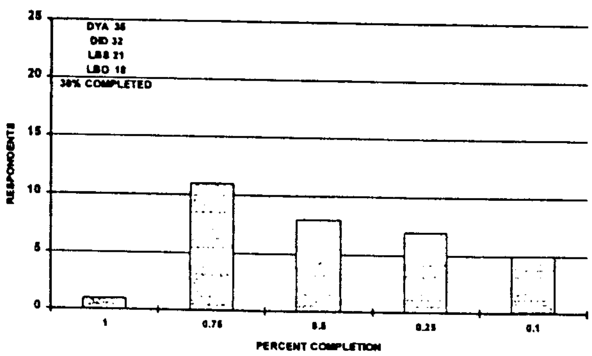
SPLIT OF TURNAROUND WORK



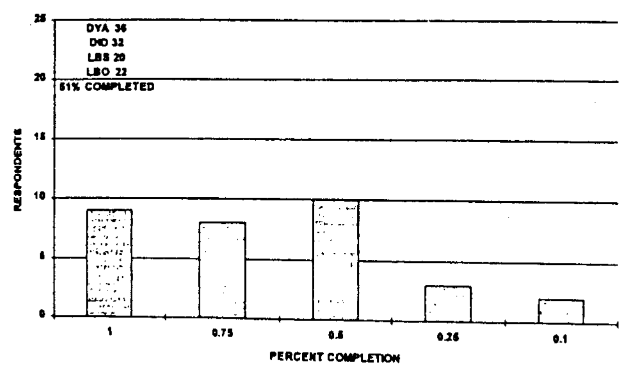
SCAFFOLDING



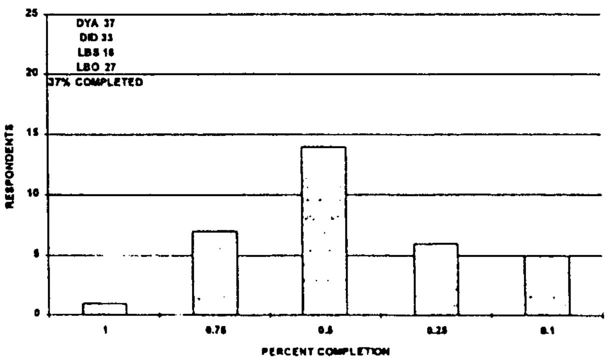
PREHUNG PIPING



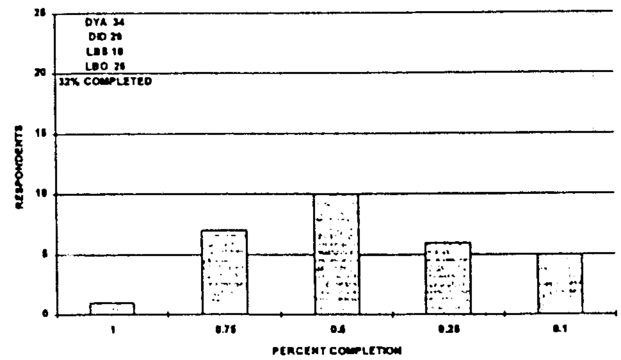
FOUNDATION WORK



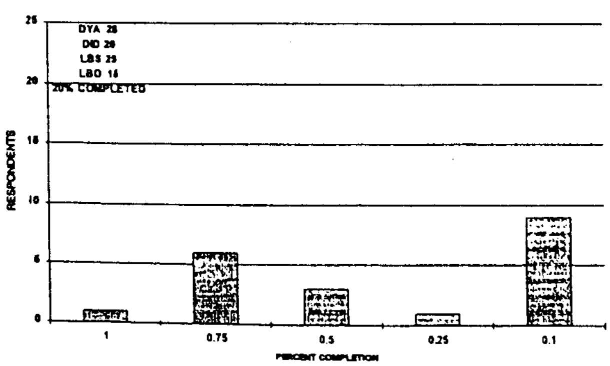
INSULATION WORK



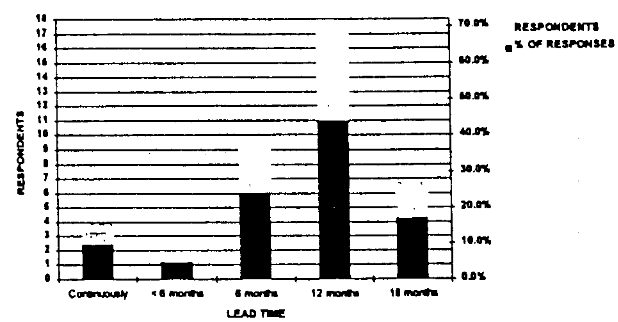
EQUIP/PIPING INSPECTIONS

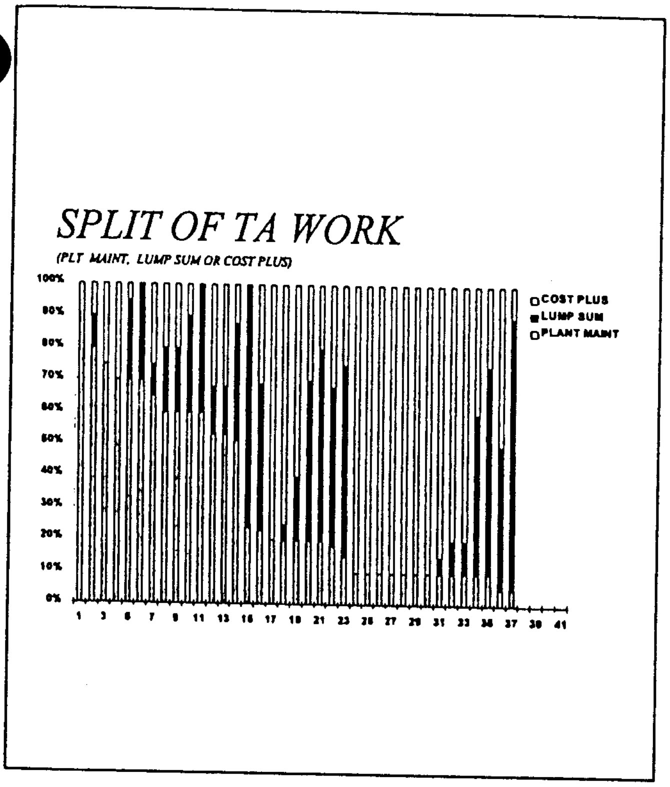


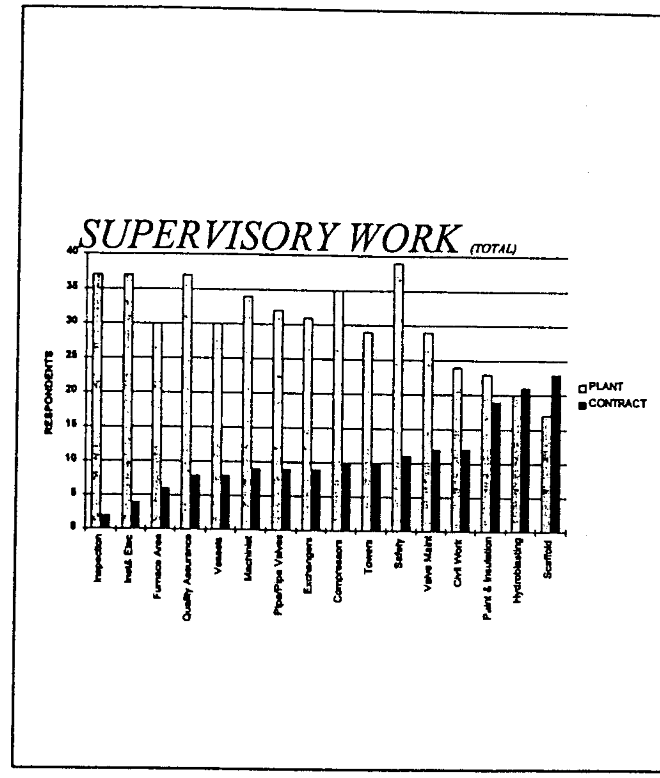
PRE-TURNAROUND HOT WORK

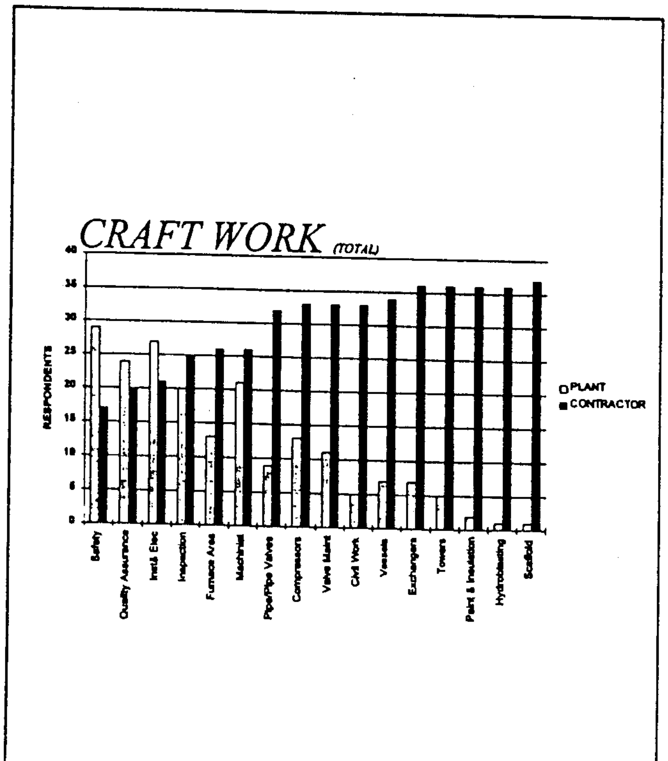


TURNAROUND PLANNING LEAD TIME




SPLIT OF TA WORK
(PLT MAINT, LUMP SUM OR COST PLUS)
COST PLUS
LUMP SUM
PLANT MAINT


SUPERVISORY WORK (TOTAL)
RESPONDENTS
PLANT
CONTRACT
Inspection
Inst& Elec
Furnace Area
Quality Assurance
Vessels
Machinist
Pipe/Pipe Valves
Exchangers
Compressors
Towers
Safety
Valve Maint
Civil Work
Paint & Insulation
Hydroblasting
Scaffold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Quality Assurance
Inst& Elec
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Furnace Area
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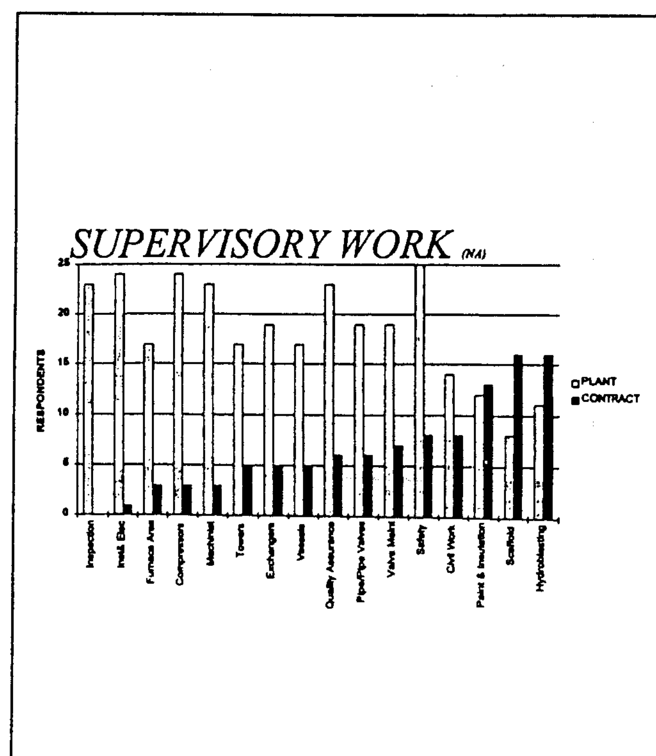
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Inspection
Inst& Elec
Furnace Area
Compressors
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Safety
Civil Work
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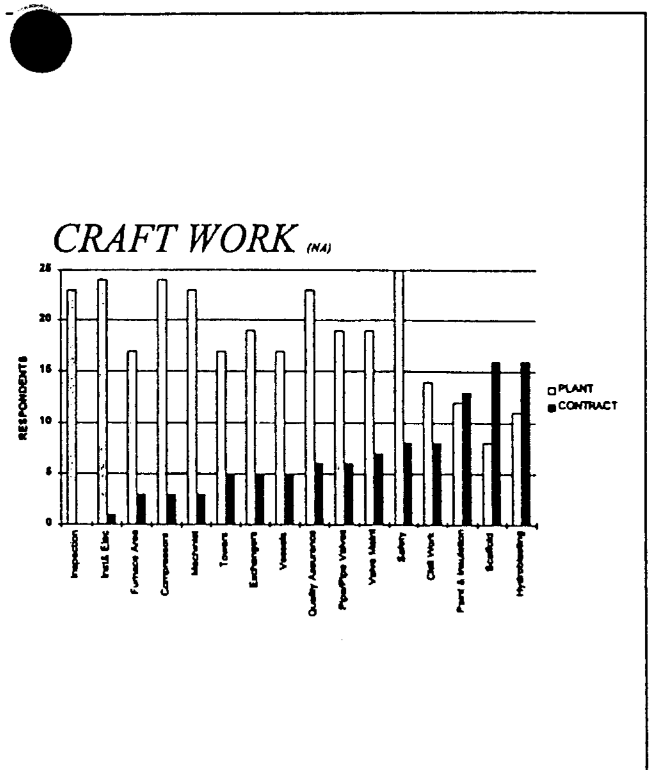
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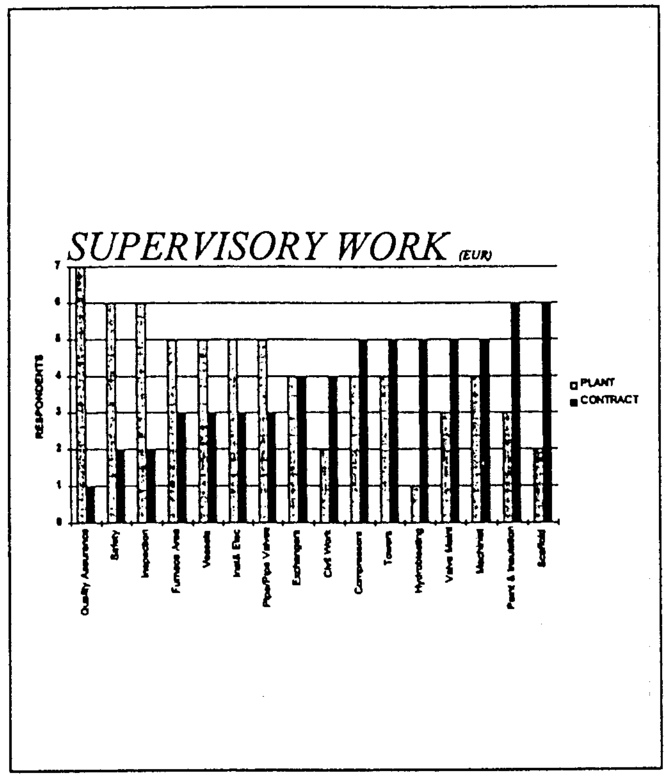
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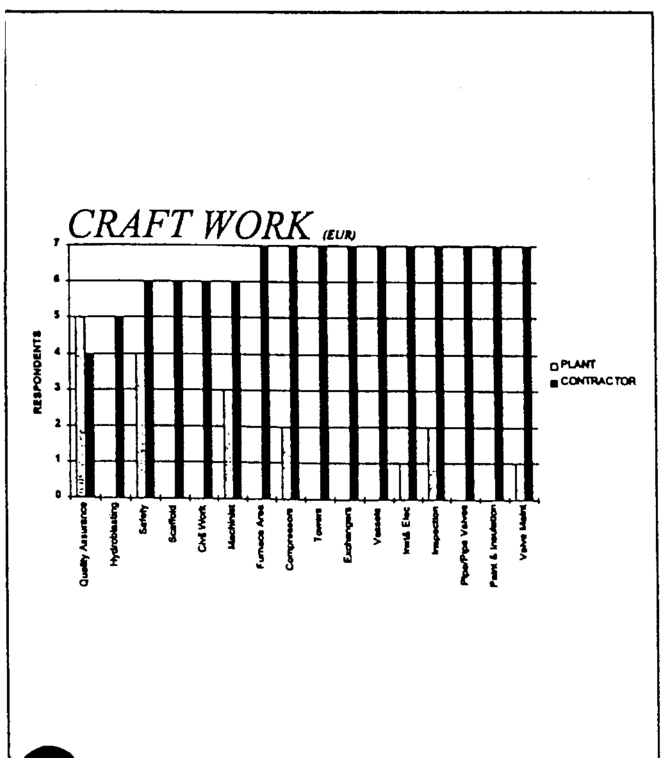
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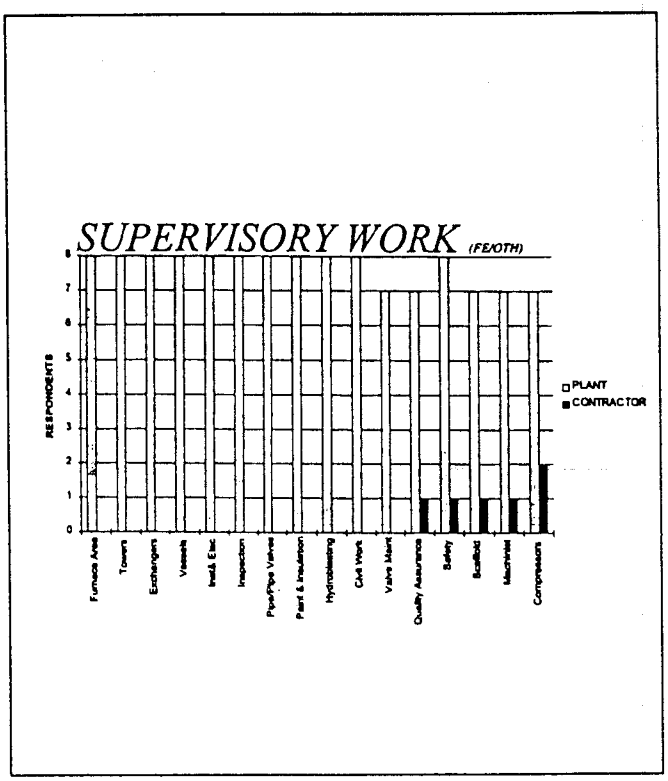
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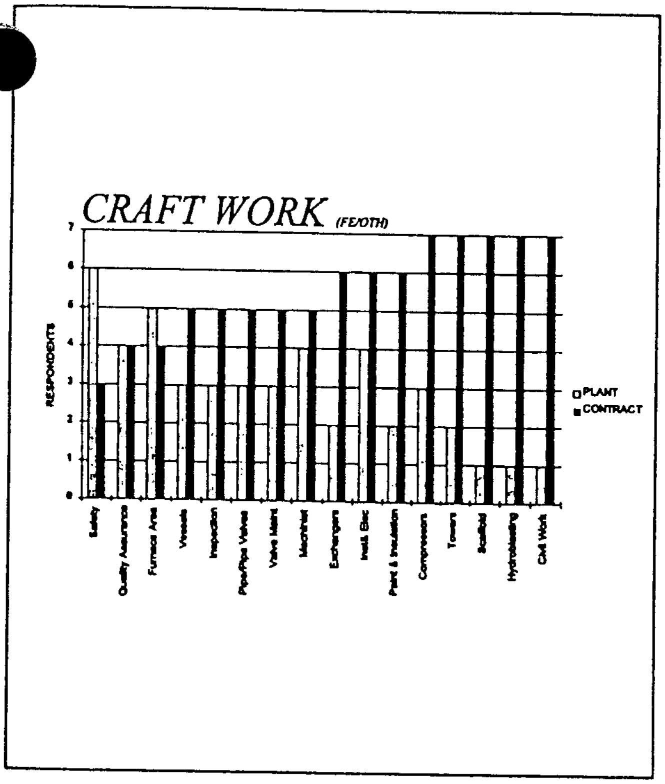
Machinist
Compressors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CONTRACT
Safety
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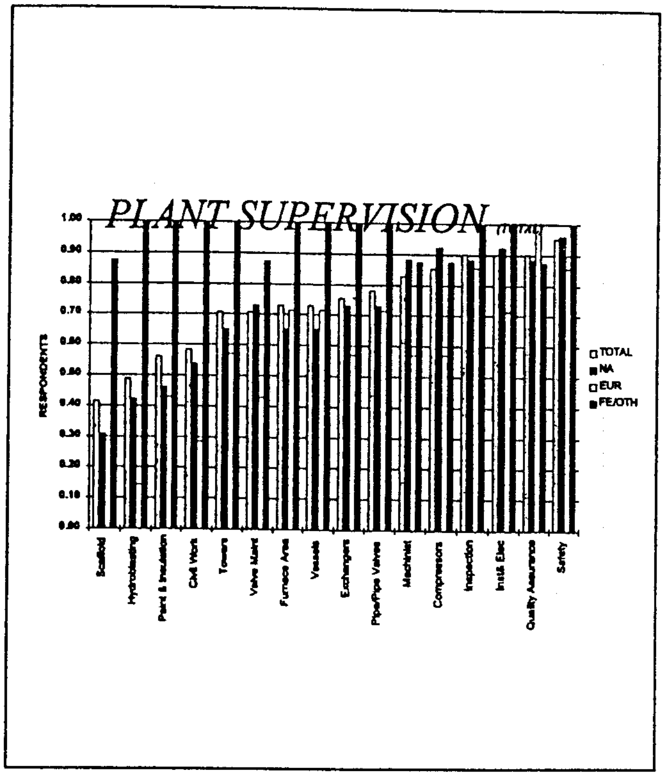
Compressors
Towers
Scaffold
Hydroblasting
Civil Work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RESPONDENTS
TOTAL
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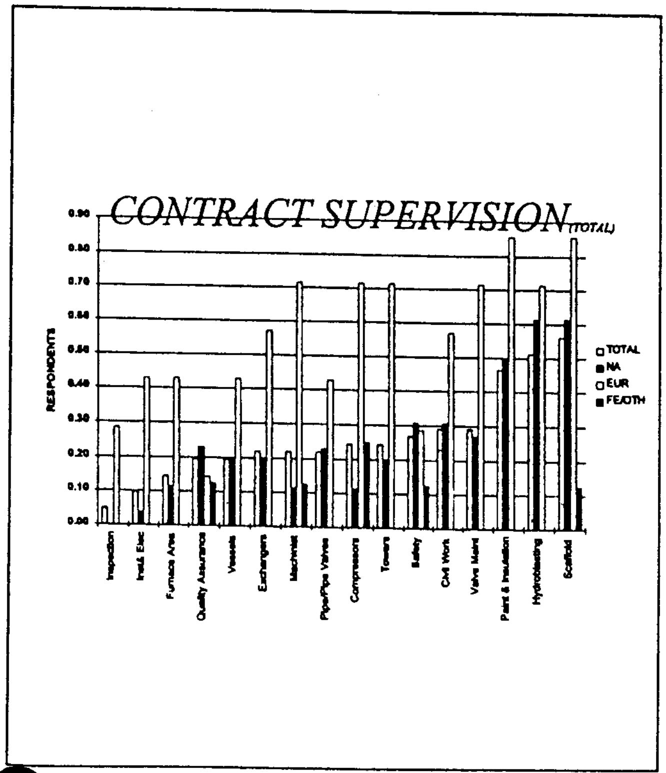
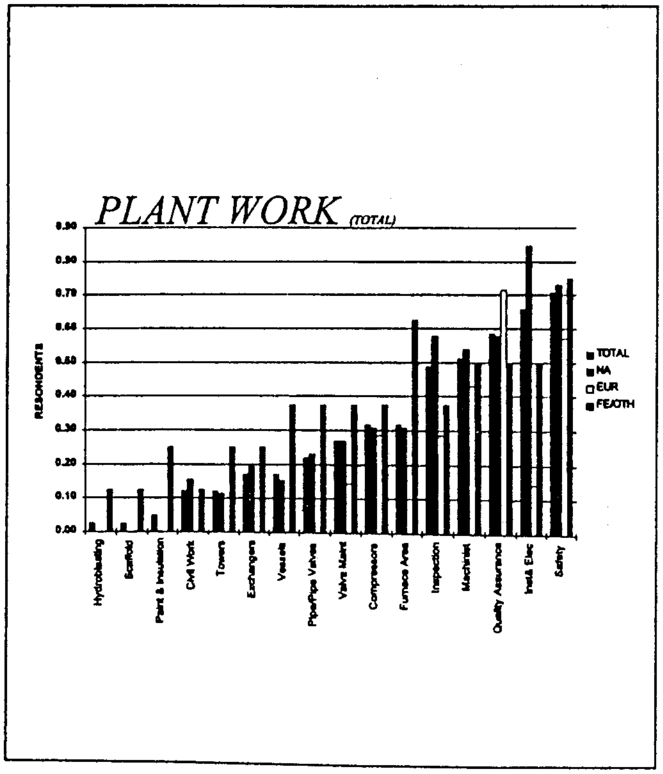
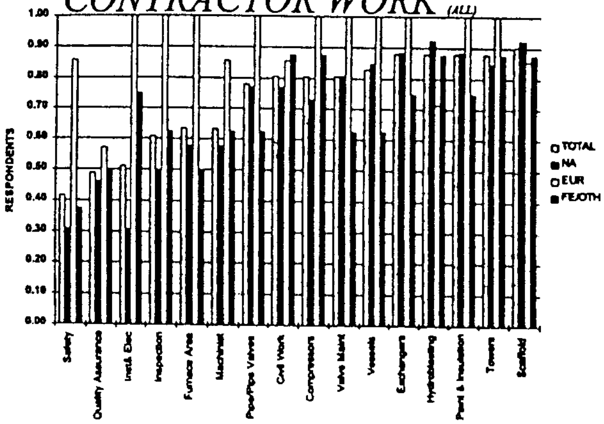
EUR
FE/OTH

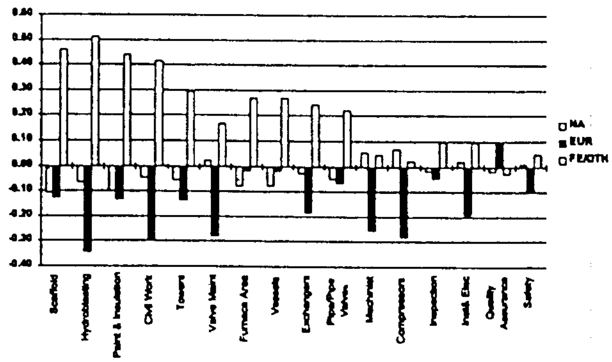

CONTRACT SUPERVISION (TOTAL)
RESPONDENTS
TOTAL
NA
EUR
FE/OTH


PLANT WORK (TOTAL)
RESPONDENTS
TOTAL
NA
EUR
FE/OTH

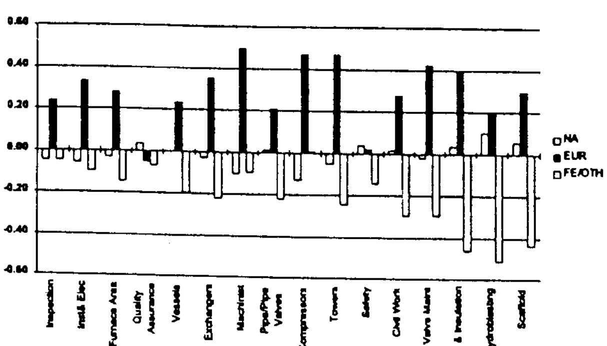
CONTRACTOR WORK (ALL)



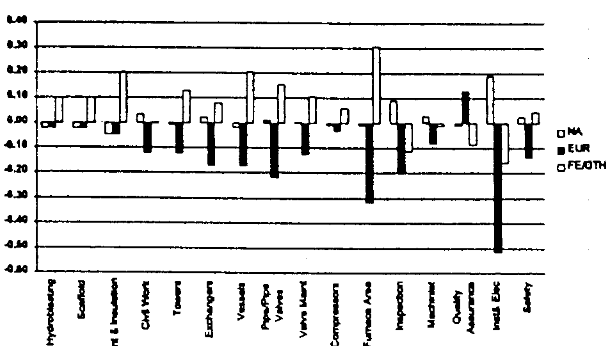
DIFFERENCE IN PLANT SUPERVISION



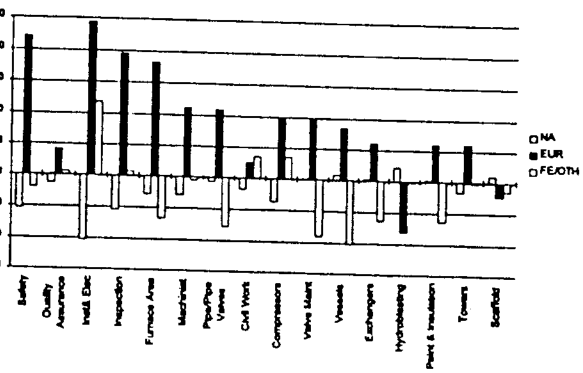
DIFFERENCE IN CONTRACT SUPERVISION



DIFFERENCE IN PLANT WORKERS



DIFFERENCE IN CONTRACT WORKERS



RELIEF VALVES (TOTAL)

AL REPONSES	YES	YES,SOME	NO		
ECTED PRIOR TO	61%	7%	29%		
ES UNDER RVS	34%	59%	7%		
HARGE VALVES	20%	56%	24%		
AY VALVE	7%	34%	56%		
RE RELIEF VALVES	54%	10%	37%		
	SHOP	ON-LINE			
OF TESTING	100%	12%			
	PROD	MAINT	TECH	CONTRACTOR	SAFETY OT
D INSPECTION	66%	56%	7%	5%	2%
	YES	NO			
RE RV POOL	66%	34%			
	ADMINS	LOCK&CHAIN	KEYED VALVE	SPECIAL BLIND	OTHER
RE VALVE OPEN	44%	37%	24%	10%	32%

RELIEF VALVES

TH AMERICA	YES	YES,SOME	NO		
CTED	8%	4%	-10%		
ES UNDER	0%	-1%	0%		
HARGE VALVES	0%	-2%	3%		
AY VALVE	0%	4%	-6%		
E RELIEF VALVES	-8%	6%	2%		
	SHOP	ON-LINE			
TESTING	0%	-1%			
	PROD	MAINT	TECH	CONTRACTOR	SAFETY OT
D INSPECTION	11%	-2%	0%	-5%	-2% -
	YES	NO			
E RV POOL	-15%	-22%			
	ADMINS	LOCK&CHAIN	KEYED VALVE	SPECIAL BLIND	OTHER
RE VALVE OPEN	18%	-10%	-24%	2%	11%

RELIEF VALVES

OPE	YES	YES,SOME	NO		
CTED	-4%	-7%	14%		
ES UNDER	9%	-1%	-7%		
HARGE VALVES	9%	1%	-10%		
AY VALVE	7%	23%	-28%		
E RELIEF VALVES	46%	-10%	-37%		
	SHOP	ON-LINE			
TESTING	0%	2%			
	PROD	MAINT	TECH	CONTRACTOR	SAFETY O
D INSPECTION	-52%	1%	7%	9%	12% .
	YES	NO			
E RV POOL	-37%	37%			
	ADMINS	LOCK&CHAIN	KEYED VALVE	SPECIAL BLIND	OTHER
RE VALVE OPEN	-44%	21%	76%	5%	-17%

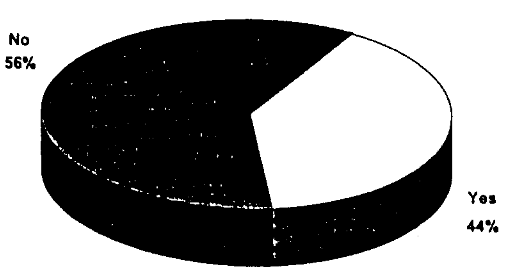
RELIEF VALVES (CONT'D)

AST	YES	YES,SOME	NO			
CTED	-23%	-7%	21%			
ES UNDER	-9%	4%	5%			
HARGE VALVES	-7%	6%	1%			
AY VALVE	-7%	-34%	44%			
E RELIEF VALVES	-16%	-10%	26%			
	SHOP	ON-LINE				
TESTING	0%	0%				
	PROD	MAINT	TECH	CONTRACTOR	SAFETY	OT
D INSPECTION	9%	6%	-7%	8%	-2%	1
	YES	NO				
E RV POOL	-16%	-24%				
	ADMINS	LOCK&CHAIN	KEYED VALVE	SPECIAL BLIND	OTHER	
RE VALVE OPEN	-19%	13%	13%	-10%	-19%	

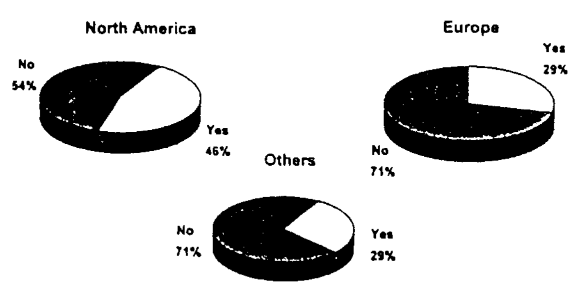
SAFETY TOPICS

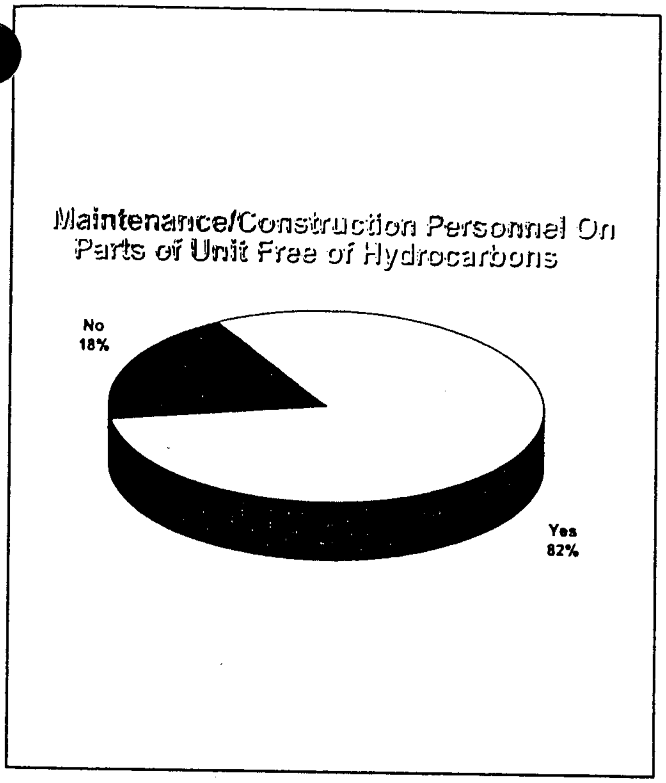
- Construction Personnel On Unit During Safing
- Fire Retardant Clothing
- Safety Monitoring
- Training
- Permit Philosophy
- Lockout/Tagout Philosophy
- Work Schedules
- Average Number Of Injuries

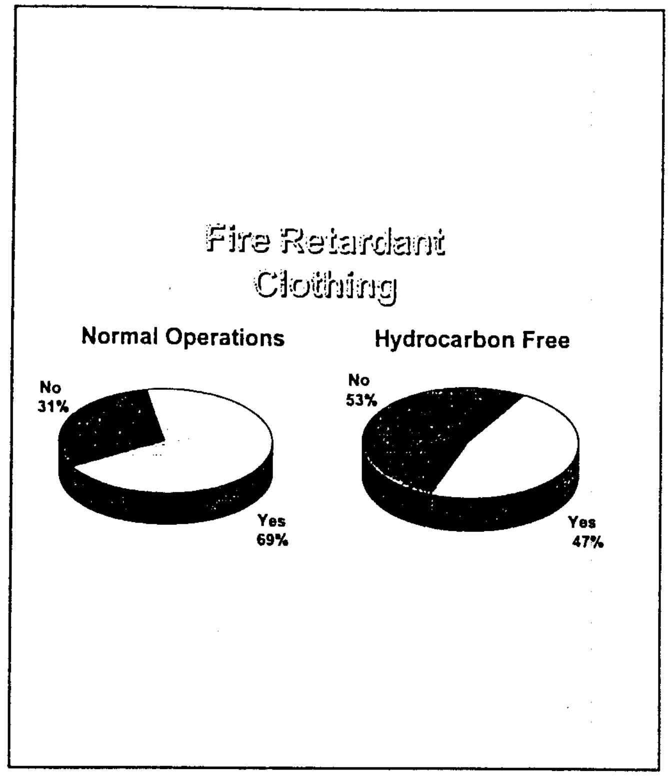
Maintenance/Construction Personnel On Unit While Hydrocarbon Freeing

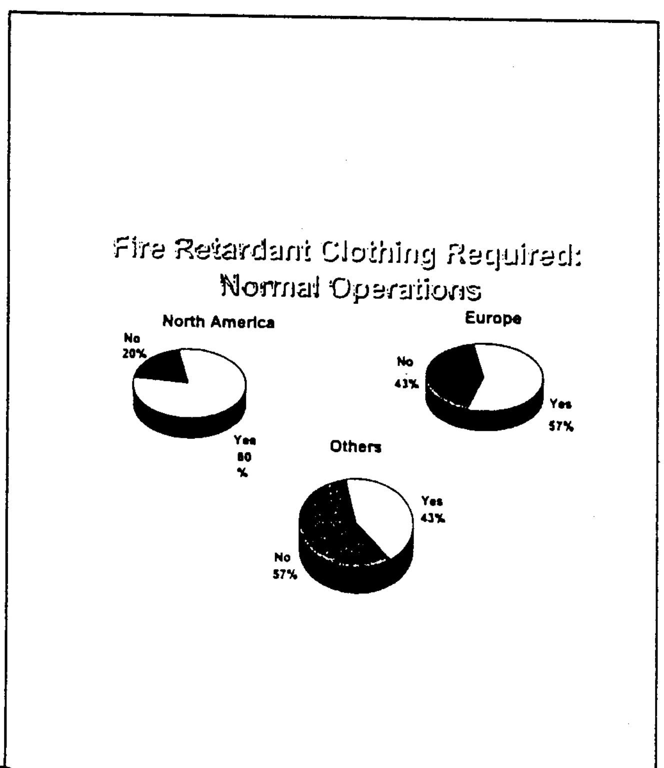


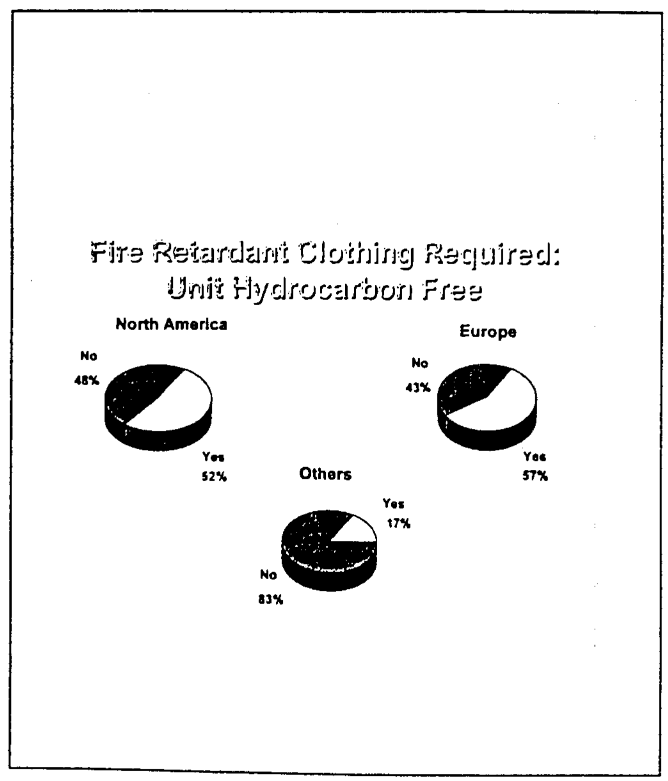
Geographic Regions Maintenance/Construction Personnel On Unit While Hydrocarbon Freeing

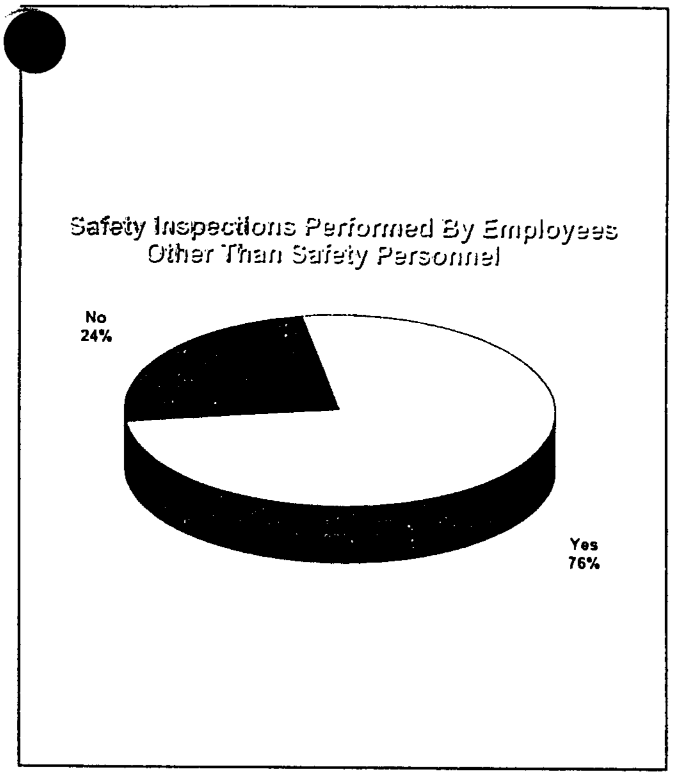


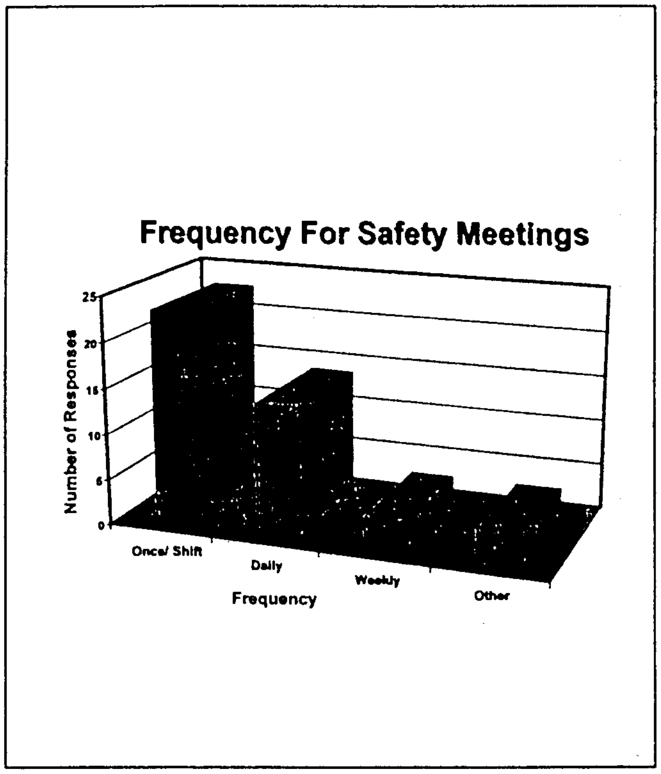

Maintenance/Construction Personnel On Parts of Unit Free of Hydrocarbons
No
18%
Yes
82%

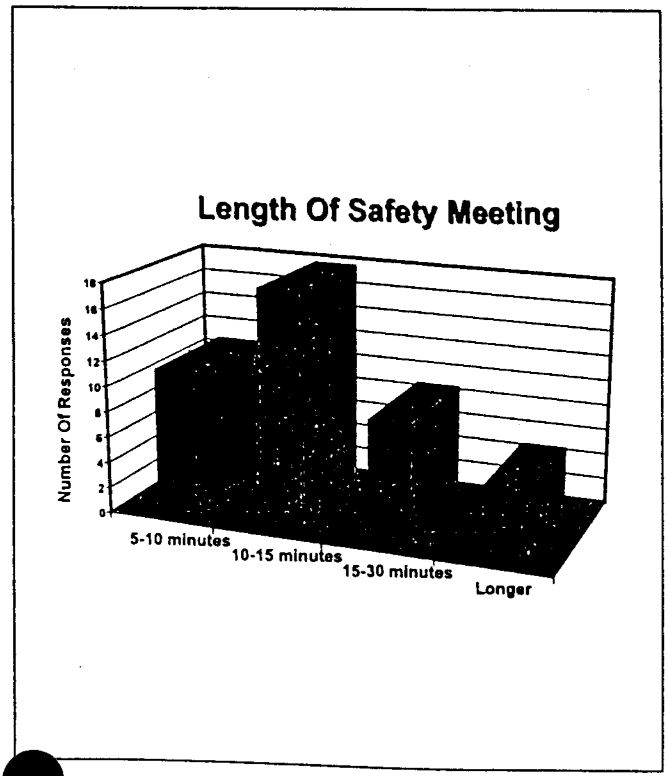

Fire Retardant Clothing
Normal Operations
Hydrocarbon Free
No
31%
Yes
69%
No
53%
Yes
47%

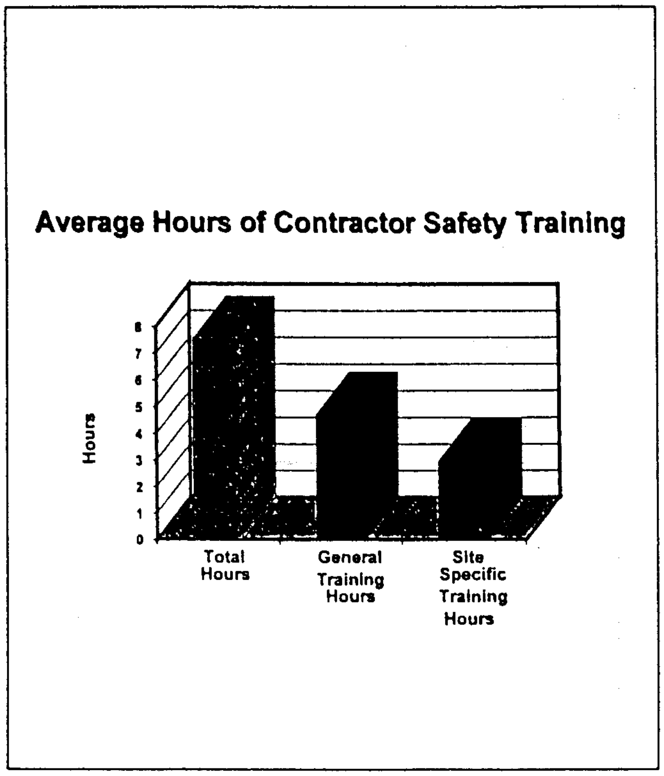

Fire Retardant Clothing Required: Normal Operations
North America
No
20%
Yes
80
%
Europe
No
43%
Yes
57%
Others
Yes
43%
No
57%


Fire Retardant Clothing Required: Unit Hydrocarbon Free
North America
No
48%
Yes
52%
Europe
No
43%
Yes
57%
Others
Yes
17%
No
83%

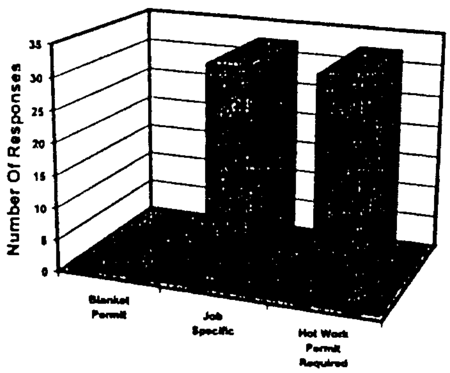

Safety Inspections Performed By Employees Other Than Safety Personnel
No 24%
Yes 76%


Frequency For Safety Meetings
Number of Responses
0
5
10
15
20
25
Once/ Shift
Daily
Weekly
Other
Frequency


Length Of Safety Meeting
Number Of Responses
0
2
4
6
8
10
12
14
16
18
5-10 minutes
10-15 minutes
15-30 minutes
Longer


Average Hours of Contractor Safety Training
Hours
0
1
2
3
4
5
6
7
8
Total Hours
General Training Hours
Site Specific Training Hours

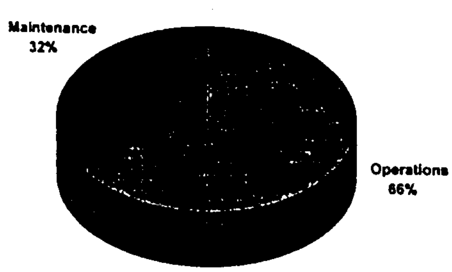
Permit Type: Unit Hydrocarbon Free



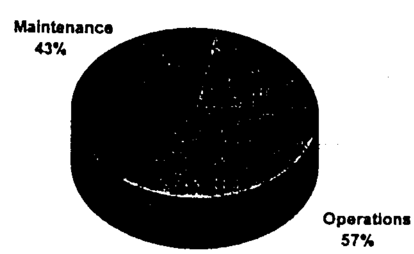
Permit and Lock Out Philosophy

- **Operations Universally Responsible For Writing, Approving, and Closing Permits**
- **Battery Locks**
  - Used By Minority of Plants
  - 38% Before and After Hydrocarbon Free
- **System Locks**
  - 47% During Hydrocarbon Freeing
  - 60% After Hydrocarbon Free
- **Personal Locks**
  - Used Equally Before and After Unit Hydrocarbon Free
- **Tags**
  - Majority Use Tags: About 60%
  - Before And After Hydrocarbon Free

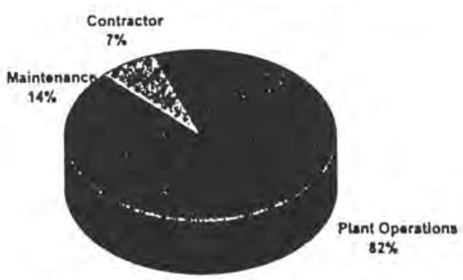
Primary Responsibility For Lockout Before Hydrocarbon Free



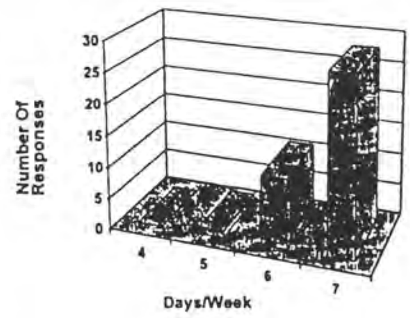
Primary Responsibility For Lockout After Hydrocarbon Free



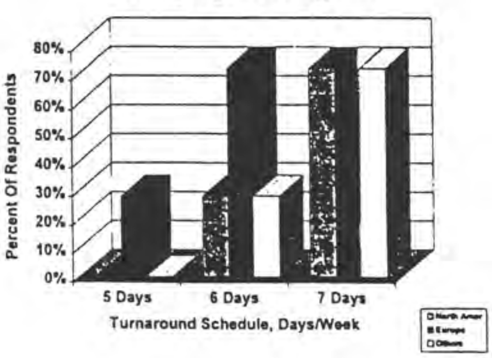
Who Tracks Blind Installation



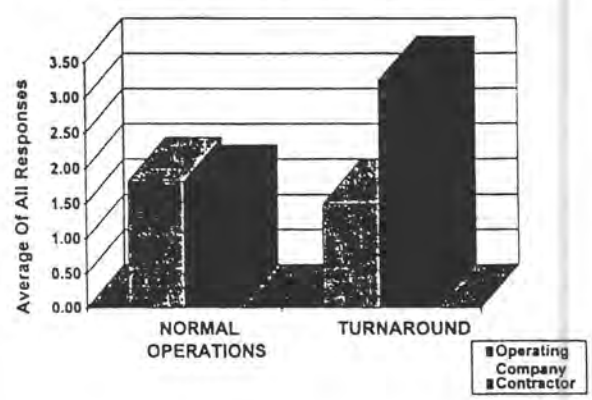
Turnaround Schedule

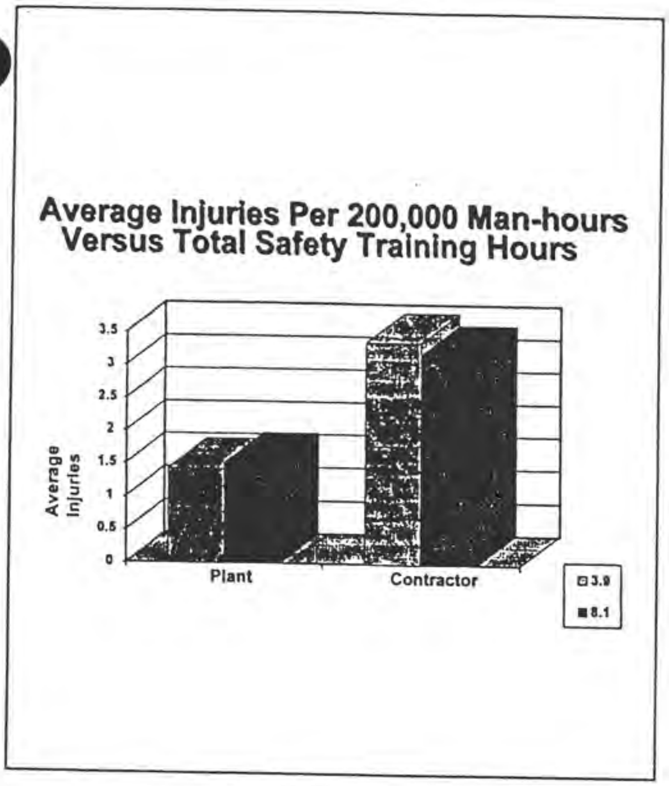


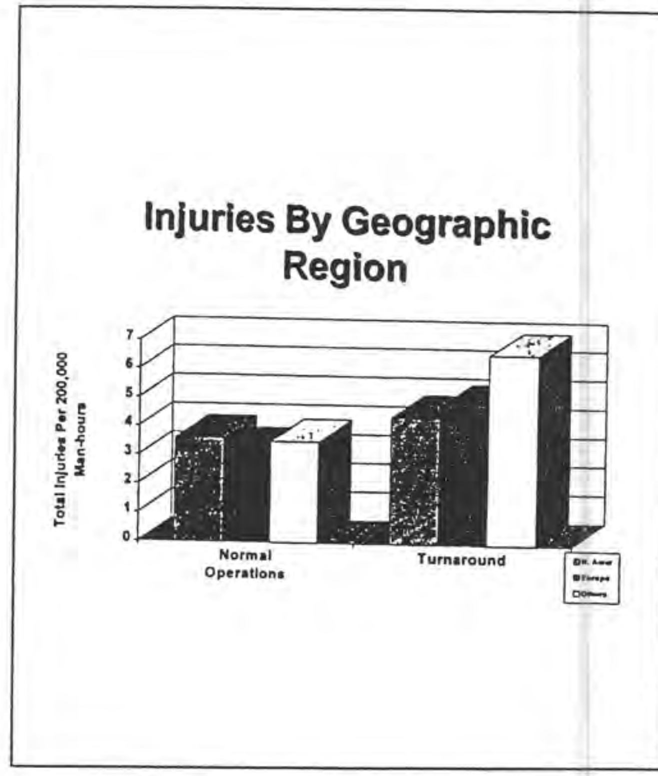
Maintenance Work Schedules By Geographic Region

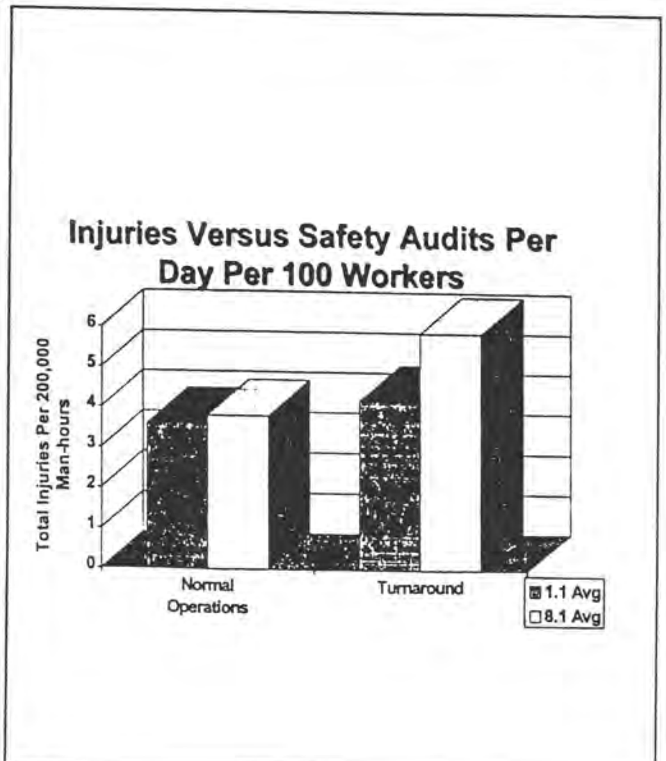


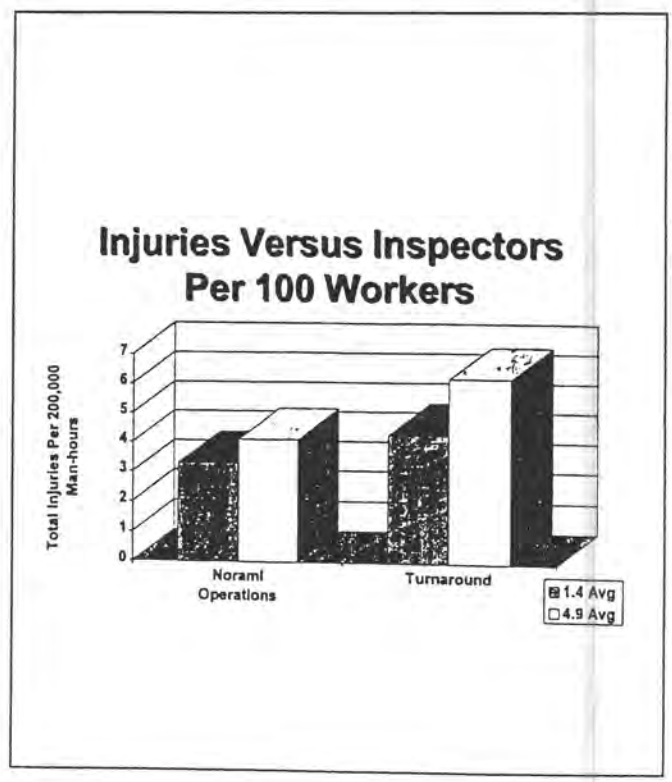
Recordable Injuries Per 200,000 Manhours



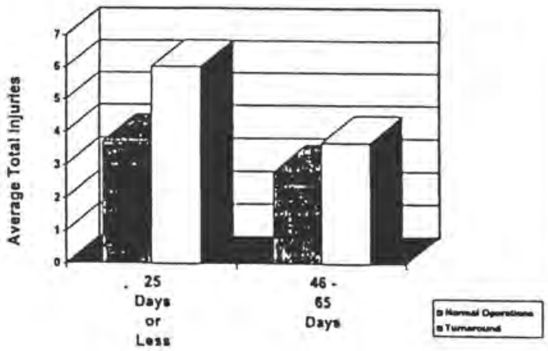

Average Injuries Per 200,000 Man-hours
Versus Total Safety Training Hours
Average Injuries
0
0.5
1
1.5
2
2.5
3
3.5
Plant
Contractor
3.9
8.1


Injuries By Geographic Region
Total Injuries Per 200,000 Man-hours
0
1
2
3
4
5
6
7
Normal Operations
Turnaround

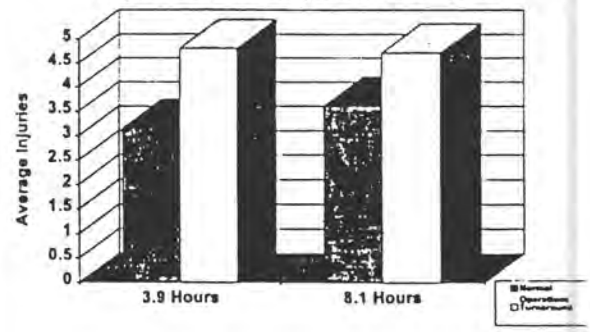

Injuries Versus Safety Audits Per Day Per 100 Workers
Total Injuries Per 200,000 Man-hours
0
1
2
3
4
5
6
Normal Operations
Turnaround
1.1 Avg
8.1 Avg


Injuries Versus Inspectors Per 100 Workers
Total Injuries Per 200,000 Man-hours
0
1
2
3
4
5
6
7
Norami Operations
Turnaround
1.4 Avg
4.9 Avg

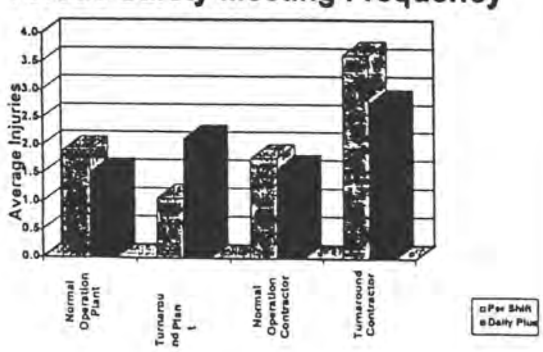
Turnaround Length Versus Injuries Per 200,000 Man-hours



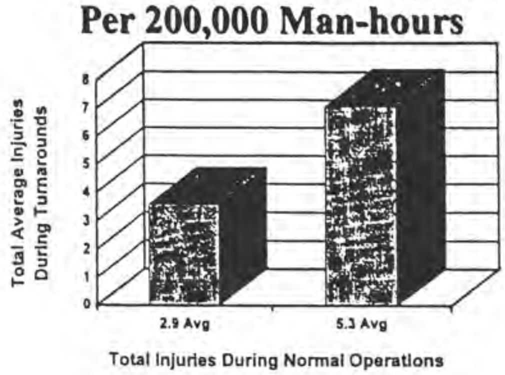
Total Hours Safety Training Versus Injuries Per 200,000 Man-hours



Average Injuries Per 200,000 Manhours Versus Safety Meeting Frequency



Plant Safety Versus Injuries Per 200,000 Man-hours



Factors Effecting Employee Injuries

- × Number Of Audits Per Day
- × Number Of Inspectors
- × Length Of Turnaround
- × Short Versus Long Work Schedule
- × Total Hours Of Safety Training
- × Safety Meeting Frequency
- ✓ Plant Safety Record During Normal Operations

SAFETY TOPICS REVIEW

- Construction Personnel On Unit During Safing
  - Majority Do Not Allow While Hydrocarbons In Units
  - Large Majority Allow On Parts Of Unit Hydrocarbon Free
- Fire Retardant Clothing
  - Majority Required During Normal Operations; Not Required During Shut down
- Safety Monitoring
  - Majority Use Personnel Outside Of Safety For Inspections
  - Average Safety Inspectors - 2.3 Per 100 Workers; Lowest Ratio In Far East, Pacific Rim & Others
- Training
  - 7.5 Hours Contractor Safety Training; Fewest In Europe - 3.8 Hours
  - Safety Meetings Mostly Held Per Shift
  - Safety Meetings Last Between 5-15 Minutes

SAFETY TOPICS REVIEW

- Permit Philosophy
  - Very Few Use Blanket Permits
  - Operations Responsible
  - Majority In Europe Maintenance Closes
  - Far East, Pacific Rim & Others Half Allow Maintenance To Write
- Lockout/Tagout Philosophy Before & After Hydrocarbon Free
  - North America Before: Operations; After: Operations
  - Europe Before: Operations; After: Maintenance
  - Far East, Pacific Rim & Others Before: Operations; After: Operations

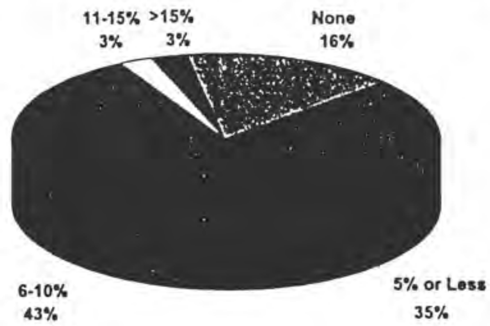
SAFETY TOPICS REVIEW

- Work Schedules
  - North America, Far East, Pacific Rim & Others - 7 Days/Week
  - Europe - 6 Days/Week
- Injuries
  - Turnaround: Plant - 1.5, Contractor - 3.25
  - Key Factor In Reducing Turnaround Injuries: Good Plant Safety Record During Normal Operations

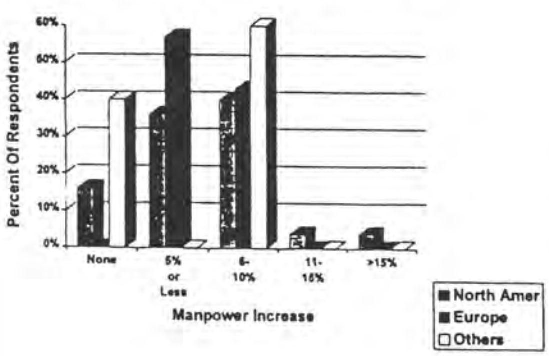
Environmental Topics

- Effects Of Complying With Regulations
- Quench System Entry
- Flares
- Fugitive Emissions

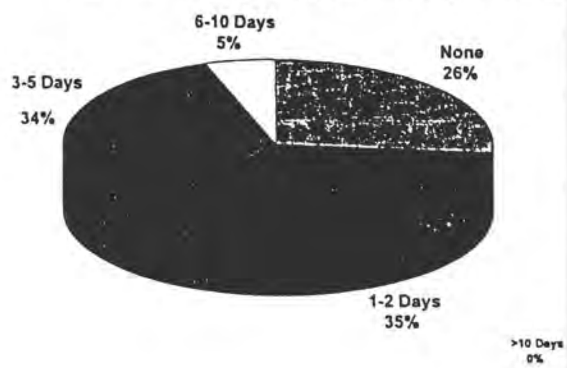
Increase in Turnaround Manpower Due To Environmental Regulations



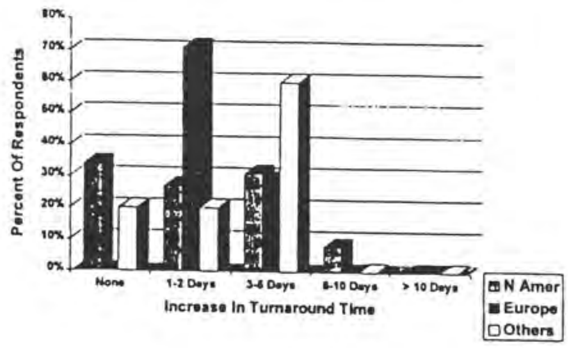
Manpower Increase Due To Environmental Regulations



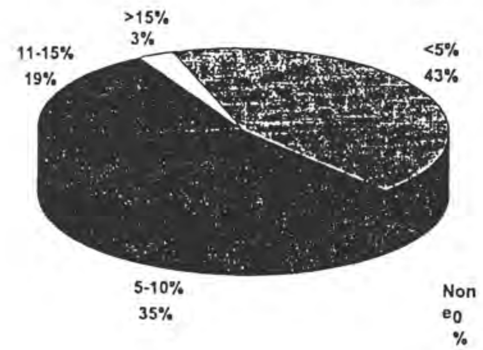
Increase in Turnaround Time Due To Environmental Regulations



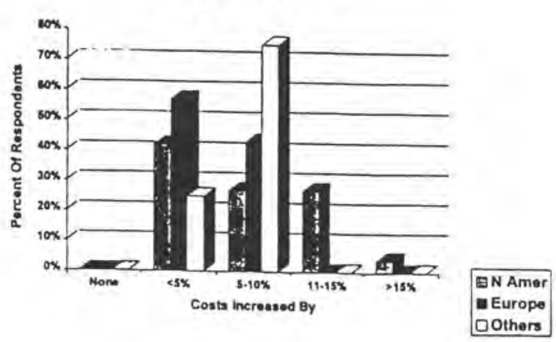
Increased Turnaround Time Due To Environmental Regulations



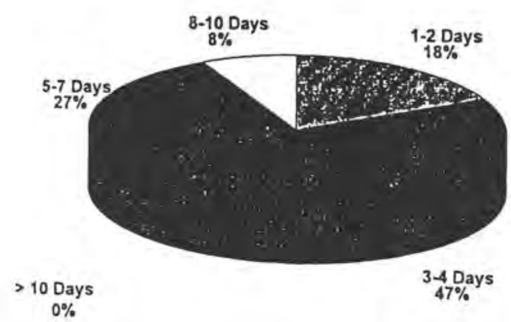
Increase in Turnaround Costs Due To Environmental Regulations



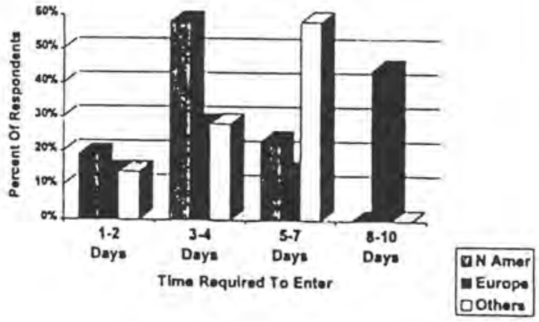
Increased Turnaround Costs Due To Environmental Regulations



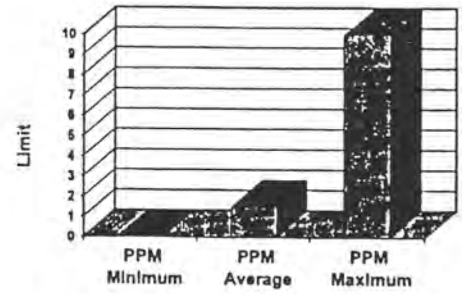
Time Required to Comply With Regulations For Quench System Entry



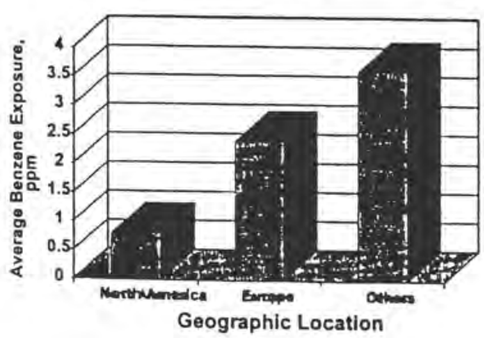
Time Required To Comply With Environmental Regulations For Quench System Entry



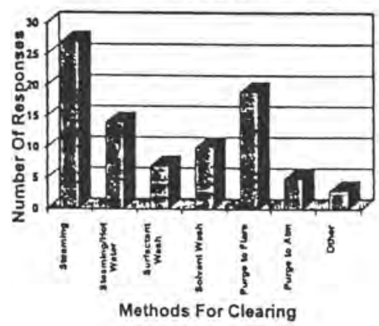
Allowable Benzene Exposure For Quench System Entry



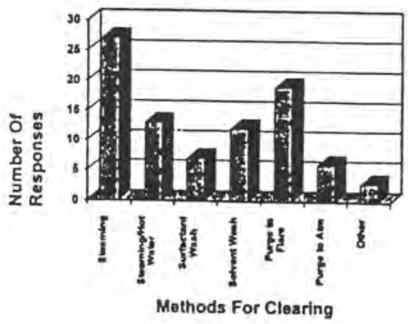
Allowable Benzene Exposure For Quench System Entry



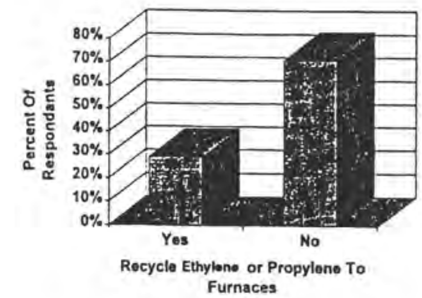
Methods Tried To Clear Quench System During Last Turnaround



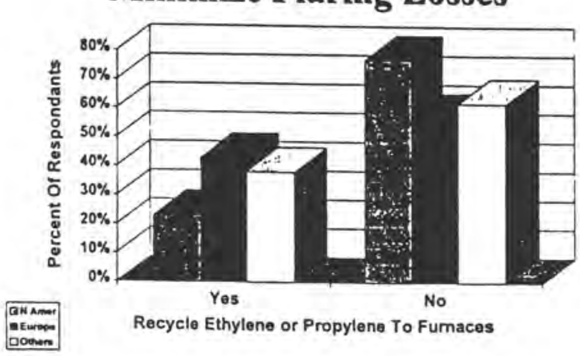
Method(s) Selected For Use At Next Turnaround For Clearing Quench System



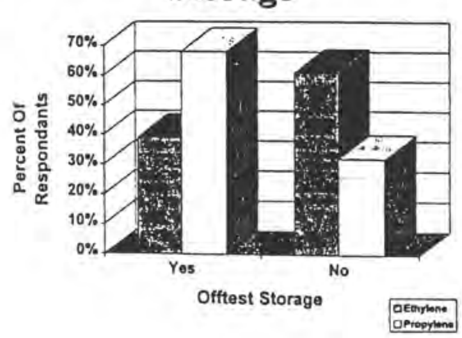
Minimize Flaring Emissions



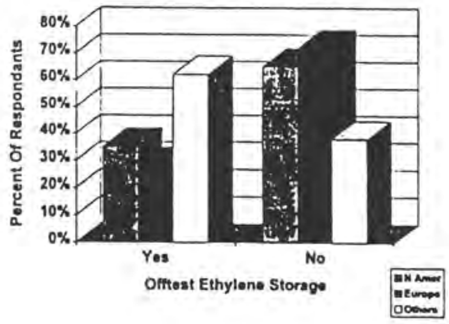
Minimize Flaring Losses



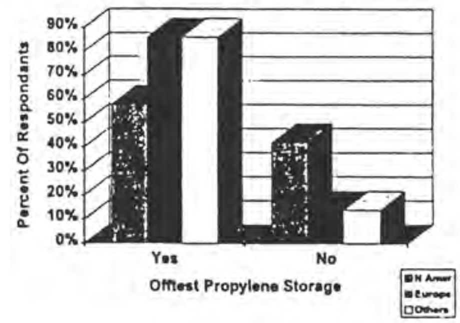
Minimize Flaring With Offtest Storage



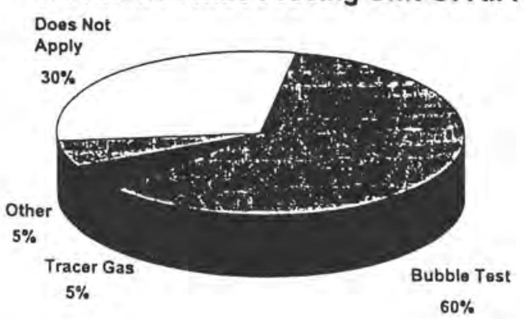
Minimize Flaring With Offtest Ethylene Storage



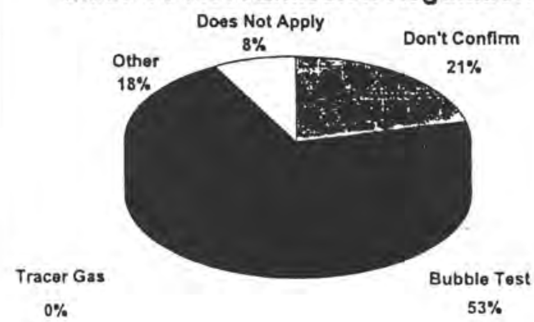
Minimize Flaring With Offtest Propylene Storage



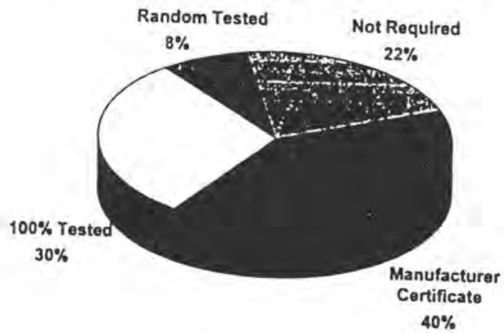
How Do You Monitor For Potential Emissions While Freeing Unit Of Air?



How Do You Shop Confirm Valve Repairs Made To Meet Emission Regulations?



What Monitoring Is Used For New Valves Prior To Installation In Emission Regulated Service?



Environmental Topics

- Effects Of Complying With Regulations
  - Increased Manpower: 10% or Less
  - Increased Turnaround Time: 1-3 Days
  - Increased Turnaround Costs: 10% or Less
- Quench System Entry
  - Increased Time To Safe: 3-4 Days
  - Average Benzene Level For Entry: 1.5 PPM
- Flares
  - 30% Recycle Crack Offtest Product
  - 40% Europe & Others Recycle Crack
  - 40% Have Offtest Ethylene Storage
  - 70% Have Offtest Propylene Storage
- Emissions Monitoring
  - Commission Unit For Restart: Bubble Test
  - Shop Confirm Valves: Bubble Test
  - Confirm New Valves: Manufacturer Certificate

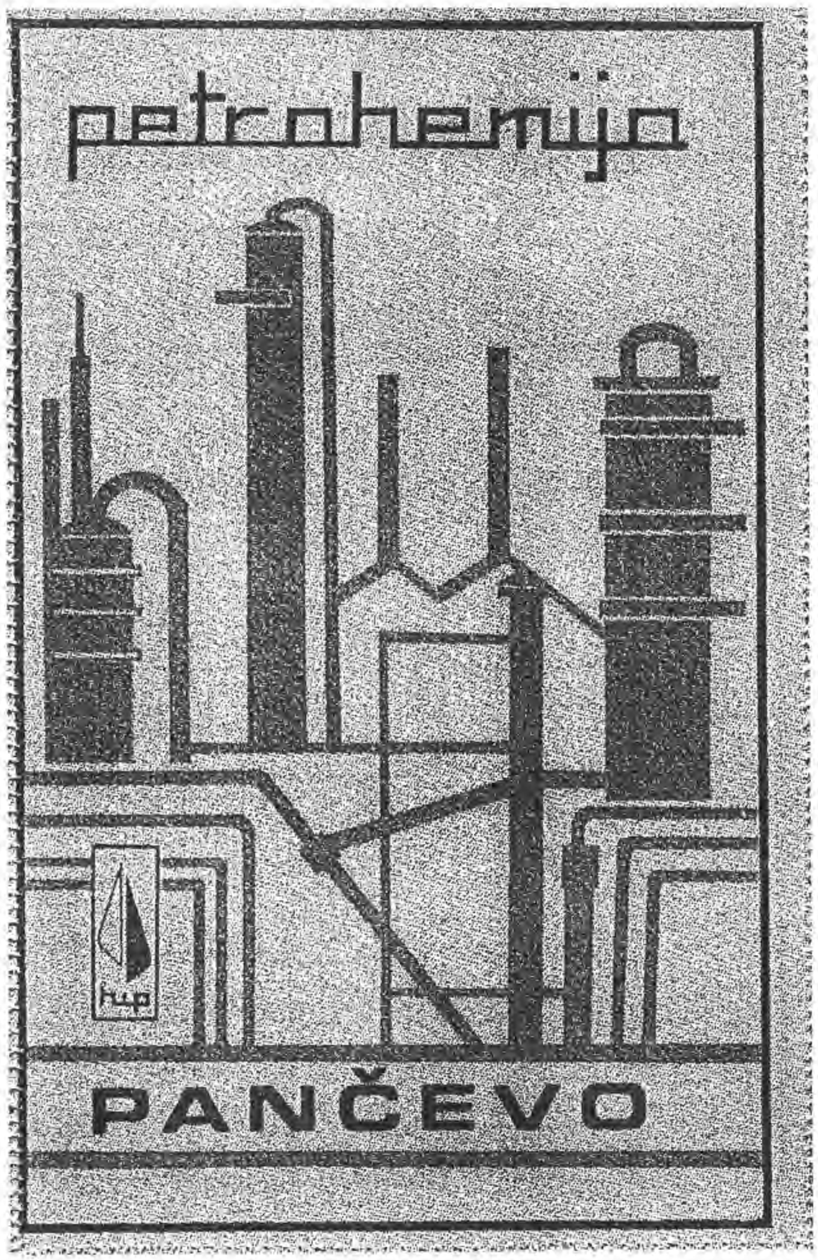
APPENDIX C

DCS and Advanced Process Control – by ABB Inc.

Document is in CONFIDENTIAL VERSION only

APPENDIX D

Chevron Phillips Polyethylene Technology

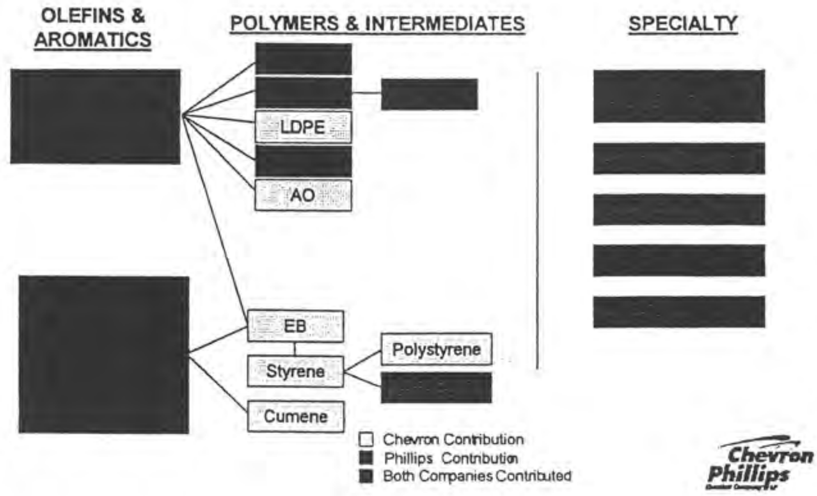


Chevron Phillips Chemical Company LP

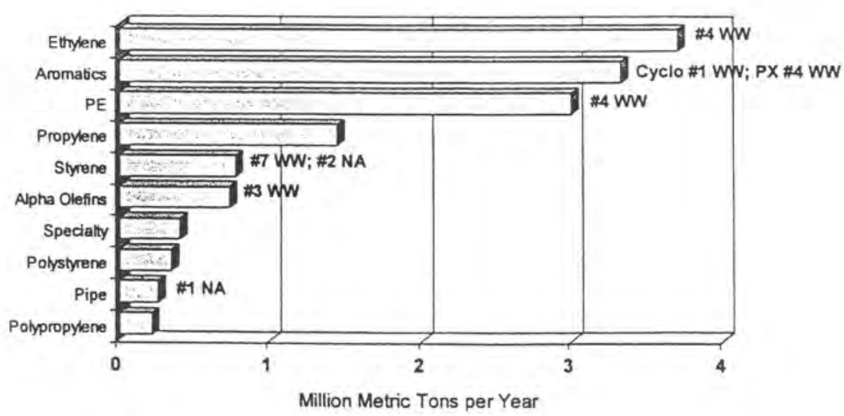
PRESENTATION TOPICS

- Introduction to Chevron Phillips Chemical Company
- Overview of PE Loop Slurry
- Product Scope
- Conclusions

CHEVRON PHILLIPS CHEMICAL COMPANY
LARGER, MORE DIVERSIFIED ASSET PORTFOLIO

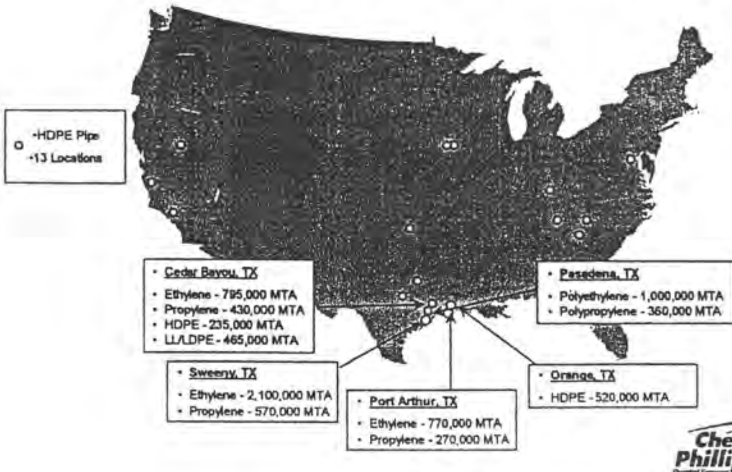


COMBINED CAPACITIES OF CHEVRON PHILLIPS CHEMICAL COMPANY



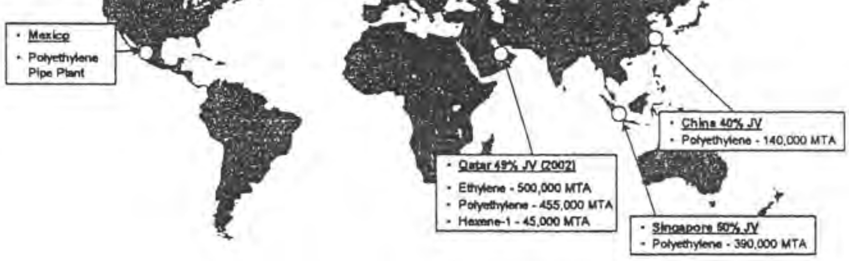
Chevron Phillips

CHEVRON PHILLIPS CHEMICAL COMPANY
OLEFINS / POLYOLEFINS
COMBINED US OPERATIONS



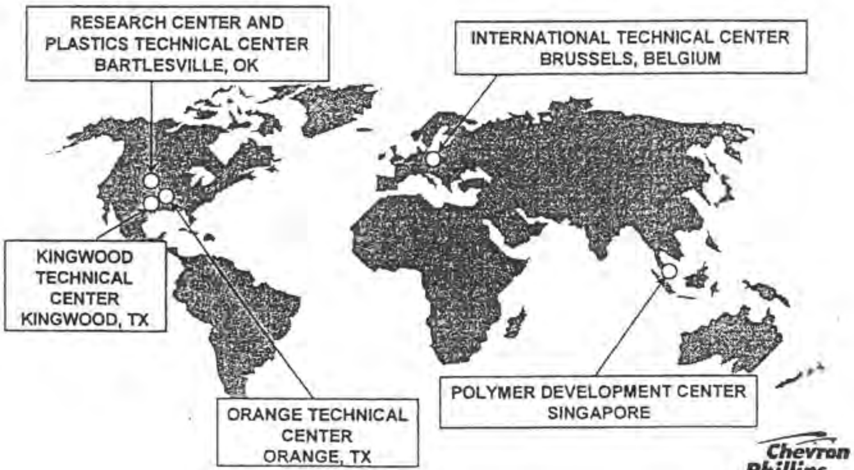
Chevron Phillips

CHEVRON PHILLIPS CHEMICAL COMPANY
OLEFINS / POLYOLEFINS
COMBINED INTERNATIONAL OPERATIONS



Chevron Phillips

CHEVRON PHILLIPS WORLDWIDE POLYMER SUPPORT FACILITIES



CHEVRON PHILLIPS CHEMICAL COMPANY NEW LICENSING PORTFOLIO

- POLYETHYLENE & POLYETHYLENE PIPE TECHNOLOGY
- AROMAX® - BENZENE FROM C_6 & C_7 PARAFFINICS
- ELUXYL® - PARAXYLENE
- OXYGEN SCAVENGING POLYMER (OSP)
- POLYPROPYLENE PRODUCER
- NORMAL ALPHA OLEFIN - MAKES BUTENE-1, HEXENE-1,...
- 1-HEXENE - PRODUCES A VERY CLEAN STREAM OF 1-HEXENE

Chevron Phillips

CHEVRON PHILLIPS POLYETHYLENE TECHNOLOGY HAS WORLDWIDE ACCEPTANCE

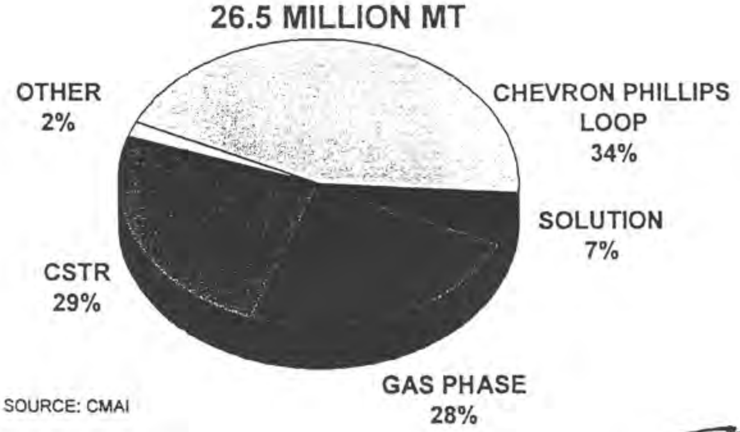
- PRODUCTION INCREASES OF 2,450,000 MTA SINCE 1996
- PUBLISHED CAPACITY IN EXCESS OF 8,100,000 MTA
- 86 COMMERCIAL REACTORS
- LICENSEES IN THE US AND 15 OTHER COUNTRIES

Chevron Phillips

NUMBER ONE HDPE PROCESS IN THE WORLD

(WW CAPACITY)

26.5 MILLION MT



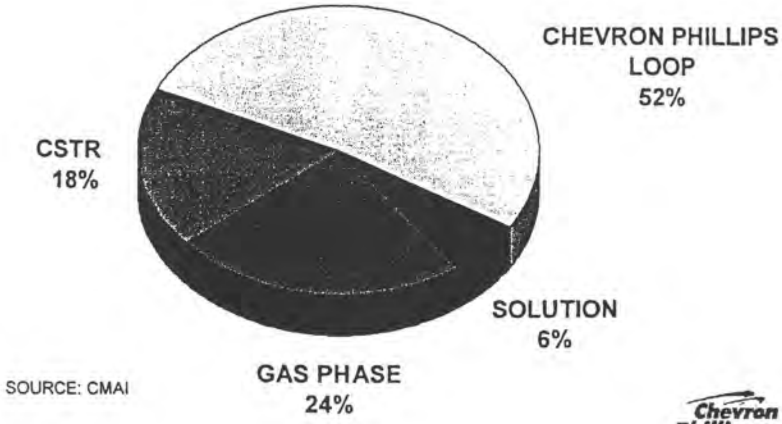
SOURCE: CMAI

Chevron Phillips

NUMBER ONE HDPE PROCESS IN THE U.S.

(US CAPACITY)

7.5 MILLION MT

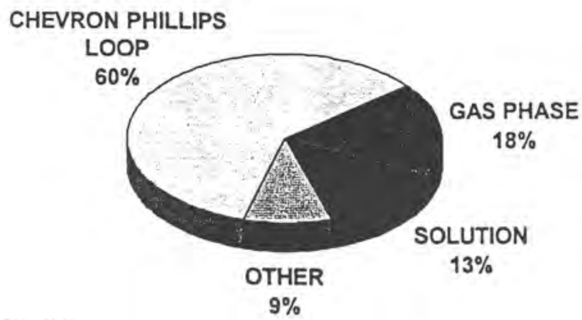


SOURCE: CMAI

Chevron Phillips

NUMBER ONE HIC AND INDUSTRIAL BLOW MOLDING RESINS IN U.S.

HDPE MARKET SHARE BY PROCESS

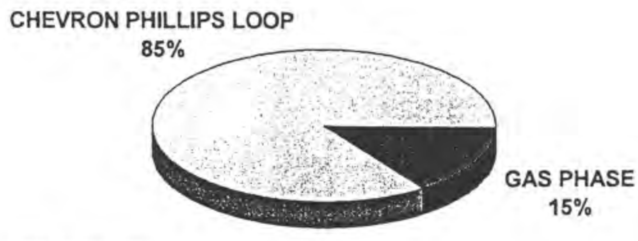


SOURCE: SRI

Chevron Phillips

NUMBER ONE LIQUID FOOD BLOW MOLDING RESINS IN U.S.

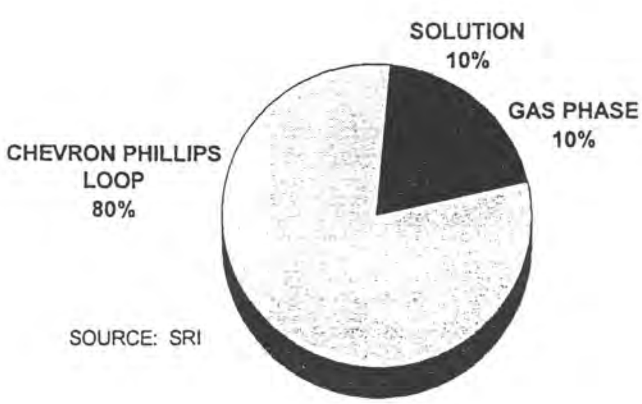
HDPE MARKET SHARE BY PROCESS



SOURCE: SRI

NUMBER ONE HDPE PIPE RESINS IN U.S.

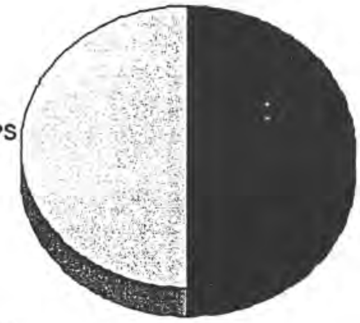
MARKET SHARE BY PROCESS



SOURCE: SRI

NUMBER ONE GEOMEMBRANE RESINS IN U.S.

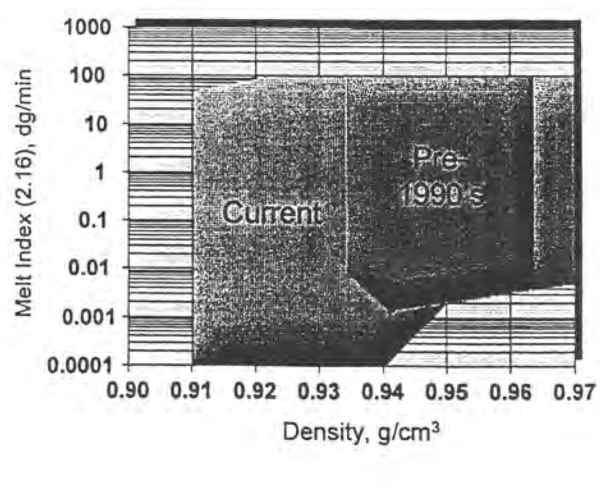
MARKET SHARE BY PROCESS



SOURCE: SRI

Chevron Phillips

PROPRIETARY CATALYSTS ALLOW FOR LOWER DENSITY RANGE OF CHEVRON PHILLIPS POLYETHYLENE PROCESS



Chevron Phillips

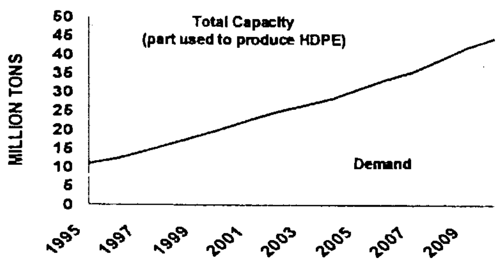
Global polyethylene demand summary (million metric tons)

	1998	1999	2000	2001	2002	2003	2004	2005	2010	Average Annual Growth Rate, % 1999-2004	2005-2010	
LDPE	15.5	16.1	16.3	16.9	17.1	17.4	17.7	17.8	18.0	1.9	0.2	
LLDPE	10.4	11.3	12.0	13.3	14.8	16.2	17.8	19.4	28.4	9.4	7.9	
LDPE + LLDPE	25.9	27.4	28.4	30.2	31.9	33.6	35.5	37.2	46.4	5.3	4.5	FILMS
% LLDPE	40	41	42	44	46	48	50	52	61			
HDPE	19.2	21.3	22.6	24.5	26.1	27.8	29.6	31.2	41.0	6.8	5.6	
Total Polyethylene	45.1	48.7	51.0	54.7	57.9	61.4	65.1	68.4	87.4	6.0	5.0	

Chevron Phillips

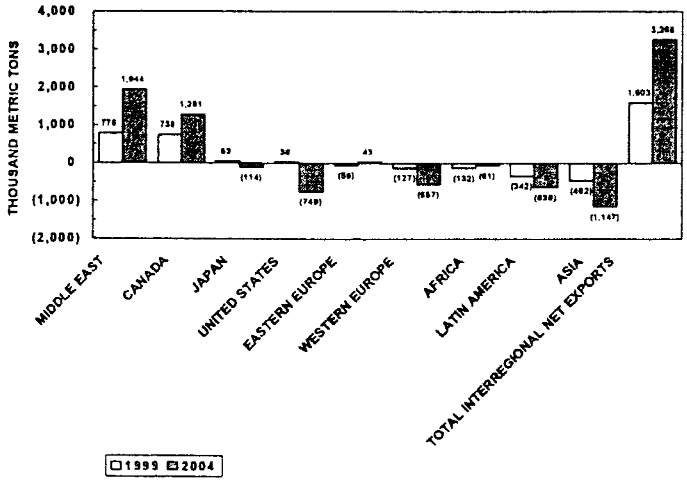
LLDPE outlook (Chem Systems)

LLDPE DEMAND, 1999-2010



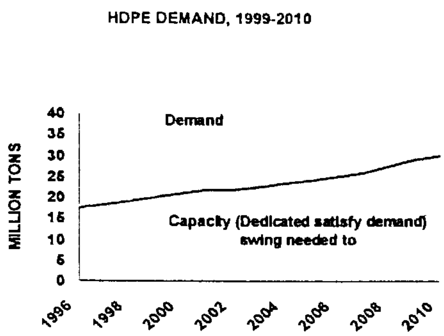
Chevron Phillips

Global LLDPE trade pattern[1]

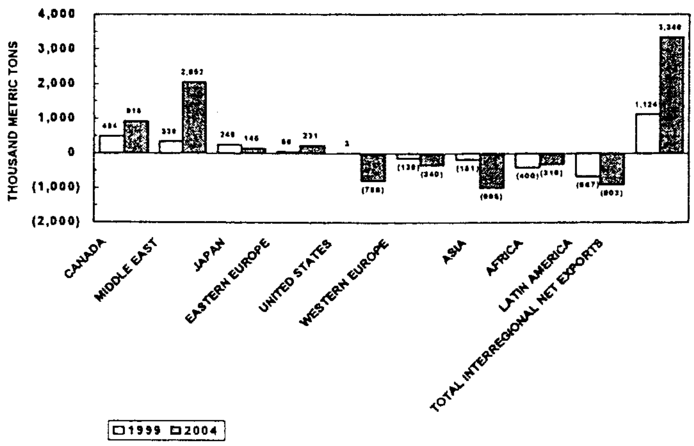


[1] NEGATIVE INDICATES NET IMPORTER

HDPE outlook (Chem Systems)



Global HDPE trade pattern[1]



[1] NEGATIVE INDICATES NET IMPORTER

Chevron Phillips

Western Europe – HDPE Demand

2002 Thousand Metric Ton (Chem Systems)

	Demand	Growth(%)
BLOW MOLDING	1980	4.2
INJECTION MOLDING	1160	3.7
PIPE & CONDUIT	960	7.8
FILM	870	4.9
FIBER	110	1.3
SHEET	100	5.0
WIRE & CABLE	50	3.0
ROTOMOLDING	40	4.5
TOTAL	5270	4.8

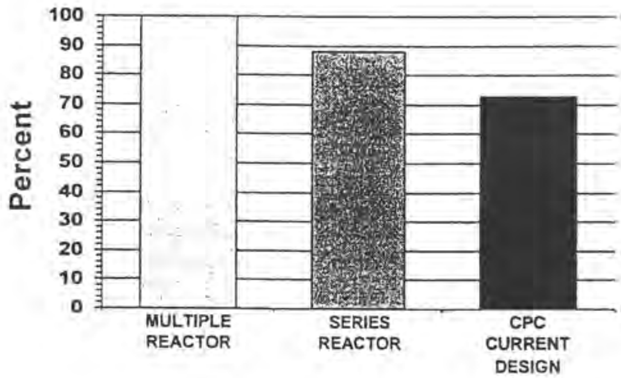
Chevron Phillips

Chevron Phillips Chemical Company LP

SLURRY LOOP REACTOR IS NOT LIMITED IN CAPACITY

250,000 MTA	LARGEST PLANT BUILT TO DATE
320,000 MTA	DESIGN COMPLETE, CONSTRUCTION TO BEGIN SOON
400,000 MTA	FEASIBILITY STUDY COMPLETE, NEGOTIATIONS UNDERWAY

CPC LOOP CAPITAL COST COMPARISON TO MULTIPLE REACTORS SYSTEMS
(ESTIMATE OF CAPITAL COST)



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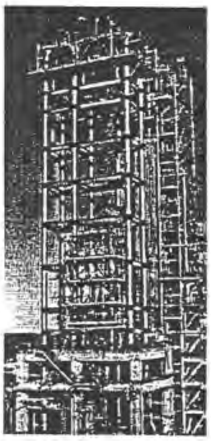
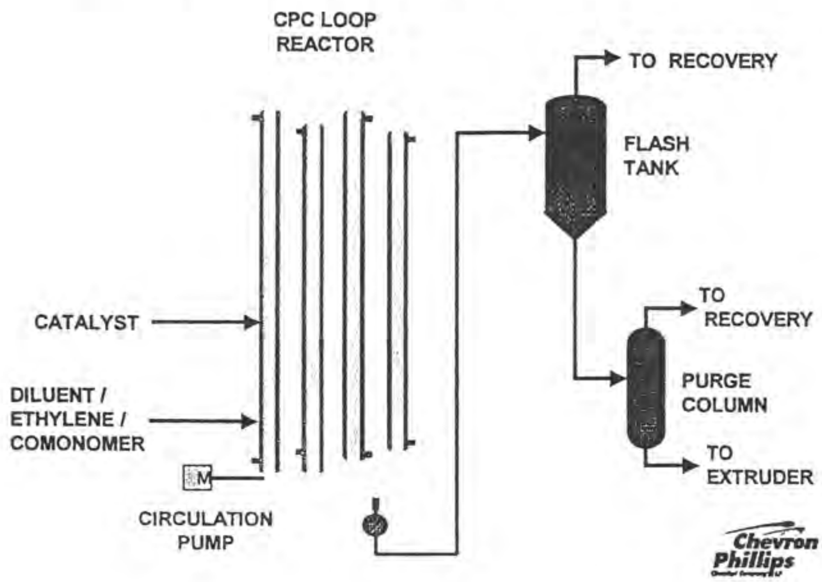
Pipe Loop Reactor Advantages



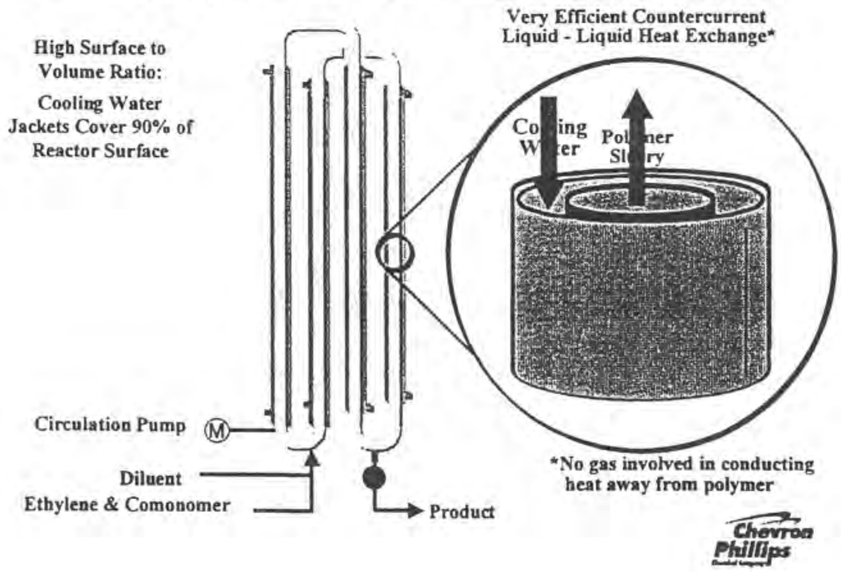
- Simple Design
- Easy To Operate
- Rapid Transitions
- Modular Design

Chevron Phillips

CPC Polyethylene Process



CPC Loop Reactor Has High Heat Removal



FEATURES OF CPC LOOP REACTOR PROCESS

- Transport Diluent has Low Boiling Temperature and High Swelling Temperature
- Uses Polymerization Grade Feedstocks – the same as Other PE Processes
- Has High Productivity so no Catalyst Removal is Necessary
- Has High Heat Removal Capability at Relatively Low Temperature
- Has a Uniform, Turbulent Transport Velocity to Maximize Mixing and Heat Transfer with Minimal Eddying

Chevron Phillips

TYPICAL COMMERCIAL PIPE LOOP REACTOR

Volume - 40-150 m^3

Area/Volume - 6-7 m^2/m^3

Chevron Phillips

COMMERCIAL LOOP REACTOR KINETICS

- Heat Transfer Coefficient
  = 800 - 1200 kcal/m^2/C/hr
- Typical Ethylene Conversion
  per Pass = 97+ %
- Typical Residence Times 1 HR.~

PROCESS IMPROVEMENTS

- Improved Reactor Pump
- Increased Reactor Size
- Improved Catalyst Feed
- Continuous Product Take-off
- In-line Process Heat Exchangers to Help Devolatization
- Modified Flash System
- Reduced Compressor Requirements
- Improved Recycle System
- Streamlined Product Flow

TECHNOLOGY PACKAGE

- Kickoff Premises Meeting
- Orientation Meeting
- Technology Manuals
- Laboratory Analysis Manuals
- Process Design Package
- Review of Process Design Package with Licensee

Chevron Phillips

TECHNOLOGY PACKAGE

- Technical Assistance During Mechanical Design and Construction of Plant
- Review of Mechanical Flowsheets
- Hazop Assistance
- Training of Licensee Operating and Laboratory Personnel
- Plant Inspection
- Plant Startup Assistance

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PROCESS DESIGN PACKAGE

- Process Design Premises
- Process Description
- Heat and Material Balances
- Process Flow Diagrams
- Equipment List
- Specifications and Load Sheets

Chevron Phillips

PROCESS DESIGN PACKAGE

- Utility Summary
- Preliminary Process Hazards Analysis
- Waste Minimization Report
- Review Of Process Design Package With Licensee

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WORLDWIDE STATUS OF CPC LINEAR POLYETHYLENE PROCESS

Worldwide Polyethylene Licensees

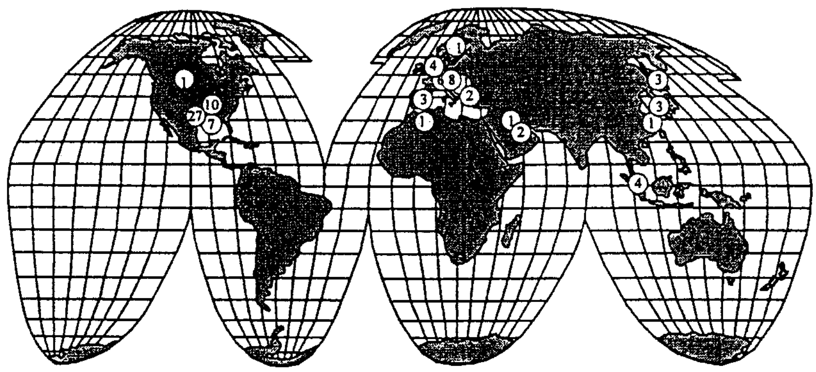
- UNITED STATES
- UNITED KINGDOM
- BELGIUM
- SPAIN
- HUNGARY
- NORWAY
- GERMANY
- THAILAND*
- ALGERIA
- YUGOSLAVIA
- IRAQ
- SINGAPORE
- JAPAN
- KOREA
- CHINA (PRC)
- QATAR*

*LOI Signed

Chevron Phillips

CPC LICENSED POLYETHYLENE PLANTS

(NUMBERS INDICATE NUMBER OF REACTORS)



Total Number* of CPC Loop Reactors <u>86</u>!

* Built or under construction

Chevron Phillips

CPC RECENT EXPERIENCE

1997 – PPSC2 (Singapore)	210,000 MTA
1998 – Shanghai Golden (China)	100,000 MTA
1999 – Fina Oil & Chemical (U.S.)	180,000 MTA
2001 - POLYMED (Algeria)	130,000 MTA
2001 – Formosa Plastics (U.S.)	250,000 MTA
2002 – Qatar Chemical (Qatar)	475,000 MTA
2002 – Cedar Bayou (U.S.)	320,000 MTA
200x - Qatar Chemical (Qatar)	750,000 MTA
Since 1997	2,450,000 MTA

Chevron Phillips

INFORMATION EXCHANGE PROGRAM

- Bi - Annual Information Exchange Meetings with Other Licensees
- Individual Licensee Meetings on Periodic Basis
- Information Exchange Through Correspondence

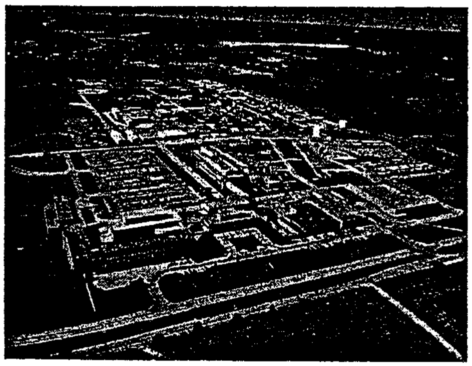
Chevron Phillips

INFORMATION EXCHANGE BENEFITS

- Plants can be Updated as Soon as Improvements in Process Operation are Developed
- Resins can be Continuously Improved as New Technology is Commercialized
- Expertise Level of Licensee Operating Personnel can be Broadened by Exposure to Peer Groups from Other Operating Plants

Chevron Phillips

U.S. RESEARCH & DEVELOPMENT FACILITY



- Complete
- Modern
- Dedicated to Polymer Research

Chevron Phillips

U.S. RESEARCH & DEVELOPMENT FACILITY

- Bench Scale Reactors
- ~~Two~~ 3 Loop Reactor Pilot Plants
- Extrusion Pilot Plant
- Plastics Technical Center
- Evaluations Laboratory

Chevron Phillips

SCOPE OF R & D ACTIVITIES

- Evaluate New Catalysts in the Continuous Process
- Develop Polymerization Conditions and Process Technology for Commercial Use of New Catalyst
- Produce Polymers for PTC Evaluations

Chevron Phillips

SCOPE OF R & D ACTIVITIES (Cont.)

- Assist CPC Licensee and Commercial Plants
- Develop Improved Process Technologies
- Explore Lower Cost Routes for Manufacturing Current Products

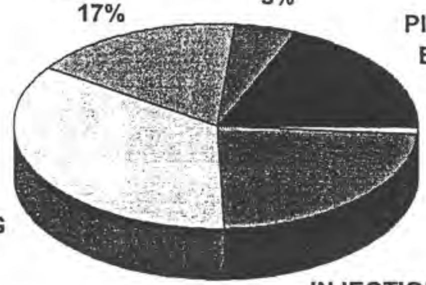
Chevron Phillips

CPC

PE PRODUCT

LINE

North America HDPE Demand by Application



Source: ChemSystems

Chevron Phillips

Broadest Product Line

- BLOW MOLDING
- PIPE
- GEOMEMBRANE
- SHEET & THERMOFORMING
- INJECTION MOLDING
- ROTATIONAL MOLDING
- FILM
- STRETCHED TAPE & MONOFILAMENT
- WIRE & CABLE COATING

Chevron Phillips

CPC HDPE Blow Molding Resins For Household and Industrial Chemical (HIC) Containers

Chevron Phillips

CPC HDPE Blow Molding Resins For Household and Industrial Chemical (HIC) Containers

	DENSITY	MELT INDEX	ESCR
HHM 4903	0.949	0.30	500
HHM 5202	0.952	0.35	50
HHM 5502	0.955	0.35	45

Chevron Phillips

Blow Molding Resins for Large Tough Parts

Chevron Phillips

Blow Molding Resins for Large Tough Parts

	HXM 50100	HXM TR-570	HXM TR-550
DENSITY, gm/cm^3	0.950	0.953	0.951
MELT INDEX (21.6), dg/min	10	5	2
ESCR (Cond. A), F_{50} hrs	800	>1000	>1000
IMPACT*, dm	30	61	76

* 34-LITER CONTAINER, NOMINAL FILL, 23°C

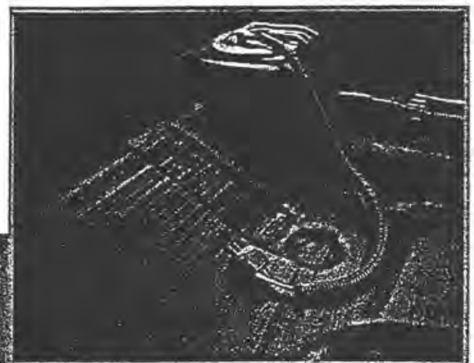
Chevron Phillips

CPC HIGH-PERFORMANCE L-RING DRUM RESIN

Chevron Phillips

CPC

HIGH-PERFORMANCE



FUEL TANK
RESIN

Chevron Phillips

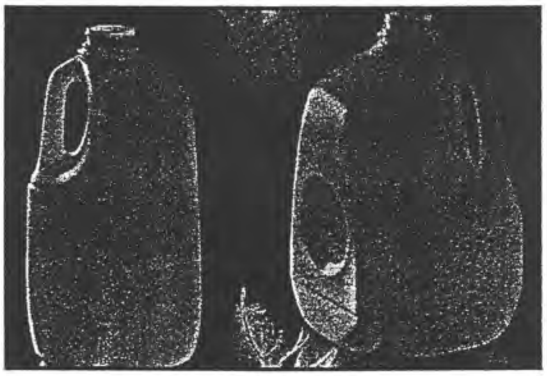
CPC ADVANCED HIGH-PERFORMANCE FUEL TANK RESIN

	SLURRY LOOP RESIN*	CPC C579
DENSITY, g/cm³	0.946	0.945
MELT INDEX (21.6), dg/min.	6	5
TENSILE IMPACT, kJ/m²	395	765
ESCR (Cond. B, 10%), F_{50} hrs	675	>2000

* Most popular resin sold for use in automotive fuel tanks in Europe.

Chevron Phillips

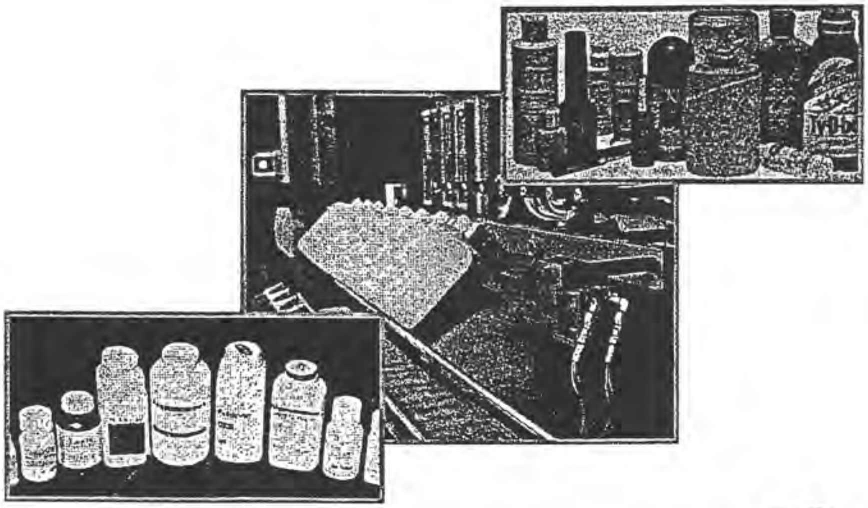
CPC Blow Molding Resins for Water, Juice and Milk



CPC Blow Molding Resins for Water, Juice and Milk

	EHM 6006	EHM 6007
DENSITY, g/cm^3	0.964	0.964
MELT INDEX, g/10 min.	0.75	0.70
FLEX MODULUS, kg/cm^2	16,800	17,000
ESCR (Cond. A), F_{50} hrs	18	15
DIE SWELL, % (UNILOY)	45	39

INJECTION BLOW MOLDING



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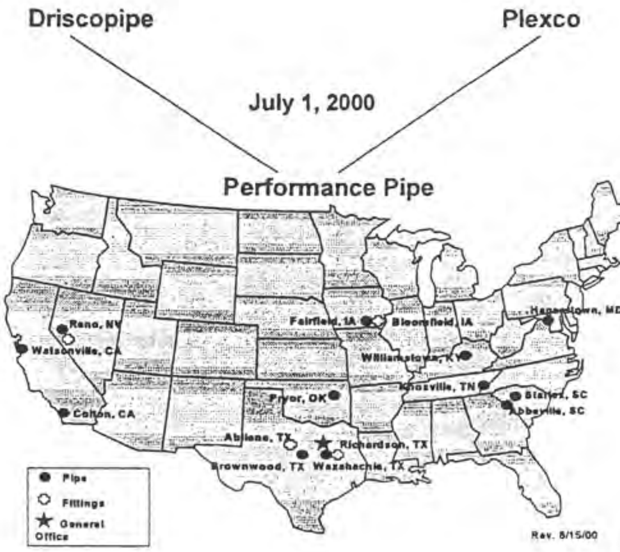
INJECTION BLOW MOLDING RESINS

	HHM 5202 ZN	HHM 5502 ZN	HMN 5710
DENSITY, g/cm^3	0.952	0.955	0.957
MELT INDEX (2.16), dg/min.	0.35	0.35	1.00
ESCR (Cond. A, 10%), F_{50} hrs	50	45	30

Chevron Phillips



APPLICATIONS

Water

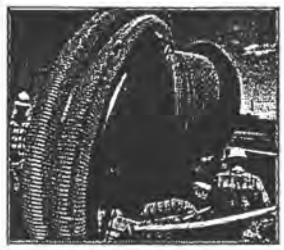
- Potable Water
- Reclaimed Water

Sewer

- Force Mains
- Gravity Sewer
- Slip Lining
- Directional Drilling

PIPE APPLICATIONS

Water Distribution



Conduit

Sewer

APPLICATIONS

Gas

- Gas Utilities
- Methane Gas (Landfills)
- Gas Gathering, Oil and Gas Fields

Mining

- Coal
- Metals (gold, copper, etc)
- Sand
- Slurry Lines
- De watering Lines
- Chemical Lines

PIPE APPLICATIONS

Natural Gas

Mining

Slip Lining

Chevron Phillips

APPLICATIONS

Plant Piping

- Fire Water Lines
- In Plant Piping
- Chemical Lines

Duct

- Electrical
- Telecom

Other

- Geothermal
- Custom Products

Chevron Phillips

COMMERCIAL PIPE SIZES

Sizes - 1/2" - 54" (10 mm – 1.4 m)

Pressure - 45 PSI - 190 PSI

Dimensions

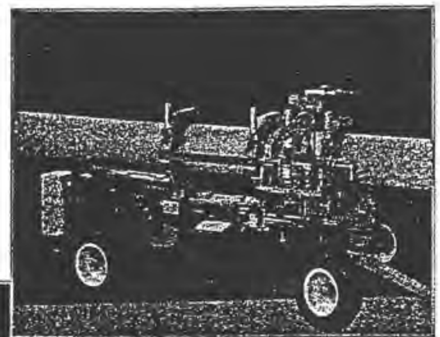
- Iron Pipe Size
- Ductile Iron Size
- Metric

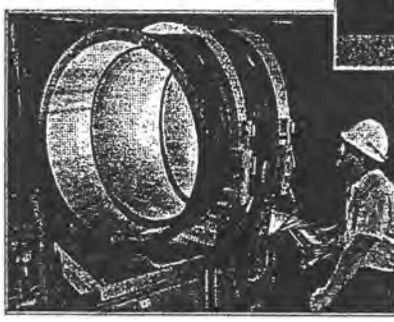
CPC ADVANCED PIPE RESINS

	HHM TR-418	HHM TR-480
DENSITY*, g/cm^3	0.950	0.954
MELT INDEX, dg/min	0.25	0.25
ESCR (Cond. C), F_{50} hrs	>5000	>5000
HYDROSTATIC DESIGN BASIS, kg/cm^2		
$20^{0}C$	88	112
$60^{0}C$	56	56

* contains pigment

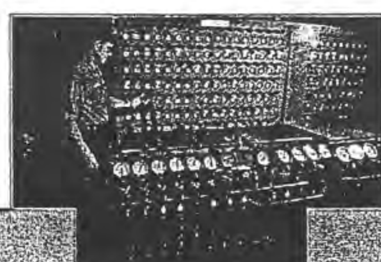
Polyethylene Pipe Joint Technology



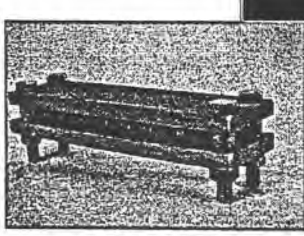


Chevron Phillips

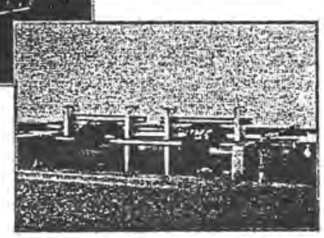
Extensive Pipe Testing Capability



HYDROSTATIC



RING ESCR



SLOW CRACK GROWTH

Chevron Phillips

CPC Advanced Pipe Resins

	HOSTALEN GM 5010 T2	UNION CARBIDE DGDA 2480	CPC HHM TR-480	CPC HHM TR-418
HYDROSTATIC DESIGN BASIS, Kgf/cm^2				
23°C	112	112	112	88
60°C	56	56	56	56
SLOW CRACK GROWTH RATE, Days To Failure	8-16	>16	>32	>32
RING ESCR, Hr	190	220	>1000	>1000

Chevron Phillips

CPC Advanced PE100 Pipe Resin

	TR-480	H516
NATURAL DENSITY, g/cm^3	0.944	0.950
MELT INDEX, dg/min.	0.10	0.10
TENSILE STRENGTH, psi (Mpa)	3200 (22)	3700 (26)
PENT, HOURS	150	>1000
HYDROSTATIC DESIGN BASIS, psi (Mpa)		
73°F (23°C)	1600 (11)	1600 (11)
140°F (60°C)	800 (5.5)	1000 (6.9)
PPI DESIGNATION	PE 3408	PE 3408
ISO 9080	PE 80	PE 100

Chevron Phillips

PIPE LICENSE OFFERINGS:

Market Survey

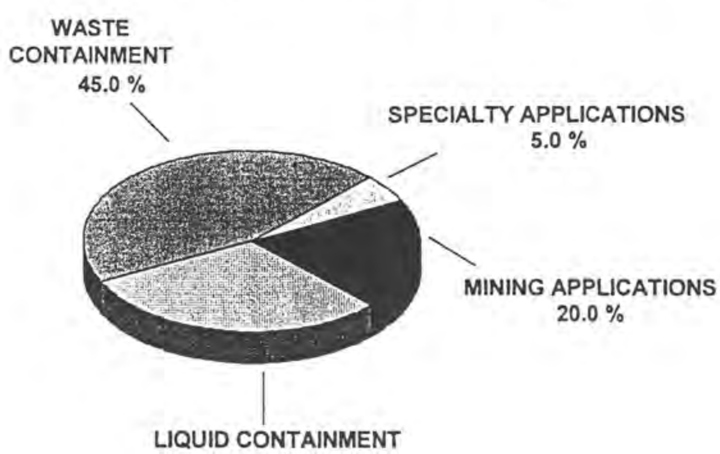
Plant Layout, Design and Operation

Applications and Sales

Training, Lab and Technical Support

Chevron Phillips

U.S. AND CANADIAN GEOMEMBRANE MARKET BY APPLICATIONS



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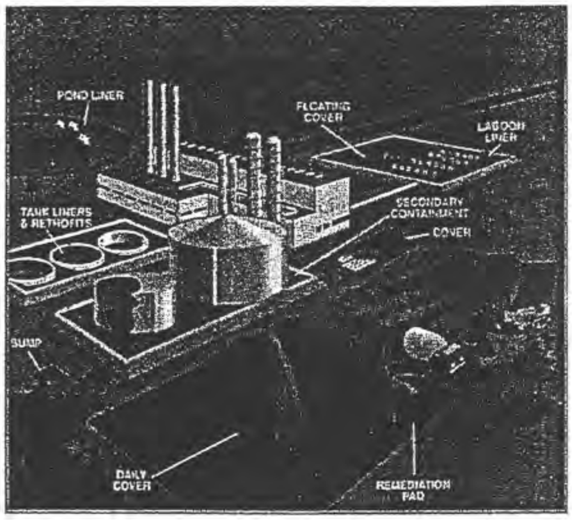
LDLPE GEOMEMBRANE APPLICATIONS



Chevron Phillips

CPC ADVANCED GEOMEMBRANE RESIN

	UNIPOL GAS PHASE RESIN	UNIPOL GAS PHASE RESIN	CPC TR-400G
DENSITY, g/cm^3	0.940	0.933	0.938
MELT INDEX (21.6), dg/min	20	14	13
TENSILE STRENGTH (Yield), kg/cm^2	195	175	200
TENSILE IMPACT, kJ/m^2	290	340	390
SP-NOTCHED CONSTANT TENSILE LOAD* (ASTM D5397 Appendix), hrs	970	>1,000	>1,000
PROCESSABILITY, Round Die	Ok	Poor	Excellent

* a.k.a. Landers ESCR

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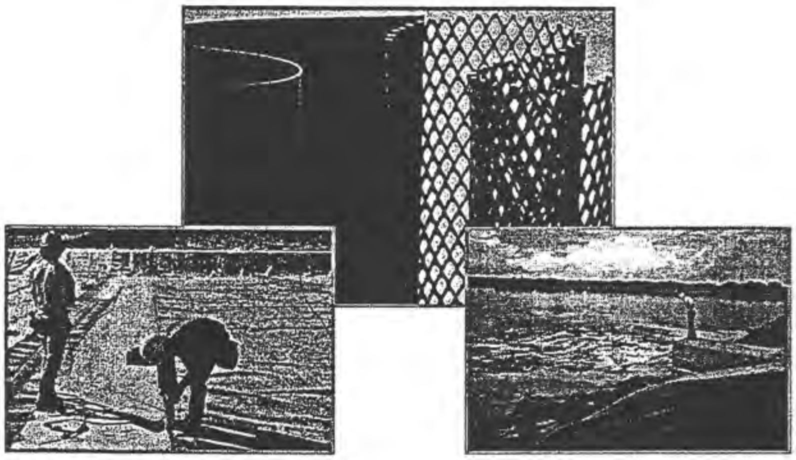
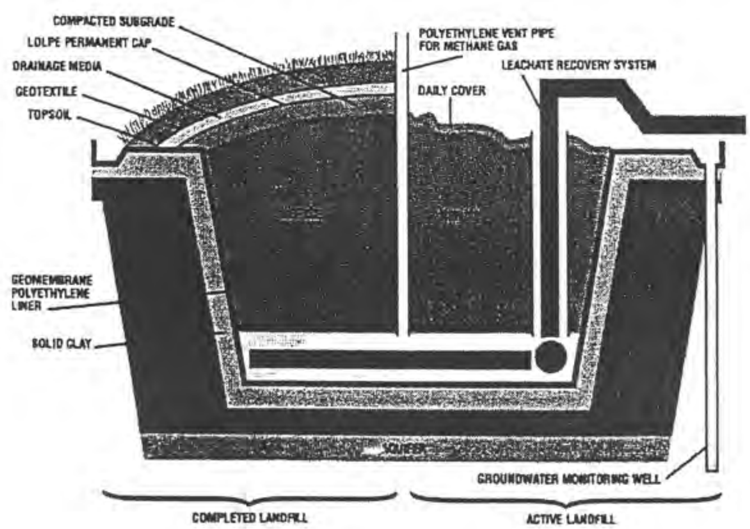
GEOMEMBRANE APPLICATIONS



HDPE / MDPE / LDLPE LANDFILL APPLICATIONS



CPC ADVANCED GEOMEMBRANE RESIN: LANDFILL CAP

	GAS PHASE VLDPE	CPC K203
DENSITY, g/cm^3	0.911	0.924
MELT INDEX (2.16), dg/min.	0.30	0.21
TENSILE STRENGTH (Yield), Kg/cm^2	80	130
ESCR (Cond. B 10%), F_{50} hrs	>2,000	>2,000
WEATHERABILITY	Failures	Acceptable

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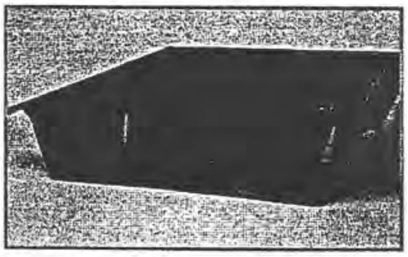
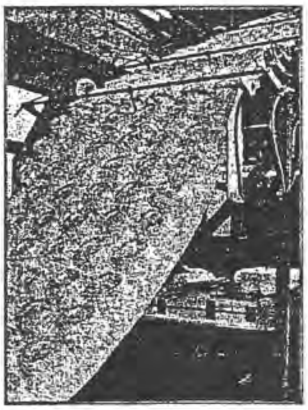
SHEET EXTRUSION / THERMOFORMING APPLICATIONS





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CPC ADVANCED SHEET EXTRUSION THERMOFORMING RESINS

	HMN 5202	HXM 50100	HHM 4903	HHM TR-400
DENSITY, g/cm³	0.952	0.950	0.949	0.935
MELT INDEX (HLMI)	0.35	(10)	0.30	500
ESCR (Cond. A)	50	800	500	>1000

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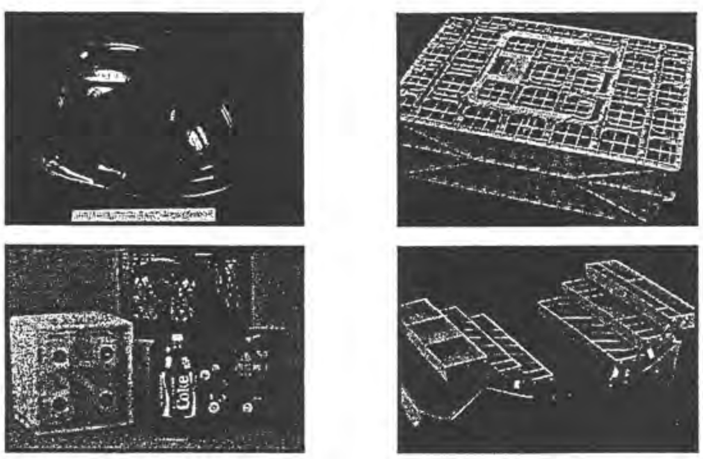
INJECTION MOLDING APPLICATIONS REQUIRING TOUGHNESS



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INJECTION MOLDING RESINS FOR TOUGHNESS

	HMN 4550	HMN 5060	HMN 5580	HMN 6060
MELT INDEX (2.16), dg/min	5.0	6.0	8.5	7.5
DENSITY, g/cm^3	0.945	0.950	0.956	0.963
ESCR (Cond. A), F_{50} hrs	40	15	10	10

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INJECTION MOLDING APPLICATIONS REQUIRING GOOD PROCESSABILITY

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INJECTION MOLDING RESINS FOR PROCESSABILITY

	HMN 55100	HMN 54140	HMN 55180
MELT INDEX (2.16), dg/min.	9.5	14	20
DENSITY, g/cm^3	0.955	0.954	0.955
ESCR (Cond. A), F_{50} hrs	<10	5	N/A*

Chevron Phillips

Applications Requiring High-Flow Resin

Chevron Phillips

CPC Advanced High-Flow Injection Molding Resin

	GAS PHASE RESIN	CPC B587
MELT INDEX (2.16), dg/min	61	64
DENSITY, g/cm^3	0.953	0.953
FLEXURAL MODULUS, kg/cm^2	12,400	13,100
INJECTION MOLDING EVALUATION		
BOWL IMPACT, joules		
Ambient Temperature	13.0	20.0
-18^{o}C	13.6	17.4
WARPAGE, mm	15.1	10.8

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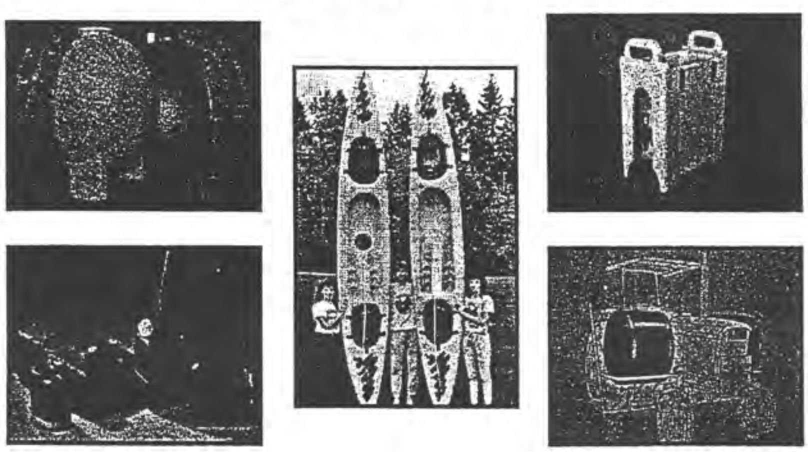
ROTATIONAL MOLDING APPLICATIONS



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CPC ROTATIONAL MOLDING RESINS

	TR-938	TR-942	TR-950	TR-954
DENSITY, g/cm^3	0.938	0.942	0.950	0.954
MELT INDEX (2.16), dg/min	3	3	6	8
ESCR (Cond. A), F_{50} hrs	>1000	175	20	10

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HDPE BLOWN FILM APPLICATIONS

Chevron Phillips

CPC HDPE MEDIUM MOLECULAR WEIGHT RESIN FOR FILM

	TR-130	TR-140	TR-144	TR-166
DENSITY, g/cm^3	0.939	0.947	0.947	0.963
MELT INDEX	0.20	0.28	0.18	6.00
MWD	medium	medium	medium	narrow
DART IMPACT	90	75	90	115*

*DETERMINED ON CAST FILM

Chevron Phillips

CPC HIGH MOLECULAR WEIGHT RESIN FOR FILM

	MOBIL HTA 001	CPC TR-168
DENSITY, g/cm^3	0.948	0.950
MELT INDEX (21.6), g/10min.	9	10
BLOW FILM PROPERTIES*		
SPENCER IMPACT, mJ	520	530
DART DROP, g	220	210
ELMENDORF TEAR, g		
MD	17	17
TD	160	250

*FLH= 8 die diameters, BUR= 4, THICKNESS=25 microns

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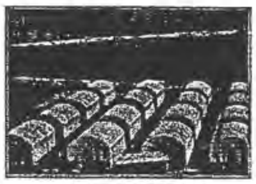
LLDPE BLOWN FILM APPLICATIONS

STORAGE BAGS

PLIABLE MERCHANT BAGS

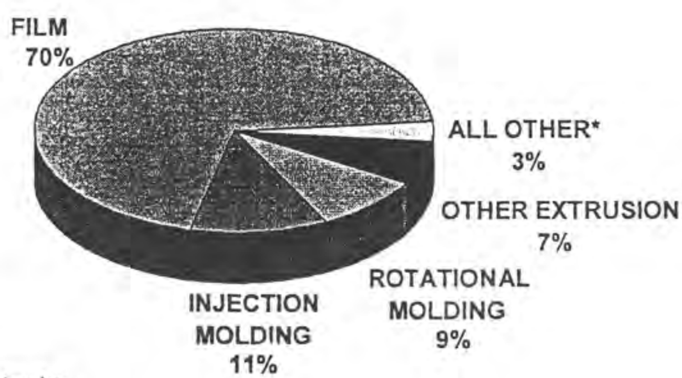


GREENHOUSES

PRODUCE BAGS

North America LLDPE Demand by Application

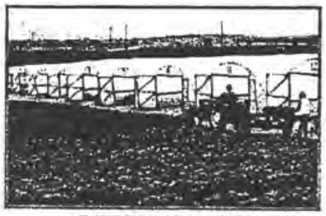
Total 4,381,000 MT



* Including extrusion coating & blow molding

Source: ChemSystems

LOW DENSITY LINEAR POLYETHYLENE APPLICATIONS



GREENHOUSES

TUBING

SILAGE WRAP

SHIPPING SACKS

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CPC LDLPE COMPARED TO LLDPE

	GAS PHASE LLDPE	OCTENE SOLUTION LLDPE	CPC D252 LDLPE
DENSITY, g/cm^3	0.920	0.921	0.921
MELT INDEX			
(2.16), dg/min	0.8	1.0	0.2
DART IMPACT			
(66 cm), g	150	300	350
ELMENDORF TEAR, g			
MD	145	340	170
TD	370	600	580

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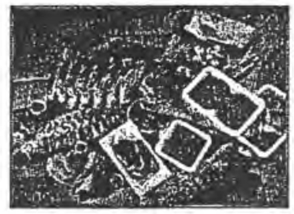
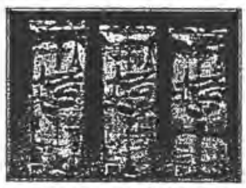
mLLDPE FILM FOR PACKAGING APPLICATIONS

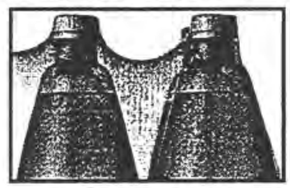
PRODUCE PACKAGING



MEAT PACKAGING



BREAD PACKAGING



BEVERAGE WRAP

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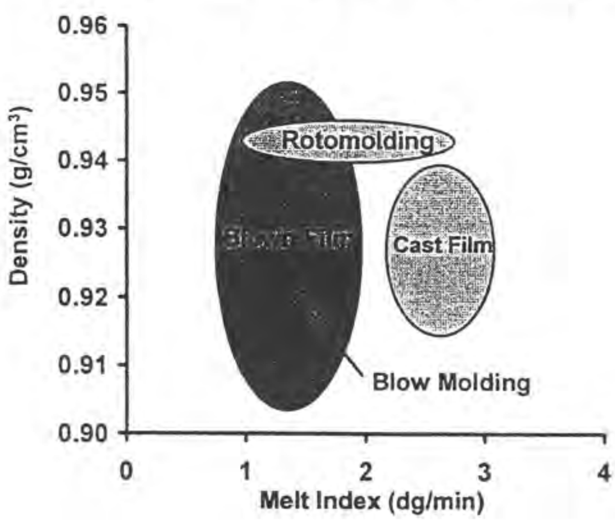
CPC METALLOCENE RESINS



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PHYSICAL PROPERTIES OF SOME CPC METALLOCENE POLYETHYLENE RESINS*

	D143	D139	D350
DENSITY, g/cm³	0.916	0.918	0.933
MELT INDEX (2.16), dg/min	1.3	1.0	1.0
HAZE, %	4	5	7
1% SECANT MODULUS, psi	21000	34000	61600
DART DROP (66 cm), g	>1,100	> 810	120
HEAT SEAL INITIATION TEMP. @ 0.3 lbf/in.,°C	101	104	120

*25-micron blown film

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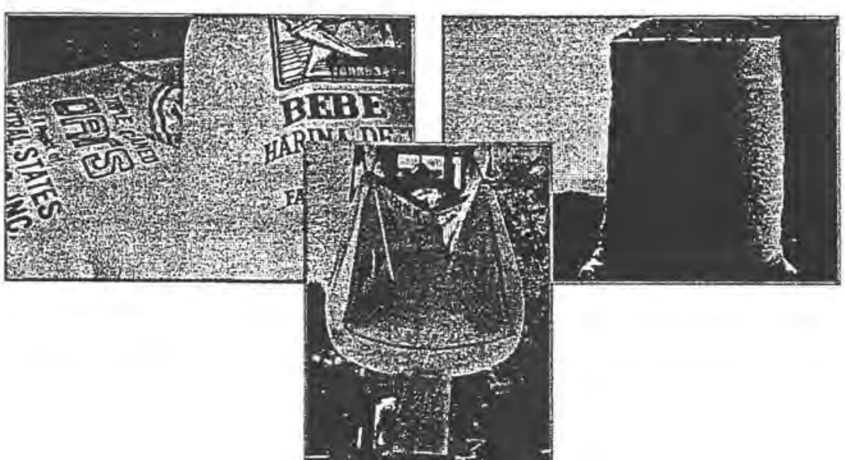
Often blends of PE & PP

STRETCHED TAPE AND MONOFILIMENT



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CPC RESINS FOR STRETCHED TAPE

	HHM TR-147	HMN 5710
DENSITY, g/cm^3	0.951	0.957
MELT INDEX, g/10 min.	0.6	1.0
MOLECULAR WEIGHT DISTRIBUTION	MEDIUM	NARROW
TENSILE AT BREAK*, kg/cm^2	450	475
ELONGATION AT BREAK*, %	540	570

* USING MONO-ORIENTED 60μ FILM

Chevron Phillips

COMMERCIAL SRETCHED TAPE EVALUATION BY WINDMÖLLER AND HÖLSCHER

	MARLEX HMN 5710	REQUIREMENT
LINE SPEED, m/min.	250	>230
TENACITY, g/denier	5.6	>5.3
ELONGATION, %	28.2	>25

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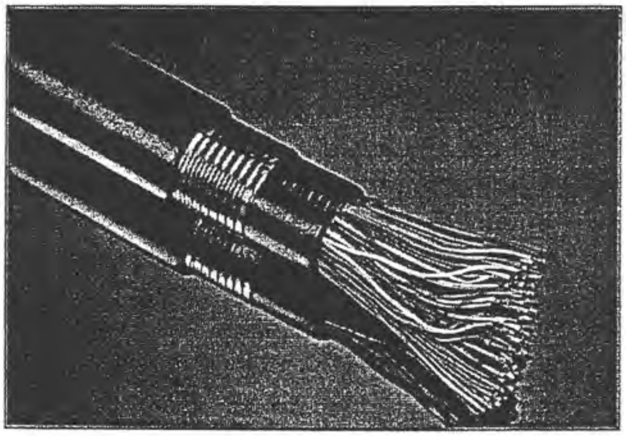
CPC POLYETHYLENE FOR TELECOMMUNICATION SINGLES APPLICATION



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CPC POLYETHYLENE FOR TELECOMMUNICATIONS INSULATION

	TR-210	TR-226
DENSITY, g/cm³	0.944	0.944*
MELT INDEX (2.16), dg/min.	0.85	1.5
ESCR	500	100

*Unfoamed Density

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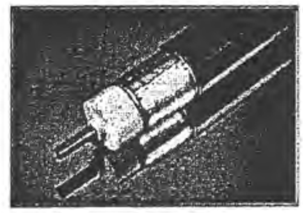
CPC POLYETHYLENE FOR CABLE JACKETED APPLICATIONS

FIBER OPTICS



OCEAN

POWER

Chevron Phillips

CPC POLYETHYLENE FOR CABLE JACKETING

	TR-230	TR-232	TR-250
DENSITY, g/cm³	0.946	0.950	0.960
MELT INDEX (2.16), dg/min.	0.55	0.25	0.25
ESCR	>1000	>1000	200

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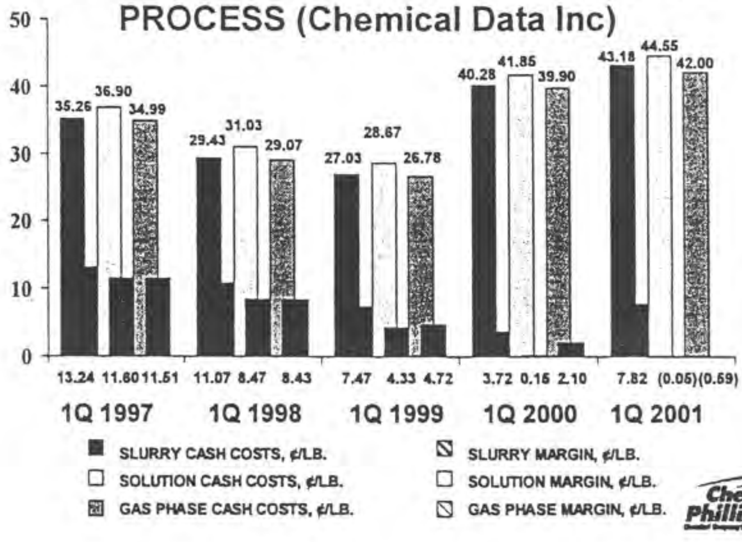
CONCLUSIONS

COMPARISON OF TOTAL CASH COSTS AND MARGIN FOR HDPE MADE IN THE U.S. BY PROCESS (Chemical Data Inc)



COMPARISON OF 5 YR AVERAGE OF MARGIN (¢/LB) FOR HDPE MADE IN U.S. 1997 THRU 2001
(CHEMICAL DATA INC.)

CPC SLURRY LOOP	SOLUTION	GAS PHASE
8.664	4.90	5.234

CHEVRON PHILLIPS ADVANTAGE BY OVER 3¢/LB

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WORLD-CLASS SLURRY LOOP PROCESS FOR POLYETHYLENE

- WORLD-WIDE RECOGNITION OF MARLEX
- ADVANCED REACTOR & CUTTING EDGE CATALYST
- RESINS ARE INDUSTRY STANDARDS
- HIGHEST PROFITABILITY
- QUICK TRANSITIONS AMONG RESINS
- HDPE AND LLDPE CAPABLE

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APPENDIX E

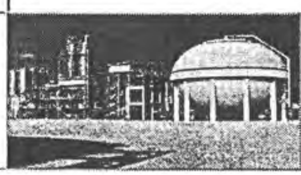
Novolen® Polypropylene Technology

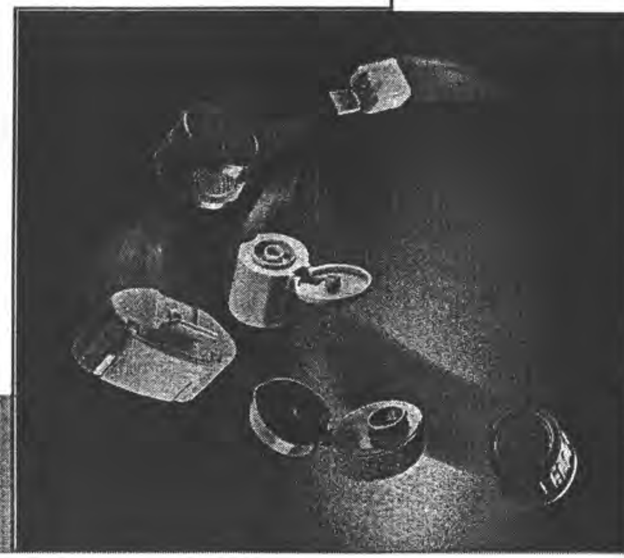
Polypropylene
Novolen Technology Holdings

HIP Presentation,

Bloomfield, NJ

11 September 2002





Novolen TECHNOLOGY

A joint venture of ABB and Equistar

Outline

- Novolen Technology Holdings (NTH)
- The Basics of Polypropylene
- Polypropylene Applications
- World Polypropylene Markets
- Process
- Commercial Products
- Novolen Technical Support
- Summary

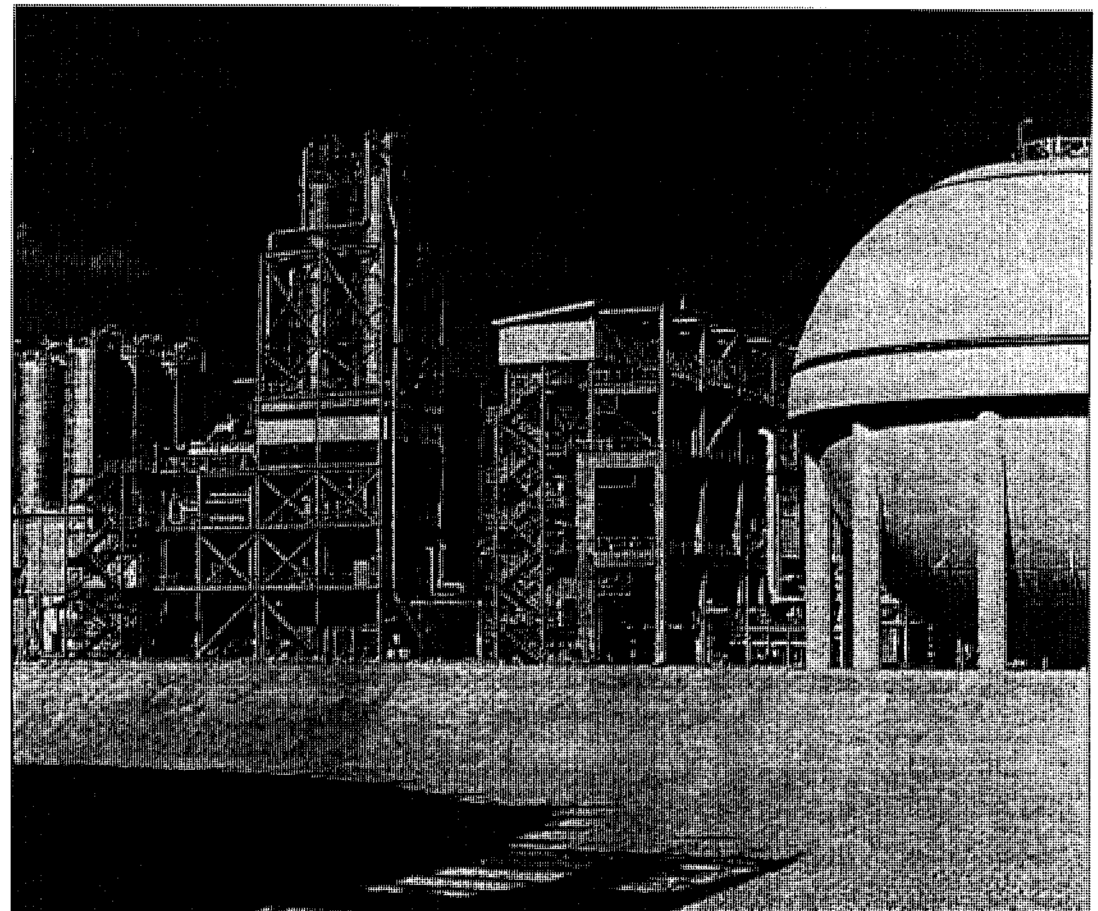
Novolen Technology Holdings

- One of the requirements for the formation of Basell in 2000 was the need to divest the Novolen Polypropylene process technology developed and supported world-wide by BASF (Targor)
- Novolen Technology Holdings was formed as an 80/20 joint venture of ABB and Equistar Chemicals
- A partnership was also arranged with Engelhard to support the commercial manufacture of catalysts for this process

Novolen TECHNOLOGY
A joint venture of ABB and Equistar

ABB - Engineering and Marketing Partner

- R & D
- Basic Engineering
- EPC
- Catalyst Supply
- Commissioning/Startup
- Technical Support unmatched by competitors
- Project Financing (ABB Financial Services)
- Product Off-Take
- Optimization/Integrated Solutions (C3 → PP)



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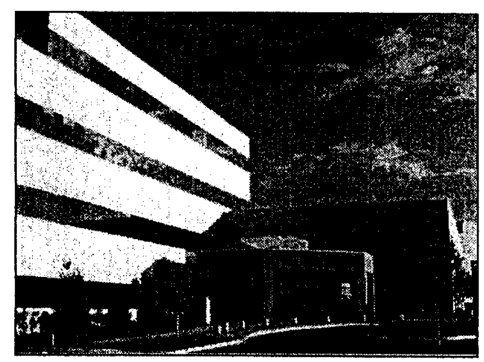
EQUISTAR - Research & Development Partner

- Major polyolefins manufacturer
- #1 North American propylene producer
- World class polyolefins research & development capabilities
- Novolen® licensee with more than 20 years of operating experience
- Novolen® pilot plant facility



Novolen TECHNOLOGY
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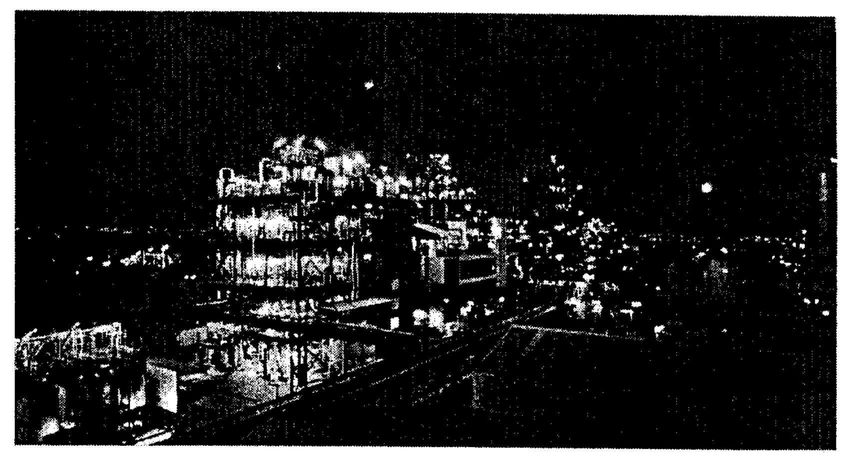
ENGELHARD
Change the nature of things.

- Catalyst Partner

- Leading Catalyst manufacturer
  - Focus on developing and producing catalysts
  - Manufacturing plants in different continents
  - Long history of catalyst production
  - Strong focus on catalyst research
  - Worldwide business
  - Established as reliable partner



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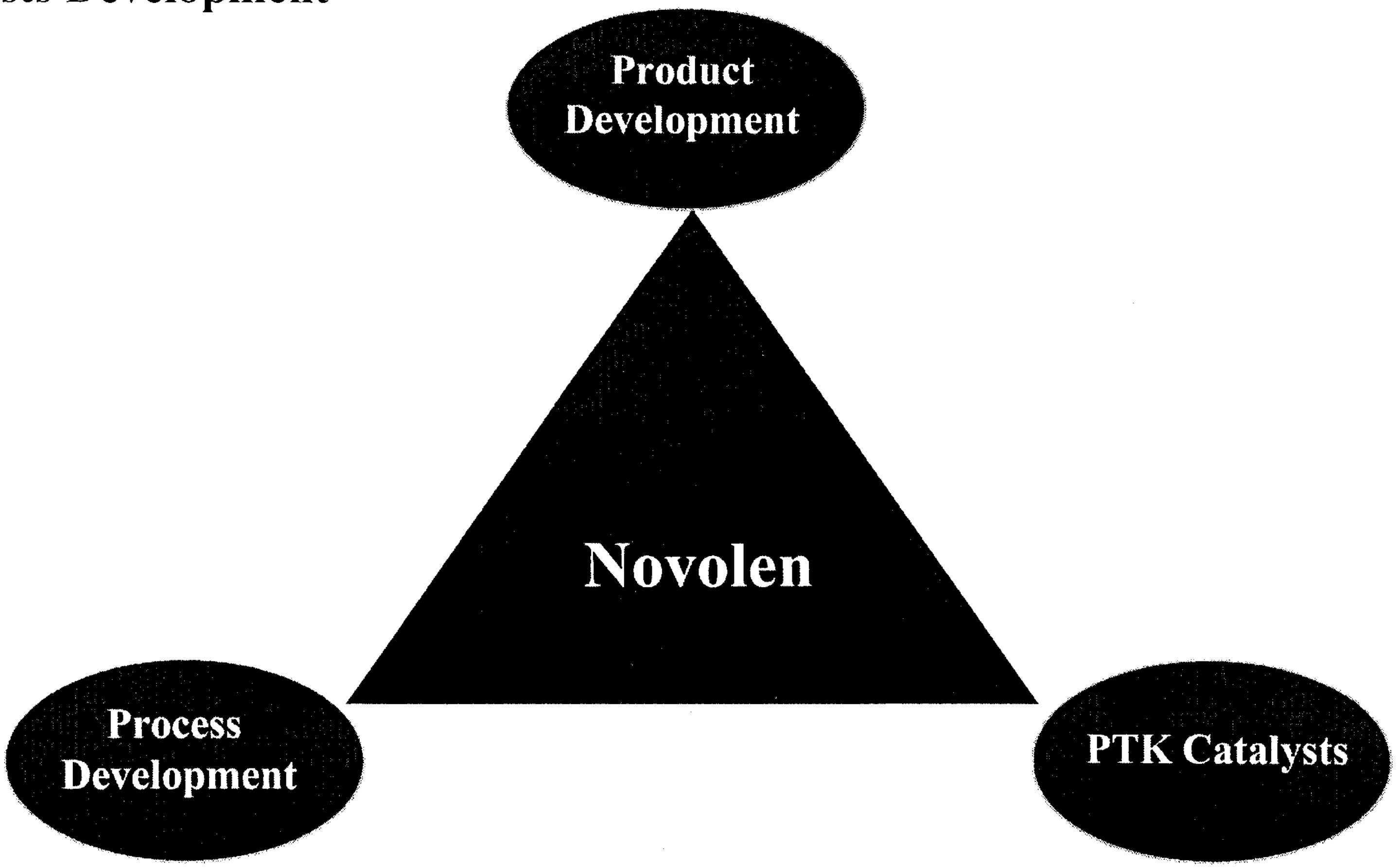
Pillars of the Novolen® Technology Business

The three pillars which comprise the Novolen® business are Product, Process and Catalysts Development



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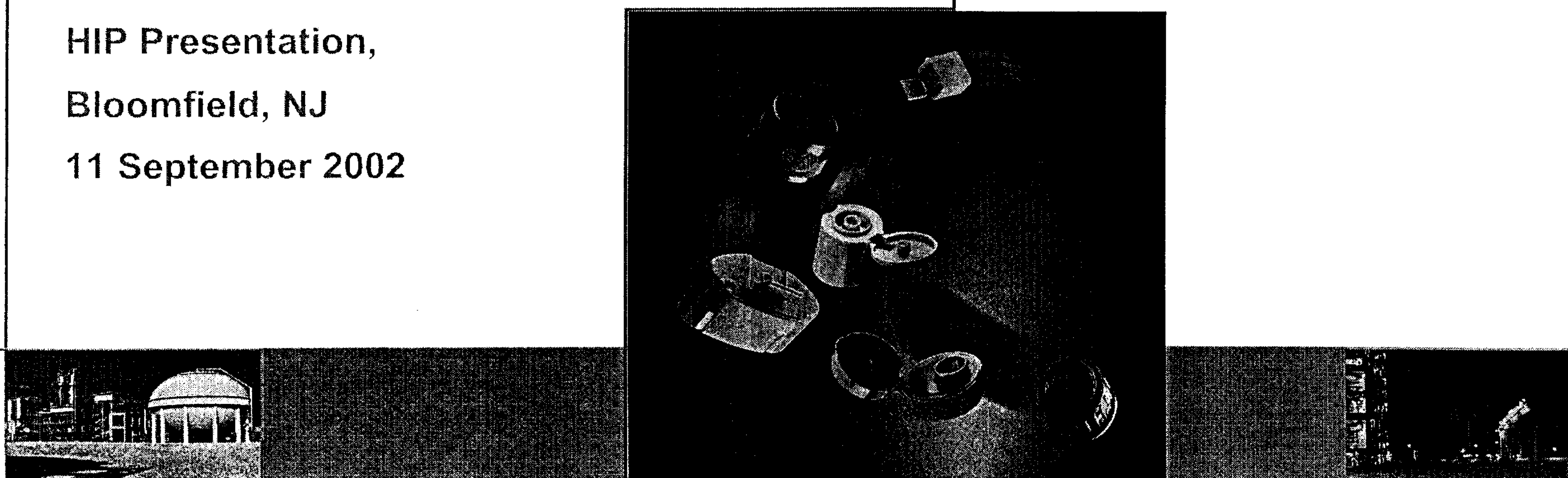
Polypropylene
The "Versatile" Polymer

HIP Presentation,

Bloomfield, NJ

11 September 2002



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Polypropylene

- First synthesized in a useful form in 1954 with Natta's development of stereospecific catalysts
- Polypropylene has grown to become one of the world's major polyolefins finding wide utilization in specialty and commodity applications
- It can also be synthesized in a number of different compositions
- Each of these compositions is unique and provides a spectrum of properties allowing Polypropylene to be used in applications ranging from raffia to high technology automotive applications

Polypropylene Compositions

- **Homopolymers**
  - **P-P-P-P-P-...-P-P-P-P-P...-P-P-P-P**
  - Polymer chain consists of propylene units only
- **Random Copolymers**
  - **P-P-P-C-P-P-C-P-...-P-P-C-P-P-P-P**
  - Polymer chain consists of propylene units and randomly distributed comonomer units (Comonomer: C_2, C_4)
- **Impact Copolymers (Heterophasic copolymers)**
  - **P-P-P-P-...-P - [P-E-P-E-E-P-...-E-P] - [E-E-E-...-E-E]**
  - Multiphase copolymers: homopolymer matrix and a dispersed phase of ethylene-propylene rubber
- **Random/Impact Copolymers (Random heterophasic copolymers)**
  - **P-P-C-P-...-P - [P-E-P-E-E-P-...-E-P] - [E-E-E-...-E-E]**
  - Multiphase copolymers: random copolymer matrix and a dispersed phase of ethylene-propylene rubber

Novolen TECHNOLOGY
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Characteristics of Polypropylenes

- All types of Propylene polymers share a number of key properties
  - Extremely versatile in processing and applications
    - Injection and blow molding, thermoforming, films, fibers, non-wovens,pipe, etc
  - Well balanced mechanical properties
    - stiffness / toughness / hardness
  - High heat deflection
  - Hard surface / scratch resistance
  - Excellent chemical resistance
  - Environmental stress crack resistance
  - Excellent dielectric properties
  - Low organoleptics (taste and odor)

Characteristics of Polypropylenes

- Homopolymers
  - High stiffness
  - Very high heat deflection characteristics
    - Steam sterilizable
  - Contact clarity
- Random Copolymers
  - Lower stiffness
  - High heat deflection characteristics
    - Can be hot filled
    - Steam sterilization possible
  - “See-through” clarity

Characteristics of Polypropylenes

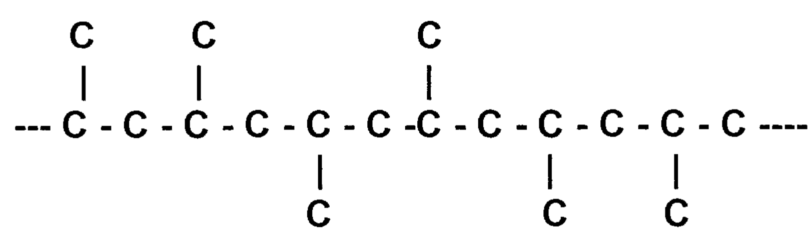
- Impact Copolymers and TPOs
  - Medium to high stiffness
  - High impact resistance is possible even at sub-ambient temperatures
  - High heat deflection characteristics
    - Can be hot filled
    - Steam sterilizable possible
  - Opaque
- Random-Impact Copolymers
  - Low stiffness
  - "Soft touch"
  - Toughness

Tacticity

The first polymerization of Propylene produced a material that was unlike that with which we are familiar

This was the “Atactic” form, a waxy, low-melting polymer.

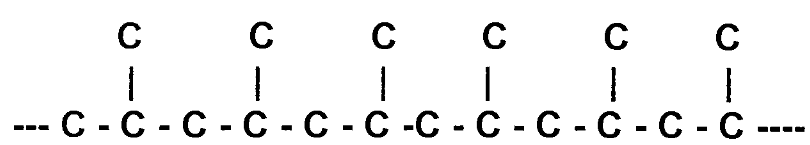
Atactic PP: no defined order to the placement of the monomer units



Tacticity

Natta's discovery of stereospecific catalysts provided the means to produce "Isotactic" Polypropylene, a hard, rigid thermoplastic

Isotactic PP: regular placement of the monomer units



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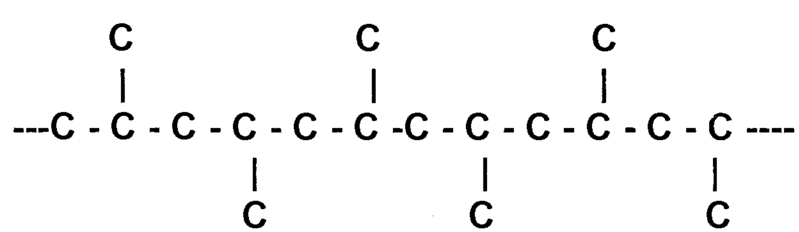
Tacticity

A third form of Polypropylene also exists and has, recently, been introduced on a semi-commercial basis.

It is characterized by its lower stiffness and heat resistance and its potential commercial niche is not well defined

Syndiotactic PP: alternating placement of the monomer units



Tacticity of Polypropylene (Summary)

- Isotactic Polypropylene
  - stereoregular arrangement of CH3 side groups
  - high crystallinity
  - high melting point (approximately 170 °C)
  - high stiffness & hardness
  - good heat distortion behavior
  - common Polypropylene materials have up to 99 % isotacticity
- Atactic Polypropylene
  - irregular arrangement of CH3 side groups
  - amorphous, not crystalline
  - waxy, sticky; By-product, applications : adhesives , bitumen additive
- Syndiotactic Polypropylene
  - alternating stereo arrangement of CH3 side groups
  - can be made by certain metallocene catalysts

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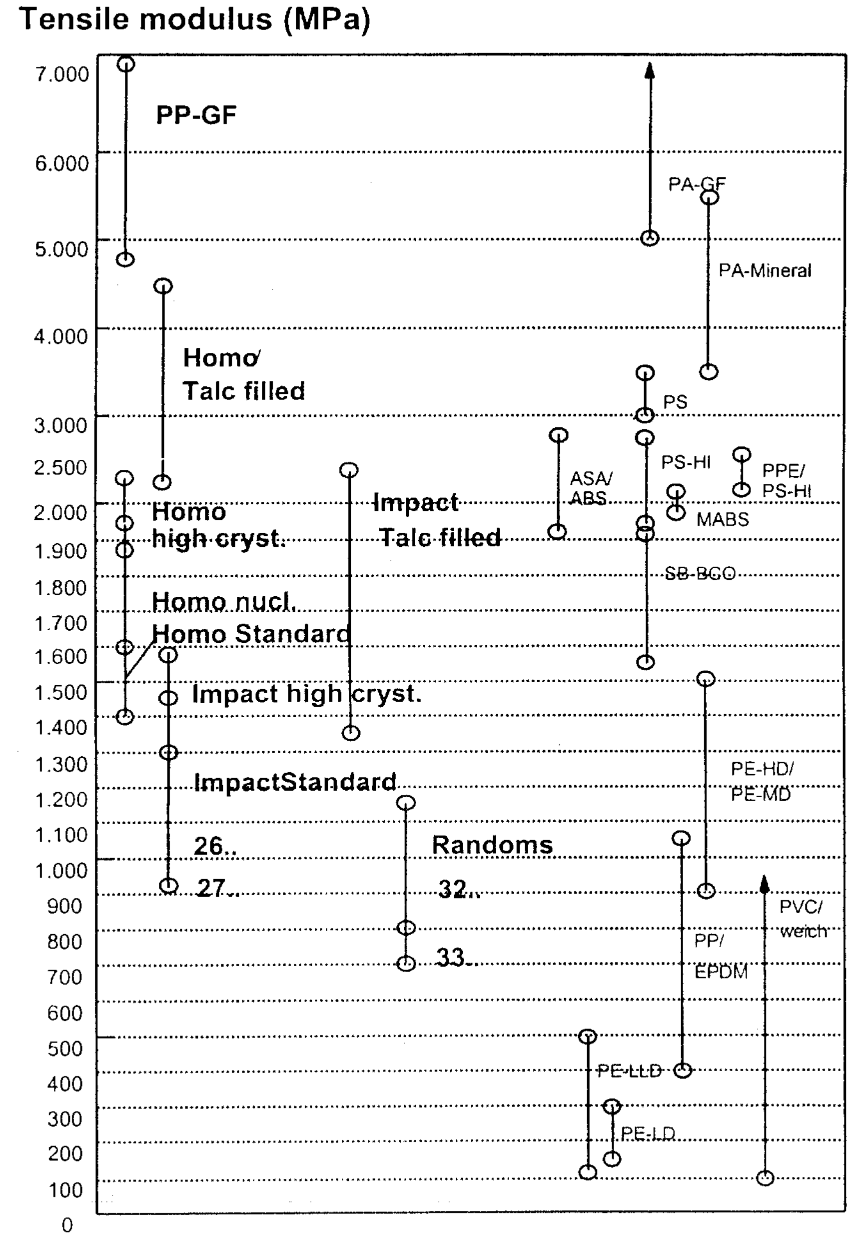
Specific Volumes of Plastics and other Materials

Volume/ Density- Ratios for different Materials (reciprocal densities; cm^3/g)

Thermoplastics		Other materials	
PP	~ 1.1	Paper / Cardboard	~ 0.91
PE-LD	~ 1.08	Glass	~ 0.45
PE-HD	~ 1.05	Aluminium	~ 0.37
PS/SB	~ 0.95	Steel	~ 0.13
PA	~ 0.9		
PVC	~ 0.77		
PET	~ 0.72		

PP Product Categories/Stiffness vs. Other Polymers



Novolen TECHNOLOGY
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Polypropylene / Product Characterization

- Melt Flow Rate (MFR) at 230 °C / 2.16 kg
  - analagous to flowability and molar mass
- Mechanical properties
  - Tensile or flexural modulus (stiffness)
  - Shear modulus (stiffness)
  - Tensile strength (tenacity)
  - Charpy or Izod impact strength (impact resistance)
    - Notched and unnotched
  - Rockwell or ball indentation hardness

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Polypropylene / Product Characterisation

- Thermal properties
  - Melting temperature (product characterization)
  - Heat deflection temperature (heat resistance)
- Other properties
  - Haze (transparency)
  - Gloss (appearance)
  - Density (not normally used for PP)

Propylene Polymers / Typical Properties

Property	Unit	Homopolymers		Impact Copolymers	Random-Copolymers	Random-Impact Copolymers
		Standard	HCPP			
Tensile Modulus	MPa	1500	2300	800 - 1600	600 - 1000	100 - 650
Ball indent.hardness	MPa	76	95	30 - 60	30 - 60	10 - 35
Impact strength (Charpy)						
+ 23 °C	kJ/m^2	NB	60	NB	NB	NB
- 30 °C	kJ/m^2	15	11	70 - NB	15 - 20	NB
Melting temp. (DSC)	°C	163	165	162	130 -150	135 - 145
Vicat A	°C	154	158	150	110 - 135	105 - 120
Transparency (d = 1 mm)	%	40	45	2 - 5	50 - 70 90 - 93 (nucl.)	10 - 30

NB - no break

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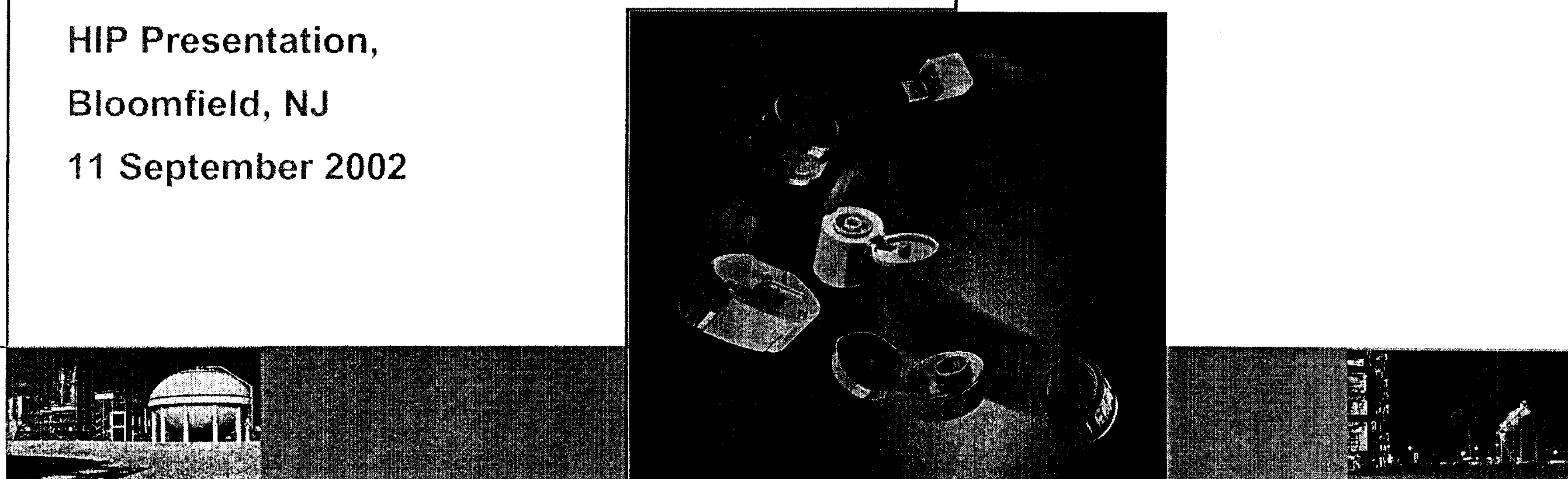
Polypropylene Products and Applications

HIP Presentation,

Bloomfield, NJ

11 September 2002



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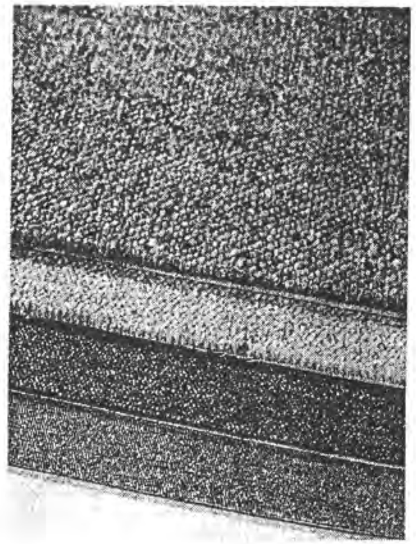
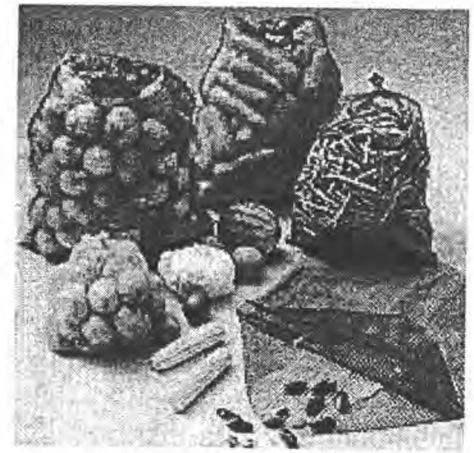
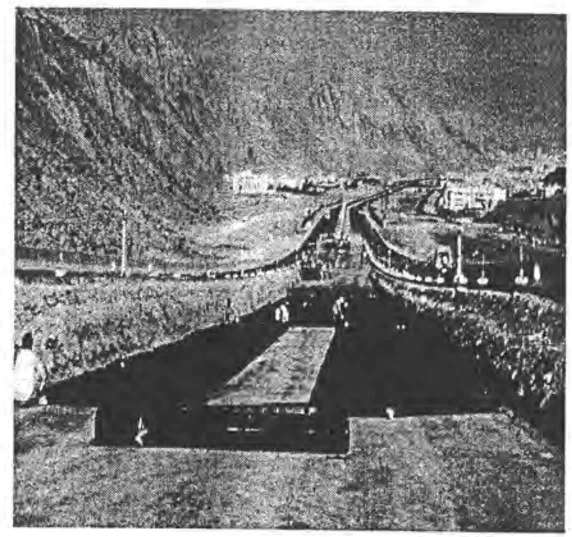
Fiber Applications

- Carpeting
  - Facing and backing
- Apparel
- Automotive
- Upholstery
- Hygiene Industry
  - Non-wovens / spun-bonded
- Medical Application
- Industrial Fibers
- Geotextiles
- Agritextiles

Fiber Applications







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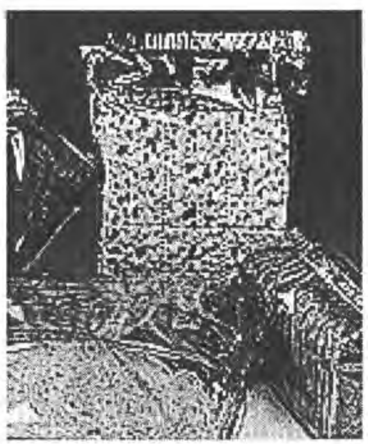
Fiber Processing

- Continuous Filaments/ Bulked (CF/BCF)
- Non-wovens
- Staple Fibers
- Raffia
- Slit Film
- Partially Oriented Yarn (POY)

Cast and BOPP Films

- Applications
  - Food packaging
    - Snack food
    - Meat wrap
    - Pasta
    - Bags / overwraps
    - Baked goods
    - Frozen food
  - Textile
  - Medical
  - Industrial

Cast and BOPP Films



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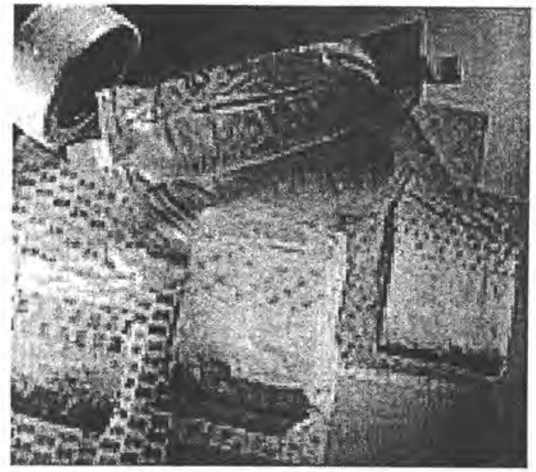
Cast and BOPP Films



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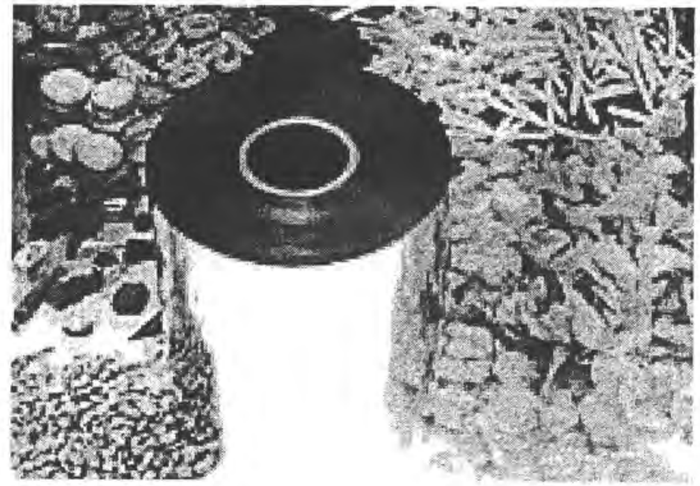
Cast and BOPP Films



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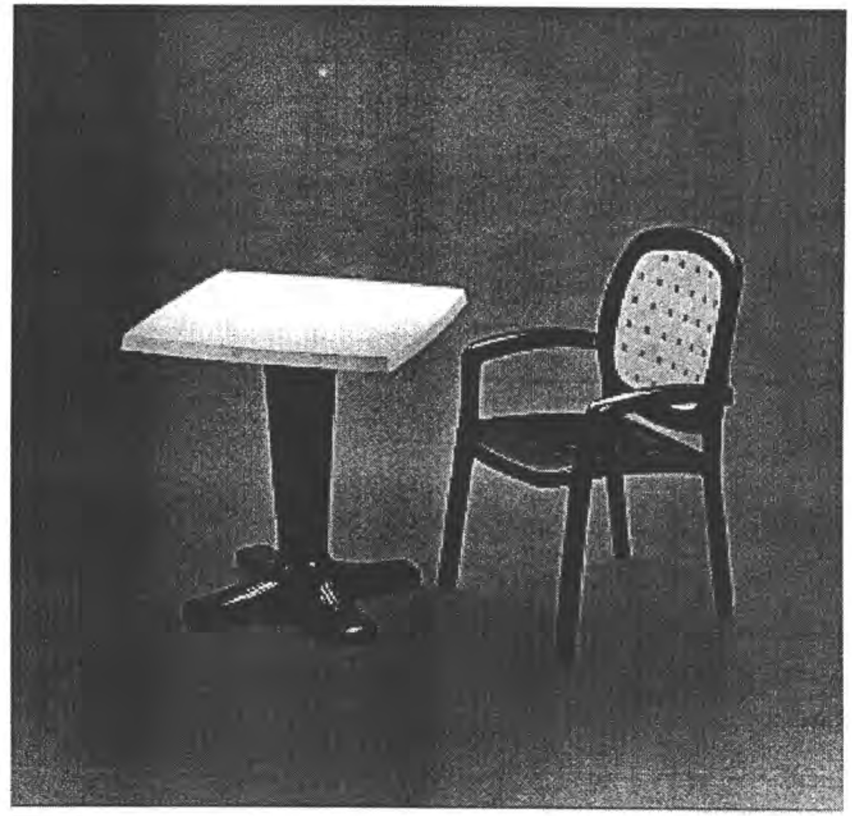
Critical Product Requirements

- The product requirements for Fiber, BOPP, and Cast Film Applications are very rigorous
- Product consistency
  - Within lot
  - Lot-to-lot
- Purity / cleanliness
  - Residues
  - Gels
- Drawdown
- Tenacity
- Processability

Injection Molding: Furniture

- Requirements
  - Good aesthetic properties
  - Scratch resistance
  - Dimensional stability
  - Processability
  - Stiffness / Impact balance
  - Low warpage
- Products
  - High Crystallinity Homopolymers
  - High Crystallinity Impact Copolymers

Injection Molding: Furniture



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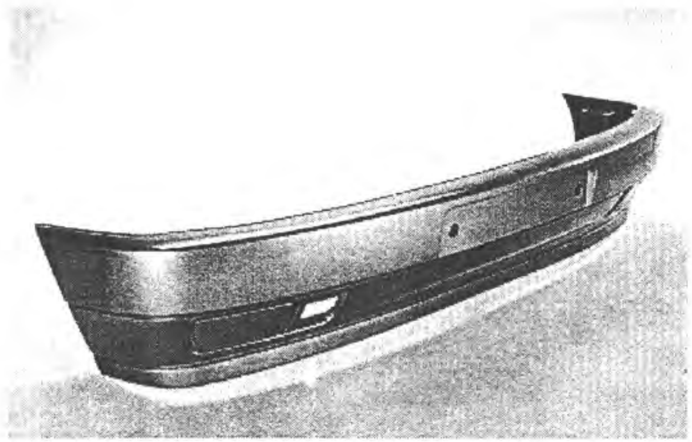
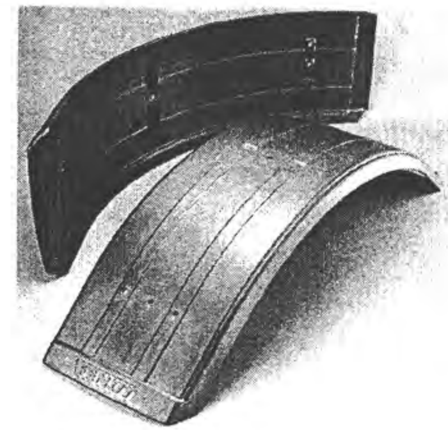
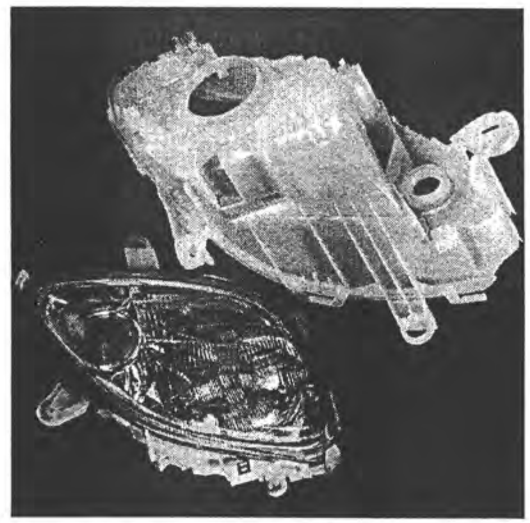
Injection Molding: Automotive

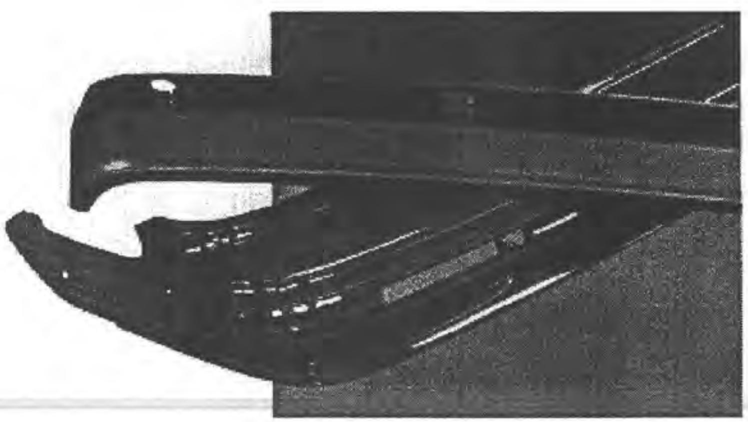
- Requirements
  - Good aesthetic properties
  - Paintability
  - Dimensional control and stability
    - High heat (under the hood and lighting) applications
  - Processability
  - Stiffness / Impact balance
    - High sub-ambient impact resistance
- Products
  - High Crystallinity Homopolymers
  - Medium to High Impact Copolymers and TPOs

Injection Molding: Automotive









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Injection Molding: Food Packaging

- Requirements
  - Good aesthetic properties
  - Scratch resistance
  - Dimensional stability
  - Processability
  - Stiffness / Impact balance
  - Low warpage
  - Good organoleptic properties
- Products
  - High Flow Homopolymers
  - Medium to High Flow Impact Copolymers

Injection Molding: Food Packaging

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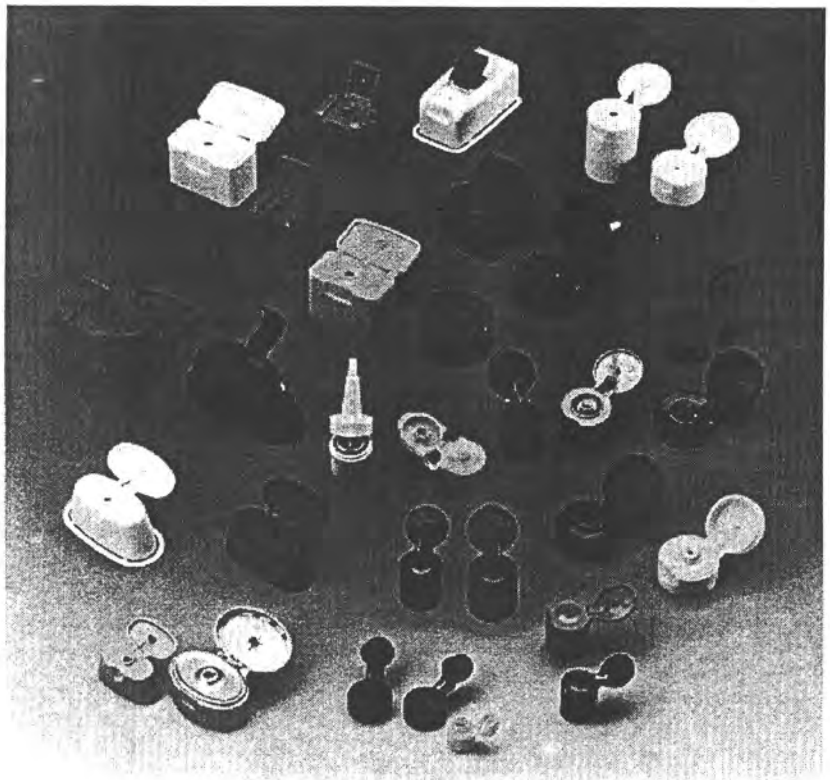
Injection and Compression Molding: Caps and Closures

- Requirements
  - Integral ("living") hinge
  - Property balance
    - Impact
    - Low creep (torque retention)
  - Easy flow / short cycle times
  - Good optical properties
  - Scratch resistance
  - Low taste and odor
  - Dimensional stability
- Products
  - All types of Polypropylenes
    - Determined by specific application requirements

Injection and Compression Molding: Caps and Closures

Injection Molded

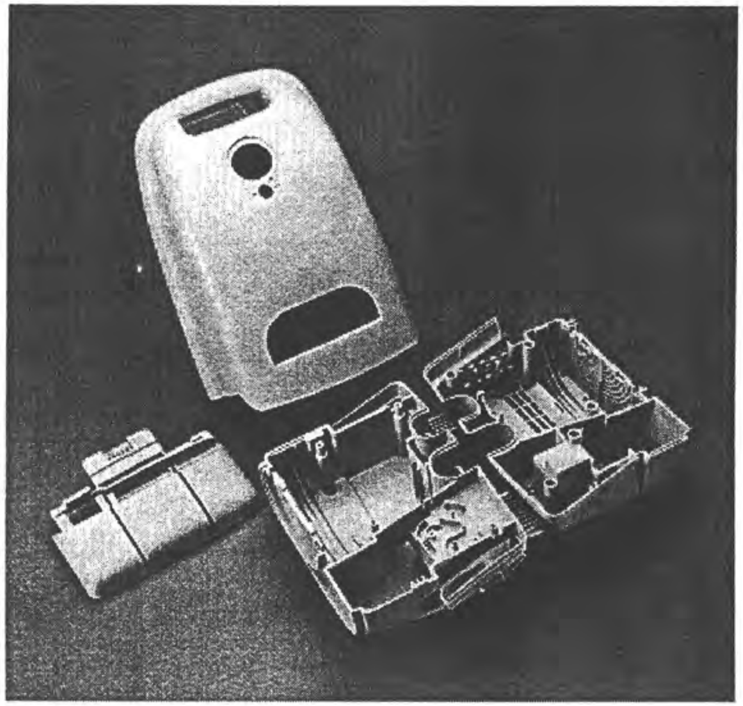


Compression Molded

Injection Molding: Appliances

- Requirements
  - Aesthetics - Gloss and scratch resistance
  - Dimensional stability
  - Food contact approval
  - Heat resistance
  - Processing
- Products
  - High Crystallinity Homopolymers
  - High Crystallinity Impact Copolymers

Injection Molding: Appliances



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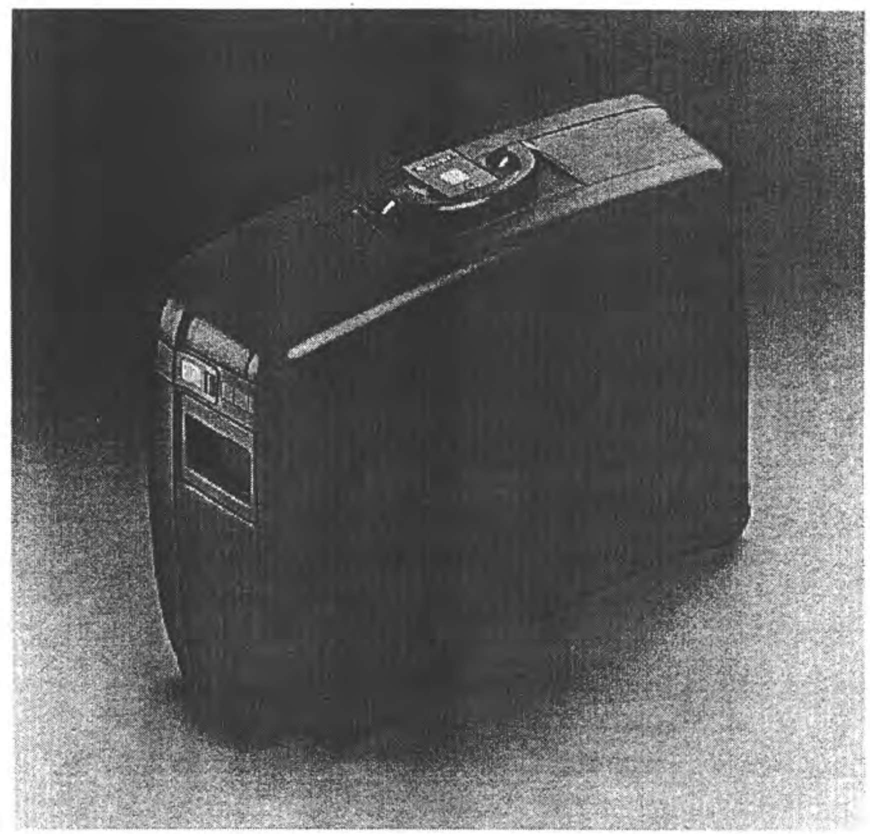
Injection Molding: Luggage

- Requirements
  - High Impact resistance
  - Dimensional stability
  - Good stiffness
  - Light weight
  - Good surface quality
  - Low warpage
- Products
  - Medium to High Flow Impact Copolymers
  - Nucleation to improve stiffness

Injection Molding: Luggage



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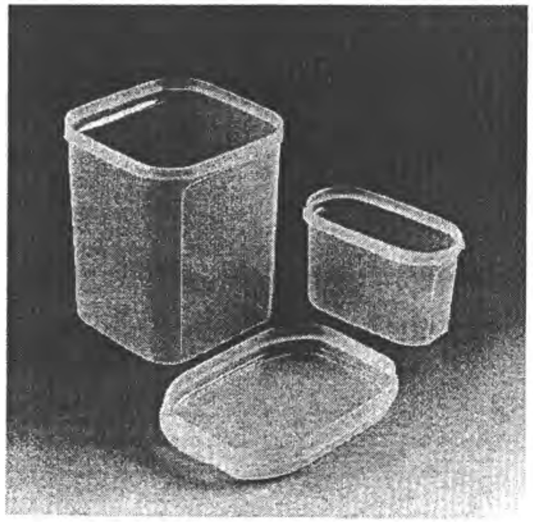
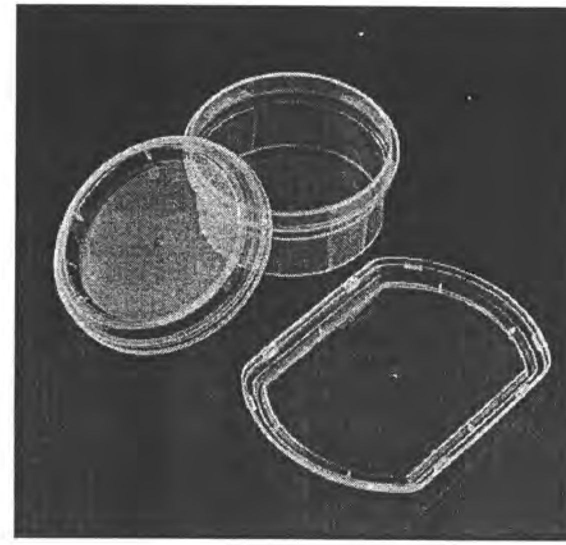
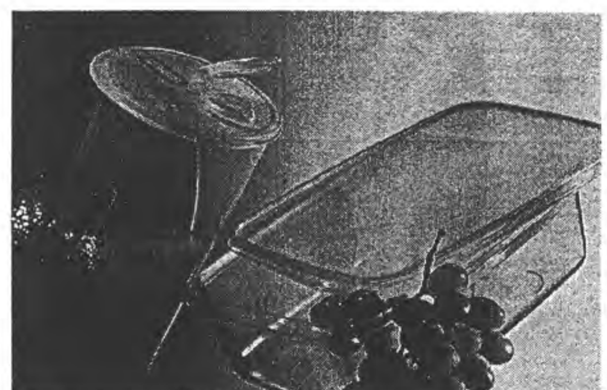
Injection Molding: Household Products

- Requirements
  - Good aesthetic properties
  - Good organoleptic properties
  - Scratch resistance
  - Dimensional stability
  - Processability
  - Stiffness / Impact balance
  - Low warpage
- Products
  - High Crystallinity Homopolymers
  - Medium to High Flow Impact Copolymers
  - Clarified Random Copolymers

Injection Molding: Household Products







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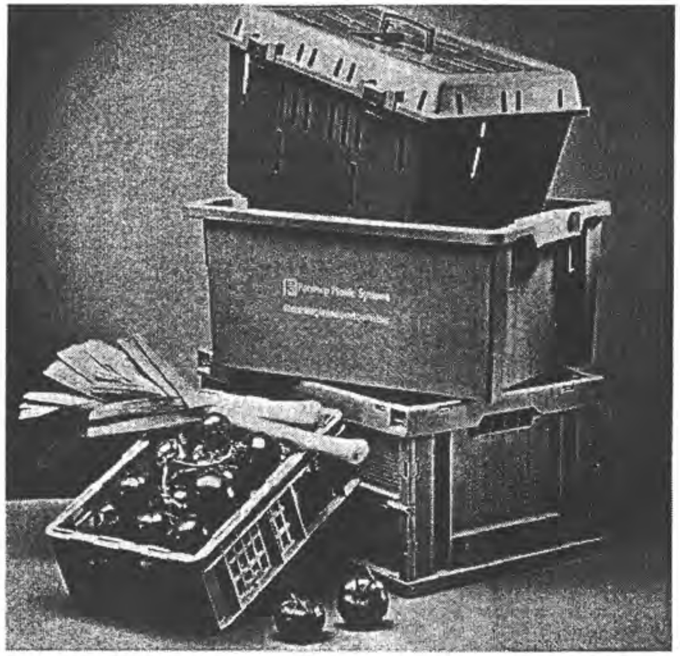
Injection Molding: Other Applications

- Requirements
  - Impact/stiffness balance
  - Dimensional stability
  - Aesthetics - gloss / clarity / mar resistance
  - Light weight
  - Processability
- Products
  - All types of Polypropylenes
    - Determined by specific application requirements

Injection Molding: Other Applications



Blow Molding

- Requirements
  - Good aesthetic properties
  - Melt strength
  - Dimensional stability
  - Processability
  - Clarity
  - Good organoleptic properties
- Products
  - Clarified Random Copolymers

Blow Molding

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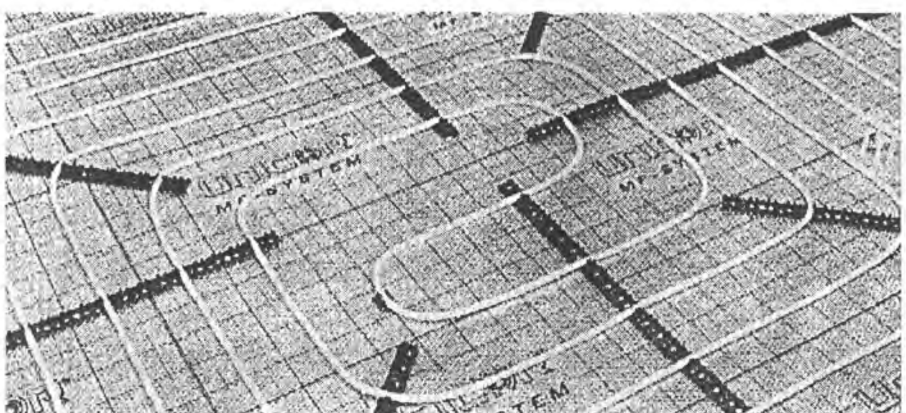
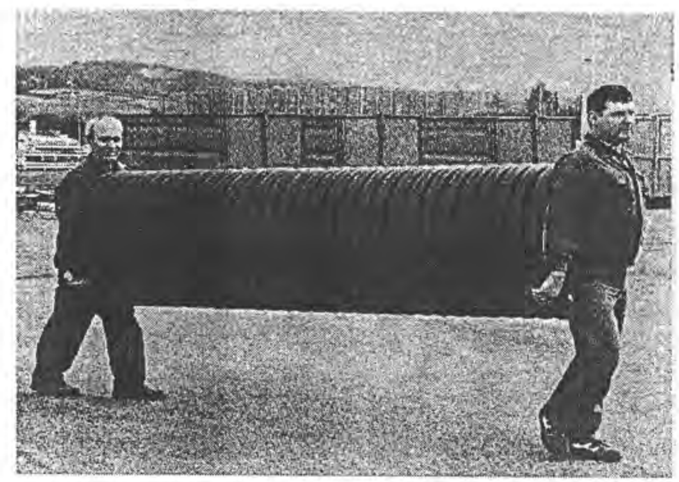
Pipe Applications

- Polypropylenes are used world-wide for a variety of piping applications
  - Pressure pipe - hot and cold water - domestic service (RCP)
  - Industrial pressure pipe - aggressive chemical service (HPP)
  - Domestic Drain-Waste-Vent (HPP - ICP)
  - Electrical conduit (ICP)
  - Under floor and in-wall heating systems (RCP)
  - Drainage systems (ICP)
  - Drinking water (RCP)
  - Appliances (RCP)

Pipe Applications





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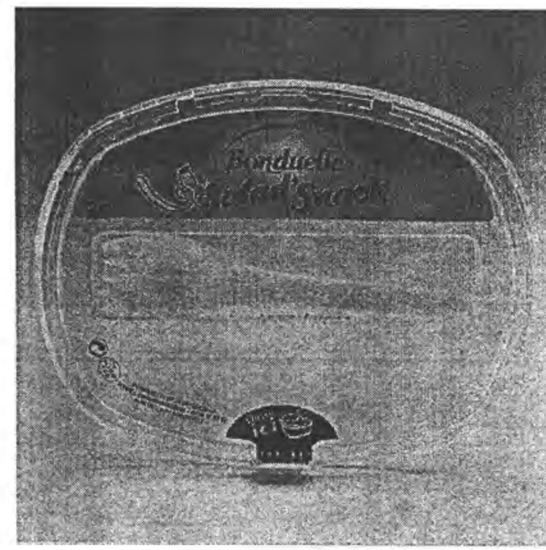
Thermoforming Applications

- Polypropylene has made major strides in thin-wall food packaging using thermoformed, extruded sheet
- Its light weight, rigidity and impact balance, good organoleptics, and appearance have made it the future material of choice for these applications
- Random copolymers can provide exceptionally clear containers for content display
- Impact copolymers can provide the necessary impact strength required for refrigerator and freezer storage.
- Homopolymers can provide high stiffness for economical, thin-wall containers
- Co-extrusion is easily utilized to provide exceptional barrier properties for long shelf life

Thermoforming Applications



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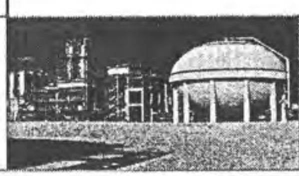
General Marketing Data
World Markets



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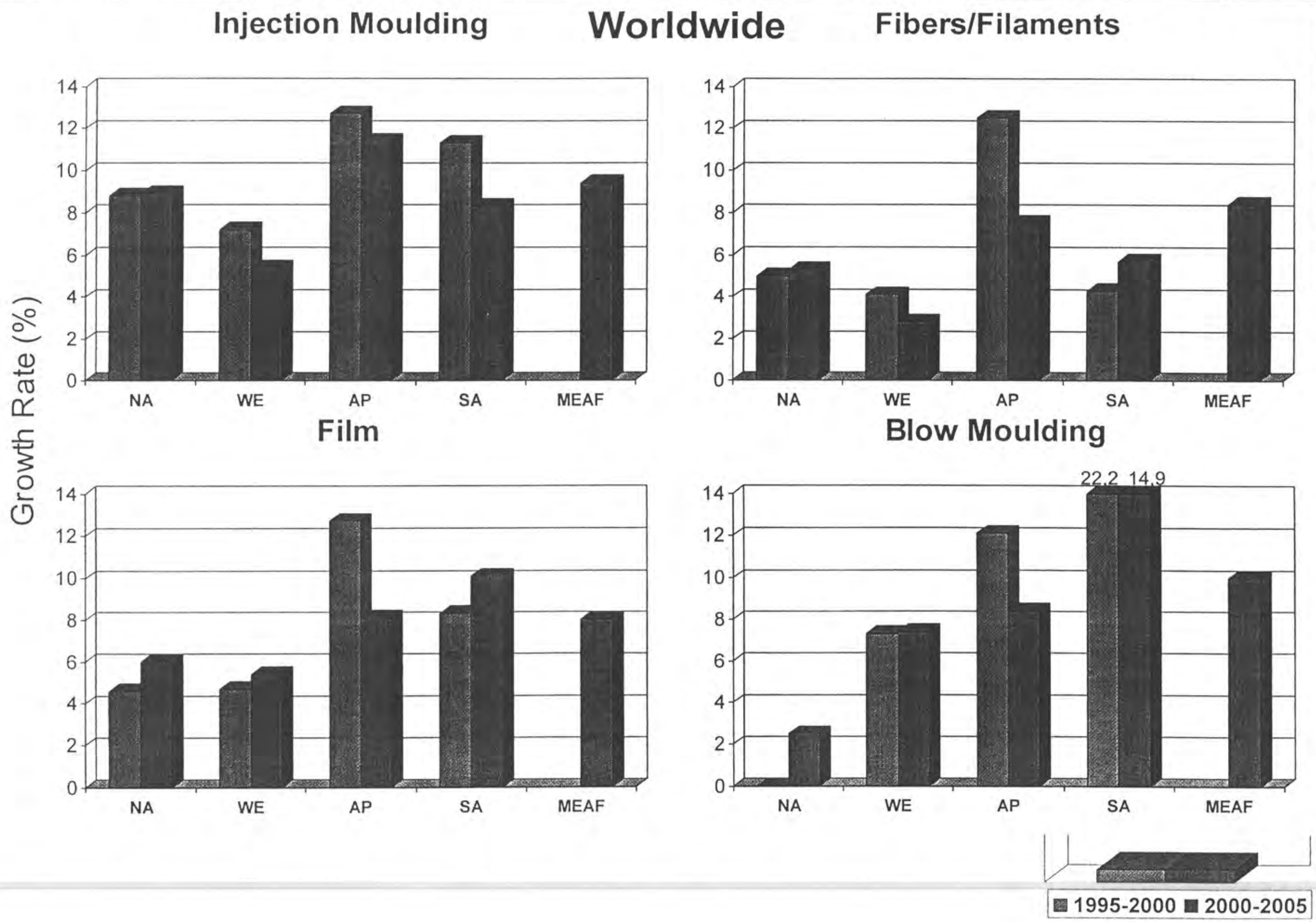
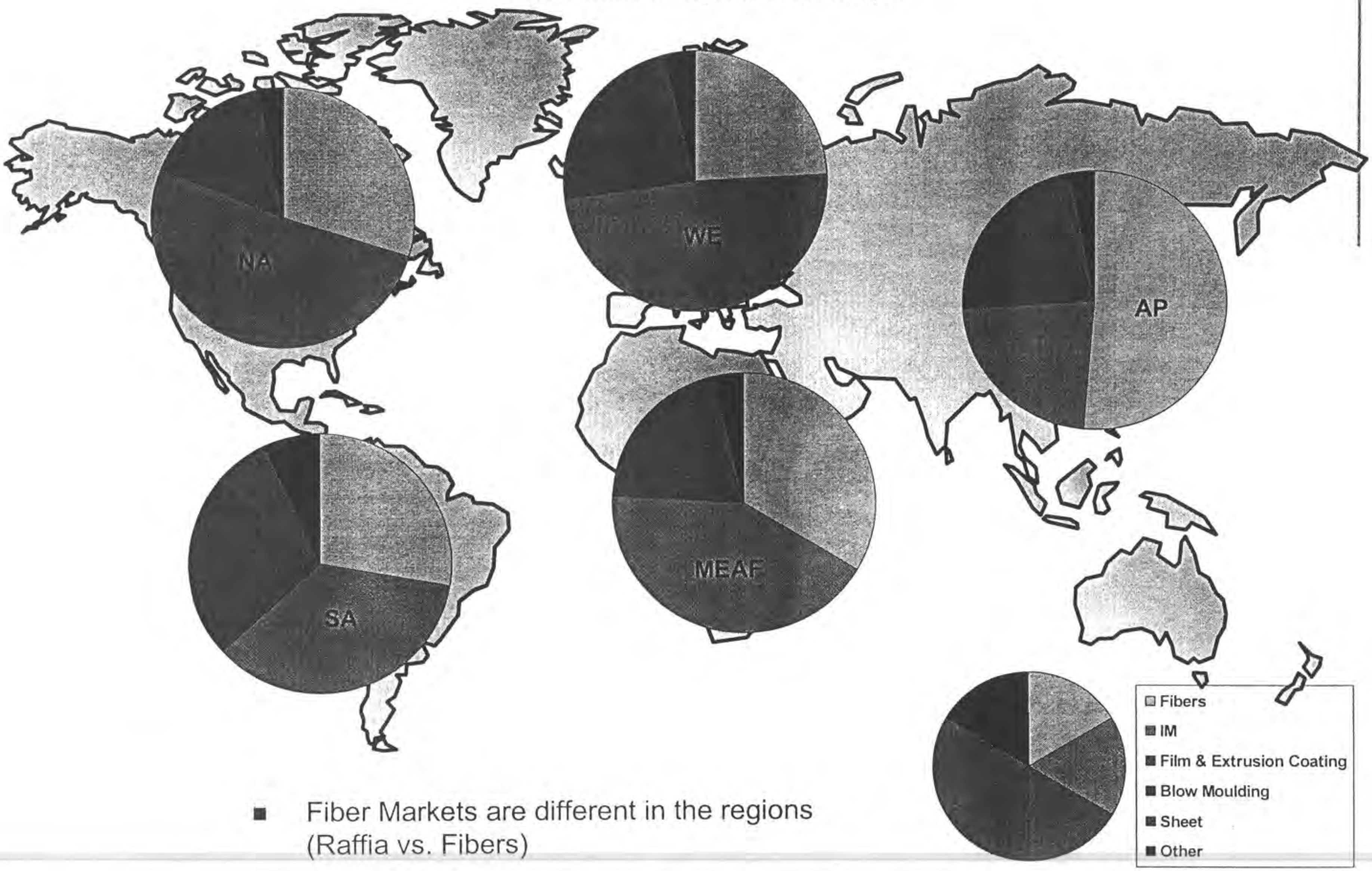
Growth Rates of Selected Conversion Processes

Worldwide



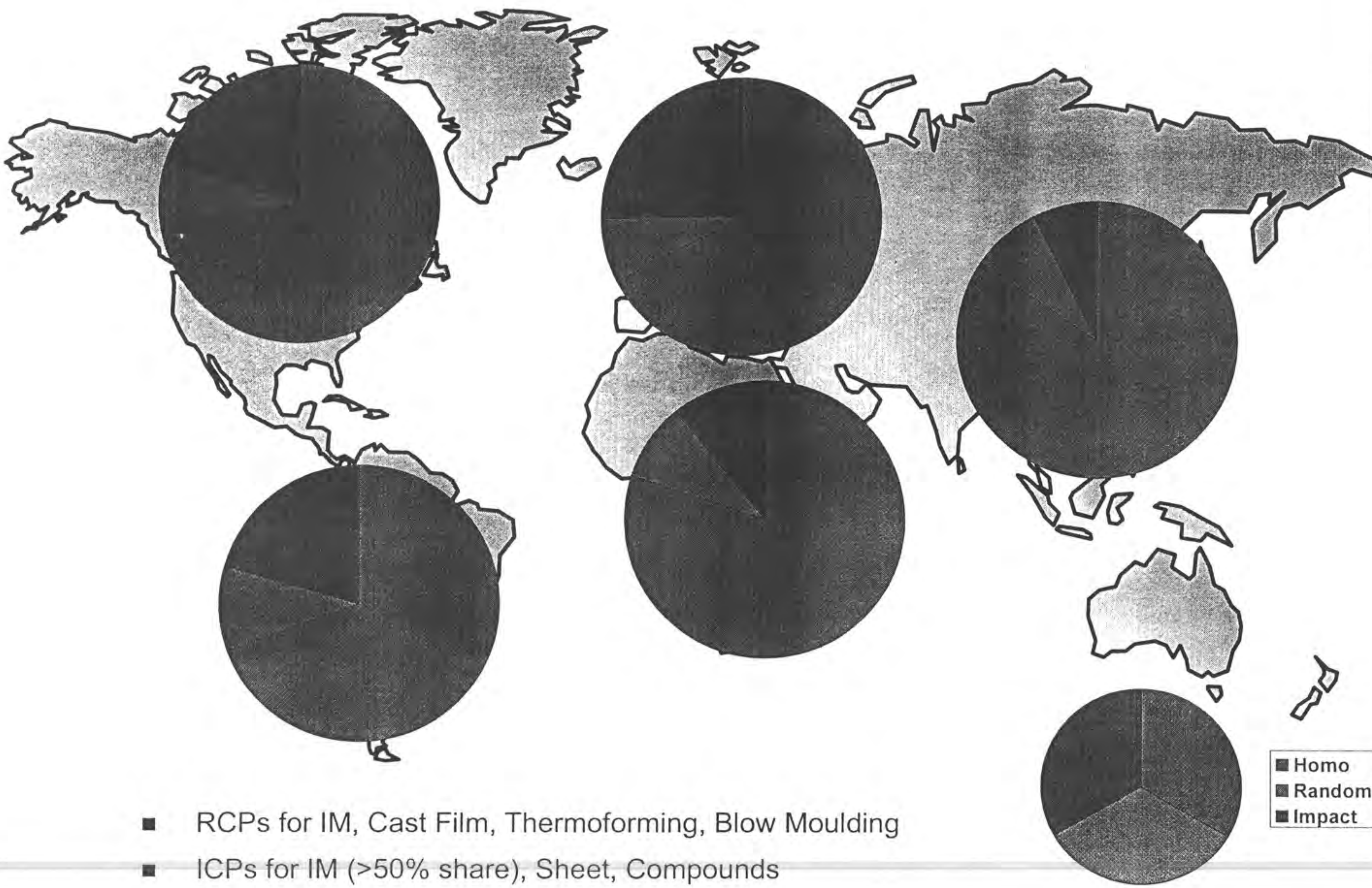
Conversion Processes in different regions

Not included: Japan, East Europe



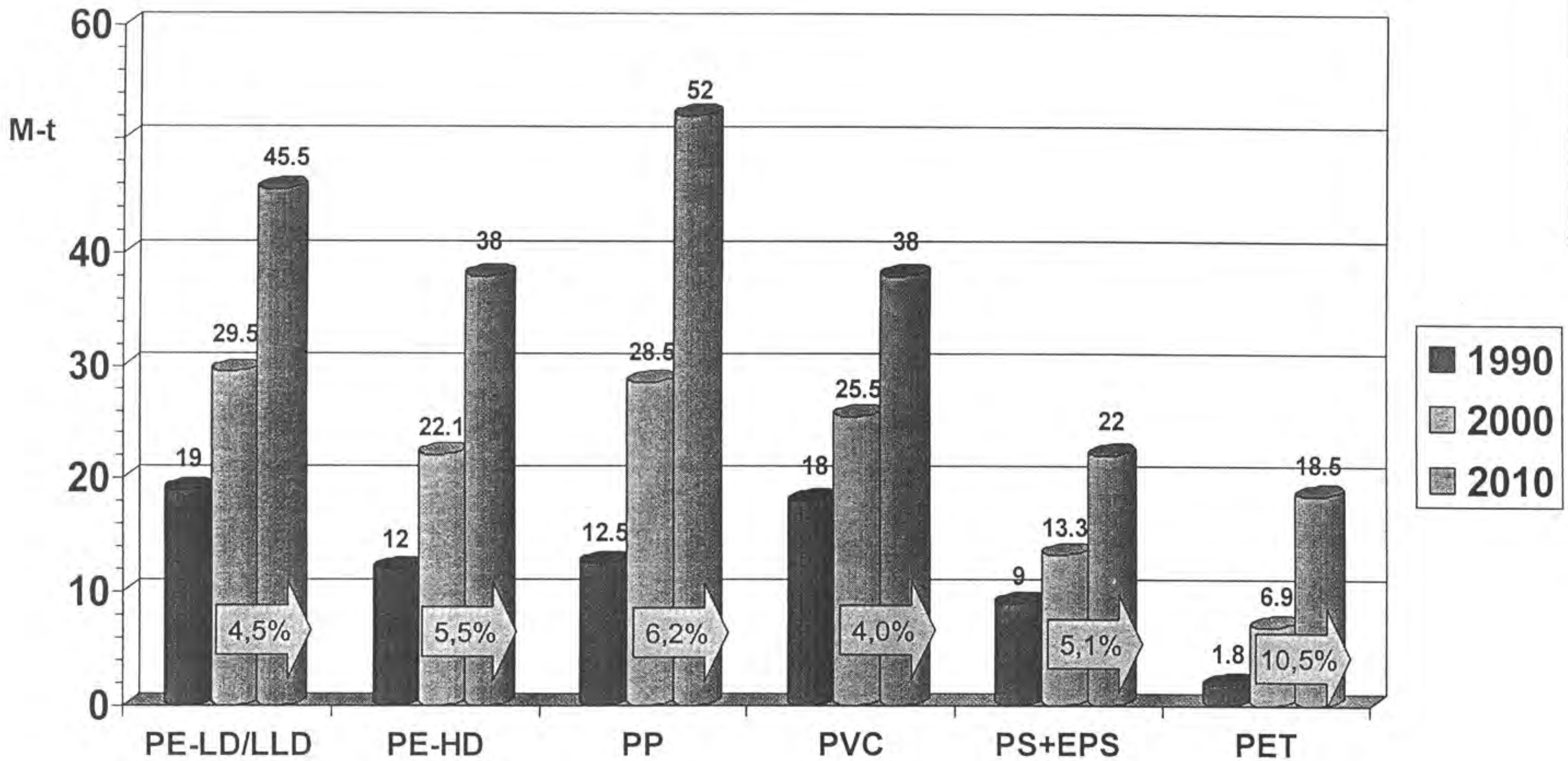
- Fiber Markets are different in the regions (Raffia vs. Fibers)

Share of Homo-, Random and Impact PP



- RCPs for IM, Cast Film, Thermoforming, Blow Moulding
- ICPs for IM (>50% share), Sheet, Compounds

Major Thermoplastics (World Consumption 1990 - 2010)



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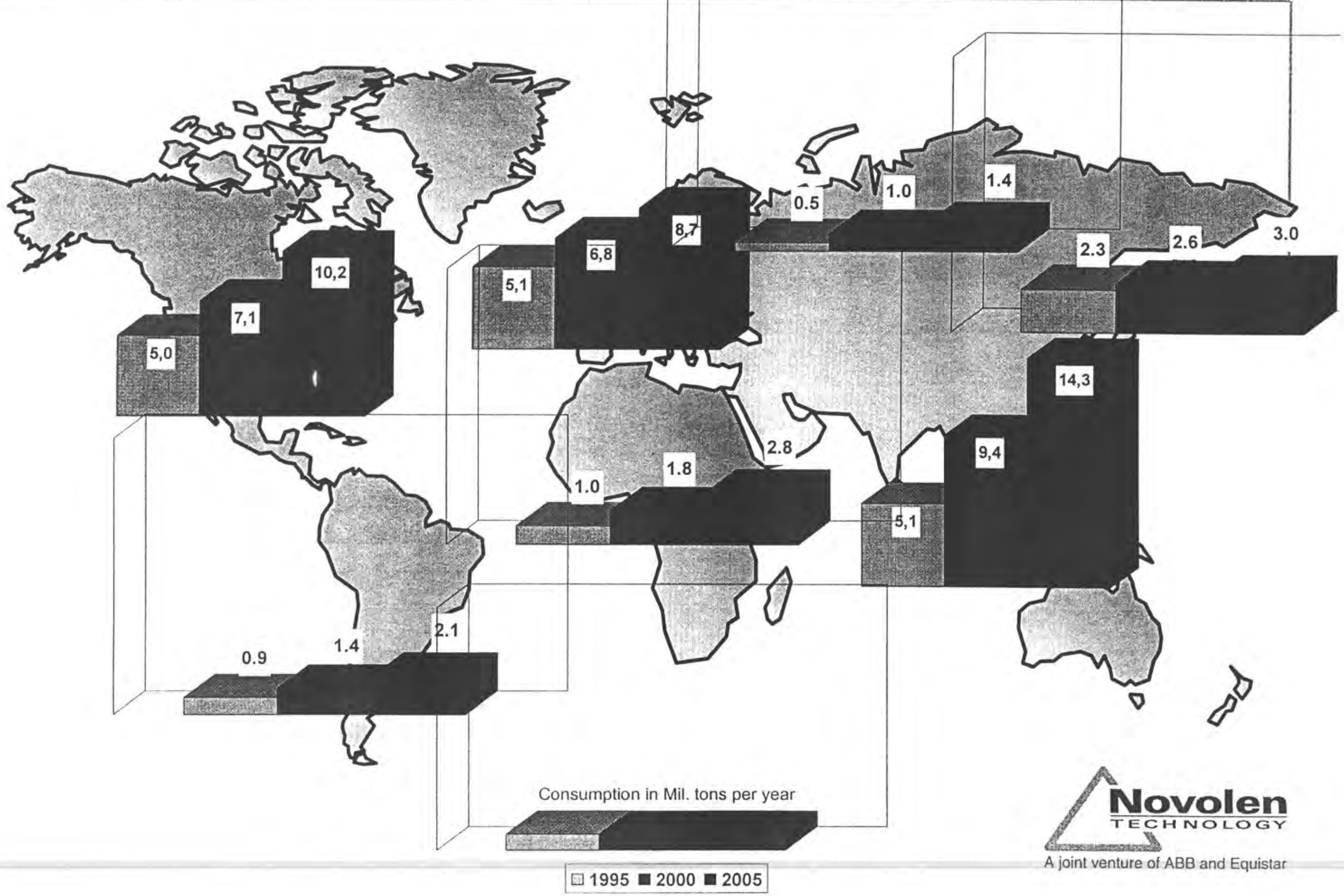
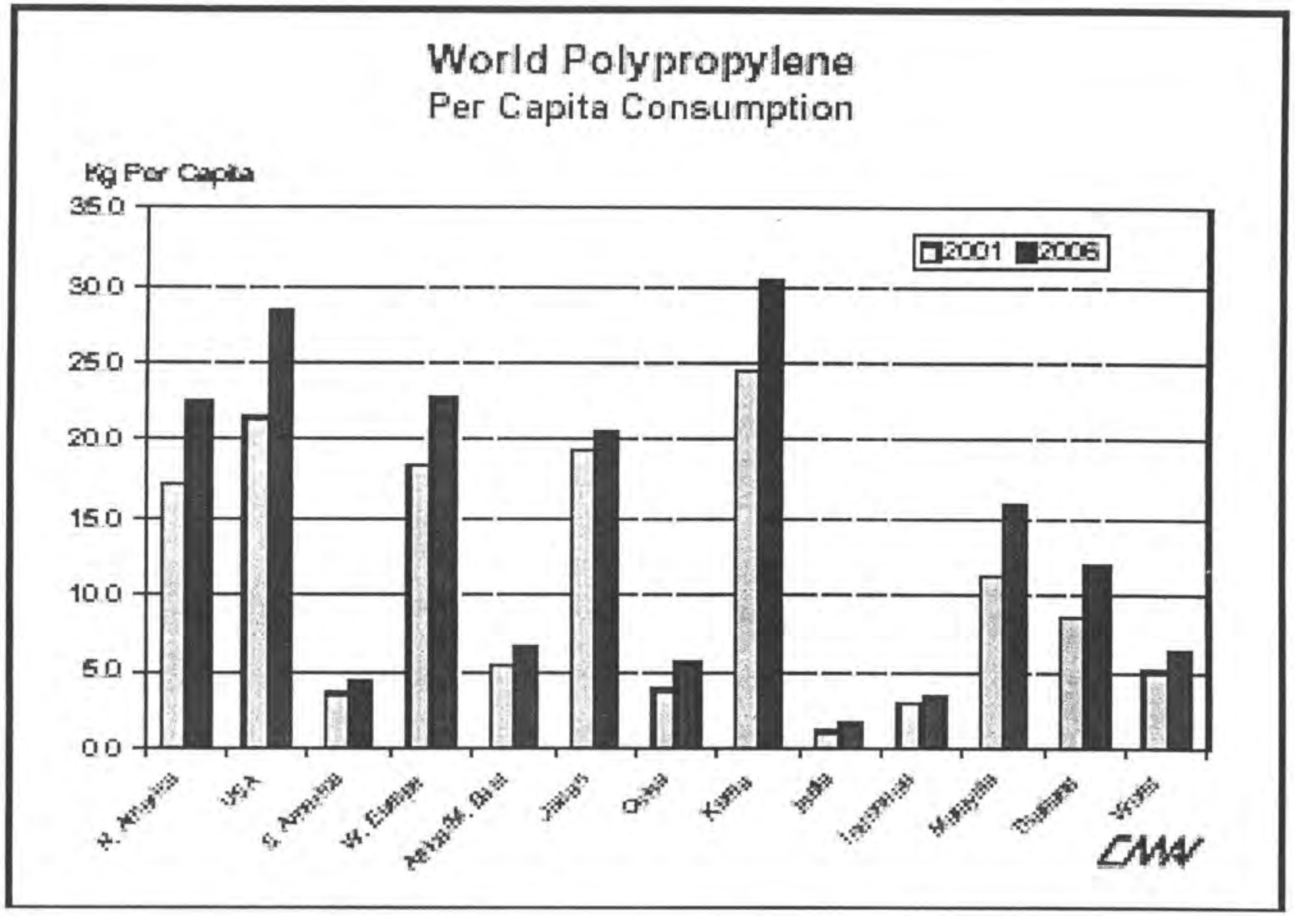
PP Consumption 1995 - 2000 - 2005





Courtesy: CMAI

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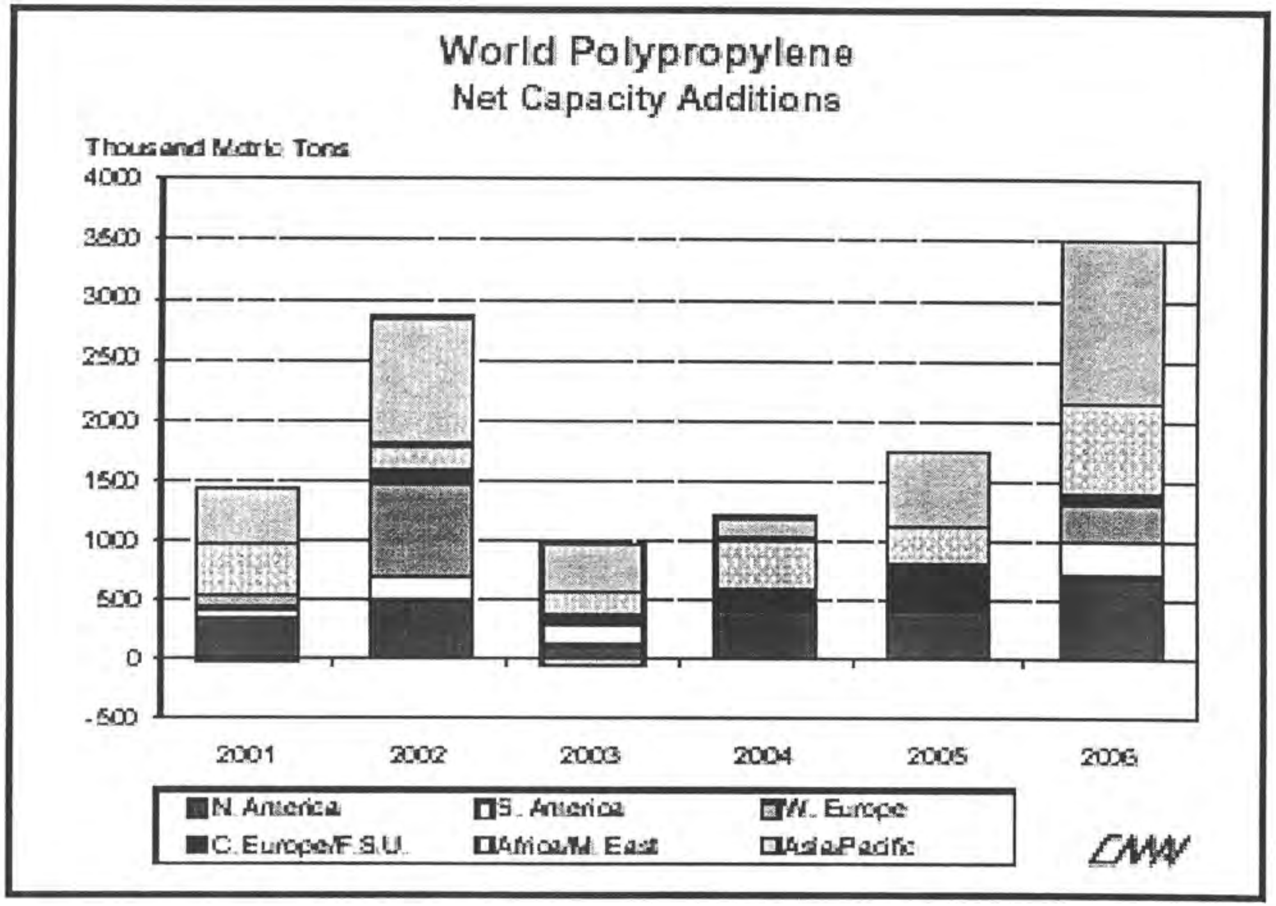

Courtesy: CMAI

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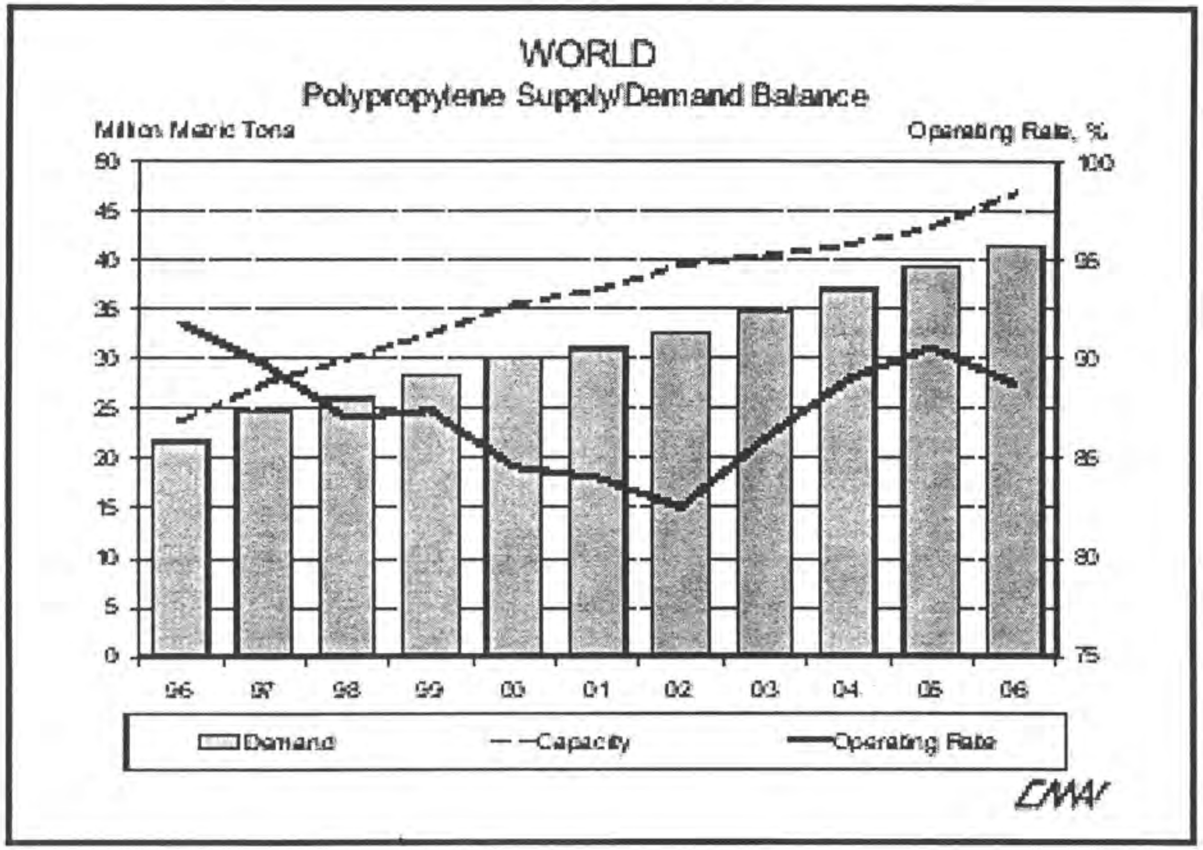

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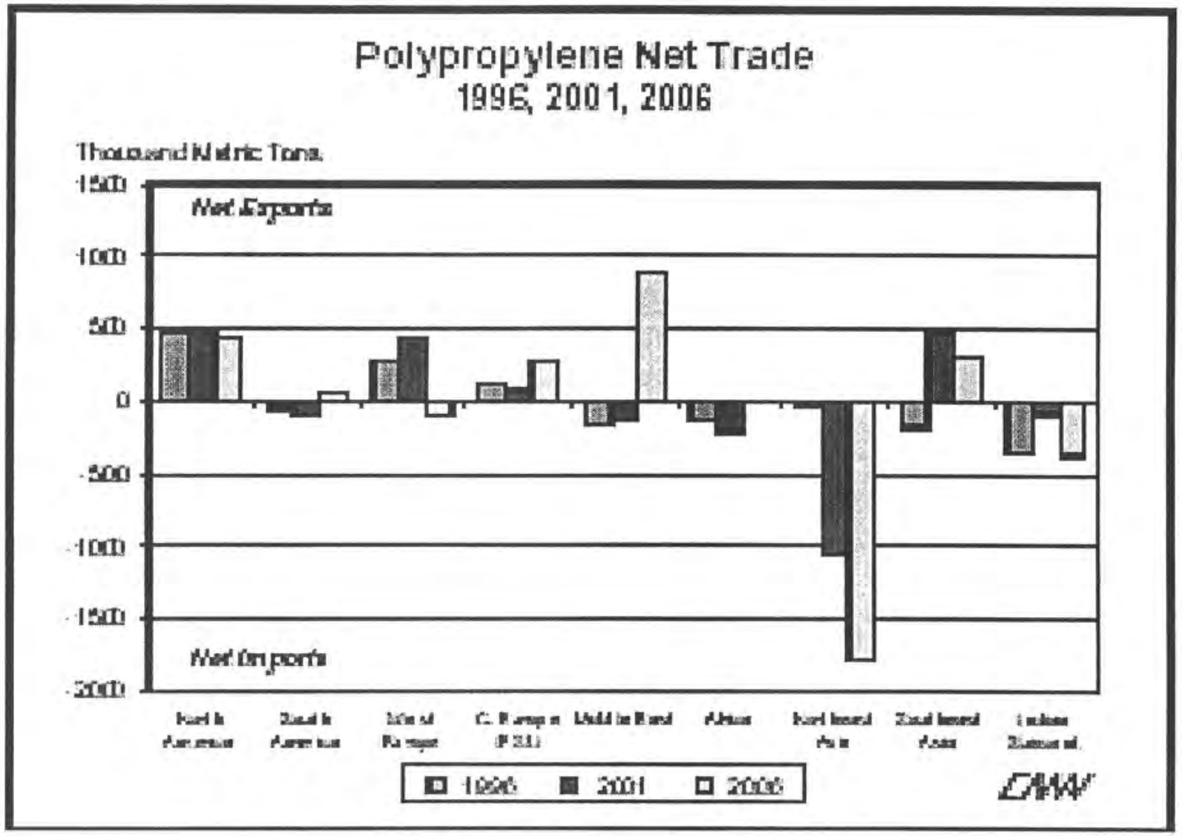

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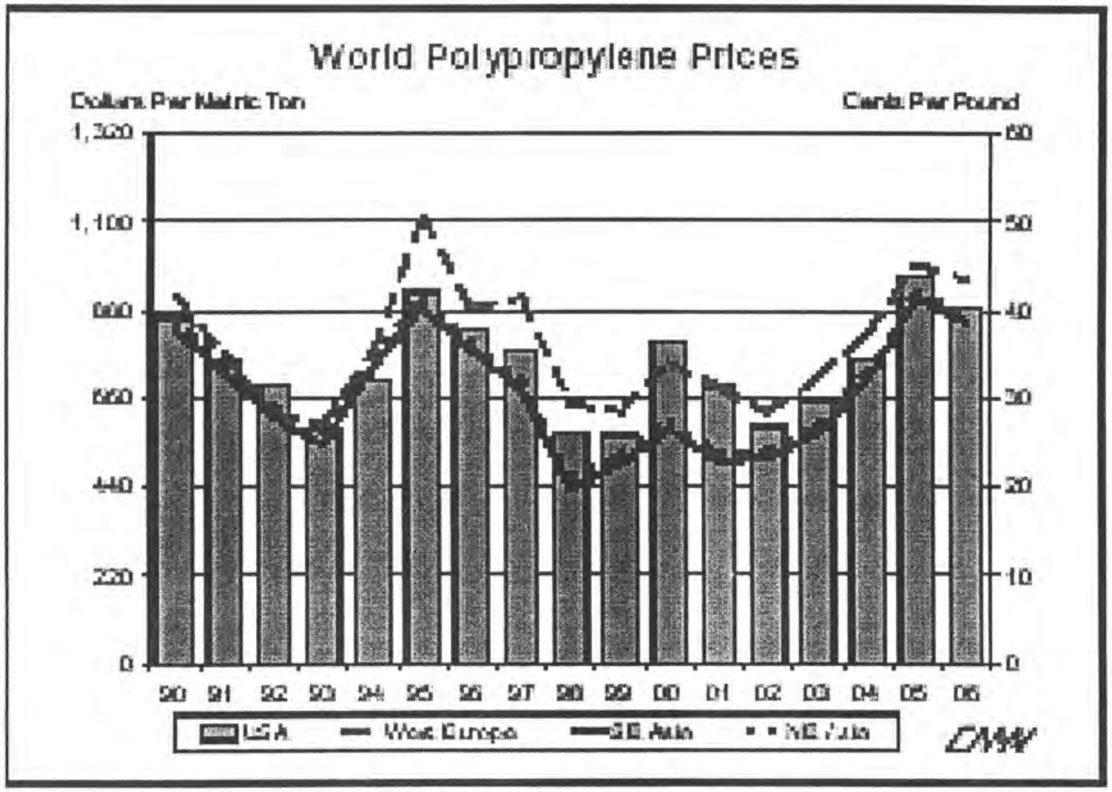

Courtesy: CMAI

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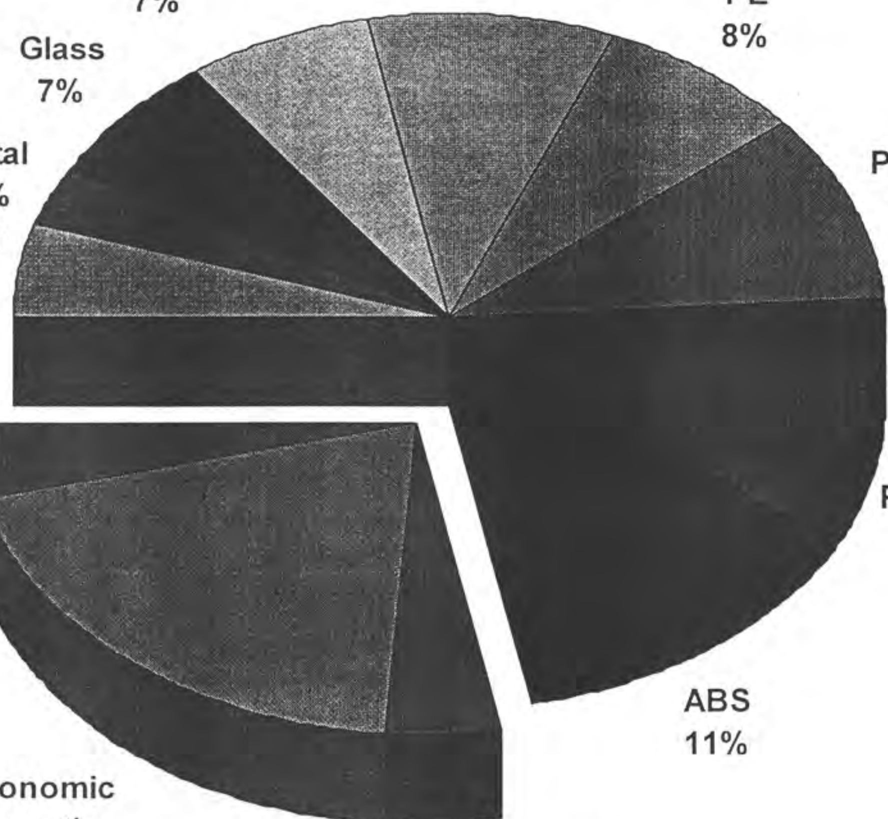
Reasons for PP Growth

Western Europe 1993-2000

72% substitution



Source: BASF

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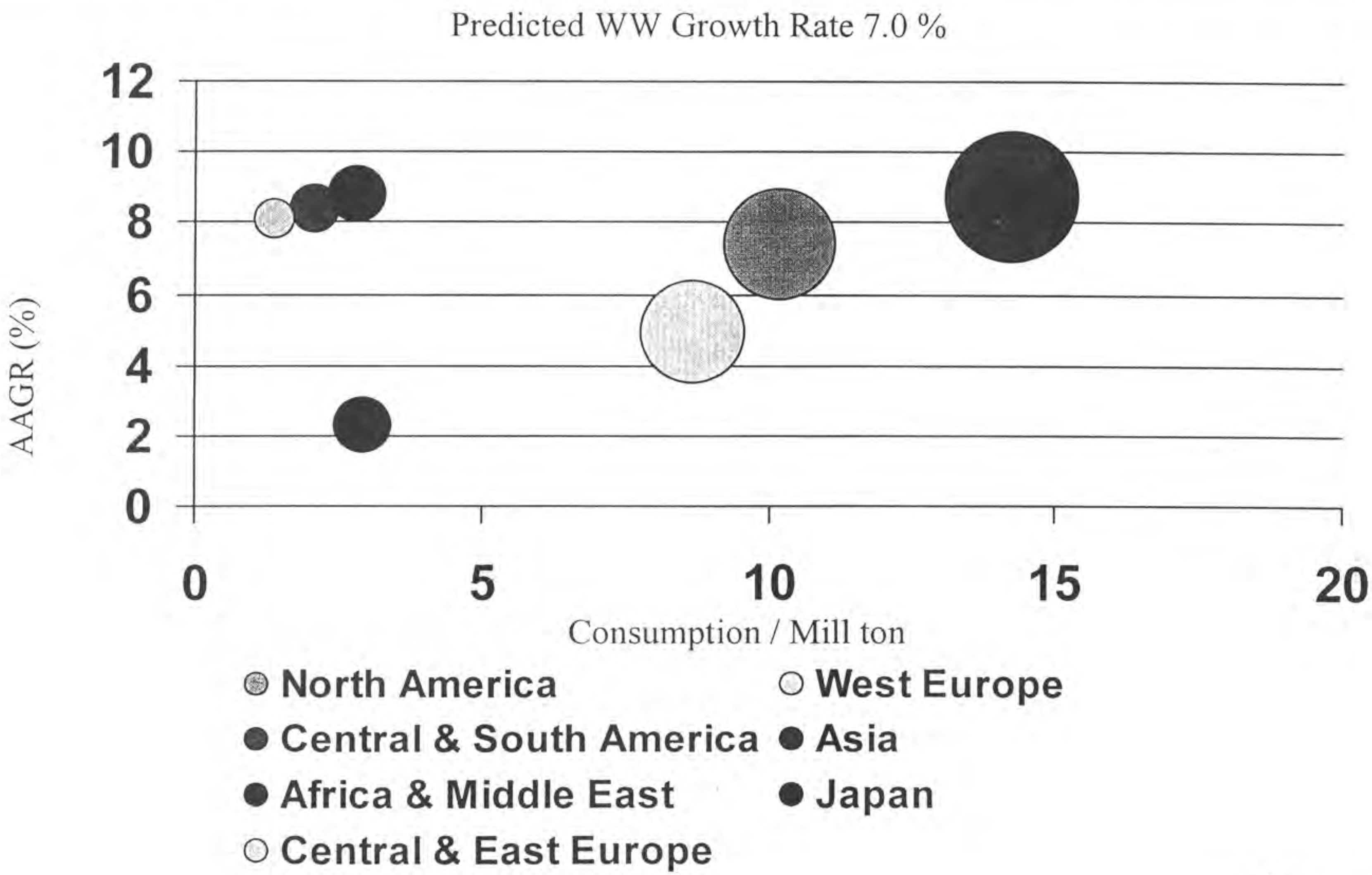
PP Consumption & Growth Rate 2000 - 2005



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Worldwide Trends***

- Overall demand and per capita consumption will increase and remain strong
- Material substitution will remain a major driver for increased demand
- Utilization rates will continue to drop through 2002 but will begin to recover in late 2003 and into 2004. Pricing will follow a similar trend.
- Utilization rates and pricing are expected to drop in the 2005-2006 timeframe
- The Middle East will be the largest exporter by 2006 and Northeast Asia will be the largest importer
- Further industry consolidation may be anticipated through mergers, alliances, and acquisitions
- Volatility in energy costs and unforeseen events will have significant bearing on the direction of the worldwide market

Courtesy: CMAI

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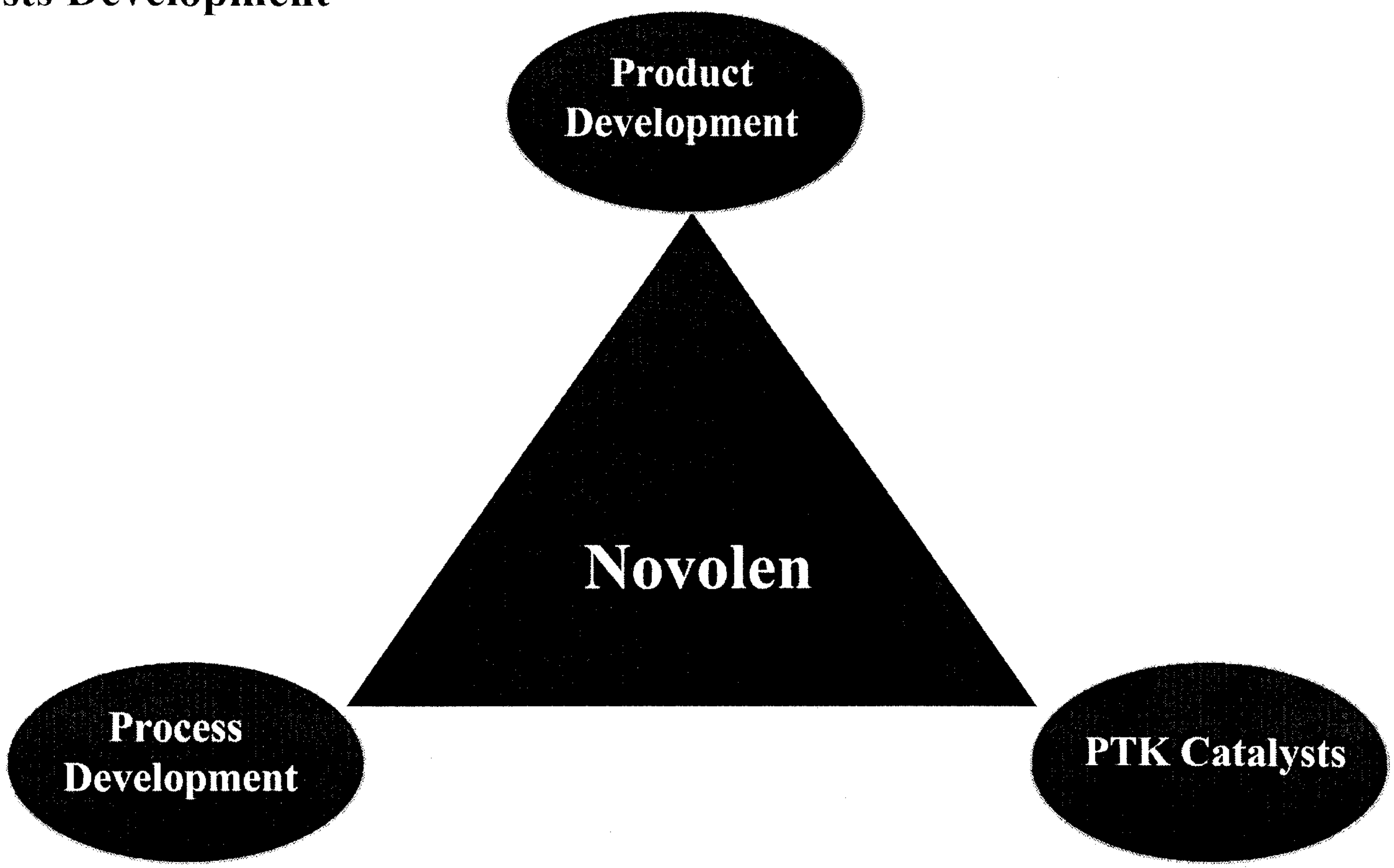
Pillars of the Novolen® Technology Business

The three pillars which comprise the Novolen® business are Product, Process and Catalysts Development



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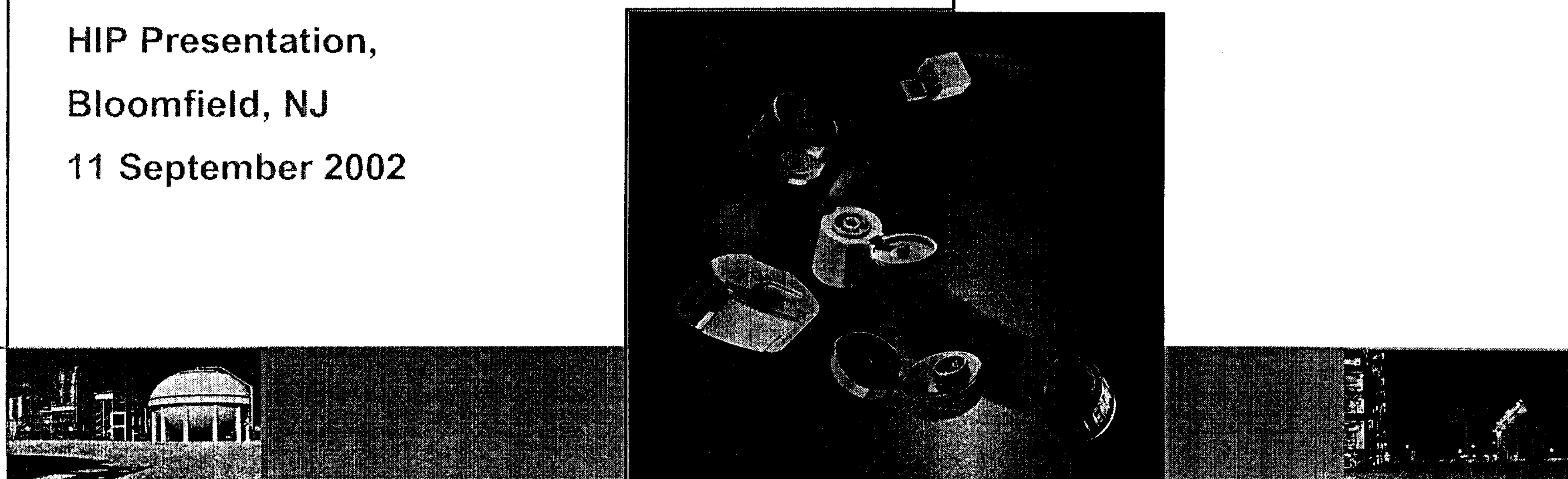
Commercial Polypropylene Products

HIP Presentation,

Bloomfield, NJ

11 September 2002



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Polypropylene Commercial Products

- Specific Polypropylene product grades are generally determined by the requirements of the process and the intended end-use
- The Novolen process platform is capable of producing the entire range of Polypropylene products on a commercial basis
- The representative products shown in the following tables are typical of any commercial product offerings

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NTH Grade Slate - Extrusion (1)

Product	MFR 230/2.16 [g/10 min] ISO 1133	Polymer Type	Special Modification	Applications
Pipes				
2412 E	0,3	B	HW	Sewage pipes
3212 E	0,3	R	HW	Pressure pipes, hot & cold water systems
Tapes/Monofile/Strapping				
1102 G	0,9	H		Strapping, geogrid
1102 H	1,8	H		Tapes, high tenacity
1102 J	2,5	H		Tapes, carpet backing
1102 K	3,5	H		Technical textiles, carpet backing
1102 L	5	H		Tapes
1102 M	8	H		Split fibres, wrapping yarns
Thermoforming				
1102 G	0,9	H		Sheets
1102 H	1,8	H		Dairy products, desserts
1102 J	2,5	H		General Thermoforming
1142 K	3,2	H	NU	Thermof. high transparency, dairy products, desserts
1084 K	3,5	H	NU , AS	High stiffness, dairy products, desserts
1102 K	3,5	H		Dairy products, desserts
1102 L	5	H		General Thermoforming
1184 L	5,5	H	NU, AS	Dairy products, desserts
1102 M	8	H		Dairy products, desserts
2500 H	2	B		Special Applications, higher Impact
2300 L	6	B		High Impact, good surface properties
3202 H	1,8	R		Special applications, higher transparency

AB = Anti-blocking agent
AS = Antistatic agent
CR = Controlled rheology (narrow molar mass distribution)
GA = Antigasfading stabilisation
NU = Nucleation
HW = Long term heat stabilization
SL = Slip agent

UV = UV-Stabilization
H = Homopolymer
B = Block-Copolymer
R = Random-Copolymer

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NTH Grade Slate - Extrusion (2)

Films (unstretched)				
1102 M	8	H		Cast film, without film-processing additives
1125 MC	8,5	H	AB, SL, CR	Cast film, medium slip
1128 MC	8,5	H	CR	Cast film, high slip
1102 N	10,5	H		Lamination, without film-processing additives
1128 N	10,5	H	AB, SL	Cast film, high slip and high antiblocking behaviour
3202 H	1,8	R		Blown film, without film-processing additives
3200 MC	8	R	CR	Good weld strength, without film-processing additives
3225 MC	8	R	AB, SL, CR	Good weld strength, high slip formulation
3236 MC	8	R	AB,AS, SL,CR	Good weld strength, high slip + antistatic formulation
3300 MC	8	R	CR	Flexible and tough, without film-processing additives
3325 MC	8	R	AB, SL, CR	Flexible and tough, high slip formulation
3520 L	6	R		Very flexible film, sealing layer coextrusion
OPP-Films (stenter frame process)				
1104 H	2	H		Narrow MFR-range, metallizable
1104 K	3,2	H		Narrow MFR-range, metallizable
3520 L	6	R		Sealing layers, SIT 105°

AB = Anti-blocking agent
AS = Antistatic agent
CR = Controlled rheology (narrow molar mass distribution)
GA = Antigasfading stabilisation
NU = Nucleation
HW = Long term heat stabilization
SL = Slip agent

UV = UV-Stabilization
H = Homopolymer
B = Block-Copolymer
R = Random-Copolymer

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NTH Grade Slate - Extrusion (3)

Staple fibres				
1101 L	6	H	GA	Coarser fibres, high strength
1101 M	9	H	GA	Coarser fibres, high strength
1101 N	12	H	GA	Finer fibres
1191 N	12	H	GA	Hygiene Non woven fabric (NWF)
1101 R	24	H	GA, CR	Carpet yarn
1101 S	24	H	GA	Carpet yarn
BCF/CF				
1101 NC	11,5	H	GA, CR	CF-High Tenacity
1101 N	12	H	GA	Carpet yarns, continuous filaments
1101 P	18	H	GA	Carpet yarns, continuous filaments
1101 S	24	H	GA	Carpet yarns, wider MMD
1101 R	24	H	GA, CR	Technical applications, geotextiles
1101 RC	25	H	GA, CR	POY yarns
1102 RC	25	H	CR	POY yarns
1101 SC	35	H	GA, CR	POY yarns
1102 SC	35	H	CR	POY yarns
Non wovens (spunbonded)				
1101 RC	25	H	GA, CR	Spunbonded nonwovens
1102 RC	25	H	CR	Spunbonded nonwovens
1101 SC	35	H	GA, CR	Spunbonded nonwovens
1102 SC	35	H	CR	Spunbonded nonwovens
Blow Moulding				
1102 H	1,8	H		General applications, high stiffness & HDT
3240 H	1,8	R	Nu	High transparency, cosmetics, food
3340 H	1,8	R	Nu	High clarity, higher impact strength
3240 NC	12	R	Nu	High clarity, ISBM

AB = Anti-blocking agent
AS = Antistatic agent
CR = Controlled rheology (narrow molar mass distribution)
GA = Antigasfading stabilisation
NU = Nucleation
HW = Long term heat stabilization
SL = Slip agent

UV = UV-Stabilization
H = Homopolymer
B = Block-Copolymer
R = Random-Copolymer

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NTH Grade Slate - Injection Molding (1)

Product	MFR 230/2.16 [g/10 min] ISO 1133	Tensile Modulus [MPa] ISO 527	Addi-tives	Applications
Homopolymers				
1040 N	12	2000	NU	Furniture
1040 RC	23	2000	NU	Furniture, thinwalled packaging, housings
1043 RC	23	2200	NU	Furniture, car lamp housings, replacement of mineral filled compounds
1100 H	2.1	1450		Closures, general injection moulding
1100 L	6	1500		Closures, housewares, general injection moulding
1100 N	12	1550		Closures, furniture, housewares, general injection moulding
1100 RC	23	1500		Thinwalled packaging, closures, furniture
1100 UC	75	1550		Thinwalled packaging, closures, medical lab equipment and diagnostica
1100 VC	120	1550		Techn. Applications
1102 H	1.8	1450		Caps and Closures, general injection moulding
1148 RC	23	1650	NU,AS	Thinwalled packaging, closures, housewares, housings
1148 TC	53	1600	NU,AS	Thinwalled packaging, desserts and yoghurt pots
1148 UC	75	1700	NU,AS	Thinwalled packaging, dessert and yoghurt pots, housewares
1150 N	12	1550	SL	Thinwalled packaging, closures
Random copolymers / transparent polymers				
3048 TC	53	2000	NU,AS	High-transparency, thinwalled packaging, housewares
3240 H	1.8	1250	NU	High-transparency housewares
3240 NC	12	1100	NU	High-transparency housewares
3246 RC	23	1100	NU,AS ,SL	Housewares, Syringes
3248 RC	23	1100	NU,AS	High-transparency housewares
3248 TC	48	1150	NU,AS	High-transparency thinwalled packaging, housewares
3300 MC	8	700		Flexible packaging
3340 NC	12	870	NU	High-transparency housewares
3348 SC	30	820	NU,AS	High-transparency flexible housewares

SL = slip agent NU = nucleated AS = antielectrostatic agent

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NTH Grade Slate - Injection Molding (2)

Impact copolymers				
2240 P	15	1600	NU	Housewares, furniture, cylindrical containers, crates and containers
2248 P	16	1550	NU,AS	Housewares, furniture, cylindrical containers, crates and containers
2248 S	30	1500	NU,AS	Cylindrical containers, Pails, Crates
2248 TC	48	1550	NU,AS	Housewares, thinwalled injection mouldings, margarine tubs
2248 VC	92	1750	NU,AS	Thinwalled injection moulding
2249 L	6	1500	NU,AS	Compression Moulded Caps
2249 P	15	1600	NU,AS	Caps and closures (injection moulding)
2300 K	4	1200		Crates and containers, closures
2300 L	6	1250		General injection mouldings, housewares, closures, cylindrical containers, furniture
2340 P	15	1400	NU	Housewares, cylindrical containers, crates and containers, furniture
2348 M	8	1400	NU,AS	Cylindrical containers
2348 TC	48	1350	NU,AS	Thinwalled packaging, housewares, closures
2440 K	3.5	1250	NU	Crates and containers
2440 P	16	1250	NU	Housewares, general injection mouldings
2448 L	6	1150	NU,AS	Cylindrical containers
2448 TC	54	1250	NU,AS	Thinwalled packaging, housewares, cylindrical containers
2500 H	2	1100		Crates and containers
2500 MC	8.5	1000		Crates and containers, luggage
2600 M	7.5	1150		Crates and containers, luggage, housewares
2600 PC	15	1000		Thinwalled packaging, cylindrical containers, housewares
2600 TC	48	950		Thinwalled packaging, housewares
2640 L	5	1200	NU	Crates, luggage (high toughness)
2640 PC	14	1200	NU	Crates, luggage (high stiffness and toughness, good flowability)
2700 L	6	900		Cable wheels, automotive
2800 J	3.8	800		Automotive, compounds
2900 H	2.1	650		Automotive, compounds
2900 NC	10	550		Automotive, compounds

SL = slip agent NU = nucleated AS = antielectrostatic agent

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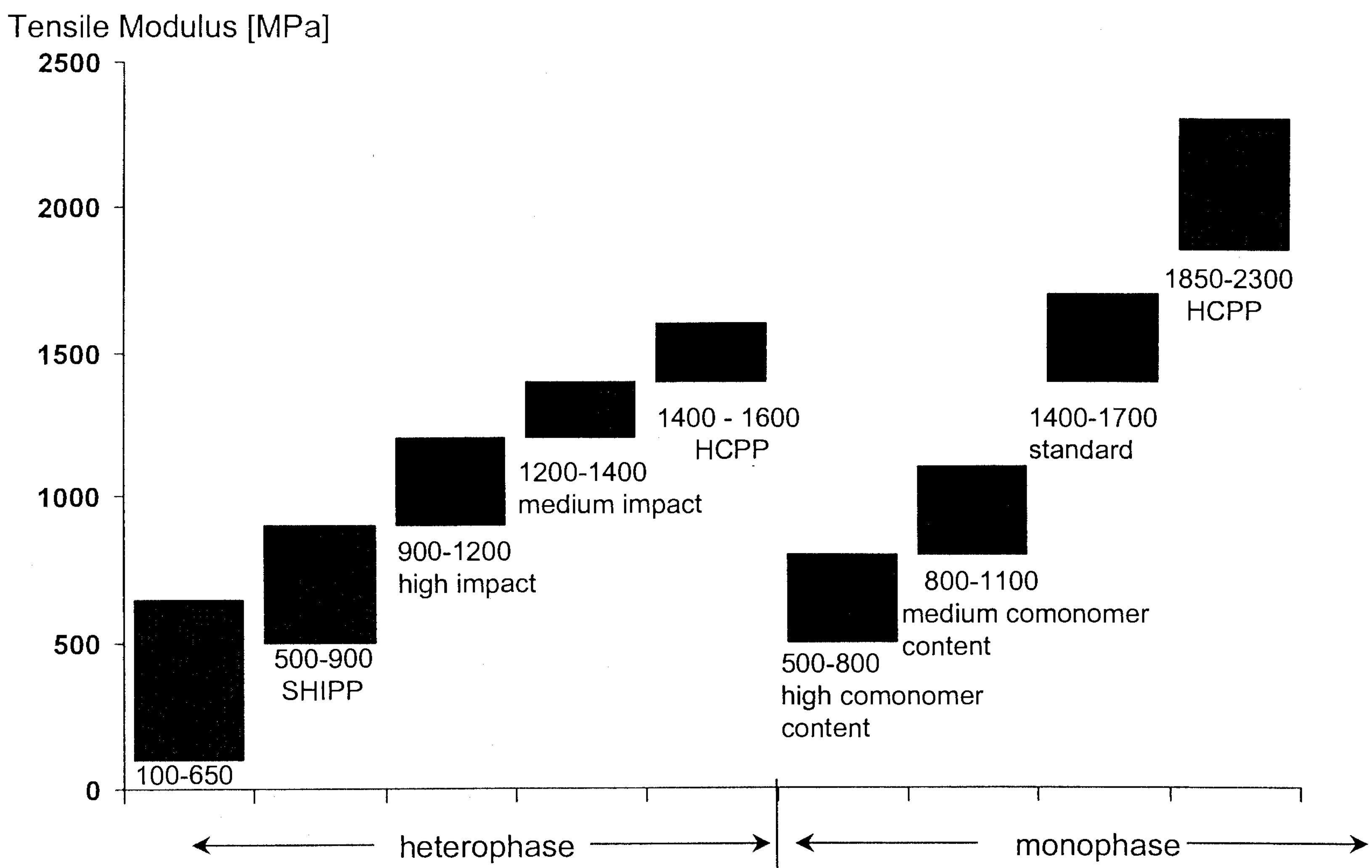
A joint venture of ABB and Equistar

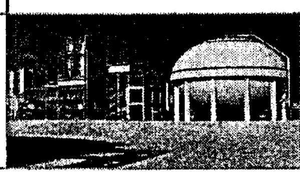
Polypropylene: Modulus for Different Product Categories

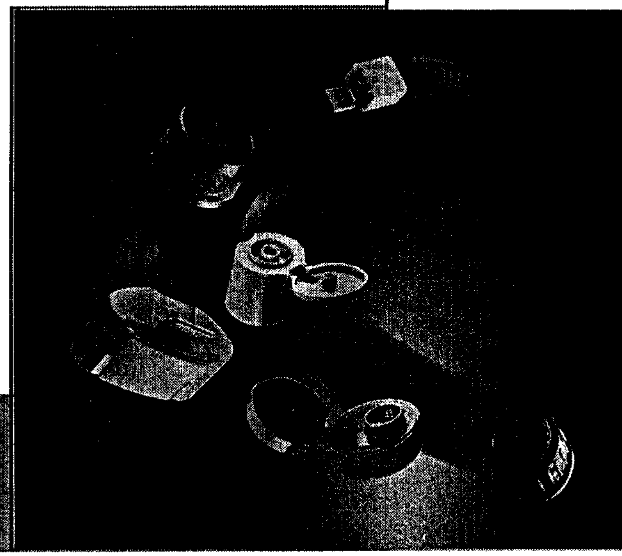


Novolen TECHNOLOGY

A joint venture of ABB and Equistar

Novolen Technical Support ABB Lummus and Equistar Chemicals, LP





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Equistar/Novolen History

- Novolen licensee since late 1970's
- First US producer of in-situ impact copolymers
- Active in catalyst and product development
- Four 25 m^3 reactor trains in Morris, IL
  - one single reactor train (HPP and RCP)
  - three series reactor trains (HPP, RCP, ICP, and TPO)

NTH Organization

- Cincinnati Technical Center (CTC)
  - Catalyst Development
  - Polymer Structure
  - Product Development and Technical Support
- Process Research Center (Morris, IL)
  - Novolen Pilot Plant
  - Two - 800 L reactors in series
- Mannheim, Germany
  - Product Development
  - Process Technology
  - Licensing and Marketing

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NTH Resources

- Dedicated staff at CTC assigned to Novolen
- The entire Equistar R&D staff and laboratory resources at CTC are at the disposal of NTH
- The 800 L Novolen pilot plant in Morris, IL, and associated support staff are committed to a minimum of six months each year to NTH to conduct Product and Process Development programs
  - These programs may either be internally (NTH) directed or directed by specific licensee needs
- Additional Process Development support is available through ABB facilities in Bloomfield, NJ, and Houston, TX

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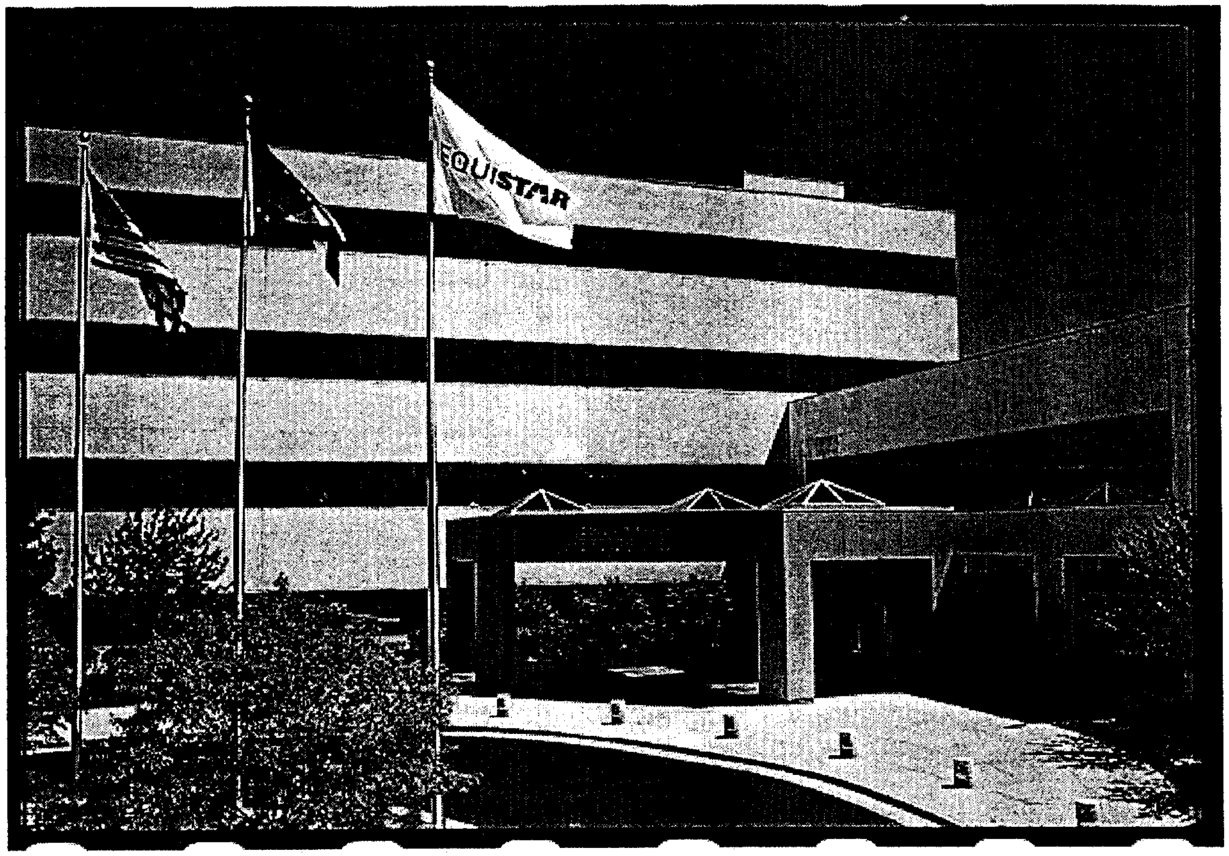
Equistar Technology Center, Cincinnati, OH



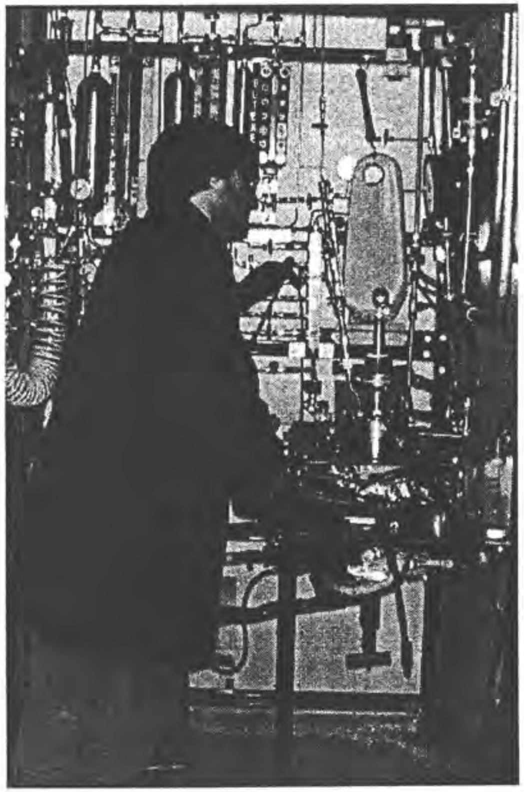
Novolen TECHNOLOGY

A joint venture of ABB and Equistar

Equistar Technology Center

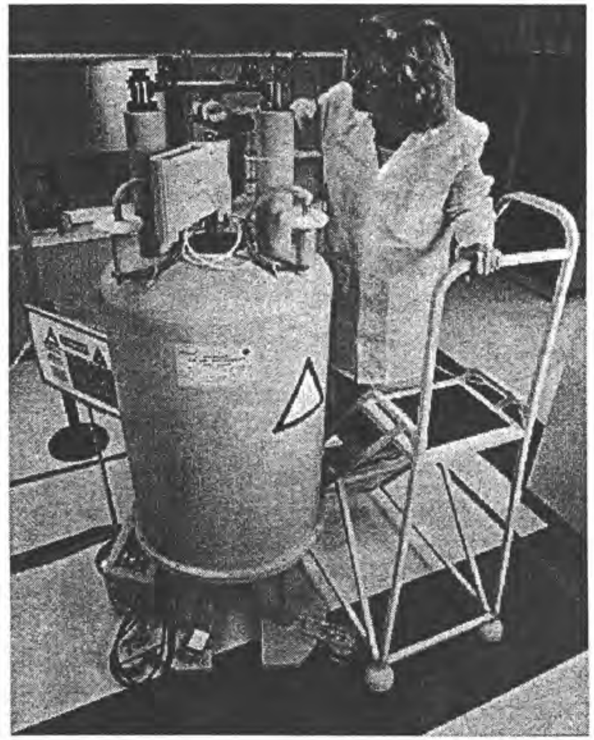
- 250,000 square foot facility containing
  - Technical Service support functions
  - Catalyst research and development labs
  - Comprehensive fabrication lab
  - Analytical and polymer testing labs

CTC Facilities



Bench Scale Reactor

Dynamic Rheometer



Nuclear Magnetic Resonance Spectroscopy

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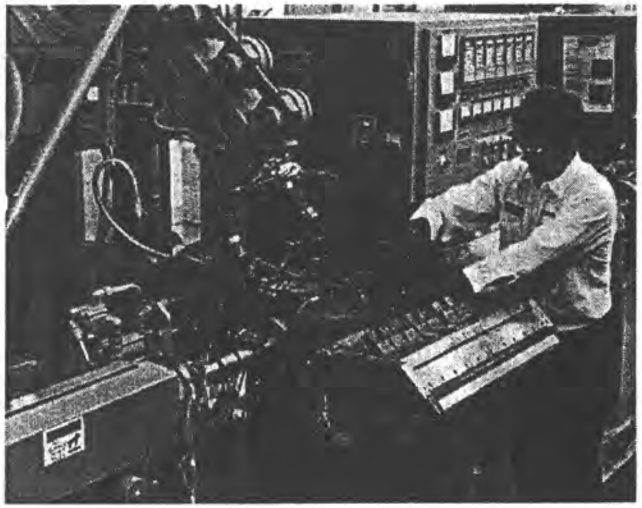
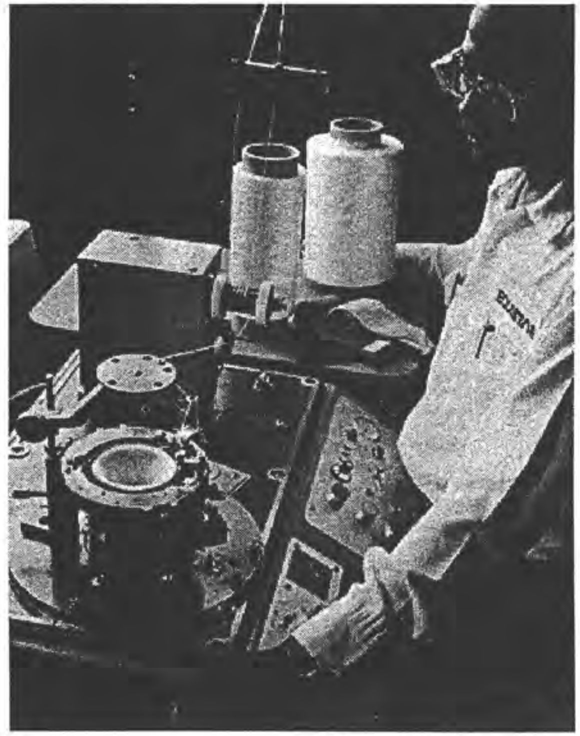
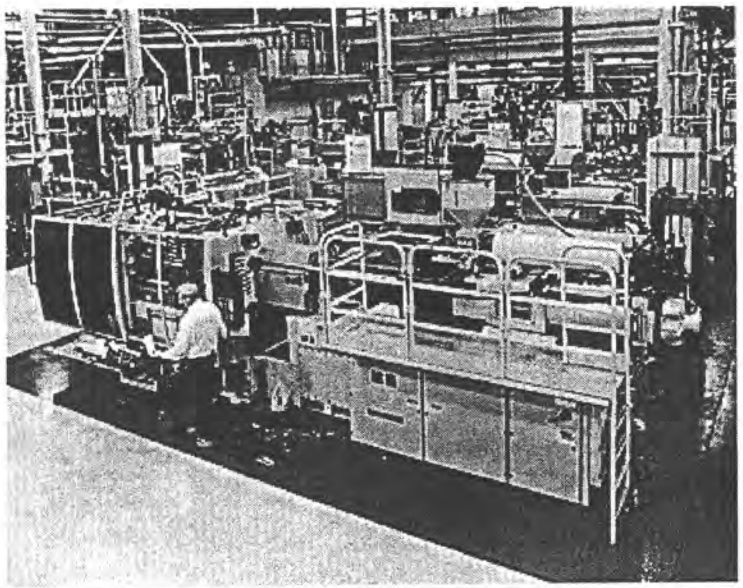
CTC Facilities



4+ Layer Coextrusion Sheet Line



Fiber Knitting Machine



Husky 300 Ton Injection Molding Machine

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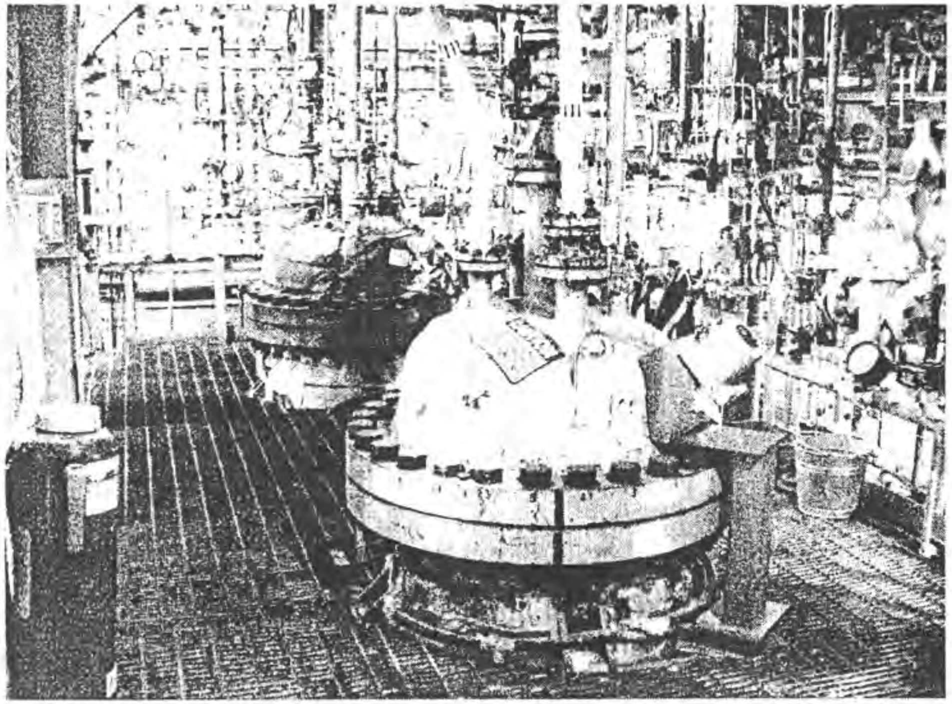
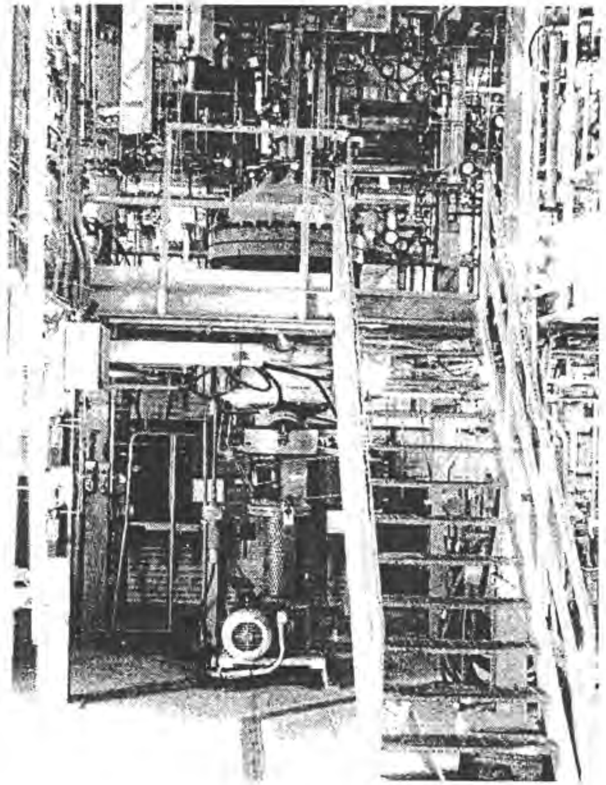
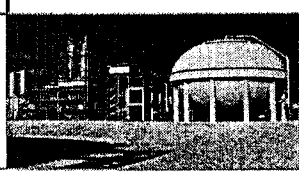
Novolen Pilot Plant

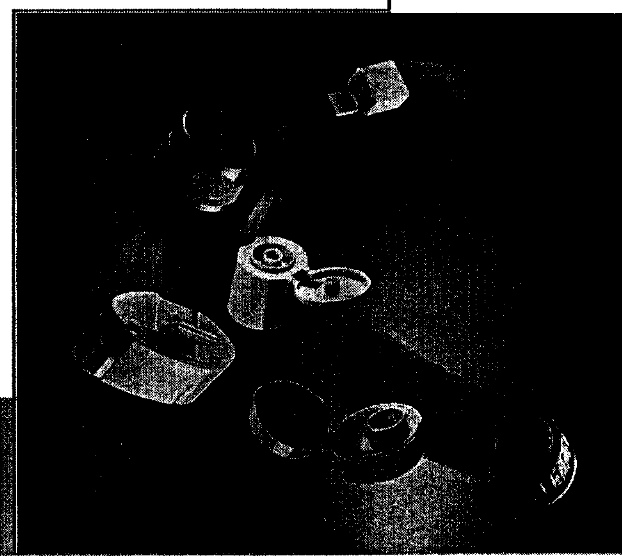




Pilot Plant Polypropylene Reactors

Summary





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Summary

- The versatility of Polypropylene has been well documented by the broad range of applications in which it is used
- Market projections continue to predict a healthy, world-wide growth rate (~6+ %) for Polypropylene
- This growth will be fueled by sustained growth in established markets, expanded consumption in areas such as China and continued substitution of high performance thermoplastics as users take advantage of Polypropylene's light weight and product design flexibility
- The Novolen platform has demonstrated the capability to produce the entire spectrum of Polypropylene products using a single catalyst system and an economical, versatile process technology
- Of all the Polypropylene technology licensors, NTH has a unique position in that it can provide complete technical support as a "non-competitor"

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The Choice for **YOUR** Future Business

Problems of Revised Bulk Loop Process

- **200 KTA plant in Austria with start-up in May 2000**
  - ➔ Plant is not operating according to announced supercritical conditions
  - ➔ If supercritical is eventually successful, there are disadvantages:
    - ◆ Operating at much higher pressure
    - ◆ Plant will be considerably more expensive
    - ◆ No product advantages seen in the marketplace
  - ➔ Plant has not reached full output
  - ➔ Plant has produced up to now only limited numer of homopolymers in standard bulk loop mode
  - ➔ Plant cannot be considered till now as a fully operational reference plant
- **No licensees**

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Rev. 1

28 Oct 02

nology Comparison:
ʾhase Processes
ɴ vs. BP / INNOVENE

ιPEX Advantages

Low Equipment Count:
NOVOLEN & INNOVENE Equipment count similar low; NOVOLEN has the **smallest reactor of all gas-phase processes.**

High yield / reactor volume:
NOVOLEN's ratio of total reactor volume / polymerisation volume = 1.3; BP'S value > 2;
NOVOLEN best yield ratio of all gas-phase processes

2) Process Related OPEX Advantages

Operation conditions:
NOVOLEN & INNOVENE have identical conditions, the polymerization cooling principle is identical, both process have no big rotating equipment (in the sense of pumps, compressors, etc.).

NOTE: all today's gas-phase processes use the same cooling principle (monomer evaporation cooling) as being invented and successfully introduced by BASF for the NOVOLEN process in the early 60s.

Catalyst transition:
NOVOLEN has only **one** catalyst, **one** co-catalyst and **one** stereomodifier for the whole product-range.
INNOVENE needs **one** catalyst, **one** co-catalyst and **two** stereomodifiers for the whole product-range

3) CAPEX/OPEX General

Homopolymers:
CAPEX: There is a disadvantage for NOVOLEN vs. INNOVENE of about 5-10% over the entire capacity range.
OPEX: These costs were found to be identical amongst all the main competitors, highly

sensitive on the raw-material cost; no advantage for INNOVENE.

Impact Co-polymers:
CAPEX: up to a capacity of 150 kta similar costs NOVOLEN vs, INNOVENE; for larger capacities clear advantage of about 12% for NOVOLEN.

OPEX: again identical costs.

Additional Advantages from NOVOLEN:
1) OSBL CAPEX: NOVOLEN has the smallest flare-load requirement among all the competitors thus reducing OSBL CAPEX
2) Space requirements: NOVOLEN has the smallest polymerisation unit among all the competitors; advantageous at clients with area restrictions and high land-costs (e.g. land-saving important for Chinese clients).

Concluding: Especially in the highly focused sector of >200 kta PP-plants for high-value products (i.e. including Impact-Copolymers) NOVOLEN is advantageous vs. BP; moreover NOVOLEN is standing out amongst **all** the competitors being the one with the **lowest investment-costs** in this sector.

NOTE: The above statements are based on "Polypropylene Technology Review Report" by Nexant ChemSystems, dated November 2001.

4) Product Transition Times

INNOVENE grade change times claims are based on a theoretical model which still has to be proven. They apply only for changes in MFI during Homopolymer operation. These times cannot be achieved for sophisticated grade-changes e.g. from inj. moulding to film & fibre grades with high product-quality requirements.
For the general transition from Homopolymers to Random-Copolymers also BP has longer grade change times as claimed (i.e. 1 hour).

Concluding: The very short grade-change times of 1 hour claimed by BP apply for MFI changes in commodity products only.

5) Comparison of Commercial Success since 1997:

Since 1997 a total of approx. 8.300 kta of PP-licenses have been awarded.
The table below shows the sub-totals of licensed capacity for both competitors.
Furthermore it shows the percentage of competitive (open) awards won by each of them.

	Awards	% of all awards	% of all open awards
NOVOLEN	2.000 kta	26 %	48 %
INNOVENE	1.200 kta	16 %	7 %

6) Metallocene Technology

NOVOLEN:

- Novolen metallocene catalyzed PP products have been successfully produced and commercialized since 1999.
- Novolen has the rights to develop metallocene technology and produce metallocene products.
- Novolen metallocene technology will be available for licensing in Q1 2003.
- Novolen metallocene technology is a drop-in technology.

INNOVENE:

- Innovene doesn't have metallocene technology.

ANNEX: Selected Bench-mark Features from NOVOLEN

1) Operational safety during emergency shut-down:
Due to the uniform powder-bed gas through-flow no risk of lump formation, especially during Random & Impact-Copolymer operation.
No local superheating due to perfect moved powder-bed with an internal circ. rate of approx. 2500 t/h.

2) Operational safety due to patented peroxide feeding system
In case of peroxide self-ignition the special developed mechanical features stop the reaction and avoid damages.

3) Special extruder cooling system
Sophisticated uniform cooling system to prevent barrel-cracking and "banana"-extruders.

4) Optional Desorber
This proven process unit reduces the monomer content of the PP-pellets below the detectable limit. Therefore big safety (e.g. no purging at silo-farm and silo-trucks) & environmental advantages are to be encountered.

5) Extrusion melt-degassing
Lowest hydrocarbon-content in case of controlled-rheology products; by-products are nearly completely removed.

6) Personnel training
Dynamic simulation training (Novolen ^{OTS}= Operator Training Simulator) available which simplifies and improves personnel training; alongwith tailor-made training manuals are given.

APPENDIX F

MTBE Unit Conversion to Iso-Octene/Iso-Octane Production – by CDTECH

Document is in CONFIDENTIAL VERSION only

APPENDIX M

U.S. Sources of Supply

U.S. SOURCES OF SUPPLY

Heaters

ABB LUMMUS HEAT TRANSFER
1515 Broad Street
Bloomfield, NJ 07003-3096
Phone: 973-893-3136
Fax: 973-893-2106

PETRO CHEM
8282 S. Memorial, Suite 120
Tulsa, OK 74133
Phone: 918-254-8000
Fax: 918-250-5107

BORN INCORPORATED
408 N. Boston Avenue
Tulsa, OK 74103
Phone: 918-582-2186
Fax: 918-582-5163

TULSA HEATER
4500 South Garnett, Suite 800
Tulsa, OK 74146-5213
Phone: 918-665-6512
Fax: 918-665-2019

Carbon Steel Towers with Stainless Steel Clad

GENERAL WELDING
6800 Old Katy Road
Houston, TX 77024
Phone: 713-869-6401
Fax: 713-869-5405

JETT WELD
12118 FM 529
Houston, TX 77041
Phone: 713-937-6200
Fax: 713-937-0178

MCIVER & SMITH
1015 Judiway
Houston, TX 77018
Phone: 713-682-3633
Fax: 713-682-1231

PROFESSIONAL PROJECTS INC.
18115 Telge Road
Cypress, TX 77429
Phone: 713-351-6315
Fax: 713-351-2382

VESSEL TECHNOLOGY
FM 2011 South
Rt. 3, Box 58A
Longview, TX 75603
Phone: 903-643-9111
Fax: 903-643-9682

SAUDER CUSTOM FABRICATORS
220 Weaver
Emporia, KS 66801
Phone: 316-342-2550
Fax: 316- 343-1681

ADDISON FABRICATION
U.S. Highway 278 West
Addison, AL 35540
Phone: 205-747-1546
Fax: 205-747-1130

HOWE BAKER
3102 East 5"
Tyler, TX 75710
Phone: 903-595-7996
Fax: 903-595-7886

Carbon Steel Towers

General Welding
6800 Old Katy Road
Houston, TX 77024
Phone: 713-869-6401
Fax: 713-869-5405

JETT WELD
12118 FM 529
Houston, TX 77041
Phone: 713-937-6200
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Emporia, KS 66801
Phone: 316-342-2550
Fax: 316-343-1681

ADDISON FABRICATION
U.S. Highway 278 West
Addison, AL 35540
Phone: 205-747-1546
Fax: 205-747-1130

HOWE BAKER
3102 East 5"
Tyler, TX 75710
Phone: 903-595-7996
Fax: 903-595-7886

Reactors

GENERAL WELDING
6800 Old Katy Road
Houston, TX 77024
Phone: 713-869-6401
Fax: 713-869-5405

BEAIRD
3350 Hwy 6 South, Suite 420
Sugarland, TX 77478
Phone: 281-565-7421
Fax: 281-565-7422

NOOTER CORPORATION
1400 South Third St.
St. Louis, MO 63104-4430
Phone: 314-621-6000
Fax: 314-421-7580

INDUSTRIAL ALLOY FABRICATORS, INC.
15405 Leeds Lane
Houston, TX 77040
Phone: 713-466-6091
Fax: 713-937-0632

VESSEL TECHNOLOGY
FM 2011 South
Rt. 3, Box 58A
Longview, TX 75603
Phone: 903-643-9111
Fax: 903-643-9682

MCIVER & SMITH
1015 Judiway
Houston, TX 77018
Phone: 713-682-3633
Fax: 713-682-1231

STRUTHERS INDUSTRIES, INC.
1500 Thirty-Fourth Street
Gulfport, MS 39501
Phone: 228-864-5410
Fax: 228-864-5555

SAUDER CUSTOM FABRICATORS
220 Weaver
Emporia, KS 66801
Phone: 316-342-2550
Fax: 316-343-1681

ADDISON FABRICATION
U.S. Highway 278 West
Addison, AL 35540
Phone: 205-747-1546
Fax: 205-747-1130

HOWE BAKER
3102 East 5th
Tyler, TX 75710
Phone: 903-595-7996
Fax: 903-595-7886

Carbon Steel Drums (Light wall)

VESSEL TECHNOLOGY
FM 2011 South
Rt. 3, Box 58A
Longview, TX 75603
Phone: 903-643-9111
Fax: 903-643-9682

JETT WELD
12118 FM 529
Houston, TX 77041
Phone: 713-937-6200
Fax: 713-937-0178

MCIVER & SMITH
1015 Judiway
Houston, TX 77018
Phone: 713-682-3633
Fax: 713-682-1231

PROFESSIONAL PROJECTS INC.
18115 Telge Road
Cypress, TX 77429
Phone: 713-351-6315
Fax: 713-361-2382

GENERAL WELDING
6800 Old Katy Road
Houston, TX 77024
Phone: 713-869-6401
Fax: 713-869-5405

ADDISON FABRICATION
U.S. Highway 278 West
Addison, AL 35540
Phone: 205-747-1546
Fax: 206-747-1130

HOWE BAKER
3102 East 5t'
Tyler, TX 75710
Phone: 903-595-7996
Fax: 903-595-7886

Carbon Steel Drums (Heavy wall)

GENERAL WELDING
6800 Old Katy Road
Houston, TX 77024
Phone: 713-869-6401
Fax: 713-869-5405

BEAIRD
3350 Hwy 6 South, Suite 420
Sugarland, TX 77478
Phone: 281-565-7421
Fax: 281-565-7422

NOOTER CORPORATION
1400 South Third St.
St. Louis, MO 63104-4430
Phone: 314-621-6000
Fax: 314-421-7580

JETT WELD
12118 FM 529
Houston, TX 77041
Phone: 713-937-6200
Fax: 713-937-0178

ADDISON FABRICATION
U.S. Highway 278 West
Addison, AL 35540
Phone: 205-747-1546
Fax: 205-747-1130

VESSEL TECHNOLOGY
FM 2011 South
Rt. 3, Box 58A
Longview, TX 75603
Phone: 903-643-9111
Fax: 903-643-9682

HOWE BAKER
3102 East 5"
Tyler, TX 75710
Phone: 903-596-7996
Fax: 903-596-7886

Carbon Steel/Stainless Steel Internals

NORTON CHEMICALS
5210 Woodway, Suite 9000 Houston, TX 77056-1724
Phone: 713-627-7667 Fax: 713-627-7567

KOCH-GLITSCH
8285 El Rio, Suite 130 Houston, TX 77054
Phone: 713-747-3330 Fax: 713-747-3320

SULZER CHEMTECH
2901 Wilcrest Drive, Suite 450 Houston, TX 77042
Phone: 713-780-4200 Fax; 713-780-2848

NUTTER INC.
639 West 41st Street Tulsa, OK 74170
Phone: 918-446-6672 Fax: 918-446-5321

Air Cooled Heat Exchangers

GEA RAINEY
5202 West Channel Road
Catossa, OK 74105
Phone: 918-266-3060 Fax: 918-266-2464

HUDSON PRODUCTS
6464 Savoy Drive, Suite 800
Houston, TX 77036
Phone: 713-914-5700 Fax: 713-914-5991

HAMMCO AIR COOLERS
6900 North Highway 169
Owasso, OK 918-272-9675
Phone: 918-272-9675 Fax: 918-272-9585

SMITHCO
6312 South 29th West Avenue
Tulsa, OK 74131
Phone: 918-446-4406 Fax: 918-445-2857

Shell and Tube Heat Exchangers

HUGHES-ANDERSON
1001 North Fulton
Tulsa, OK 74115
Phone: 918-836-1681
Fax: 918-836-5967

YUBA HEAT TRANSFER
3515 Dawson Road
Tulsa, OK 74101
Phone: 918-234-6000
Fax: 918-235-3345

OHMSTEDE INC.
895 North Main St.
Beaumont, TX 77701
Phone: 409-833-6375
Fax: 409-833-6735

SLAGLE MANUFACTURING CORP.
909 N. Wheeling
Tulsa, OK 74110
Phone: 918-584-2434
Fax: 918-584-3167

KRUEGER ENGINEERING & MFG. CO.
12001 Hirsch Road
Houston, TX 77050
Phone: 281-442-2637
Fax: 281-442-6668

ENERGY EXCHANGER COMPANY
Energy Industrial Park
1844 North Garnett Road
Tulsa, OK 74116-1612
Phone: 918-437-3000
Fax: 918-437-7144

STRUTHERS INDUSTRIES, INC.
1500 Thirty-Fourth Street
Gulfport, MS 39501
Phone: 228-864-5410
Fax: 228-864-5555

SHELL &TUBE INC.
2765 Dawson Road
Tulsa, OK 74110
Phone: 918-832-0505
Fax: 918-832-0504

API Centrifugal & Reciprocating Compressors Including Drives

DRESSER RAND
1200 West Sam Houston Parkway North
Houston, TX 77043
Phone: 713-973-5321
Fax: 713-935-3490

A.C. COMPRESSOR
397 North Sam Houston Pkwy East Houston, TX 77060
Phone: 281-272-4700 Fax: 281-272-4704

ELLIOTT COMPRESSOR
2001 West Sam Houston Pkwy North Houston, TX 77043-2498
Phone: 713-984-3825 Fax: 713-984-3905

NEUMANN ASSOCIATES
1035 Dairy Ashford Houston, TX 77079 Phone: 281-497-5113 Fax: 281-497-5047

API Centrifugal Pumps Including Drives

FLOWSERVE/INGERSOLL DRESSER PUMP
4214 Bluebonnet
Stafford, TX 77477
Phone: 281-240-4120
Fax: 281-240-5182

SULZER BINGHAM
2901 Wilcrest, Suite 345 Houston, TX 77042
Phone: 713-780-4200 Fax: 713-974-6621

GOULDS PUMPS, INC.
4500 Bissonnet, Suite 300 Bellaire, TX 77401
Phone: 713-668-3323 Fax: 713-668-4412

DAVID BROWN UNION PUMP
10812 Fallstone Road, Suite 404 Houston, TX 77099
Phone: 713-933-2900 Fax: 713-933-8262

SUNDSTRAND FLUID HANDLING 14845 West 64th Avenue
Arada, CO 80007
Phone: 303-425-0800 Fax: 303-425-0896

Distributed Control System (DCS) Equipment

HONEYWELL
8440 Westglen Drive
Houston, TX 77063
Phone: 713-780-6626
Fax: 713-780-6676

ABB AUTOMATION
3010 Briarpark Drive
Houston, TX 77042
Phone: 713-821-8943
Fax: 713-821-3510

ROSEMOUNT/FISHER
12603 Southwest Freeway
Stafford, TX 77477

FOXBORO, INC.
10707 Haddington Drive
Houston, TX 77043
Phone: 713-292-5511
Fax: 713-647-7687

Hydrogen Purification Unit (PSA)

AIR PRODUCTS
7201 Hamilton Blvd.
Allentown, PA 18195-1501
Phone: 610-481-4544
Fax: 610-481-3406

AIR LIQUIDE
3602 West 11th St.
Houston, TX 77008
Phone: 713-438-6736
Fax: 713-438-6855

UOP LLC
13105 Northwest Freeway, Suite 600
Houston, TX 77040-6312
Phone: 281-744-2800
Fax: 281-744-2880

Pipe Supports

AITKEN, INC.
4920 Airline Drive
Houston, TX 77022
Phone: 713-692-3340
Fax: 713-699-5186

PIPE SUPPORTS, INC.
2579 Lester St.
Harvey, LA 70058
Phone: 504-367-7484 Fax: 504-367-7473

EVERITT INDUSTRIAL SUPPLY
523 Crockett
Houston, TX 77530
Phone: 281-452-6464 Fax: 281-452-6660

GREAT WESTERN SUPPLY
10616A Hempstead Highway
Houston, TX 77092
Phone: 713-6814786 Fax: 713-681-8712

Pipe, Valves, Flanges, Fittings

McJUNKIN CORPORATION
4732 Darian
Houston, TX 77028
Phone: 713-320-2716 Fax: 713-675-6942

SUNBELT SUPPLY CO.
8363 Market St.
Houston, TX 77001
Phone: 713-672-2222 Fax: 713-672-2725

RADNOR ALLOYS
8300 Breen Road
Houston, TX 77240
Phone: 713-466-1600 Fax: 713-466-3303

VAN LEEUWEN PIPE & SUPPLY
15333 Hempstead Hwy.
Houston, TX 77040
Phone: 713-466-9966 Fax: 713-466-2889

KURVERS
1500 S. Dairy Ashford, Suite 4444
Houston, TX 77047-77077
Phone: 281-496-3375 Fax: 281-496-7706

MAINTENANCE ENGINEERING, INC.
3711 Clinton Drive
Houston, TX 77251
Phone: 713-222-2351 Fax: 713-223-5318

FLOWSERVE
4214 Bluebonnet
Stafford, TX 77477
Phone: 281-240-4120 Fax: 281-240-5182

INDUSTRIAL PIPING SPECIALIST
9720 Beechnut, Suite 100
Houston, TX 77036
Phone: 713-988-9100 Fax: 713-988-7201

SIMS OF TEXAS
1535 Mooney Road
Houston, TX 77093
Phone: 281-987-0550 Fax: 281-987-0580

S.W. STAINLESS
8505 Monroe
Houston, TX 77061
Phone: 713-943-3790 Fax: 713-948-5600

Instrumentation (All Field Instruments including Control Valves & Safety Valves)

ABB INDUSTRIAL SYSTEMS
3010 Briarpark Drive
Houston, TX 77042
Phone: 713-821-8943 Fax: 713-821-3510

ABB INSTRUMENTATION
3010 Briarpark Drive
Houston, TX 77042
Phone: 713-821 -
Fax: 713-821

ABB PROCESS ANALYTICS, INC.
1880 S. Dairy Ashford, Suite 370
Houston, TX 77077
Phone: 281-556-8102 Fax: 281-556-8157

APPLIED AUTOMATION, INC.
7101 Hollister Road
Houston, TX 77003
Phone: 713-939-3212 Fax: 713-939-9050

FISHER TRANSMITTERS
4230 Greenbrier
Stafford, TX 77497
Phone: 281-274-1825 Fax: 281-274-6420

FOXBORO
10707 Haddington St.
Houston, TX 77043
Phone: 713-722-5365 Fax: 713-932-0222

DANIEL FLOW PRODUCTS
9753 Pine Lake Drive
Houston, TX 77024
Phone: 713-467-6000 Fax: 713-827-3808

DRESSER VALVE & CONTROLS
11100 West Airport Blvd.
Stafford, TX 77477
Phone: 281-983-1532 Fax: 281-564-7463

HONEYWELL
8440 Westglen Drive
Houston, TX 77063
Phone: 713-780-6626 Fax: 713-780-6676

FISHER CONTROLS
12603 Southwest Freeway
Stafford, TX 77477
Phone: 281-274-0500 Fax: 281-274-0597

PUFFER SWEIVEN
4230 Greenbrier
Stafford, TX 77477
Phone: 281-274-1825 Fax: 281-274-6482

FISHER ROSEMOUNT
12603 Southwest Frwy, Suite 400
Stafford, TX 77477
Phone: 281-274-0500 Fax: 281-274-0597

MASONELIAN
11100 West Airport Blvd.
Stafford, TX 77477
Phone: 281-983-1538 Fax: 281-564-7463

AWC
4940 Timber Creek
Houston, TX 77017
Phone: Fax:

ANDERSON GREENWOOD CROSBY
43 Kendrick Street
Wrentham, MA 02093
Phone: 508-384-4572 Fax: 508-384-3152

RAWSON & CO.
2010 McAllister
Houston, TX 77092
Phone: 713-684-1400 Fax: 713-684-1409

DWYER INSTRUMENTS
13507 Lake View
Houston, TX 77205
Phone: 281-446-1146 Fax: 281-446-0696

BARTON INSTRUMENT SYSTEMS
11413 Todd Street
Houston, TX 77066
Phone: 713-682-1291 Fax: 713-682-2018

McDANIEL c/o HATFIELD INC.
11922 Cutten Road
Houston, TX 77066
Phone: 281-397-4426 Fax: 281-893-9247

FLUIDIC TECHIQUES
c/o Baro Company
10525 Kinghurst
Houston, TX 77099
Phone: 281-561-0900 Fax: 281-561-0826

PERRY EQUIPMENT
P.O. Box 640
Mineral Wells, TX 76068
Phone: 817-325-2675 Fax: 817-325-4622

MAGNETROL
c/o TECH-QUIP
11711 Playa Court
Houston, TX 77034
Phone: 281-484-4830 Fax: 281-484-5456

ABB PASTECH
6100 West by Northwest Blvd., Suite 160
Houston, TX 77042
Phone: 713-460-9541 Fax; 713-460-5918

ORANGE RESEARCH OF TEXAS
7702 FM 1960 East, Suite 106
Humble, TX 77346
Phone: 281-852-6150 Fax: 281-852-7150

PENBERTHY c/o RAWSON & CO.
P.O. Box 924288
Houston, TX 77292-4288
Phone: 713-684-1400 Fax: 713-684-1409

THERMO ELECTRIC
109 North 5th St.. Suite 200
Saddle Brook, NJ 07663
Phone: 1-800-766-4020
Fax: 1-201-843-4568

ALPHA MEASUREMENT SYSTEMS, INC.
14409 Cornerstone Village Drive
Houston, TX 77014
Phone: 281-440-0081
Fax: 281-440-0085

TELEDYNE ANALYTICAL
c/o Greson Technical Sales & Service
8040 Eastex Freeway Beaumont, TX 77704
Phone: 713-225-3384 Fax: 409-899-2356

GROTH PRODUCTS CORP.
1202 Hahlo
Houston, TX 77020
Phone: 713-675-6151
Fax: 713-675-7639

VALTEK INTERNATIONAL
5500 NW Central Drive, Suite 140
Deer Park, TX 77536
Phone: 713-690-4447
Fax: 713-895-7774

WINGO EQUIPMENT
25222 Glenloch Drive
Spring, TX 77380
Phone: 281-367-9000
Fax: 281-363-2366

YOKAGAWA CORPORATION OF AMERICA
5010 Wright Road, Suite 100
Stafford, TX 77477
Phone: 281-340-3816
Fax: 281-340-3838

Flare Tips

KALDAIR INCORPORATED
15810 Park Ten Place, Suite #195
Houston, TX 77084
Phone: 281-492-2285 xt 247
Fax: 281-492-2399

NAO
1284 East Sedgley Ave.
Philadelphia, PA 19134
Phone: 215-743-5300
Fax: 215-743-3018

JOHN ZINK
11920 East Apache
Tulsa, OK 74116
Phone: 918-234-1800 Fax: 918-234-2700

CALLIDUS TECHNOLOGIES
7130 South Lewis, Suite 635
Tulsa, OK 74136
Phone: 918-496-7599 Fax: 918-496-7587

FLAREGAS CORP.
100 Airport Executive Park #103
Manvet, NY 10954-5289
Phone: 914-352-8700 Fax: 914-352-4464

ZEECO
c/o Heat Transfer Specialists
2115 Cypress Landing, Suite 100
Houston, TX 77090
Phone: 281-580-6700 Fax: 281-580-6747

Welding Rods

HOBART BROS.
4411 Darien
Houston, TX 77028
Phone: 713-674-4722 Fax: 713-674-4214

LINCOLN ELECTRIC
3602 West 1 11th St.
Houston, TX 77008
Phone: 713-868-0333
Fax: 713-438-6870

MILLER ELECTRIC
1615 West 24" St.
Houston, TX 77008
Phone: 713-880-5533
Fax: 713-880-8961

The above is a "Preliminary List of Vendors" to be used on this project and is subject to change. All companies listed above are U.S. Suppliers.