API PRS Subcommittee
May 19, 2004

API RBI PRD Module Update

The Equity Engineering Group, Inc.

E2G The Equity Engineering Group, Inc.

API RBI PRD Module

- Provide PRS Subcommittee with an Update
- Solicit Direct Involvement of PRD RBI Methodology from PRS Subcommittee PRS Experts

API RBI PRD Module

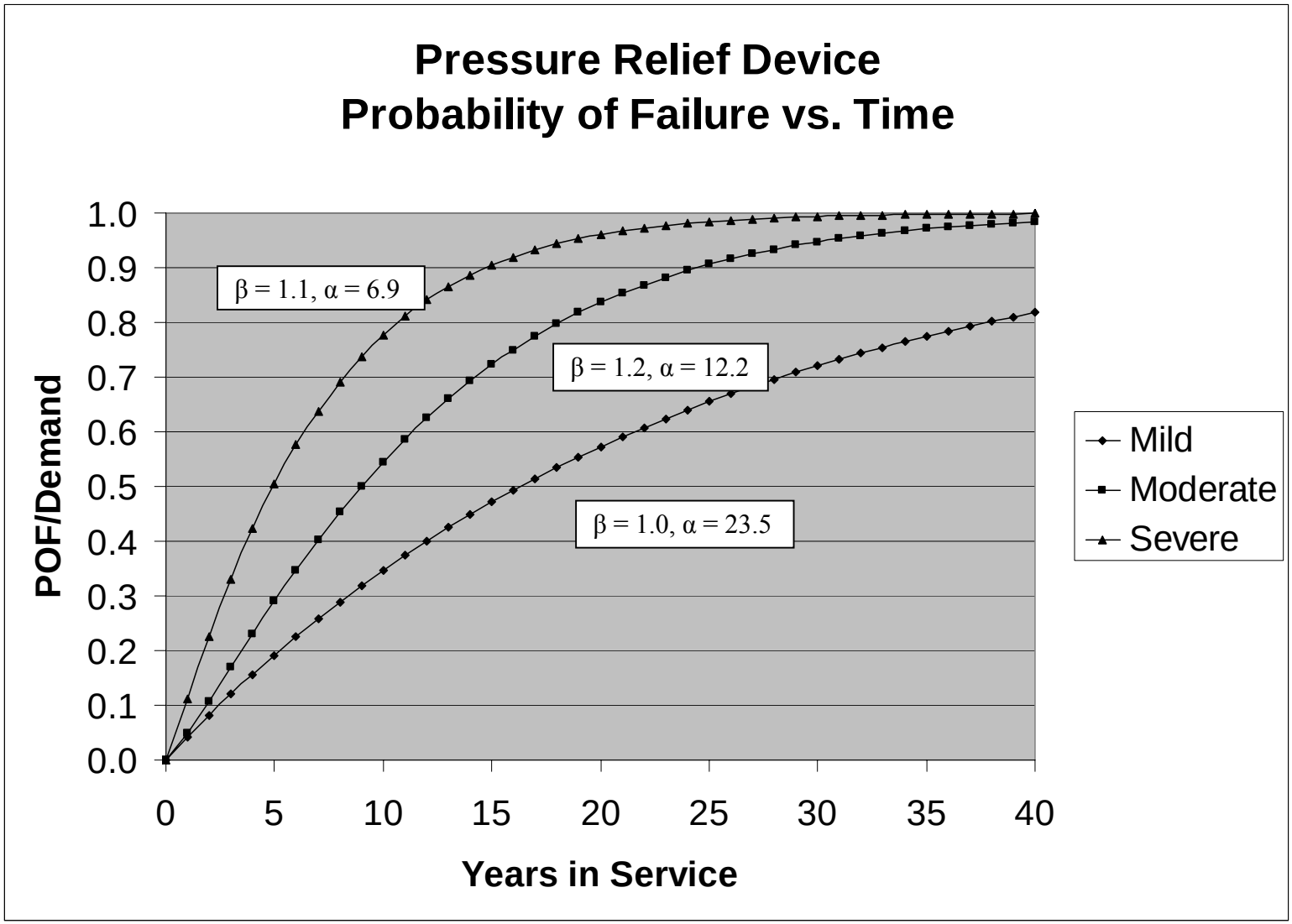
- Use Actual Failure/Leakage Database for Default Mild, Moderate and Severe Services
- Inspection History Used to Modify Failure Data
- Document Inspection History
- Direct Link PRD Module to Fixed Equipment
- Automate Demand Rate and Overpressure Potential based on Applicable Overpressure Scenarios
- Status of Modifications
- How can PRS Subcommittee Help?

API RBI PRV Module

- Use Actual Failure Database for Default Mild, Moderate and Severe Services
  - E^2G Made attempts to access the CCPS Industry Data
  - Created "Seed" Database from E2G's PRD Failure Data, could use more data.
  - Fail to Open (FAIL)
    - Stuck or Fails to Open (FTO)
    - Includes Valve Partially Opens (VPO)
    - and Opens Above Set Pressure (OASP)
  - Leakage Failure (LEAK)
    - Includes Leakage Past Valve (LPV),
    - Spurious/Premature Opening (SPO)
    - and Valve Stuck Open (VSO)

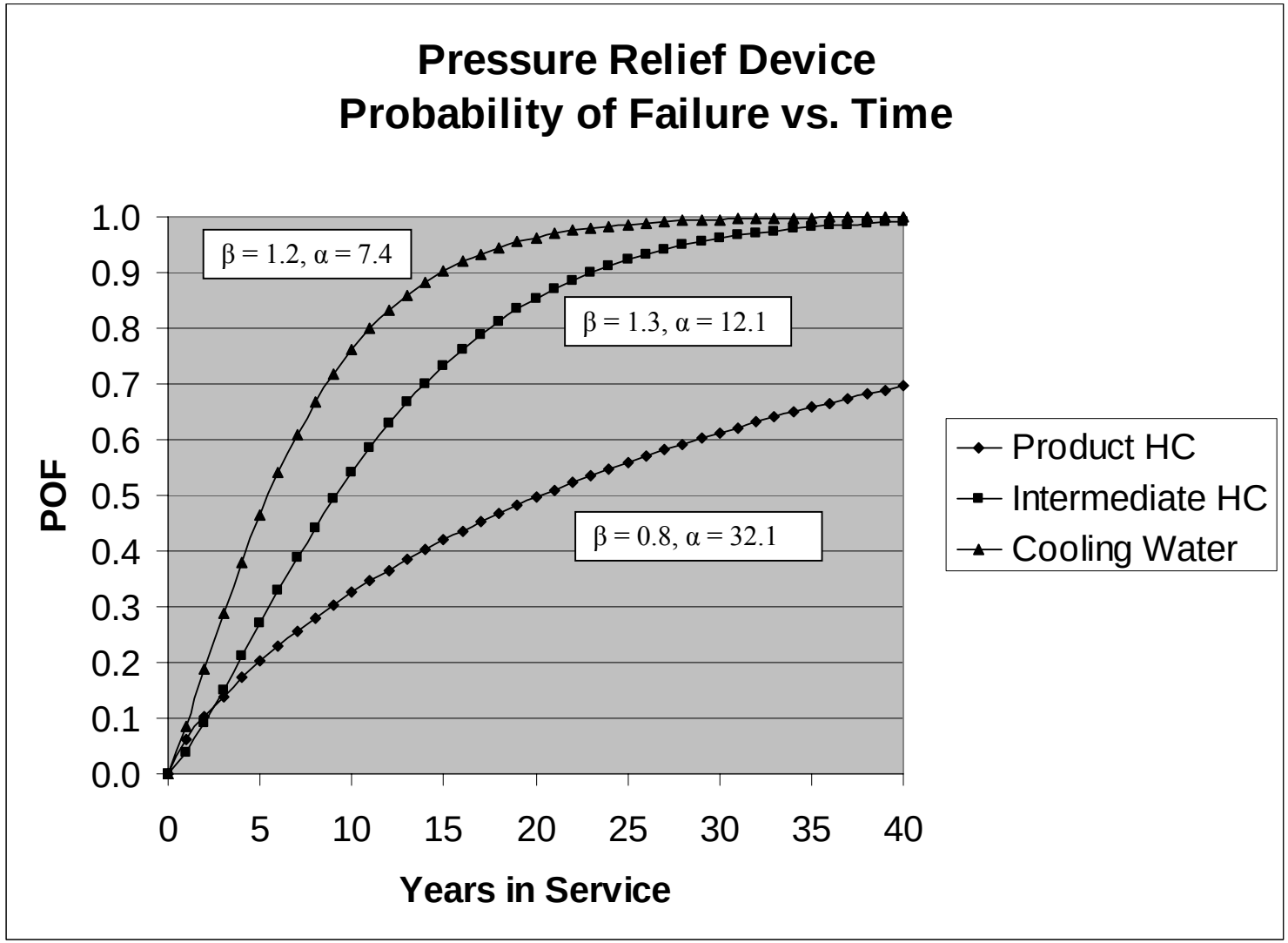
API RBI PRV Module

- Actual Failure Database for Default Mild, Moderate and Severe Services



API RBI PRV Module

- Actual Failure Database for CW, Intermediate HC and Product HC Services



API RBI PRV Module

- Use Actual Failure Database for Default Mild, Moderate and Severe Services

	Fluid Service Classification	Fluid Service Classification
Fluid	**Mild, Moderate, or Severe Pass/ Fail Data**	**Mild, Moderate, or Severe Leak Data**
H_2S	Severe	Moderate
Crude / Heavy HC	Severe	Mild
Rich / Lean Amine	Severe	Mild
Chemical- Liquid	Severe	Mild
Cooling Water	Severe	Mild
Corrosive HC Vapor	Severe	Moderate
Corrosive Liquid	Severe	Severe
Lube, Cycle and Seal Oils	Moderate	Moderate
Chemical - Gas	Moderate	Moderate
Intermediate HC	Moderate	Moderate
Air	Moderate	Mild
HC Vapor	Mild	Moderate
Process Water	Mild	Moderate
LPG/ NGL	Mild	Mild
BFW/ Condensate	Mild	Severe
Steam	Mild	Severe
Product HC	Mild	Moderate

API RBI PRV Module

- Use Actual Failure Database for Default Mild, Moderate and Severe Services
  - Default FAIL and LEAK (Mild, Moderate and Severe) curves provided in software (Weibull alphas, and betas)
    - User Selected Pick List
    - User can substitute own data (Weibull Parameters)
    - Historical inspection results used to modify default curve for EACH PRD
  - Presence of bellows
    - Has no impact on FAIL or LEAK Case
    - However, add superimposed BP to Consequence Analysis
    - Minor Impact of LEAK Data, use separate mild, moderate and severe default curves
  - Temperature
    - Currently, data shows no significant impact on FAIL
    - Significant Impact on LEAK Case
    - Use modifier on default LEAK Weibull Curve
    - Need more data for high temperature PRDs

API RBI PRV Module

- Inspection History Used to Modify Failure Data
  - Each PRD will have its inspection and testing history tracked
  - Each PRD will start out on its own specific POF and POL curve (unique set of Weibull α and β values) based on the Mild, Moderate or Severe default curves
  - A Bayesian Updating scheme will be utilized to adjust each PRV's Weibull parameters
    - Based on the PRV's complete inspection history
    - Utilizes "inspection effectiveness" similar to fixed equipment
  - PRDs Weibull parameters (POF curve) will be adjusted after each inspection
  - Allows experience and knowledge gained at the inspection interval to fine tune initial POF curve chosen for the PRV.

API RBI PRV Module

- Document Inspection History
  - Include past history, no limit on number of inspections
  - Track time in-service between inspections
  - Track PASS/FAIL/LEAK

Valve History (J318) Delete History

	Last Inspect	Inspect Result	Prepop Test	Pressure	Insp. Cost	Description	Prob	Cons	Freq	Duedate
◉	8/19/1999	Pass	Yes	42		Leaked, inlet light deposits, outlet heavy deposits, nozzle and disc fouled, guide and spring good.	LOW	HIGH	48	8/19/2003
○	9/20/1994	Pass	Yes	40		Would not reseat, Inlet and outlet light deposits, nozzle and disc cut and corroded, guide and spring			0	
○	8/23/1989	Pass	No			Inlet and outlet light deposits, nozzle fouled, disc cut, guide and spring good.			0	
○	10/29/1987	Pass	Yes	42		Would not reseat, Inlet and outlet heavy deposits, nozzle and disc cut and corroded, guide corroded,			0	

API RBI PRV Module

-- Inspection Updating Results --

```
PRD Installation Date. . . . . .  DATEINST = 1-JAN-1988
Default Alpha Parameter - FTO. . . . . ALPHA =    18.8000  years
Default Beta Parameter - FTO. . . . . BETA =     1.0000
Default Probability of Failure on Demand. PPOFOD_DEF =     0.1476
Default Alpha Parameter - Leakage. . . . . ALPHALK =     7.9200  years
Default Beta Parameter - Leakage. . . . . BETALK =     1.3000
Default Probability of Leakage. . . . . PPOL_DEF =     0.2468
```

-- Historical Inspection Summary --

Date of Inspection	Actual Duration	Inspect. Effect.	Result (P/F)	Leak (Y/N)	Ohaul (Y/N)	Ohaul Durtn	Updtd Alpha	Updtd POFOD	Updtd Alplk	Updtd POL
1-JAN-1991	3.00	A	PASS	NO	YES	3.0	19.1	0.14	8.3	0.23
1-JAN-1994	3.00	A	FAIL	NO	YES	3.0	11.9	0.22	8.3	0.23
1-JAN-1997	3.00	A	PASS	NO	NO	3.0	12.3	0.21	8.7	0.22
1-JAN-2000	3.00	A	FAIL	NO	YES	6.0	10.7	0.42	8.7	0.46
1-JAN-2003	3.00	A	PASS	NO	YES	3.0	11.2	0.23	9.0	0.21

API RBI PRV Module

- Direct Link to Fixed Equipment
  - The new PRD Module will link PRDs to their protected equipment
    - Handles equipment protected by multiple PRVs
    - Handles multiple pieces of equipment protected by common PRV(s)
  - Significantly reduces amount of input for PRDs. Links PRD to inventory group, operating and design conditions, fluid properties and most importantly to the damage state of the protected equipment
  - PRV RBI can be performed without fixed equipment RBI, with much more input required.
  - Consequence Analyses as a result of PRD failure will be performed using the consequence modeler in the fixed equipment module.
  - Following sample output is for a Vessel at one pressure in its current damage state

API RBI PRD Module

-- Fatality Area - Leak Case--

Event Description	Event Probability	Consequence Area(ft^2)	Risk Area(ft^2)
Phys. Explosion (Vapor)	0.0000	238600	0
Vapor Cloud Explosion	0.0695	52104	3620
Flash Fire	0.0695	732	51
Fire Ball	0.0000	0	0
Pool Fire	0.0000	0	0
Jet Fire	0.1389	42262	5872
Safe Release	0.7211	0	0
Totals	1.0000	---	9543

-- Fatality Area - Rupture Case--

Event Description	Event Probability	Consequence Area(ft^2)	Risk Area(ft^2)
Phys. Explosion (Vapor)	9.000E-04	238600	215
Vapor Cloud Explosion	2.250E-04	5137000	1156
Flash Fire	2.250E-04	413900	93
Fire Ball	4.500E-04	0	0
Pool Fire	0.0000	0	0
Jet Fire	0.0000	42262	0
Safe Release	0.0000	0	0
Totals	1.800E-03	---	1464

API RBI PRV Module

- Direct Link to Protected (Fixed) Equipment
  - A consequences analysis for four additional overpressure cases (PR of 1.3, 1.5, 2.0 and 4.0) will be performed for each piece of equipment being protected by the PRD being assessed.
  - Development of damage mechanism characteristic opening area (COA) philosophy allows pressure to effect release opening area and probability of rupture
  - Recognizes the fact that damaged vessels are at higher risk to failed PRD than undamaged vessels

API RBI PRV Module

- Automate Demand Rate and Overpressure Potential based on Applicable Overpressure Scenarios
  - User selects applicable overpressure scenarios from choice list
  - Software provides default demand rates (DR) and probability of potential overpressures (PR) to the selected overpressure scenarios – Allows User to Override
  - Calculate Consequence for each overpressure scenario using the demand rate on the PRD at four likely overpressure ratios
  - Calculates a weighted consequence as a result of the PRD failing to open on demand

Table 5.1: Default Demand Rates

Overpressure Demand Case	Demand Rate	$DRATE_i$ (events/year)	Reference
Fire	1 per 10 years	0.1	10.7
Blocked Discharge with Administrative Controls in Place	1 per 20	0.05	10.11
Blocked Discharge without Administrative Controls	1 per 10	0.1	10.11
Loss of Cooling Water Utility	1 per 12.5	0.08	10.7
Loss of Instrument Air	1 per 20	0.05	10.10
Thermal Relief with Administrative Controls in Place	1 per 20	0.05	Assumed same as Blocked Discharge
Thermal Relief without Administrative Controls	1 per 10	0.1	Assumed same as Blocked Discharge
Electrical Power Supply failure	1 per 12.5	0.08	10.7
Control Valve Failure	1 per 10	0.1	10.1
Tower P/A or Reflux Failures	1 per 12.5	0.08	Assumed same as electrical Power Failure
Runaway Chemical Reaction	1 per 50	0.02	10.7
Overfilling	1 per 15	0.067	
Hot Oil Contact with Water	1 per 15	0.067	
Heat Exchanger Tube Rupture	1 per 100	0.01	10.5

Table 7.2 – Overpressure Demand Case Severity and Overpressure Probability Distribution

Demand Case Severity	Overpressure Demand Cases	Description	Potential Overpressure Ratio			
			1.3	1.5	2.0	4.0
1	Blocked Discharge against Centrifugal Pump, Thermal relief	Overpressures typically will be less than hydrotest, resulting in potential for leaks, virtually no potential for vessel rupture	70%	20%	10%	0%
2	Fire, Outlet control valve failure, Blocked Discharge	An increase in the potential of leaks and cracking in damaged vessel components, still very unlikely, that a rupture will occur.	55%	25%	15%	5%
3	Loss of Cooling, Inlet control valve failure, Loss of tower P/A or reflux	Follows a typical industry trend of potential overpressures.	40%	30%	20%	10%
4	Heat Exchanger Tube Rupture	Will result in overpressures well over hydrotest with a very high potential of leaks and cracks developing in damaged equipment, Higher potential for vessel rupture	20%	20%	30%	30%
5	Runaway Chemical Reaction, HP/LP Interface with Gas Breakthrough	Highest potential for vessel rupture	0%	10%	30%	60%

API RBI PRV Module

- The calculation of risk for a PRD failing to open upon demand is calculated for EACH applicable demand case using the demand rate, the probability of failure of the PRD and the calculated overall consequence of failure for the demand case as follows:

$$Risk_{DC} = PF_{DC} \times Cons_{DC}$$ Equation 8.1

- The overall risk is then determined by adding up the individual risks associated with the applicable demand cases as follows:
-

$$Risk_{total} = \sum_{i=1}^{n} PF_i \times Cons_i$$ Equation 8.2

- where *i* represents each of the *n* number of applicable overpressure demand cases.

API RBI PRD Module

Weighted results for four overpressure cases

-- FTO Risk at Future Test Interval --

Demand Case	DRate (dmnds/yr)	POF (fails/yr)	Fatal Conseq (ft2)	Equip Conseq (ft2)	Fatal Risk (ft2)	Equip Risk (ft2)	Fatal Risk ($)	Equip Risk ($)	Total Risk ($)
Fire	0.0100	0.0051	2881	791	10.9	4.0	5447	2012	7459
Blocked Discharge	0.1000	0.0509	1517	558	77.2	28.4	38601	14201	52802
Inlet CV Failure	0.1000	0.0509	2764	1023	141.7	52.1	70345	26041	96386
Thermal Expansion	0.1000	0.0509	2140	791	109.8	40.2	54473	20121	74594
Chemical Runaway Rx	0.0200	0.0102	7725	2881	78.7	29.3	39327	14667	53994
Totals	---	---	---	---	416.4	154.1	208193	77042	285235

-- Leakage Risk at Future Test Interval --

Description Cost	Consequence ($)	Risk ($)
Fluid Cost	29635	17014
Environmental Cost	5000	2871
Shutdown Cost	50000	28707
Lost Production	60000	34448
Totals	144635	83040

Total Risk is $368275

API RBI PRV Module

- Automate Demand Rate and Overpressure Potential based on Applicable Overpressure Scenarios
  - Advantages
    - User only needs to select the applicable overpressure scenarios, available from plant relief studies
    - Recognizes the fact that PRDs may have many different overpressure scenarios, each scenario having its own demand rate and likely overpressure upon PRD failure
    - Gives User expert guidance on typical PRD demand rates and potential overpressures, provide default values
    - Enables the criticality of the PRD service to impact Risk, i.e. more critical services result in more risk

API RBI PRV Module

- Status of Modifications
  - PRD Module Draft Technical Document Written
    - PRV Technical Working Group Review
    - Ballot by??
  - PRD Failure/Leakage Database
    - Failure and Leakage Rate “Seed” Databases Complete
    - Able to accept additional data
    - Need Pilot PRV and Rupture Disk Data
  - PRD Software Development
    - XCEL Database tool complete, proof of concept
    - Backbone FORTRAN coding complete
    - Testing on-going
  - Incorporation into API RBI Rev. 6.0 end of 2004??

PRESSURE RELIEF DEVICES (PRD) TECHNICAL MODULE

DRAFT 2 – April 2004

American Petroleum Institute

API RBI PRV Module

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API RBI PRV Module

- How can PRS Subcommittee help?
  - Provide expert review of PRD Technical Document
    - Table 5.1 - Default Demand Rates
    - Table 7.2 - Default Demand Case Severity and Overpressure Potential Distribution
  - Provide additional PRD Reliability/Failure data, particularly for POPRV and RDs
  - Test Drive Software
    - Reality Checks

API RBI User Group

ADGAS	SGS (Shell)	Portuguese Welding
Amerada Hess	Flint Hills Res.	Petro-Canada
BP	Irving Oil	Placid Refining
Berwanger	Italian Welding Inst.	Saudi Aramco
ChevronTexaco	JGC Plantech	Suncor
Coastal, Aruba	Lyondell Equistar	Sunoco
ConocoPhillips	Marathon Ashland	TotalElfAtofina
DNV	PDVSA	Valero
Dow	Petrobras	