Appendix A
Individual P2/WM Projects

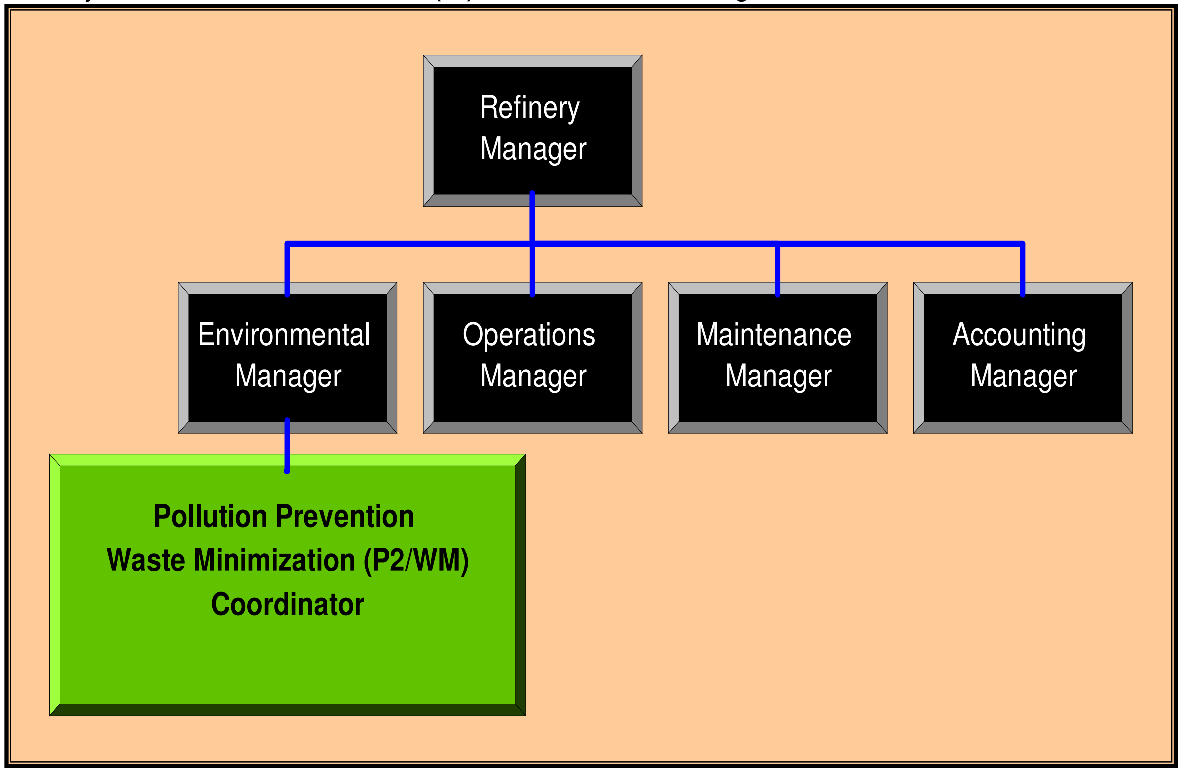
P2/WM Initiatives Designated as **"Minimum" voluntary efforts** most refineries in the evaluation have implemented.

Designated as A1 through A10

(Note: there may be additional, minimim initiatives many refineries in the Region 8 have implemented but were not included in this document)

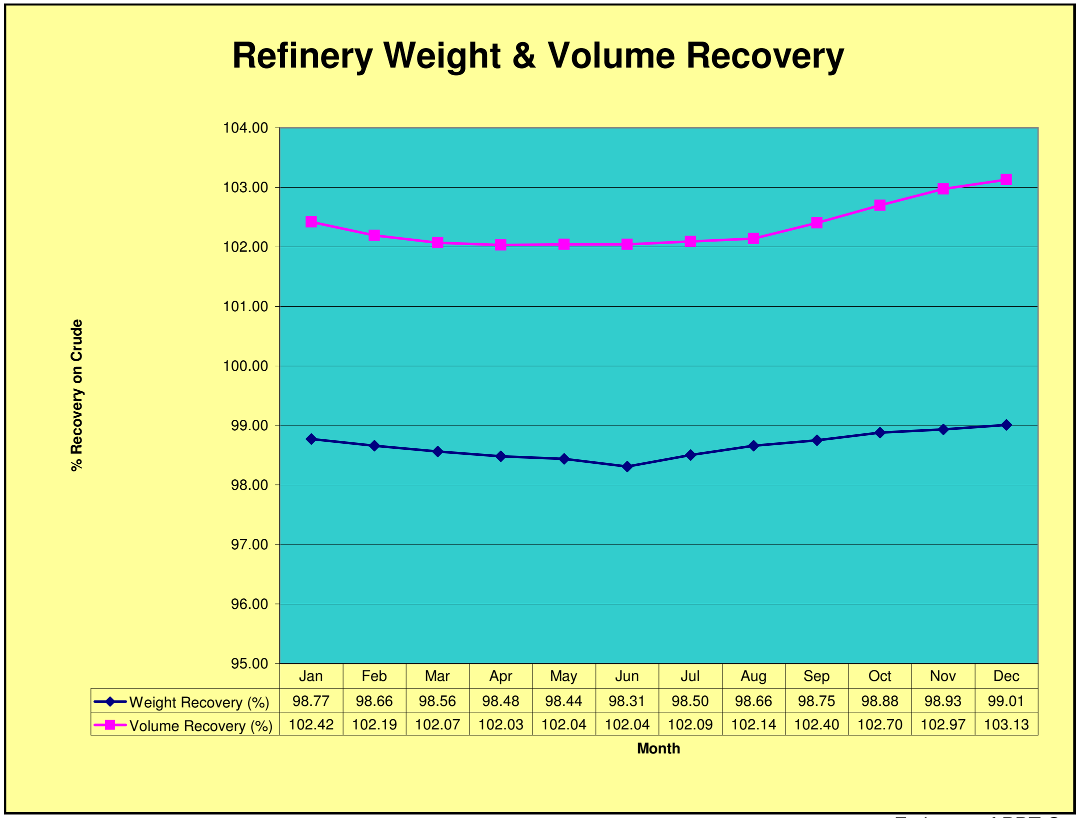
Pollution Prevention and Waste Minimization (P2/WM) Profiles Emphasizing **PBT*** Chemical Reductions for Petroleum Refineries
*(Persistent, Bioaccumulative and Toxic)

Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries **A1**



All refineries in the evaluation had designated a Pollution Prevention or Waste Minimization (P2/WM) Coordinator. Generally, this position provides the advantage of a single point of contact accountable for measurement, reporting and follow through of P2/WM initiatives.

P2 Initiative Description	PBT **Constituent(s)**	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents **(lbs./yr., 50,000 bpd basis)**	Non-PBT waste and/or **Constituent(s)**	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents **(lbs./yr., 50,000 bpd basis)**
A1. Designate a Waste Minimization and/or Pollution Prevention (WM/P2) Coordinator (procedure modifications) : Designating a specific person or position enhances WM/P2 prospects since at least one person becomes accountable to assess P2 opportunities and measure gains.	benzo (a) pyrene Mercury (Hg) PCBs	Significant benefits evident but not practicably quantifiable for this project.		



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Weight Recovery (%)	98.77	98.66	98.56	98.48	98.44	98.31	98.50	98.66	98.75	98.88	98.93	99.01
Volume Recovery (%)	102.42	102.19	102.07	102.03	102.04	102.04	102.09	102.14	102.40	102.70	102.97	103.13

Source: example calculations only and not necessarily representative of any refinery in the evaluation.

Refiners may choose and implement differing methods of gauging recovery or "yield" of products on crude oil input. Achieving a degree of accuracy can be tedious for many of the figures but the regular tracking of this recovery is often crucial for minimizing hydrocarbon loss. Volume figures can typically exceed 100 % recovery on crude because of normal volume gains during cracking and similar processing.

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
A2. Regular evaluation of weight yield/volume yield (or "recovery) (procedure modifications) : Regular assessment of hydrocarbon loss is crucial to P2 efforts since a seemingly insignificant 0.01 % weight loss translates into approximately 40,000 - 50,000 lbs. hydrocarbon loss per month for a relatively small 50,000 BPD refinery. It is very difficult to reduce hydrocarbon losses to the environment if the refinery weight yield is not regularly completed to attempt quantification of the loss.	Benzo (a) pyrene	27	TPH	547,500
	Mercury (Hg)	0.27	Benzene	1,369

BaP reduction estimate = 50ppm BaP in hydrocarbon x 10^-6 x 0.0001 HC loss improvement factor x 0.50,000 bpd x 300 lb/bbl x 365 days/yr
Hg reduction estimate = 0.5 ppm Hg in hydrocarbon x 10^-6 x 0.0001 HC loss improvement factor x 50,000 bpd x 300 lb/bbl x 365 days/yr
Total Petroleum Hydrocarbon (TPH) or HC loss reduction = 50,000 bpd x 300 lb/bbl x 0.0001 HC loss improvement factor
Benzene reduction estimate = 0.0025 lb benzene/lb crude x 50,000 bpd x 300 lb/bbl x 365 days/yr x 0.0001 HC loss improvement factor

Depending on raw water hardness and refinery size, segregating lime softner wastes can reduce hazardous waste generation by 300 - 500 tons per year (tpy) for regional refineries.

This can be done with separate, non-oily conveyance systems, with sedimentation basins or other methods. Whatever the method, the main objective is to avoid contact of these wastes with oily process sewers. Wastes such as lime softner sludges also have the potential for beneficial use if they are not contaminated with oily wastes.

"Hot process" lime softner vessel with non-oily wastes in conical bottom managed separately from oily wastes (conical bottom behind brick wall)

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
A3. Segregation of oily from non-oily wastes (procedure modifications) : Segregation of these wastes significantly reduces total oily waste generation by avoiding contact of non-oily wastes with oily process sewers. Examples of non-oily process wastes to segregate from oily process wastewater systems include water softner sludges generated from lime softening for boiler water (& some cooling waters), boiler blowdown solids, etc.	Benzo (a) pyrene	30	F037 sludges	600,000

BaP reduction estimate = 50ppm BaP in waste x 10^-6 x 300 tpy lime waste to F037
F037 sludges reduction estimate = 300 tpy lime sludges contaminated by oily process sewer x 2000 lb/ton

Wastewater management areas open to windblown particulate, storm silt, etc. can surprisingly add to oily waste generation with accumulation of these solids in units.

Wastewater management areas designed to minimize storm silt inflow. Slats in fence can reduce added waste volumes by a surprising 20 - 30 % in areas such as Wyoming.

P2 Initiative Description	PBT **Constituent(s)**	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents **(lbs./yr., 50,000 bpd basis)**	Non-PBT waste and/or **Constituent(s)**	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents **(lbs./yr., 50,000 bpd basis)**
A4. Significant control of stormwater and windblown solids entering oily wastewater system (equip. & technology modifications, procedure modifications, housekeeping, maintenance, training) : Successful, significant control of non-contaminated storm solids can avoid generation of hundreds of tons of oily waste by avoiding flow through oily wastewater system. These solids become coated with oil in process sewers and are subsequently deposited as waste in downstream separators, etc. Controls included fencing or covering of oily wastewater management structures (ex: ABTU's, equalization basins), curbing & paving earthen areas which could drain to oily wastewater system, sediment retention at oily sewer grates, re-routing stormwater, etc.			oily sludges	400,000

oily sludge reduction estimate = 1000 tpy avg. oil sludge generation x 0.2 reduction factor x 2000 lbs/ton

Spent/used drums often contain several pounds of residual chemicals. Minimizing use of drums significantly reduces the volume and toxicity of wastes from the combined residues in several hundred drums of chemicals consumed in a year. The photo to the right is an example of a portable chemical container which is normally refilled with no residual waste.

P2 Initiative Description	PBT **Constituent(s)**	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents **(lbs./yr., 50,000 bpd basis)**	Non-PBT waste and/or **Constituent(s)**	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents **(lbs./yr., 50,000 bpd basis)**
A5. Minimize use of drums for chemical additives (procedure modification): Minimizing use of drums prevents pollution by reducing the wasted residual which is not recovered from each chemical additive drum (normally > 1 gal. or 8 lbs.). Since it is not unusual for even a small refinery to use over 200 different chemical additives and potentially over 500 - 1,000 drums in a year, this effort yields significant P2 benefits. Methods normally consisted of requiring chemical vendors to supply chemicals in refillable, "PORT A FEED" or similar containers supplied by vendors.	benzo (a) pyrene Mercury (Hg)	0.20 1	TPH	2,800

BaP reduction estimate = 200 of 500 chemical drums with BaP component x 10 lbs residual/drum x 100 ppm BaP in residual

Hg reduction estimate = 10 of 500 chemical drum containing 0.1 lbs each of Hg as polymer, grout or coating catalyst component

TPH reduction estimate = 200 of 500 drums with TPH component x 2 gal TPH residual x 7 lb/gal

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
A6. Personnel training (training): Regular and pertinent training for management and operating personnel is one of the most significant WM/P2 initiatives since it is the properly motivated and knowledgeable worker who must implement WM/P2 initiatives.	benzo (a) pyrene Mercury (Hg) PCBs	Significant benefits evident but not practicably quantifiable for this project.		

Chromates can be released in cooling tower "drift" (the mist seen emanating from cooling towers) and from accumulations in cooling tower basin sludges and in wastewaters.

To a certain extent, cooling tower drift can contain whatever contaminants/chemicals are in the cooling water system since the drift can be in aerosol form vs. simple water vapor from evaporation. In addition, reducing toxicity of chemicals in cooling water system minimizes releases to land and water in the form of cooling tower basin sludges and blowdown wastewaters.

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
A7. Eliminate use of chromate corrosion inhibitors and pentachlorophenol biocides in cooling tower system (technology modification): WM/P2 is achieved since the relatively large volumes of cooling tower basin wastes will not contain these hazardous constituents. Most common P2 practice was to convert to phosphate corrosion inhibitors and to chlorine and or bromine-based biocides.			Chromium Pentachlorophenol	21,918 13,151

Cr reduction estimate = 200 gpm (blowdown + drift) x 8.34 lb/gal x 1440 min/day x 365 days/yr x 25 ppm Cr residual / 10E6

PCP reduction estimate = 200 gpm (blowdown + drift) x 8.34 lb/gal x 1440 min/day x 365 days/yr x 15 ppm PCP residual / 10E6

Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
A8. Eliminate use of Poly Chlorinated Biphenyls (PCBs) in electric transformers (material substitution): In most cases, this was achieved by: (1) draining PCB dielectric oil from transformers; (2) adding non PCB oil; (3) placing transformer back in service for at least the TSCA regulatory requirement of 90 days and; (4) testing the dielectric oil for PCB content < 50 parts per million (ppm). IF necessary, the process was repeated until the PCB content < 50 ppm. Some refiners changed out whole transformers. Both initiatives reduced PCB pollution from future transformer leaks, accidents, etc.	PCBs	150,000		

PCB reduction estimate = 100 gallons/transformer x 15 lb/gal x 200 transformers x 0.5 (assume 50 % PCB content)

Mercury-Containing Flow Meters

Description:
Flow meters are used for measuring water flows and steam pressure at larger plants, such as water and sewage plants, power stations and heating plants.

How to Identify:
A variety of different sizes and shapes can be found. Ask the personnel at the plant for help and ask how much they know about the equipment. If the equipment has been replaced and or repaired, check drains located nearby for possible contamination.

Amount of Mercury:
Always assume that the flow meter does contain mercury until you can find the facts about the manufacturer and the model. Some models do contain large quantities of mercury - 5 kilograms and more.

Safe Removal:
If the device is small enough to be contained in a airtight package, consult a mercury recycler about how to ship properly to avoid spillage.
If the device is too large to be shipped in an airtight container (such as the devices pictured above), the mercury will need to be poured out of the device into a separate container. Given the potential for spills, such operations require that you are prepared to contain possible spills, that you have appropriate airtight, unbreakable containers for the mercury, that you have personal protective equipment on hand, that you provide adequate ventilation, and that Occupational Health and Safety regulations are followed. Thus, the typical demolition contractor should inform the building owner when such a device is encountered, so that a contractor with the necessary equipment and experience can remove the device.

Safe Disposal:
The mercury drained from the device, as well as the parts of the meter that have been in contact with mercury should be regarded as mercury waste and properly disposed of with a mercury recycler.

Refiners have eliminated the use of mercury in numerous instrument applications such as steam and gas metering equipment (similar to the one at left). They have also discontinued use of mercury in larger volume applications with large storage tank vacuum breakers, etc.

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
A9. Eliminate use of mercury in instruments and other equipment (material substitution, technology modification): This initiative results in significant P2 by removing instruments, storage tank vacuum "breakers" and other equipment containing mercury and significantly reduce the release of mercury into the environment from equipment leaks, accidents, fires and other mishaps. This was normally achieved by replacement of mercury-containing equipment with digital instruments.	Mercury (Hg)	100		

Hg reduction estimate = 50 Hg metering units x 20 lb Hg/unit x 0.1 (10 % failure or Hg loss rate)

Valuable P2/WM initiatives can be "low tech" and still provide significant benefits. The dewatering pad in the figure to the left provides a readily available area with adequate maneuvering space for heavy equipment. Wastes are placed on the pad and water/oil/fluids allowed to drain to the sloped, collection portion of the pad (left of center). The need for such dewatering can occur on a daily basis during some refinery maintenance activities. The fluids can then be collected and managed in the facilities' wastewater treatment system with significant reduction in the volume and toxicity of remaining solids.

However, such pads can be relatively expensive with special design features such as sloping, reinforcement, liners, etc. Depending on size and other design features, the cost for these areas can range from $100,00 - 300,000 +.

Liquids drain to one corner by design.

Remaining solids significantly dryer without cost and energy requirement of more elaborate equipment.

P2 Initiative Description	PBT **Constituent(s)**	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents **(lbs./yr., 50,000 bpd basis)**	Non-PBT waste and/or **Constituent(s)**	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents **(lbs./yr., 50,000 bpd basis)**
A10. Maximize de-oiling/de-watering of oily wastes wherever practicable and as soon in the process as practicable (process modification): Results in significant P2 with recovery of hydrocarbons (HC) and avoids environmental costs of shipping water with wastes and saves energy with less water in wastes going to fuels programs, etc.	1. Benzo(a)pyrene	2	TPH	400,000

BaP reduction estimate = 1000 tpy oily wastes x 2000 lb/ton x 5 ppm BaP in oil component / 10^6 x 0.2 (20 % oil)

TPH reduction estimate = 1000 tpy x 2000 lbs/ton x 0.2 (20 % oil component)

Appendix B
Individual P2/WM Projects

P2/WM initiatives designated as potentially newer or innovative, voluntary efforts initiatied by petroleum refineries in the evaluation.

Designated as B1 through B21

(Note: there are likely additional, P2/WM innovations many refineries in the region have implemented that were not included in this document)

Ammonia adsorption refrigeration unit

Flares are a necessity at most refineries. They provide a safe outlet for gases which can not be used/consumed to make products at a given time. Within limits, flaring rates can be controlled but the flare must remain an available relief device. This refinery has installed a adsorption/ refrigeration unit to cool, condense and recover much of the hydrocarbons that would otherwise be flared.

This process reduces hydrocarbon losses by approximately 2,000,000 gallons per year of light petroleum gases and gasoline-range materials.

P2 Initiative Description	PBT **Constituent(s)**	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents **(lbs./yr., 50,000 bpd basis)**	Non-PBT waste and/or **Constituent(s)**	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents **(lbs./yr., 50,000 bpd basis)**
B1. Flare gas recovery (technology modification, energy efficiency/conservation): Refinery gases normally flared to atmosphere and lost are recovered by novel refrigeration/ adsorption process for sales or use in refinery.	Benzo (a) pyrene Mercury (Hg)	12 2	TPH	12,000,000

Bap reduction estimate = 12,000,000 lbs hydrocarbons prt year x 0.000001 BaP component

Hg reduction estimate = 12,000,000 lbs hydrocarbon (as propane) x 20,000 btu/lb x 1 MWh/3,412,000 btu x 0.00003 lb Hg/MWh/yr x 0.5 (50% energy savings for electrical power to operate refrigeration unit)

(this also assumes electrical generation savings from hydrocarbon btu content thru co-generation or electrical power savings)

Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries

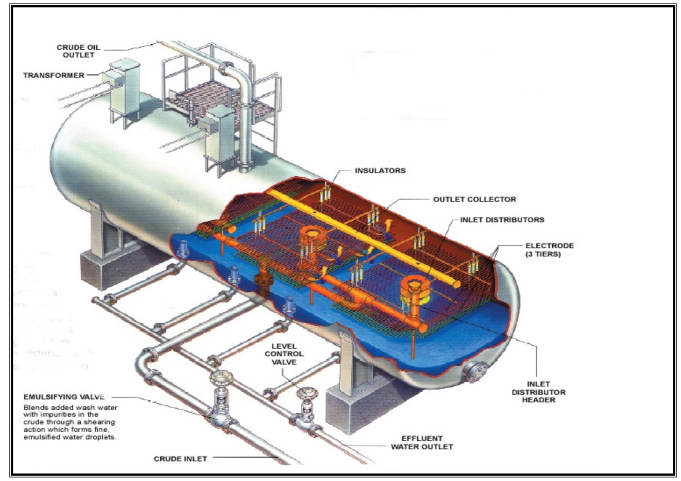
B2

One of the first opportunities for P2/WM in a refinery would be with crude oil, the raw material. A refiner running 50,000 barrels per day (bpd) is processing approximately 15,000,000 lbs. of material each day. If only an added 0.01 % (0.0001) of the crude oil feed is contaminants, it could lead to as much as 500,000 lbs. (250 tons) of additional waste each year.

Efficient contaminant removal is very dependent on frequent and reliable information for the exact location (level) of the oil-brine (oil-water) interface in the desalter vessel. This vessel is utilized to remove contaminants from incoming crude oil. This continuous level indication provides better control of make-up water volumes and other parameters for more efficient desalter operation. Upgrading the desalter monitoring system with an interface probe better accomplishes the desalting objectives by providing continuous information on this interface and other operating parameters. The result is fewer contaminants in crude oil with a consequent reduction in downstream corrosion and other waste generation. An added P2/WM benefit is reduced hydrocarbon losses in the brine, desalter effluent.

Crude oil desalter unit with interface probe at oil-brine interface inside vessel.

Simple schematic of crude oil desalter vessel (Petreco International).



P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B2. Oil/water interface probe installed in crude oil desalter unit (equipment modification): Continuous level detection of oil-water interface with Agar probe significantly reduces oil losses to brine effluent of desalter unit and reduces corrosive contaminants in crude oil leading to downstream generation of hazardous wastes in fractionating towers, heat exchangers, etc..	Benzo (a) pyrene	1	TPH	50,000
	Mercury (Hg)	1		

BaP reduction estimate = 250 tons oily waste x 2000 lb/1 ton x 1 ppm BaP oily waste content / 10^6

Hg reduction estimate = 250 tons oily waste x 2000 lb/1 ton x 1 ppm Hg oily waste content / 10^6

TPH reduction estimate = 250 tons oily waste x 2000 lb/1 ton x 0.1 fraction oil in oily waste content

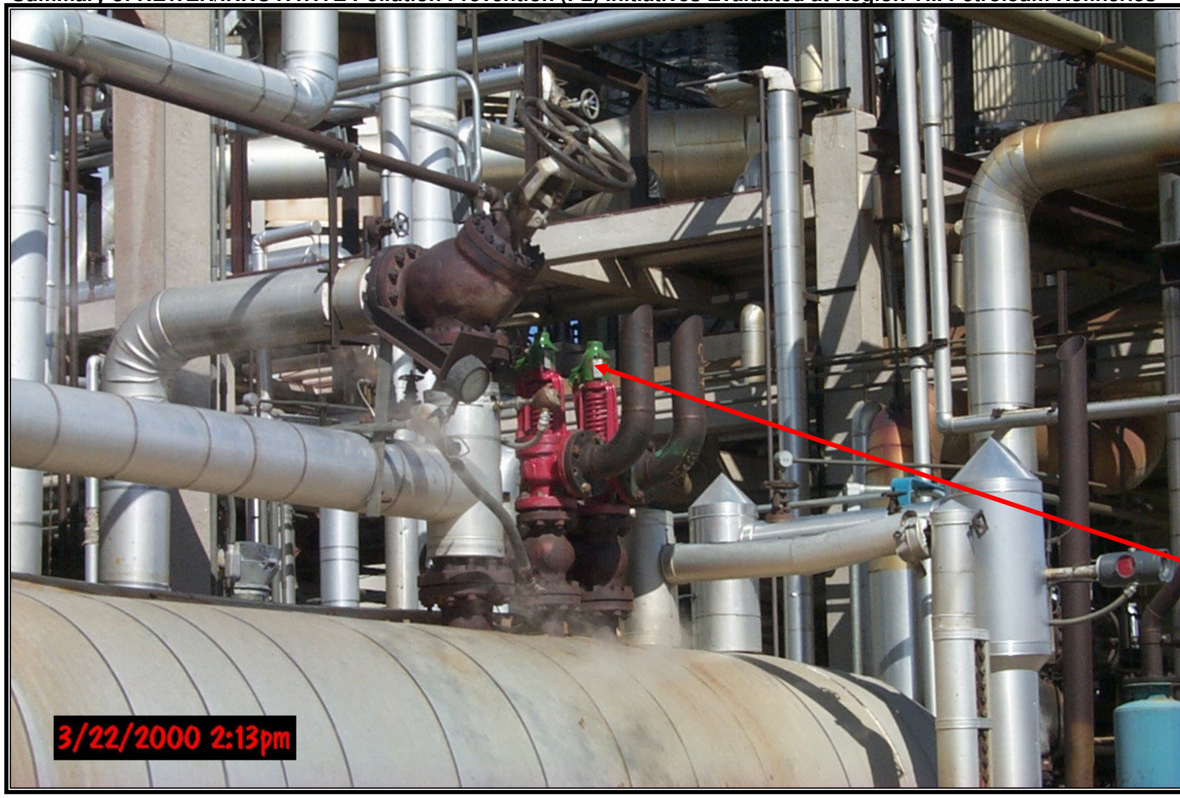
As discussed in the previous "# N2" case, improved treatment of incoming crude oil results in P2/WM benefits by removing, segregating and treating the contaminants before they generate corrosion and wastes in downstream process units.

This refiner has provided additional crude oil processing & treating equipment to provide further P2/WM benefits upstream of the crude desalter.

Additional crude oil treating vessel to improve crude feed quality and reduce associated wastes.

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B3. Additional crude treating/ conditioning vessels upstream of crude oil desalter (equipment modification): Additional vessel installed upstream of crude oil desalter units to improve desalter performance with more gentle waterwash (avoiding tight emulsions), more residence time for sediment removal. This results in less hazardous waste generation and hydrocarbon loss to brine wastewaters. Improved removal of sediments upstream of desalter reduces plugging in the desalter brine draws consequently reducing concerns such as "vortexing" which leads to oil loss with brine wastewater.	Benzo (a) pyrene	0.1	TPH	5,470
	Mercury (Hg)	0.1		

all reduction estimates above are assuming 10 % of previous case # B2 (further 10 % improvement/reduction in crude feed contaminants)



Relief valves (RV) are often utilized in petroleum and chemical process industries to "relieve" pressure in vessels when the pressure exceeds a threshold considered dangerous or otherwise ill-advised. These valves are designed to open or "relieve" at a certain pressure and close or "re-seat" when the pressure returns to below the design threshold. The idea is for these valves to only sporadically open when absolutely necessary and release vapors or fluids that are often hazardous such as benzene, vinyl chloride, ethylene oxide and other materials utilized in these and other industries. Relief valves should be periodically maintained and tested to assure they open and close at the proper pressures. If the valves are not properly maintained, corrosion, scale and other deterioration can prevent them from fully closing, allowing continued, unnecessary release/waste of hazardous process materials.

Large relieve valves (RV) releasing contaminants when open

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B4. Acoustic meters for large Relief Valves (RV) (equipment modification): Acoustic meters installed on larger relief valves offers better detection of relief valve operation, reseating (closing), etc. This significantly reduces hydrocarbon losses. These acoustic meters are more reliable than hydrocarbon (HC) sensors due to HC sensors being more vulnerable to corrosion & their more "fickle" nature in general.	Benzo (a) pyrene	0.2	TPH	438,000
	Mercury (Hg)	0.08		

BaP reduction estimate = 10 leaking RVs x 5 lb/hr leak rate x 8,760 hrs/yr x 0.5 ppm BaP/ 10^6

Hg reduction estimate = 438,000 lbs TPH x 20,000 Btu/lb x 1 MWh/3,412,000 Btu x 0.00003 lb Hg/MWh/yr x (assuming approx. electrical power energy equivalent of hydrocarbon loss)

TPH reduction estimate = 10 leaking RVs x 5 lb / hr leak rate x 8,760 hrs/yr

Low-emission flare tip

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B5. Mass flow meters in flare system (equipment modification): Measuring flare gas flowrates is crucial step to reducing unnecessary hydrocarbon gas losses to refinery flare system. Mass flow measurement are often an innovative, significant improvement over volume flow measurements which are more vulnerable to erroneous fluctuations, corrosion, etc.	Benzo (a) pyrene	0.01	TPH	5,475
	Mercury (Hg)	0.001		

BaP reduction estimate = 5,475 lbs TPH HC/yr x 0.00001 lb. BaP/lb flare gas from flare combustion

Hg reduction estimate = 5,475 lbs TPH x 20,000 Btu/lb x 1 MWh/3,412,000 Btu x 0.00003 lb Hg/MWh/yr (assuming approx. electrical power energy equivalent of hydrocarbon loss)

TPH reduction estimate = 50,000 bpd x 300 lb/bbl x 0.000001 HC loss improvement factor x 365 days/yr

Photos unavailable (may become available at a future date)

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B6. Manufacture of sodium hydro- sulfide from spent caustic(material purification, energy conservation, process modification): Spent caustic solutions are recovered and purified to manufacture sodium hydrosulfide, a valuable component in metals refining & pharmaceutical production.	Mercury (Hg)	0.01	spent caustic soda	576,000
			VOC	10
			NOX	1,233
			Carbon Monoxide (CO)	83
			Sulfur Dioxide	755
			Particulates (PM 10)	181

Hg reduction estimate = 3 MWh/ton caustic produced x 576,000 lbs x 1 ton/2000 lbs x 0.5 lb caustic/1 lb solution x 0.00003 lb/MWh/yr Hg emissions

(Notes: Casutic soda is very energy intensive to produce; this is estimate of energy useage & consequent Hg emissions for production of this amount of caustic. Electrical use estimates provided by caustic producers association and Chemlink Consultants)
Spent caustic reduction estimate = 3,000 gal/month x 16 lb/gal x 12 months/yr (basis is initial use of 50 % fresh solution)

All Non-PBT estimates from EPA eGrid Database Version 2.01 calculator site for electrical power generation emission estimates.

Photos unavailable (may become available at a future date)

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B7. Large volume gas compressor speed control (energy conservation, equipment modification):Saved over 25% electrical usage for one of the largest compressors in the refinery by trimming speed and amperage use of compressor in proportion to gas flow rates. Energy use is more in line with compressor duty at any given time.	Mercury (Hg)	0.11	VOC	90
			NOX	10,619
			Carbon Monoxide (CO)	712
			Sulfur Dioxide	6,501
			Particulates (PM 10)	1,559

Hg reduction estimate = 15,000 MWh power usage x 0.25 (25 % savings) x 0.00003 lb Hg/MWh

All Non-PBT estimates from EPA eGrid Database Version 2.01 calculator site for electrical power generation emission estimates.

Photos unavailable (may become available at a future date)

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B8. Oxygen analyzers installed in flue gas stacks (equipment modification): Significant energy savings achieved with control of excess air/oxygen to furnaces (don't have to invest energy to preheat much more incoming air). Higher efficiency heater installed at Alkylation Unit (AU) and direct-fired asphalt tank heaters.	Mercury (Hg)	2	VOC	1,245
			NOX	147,736
			Carbon Monoxide (CO)	9,911
			Sulfur Dioxide	90,448
			Particulates (PM 10)	21,691

Hg reduction estimate = 20,000,000 Btu/hr. savings x 8760 hrs/yr x 1 MWh/3,413,000 Btu x 0.00003 lb Hg/MWh (assuming 20 MM Btu/hr savings with improved heater efficiencies, etc. converted to approx. electrical power energy equivalent)

All Non-PBT estimates from EPA eGrid Database Version 2.01 calculator site for electrical power generation emission estimates.

Photos unavailable (may become available at a future date)

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B9. Vacuum distillation unit eductors equipped with surface condensers & gas routed to crude unit furnaces (equipment modification, energy conservation): Eductors lower pressure in vacuum towers to lower distillation temperature requirements. They also function to recover overhead vapors from distillation. Hydrocarbon loss significantly reduced with improved heat exchange system to condense vacuum tower overhead vapors. Fuel gas formerly lost now goes to distillation unit furnaces to lower energy demands.	Benzo(a)Pyrene	27	TPH	547,500

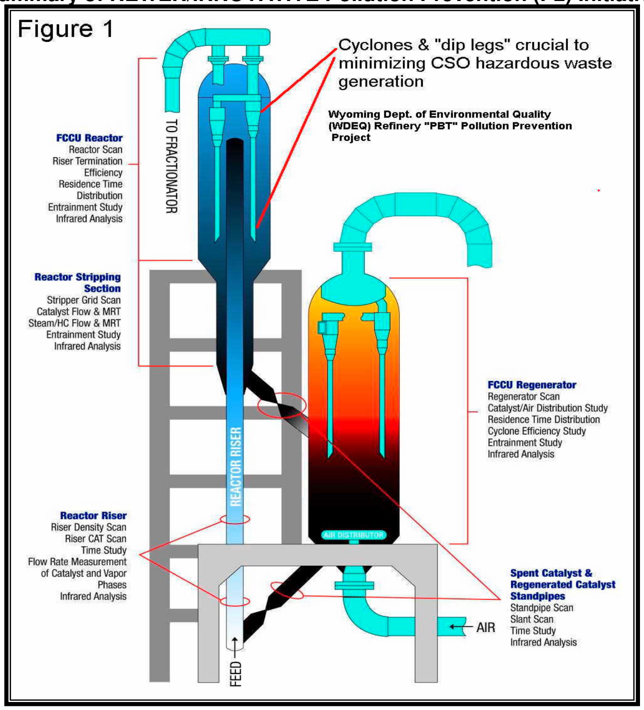
BaP reduction estimate = 5 bbl/day HC recovery x 365 days/yr x 300 lb/bbl x 50 ppm Bap x 1/10^6 (estimating 5 bpd HC loss prior to condenser installation)

TPH reduction estimate = 5 bpd HC recovery x 365 days/yr x 300 lb/bbl

Photos unavailable (may become available at a future date)

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B10. Air cooler at Hydrodesulfurizer (HDS) unit (equipment modification, energy conservation): Hazardous waste generated from conventional cooling water loop heat exchanger bundles is avoided and energy conservation achieved with reduced use of cooling water pumps and chemicals with use of air coolers/heat exchangers in place of cooling water.	Benzo(a)Pyrene	0.10		

BaP reduction estimate = 10 tpy HETX & Ctwr sludges x 2000 lb/ton x 5 ppm BaP / 10^6



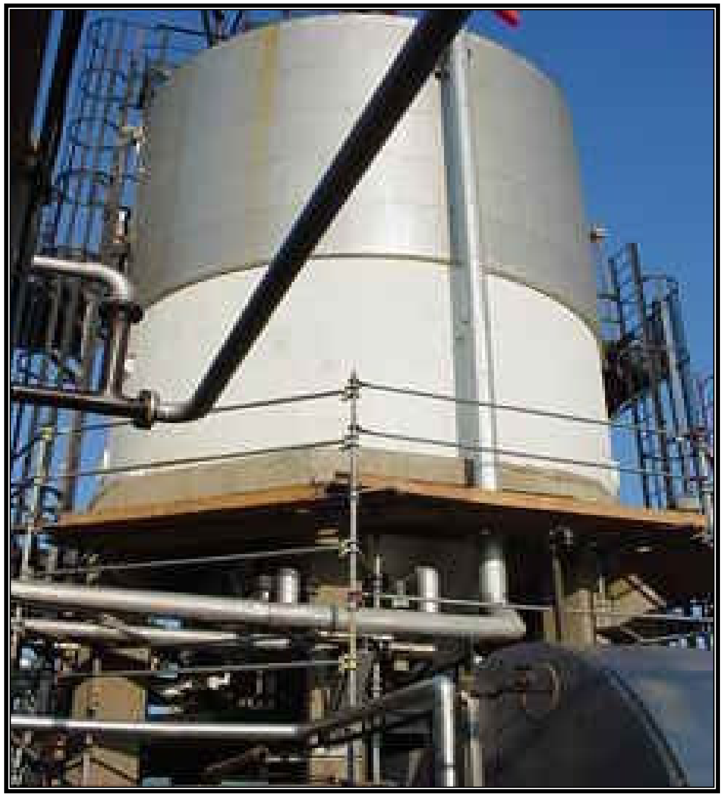
The original cyclone design had extended dip legs . This was thought to have resulted in significanlty reduced cyclone efficiency due to catalyst deposits plugging dip legs and bottom flap valves. These dip legs and valves must discharge captured catalyst for cyclone to work properly. Efficient operation of these dip legs and valves is crucial to assure recovery and recycle of FCCU catalyst.

<u>P2 Initiative Description</u>	PBT <u>Constituent(s)</u>	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents <u>(lbs./yr., 50,000 bpd basis)</u>	Non-PBT waste and/or <u>Constituent(s)</u>	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents <u>(lbs./yr., 50,000 bpd basis)</u>
B11. Fluid Catalytic Cracking Unit (FCCU) cyclone modifications (technology modification): Cyclone equipment used to separate fine catalyst particulates from clarified slurry oils ("CSO" or heavy fuel oils) modified to significantly reduce source of listed hazardous waste.	Benzo(a)Pyrene	40	K170 listed haz. waste	400,000
	Mercury (Hg)	0.40		

BaP reduction estimate = 400,000 lbs/yr reduction x 100 ppm BaP component x 1/10^6

Hg reduction estimate = 400.000 lbs/yr reduction x 1 ppm Hg component x 1/10^6

K170 listed haz. waste reduction estimate provided by refinery and converted to approx. 50,000 bpd basis

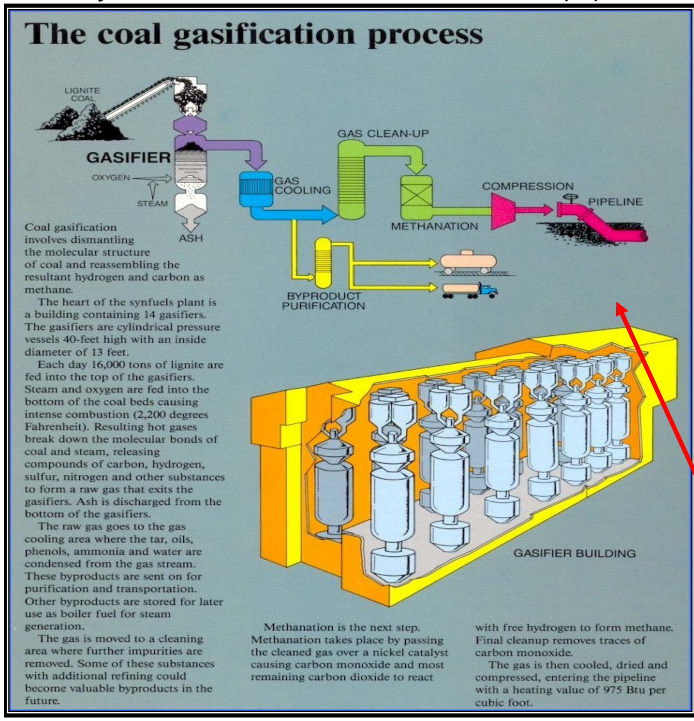


Large-volume storage tanks may contain numerous contaminants in the layer of water normally accumulating in the bottom of the tank. These contaminants can include rust/scale, hydrocarbons, dissolved chemicals (from additives, etc.) and emulsions. Installation of additional separation and treatment significantly reduces these contaminants.

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B12. Pretreatment of large-volume storage tank water draws (technology modification): Additional, modified oil/water/solids separator in place for storage tank field water draws. This significantly reduces oil contamination of wastewater and improves oil recovery.	Benzo(a)Pyrene	14	TPH	547,500

BaP reduction estimate = 5 bpd oil loss recovery estimate x 365 days/yr x 300 lbs/bbl x 25 ppm BaP x 1/10^6

TPH reduction estimate = 5 bpd oil loss recovery estimate x 365 days/yr x 300 lbs/bbl (assume approx. 5 bpd additional oil recovery rate for vessel in combination with conventional separator,etc.)



Preparation/loadout of Clarified Slurry Oil (CSO) hazardous waste for shipment to DGC plant

Simplified diagram of Dakota Gasification Co. (DGC) process for coal and selected refinery hazardous wastes

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B13. Gasification of (Clarified Slurry Oil (CSO) listed hazardous wastes, crude oil tank bottoms and other wastes (reformulation of products, substitution of raw materials): Wastes are sent to gasification plant to produce clean, on-specification gas and liquid fuels instead of incineration.	Benzo(a)Pyrene Mercury (Hg)	40 0.40	K170 listed haz. waste	400,000

BaP reduction estimate = 400,000 lbs/yr to gasification x 100 ppm BaP component x 1/10^6

Hg reduction estimate = 400.000 lbs/yr reduction x 1 ppm Hg component x 1/10^6

K170 listed haz. waste reduction estimate of 200 tons x 2000 lb/ton (estimated by refinery based on shipments to DGC plant)

Salt towers are utilized to dry heater oil and other feed to "Doctor Plant". This Doctor process uses lead and caustic soda to sweeten (remove or transform undesirable sulfur compounds) the feed to the unit for producing heater oil and other blending stocks. The salt towers were added to reduce moisture present in some of the feedstock. This moisture in feed often increased the rate of lead and caustic treating chemical usage and, consequently, increased the amount of wastes generated in the process.

The additional equipment installed at this unit also included provisions for using steam condensate near the end of the process (where water is utilized to remove contaminants from the processed intermediate) and filters to reduce solids, sulfur and lead released to process sewers.

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B14. Salt tower treaters, filter systems and steam condensate use improves fuel oil sweetening process which uses lead and caustic soda (equipment modifications): Process enhancements significantly reduces volume of treating solution required, resulting in energy savings and reduced contaminant/waste generation.	Benzo(a)Pyrene	22	Lead (Pb)	300
	Mercury (Hg)	2	Caustic soda	10,000

BaP reduction estimate = 5 gpm water contaminant reduction x 1440 min/day x 365 days/yr x 8.34 lb/gal x 1 ppm BaP (in oily TSS)

Hg reduction estimate = 5 gpm water contaminant reduction x 1440 min/day x 365 days/yr x 8.34 lb/gal x 0.1 ppm Hg (in oily TSS)

Pb reduction estimate = 10,000 lb caustic solution reduction x 0.03 (approx. 3% or greater Pb)

Caustic soda reduciton estimate = assume approx. 10,000 lb/yr caustic waste reduction

Efficient heat transfer is crucial in many process units for **either adding or removing heat** from process streams. Heat exchanger (HETX) systems at the alkylation unit are used to cool process steams to remove hydrofluoric (HF) acid and hydrocarbons for further use and/or processing. Alkylation units produce high octane alkylate for gasoline blending and the process reactions normally favor cooler temperatures.

Piping, control valves and an additional control loop were added to maximize heat transfer/cooling by automatically routing process streams through the heat exchangers offering the more efficient heat transfer (based on temperature measurements in the control loop). The improved HETX significantly reduced HF & hydrocarbon emissions and returned more of these components to the process for recycle and/or sales.

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B15. Improved heat exchanger control (equipment modifications): Added control equipment for more efficient routing of alkylation vent gas through Heat Exchangers (HETX) to reduce hydrofluoric Acid (HF) venting and improve overall gas (primarliy propane) recovery at unit.			hydrofluoric acid (HF)	1,825
			VOC	1,825

HF reduction estimate = assume 5 lbs/day HF recovery x 365 days/yr

VOC reduction estimate = assume 5 lb/day propane recovery x 365 days/yr.

Heater burner/inlet assembly modified for Acid Soluble Oil (ASO) combustion. ASO is a unique and complex mixture of waste oils generated during the alkylation process. ASO has significant Btu

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B16. Convert furnace burner to use Acid Soluble Oil (ASO) (equipment modifications): recover BTU value of ASO instead of offsite waste shipment.			TPH	54,750

TPH reduction estimate = 0.5 bpd x 365 days/yr x 300 lb/bbl

Chloride guard beds for hydrogen-rich gas stream to Distillate Desulfurizer (DDS)

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B17. Chloride guard beds for H2-rich gas compressor (technology modification): adsorption beds installed to remove chlorides & other corrosive material in hydrogen-rich feed to compressor for distillate desulfurizer unit (DDU) achieving P2 with reduced contaminants/waste and less compressor downtime, etc.	Mercury (Hg)	0.15		

Hg reduction estimate = 5,000 MWh annual power/downtime savings w. compressor x 0.00003 lb Hg/MWh

New tank mixer on slop tank helps assure effective use of de-emulsifying chemicals and other agents which are often needed for refinery slop tank operating efficiency. Due to the variety of sources of slop oils and their complex makeup, slop oil tanks often require more attention to control emulsions which significantly contribute to hazardous waste generation.

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B18. Improved slop oil recovery with mixer for chemical addition (equipment modification); tank mixer added to improve efficiency of de-emulsifying agent in slop oil "rag layer") for P2 with less slop oil going to wastewater and/or hazardous waste.	Benzo(a)Pyrene Mercury (Hg)	5 0.11	K049 listed haz. waste	109,500

BaP reduction estimate = 109,500 lbs/yr slop waste reduction x 50 ppm BaP component x 1/10^6

Hg reduction estimate = 109,500 lbs/yr slop waste reduction x 1 ppm Hg component x 1/10^6

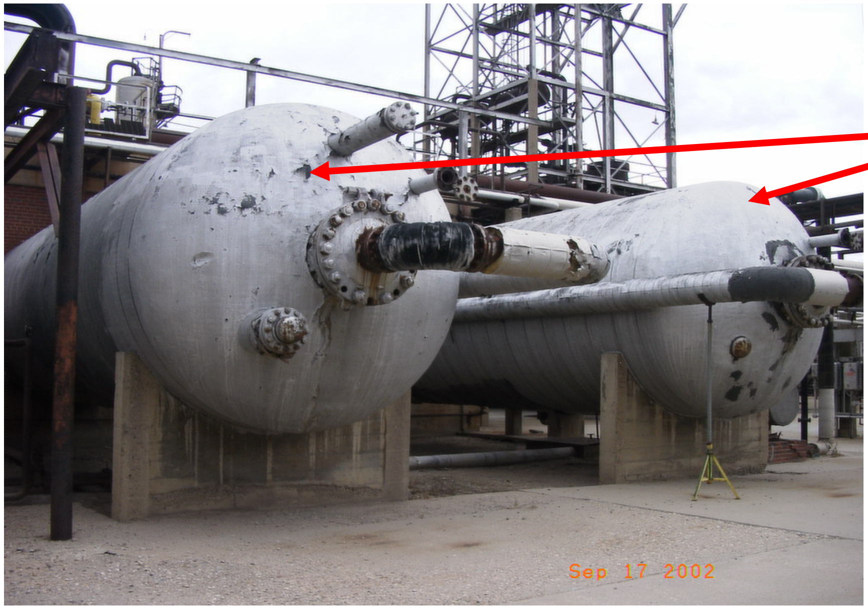
K049 waste reduction estimate = 1 bpd additional slop separation/recovery x 365 days/yr x 300 lb/bbl (oil contaminants not going to waste layer)

Additional piping added to utilize hydrogen-rich gas produced by one unit ("Ultraformer") and needed by another (Distillate Desulfurizer-DDU). Previously, the hydrogen content of this gas was not utilized and sometimes lost to flaring.

Installation of piping to recover this process stream significantly reduced flaring and provided hydrogen for the DDU process. This also provided significant P2/WM since the production of hydrogen is a very resource and energy intensive process.

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B19. Energy and resource recovery with added piping to use hydrogen-rich gas from ultraformer to Distillate Desulfurizer (DDU) for process use (equipment modification, process modification): This stream was more or less "wasted" in flare system or inefficiently used as fuel gas where hydrogen-rich gas was not needed.			TPH or HC gas	9,125

TPH or Hydrocarbon (HC) reduction estimate = assume approximately 25 lbs day to flare x 365 days/yr



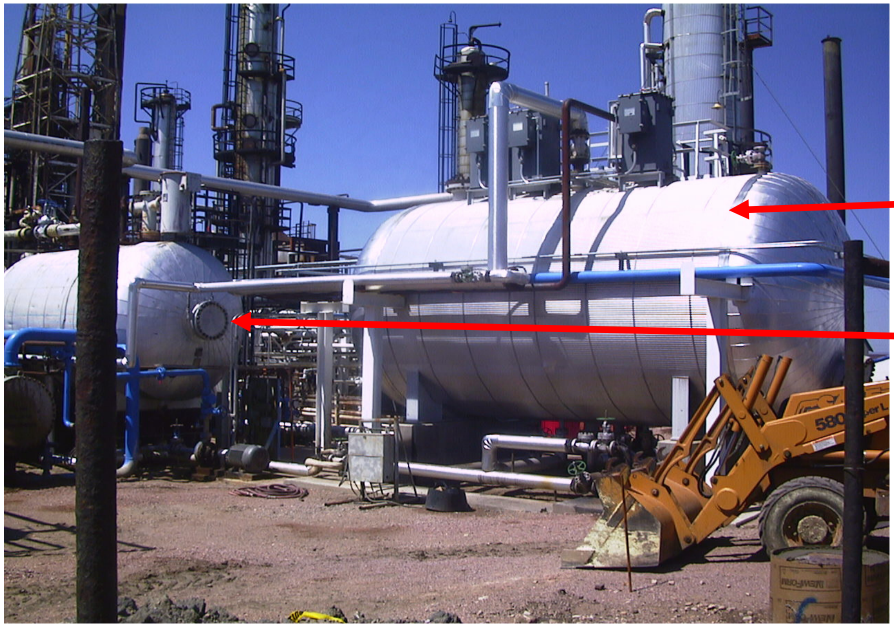
Vessels for segregation, storage & loadout of various types of spent caustic. Several types of spent caustic are generated by a variety of treating processes in refineries. Spent caustic is one of highest volume wastes generated by many refiners.

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B20. Segregation & recovery of spent caustic for cresylic acid manufacture (procedure modification, substitution of raw materials): Different types of spent caustic are segregated, collected and used for making cresylic acid instead of treated and disposed.	Benzo(a)Pyrene Mercury (Hg)	8 0.002	spent caustic	1,609,650

BaP reduction estimate = 1,609,650 lbs/yr spent caustic x 5 ppm BaP component (avg.) x 1/10^6

Hg reduction estimate = 1,609,650 lb/yr spent caustic x 0.03 (normally approx. 3 % when spent) x 1 ton/2000 lb x 3 MWh/ton caustic produced x 0.00003 lb Hg/MWh

Spent caustic reduction estimate = 250 gpd cresylic caustic + 65 gpd sulfidic caustic = 315 gpd x 14 lb./gal x 365 days/yr



Additional 2nd stage crude oil desalter to improve crude oil feedstock, reduce hydrocarbon losses, oily waste generation, etc.

Original, 1st stage desalter

P2 Initiative Description	PBT Constituent(s)	Estimate of PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT Constituent Eliminated from emissions, wastes or effluents (lbs./yr., 50,000 bpd basis)
B21. Crude oil desalter upgrade (equipment modifications): Desalter equipment upgraded to more efficiently remove salt and other impurities from crude oil, resulting in significantly reduced oil loss to wastewater and reduced generation of corrosion-derived hazardous waste in equipment downstream of the desalter (distillation/fractionating tower trays, overhead systems, etc.).	Benzo (a) pyrene	1	TPH	50,000
	Mercury (Hg)	1		

BaP reduction estimate = 250 tons oily waste x 2000 lb/1 ton x 1 ppm BaP oily waste content / 10^6

Hg reduction estimate = 250 tons oily waste x 2000 lb/1 ton x 1.0 ppm Hg oily waste content / 10^6

TPH reduction estimate = 250 tons oily waste x 2000 lb/1 ton x 0.1 fraction oil in oily waste content