1.0 EXECUTIVE SUMMARY

1.1 Incident synopsis

On March 23, 2005, at 1:20 p.m., the BP Texas City Refinery suffered one of the worst industrial disasters in recent U.S. history. Explosions and fires killed 15 people and injured another 180, alarmed the community, and resulted in financial losses exceeding $1.5 billion. The incident occurred during the startup of an isomerization[1] (ISOM) unit when a raffinate splitter tower[2] was overfilled; pressure relief devices opened, resulting in a flammable liquid geyser from a blowdown stack that was not equipped with a flare. The release of flammables led to an explosion and fire. All of the fatalities occurred in or near office trailers located close to the blowdown drum. A shelter-in-place order was issued that required 43,000 people to remain indoors. Houses were damaged as far away as three-quarters of a mile from the refinery.

The BP Texas City facility is the third-largest oil refinery in the United States. Prior to 1999, Amoco owned the refinery. BP merged with Amoco in 1999 and BP subsequently took over operation of the plant.

1.2 Scope of Investigation

Due to the significance of the disaster, the U.S. Chemical Safety and Hazard Investigation Board (CSB) investigated not only BP'S safety performance at Texas City, but also the role played by BP Group

[1] The refining isomerization process converts straight chain normal pentane and normal hexane streams to the higher octane branched hydrocarbons isopentane and isohexane that are used for gasoline blending.

[2] The raffinate splitter is a distillation tower that takes raffinate, a non-aromatic, primarily straight-chain hydrocarbon mixture and separates it into light and heavy components.

management, based in London, England.[3] The CSB further examined the effectiveness of the Occupational Safety and Health Administration (OSHA), which has primary U.S. federal government oversight responsibility for worker safety.

1.2.1 BP Group and Texas City

The Texas City disaster was caused by organizational and safety deficiencies at all levels of the BP Corporation. Warning signs of a possible disaster were present for several years, but company officials did not intervene effectively to prevent it. The extent of the serious safety culture deficiencies was further revealed when the refinery experienced two additional serious incidents just a few months after the March 2005 disaster. In one, a pipe failure caused a reported $30 million in damage; the other resulted in a $2 million property loss. In each incident, community shelter-in-place orders were issued.

This investigation was conducted in a manner similar to that used by the Columbia Accident Investigation Board (CAIB) in its probe of the loss of the space shuttle. Using the CAIB model, the CSB examined both the technical and organizational causes of the incident at Texas City.

The CAIB report stated that NASA's organizational culture and structure had as much to do with this accident as did the immediate cause.[4]

[3] BP Group management is the global corporate management responsible for business operations, including refining and marking (R&M).

[4] Immediate causes are the events or conditions that lead directly or indirectly to an incident, such as mechanical failure or human error (CCPS, 1992a). The immediate cause of the Columbia space shuttle disaster was striking of the left shuttle wing by a piece of insulating foam that separated from the external tank about a minute after launch. During re-entry, superheated air melted the area damaged by the foam strike, weakening the structure, leading to the subsequent failure of the structure and break up of the shuttle (CAIB report, 2003, vol. 1, p.9).

The CAIB also observed that:

> Many accident investigations make the same mistake in defining causes. They identify the widget that broke or malfunctioned, then locate the person most closely connected with the technical failure: the engineer who miscalculated an analysis, the operator who missed signals or pulled the wrong switches, the supervisor who failed to listen, or the manager who made bad decisions. When causal chains are limited to technical flaws and individual failures, the ensuing responses aimed at preventing a similar event in the future are equally limited: they aim to fix the technical problem and replace or retrain the individual responsible. Such corrections lead to a misguided and potentially disastrous belief that the underlying problem has been solved (CAIB, 2003).

Simply targeting the mistakes of BP's operators and supervisors misses the underlying and significant cultural, human factors,[5] and organizational causes of the disaster that have a greater preventative impact.[6] One underlying cause was that BP used inadequate methods to measure safety conditions at Texas City. For instance, a very low personal injury rate at Texas City gave BP a misleading indicator of process safety performance. In addition, while most attention was focused on the injury rate, the overall safety culture and process safety management (PSM)[7] program had serious deficiencies. Despite numerous previous fatalities at the Texas City refinery (23 deaths in the 30 years prior to the 2005

[5] "Human factors refer to environmental, organizational, and job factors, and human and individual characteristics, influence behaviour at work in a way which can affect health and safety" (HSE, 1999).

[6] The Center for Chemical Process Safety (CCPS) states that identifying the underlying or root causes of an incident has a greater preventative impact by addressing safety system deficiencies and averting the occurrence of numerous other similar incidents, while addressing the immediate cause only prevents the identical accident from reoccurring (CCPS,1992a).

[7] CCPS defines process safety as a "discipline that focuses on the prevention of fires, explosions and accidental chemical releases at chemical process facilities." Process Safety Management (PSM) applies management principles and analytical tools to prevent major accidents rather than focusing on worker occupational health and safety issues, such as fall protection and personal protective equipment (CCPS, 1992a).

disaster) and many hazardous material releases, BP did not take effective steps to stem the growing risk of a catastrophic event.

Cost-cutting and failure to invest in the 1990s by Amoco and then BP left the Texas City refinery vulnerable to a catastrophe. BP targeted budget cuts of 25 percent in 1999 and another 25 percent in 2005, even though much of the refinery's infrastructure and process equipment were in disrepair. Also, operator training and staffing were downsized.

1.2.2 OSHA

OSHA enforcement at the BP Texas City refinery was also examined. In the years prior to the incident OSHA conducted several inspections, primarily in respose to fatalities at the refinery, but did not identify the likelihood for a catastrophic incident, nor did OSHA prioritize planned inspections of the refinery to enforce process safety regulations, despite warning signs. After this incident OSHA uncovered 301 egregious willful[8] violations for which BP paid a $21 million fine, the largest ever issued by OSHA in its 35-year history. Prior to OSHA issuing citations, the refinery had two additional serious incidents. Despite the large number of major violations on the ISOM unit, and these two additional serious incidents in 2005, OSHA did not conduct a comprehensive inspection of any of the other 29 process units at the Texas City refinery.[9]

[8] A "willful" violation is defined as an "act done voluntarily with either an intentional disregard of, or plain indifference to, the Act's requirements." Conie Construction, Inc. v. Reich, 73 F.3d 382, 384 (D.C. Cir. 1995). An "egregious" violation, also know as a "violation-by-violation" penalty procedure, is one where penalties are applied to each instance of a violation without grouping or combining them.

[9] The settlement agreement between OSHA and BP from the ISOM incident and other investigations did require BP to retain a PSM expert to conduct comprehensive audits at the Texas City refinery to assess the "robustness of the PSM systems." United States of America Occupational Safety and Health Administration, BP Products North America Inc. Settlement Agreement, September 21, 2005.

OSHA's national focus on inspecting facilities with high personnel injury rates, while important, has resulted in reduced attention to preventing less frequent, but catastrophic, process safety incidents such as the one at Texas City. OSHA's capability to inspect highly hazardous facilities and to enforce process safety regulations is insufficient; very few comprehensive process safety inspections were conducted prior the ISOM incident and only a limited number of OSHA inspectors have the specialized training and experience needed to perform these complex examinations.

1.3 Incident Description

On the morning of March 23, 2005, the raffinate splitter tower in the refinery's ISOM unit was restarted after a maintenance outage. During the startup, operations personnel pumped flammable liquid hydrocarbons into the tower for over three hours without any liquid being removed, which was contrary to startup procedure instructions. Critical alarms and control instrumentation provided false indications that failed to alert the operators of the high level in the tower. Consequently, unknown to the operations crew, the 170-foot (52-m) tall tower was overfilled and liquid overflowed into the overhead pipe at the top of the tower.

The overhead pipe ran down the side of the tower to pressure relief valves located 148 feet (45 m) below. As the pipe filled with liquid, the pressure at the bottom rose rapidly from about 21 pounds per square inch (psi) to about 64 psi. The three pressure relief valves opened for six minutes, discharging a large quantity of flammable liquid to a blowdown drum with a vent stack open to the atmosphere. The blowdown drum and stack overfilled with flammable liquid, which led to a geyser-like release out the 113-foot (34 m) tall stack. This blowdown system was an antiquated and unsafe design; it was originally installed in the 1950s, and had never been connected to a flare system to safely contain liquids and combust flammable vapors released from the process.

The released volatile liquid evaporated as it fell to the ground and formed a flammable vapor cloud. The most likely source of ignition for the vapor cloud was backfire from an idling diesel pickup truck located about 25 feet (7.6 m) from the blowdown drum. The 15 employees killed in the explosion were contractors working in and around temporary trailers that had been previously sited by BP as close as 121 feet (37 m) from the blowdown drum.

1.4 Conduct of the Investigation

Investigators from the CSB arrived at the facility on the morning of March 24, 2005. During the investigation, the CSB reviewed over 30,000 documents; conducted 370 interviews; tested instruments; and assessed damage to equipment and structures in the refinery and surrounding community. Electronic data from the computerized control system and process information from five years of previous startups were also examined. The CSB investigation team was supplemented by experts in blast damage assessment, vapor cloud modeling, pressure relief system design, distillation process dynamics, instrument control and reliability, and human factors.

Several analytical tools were used by CSB in its investigation of the BP incident, including timeline construction and logic tree causal analysis. See Section 2.3 for an incident timeline, Appendix A for an organizational timeline leading up to the incident, and Appendix B for the logic tree.

This investigation was coordinated with OSHA; the U.S. Environmental Protection Agency (EPA); the Texas Commission of Environmental Quality (TCEQ); and BP's investigation team.

1.5 Key Technical Findings

1. The ISOM startup procedure required that the level control valve on the raffinate splitter tower be used to send liquid from the tower to storage. However, this valve was closed by an operator and

the tower was filled for over three hours without any liquid being removed. This led to flooding of the tower and high pressure, which activated relief valves that discharged flammable liquid to the blowdown system. Underlying factors involved in overfilling the tower included:

- The tower level indicator showed that the tower level was declining when it was actually overfilling. The redundant high level alarm did not activate, and the tower was not equipped with any other level indications or automatic safety devices.
- The control board display did not provide adequate information on the imbalance of flows in and out of the tower to alert the operators to the dangerously high level.
- A lack of supervisory oversight and technically trained personnel during the startup, an especially hazardous period, was an omission contrary to BP safety guidelines. An extra board operator was not assigned to assist, despite a staffing assessment that recommended an additional board operator for all ISOM startups.
- Supervisors and operators poorly communicated critical information regarding the startup during the shift turnover; BP did not have a shift turnover communication requirement for its operations staff.
- ISOM operators were likely fatigued from working 12-hour shifts for 29 or more consecutive days.
- The operator training program was inadequate. The central training department staff had been reduced from 28 to eight, and simulators were unavailable for operators to practice handling abnormal situations, including infrequent and high hazard operations such as startups and unit upsets.
- Outdated and ineffective procedures did not address recurring operational problems

during startup, leading operators to believe that procedures could be altered or did not have to be followed during the startup process.

2. The process unit was started despite previously reported malfunctions of the tower level indicator, level sight glass, and a pressure control valve.

3. The size of the blowdown drum was insufficient to contain the liquid sent to it by the pressure relief valves. The blowdown drum overfilled and the stack vented flammable liquid to the atmosphere, which fell to the ground and formed a vapor cloud that ignited. A relief valve system safety study had not been completed.

4. Neither Amoco nor BP replaced blowdown drums and atmospheric stacks, even though a series of incidents warned that this equipment was unsafe. In 1992, OSHA cited a similar blowdown drum and stack as unsafe, but the citation was withdrawn as part of a settlement agreement and therefore the drum was not connected to a flare as recommended.[10] Amoco, and later BP, had safety standards requiring that blowdown stacks be replaced with equipment such as a flare when major modifications were made. In 1997, a major modification replaced the ISOM blowdown drum and stack with similar equipment, but Amoco did not connect it to a flare. In 2002, BP engineers proposed connecting the ISOM blowdown system to a flare, but a less expensive option was chosen.

[10] A flare system is process plant disposal equipment designed to receive and combust waste gases from emergency relief valve discharge or process vent. In an oil refinery, flares convert flammable vapors to less hazardous materials. Flare system equipment includes a vessel, or "knockout drum," that is sized appropriately to safely contain any liquid discharge. After the liquid is removed, the remaining gases are safely combusted by a flare burner. OSHA withdrew the citation after Amoco argued that the design of the atmospheric blowdown stack was consistent with industry standards.

5. Occupied trailers were sited too close to a process unit handling highly hazardous materials. All fatalities occurred in or around the trailers.

6. In the years prior to the incident, eight serious releases of flammable material from the ISOM blowdown stack had occurred, and most ISOM startups experienced high liquid levels in the splitter tower. Neither Amoco nor BP investigated these events.

7. BP Texas City managers did not effectively implement their pre-startup safety review policy to ensure that nonessential personnel were removed from areas in and around process units during startups, an especially hazardous time in operations.

1.6 Key Organizational Findings

1. Cost-cutting, failure to invest and production pressures from BP Group executive managers impaired process safety performance at Texas City.
2. The BP Board of Directors did not provide effective oversight of BP's safety culture and major accident prevention programs. The Board did not have a member responsible for assessing and verifying the performance of BP's major accident hazard prevention programs.
3. Reliance on the low personal injury rate[11] at Texas City as a safety indicator failed to provide a true picture of process safety performance and the health of the safety culture.
4. Deficiencies in BP's mechanical integrity program resulted in the "run to failure" of process equipment at Texas City.

[11] OSHA's Recordable Occupational Injury and Illness Incidence Rate, which does not include fatalities, is normalized to allow for comparisons across workplaces and industries. The rate is calculated as the number of recordable incidents for each 100 full-time employees per year, based on 2,000 hours worked per employee per year. BP's calculation of injury rate was the same as OSHA's, but included fatalities, and counted fatalities the same as injuries.

5. A "check the box" mentality was prevalent at Texas City, where personnel completed paperwork and checked off on safety policy and procedural requirements even when those requirements had not been met.
6. BP Texas City lacked a reporting and learning culture. Personnel were not encouraged to report safety problems and some feared retaliation for doing so. The lessons from incidents and near-misses, therefore, were generally not captured or acted upon. Important relevant safety lessons from a British government investigation of incidents at BP's Grangemouth, Scotland, refinery were also not incorporated at Texas City.
7. Safety campaigns, goals, and rewards focused on improving personal safety metrics and worker behaviors rather than on process safety and management safety systems. While compliance with many safety policies and procedures was deficient at all levels of the refinery, Texas City managers did not lead by example regarding safety.
8. Numerous surveys, studies, and audits identified deep-seated safety problems at Texas City, but the response of BP managers at all levels was typically "too little, too late."
9. BP Texas City did not effectively assess changes involving people, policies, or the organization that could impact process safety.

1.7 Recommendations

1.7.1 New Recommendations

As a result of this investigation, the CSB makes recommendations to the following recipients:

- BP Group Executive Board of Directors
- BP Texas City Refinery
- U. S. Occupational Safety and Health Administration (OSHA)

- American Petroleum Institute (API)
- United Steelworkers International Union and Steelworkers Local 13-1
- Center for Chemical Process Safety (CCPS)

Section 13 of this report provides the detailed recommendations.

1.7.2 Previously Issued Recommendations

The CSB issued recommendations during the course of the investigation. This section provides a brief description; Appendix C provides the full text of each.

1.7.2.1 Safety Culture Recommendation

On August 17, 2005, the CSB issued an urgent safety recommendation to the BP Group Executive Board of Directors that it convene an independent panel of experts to examine BP's corporate safety management systems, safety culture, and oversight of the North American refineries. BP accepted the recommendation and commissioned the BP U.S. Refineries Independent Safety Review Panel, chaired by former Secretary of State James Baker, III ("Baker Panel"). The scope of the Baker Panel's work did not include determining the root causes of the Texas City ISOM incident.

"The Report of the BP U.S. Refineries Independent Safety Review Panel" was issued January 16, 2007. The Baker Panel Report found that "significant process safety issues exist at all five U.S. refineries, not just Texas City," and that BP had not instilled "a common unifying process safety culture among its U.S. refineries." The report found "instances of a lack of operating discipline, toleration of serious deviations from safe operating practices, and [that an] apparent complacency toward serious process safety risk existed at each refinery." The Panel concluded that "material deficiencies in process safety performance exist at BP's five U.S. refineries."

The Baker Panel Report stated that BP's corporate safety management system "does not effectively measure and monitor process safety performance" for its U.S. refineries. The report also found that BP's over-reliance on personal injury rates impaired its perception of process safety risks, and that BP's Board of Directors "has not ensured, as a best practice, that BP's management has implemented an integrated, comprehensive, and effective process safety management system for BP's five US refineries." The report's 10 recommendations to BP addressed providing effective process safety leadership, developing process safety knowledge and expertise, strengthening management accountability, developing leading and lagging process safety performance indicators, and monitoring by the Board of Directors the implementation of the Baker Panel's recommendations.

1.7.2.2 Trailer Siting Recommendations

On October 25, 2005, the CSB issued two urgent safety recommendations. The first called on the American Petroleum Institute (API) to develop new guidelines to ensure that occupied trailers and similar temporary structures are placed safely away from hazardous areas of process plants; API agreed to develop new guidelines. A second recommendation to API and the National Petrochemical and Refiners Association (NPRA) called for both to issue a safety alert urging their members to take prompt action to ensure that trailers are safely located. API and NPRA published information on the two recommendations, referring to the CSB's call for industry to take prompt action to ensure the safe placement of occupied trailers away from hazardous areas of process plants.

1.7.2.3 Blowdown Drum and Stack Recommendations

On October 31, 2006, the CSB issued two recommendations regarding the use of blowdown drums and stacks that handle flammables. The CSB recommended that API revise "Recommended Practice 521, Guide for Pressure Relieving and Depressuring Systems," to identify the hazards of this equipment, to address the need to adequately size disposal drums, and to urge the use of inherently safer alternatives

such as flare systems.

The CSB issued a recommendation to OSHA to conduct a national emphasis program for oil refineries focused on the hazards of blowdown drums and stacks that release flammables to the atmosphere and on inadequately sized disposal drums. The CSB further recommended that states that administer their own OSHA plan implement comparable emphasis programs within their jurisdictions.

1.7.2.4 Additional Recommendations from July 28, 2005, Incident

The CSB also made two recommendations as a result of its investigation of the July 28, 2005, incident in the Resid Hydrotreating Unit (RHU) of the BP Texas City refinery, one of two incidents after the March 23, 2005, incident.[12] The RHU had a major fire that resulted in a shelter-in-place for 43,000 people and a reported $30 million in plant property damage. In October 2006, the CSB released a Safety Bulletin on the findings of its investigation of the incident, available at www.csb.gov.

1.8 Organization of the Report

Section 2 describes the events in the ISOM startup that led to the explosion and fires. Section 3 analyzes the safety system deficiencies and human factors issues that impacted unit startup. Sections 4 through 8 assess BP's systems for incident investigation, equipment design, pressure relief and disposal, trailer siting, and mechanical integrity. Because the organizational and cultural causes of the disaster are central to understanding why the incident occurred, BP's safety culture is examined in these sections. Section 9 details BP's approach to safety, organizational changes, corporate oversight, and responses to mounting safety problems at Texas City. Section 10 analyzes BP's safety culture and the connection to the management system deficiencies. Regulatory analysis in Section 11 examines the effectiveness of

[12] On August 10, 2005, the BP Texas City refinery experienced the third major mechanical integrity-related incident of that year, this one in the Cat Feed Hydrotreating Unit (CFHU); it resulted in a shelter-in-place order and $2 million in property damage.

OSHA's enforcement of process safety regulations in Texas City and other high hazard facilities. The investigation's root causes and recommendations are found in Sections 12 and 13. The Appendices provide technical information in greater depth.