Root Cause Analysis Report
Tesoro Golden Eagle Refinery
Refinery Power Outage

Summary of Event:

The Golden Eagle Refinery (Refinery) experienced a partial electrical outage December 10, 2010 at 10:12 hrs when a transformer at Switching Station #7 failed. A CWS Level 1 report was made at that time. The outage triggered emergency shutdowns at multiple units, which resulted in excess flaring and visible smoke. At 10:29 hrs, the Refinery raised the CWS to a Level 2 warning, as the smoke and plumes from the flaring was going off-site to the surrounding area. Refinery Health & Safety personnel, local agencies (BAAQMD & CCCHSD), and contractors (Odor Science & Engineering) were dispatched into the community to assess offsite impact. No offsite odors were detected. The CWS Level was downgraded from Level 2 to Level 1 at 11:54 hrs since flaring and the related smoke had significantly reduced and no health impacts were expected. The CWS Level was reduced from Level 1 to Level 0 at 12:29 hrs when impacts became limited to on-site only, and units were preparing to start up. Plant wide electrical power was restored at 17:25 hrs.

A brief timeline follows:

10:12 hrs:	Loss of power at multiple units. CWS Level 1 issued
10:20 hrs:	Fire reported at Switching Station 7
10:23 hrs:	BAAQMD notified via phone of the outage (BAAQMD was already onsite for other business)
10:29 hrs:	CWS Level 2 issued
10:30 hrs	Dispatched OS&E for community patrol to assess visibility or odors.
10:35 hrs:	Fire at Switching Station 7 extinguished
10:40 hrs:	Switching Station 7 was shut down
10:53 hrs:	CCHS arrived at EOC
11:00 hrs:	Sheriff arrived at EOC
11:15 hrs:	Received report from Tesoro Health and Safety representative of no offsite impact
11:54 hrs	Downgraded CWS Level from 2 to 1
12:27 hrs	Downgraded CWS level from 1 to 0
20:14 hrs:	Plant wide electrical power restored

Agency Notification and Response:

The following agencies were immediately notified: Contra Costa Health Services (CCHS) via the CWS, the Bay Area Air Quality Management District (BAAQMD) via the CWS and phone, Contra Costa Fire Protection District, and the Contra Costa County Office of Emergency Services. The following agencies responded with personnel to the scene: CCHS, BAAQMD, and Contra Costa Sheriff.

[Note: Notifications over the CWS terminal: CWS level 1 notifies CCHS, Contra Costa OES, and the Contra Costa Sheriff with a specific message. Additional notice informs BAAQMD, Contra Costa Fire Protection District, Martinez Police, Antioch Police, Pinole Police and Richmond Police. CWS level 2 notifies CCHS, Contra Costa OES, Contra Costa Sheriff and BAAQMD with a specific message. Additional notice informs Contra Costa Fire Protection District, California Highway Patrol, California Dept. of Health, San Ramon Valley Fire, Martinez Police, Antioch Police, Pinole Police and Richmond Police.]

Emergency Response Actions:

Operations personnel shut down the units and safely responded to the emergency

Material Released:

Hydrocarbon compounds were routed to the flare system as a result of the emergency shutdown. These compounds were mostly consumed (burned off) during the combustion process, resulting in the release of carbon dioxide and other gases present during combustion. SO2 emissions from the flares exceeded 500 pounds.

Meteorological Conditions:

The weather was clear with wind direction varying from the North NorthEast with a wind speed of 2-3 mph. The temperature was about 55 degrees F.

Injuries:

An employee received a burn on his hand. He was treated on-site and released back to work. An operator was exposed to MDEA. He was treated on-site and released back to work. Both injuries were first aid.

Community Impact:

Assessments by Tesoro Health and Safety, Odor Science and Engineering, BAAQMD and CCCHS reported no offsite impact other than visible smoke.

Incident Investigation of the event:

At 10:12 AM on December 9, 2010, the refinery experienced a plant-wide partial power outage. The loss of power caused a number of units to go to the refinery flares. There was significant flaring, which ultimately was classified as a CWS level 2 event. The CWS level 2 notification alerts the public that an event is occurring that may require sensitive individuals to take precautionary action. A Community Warning System (CWS) level 2 event requires a root cause analysis report submittal to Contra Costa Health Services.

The initiating event of the outage occurred at Switching Station #7 (SS#7). Smoke was noticed emanating from SS#7. A non-emergency response employee grabbed a fire extinguisher to put out the fire. He evacuated the area as an explosion occurred at SS#7. The employee's hand was burned and he was hit by some debris. His injuries required first aid treatment. Emergency response crews responded to extinguish the fire.

SS#7 feeds 50 unit, #4 HDS, #4 Gas compressors, #2 HDS feed pump, 6 Boiler, the Central Maintenance Building, Tract 3 and Avon Wharf. Loss of electrical power shutdown these units/areas. However, in addition to those areas, the following units shutdown: #3 Reformer, RFS, BSU, SRU, SCOT, #1HDS, #2 Hydrogen Plant, #3 HDS, #1 Hydrogen Plant, Hydrocracker Stage 1, Hydrocracker Stage 2, HDA, #2HDS, FCCU, #4 Gas, #3WTP, WWTP, ARU and the Alky. Loss of power at #1 Hydrogen Plant resulted in warming of the Methyl Diethanolamine (MDEA) and its subsequent release, which exposed an operator to MDEA.

Power was restored to the refinery by 6:30 PM. The CWS level 2 flare event lasted until 11:54 PM when it was downgraded to CWS level 1.

Focus of the investigation:

The investigation focused on two primary areas: the failure mechanism at SS#7 and the widespread loss of power beyond the units fed by SS#7.

A fault occurred at SS#7 where main breaker 1710 opened. However, main breaker 1720 did not open to isolate the fault and tie breaker 1725 remained closed. The widespread loss of power resulted from a lack of relay coordination in the refinery electrical distribution system.

Main breaker 1710 most likely opened due to damage caused by the explosion in the SS#7 cubicle. It was concluded the explosion itself was a result of a 3 phase short circuit within cubicle 5 at SS#7. Cubicle 5 is made up of two sections, 5A and 5 B. An electrical fault occurred in the Control Power Transformer (CPT) in cubicle 5B. There is no physical isolation between the two cubicles and this allowed "ionized air" to migrate from 5B to 5A, ultimately resulting in the explosion.

As part of the forensic analysis of the failed equipment, a 3rd party contractor found a short circuit in the primary winding of the CPT. During the investigation, several causes of the short circuit were identified. The failed CPT was suspected to have a manufacturing defect. During the investigation of the SS#7 fire, a second faulty CPT was found at SS#8. Both the faulty SS#8 CPT and the CPT that faulted at SS#7 were from the same manufacturer and had approximately the same manufacturing date. A possible conclusion is that there was a manufacturing defect in both CPTs.

In addition to a possible manufacturing defect, another possible conclusion is transients on the 12 KV systems damaged the CPT and coupled with a failure of the CPT fuse to operate causing the larger 12 KV power outage event. The CPT fuse rating was too high

for its service. It should have been no more than 250% of Full Load Amps (FLA) but it was 500% of FLA.

The protective relay coordination system did not work as intended:

The intent of protective relays is to protect the equipment by isolating over currents and faults. This is done by limiting both time and current such that the equipment is protected by opening up the circuit. The objective is to isolate the power as close to the fault as possible while continuing to power other devices not affected by the fault. The best point of isolation for this incident would have been the protection at the Control Power Transformer (CPT) and then the protection at the SS#7 main feeder breaker 1720.

For this fault at SS#7 there were several factors discovered during the investigation including:

1. The primary fuses for the CPT should have isolated the fault by limiting the current to the CPT and therefore preventing the transformer from faulting and also removing the fault from the 15kV substation circuit 1102. One of the two fuses did operate (blew) and the other was found out of its clips after the explosion. The fuses where discovered to be rated incorrectly for this CPT.
2. The FW feeder breaker 5-2 opened while SS#7 main breaker 1720 remained closed. The protection relays at the SS#7 main breaker (a) ANSI 32 device which is a directional power relay and (b) ANSI 51-GS device which is a ground sensor relay did not see the fault before the instantaneous protection at Foster Wheeler (FW) Cogeneration Plant feeder breaker. A Direct Transfer Trip (DTT) scheme would have opened both the 5-2 breaker and the 1720 breakers simultaneously.
3. All other breakers at SS#7 remain closed with the exception of main breaker 1710 which opened. The upstream FW breaker 7-1 remained closed. No relays operated at SS#7, therefore, it was determined protection did not trip the breaker. Main breaker 1710 most likely opened due to damage caused by the explosion in the SS#7 cubicle. Note: the existing relays do not have event capability which would have aided in determining why breaker 1710 opened. A project exists that will install a protective relay at breaker 1710 (and other breakers at SS#7) which will have this event capability. This project is anticipated to be complete at the end of 2011.

Note: At FW plant, a gas turbine and the steam turbine tripped off line. The voltage on the FW bus was reported to have sagged to 7.5kV.

CPT Fuse rating was incorrect:

For a transformer, the industry standard is to follow the NEC guidelines for sizing the fuse as a percentage of the transformer rated current. For this 45kVA CPT, the primary current is rated at 4 Amps. The existing primary fuses were rated at 15kV, 20 Amps and

has a maximum rating of 50 kA symmetrical interrupting current. The melt times for the existing fuses were as follows:

- 600 seconds at 10 x Full Load Amps (FLA)
- 70 seconds at 15 x FLA
- 6 seconds at 25 x FLA

National Electric Code (NEC) guidelines recommend sizing fuses for transformers as a maximum of 250% of rated current which for this CPT the fuse rating should have not exceeded 4 Amps x 2.5 or 10 Amps. After completion of a coordination study, it was determined that a 7 Amp fuse was the proper size to install. The melt time for a typically rated 7 Amp fuse with the other ratings of 15kV and 50kA rating is as follows:

- 0.9 seconds for 10 x FLA (clearing time of 2 seconds)
- 0.2 seconds for 15 x FLA (clearing time: 0.4 seconds)
- 0.04 seconds for 25 x FLA (clearing time of 0.075 seconds)

SS#7 was designed and built in 2002. The design was completed by a 3rd party. There was an error in the original design regarding the rating of the CPT fuse. This error was not caught during the review of the design, nor was it detected during the installation of the CPT. The slow reaction of the erroneous fuse allowed the short circuit to continue for a longer period and failed to keep the fault localized at the CPT. The function of the primary fuse is to interrupt overloads or short circuits. Had the primary fuse been correct, the refinery's 12kV system would likely have not been affected by the short circuit in the CPT.

Root Causes:

The causal analysis for this incident yielded the following root causes and corrective actions (see table):

Root Cause #1: The CPT faulted due to a short circuit in the primary winding.

Root Cause #2: The primary fuse design error in the CPT was not detected during the design review phase nor during construction of the Switching Station #7. The primary fuse installed to protect the CPT was overrated and exceeded the normal National Electrical Code (NEC) and industry sizing guidelines.

Root Cause #3: The physical isolation between the CPT and the incoming buss was insufficient to isolate the ionization.

Root Cause #4: The refinery electrical protection relays are not optimally coordinated. This caused a more widespread loss of power than should have occurred with the loss of Switching Station #7.

Corrective Actions:

	Corrective Actions	Anticipated Date of Completion	Root Cause
1	Replace the existing CPT and CPT primary fuses with fuses that have a faster melting time. (Per NEC 450, this should be no greater than 300%). This recommendation is targeted at CPTs in switching station 7 and switching station 8.	9/30/11	1, 2
2	Review the Engineering technical review process to ensure that the electrical protection coordination is covered. If not, revise review process accordingly. Note - a coordination study will capture issues with CPT fuses.	6/30/12	2
3	Create the current Factory Acceptance Test (FAT) Checklist to include review the fuse and breaker sizes to ensure the ratings are equivalent to design specifications	6/30/12	2
4	Consider upgrading the SS#7 internal barrier between CPT and Incoming cable compartments	12/1/11	3
5	Ensure refinery wide coordination study is completed. Note - Tesoro had already contracted with Power Engineers to do a refinery-wide coordination study, which was in progress at the time of the incident. Switching station 7 has top priority for completion in this study.	12/31/11	4
6	Consider replacing existing Electro-Mechanical relays at SS#7 that are not able to meet coordination requirements with relays that are able to meet these requirements. Note - microprocessor relays are one candidate to meet the coordination requirements.	12/1/11	4