2024 TEST REPORT

TEXAS A&M ENGINEERING TEEX EXTENSION SERVICE TESTED

TEXAS A&M ENGINEERING TEEX EXTENSION SERVICE

TEEX-Tested Report for

TOTAL SAFETY®

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September 30, 2024

TEEX-Tested® Report: Total Safety- Centralized Confined Space Monitoring Service

Submitted to Total Safety U.S., Inc. on behalf of the Texas A&M Engineering Extension Service (TEEX) Testing and Innovation Center (TT&IC):

Date: 24 Sep 2024

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Accepted on behalf of Total Safety U.S., Inc.

Date: _____

By: _____

Printed Name: _____

Title: _____

Summary of TEEX-Tested Results for Total Safety – Centralized Confined Space Monitoring Service

CRITERION	RESULTS
Real-Time Monitoring of Atmospheric Conditions inside the Confined Space	The Total Safety CCSM system utilizes a SPM (Single Point Monitor) for gas detection and a thermometer built into the camera apparatus for temperature monitoring. The Area Monitoring CCSM can monitor 23 different gases and can measure temperature at a +/- of 8 degrees The temperature reading was consistently monitored on the CCSM operator's screen to ensure appropriate working conditions and hazardous environments. To test the gas detection capabilities, CO2 was released into the confined space using a fire extinguisher. The system recognized the rising LEL levels, and the alarm activated once the reading reached 2, which exceeded the established OSHA standard. The system also observed a displacement in O2 which was alerted to the CCSM operator on the monitoring interface.
Installation Time	The installation for this scenario took roughly four hours to set up for monitoring 6 manways within a 100 ft radius on 3 vessels.
Monitoring System Detection Capabilities	The system consists of a mobile monitoring station with a 65-inch screen and 3 standard computer monitors. The monitoring station can display a maximum of 12 monitored locations or 24 cameras. The sensor displays include a gas detection dashboard, PPE settings, camera controls, incident reporting, temperature readings, real-time headcounter, system check status, a screenshot feature, and a logbook.
Attendant Observation and Attentiveness	The quality of the attendant during the test was consistent with promptly recognizing and attending to hazardous situations. The attentiveness of the CCSM operator is maintained by a mandatory rotation of roles every two hours and systematic attention checks that pop up on the monitoring screen every 30 minutes. A record of the response time for these attention checks is maintained to ensure quality operating personnel.
Rover Capability	Total Safety rovers are personnel dispatched to assist in equipment maintenance, installation, equipment relocations, system checks, and safety checks. They are stationed in the immediate area of the work being conducted with a maximum ratio of 2 rovers to every 12 manways. The CCSM operator communicates with the rover by using an external Total Safety radio to dispatch them to a desired location for assistance. Rovers are also trained to extinguish small fires. The plant normally provides rescue and fire extinguishing equipment and personnel. Total Safety can provide these services if requested. The number of rovers may increase due to the layout and locations of the manholes being monitored.

Communications	The communication system was reliable in communicating both ways between the CCSM operator and the evaluator. Slight delays were noted due to the CCSM operator having to manually dial the dispatch number for the specific manways. CCSM operators can open a two-way communication line, but the entrant must physically press the push-to-talk button on the hub to initiate the call. If the entrant cannot get to the button, signals are used to get ahold of the operator.
Alarm System	The CCSM System consists of an internal and external alarm. When gas is detected, the alarm will automatically sound. In the case the CCSM operator detects an emergency, the alarm can be sounded through the monitoring station interface. There is an option to sound all alarms at the site for mass evacuation or just an individual manway alarm. There are two types of alarms: high and low. The high alarm sounds and visually flashes while the low alarm just flashes. High and low alarms are set to reflect OSHA standards but can be modified to fit plant needs if desired. Typically, only high alarms trigger an evacuation.
System Stability	System stability is reliable. The display glitched once and briefly shut down the monitoring software due to an issue with the RAM. This was resolved quickly and found to be an installation issue on the server.
Worker Training	Before permitting entrance to the CCSM service, a Total Safety staff member trains all confined space entrants on the Total Safety system. This training highlights how the system works, what the alerts mean, proper evacuation protocol, entry and exit dynamics, and communication with the operator. This training course consists of a visual briefing and a tour of the equipment set-up. At the end of the training, each worker takes a test to confirm their understanding of the system and the proper protocol. Upon completion, workers are put on a cleared access list to enter the confined space.
Boundaries of Service	Total Safety acts as a monitor and facilitator for emergency response. The boundaries of their service stop at notification of an emergency. Total Safety does not conduct rescue operations and relies on the plant for any safety equipment and rescue protocol. Independent of CCSM service, customers may contract for Total Safety rescue services.

Acknowledgments

This TEEX Tested Report could not have been accomplished without the help of TEEX's Emergency Services Training Institute (ETSI) and Disaster City. Disaster City's world class facilities were essential to the operational assessment of the Total Safety system. This TEEX Tested Report was written by TT&IC staff including Director Ray Ivie, Technology Evaluator Mike Avolio, and Graduate Student Workers Madison Farrell and Rylee Welch.

Texas A&M Engineering Extension Service (TEEX) Testing & Innovation Center (TT&IC) conducts performance assessments in operational environments by experienced professionals using representative facilities and environments from which the product is expected to perform in. Operators perform functions that are expected in operational service and assess the products and solutions using the manufacturer's guidelines and instructions to assess performance. TEEX tests follow a process including standards reviews, metrics development, expert panel reviews, test plan and scenario development, and quantitative and qualitative measurements and surveys. This report is a summation of the functionality, reliability, and performance results.

The Total Safety – Centralized Confined Space Monitoring Service has been TEEX-Tested® based on the specific methodology presented in this report. TEEX hereby disclaims and any recipient of this report waives any warranties, whether expressed or implied, including without limitation and implied warranties of the merchantability, fitness for a particular purpose, or non-infringement. Any recipient of this report accepts the report "as is" and acknowledges that TEEX has no responsibly nor liability to the recipient. This report does not constitute an endorsement by TEEX.

TEEX-Tested® Report for Total Safety
Conducted by:
TEEX Testing and Evaluation Center (TT&IC)
Texas A&M Engineering Extension Service (TEEX)

Distribution: Open

Executive Summary

The Texas A&M Engineering Extension Service's Testing and Innovation Center (TT&IC) conducted a TEEX-Tested® assessment on the Total Safety – Centralized Confined Space Monitoring Service to provide training and acquisition decision makers with information regarding the service's' operational performance. TEEX-Tested assessments follow a similar process to Military Utility Assessments (MUA) and National Urban Security Technology Laboratory NUSTL's SAVER assessment process to assess the technology's performance in an operational setting. Experienced professionals representing the targeted user base participated in the assessment.

Total Safety's Centralized Confined Space Monitoring (CCSM) Service is used for real-time remote monitoring of permit-required confined spaces. This service is designed to replace the in-person watcher role in compliance with Occupational Health and Safety Administration (OSHA) standards 1910.252 and 1910.146. The area monitoring system can detect 6 hazardous gases (1 being a specific PID (VOC sensor from a selection of 23 types), monitor temperature levels, visually observe worker actions in case of an emergency, communicate with entrants, and record entrant tasks for training utilization. To accomplish this, Total Safety temporarily installs portable monitoring equipment at confined space workplaces and provides staff to oversee the monitoring system.

The Total Safety – Centralized Confined Space Monitoring (CCSM) Service consists of an SPM, a gas detection probe, temperature monitors, alarm system, internal and external cameras, push to talk communication, and a badge reader. These components are monitored by a CCSM operator through a 65-inch TV and 3 standard computer monitors. One CCSM operator can monitor a maximum of 12 confined spaces or 24 cameras. The service also includes rovers in charge of moving cameras, maintenance issues, and entrant quality checks. In the case of an emergency, the CCSM operators' job is to notify the appropriate response entities for assistance, as agreed upon during preparations. Total Safety's service stops at this notification and does not include an emergency response team.

The Total Safety team initiates pre-planning protocols with the customer prior to site arrival. Pre-planning protocols are done to ensure the proper equipment, staffing, and system requirements are verified prior to installation. For installations, Total Safety coordinates with the customer for basic maneuvering equipment such as cranes or pulleys to hoist the equipment to/from the appropriate manway. An independent point to point wireless communications network (provided by Total Safety) is established to each sensor/monitoring system. The centralized monitoring station can be utilized out of the Total Safety trailer or moved into an alternate location at the site. Each component aside from the alarm has an IP address that is linked to the monitoring station.

For this operational assessment, TT&IC provided 6 manways within TEEX Disaster City's confined space vessel props 140 and 142 to test the service provided by Total Safety. Assessments were conducted utilizing TEEX confined space instructors who served as subject matter experts (SMEs) for this evaluation. The selected SMEs have 10-15+ years of experience working in confined spaces. 8 realistic scenarios were then used to operationally test the monitoring service.

In 2013, TEEX TT&IC performed a TEEX Tested Assessment on the system. This report will focus on the CCSM service and updates to the system since the 2013 report.

As a result of reviewer feedback and testing, we conclude that the Total Safety – Centralized Confined Space Monitoring Service successfully monitored confined spaces in compliance within the OSHA standards 1910.146 and 1910.252. This assessment concludes:

- The sensors and monitoring personnel detected hazardous conditions and alerted workers and authorities in a timely manner similar, if not faster, than a watch stander.
- Technical issues were resolved by Total Safety Staff and corrected within a timely manner.
- Confined Space Workers felt safe working while being monitored by the Total Safety monitoring service.
- Cameras allowed the CCSM operator to have an internal view of the vessel that a standard watcher does not have access to monitor.

Functions

Single Point Monitor (SPM) - Black box outside of the manway where air is monitored and analyzed from sensor probe within the confined space.

Inside/Outside Hub – Yellow box inside and outside of confined space. Inside Hub contains the push to talk communications system, while the Outside Hub contains the badge in interface and an additional communication system.

Flight Desk – Monitoring station where the CCSM operator oversees confined space work and utilizes Total Safety software for gas detection, heat detection, and personnel management.

Gas Detection Probe – Tubing within the confined space that distributes air from within the confined space to the SPM for monitoring and analysis.

Centralized Confined Space Monitoring (CCSM) - Combined system for electronic access control, video monitoring, continuous atmospheric monitoring, two-way communication, visual and audible alarms.

CCSM Operator – Total Safety staff member stationed at the monitoring station in charge of watching cameras for potential hazards, coordination with operations and rovers, and configuring the monitoring interface.

Rover – Total Safety staff members stationed in the immediate area where work is conducted to supervise and assess hazardous situations, conduct equipment maintenance, and relocate cameras as required.

Entrant – Personnel working in a confined space.

Uninterruptable Power System (UPS) – Backup Power Supply

Manway – Confined Space Entry Point.

Vessel – Closed container where confined space work is conducted.

HID – Badge Proximity Reader used by Total Safety system to control access into and out of the confined space.

Total Safety Trailer- Total Safety transports equipment in a self-contained trailer with onboard UPS hookups for the monitoring station(s). If connected to on-site power, monitoring can be done from within the trailer.

Contents

Introduction

The following TEEX-Tested report represents findings of operational test results to meet the needs of confined space personnel. The Texas A&M Engineering Extension Service (TEEX) Testing & Innovation Center (TT&IC) leverages TEEX facilities, national and organizational standards, TEEX instructors, and TEEX students during testing. The TEEX-Tested mark is TEEX's premier offering for designing and executing testing for disruptive and innovative technologies and is a sign that a technology performs as intended under acceptable, repeatable, and real-world conditions.

This report provides an impartial third-party product evaluation of the Total Safety - Centralized Confined Space Monitoring (CCSM) Service. This assessment was performed according to our seven step TEEX-Tested methodology in July 2024 at TEEX's Brayton Fire Training Field's Disaster City, located at 1595 Nuclear Science Rd, College Station, Texas 77845 and includes testing and evaluation of the service under operational conditions by subject matter experts (SMEs) who are TEEX confined space instructors.

The Total Safety - Centralized Confined Space Monitoring Service's objective is to substitute monitoring equipment for traditional watch standers. This technology utilizes a centralized remote monitoring system that seeks to lessen the reliance on in-person watchers by enhancing oversight to increase risk mitigation. Total Safety introduces a new element of precaution through constant surveillance of work within confined spaces to identify and assess incidental situations. This system also has recording capabilities that can be used to generate an after-action report with monitoring data that can be utilized by each site to improve incident management and prevent potential risk factors.

Total Safety's website describes the product as:

"Total Safety's patented Centralized Confined Space Monitoring™ System maximizes worker safety by monitoring confined spaces remotely from a central control room. CCSM includes an innovative risk control process to employ dedicated equipment with trained safety technicians. Each system uses five types of technology which includes badge/ID reader technology, fixed gas monitoring, closed-circuit cameras, audible and visual alarms, and push-to-talk communications."

As no operational field test can include all applications and scenarios that could be encountered, a representative set of testing criteria, conditions, and permit-required confined spaces were selected to simulate operations by TEEX confined space instructors (SMEs) and collect data, observations, and end user feedback. The sections that follow outline the methodology and test plan utilized during the confined space monitoring system product evaluation, as well as observations, results, and takeaways.

Service Components

The Total Safety – Centralized Confined Space Monitoring System is comprised of hardware and software components designed to provide visual and auditory monitoring components to the manways.

System Components (Provided by Total Safety)

- Flight Desk (monitoring station)- *Figure 1*
- Evacuation Alarms- *Figure 2*
- Single Point Monitor (SPM)- *Figure 3*
- Intercoms
- Inside/Outside Hub- *Figure 4/5*
- Badge Readers- *Figure 5/6*
- Badges
- Power Cords
- Antennas- *Figure 7*
- UPS
- Gas Detection Probes
- Gas Detection Apparatus (inside SPM)
- Cameras (with temperature sensor)- *Figure 8*
- Thermal Cameras
- Mounts: Carbon Steel Clasps, Zip-Ties, Ropes
- Radios
- Five extra sets of equipment on site for spare and training

Photos of the assembled technology if appropriate

Figure 1: Flight Desk

Figure 2: Evacuation Alarm

Figure 3: Single Point Monitor (SPM)

Figure 4: Internal Hub

Figure 5: External Hub + Badge Reader

Figure 6: Badge Reader in Use

Figure 7: Data/Communications Antenna

Figure 8: Camera

Software

The monitoring station contains proprietary software and applications created by Total Safety for use as a part of their service. The software is operated within their system on servers, storage devices, and within monitoring equipment. Issues with software are managed by the Total Safety staff who are cross trained in IT help and monitoring operations.

System Setup

Total Safety transports equipment to the site in a self-contained trailer. The trailer requires an electrical hookup and has onboard UPS systems for each monitoring station. If the monitoring station is utilized outside of the trailer, like in this operational assessment, coordination is needed to ensure the equipment is maneuverable to the desired location. A forklift or ramp may be requested as the monitoring station weighs roughly 600 pounds.

Staffing

Total Safety cross trains staff to function as installers, rovers, monitors, and on-site IT and communication troubleshooters. This makes rotation between roles seamless and ensures on ground support is provided in all aspects.

Site Specific Pre-Coordination

Total Safety service begins its planning and coordination process approximately 45 days prior to on-site set-up. Total Safety plans several meetings with the customer to judge the quantity of resources needed based on site specific demands. Elements considered include the quantity of confined spaces, area of operations, equipment needs, permit coordination, statement of work, site-specific protocol, and installation support. Total Safety aims for a 6–8-hour set window-up but allocates 4-5 days beforehand in case a longer installation time is needed due to ongoing operations, weather, or other factors. The time of set-up and quantity of supplies will depend on the needs of the customer.

Service Boundaries

The CCSM service starts with a site specific pre planning and coordination process. This ensures that the service is best tailored to the needs of the customer. Following this, the Total Safety staff coordinates the set-up of the equipment at the site. During confined space work, two rovers are dispatched to cover a maximum of 12 manways to assist in maneuvering equipment, safety checks, and maintenance issues. One CCSM operator monitors a maximum of 12 entry points or 24 cameras and rotates roles every 2 hours to ensure attentiveness. In the case of an emergency, the service stops at notification to the pre-arranged site operations center, designated rescue/emergency center or predetermined municipal fire/rescue department. The Total Safety service does not include rescue personnel.

Methodology

Scope: The purpose of this evaluation is to conduct an impartial third-party assessment of the Total Safety- Centralized Confined Space Monitoring Service in a realistic and safe training environment with multiple users of various skill and experience levels. The overall objective is to assess the quantitative and qualitative aspects of the service and equipment and its potential training value and purpose. This evaluation is based on the knowledge, experience, and feedback of SMEs and quantitative and qualitative data collected during testing.

The TEEX-Tested methodology is based on a seven-step protocol designed to assess technology in the appropriate testing environment that ensures the product functions as intended and will function in the appropriate contexts. Figure 6 is a diagram of the TEEX-Tested journey, and an explanation of the seven-step process as applied to the Total Safety CCSM Service.

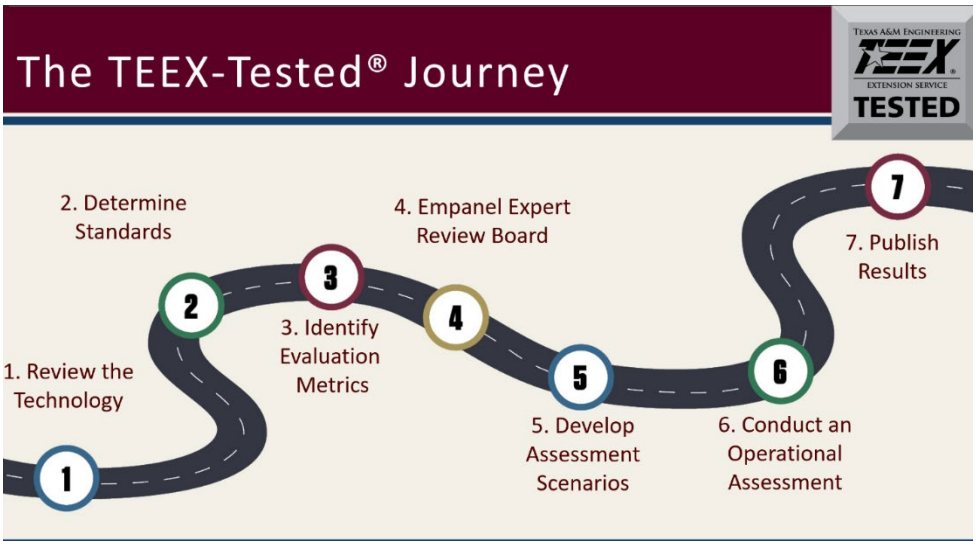

Figure 9: A Graphic Representation of the TEEX-Tested Protocol

Step 1 – Review the Technology:

- The TT&IC team met with Total Safety staff to learn about the boundaries, installation, and specifics of the service.
- Each of the system components were explained in-depth to give TT&IC staff a complete understanding of how the technology is meant to function.
- The TT&IC team and evaluators received the introduction briefing that customers receive.

Step 2 – Determine Standards:

- The TT&IC team determined the standards that would be evaluated and identified applicable evaluation metrics that would allow for proper analysis and testing of the service.
- The TT&IC staff reviewed OSHA 1910.146 and 1910.252 for requirements and standards for safe operations and procedures.

Step 3 – Identify Evaluation Metrics:

- In conjunction with TEEX Confined Space instructors and Total Safety staff, the TT&IC team determined evaluation metrics that provide quantitative, qualitative, and other measurements to best evaluate the product.

Step 4 – Empanel Expert Review Board:

- The panel of SMEs consisted of 3 TEEX Confined Space Instructors. SMEs recommended and vetted metrics and environments to ensure they represent operational settings and procedures.

Step 5 – Develop Assessment Scenarios:

- The TT&IC team created realistic, fair, and impartial testing scenarios leveraging state-of-the art TEEX facilities and appropriate standards and evaluation metrics.
- SMEs reviewed and approved the TT&IC developed test plan and scenarios as representative of normal operations and environments.

Step 6 – Conduct an Operational Assessment:

- The TT&IC team conducted operational testing on the service, procedures and equipment in a realistic and safe training environment with multiple users of various skill and experience levels and collected the resulting data, observations, and end user feedback for analysis.

Step 7 – Publish Results:

- This comprehensive TEEX-Tested report captures results, analyzes, and communicates relevant data for community leadership and acquisition decision makers.

Location

The evaluation of the Total Safety- Centralized Confined Space Monitoring Service was conducted at TEEX's Brayton Fire Training Field's Disaster City, 1595 Nuclear Science Rd, College Station, Texas 77845.

Map of TEEX Brayton Field and Disaster City

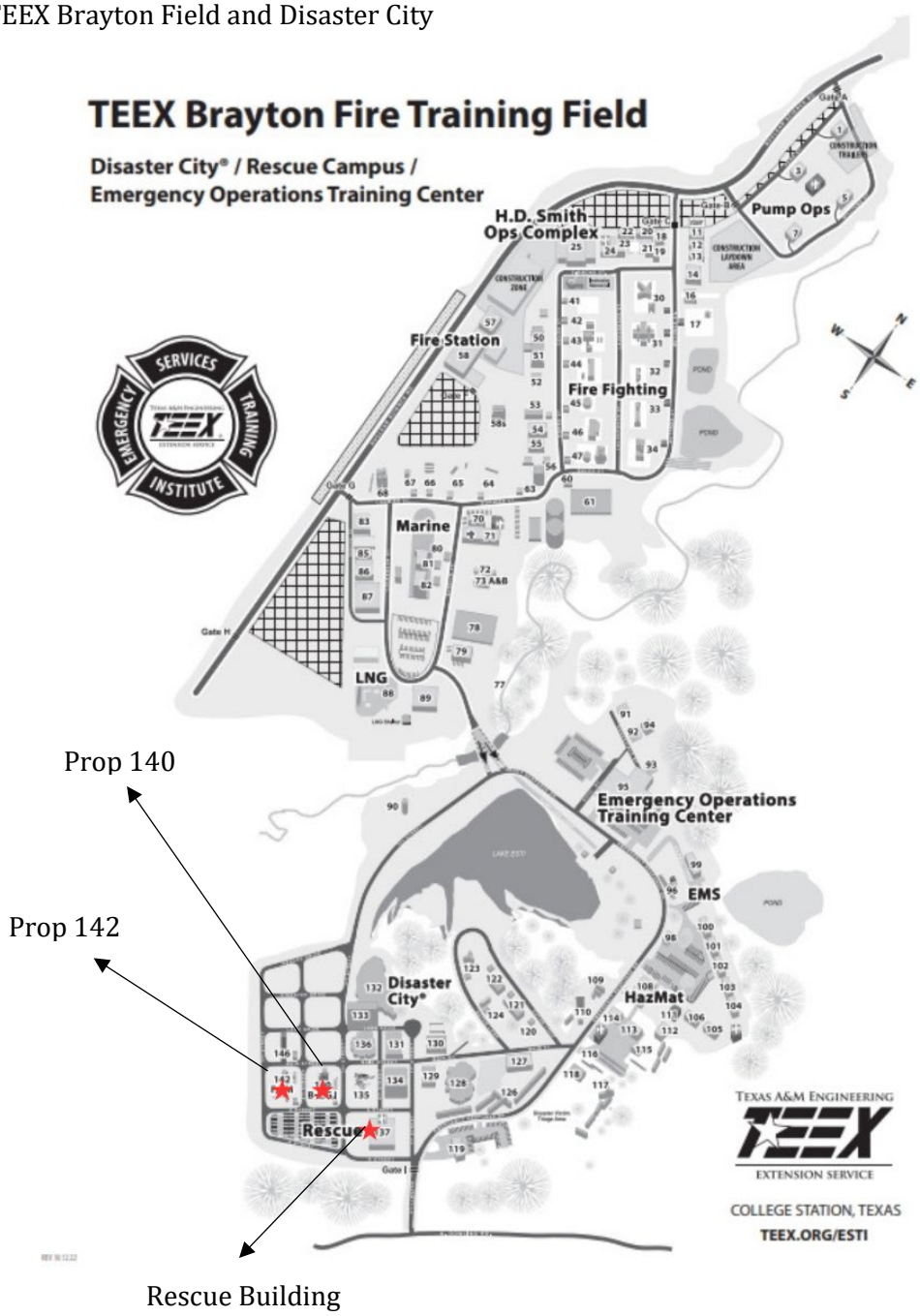

Figure 7: Overhead Map of the TEEX Brayton Fire Training Field + Disaster City

Confined Space Vessel props 140-D Horizontal Vessel, 142-J Scaffold Vessel, and 142-M Hyperbaric Chamber at TEEX's Brayton Fire Training Field's Disaster City were used for this operational assessment. Within each vessel, 2 manways were used, resulting in 6 manways being monitored. The monitoring system and CCSM operator were set up and manned from the TEEX Rescue Building in classrooms 103/104.

Figure 10: Props used in test Total Safety Monitoring System Service

Equipment Location

Total Safety Equipment is differentiated by "set" numbers for visualization on the CCSM operator's screen. This "set" number differentiates which manway is monitored by which set of equipment.

Total Safety can introduce an alternative manway labeling system synonymous with site-specific nomenclature to ensure effective communication between entities.

3 horizontal and 3 vertical manways were used. The table below outlines which set numbers were assembled on each confined space.

Set Number	33	53	55	147	177	71
Manway	H3	H2	V2	V3	V1	H1
Prop	142-M	142-M	142-J	142-J	140-D	140-D

Table 1: Set Number, Confined Space Manways, and Prop Labels

H= Horizontal

V=Vertical

Test Plan

The test plan used to evaluate the Centralized Confined Space Monitoring Service was developed similarly to those used in industry and the military testing but tailored to the unique characteristics of the service that evaluated in realistic conditions by users of all ability, skill, and experience levels. The TT&IC determined that this evaluation would not focus on the specific technical aspects of the hardware and software, since the individual sensors have been tested elsewhere, but rather on its performance as an overall system service. This allowed for the operational assessment to test the services ability to monitor safe operations in confined spaces leveraging sensor equipment and monitoring tools versus an assigned watch stander.

Centralized Confined Space Monitoring Service Scenarios Used during the Evaluation

Scenario 1: Worker entry into vessel, check ID scanner, simulate work and movement in vessel. Worker communicates with monitoring station. Monitoring station view and clarity of sensors.
Scenario 2: Worker in vessel simulates fire with grill lighter in work area. Thermal sensitivity using hand warmer.
Scenario 3: Worker in vessel simulates sparking using torch ignitor in work area. Check detection and response by monitor.
Scenario 4: Unauthorized person entering space.
Scenario 5: Man down in vessel. Silently collapse to see if the operator detects, time for monitor to detect and alert.
Scenario 6: Loss of power, unplug AC power cord, UPS should pick up with interrupted power.
Scenario 7: Smoldering Fire with hand warmer
Scenario 8: Spray CO_2 into vessel
Randomized Sub-Scenarios: Worker PPE violations, phone usage violations, work conducted not in the workers scope of work

These scenarios were each performed multiple times to ensure appropriate data collection. They were performed individually, sequentially, randomized, and simultaneously to ensure real-world scenarios were replicated.

Sequence of Total Safety- CCSM Service Testing Events

30 July 2024

1. Total Safety Team and TT&IC Staff arrive at the Rescue Building-Disaster City training room.
2. TEEX personnel conduct Disaster City safety brief and event action plan (EAP) review.
3. Walk-through of site props to confirm selection of confined spaces for testing.
4. Install and set-up Monitoring Service in/on Disaster City props (140/142).
5. Designate area and set-up monitoring station in training room.

31 July 2024

1. Total Safety Team, SMEs, and TEEX personnel meet at Rescue Building-Disaster City training room for an in brief and safety briefing.
2. Finalize antenna positions and establish network connection between sensor/monitoring locations and monitoring station.
3. Total Safety Staff finalize set-up of monitoring stations and conduct system checks of confined space sensors.
4. Regroup at Rescue Building training room.
5. Total Safety staff conducts normal customer training to evaluators/SMEs via PowerPoint presentation and hands on instruction at the Total Safety system set-up trailer.
6. Evaluator SMEs take a 10-question quiz regarding the training received followed by Total Safety issuing simulated permits for cleared entry to evaluator SMEs. Personnel deploy to props 140/142 and training room.
7. Test Sequence 1 – Sequential.
8. Test Sequence 2 – Randomized.
9. Test Sequence 3 – Simultaneous.
10. Gather SMEs for an after-action report and administer post assessment surveys.
11. Total Safety personnel panel discussion discussing further questions and observations.
12. Total Safety uninstalls and repacks system equipment in trailer.
13. Wrap up & TT&IC staff hosts discussion regarding observations.

Analysis and Results

The metrics measured in the TEEX-Tested assessment are grouped into three categories: quantitative metrics, qualitative metrics, and other value considerations. This section details the observations made and the subsequent results of the assessment.

Quantitative Metrics

The TEEX-Tested quantitative metrics are a set of defined measurements that provide an objective perspective to the evaluation. Quantitative metrics are typically reported using numerical data.

Complete Set Up Time: Total Safety aims for 6-8 hours of set-up but is dependent on-site size and number of manways being monitored. Total Safety would normally allocate 4-5 days before work starts to set up the entire system and ensure all equipment is functional. Set-up time will vary based on customer needs.

Monitoring Station Set Up: An 8'x8' area is the preferred minimum area for the flight desk to be set-up outside of the trailer.

It took the monitoring station approximately 16 minutes to establish an online connection with the other equipment post set up. The set-up time for the monitoring station will vary based on site capabilities as it weighs 600lbs and requires pre-planning from Total Safety and the site to assess the most efficient transportation method. Use of a crane or forklift might have to be arranged to ensure successful movement.

Power Requirements: Non-GFCI power is standard for the system, but GFCI power can be utilized.

In this operational assessment, GFCI power was the only available option to connect to the SPM. Due to this, the SPM was plugged directly into the power source without the UPS. The UPS was charged prior to testing on compatible non-GFCI power. If a power outage occurs while using GFCI power, the SPM would have to be unplugged from the power outlet and plugged into the UPS. With non-GFCI power, the UPS and SPM are connected, and the system recognizes the loss of power and simultaneously switches to the UPS without any manual cord switching.

Note: It was noted that non-GFCI power is nearly always available in or near confined spaces for use.

UPS Battery Life: The UPS provides backup power to the monitoring system and typically lasts 41-43 minutes when fully charged and does not require non-GFCI power for charging. The UPS that provides backup power to the field equipment typically lasts around 30 minutes when fully charged. The battery life noted is subjected to change due to external factors.

Battery Recharge: The UPS system needs to be charged through non-GFCI power. If non-GFCI power is not available at the site, similar to this operational assessment, the UPS will require charging ahead of time using non-GFCI power.

During pre-installation planning, Total Safety will ensure the appropriate power configuration is utilized based on site availability.

Camera: The standard camera is a 1280x960 resolution with 4x zoom capabilities.

The cameras do not pan physically but can be adjusted once zoom is initiated. If the worker is out of frame, the operator will request a rover to reposition the camera. In larger confined spaces, the camera can be adjusted while the worker remains inside; otherwise, the worker must exit the space to allow the rover to reposition the camera.

Thermal Camera: The thermal camera has full spectrum color with 8x zoom capabilities and does not pan physically but can be adjusted digitally once zoom is initiated.

The thermal camera (EOIR) provides full spectrum color and detects heat signatures up to 1000°F. Thermal cameras can be used alone or alongside standard cameras.

In bright environments, the CCSM operator may have difficulty monitoring with the standard camera due to sunlight or glare. The thermal camera is not affected and will continue to detect fire and sparking.

A handwarmer placed in the manway to simulate a smoldering fire was accurately detected by the thermal camera at 140°F, close to the advertised average of 135°F.

Note: Thermal cameras are considered additional and are not traditionally installed unless requested.

Detection of Hazardous Condition (Preventative): The CCSM monitor displays 6 chosen gas levels, with baseline ranges set according to OSHA standards. 23 different gases can be detected. To change gas detection, Total Safety changes the sensor in their safe core detection unit and verifies the software is reading the proper sensor. Sensitivity of the corresponding detection ranges can be adjusted as needed. If levels deviate from these standards, the live dashboard will show a hazardous condition, marking the affected gas in red instead of green, prompting the attendant to initiate emergency procedures. The alarm will automatically engage, as seen in Figure 11, if the levels observed exceed the baseline range set.

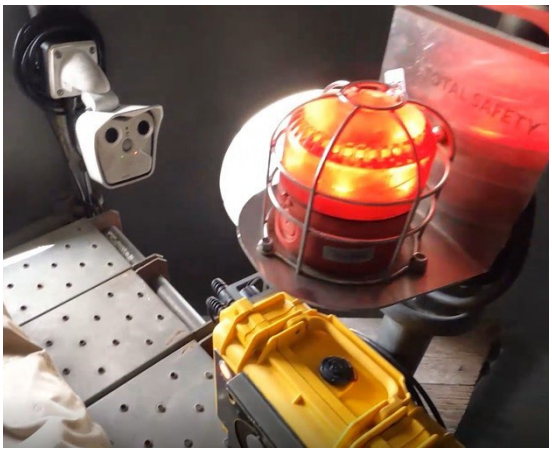

Figure 11: Alarm sounding with flashing light

The system also includes a temperature reading, with baseline levels indicated in red on the camera display when a rapid increase is detected. In cases of potential heat stress conditions, the attendant will advise the worker on best practices during the badge-in process. Total Safety utilizes the company site protocols for alerts and responses. The effectiveness of hazard prevention largely depends on the attendant's attentiveness.

CCSM Gas Coverage	
• CO • H2S • SO2 • O2 • NO • NO2 • CO/H2S • NH3 • H2 • HCN • HCl • Cl2 • ClO2	• CO High • CO/H2 High • IR CH4 • IR CO2 • IR HC • PID • LEL (Pent) • LEL (Meth) • LEL (CH4 % Volume)

Table 2: Gas selection monitoring system is capable of monitoring. Customer selection.

Detection of Fire: Fire was detected in an average of 3 seconds during sequence 1 and 2 scenarios. Upon detection of fire, the CCSM operator sounded the alarms instantaneously.

Detection of Sparking: Sparking was detected in an average of 7 seconds during sequence 1 and 2 scenarios. Sparking is considered normal in confined space work. During this scenario the operator would ensure containment measures were in place by communicating with the rover, on site operations, and the entrant.

Detection of Worker Distress: Worker distress was detected in an average of 7 seconds during sequence 1 and 2 scenarios.

Detection of Dangerous Heat Levels: Temperature is monitored on CCSM operator's screen. The normal camera has a +/- temperature threshold of 8°F and the thermal camera has a +/- of 0.5°F. Heat protocols are adopted using the customers' policies. Throughout the operational testing, internal temperatures rose to over 100°F. The CCSM operator kept a close eye on heat levels to ensure entrants' safety.

Automated Detection System Alert: If gas levels are detected the alarm will automatically sound. Two alarms sound automatically post detection, the high alarm and/or low alarm. The high alarm is a loud siren with a flashing red light. The low alarm only flashes the red light without sounding an audible alarm. High and low alarms are set at the OSHA required limits but can be modified to fit plant needs if desired. Typically, only high alarms trigger an evacuation.

Process for control room attendant to alert the worker: For the control room attendant to communicate with the worker, the communication line is opened via a computer screen keypad. The internal and external hubs are differentiated using a unique numerical address input.

Process for entrant to alert control room attendant: The confined space worker alerts the CCSM operator by utilizing a push-to-talk button on the internal hub within the confined space. If the entrant

cannot reach the internal hub communication button, non-verbal communication signals taught in training are used to alert the CCSM operator of a dangerous condition.

System Checks: Before work begins, Total Safety conducts system checks on all the equipment. This system check involves verifying connectivity and functionality of the badge-reader, communications, entry protocol, alarms, camera angles, and gas detection at the sensor base. The system checks of the 6 confined space manholes used during the assessment took 37 minutes.

Qualitative Metrics

The TEEX-Tested qualitative metrics are a set of measurements based on human judgement that subjectively evaluate a product and or its technology.

System Stability: The system remained stable throughout the majority of operational testing, with only minor issues observed.

During operational testing, the monitoring screen crashed requiring the CCSM operator to restart the monitoring application. Total Safety staff found that the issue stemmed from the computer's RAM reporting 98% usage, despite actual usage being lower. Once the memory update resolved this, no further stability issues were observed. TEEX staff noted that the server used by Total Safety was new and had not been utilized operationally before.

The power source seamlessly transferred to the UPS when power loss occurred. The system remained stable when connected to the UPS.

System Reliability: System reliability is good. Total Safety uses in-house tech support who is on site and ready to assist when issues arise. When a few technical issues surfaced, the Total Safety staff was able to resolve the issues quickly.

Functionality of Equipment: Issues with faulty cords, thermal cameras, and antennas were observed during operational testing which slowed down set-up time and resulted in mid-test adjustments. Total Safety mitigates this risk of unfunctional equipment by installing the system days in advance and providing five sets of backup equipment to swap out if needed.

Quality of Training: The training provided by Total Safety provides workers with a general overview of the system and the equipment. Their training consists of an introductory presentation, knowledge test, and hands-on equipment familiarization. The knowledge test is utilized to confirm the customers' understanding of their policies and an added agreement to follow Total Safety protocols.

Quality of Communication: The communication was very clear, with no latency experienced. Antenna distance and placement is site dependent to ensure continuous, quality communications between outside hubs and Flight Desk.

Quality of Video: Video quality was clear and detailed. The sunlight periodically caused a camera glare which interfered with the CCSM operators' ability to assess situations.

Switching to a thermal camera eliminated the glare, allowing the operator to fully see the workspace, glare free.

Note: Thermal cameras are considered additional and are not traditionally installed unless requested.

Customer requirements dictate procedures if a camera becomes inoperable. Work may continue if a rover is repairing or repositioning a camera within the same space as the worker.

Quality of Sensor Placement: Prior to confined space entry, there is an alarm, external hub with badge reader, camera, and SPM. Inside the confined space there is an alarm, push to talk internal hub, connected gas detection probe, and camera. During installation, the Total Safety team secured the cords to each of these devices to ensure they were not a tripping hazard or in the way of work. The sensor placement is dependent on the type of vessel and type of work being performed.

Badge Reader: Total Safety utilizes a HID "tap" entry card reader. Total Safety can issue their badges to entrants or program the site's badges to be compatible with their system. The operator has access to the entrant count for each confined space and a detailed log of entries and exits. If an unregistered badge is used to badge in, the reader will flash red signifying non approval for entry. This will be detailed on the log sheet of an attempted unauthorized entry. If the unregistered badge is not system compatible, no lights or communication will be initiated.

Alert System Volume: The alert system volume was sufficient to alert the worker to evacuate. The volume can be adjusted to ensure effectiveness in varying volume environments.

CCSM Operator Attentiveness: To ensure the CCSM operator is attentive during their shift, an automated box pops up every 30 minutes to be acknowledged by the operator. An automated log is kept recording the time it takes for the operator to click on the box. The CCSM operator changes every 2 hours.

Set Up Interference with Rescue: The equipment and cabling are secured out of the way and can be easily moved in an emergency.

Pre-Installation Check for Combustibles: Total Safety does not constitute pre-installation checks for combustibles before system set-up. The site of operations conducts pre-hazard checks and obtains a permit for Total Safety personnel to start set-up.

Other Value Considerations

This category includes critical considerations that are beyond measurable metrics and explains the perceived value of the system as a training tool.

After Action Package: When the service is complete, an after-action package is sent to the customer. This includes gas detection logs, safety observations, entry logs, manhours, alarm events, and recorded video feed. Packages are provided 1-2 weeks after the work is completed, depending on the size of the project and number of recordings made/stored.

Assumptions/Test Specifics

- Use of 3 props, 6 manways (6 cameras on monitoring station, TS ratio of 1 attendant to 12 sites or 24 cameras). Note that two attendants were stationed at the SPM for the 6 cameras.
- No Pre-Planning
- Total Safety brought 4 people for operations and set up.
- Test Area: 5,685.22 m^2

User Feedback

Feedback was collected through surveys administered to the SMEs at the end of the operational assessment to capture feedback on the equipment. 6 statements were provided regarding the assessment and the SMEs were given the response choices of 1-5. 1 being strongly disagree with the statement and 5 being strongly agree with the statement. A comment section was provided for each question and each SME was asked what they would change or add to the system. All 3 of the SMEs are TEEX Confined Space Instructors with varying years of experience outlined in Table 3 below.

SME	**Years of experience working in/around confined spaces**
#1	15+ Years
#2	15+ Years
#3	5-10 Years

Table 3: Experience level of subject matter expert evaluators

	1: Strongly Disagree	**2**	**3**	**4**	**5: Strongly Agree**
Statement 1					XXX
Statement 2			X		XX
Statement 3	X	X		X	
Statement 4		X			XX
Statement 5			XX		X
Statement 6			XX		X

Table 4: Responses via administered surveys, each X represents a SME response

Statement #1: "I felt very confident that I could safely operate the system and be alerted to any events affecting the safety of personnel working in and around the workspace."

All 3 SMEs noted that they strongly agreed with this statement. One SME noted the "quick reaction time" of the CCSM operator during the scenarios.

Statement #2: "I felt confident as a confined space worker that the monitoring system would detect and alert me of events and conditions that were unsafe to work in."

2 out of 3 SMEs noted that they strongly agreed with this statement, one noted that the CCSM service "picked up fire quick" during the scenarios. The other SME responded with a 3 noting that they were wary of non-detection during sparking scenarios.

Statement #3: "While using the service, I believe a safety watch is needed to be immediately outside of confined space work."

1 SME strongly disagreed with this statement, another disagreed and the third agreed with the statement recording a 4 on the survey. They noted that "It depends heavily on the work being done in the space. If the entrant is on a rope/cable lifeline then yes, we absolutely should have someone for at least a nonentry rescue if needed".

Statement #4: "The monitoring system does not interfere with my work in and around confined spaces."

Two of the SMEs strongly agreed with this statement. The other SME disagreed recording a 2 and noted that it "depends on type of work [and] size of space".

Statement #5 "I would recommend the monitoring system in place of on-site monitoring staff in the immediate vicinity"

One SME noted that they strongly agreed with this statement. The other two SMEs felt indifferent recording a response of a 3. One noted that it "is situationally dependent based on what is going on in/around the space."

Statement #6: "I felt the system/service detected unsafe and hazardous conditions as well or better than a dedicated human monitor at the site."

One SME noted that they strongly agreed with this statement. The other two SMEs felt indifferent recording a response of a 3. One noted "Yes and No; in some cases, absolutely in others it's still up to the interpretation of the controller at the desk".

When asked about additions or changes to the system, two responses noted a video component added to the training given. Another recommendation was for a body worn component for better communication and detection.

Areas for Improvement

- Provide entrants with an orientation video on how the system operates.
- Use of a mesh network would provide greater flexibility, range and redundancy of communications pathways.
- Record or type transcript log instead of notes for incident management.
- Handwritten notes take too much time away from visual monitoring.
- Integrate artificial intelligence (AI) to recognize fires, collapses, etc. and provide alert to monitoring personnel.
- Provide a wearable communication/ICE device to enable workers to communicate without being within arm's reach to the internal hub.

Conclusions

This report documents the testing and evaluation of the Confined Space Monitoring Service. Our product assessment placed the system and its components in realistic conditions and tested its functioning with appropriate methods in the proper environment with experienced confined space worker/rescue personnel. The TT&IC staff provided operational and technical oversight throughout the testing process assisting with execution and documentation of this product evaluation and capturing the results.

Our test plan was tailored to the unique characteristics of the training vessels to ensure the simulated environment was representative of work normally conducted in confined space vessels 140/142.

Based on our test results and user comments, we believe the Total Safety confined monitoring system meets standards for safely working in confined spaces while being monitored from a real time monitoring station with active sensors and communications.

- Our testing showed that sensors and monitoring personnel detected hazardous conditions and alerted workers and authorities in a timely manner similar, if not faster than a watch stander.
- Technical issues were resolved by Total Safety Staff and corrected in a timely manner.
- Confined Space Workers felt safe working while being monitored by the Total Safety monitoring service.
- The Total Safety Monitoring Service complies with the OSHA standards 1910.146 and 1910.252.

The findings and observations presented in this report are subject to limitations based on assigned workers, evaluation location, and the time allotted to perform the assessment. Every effort was made to replicate the operational environment for this evaluation. It should also be noted that even the best test plan and expert testing personnel cannot account for every possible real-world situation encountered or intentional act to circumvent the system; therefore, an evaluation of this type cannot capture every scenario.

References

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