

ABS Group

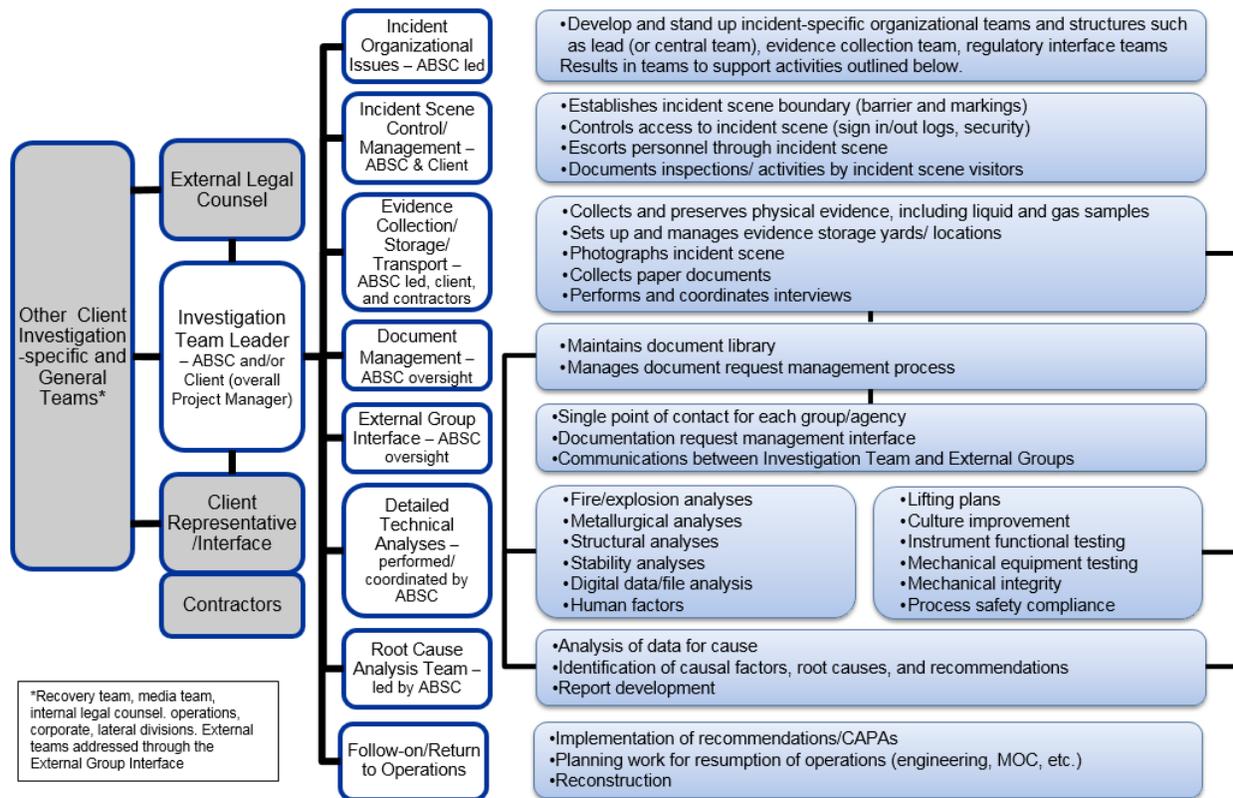
Incident Response Experience

Clients call us for incident investigation/root cause analysis support when they:

- ✓ Have a major accident or incident and need additional investigation expertise, technical expertise, regulatory interface support, and recommendation implementation support
- ✓ Know they will face issues with regulators, insurance companies, or customers
- ✓ Know there is the potential for serious litigation
- ✓ Have a chronic issue they need assistance with solving
- ✓ Want an outsider's view of an incident
- ✓ Minimize business interruption risks and quickly restore operational capabilities

Table 1 provides a partial summary of the investigations performed by ABS Group personnel.

We can provide a comprehensive response to an incident – from simple to complex. The figure below outlines the various roles and activities that ABS Group can provide to support an organization following an incident. **We tailor our approach and our team to YOUR specific needs.**



ABS Group personnel have performed hundreds of investigations from minor to catastrophic safety incidents, quality issues, reliability problems, equipment failures, environmental releases/excursions, ship mishaps, software issues, nuclear occurrences, and petrochemical/refining plant accidents. Not only do we perform the investigation, we manage the overall organizational response to the incident, including interfaces with regulators (OSHA, EPA, CSB, FDA, DOE, BSEE, etc.), insurance companies, and attorneys.

In addition to the causal analyses we perform (causal factors and root causes) to improve system

performance, we also help clients minimize business interruption impacts, avoid significant losses in court, or achieve greatly reduced fines from regulators. We accomplish this quickly and fairly in a proactive relationship with all parties.

Incident Organizational Issues

- Put together teams and organizational processes to deal with temporary needs created by the incident based on protocols developed by ABS Group

Incident Scene Control/Management

- Make the site safe for access
- Develop and implement a site control agreement and other protocols
- Control access to the incident scene (e.g., barriers, signage, access logs)
- Supply field personnel to augment your staff
- Escort personnel in the incident scene

Evidence Collection/Storage

- Identify, collect and preserve physical, paper, and position evidence
- Identify, collect, and preserve liquid, gas, and metallurgical samples
- Photograph the incident scene
- Set up and manage evidence storage yards/locations
- Perform and coordinate interviews

External Group (Regulatory/Agency/Community) Interface

- Provide single point of contact of each group
- Document request management interface
- Provide communications
- Evaluate facility policies and procedures
- Defend against sanctions and suits
- Act as expert witnesses

Technical Support Services

- Fire and Explosion Investigation (FEI)
- Blast modeling
- Metallurgical analyses
- Structural
 - Analyses for code compliance and extreme loads
 - Condition and damage assessments
 - Repair design
 - Stability analyses
- Digital data/file analyses
- Human factors
- Lifting plans
- Culture improvement
- Instrument functional testing
- Mechanical equipment testing
- Mechanical integrity
- Process safety compliance

Perform Root Cause Analysis

- Lead investigation activities
- Coordinate data/evidence gathering
- Identify causal factor and root causes
- Develop recommendations

Follow-on Services - Recommendation Implementation and Reconstruction

- Plan demolition and equipment removal
- Evaluate safe return to operations
- Provide reconstruction/design verification
- Provide recommendation tracking and implementation
- Provide training on safety, risk, and integrity management
- Assess and improve safety culture
- Perform inspections to prevent future incidents
- Provide expert witness testimony

Incident Organizational Issues – This task involves developing and putting in place temporary teams and organizational processes to deal with the issues created by the incident. This work is typically driven by the generic protocols developed by ABS Group and tailored to the specific client needs. Example issues include (1) structuring a central team to make decisions rapidly during the initial stages of the investigation, (2) identifying single points of contact for major groups, and (3) assigning personnel to respond to and control external and internal requests for data, information, and communications flow.

Incident Scene Control/management – Securing and controlling access to the incident scene preserves evidence and protects personnel from hazards. ABS Group can assist in several areas, including:

1. Defining hazards, their extent, and planning for removal of those hazards
2. Evaluating the structural integrity of damaged equipment and planning for shoring/stabilization
3. Developing site control agreements and protocols to quickly secure and control access to the incident scene
4. Identifying areas with potential evidence
5. Establishing incident scene barriers, signage, and access logs to control access to the incident scene
6. Setting up and managing evidence storage yards for long-term preservation of evidence
7. Escorting personnel within the incident scene area
8. Providing field personnel to assist in performing the above activities

Evidence Collection/Storage – As evidence is identified, it needs to be properly documented, collected, and stored. Following the guidance in the data gathering and preservation chapter in our *Root Cause Analysis Handbook*, we use evidence preservation and collection protocols to guide this work. ABS Group can provide personnel to:

1. Identify, collect, and preserve physical data collected from the incident scene
2. Photograph and sketch the incident scene and maintain an inventory of all images
3. Identify, collect, and preserve various types of samples, including:
 - a. liquids from tanks, pipes, and sumps
 - b. gas/vapor samples from tanks, piping, and cylinders
 - c. scrapings from the sides of pipes and tanks
 - d. metallurgical samples from pipes, tanks, and tools/equipment
4. Set up and manage evidence storage yards/locations for long-term preservation and storage of evidence, including developing the layout of the yard and marking a grid on the yard to facilitate evidence layout, signage, documentation, and access control
5. Perform interviews of personnel, including documentation.
6. (1) Document any inspections of evidence in the field, (2) assist in planning evidence removal, (3) document removal of evidence, (4) set up and manage the evidence storage yard, and (5) serve as a custodian of the evidence that is collected.

External Group (Regulatory/Agency/Community) Interface – Each agency has its own authority, direction, and protocols. ABS Group has direct experience with OSHA, CSB, EPA, BSEE, Department of Homeland Security, U.S. Coast Guard, and others. We will guide you through the process, including providing a single point of contact, providing documentation request management and communications, and evaluating the procedures and policies against regulatory standards.

Technical Support Services – Each investigation can involve its own spectrum of technical analysis challenges. Typical support services we provide during investigations include:

- Fire and explosion analyses
- Blast modeling
- Metallurgical analyses
- Structural
 - Analyses for code and extreme loads
 - Condition and damage assessments
 - Repair design
 - Stability analyses
- Digital data/file analysis
- Equipment inspection/verification
- Human factors assessments
- Lifting plans
- Culture improvement
- Instrument functional testing
- Mechanical equipment testing
- Mechanical integrity
- Process safety compliance
- Sonar interpretation

ABS Group can perform or facilitate each of these technically challenging analyses. As an example, fire and explosion analyses can include:

- Site surveys to document fire and blast damage
- Analyses to define point(s) of release, ignition sources, extent of flammable cloud, fire patterns/thermal exposures, explosion energy, and blast contours to distinguish between the origin and knock-on events
- Dispersion, fire, explosion, and structural modeling, including computational fluid dynamic and finite element modeling to determine (or exclude) potential initiating events, the sequence of follow-on events, and the event timeline. The analysis is often used to deny competing theories, defend false claims, and develop/design adequate structures for future application
- Follow-on structural repair design and construction administration services to minimize business interruption impacts and expedite return to normal business operations.

Perform a Root Cause Analysis (RCA) – A thorough investigation of the incident is needed to identify root causes to develop actions that address the underlying causes. A comprehensive RCA will find the causal factors and the root causes. The ABS Group’s SOURCE™ approach uses field-tested techniques to perform an RCA and help you understand what caused an incident, prevent recurrence, and promptly restore the confidence of workers, management, regulators, and the public. We facilitate the investigation by: (1) collecting, organizing, and analyzing data, (2) identifying causal factors and root causes, (3) developing recommendations, and (4) keeping the team on track and organized throughout the analysis process.

Follow-on Services

Engineer Demolition or Removal of Equipment – ABS Group can evaluate damaged structures and equipment for integrity and determine safe ways to deconstruct and repair the equipment.

Recommendation Implementation and Follow-up Activities – ABS Group personnel are experts in all process safety management elements, including management of change, mechanical integrity, procedures, training, and process safety information. We can also provide structural repair design and construction administration support services closely coordinated with work by repair contractors. We have expert project managers, auditors, and inspectors to get the work done on time and on budget. We can use our Web-based action tracking system to manage and communicate progress to completion.

Culture Assessment, Inspections, Audits, and Training – ABS Group can provide additional services that may be required following an incident, such as organizational culture assessment and change, equipment inspections, audits, and training.

Serve as an expert witness – Regulatory citations and civil litigation are often an outcome of major incidents. To defend these, ABS Group provides recognized technical experts with the experience and gravitas to develop technical arguments and serve as expert witnesses.

Rapid Response

The investigation process should start immediately after the incident. Call +1-331-303-2272 to talk DIRECTLY to one of our lead investigators - 24 hours a day. Our investigators will start assisting you immediately with remote assistance while we are deploying our personnel to your site. O

We can provide as much or as little assistance as you need, by:

- Leading the overall investigation response (with some or all the activities shown on page 1)
- Leading selected incident response activities
- Providing onsite assistance and coaching
- Providing remote assistance and coaching
- Providing independent report review services

With over 70 offices on six continents, we will provide assistance wherever and whenever you need it. This is just a partial listing of the countries where we have provided investigation or investigation training services.

United States
Mexico
Canada
Singapore
Chile
Venezuela
Brazil
United Kingdom

Papua New Guinea
Qatar
Saudi Arabia
Angola
Georgia
Azerbaijan
Kazakhstan
Germany

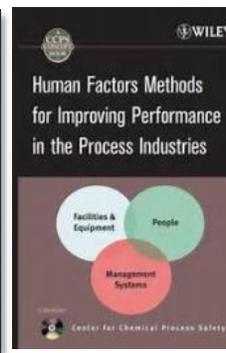
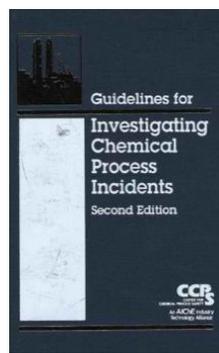
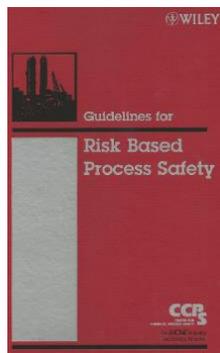
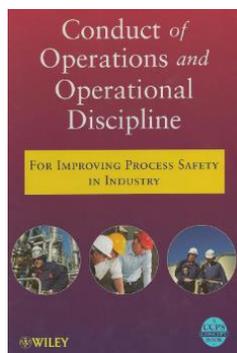
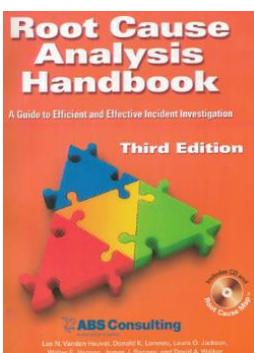
France
Hungary
Bahrain
Malta
Denmark
Oman

Contact us on our 24-hour help line, or contact your local office (see www.abs-group.com/office-locator).

We Wrote the Book

ABS Group personnel have contributed to numerous publications and articles related to incident investigation and root cause analysis. The following is a partial list of incident investigation/root cause analysis-related books and articles authored or co-authored by ABS Group personnel.

- *Guidelines for Investigating Chemical Process Incidents, 2nd Edition*, Center for Chemical Process Safety (CCPS)
- *Guidelines for Risk-based Process Safety*, CCPS
- *Root Cause Analysis Handbook*, Rothstein Associates
- *Root Cause Analysis for Beginners*, published in the July 2004 issue of Quality Progress. This article has been downloaded more than **100,000** times
- *Guidelines for Management of Change*, CCPS
- *Guidelines for Mechanical Integrity*, CCPS
- *Guidelines for Evaluating Process Plant Buildings for External Explosions and Fires*, CCPS



Incident Investigation Training Experience

ABS Group has provided incident investigation and root cause analysis training for more than 7,500 individuals from over 250 companies on 6 continents and over 50 countries. This training was provided through more than 750 courses, including more than 600 onsite courses (taught for individual companies or sites). Our courses range in length from 1 hour to 7 days, depending on the training objectives of the client. About 50% of the course time is spent in workshops and exercises, typically including one major case study. The courses are highly interactive.

We currently provide training in English, Spanish, Portuguese, Japanese, and French with other languages becoming available as we continue to expand our offerings. Our training personnel are located throughout the world and provide training literally anywhere you need.

Table 2 is a partial listing of the organizations that have selected our courses for their incident investigation/root cause analysis training needs (many consultants/competitors have also attended our public courses).

Find Out More

To find out more about our approach to investigations and root cause analysis, please contact ABS Group.

Call +1-331-303-2272 to talk DIRECTLY to one of our lead investigators - 24 hours a day

- OR -

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→ [Incident investigation/
RCA services](#)

→ [ABS Group web site](#)

→ [ABS Group worldwide
office locator](#)

Senior Manager, Investigations and Root Cause Services

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Table 1: Selected ABS Group Incident Investigations

Title	Industry Type	Brief Description
Several incipient stage fires	Chemical demilitarization	Investigation of multiple incipient stage fires at a chemical agent demilitarization facility. Multiple fires had occurred that had different causal factors but common root causes.
Failed pressurized cylinder	Chemical distribution	While a worker was filling a cylinder with an herbicide, the cylinder he was filling failed, resulting in a fatality. The investigation involved metallurgical analysis of the cylinder, as well as, investigation of the organizational systems leading to the failure.
Air Compressor RCA	Chemical processing	An air compressor failed after repeated start attempts. A number of pistons and piston skirts were damaged.
Electrocution		A contract worker was electrocuted when he stepped in a puddle with an energized, frayed extension cord. ABS Group performed the investigation.
Fire assessment and reconstruction design		ABS Group performed a post-fire structural assessment and developed rebuilding plans (e.g., development of shop drawings for fabrication and erection) for a heavily damaged industrial structure after a fire destroyed the manufacturing line and severely damaged the building structure. ABS Group assistance allowed the facility to rapidly return to full production operations following a complete rebuilding of the damaged area.
Fire following a pressure vessel plug failure		During startup of a pressure vessel, a threaded plug came loose and was ejected. The release from the vessel ignited and caused damage to equipment in the area. ABS Group provided RCA services.
Stack failure		A 200' steel stack fell onto the bag house. The stack had rapidly corroded over a period of 2 years because of problems with the materials of construction and operational problems that led to excessive chlorides in the stack plume. The investigation involved metallurgical analysis issues.
Worker Asphyxiation		A worker was asphyxiated during a confined space entry. ABS Group led a client team in performing the investigation. Because the incident occurred during a turnaround numerous contractor organizations were involved in the incident, complicating the data gathering efforts.
Release of Anhydrous Ammonia During Filling of Tanker	Chemical Transport	During the filling of an anhydrous ammonia tanker, the filling line became detached from the tanker. The release resulted in several fatalities and injuries.
Breaker Failure Results in Generator Damage	Electric utility	Failure of a substation breaker failure, combined with relay scheme issues, resulted in severe damage to a 400MW unit and 13-month outage.
Chiller System Heat Exchanger Failure		A chiller system for a gas-turbine generator unit failed. The chiller system became overpressured following some maintenance and operational issues. This led to leakage of coolant into the water system and subsequent failure of the water fin-fan unit. The investigation reassessed prior investigations to develop a more comprehensive report.
Chronic analysis of safety issues for an electric utility		Chronic analysis of personnel safety issues over a multiyear period for a power utility.
Collapse of a special-purpose crane		A purpose-built crane collapsed during its single-purpose lift. A design issue led to the collapse. ABS Group assisted our customer in structuring their organization to manage overall incident recovery and performed evidence collection.
Crane collapse during movement of heavy load		During a heavy lift using a specially designed crane for the task, the crane collapsed resulting in significant damage to the structure and crane. ABS Group's role was in structural/building assessment and initial evidence collection.
Forest fire		Investigated possible causes of forest fires in Valparaiso in April 2014 using semi-quantitative event trees to assess each of the possible causes.

Table 1: Selected ABS Group Incident Investigations

Title	Industry Type	Brief Description
Near-miss Electrocution	Electric utility	During construction operations, a contract worker climbed onto an energized high-voltage transformer. An HSE professional noticed the worker was in a prohibited area before the contractor was electrocuted.
Release of fly ash offsite		Failure of piping near a coal-fired power plant led to the release of fly ash into a nearby waterway. ABS Group supported our client by leading the root cause analysis support and limited field support.
Trending Analysis of Serious Injuries		A review of several years of serious injury data was performed to identify recurring issues and corrective actions.
Explosion and Fire	Exploration & Production – Offshore	A failure of a process gas line from microbial induced corrosion resulted in an explosion and subsequent fires that destroyed the platform. Several individuals were fatally injured as a result of the incident. ABS Group provided evidence recovery and management services, root cause analysis services, and interfaced with the federal regulator.
Explosion leading to three fatalities		While performing welding activities, an explosion occurred that resulted in propelling three tanks off the platform and killing three workers. Hot work permit issues and contractor oversight were major issues identified. ABS Group performed evidence collection, root cause analysis, fire and explosion modeling, coordinated laboratory analyses, and interfaced with BSEE and legal counsel during the investigation.
Explosion on an offshore platform		A pipeline feeding the platform failed resulting in a release, explosion, and fire. About half of the platform ended up on the sea floor. There were multiple fatalities. ABS Group performed all aspects of the investigation, including evidence management from the platform to the evidence yard, evidence analysis, root cause analysis, and interface with the regulators.
Failure of a Cable During Incident Recovery		During subsea recovery of components from a prior investigation, a cable snapped. The resulting whiplash damaged equipment, but no personnel injuries. ABS Group’s role included metallurgical analysis and RCA.
Flexible riser failure		A multi-layer flexible line failed as it was being deployed. The line slippage and failure resulted in a fire that severely damaged the deployment tensioner. ABS Group assisted with gathering field data and the root cause analysis.
Material incompatibility in subsea equipment		Investigation of a material incompatibility in undersea drilling equipment. The material selection issues arose when applicable standards changed during the design phase of subsea equipment. The update to the standard was not applied to equipment in the design process at the time of the update.
Periodic Review of World-wide Incidents		ABS Group provided incident investigation expertise to a team of client personnel performing quarterly reviews of all incidents occurring worldwide. The project involved a high-level review of all incidents and detailed inquiry into risk-significant issues. A quarterly report was produced by the working group.
Riser Chain Failure		A chain on a freestanding riser failed before the riser was placed into operation. The investigation involved design, operation, and manufacturing issues. A manufacturing issue was identified as the primary cause of the failure.
Riser Failure		While operating in about 7,000’ of water, the riser catastrophically failed and the majority fell to the sea floor. The investigation involved assessment of the original design of the riser, manufacturing operations, operational practices, and environmental conditions.
Riser Subsidence Failure		During cementing activities, failures to apply the proper tension to the riser resulted in the riser sinking into the sea floor. ABS Group performed root cause analysis services.
Riser Tensioner Cable Failures	Multiple failures of riser tensioner cables led to damage to the tensioning system and a personnel safety near miss.	

Table 1: Selected ABS Group Incident Investigations

Title	Industry Type	Brief Description
Slip Joint Failure	Exploration & Production - Offshore	Failure of a slip joint during retrieval of the lower marine riser package. The failure resulted in extended downtime.
Contaminated tensioning system		The customer experienced a significant delay in deploying a rig from the yard when the drill string tensioner was found to be damaged from contamination. The investigation involved identifying likely sources of the contamination and underlying causes of the incident.
Processing facility explosion		A skid-mounted gas-processing unit exploded during operations. A non-class 1, division 1 light had been introduced into the enclosure to provide heating. It ignited gas fumes that escaped from an idle pump.
Failure of a hot water heating boiler	Facility infrastructure	The rear wall of a boiler in an elementary school failed. Four potential scenarios were evaluated. Recommendations were made to address probable contributors to the event.
Failure of a bearing in a large compressor	Gas distribution	A large compressor for a natural gas pipeline repeatedly failed. The failure resulted in a large financial loss for the company. The causes were related to original design of the compressor and subsequent changes in the dimensions of the replacement components.
Oxygen Compressor Fails During Startup		Following an overhaul of an oxygen compressor, it failed during the “run-in” phase of restarting. After subsequent repair and under the supervision of a leading company expert, another failure occurred during startup 6 days later. Three piston skirts were damaged.
Fingerprint analysis chronic deviation analysis	Law enforcement	Performed an analysis of deviations that occur during fingerprinting analysis. The work involved developing a process flowchart and assessing deviations associated with the process.
Underlying causes of chronic issues with forensic analysis methodology		Conducted a root and cultural cause analysis that identified behavioral, organizational, cultural, group, social, and/or other similar factors that led or contributed to errors or misstatements related to a forensic analysis methodology. The SOURCE™ Methodology and Cultural Cause Analysis Methodology™ were used to analyze a vast amount of historical information gathered from interviews and documents spanning decades. The analysis determined the underlying factors to explain how and why the errors occurred and were repeated over time.
Fire/explosion at an LNG facility	LNG	The facility experienced a failure of a heat exchanger and subsequent fire. ABS Group controlled access to the incident scene, identified and collected evidence from the incident scene, and managed the storage and organization of the evidence yard.
Chronic manufacturing defects	Machining	Investigation of chronic manufacturing defects for a machine tooling facility.
Failure of a Grinding Wheel		While performing some machining operations, a grinding wheel catastrophically failed, resulting in a fatality. The investigation involved interfacing with the medical examiner on the causes of death and metallurgical analysis.
Crane Runs Off Rails and Cab Falls to Floor	Manufacturing	A bridge crane ran off the crane rails and the cab crashed to the floor. The crane operator was killed. Some mechanical issues, human errors, and human factors issues contribute to the incident.
Effectiveness of the Management of Change Process		An investigation into the underlying causes of repeated issues with a manufacturing organization’s management of change process. The assessment involved analysis of past incidents for MOC issues.
Failure of a Gas Receiver		While performing maintenance work, a nitrogen distribution receiver failed, resulting in two fatalities. The receiver was overpressurized by a compressor, resulting in the failure of a tank weld.
Fatality During Maintenance Activities	Manufacturing	An individual was crushed and killed when caught in between a stationary and moving portion of a paper machine during maintenance activities.

Table 1: Selected ABS Group Incident Investigations

Title	Industry Type	Brief Description
Fire assessment and reconstruction/ retrofit design		ABS Group performed a post-fire structural assessment and developed reconstruction design for a heavily damaged industrial structure, after a fire destroyed the manufacturing line and severely damaged the building structure. ABS Group worked closely with the owner and insurance company representatives to develop scope for repairs, which was used in making the decision to replace rather than repair the damaged structure. Due to building code changes since original construction, ABS Group developed structural retrofit design of the original foundations for increased wind loads.
Fire in an electrostatic precipitator		A fire occurred in an electrostatic precipitator in a nylon fabrication facility. The fire resulted from electrical malfunctions and processing excursions.
Manufacturing Issue		A manufacturer experienced several fires in their production lines. Initially, the client identified over 300 potential causes of the fires. The ABS Group-led team used cause and effect tree analysis to quickly narrow this list to less than 15 potential causes. The investigation also identified several other manufacturing process improvements in addition to reducing the risk of process line fires.
Metal fabrication and process failures		An analysis was conducted to identify potential causes of chronic manufacturing problems with a complex stamped and welded component used in nuclear power facilities.
Source supplier qualification record issue		A manufacturer of nuclear power plant components identified problems with certification of source suppliers. The investigation involved identification of gaps and overlaps between the various divisions of the organization.
Allision with dock		While docking operations were in progress, the machinery plant control and monitoring system (MPCMS) became overloaded and crashed. Retrofit equipment introduced noise into the MPCMS data buffers, which resulted in the overload.
Bearing failure on a main diesel engine	Marine	Following maintenance, debris left in the oil system downstream of the filter entered the bearing inserts, resulting in engine damage. Use of new flushing procedures led to the failure.
Chronic failure analysis of reverse osmosis water purification system		The client was experiencing chronic failures of a shipboard reverse osmosis water purification system. ABS Group personnel served on a team that analyzed historical data to determine failure modes and potential corrective actions.
Crane hydraulic motor failure		Two deck cranes suffered catastrophic hydraulic motor failures. The installed configuration of the crane equipment was incorrect, leading the failure of the motors.
Crew suffers breathing issues from battery off-gassing		Excessive battery charging rate and decreased capacity of the engine room ventilation system resulted in several crewmembers seeking medical attention for respiratory issues from off gassing from the batteries.
Deck cracking		Use of decking susceptible to stress corrosion cracking led to some cracking of deck plates.
Diesel generator failure		A DG piston seized during extended low-load operation. Low load reduced liner lubrication, resulting in the failure.
EDG fuel pumps failed		Simultaneous failure of the EDG fuel pumps resulted in loss of all engines. Debris in fuel system resulted in subsequent failure of the fuel pumps.
Electronic navigation system fails	Marine	Incompatibility between the new electronic navigational system and some of the existing navigational equipment resulted in several “crashes” of the navigational system.

Table 1: Selected ABS Group Incident Investigations

Title	Industry Type	Brief Description
Errors in analysis of failure data		A review of chronic failure data revealed errors and omissions with the data input by some fleet vessels. The RCA recommended improvements in the documentation interface for inputting the data and procedural guidance for data input.
Exhaust lagging fire		Exhaust gas leaks burned lagging and melted air plenum controls resulting in return to the yard for repairs. Several causes were identified, including: design issues, inadequate yard repairs, insufficient oversight by the shipyard and ship personnel, and no ongoing inspection of portions of the engine space.
Failure of main drive engine during break in period		MDE failures were observed during the break-in period following overhaul work. The hot flush procedure deposited debris downstream of the filtration equipment providing an unrestricted path into the bearing inserts.
Fuel tank corrosion		Microbial infestation resulted in excessive corrosion of the fuel tanks in several vessels of similar design. Numerous issues were identified by the investigation including removal of the tank primer during construction, contamination of the fuel used, and lack of detection capabilities on board the vessels.
Gearbox casualty		The failure of the outboard idler gear forward spud shaft bearing in the main drive engine auxiliary drive gear caused the MDE to become disabled. A low load profile lead to high torque on the component, beyond the system design requirements.
Hole in hull within 6 months of leaving builder yard		A through hole was identified in the hull of a 400' vessel that had left the builder yard just 6 months earlier. The impressed current cathodic protection system had not been used during that period.
Hull coating failure		Failure to follow manufacturer's recommendations for application of hull coatings led to premature failure of the hull coating.
Main drive engine failed on startup		The MDE failed on startup after the crew failed to pre-lube the engine. A combination of several equipment failures and the failure of the crew to confirm oil flow resulted in no pre-lube oil flow to the engine on startup. The investigation recommended several changes to hardware, including improved indications of lube oil flow.
Main drive engine mounts fail		The fasteners securing the main drive engine thrust bearing failed as a result of fatigue. Several bolts were found to have been installed in the wrong locations.
Marine accident investigation		Incident investigation support for a shipping incident. Work included cause analysis and recommendation development.
Oil spill		Investigated possible causes of an oil spill that occurred near the Port of Iquique.
Operator Crushed by Crane Arm		An operator preparing for unloading of a barge was crushed and fatally injured when he was caught between the crane boom and a fixed object. ABS Group provided RCA services.
Overhaul work not completed in a timely manner		Overhaul work delayed departure of a vessel after several issues related to fuel pump and other fuel system issues. Vendor selection processes were identified as an underlying issue.
Power assist steering device locked up		During extended high-speed maneuvers, the power assist steering mechanism locked up. An incompatible material selection for a hydraulic seal resulted in leakage from the system.
Premature failure of reverse osmosis membranes		Premature failure of the RO system membranes led to loss of potable water on board several vessels in the fleet. Maintenance work was performed incorrectly by crew personnel. Training was not provided to crews as part of the installation of the new systems on the vessels.
Premature failure of turbocharger blades	Marine	Extended operation at low loads led to poor performance of the water separator. Moisture impact on the turbocharger blades resulted in erosion of several TG blades.

Table 1: Selected ABS Group Incident Investigations

Title	Industry Type	Brief Description
Propeller inspection leads to dry docking of vessel		Initial inspection of an icebreaker’s propellers led to dry docking the vessel for repairs. After drydocking, additional analyses concluded the repairs could have been done outside the dry dock. The team developed additional guidance on dry-docking criteria.
Propeller shaft seal failure		Propeller shaft seal leakage occurred following operations in high sea state. The rescue vessel was operated beyond design limits on one of its missions, leading to overall hull damage and shaft seal leakage.
Reduction gear wear		Errors during construction of the vessel (reduction gear contact patch not set up) lead to excessive wear. The error was not detected during initial construction or by the inspector.
Replacement EDG failure		Following a catastrophic failure of an EDG, the replacement engine was damaged when it was operated in an overspeed/overload condition for several minutes. Equipment intended to prevent this condition (overspeed sensor and governor) were improperly configured during installation and these issues were not detected by inspections performed as part of installation.
Spill into harbor at dock facility		An unloading line failed during operations resulting in a spill into a harbor. ABS Group assisted the client with root cause analysis services.
Vessel construction over budget and failed to meet schedule		A vessel left the construction yard late, over budget, and still had several items to resolve after departure from the yard. Several new technology issues were identified, but project management and construction execution were the primary issues.
Emergency diesel generator failure due to debris		A connection rod bearing failed on an EDG, resulting in catastrophic engine failure. The crew failed to prevent debris ingress into the lube oil system and then failed to secure the engine and investigate the source of abnormal noise from the engine.
Analysis of chronic near miss incidents	Mining	Review and analysis of the Investigation of 30 high potential incidents (high potential for fatalities for company and contractor personnel). Work included cause analysis and recommendation development.
Analysis of fatal incidents across the organization		Review and analysis of fatalities between 2009 and 2014. Work included cause analysis and recommendation development.
Collapse of retaining wall		A retaining wall collapsed. The underlying causes were permanent use of a temporary structure, lack of appropriate maintenance, changes in operations, and changes in the design of the wall over its life. Numerous changes were instituted to prevent future failures.
Fatality investigation		Accident investigation of a fatality at a copper/gold mine using ICAM investigation methodology
Fatality investigation		Fatal accident investigation at a copper/gold/molybdenum mine using ICAM investigation methodology
Fatality investigation		Accident investigation of a fatality at a copper/gold mine using ICAM investigation methodology
Review of high potential investigations		Reviewed and analyzed six high-potential accident investigations (potential for company and contractor fatalities).
Spill at a dock facility		Investigation of a spill at the concentrate dock
Vehicle accident near miss		Incident investigation support for high-potential incident involving a crash between a bulldozer and truck. Work included cause analysis and recommendation development.
Vehicle accident with multiple fatalities		Investigation of a truck accident involving multiple fatalities at a mining site. Work included cause analysis and recommendation development.
Waste water disposal release	Mining	Investigation of an incident at the waste water disposal facility

Table 1: Selected ABS Group Incident Investigations

Title	Industry Type	Brief Description
Failure of a large compressor bearing	Natural gas distribution	A large natural gas compressor failed during operation. Two failures occurred in a six-month period. The investigation examined both failures to determine common causes and issues with recovery from the first failure.
CAPA program ineffectiveness issues	Nuclear fuel manufacturing	Investigation of the effectiveness of the corrective and preventive actions (CAPA) program.
PLC-controlled system failure		Investigation of a PLC-controlled system failure. A PLC-controlled drum processing system had malfunctioned several times over a 2-week period. The investigation focused on determining the conditions under which the malfunctions occurred.
QA-1 supplier provides defective components		Investigation of component defects from a QA-1 supplier. A supplier that had gone through the supplier qualification process had provided defective parts on numerous occasions.
Qualified suppliers list errors		Investigation of processes used for qualifying suppliers.
Safety-related interlock failures		Investigation of indication errors in safety-related interlock systems. Calibration errors led to incorrect readings from a safety-related interlock designed to prevent criticality.
KT analysis of a cracked reactor coolant pump shaft	Nuclear power	Kepner-Tregoe (KT) analysis of a cracked reactor coolant pump shaft. The customer required the use of the KT method to perform the analysis. The cracking was the result of manufacturing defects in the 11” diameter shaft.
Errors in documentation result in inappropriate waste shipments	Nuclear waste	Investigation of computer programming issues leading to shipping errors for nuclear waste containers.
Malfunction of a computer control system		Investigation of a computer control system malfunction. Coding errors led to processing errors and manufacturing of defective components.
Multiple chlorine releases	Paper production	Multiple releases of the chlorine occurred from the generation and use of chlorine dioxide in the facility. ABS Group guided a team of mill personnel through the investigation process and assisted with communication of the investigation results to site personnel.
Piping rupture and spill		Incident investigation of pulp discharge from a digester at a paper mill. Work included cause analysis and recommendation development.
Toxic gas release from a sewer system		Investigation of a toxic gas release from a sewer system at a paper mill. An unanticipated combination of materials in a sewer system resulted in the generation of toxic gases. The release of the gases resulted in a number of injuries and fatalities. The investigation focused on determining the process conditions that led to the release and the facility’s response to the incident.
Coke Furnace Explosion	Petrochemical	A coke furnace exploded during startup of the furnace.
Computer control system failure		Following a computer system modification, some of the control and display functions of the plant process computer were disabled. Although the operators were able to recover from the failure, the system sustained severe damage.
Exothermic reaction leads to explosion		Investigation of a vessel overpressurization from an exothermic reaction. The incident was the result of several management of change failures.
Explosion at a chemical facility		An operator was performing an unusual task that involved restarting a system. During the restart the materials rapidly decomposed, resulting in an explosion and several injuries. The investigation involved managing the collection and analysis of damaged equipment; interfacing with regulators, attorneys, and insurance companies; and explosion modeling.

Table 1: Selected ABS Group Incident Investigations

Title	Industry Type	Brief Description
Failure of the boiler feedwater pump	Petrochemical	A boiler feedwater pump failed catastrophically while in service. The pump remained intact, but leaks were noted at the seals just before the pump was shut down. The rotating internals of the pump were essentially destroyed, and the case itself suffered severe damage. There were no injuries.
Fire in a storage tank on recirculation		A tank on long-term recirculation detonated and resulted in the failure of the tank and a subsequent fire that destroyed a number of other tanks and caused a significant plant outage.
Fired heater malfunction		The control system for a fired heater malfunctioned that resulted in the continuous firing of the heater burner. Based on the indications available to them, the operators believed the burners were idle. By the time the operators were able to determine the heater burner was malfunctioning, the heaters tubes had been destroyed.
Flare tower failure		During a loss of cooling water incident, the flare tower developed a crack in the molecular seal area. The leak resulted in combustion taking place at lower elevations in the tower. The tower glowed red-hot; however, no further damage occurred to the facility.
Multiple confined space entry issues		Multiple issues had been experienced in short period. The incidents were examined to identify common issues and incident-specific issues.
Partial collapse of a flare tower		Investigation of the partial collapse of a flare tower. Excessive flow of ethylene to a flare tower combined with mechanical piping failures caused a partial collapse of the flare tower. Failures in maintenance activities and long-term corrosion of an inaccessible portion of the piping were the primary causes.
Repeated Incinerator Fires		Operational and design issues caused repeated near misses and an accident. The incinerator was completely destroyed as a result of the last event.
Vessel overpressurization		A reactor ruptured during operation. The reactor head was blown off, overhead piping was destroyed, and there was minor damage to the surrounding structures (e.g., cracked windows and walls). The reactor operator was shaken, but not injured. The entire plant was shut down pending investigation of the incident and repair of the damage.
Vessel overpressurization from runaway exothermic reaction		A temperature and pressure excursion occurred in a reactor while running a batch of a specialized chemical. The pressure rise caused the three rupture disks on the reactor to activate, releasing the reactor contents through their associated risers. The flow of material through two of the risers generated forces that exceeded the risers' design capacity and caused them to collapse. The collapse of the two risers damaged adjacent piping and the wall of an adjacent building.
Fire in a bag house	Pharmaceuticals	Materials that accumulated in a bag house ignited. The resulting fire destroyed the internals of the bag house and all the associated instruments.
Fire in a warehouse		A fire started in materials that were in long-term storage in a warehouse. The materials were of the wrong type and were not supposed to be stored in this configuration. The fire started because of overheating of the materials from a chemical reaction.
Natural Gas Pipeline Explosion	Pipeline	A gas pipeline failed resulting in an explosion. ABS Group performed explosion analysis to support examination of potential causal factors.
Pipeline Failure and Leak		A pipeline failed because of corrosion issues. The leak released over 20,000 barrels of crude into the soil before the leak was detected. ABS Group led the root cause analysis efforts.
Waste Pipeline Failure		A large (>30") waste pipeline failed during initial commissioning. The ABS Group-led investigation identified issues related to the design of the PVC line and the commissioning processes used.
Welder injured when pipe fell off welding stands		A welder was performing a welding operation on a pipeline when the pipe rolled off the pipe stands and crushed the worker. Equipment and operational issues were identified as causes.

Table 1: Selected ABS Group Incident Investigations

Title	Industry Type	Brief Description
Explosion at a paper mill	Pulp and paper	A decanter control system failed, resulting in carryover of flammable materials into a high-temperature vessel and an explosion of the accumulated material. Participated as a team member.
Asphalt Unloading Operations Burn	Refining	Transport driver was burned by hot asphalt during unloading operations.
DCS Blackout		The operator interface terminals failed for about 45 minutes (the automatic features remained enabled). The cause could not be definitively determined. Better monitoring methods were instituted to diagnose subsequent failures, along with enhanced recovery methods.
Environmental releases from an oil refinery		Investigation of two environmental releases at an oil refinery. Two environmental releases occurred at a refinery. Both occurred during startup of the unit. The releases caused community concerns and resulted in significant equipment damage. The repairs required shutdown of the unit for about a week. The investigation focused on the process issues that led to the releases.
Explosion and fire at a refinery		A heat exchanger failed while performing startup of the unit. The investigation focused on metallurgical analysis of the failed component. ABS Group also provided blast modeling services, onsite regulatory interface support, and incident scene control.
Explosion at a refinery		Multiple line failures lead to several explosions in a refinery. The investigation involved blast modeling, metallurgical analyses, as well as, organizational system failure analysis.
Explosion in a Refinery		A failure of a vessel outlet line resulted in an explosion and damage to several units. This investigation involved causal analysis, metallurgical analysis, and explosion modeling. ABS Group performed evidence collection, root cause analysis, fire and explosion modeling, coordinated laboratory analyses, and interfaced with several regulatory agencies during the investigation.
Fire/explosion of a coker drum at a refinery		The refinery experienced an explosion and brief subsequent fire of a Coker drum. ABS Group modeled the explosion, identified causal factors, identified root causes, and provided recommendations.
Fire/explosion of a tank in the viscosity reduction plant at a refinery		The refinery experienced an explosion and subsequent fire in the viscosity reduction plant. ABS Group identified and collected evidence from the incident scene, oversight of laboratory analysis of tank samples, oversight of tank thickness testing, modeled the explosion and fire, identified causal factors, identified root causes and provided recommendations.
Furnace explosion during startup		During startup of a gas-fired furnace, the furnace exploded resulting in a fatal injury to one of the operators. ABS Group performed evidence collection, root cause analysis, fire and explosion modeling, coordinated laboratory analyses, and interfaced with regulatory agencies and legal counsel during the investigation.
Hydrogen Compressor Failure		Catastrophic failure of a large hydrogen compressor and subsequent fire. Equipment damage and downtime losses exceeded \$500 million. ABS Group led the investigation team.
Line failure	A common line on the unit's coking units failed. Design and operational issues (temperature transients) were the underlying causes of the failure.	
Loss of power to a refinery	As a result of relay system failures, the site lost all offsite and onsite power. ABS Group led the root cause analysis effort.	
Refinery explosion	An explosion in a refinery resulted in a number of fatalities. ABS Group's role was in support of structural analysis and process safety expertise.	
Refinery explosion	An explosion in a refinery resulted in an extensive outage for the facility. The investigation involved detailed metallurgical analysis of the failed tower and analysis of corrosion and thinning mechanisms.	

Table 1: Selected ABS Group Incident Investigations

Title	Industry Type	Brief Description
Two environmental releases	Refining	Two environmental releases occurred from a refinery. Both occurred during the startup of the unit. The releases caused community concerns and caused significant equipment damage. The repairs required the shutdown of the unit for about a week.
Explosion of a waste tank during process commissioning	Semiconductors	During the commissioning of a new process, an explosion occurred in a waste tank. The ABS Group lead investigation identified design issues, procedure problems, and training issues.
Incomplete certification paperwork for nuclear waste	Shipping	In preparation for releasing a shipment, the site noted that the certification paperwork for some of the drums was not complete. The investigation focused on the processing of the data that is used to generate the large certification packages that accompany each shipment.
Electrical arcing in a boiler system	U. S. Department of Energy facilities	The control cabinet for an electrically heated boiler experienced two failures. The investigation examined both failures to determine the relationship between the two events. Repairs made following the first event, along with modifications made to a boiler control panel to enhance personnel safety during online maintenance, were found to be the causes of the second event.
Explosion in a drum during waste processing activities		During the processing of a legacy waste drum, the drum was intentionally punctured. As the drum was punctured, the drum exploded. The investigation involved consultation with explosion experts to determine the mechanism that caused the explosion.
Glovebox explosion		Investigation of a glovebox explosion at a DOE facility. An explosion occurred in a glovebox that was part of a developmental project. The explosion damaged the glovebox and required extended evacuation of the facility. Failures in the management of change process during scale-up of the process resulted in the explosion.
Undesirable chemical reaction		Investigation of an undesirable chemical reaction at a DOE facility. Maintenance activities resulted in an undesirable chemical reaction that damaged equipment and facilities. Changes in the work environment led to a situation that maintenance personnel were not expecting.
Worker's clothes ignited during grinding activities		An individual was assigned to an activity that required an extended period of grinding. As the individual became fatigued, he changed positions such that his thigh was in close proximity to the sparks generated by the grinding wheel. The sparks eventually ignited his clothing. The worker was not wearing the appropriate flame-retardant clothing.
Steam Explosion in Underground Utility System	Utilities	A steam explosion in an underground steam line lead to damage to multiple utilities, damage to the street above, and an extended loss of service to customers.

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Table 2: Partial Listing of Organizations that Have Selected ABS Group Investigation and Root Cause Analyses Training

3M Corporation	Firmenich	Phillips 66
AED, Inc.	Flint Group	Phillip Morris
Air Liquide	FMC Corporation	Phillips Lighting
Alberto-Culver	FM Global	Procter & Gamble
Albermarle	Galliano Tugs	Potlatch
Alco Chemical	General Dynamics	Praxair
Allied-Signal	General Physics	Reilly Industries
Altura Energy	Georgia-Pacific	Rochester Gas & Electric
AMD	Goodyear	Rolls-Royce
Amgen	GSK	Rowan Companies
American Midstream	Gulfstream	SABIC
Arclin	Hartford Steam Boiler	SAFCO
Anderson Consulting	Helix Energy Solutions	SASOL
Ashland	Henkel	Sandia National Laboratory
Baxter Healthcare	Hess	Saudi Aramco
Bobcat	Hewlett-Packard	S. C. Johnson
Boeing	Hexcel	Schlumberger
BP Refining	Hoechst Celanese	Seacor Ocean Transport
BP E&P	Honeywell	Shell Oil
Ashland Chemical	Hovensa	SNF
Ashland Petroleum	ICI Explosives	Springdale Ice Cream
Azerbaijan Intern'l Op. Co.	IPR Pharmaceuticals	Stepan Co.
BASF	IPSL	Stone Consolidated
BNFL	ISK Biosciences	Sud Chemie
Bechtel	ISP	Suncor
Boeing	John Deere	Syngenta Crop Protection
Boise Cascade	Johns Manville	Syncrude Canada
Boston Edison	KNPC	Targa Resources
California ISO	Korea Gas Safety Company	Total Petroleum
Canadian Natural Resources	Lion Oil	Tropicana Products
Cargill	Lockheed Martin	TVA
Carnival Cruise Lines	Los Alamos National Lab	UNOCAL Corporation
CF Industries	Louisville Met. Sewer Dist.	UOP
CLP Power	Maersk	United Pacific PLG
CIBA-GEIGY	Maritrans	URS
Celanese Canada	Marathon Oil	U.S. Air Force
Chevron R & P	Methodist Hospital	U.S. Army
Chevron-Phillips Chemical	Merck	U.S. Army Chemical Demilitarization Program
Chubb	MOL Group	U.S. Chemical Safety Board
Clariant	Motorola	U.S. Coast Guard
Clearon	Murphy E&P	U.S. Customs and Border Patrol
Colgate Palmolive	MWV (Mead Westvaco)	U.S. Department of Energy
Columbia Pipeline	National Grid	U.S. Department of Trans.
Columbia Ship Management	NiSource	U.S. EPA
Contra Costa County Health Service	Northstar Steel	U.S. Marine Corps
Cook Composites & Polymers	Nova Chemicals	U.S. Military Sealift Command
Cytec Industries	National Starch & Chemical	U.S. Navy
Dakota Gasification	Newport News Shipbuilding	U.S. NIST
Diamond Offshore	Northern Natural Gas	U.S. NTSB
Dole Fresh Vegetables	Norwegian Cruise Lines	U.S. NRC
Domino Sugar	Nutrasweet Company	U.S. NASA
Dow Corning	Oak Ridge National Lab	U.S. Steel
DowDuPont	Olin Chemicals	Valero Refining
Duke Energy	Ontario Ministry of Natural Resources	Vantage Drilling
Eastman Chemical Company	Orion Refining	Vertellus
Edison Chouest Offshore	OSG Ship Management	Washington Group
Eli Lilly	PBF Energy	Westinghouse
Enterprise Products	Pemex	Weyerhaeuser
Ergon Refining	PepsiCo	Williams
Evonik	Petrobras	Wintershall
Exponent	Petrojam	Zurich NA Insurance
Exxon	Pfizer	
FairfieldNodal	PG&E	