

# CHEMICAL PROCESSING

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## Intrinsic Safety Special Report

# Improve Plant Safety

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# Safeguard Plant Safety

The worst thing that can happen at your plant is that an employee suffers a serious injury from a preventable accident. Follow some proven maintenance pointers to keep operations safe.

By Joe Kaulfersch, Pepperl+Fuchs

**THERE IS** no substitute for proper maintenance in plants posing a danger of fire or explosion — both safety and efficiency demand it. While many guidelines for safety maintenance exist, years of experience have helped us develop some rules that we believe are essential for keeping a plant, its personnel and the surrounding community out of harm’s way. These are not meant to replace applicable industrial safety standards, but to provide general guidance. They cover three key aspects: initial inspection, programmed maintenance and apparatus failure and repair.

## INITIAL INSPECTION

It is impossible to overemphasize the importance of a comprehensive initial inspection. Safety procedures and effective preventive measures begin before your plant starts production. Prior to startup or modification of a plant with hazardous locations, ensure that qualified personnel perform a thorough inspection. The inspection should include documentation that verifies the capabilities of the plant, all field elements, all associated apparatus and the agreement between safety parameters and interconnected apparatus (Figure 1).

*Plant capability.* In verifying plant capability, ensure that protection methods are compatible with



the hazardous locations and gas groups present and that the technical rules of each protection method are followed. Make certain that all components and electrical lines in a hazardous location are explosion-proof, with continuity up to the exit point of the hazardous location, or are protected with properly installed authorized methods. This means that apparatus are correctly anchored and do not exert force on the connecting pipes, causing cracks or deformation; locking joints conform to standard and are properly tightened

Figure 1. An initial inspection should verify safety barriers, wiring correctness and other conformance issues.



and sealed; conductors leading into the junction boxes are firmly anchored with no risk of abrasion or cuts; there is no condensation forming or accumulating; the explosion-proof enclosures have a reliable external ground connection; any mixed protection methods are authorized for the specific type of hazardous location; and there is adequate space to easily remove the lid during maintenance.

For intrinsically safe installations, verify that: all electrical conductors conform to the installation standard; intrinsically safe circuit conductors are not mixed with nonintrinsically safe ones; conductors of different types of intrinsically safe circuits are properly separated and isolated from each other; diode safety barriers have an isopotential system with plant grounds conforming to the applicable standard; non-hazardous-location apparatus directly powered with voltages larger than 250 V are not present, unless protected and certified for that use; shields of conductors associated with diode safety barriers are connected to the isopotential ground; reciprocal and toward-ground isolation of all intrinsically safe circuits conform to the standard; markings specifying different measuring or regulation loops are clear; barrier input terminals are not confused with the output terminals; and installation conforms to the manufacturer's control drawing.

*Capability of field elements.* Managers, supervisors and other pertinent personnel must confirm that all apparatus installed in hazardous locations are free from risk of fire or explosion by verifying that the devices are connected with simple devices ( $V_{max} \leq .2$  V;  $I_{max} \leq 0.1$  A;  $P_{max} \leq 25$  mW;  $E_{max} \leq 25$   $\mu$ J) or covered by an authorized protection method for the specific installation zone. The method must be compatible with the gas groups and temperature class.

In the case of explosion-proof apparatus, verify that: all apparatus are installed in Division 2, or Division 1 with certain restrictions; certification is compatible with the gas group and surface temperature class of the flammable mixture present; explosion-

proof points are not damaged; all openings toward the outside of the enclosure are used or properly sealed with explosion-proof caps; all removable lids are integral, closed and tight; all threaded junctions are integral and protected against corrosion; each enclosure has an efficient, properly tightened external ground connection; and warnings stating that the power should be shut down before opening appear on the lids or the labels.

For intrinsically safe apparatus or simple electrical devices, verify that: Devices should be certified for their hazardous location and the gas groups corresponding to the flammable mixtures present. They should have a surface temperature classification compatible with the flammable mixture present (e.g., T6). Apparatus should be connected exclusively to intrinsically safe circuits, as specified by the certification documents, especially for the eventual connection to alarm safety apparatus, with connecting cables that adhere to their safety parameters. Units are powered or interconnected with associated apparatus having safety parameters compatible with the apparatus and the proper protection method. They have a grounded enclosure (or no risk of electrostatic discharge) and are installed with proper environmental protection. They do not have points of the circuit grounded or poorly isolated toward ground (only if connected with diode safety barriers without galvanic isolation) with the exception of the equipotential ground connection on the barrier. The eventual loosening of cable clamps or conductor input joints will not jeopardize the tightness of the enclosure against water and corrosive atmospheric elements.

*Capability of all associated apparatus.* This also must be carefully checked. Verify: The devices are installed exclusively in a protected nonhazardous location, unless other protection methods suitable for the hazardous location are used. The certification type is compatible with the intrinsically safe circuit to which they are connected, according to the hazardous

location and the gas group. The apparatus have safety parameters appropriate for the connection cable and other connected intrinsically safe apparatus. Separation and identification of the intrinsically safe circuit exists along the entire connection route, as required by the standards. The devices have correctly rated and installed internal fuses and an external protection device (i.e., isolator breaker) is present on the main power line.

*Agreement between the safety parameters and the associated apparatus.* Keep in mind that any apparatus certified as safe can actually become unsafe if used with other apparatus, even if these apparatus also are certified as safe. It is essential to ensure that the integrity of the devices is not compromised when working with connections. Don't let a false sense of security prevent you from checking all circuits and connections to every device. Be sure to study the schematic drawing thoroughly. Always use the interconnected apparatus documentation to verify that all connections are specified and permitted by the certification and that parameters derived by the interconnection remain compatible with values that are characteristic of the cable and the connected field elements.

#### PROGRAMMED MAINTENANCE

A program of regular inspection and repair is an extremely valuable tool. It prevents waste, downtime and the deterioration of apparatus. It should include records noting the maintenance performed, the date and the results.

*Explosion-proof apparatus.* In conducting periodic inspections of explosion-proof apparatus, it's essential to verify that all explosion-proof lids are tightened, there are no signs of deformation, cracks or corrosion in the flanged joint, tightening lid thread and pipe union, the enclosure's external grounding terminals are tightened, and the grounding conductor is integral as well as guarantees a good ground connection (Figure 2).

Keep in mind that you cannot test your apparatus without power. Therefore, take steps to eliminate the presence of flammable mixtures (determined by on-site testing with an explosion meter) before performing the calibration with the power on. During subsequent operations, continuously use the meter to verify the absence of flammable mixtures. Connect



Figure 2. Checking the tightness of lids and terminals and for corrosion and deformation is essential.

the calibration instrument to the input/output connection according to apparatus instructions. Verify the absence of flammable mixtures with the explosion meter and restore the power. Check the calibration per manufacturer's instructions and adjust if necessary. Reconnect the original connections. Close the lid and verify its tightness.

*Intrinsically safe apparatus.* Periodic inspections for intrinsically safe apparatus can be performed without a plant shutdown. However, to avoid situations of real or potential danger, ensure that:

- Instruments or verification connections do not cross the protection resistors of the barriers.
- Ground connections are not interrupted while intrinsically safe circuits are powered or are connected to other powered circuits.
- Apparatus used for the test are certified and suitable to operate in a hazardous location with explosive mixtures present and do not introduce dangerous voltages or currents in the circuit.

When possible, remove your apparatus from the plant to verify and safely test them in a nonhazardous location. Plug-in type connectors simplify this. The maintenance procedure in a hazardous location should be limited to disconnection and removal of apparatus and part of the connections, calibration adjustment of the apparatus, the use of permitted and specified test apparatus and other permitted or specified maintenance activities.

Although it may appear that there is less danger

when inspecting or repairing apparatus in a nonhazardous location, this is not necessarily true. Indeed, a more dangerous situation could develop — yet, often less care is taken as a result of the nonhazardous classification. A faulty process in a nonhazardous location can generate an explosion in a hazardous location through an interconnected circuit.

For circuits protected by diode safety barriers, verify that: each ground conductor barrier is properly tightened and maintains a total resistance up to the isopotential ground point  $\leq 1$  ohm; safety circuits (measured by nonrepetitive samples) are isolated from other ground points, and the isopotential point to which they are connected is according to the standard; and the separating distances of safety terminal blocks and conductors are respected.

For circuits protected by galvanic isolation barriers, verify that the separating distances of safety terminal blocks and conductors satisfy requirements (Figure 3).

With intrinsically safe circuits, maintenance activities are performed with the power (usually 28 V maximum voltage) on. However, when there are circuits protected by barriers, those barriers could be permanently short-circuited. This could cause a fuse to blow, rendering the barrier useless. So, always ensure that the barriers are not short-circuited and all apparatus are safely connected and have no improper contacts. When possible, remove the apparatus (particularly easy with plug-in type connectors) and check them in a lab. When it is impossible to remove the apparatus, disconnect input/output conductors and, after identifying them, connect them temporarily to the isopotential ground, or, if already grounded, keep them isolated and anchored to the free terminals of a supporting terminal block. Then connect a calibrator to the input and a calibration indicator to the output. Both must be certified for the division and gas group in which they are used. After completing verifications and calibrations, restore input and output conductors with extreme care.

#### APPARATUS FAILURE AND REPAIR

Decreasing downtime for repairs is key to reducing maintenance costs (see CP, October, p. 25). Smart planning during design — such as selecting modular and plug-in type field and control-

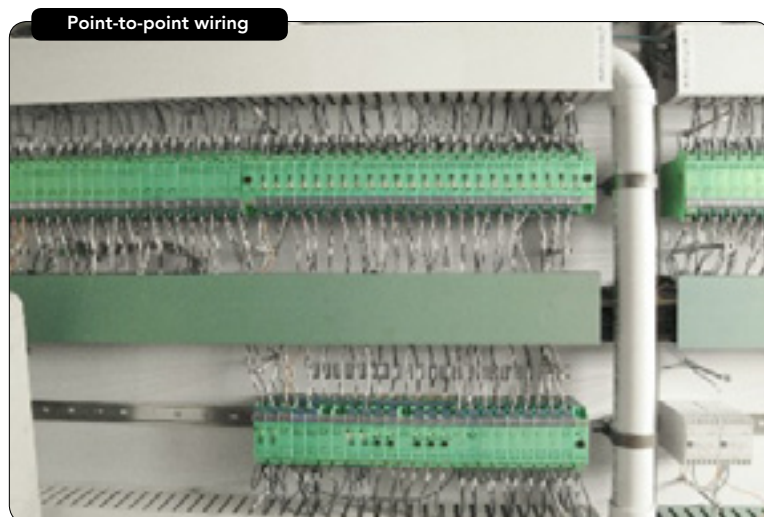


Figure 3. Point-to-point galvanic isolators simplify system design and installation in hazardous location applications.

room instrumentation and ensuring adequate spare parts to permit immediate substitution — will help to reduce your downtime and make repairs easier.

*Repairing explosion-proof apparatus.* When operating problems or machine failure involve explosion-proof plants, it's vital to determine as soon as possible the cause of the problem, identify and isolate the problem area and substitute or repair malfunctioning components. Always keep in mind that only authorized personnel must be permitted to repair explosion-proof apparatus, because equipment must not be serviced under power.

Even though diagnosing explosion-proof plants involves the same procedures used elsewhere, there is *always* danger of fire or explosion. Therefore, keep these points in mind:

- Do not perform connections not shown in the plant's schematic, unless the risks relative to safety have been analyzed.
- Only use test instruments certified for the same hazardous location and gas group as the circuits to be analyzed.
- Isolate the part of the plant where repairs must be performed. Consider the effect of the tests on interconnected circuits.
- Most importantly, do not cross or eliminate the safety protections that are present in the safety barriers and in other parts of the plant.



*Repairing intrinsically safe apparatus.* Working on intrinsically safe apparatus does not have to compromise the characteristics of intrinsic safety. The most frequent ways to ensure that apparatus are intrinsically safe are:

1. surface distances between the main line and the intrinsically safe circuit, and between two different types of intrinsically safe circuits;
2. protective coatings that increase the insulations to more than those obtainable with distances only;
3. protective fuses on main and signal transformers, and output circuit barriers;
4. signal and main transformers with dielectric rigidity that has been individually tested, and with distances and insulating or isolating materials that are guaranteed;
5. barrier resistors with construction techniques, nominal powers, values and tolerance as per the certification documentation;
6. diode or zener barriers with nominal voltage, tolerance, nominal power and assembly polarity well-defined;
7. optoelectronic coupler that is certified as a component having surface and internal distances and approved construction techniques;
8. electromagnetic relays that are certified with guaranteed surface distances between the coil circuits and the contacts or terminals for armor ground connections; and
9. functional modules, encapsulated or not, that are certified as components that are compatible with the concept of intrinsic safety.

There are some additional points to remember if an intrinsically safe apparatus must be repaired in an emergency situation. Do not modify air and surface distances of the barriers and their components. Do not substitute any component that determines its intrinsic safety (usually marked with shading on the silk screen of the printed circuit

boards and on the schematics). Only replace fuses with identical ones (rapid, medium lag, etc.) and nominal current. Do not substitute main or signal transformers, or certified modules unless with identical components supplied by the manufacturer of the apparatus. Take care in reciprocal positioning of the components and in repositioning eventual isolators or spacing collars placed on component terminals to distance them from the printed circuit board. Carefully verify the repaired card or component, to ensure the complete efficiency of all intrinsically safe protection. If soldered, make sure to accurately clean the printed circuit board and restore protective coatings.

It is often difficult for every manufacturer to supply all of the documentation necessary to perform repairs on intrinsically safe apparatus. The safer and sometimes less costly solution is to keep a series of spare cards or modules that permit an immediate substitution of the faulty unit. The defective unit can then be sent to the authorized service dealer where it can be repaired.

#### **ROUNDING OUT THE PROGRAM**

In addition to the previous maintenance criteria, always adhere to established safety practices — e.g., tell the control room operators when you are working in an area and follow lockout procedures without fail. Safety meetings, held on a regular basis, offer an opportunity to discuss various scenarios and ensure that all personnel are familiar with the correct procedures for each specific hazardous area within your plant.

Implementing effective preventive measures and training staff and operators to work safely while developing the capability to handle emergency situations is the key to continuous safe operations.

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# Don't Zone Out On Area Classifications

Electrical ratings must start with analysis of chemicals present.

By Dirk Willard, Contributing Editor

**A FIRE** erupted on May 4, 2009, at the Veolia ES Technical Solutions Hazardous Waste Facility in West Carrollton, Ohio, injuring two workers. The U. S. Chemical Safety Board suggested that poor zone classification might have contributed to the incident.

The mission of Electrical Area Classification (EAC) is to prevent a leak from leading to something far worse. However, a hazard classification has consequences beyond safety -- it can complicate efforts to fully utilize expensive plant real estate.

EAC is an arcane science. As an "expert" in EAC, let me attempt to make it less mysterious.

The first step in classifying a zone is to identify the chemistry there. Are you dealing with dust, flammable or combustible liquid, flammable gas or something harmless? If material balance information isn't available, use Material Safety Data Sheets (MSDSs) to define chemicals in the area.

The National Fire Protection Association (NFPA) provides several references to explain EAC: NFPA-30, "Flammable and Combustible Liquid Code;" NFPA-499, "Recommended Practice for the Classification of Combustible Dusts and of Hazardous Locations for Electrical Installations;" and NFPA-497, "Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous Locations for Electrical Installations in Chemical Process Areas." In addition, the American Petroleum Institute (API) offers "Rec-

ommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2."

Another resource, the National Electric Code (NEC) Standard 500, divides hazards into three classes: Class I -- gases and liquids, Class II -- dusts, and Class III -- fibers. It further categorizes liquids from A to D in order of decreasing risk. In contrast, NFPA-30 Section 1.7 defines liquids in the following categories: Class I -- flammable liquids with flash point <100°F, Class II -- combustible liquids with flash point ≥100°F and <140°F, and Class III -- combustible liquids with flash point ≥140°F. The NEC-500, upon which NFPA-497 and API-500 are based, subdivides ignitable vapors and gases into groups: A -- acetylene; B -- 1,3 butadiene, ethylene oxide, propylene oxide and H<sub>2</sub>; C -- acetaldehyde, CO, ethylene and H<sub>2</sub>S; and D, the most common -- acetone, ethanol and other hydrocarbons.

Classifying dusts and fibers is more difficult. If a dust layer forms, is less than 1/32-in. thick after 24 hours and its surface color is discernable, an area can be unclassified. Accumulated dust is more dangerous than clouds; risk is greatest when conditions are dry -- as in winter.

Another means of identification for gases and vapors used by both NFPA and API is the relative density compared to air. Heavier-than-air vapors



## “Vapors are especially dangerous because they can evaporate and recondense.”

pose a greater risk because they hug the ground. Light or hot gases rise and disperse.

Vapors and gases aren't the same. In EAC work, a vapor is a gas that condenses at 100°F or less at ambient pressure. At these conditions, a gas has a compressibility factor,  $Z$ , of 1; a wet gas has a  $Z$  less than 1. Vapors are especially dangerous because they can evaporate and recondense somewhere they're likely to start a fire -- that's why butane, with a boiling point of 31°F, is so dangerous!

Determining whether a chemical is a hazard is the most difficult challenge in EAC work. Here're some general guidelines for classification: 1) only consider NFPA-30 Class I liquids -- Class II and Class III liquids don't produce enough vapor, unless heated; 2) treat a fire danger of at least 3 in an NFPA diamond (refer to NFPA-704) as Class I; 3) categorize mixtures with >30% H<sub>2</sub> by volume as Group B (API-500, 5.5.5) and mixtures with >25% H<sub>2</sub>S as Group C (API-500, 5.5.4) -- NFPA-497 Annex B provides a rule for estimating the NEC group for mixtures of vapors or gases but it doesn't work for H<sub>2</sub> and H<sub>2</sub>S; 4) when in doubt about the chemistry use the worst case in evaluating a hazard; and 5) if you can't measure

the molecular weight (MW) of a complex organic, you can get a good estimate for n-alkanes with MWs from 80 to 1,400 via the equation in "Select the Right Hydrocarbon Molecular Weight Correlation" by Donald Schneider of Stratus Engineering:  $MW = 3.3955 \times 10^{-15} T_{bf}^6 - 1.2416 \times 10^{-11} T_{bf}^5 + 1.8256 \times 10^{-8} T_{bf}^4 - 1.3234 \times 10^{-5} T_{bf}^3 + 5.2285 \times 10^{-3} T_{bf}^2 - 0.741692 T_{bf} + 116.19$ , where  $T_{bf}$  is the boiling point.

EAC is based on the auto-ignition temperature (AIT) -- the minimum temperature at which a combustible material will burst into flame without an external ignition source. AITs reported in MSDSs often aren't tested for the particular mixture but reflect testing of a pure compound. There are no mixing rules for the AIT, which severely handicaps studies. Use the following simplification if no other data are available: for compositions containing compounds with MW exceeding 50 use AIT = 280°C; for others, use 200°C.

In later columns, I'll discuss enclosures, preparation of EAC drawings, defining envelopes and remediation.

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## Survey the Sources of Electrical Risks

A walk-down helps determine the need for purged electrical boxes.

By Dirk Willard, Contributing Editor

**MY TEAM** was ready. We only had a week to define potential sources of hazards and complete a battery-limit Electrical Area Classification (EAC) drawing. We spent an hour walking down the unit. I completed the source spreadsheet in two hours. We reviewed the spreadsheet in another hour and then sent it to the designers. They finished the EAC drawing in two days. It took several months for us to become this proficient.

An EAC drawing is crucial for reducing the risk of electricity igniting flammable, even explosive, chemicals. As my last two columns have pointed out, the effort starts with defining chemical risk (“Don’t Zone Out On Area Classifications”), followed by selecting zones around sources (“Don’t Push the Envelope”). Here, I’ll describe how sources demarcate the areas requiring purged electrical boxes.

The walk-down team, at a minimum, should include a drawing designer, a unit operator and an engineer. Before venturing into the unit, collect current versions of plot plans, an elevation drawing if available, Process and Instrumentation Drawings (P&IDs), Process Flow Diagrams (PFDs), the equipment index, material safety data sheets and material balances.

The purpose of this battery-limit survey is to identify “clouds” based on the worst-case sources. The walk-down may identify layout errors such as

a source near a road or a walkway frequently used by operators.

Developing an uncluttered EAC drawing requires care in source selection. You want a point source posing the greatest risk defined by NFPA 497 and API 500. But it’s not as simple as picking a Group B chemical over a Group D one. There are other factors -- e.g., the auto-ignition temperature (AIT), which define electrical risk. The most common Group B chemical is hydrogen, which is lighter than air. Lighter-than-air (LTA) materials have a smaller envelope. And hydrogen has a higher AIT than all Group D compounds; pure hydrogen’s AIT is 1,040°F while, for example, naphtha’s is 450°F. When both B and D chemicals are present, as in a knockout drum, define points by choosing a nozzle at the bottom for B (LTA) and an upper one for D. Use normal conditions -- if B wouldn’t be at the drum bottom then, find a nozzle where it would appear.

Consider high risk factors such as temperature, quantity and pressure. Pick points based on the greatest risk: temperatures, e.g., within 30°F of flash point, sufficient to make a Class II or Class III compound a hazard (OSHA 1910.106(a)(18)(iii):Class II); flows greater than 500 gpm; and pressures exceeding 500 psig. It’s best to select a number of points within 50 ft of the battery limit or 100 ft for high-risk sources.



## “Consider high risk factors such as temperature, quantity and pressure.”

Other factors -- for example, tall (i.e., over 25 ft) or long vessels (including heat exchangers), distillation columns and reactors where composition varies, and banks of equipment -- can complicate selecting source points. With long or tall equipment choose a point every 50 ft for heavier-than-air (HTA) compounds and every 15 ft for LTA ones. For shorter vessels, use one nozzle near the battery limit. Pick an upper flange for an HTA compound and a low nozzle for an LTA one. For vessels with diameters larger than 50 ft, refer to API 500. You can consider a flange or nozzle as part of a vessel only if it's within 10 ft. To measure the height of stacks and nozzles, I suggest a clinometer (see “Strive for a Surveyor’s Eye”).

Source designations include: pumps -- measured from centerline or seal connection; compressors -- same as for pumps; control valves -- pipe centerline; condensers -- bottom of tubesheet or shell flange; vaporizers -- top

of tubesheet or shell flange; miscellaneous heat exchangers -- top for liquids, bottom for vapors; vessels containing liquids -- top-most flange; vessels containing liquids and vapors -- top-most flange and bottom flange; and vessels containing vapor -- bottom-most flange. Also, of course, account for furnaces, diked areas, etc.

Some surveys include flanges and manual valves but many restrict sources to automatic valves and control valves. The thought behind this is that staff will detect leaking manual valves.

After completing the walk-down, prepare the source table based on the points collected and eliminate any redundant ones. Then, run material balances to evaluate compositions. Review the source table at least twice before handing it over to the designers.

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# OSHA & NFPA Compliant

Keeping Your Plant Safe

**OVER THE** last few decades, industries in the US have been plagued by fires and explosions caused by the ignition of gases, vapors, mists or combustible dust.

In testimony in front of Congress in 2008, Assistant Secretary of Labor declared that OSHA intends to step up its enforcement and regulatory activities and issue citations and stiff fines to companies that fail to comply with standards 29 CFR 1910.22\1910.176 and 29 CFR 1910.307.

In March of 2008, OSHA reissued its Combustible Dust National Emphasis Program(NEP) issuing notices to approximately 30,000 companies nationwide that they will be targeted for inspections over the next few years. The following is a listing of just some of the citations that a company could receive under the OSHA Combustible Dust NEP

## 29CFR 1910.22 GENERAL HOUSEKEEPING CITATIONS

The general housekeeping standard requires that “all places of employment, passageways, storerooms, and service areas shall be kept clean and orderly and in a sanitary condition.” OSHA has stated that they will issue citations for the presence of combustible dust under this standard if dust accumulations exceed 1/32 inch deep, cover at least 5 % of a room’s total area, and are combustible. Dust accumulations on overhead beams, joists, on top and under equipment are included in the determination of the total dust coverage area.



## 29CFR 1910.307 ELECTRICAL SAFETY CITATIONS

The electrical safety standard requires that all electrical equipment, wiring methods, and installations of equipment in hazardous locations shall be intrinsically safe and or approved for use in the classified location. Class II hazardous locations are locations that are hazardous because of the presence combustible dust. There are two divisions of Class II hazardous locations. Division 1 locations are



areas where the combustible dust is suspended in air under normal operating conditions, or where mechanical failure or abnormal operation of machinery might cause ignition, or where combustible dusts are electrically conductive. Division 2 locations are areas where combustible dust is not suspended in air under normal operating conditions, but may be suspended as a result of malfunctioning handling or processing equipment. OSHA will issue a citation if electrical equipment in the area is not intrinsically safe or approved for Class II locations.

Companies who produce combustible gases, vapors, mists or dusts should take the necessary

precautions to avoid injury and damage to their employees and facilities as well as steer clear of OSHA citations.

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Additional information about METTLER TOLEDO can be found on the website [www.mt.com](http://www.mt.com).



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