CHAMPION AEROSPACE™

TECHNICAL SPOTLIGHT

Subject: Characterization and Benefits of High and Low Tension (Voltage) Ignition System Designs

Background Information

The voltage operation of an ignition system is set by the exciter design. The igniter varies in size and firing end design based on the selection of a high, mid or low tension system. Typically, low tension igniters use a ceramic, solid body semiconductor component in the firing end to support low voltage operation. Mid/High tension igniter designs must use an alumina or other high dielectric capable insulator in the firing end. Many ignition system manufacturers select high tension ignition to eliminate the need for semiconductor designs as they have no organic manufacturing capability for this specialized component and don't recognize the benefits associated with low tension ignition systems in the areas of performance, weight, reliability, cost and temperature capability. Champion manufactures all of its ceramics in house which provides the unique ability to recommend the appropriate ignition system architecture for each and every engine. In almost all cases **Champion recommends low tension** for new ignition system applications for the lowest cost of ownership, the lowest weight option, the highest ignition system operating temperature capability and other details discussed herein.

Ignition System Characterization

Low voltage or low-tension ignition systems are characterized by system voltages up to 8 kV, but are typically in the range of 3kV to 6kV. Mid-tension ignition systems are characterized by system voltages above 8kV but less than 12kV. Mid-tension systems are not recommended and this range should be considered as "no man's land" in today's ignition system design. High-Tension systems are characterized by system voltages greater than 12kV, but typically in the range of 18kV to 26kV.

The energy delivered by the exciter is the key variable when evaluating the life of an igniter or ignition system. For example, a 3kV system that delivers 2 joules of energy should have the same igniter erosion rate and ignition capability as an 18kV system that delivers 2 joules of energy if ground and center electrode materials are identical. This assumes the voltage provided by the exciter causes the igniter to spark the same number of sparks at the same tip conditions (temperature, pressure). It is the energy that displaces/consumes the metal of the electrodes during sparking, not the voltage. It is the sheer size (firing end diameter) and the ability to include high spark erosion resistant inserts (Iridium or Tungsten Alloys) into the larger shell assemblies that increase the overall life of a system.

Low Tension Ignition Systems

General.

- Lower Overall Ignition System Cost. Higher reliability due to lower electrical stress, higher temperature capability and lower part count.
- Smaller/lighter igniter, lead and exciter. Smaller terminations.
- Significantly fewer instances of dielectric flashover/breakdown as compared to high-tension systems.
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(1) Low Tension Igniter

a. The igniter is almost impossible to quench (suppressed sparking), especially at elevated pressure (500 psig+); provides ignition capability for mission or safety critical applications

b. Improved wet spark capability over high-tension igniter. High tension igniters easily quench with fuel after short time in engine if fuel atomization/nozzle issues exist.

c. Much smaller size and weight. Typically 30% lighter than a comparable high tension igniter.

(2) Low Tension Ignition Lead

a. Leads do not require elastomeric seals or wire insulation, which begin to degrade with exposure to temperatures above 450°F/232°C. Low tension leads provide overall higher temperature rating of the termination which provides higher reliability and longer time between removals/repairs. In many cases elastomeric lead seals are not maintained properly, which lead to igniter terminal well dielectric flashover during operation.

b. Champion low tension leads utilize ceramic insulators at both terminations and a high temperature conductor wire that can increase the terminal connection operating temperature rating up to 842°F/450°C and lower incidence of termination dielectric failures. In most cases the extra operating temperature capability alleviates the requirement to air cool the ignition lead thus providing significant weight and cost savings to air-cooled ignition leads. Lead wire jacket and insulators have significantly more mechanically robust material makeup than elastomeric components.

c. Low Tension ignition leads typically have better voltage margin operation than high tension designs. High tension leads using MIL-DTL-3702 wire has 30kV operating voltage. An ignition system operating at 20kV has a safety margin of 0.5 without temperature derating. A low tension design operating at 5kV (15kV rated wire) has a safety margin of 2 with better temperature derating capability. This provides significantly lower occurrence of dielectric failure in the lead terminations.

(3) Low Tension Exciter

a. Low-tension exciter designs have simpler output networks usually consisting of an output inductor to extend the spark duration. The simpler output network generates less EMI resulting in easier broadband filtering and less chance of affecting the second channel in dual channel designs.

b. A low tension design reduces stress (high frequency oscillations associated with high tension) on the high voltage switching element, unipolarity diodes and ground reference resistant circuits thus improving reliability.

c. Not as sensitive to high altitude operation due to the much lower operating voltages. No flashover potential in the terminal wells due to high voltage stress occurring from a quenched igniter.

d. Typically smaller and lighter weight due to smaller terminations and lack of output transformer.

Disadvantages.

(1) Igniter.

a. Igniter design includes one more part and process due to the addition of a semiconductor pellet.

b. Slightly higher cost of ownership igniter when comparing its life to the cost and sparking life of the high voltage system (usually due to much smaller igniter tips on low tension systems).

(2) Lead. None

(3) Exciter. None

High Voltage Ignition Systems

General.

- Higher Cost systems due to use of elastomeric components and the need to internally cool the ignition leads. Additional engine hardware required to support air cooled ignition systems.
- Larger igniter, lead, exciter and connection terminations. Weight increase is more significant due to cooling and the engine architecture to support a cooling ignition system (shrouds, piping, clamps, cooling air connection features etc…)
- Much higher incidence of dielectric failures in operations due to temperature limiting materials.

Advantages.

(1) One less part and process in the igniter (no semiconductor).

(2) Longer igniter life potential due to size differences (particularly when using iridium center and ground electrodes). Use of these materials significantly drives cost.

(3) Igniter will quench at high pressure preventing unnecessary continuous ignition at elevated pressure (conserves igniter life). Typical new part quench pressure is 300 psig and used part quench pressure is less than 75 psig. These numbers will vary based on the exciter output voltage level. This is true for pure high-tension igniters. If the igniters use semi-conductive coatings at the igniter spark gap the igniter will behave more like a low-tension igniter initially, but transition to high tension igniter behavior after moderate use in the engine. (Quenching also has significant disadvantages- see subsequent Disadvantages section).

(4) Ignition spark can be directed into the combustor slightly further using a recessed gap design, while the low voltage system is always a surface spark.

Disadvantages.

(1) Igniter.

a. Increased Weight/Size as a result of increased dielectric requirements. Increased dielectric strength requires longer terminations, greater insulator thickness and larger internal flashover protection. All of the above lead to increased cost.

b. Quenching of igniter at high pressures will cause unnecessary dielectric stressing of the igniter, exciter and lead. It also prevents ignition for safety or mission critical flight requirements (e.g. inclement weather operation, vertical takeoff and landing, etc..)

(2) Lead.

a. Increased Weight/Size and complexity as a result of increased dielectric requirements and air-cooled configurations. Increased dielectric strength requires longer terminations, greater insulator thickness and larger internal flashover protection. All of the above lead to significantly increased cost.

b. More likely to have a dielectric and corona problems with components (i.e. elastomeric seals, insulators etc.). Demanding ignition at high combustor pressures will dielectrically stress the igniter/lead components/connections as no spark occurs at the tip. Leads to lower reliability and increased maintenance costs.

c. Elastomeric components (seals, gaskets, insulators, wire jacketing) have limited mechanical strength and can be easily damaged allowing the potential for dielectric failure.

(3) Exciter.

a. A major drawback to a high-tension system is increased EMI due to the high ionization pulse. This creates additional challenges employed in a dual channel system when attempting to keep the channels isolated.

b. The higher voltage requirements add additional weight and cost due to extra components needed to generate the high voltage. The additional parts also decrease the reliability over a low voltage system.

c. Sealing of the exciter enclosure becomes more critical in high voltage applications. Any loss of internal pressure (at altitude) can cause internal arcing within the exciter during operation.