20 Liter Spherical Explosion Test Apparatus

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1 Introduction

1.1 Technical parameters

Table 1 Technical parameters

Item	Parameter and description
Model	ETD-20L DG (for dust and gas)
Rating voltage	AC 220V, 50Hz
Rating current	10 A
Working pressure	2.0 MPa (g)
Accuracy of vacuum gauge	0.4%
Data acquisition card	12Bit, 100kHz
Pressure sensor	Dynamic range 0~1.379MPa(0~5V Output), Usable range: 0~2.758MPa(0~10VOutput). Resolution: 0.021kPa。Resonant frequency>500kHz. Non-linearity<1%。ICP type Output: 0~5V.
Ignition energy	Pyrotechnical igniter：10kJ, 2kJ, 2.5kJ; Electrostatic spark ignition: 10kJ
Gas introduction method	Manual valves
Control mode	Local control and remote control: Buttons on the control panel on control box, human interface on control box, or computer.
Software	Explosion test software “ExTest 2010” with functions of experimental process control and experimental database management and report.

A simplified version of ETD-20L DG is ETD-20L DGS. The only difference of them is that ETD-20L DGS doesn’t support electrostatic ignition.

1.2 Functions

Explosion characteristics of combustible dust and gas:

- Maximum explosion pressure p_{max}, and maximum rate of explosion pressure rise K_{st} of dust;
- Lower explosion limit (LEL) of dust, also called minimum explosible concentration (MEC);
- Limiting oxygen concentration (LOC) of dust;
- Maximum explosion pressure p_{max}, and maximum rate of explosion pressure rise K_g of gas;
- Lower explosion limit (LEL) and upper explosion limit (UEL) of gas.

1.3 Related standard

- ISO 6184/1 1985 Explosion protection systems - Part 1 : Determination of explosion indices of combustible dusts in air;
- ISO 6184/2 1985 Explosion protection systems - Part 2 : Determination of explosion indices of combustible gases in air;
- ASTM E 1226 2005 Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts
- EN 14034-1 2004 Determination of explosion characteristics of dust clouds – Part 1: Determination of the maximum explosion pressure p_{max} of dust clouds;
- EN 14034-2 2006 Determination of explosion characteristics of dust clouds – Part 2: Determination of the minimum rate of explosion pressure rise $(dp/dt)_{max}$ of dust clouds;
- EN 14034-3 2006 Determination of explosion characteristics of dust clouds – Part 3: Determination of the lower explosion limit LEL of dust clouds;
- EN 14034-4 2004 Determination of explosion characteristics of dust clouds – Part 4: Determination of the limiting oxygen concentration LOC of dust clouds

2 Mechanism

2.1 System structure

The test system consists of 20L spherical explosion chamber, control and data acquisition system (Figure 1). The explosion chamber is a double-layered stainless steel vessel (Figure 2). Water or other fluid media can be used to maintain initial temperature of explosion test. Normally water is used to cool the vessel to room temperature. On the vessel wall there are different connections: vacuum, exhaust, fuel inlet and air inlet. A glass window can be used to observe the light of ignition and explosion flames.

A fast act valve is mounted under the bottom of the vessel, which is driven by compressed air. A sample vessel with volume by 0.6L is connected to the fast act valve. The dust sample can be dispersed to the chamber by compressed air through the dispersion nozzle. On the sample vessel there is a pressure gauge with signal output function.

The cover of the vessel can be locked in a defined angle, and can be removed in another angle. Electrode rods are mounted in the vessel cover. When the cover is in locked position, a position indicator can give a signal to the control box.

One or two pressure sensor can be mounted on the vessel wall to record the dynamic pressure during experiment.

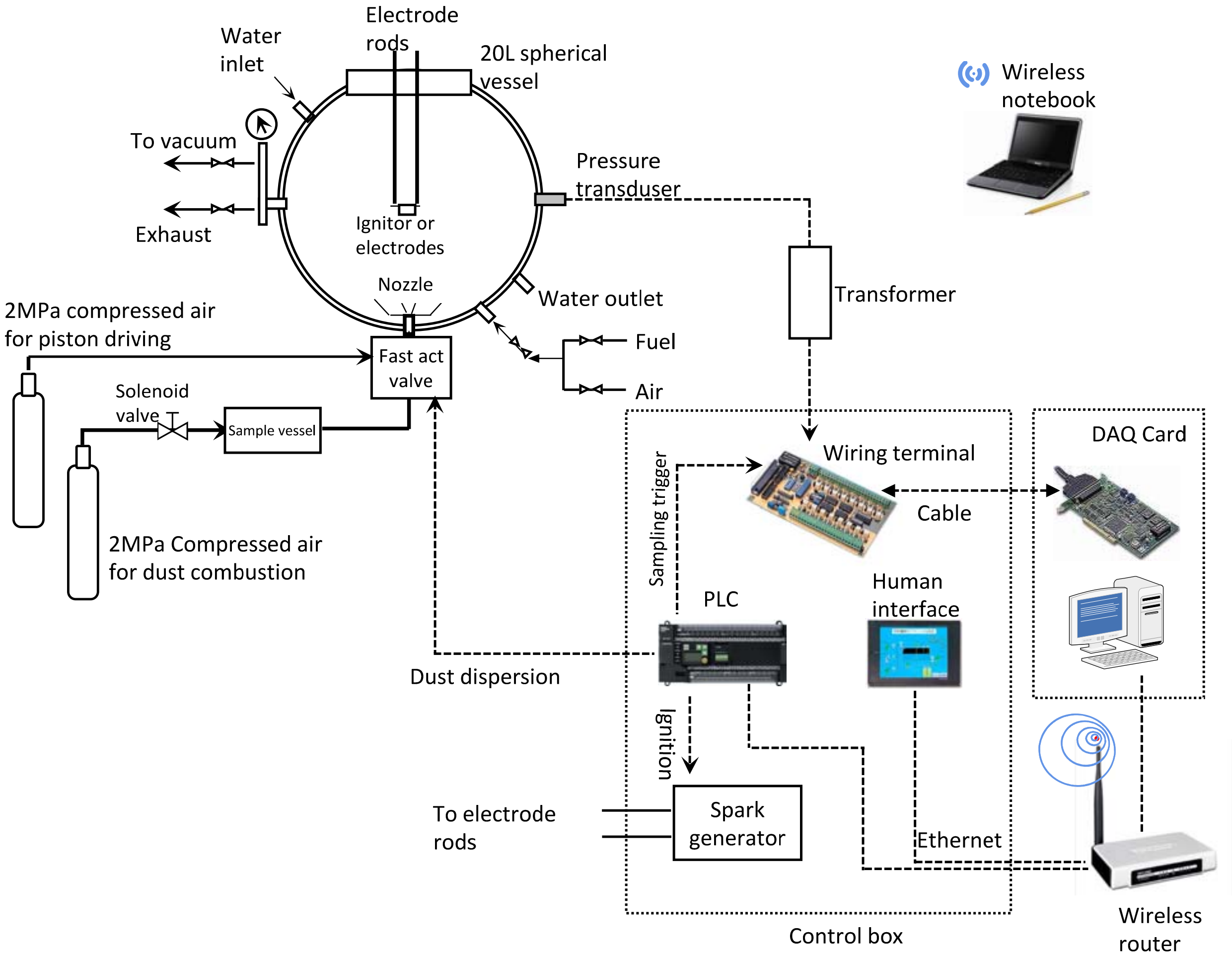

Figure 1 Schematic diagram of 20L explosion test system

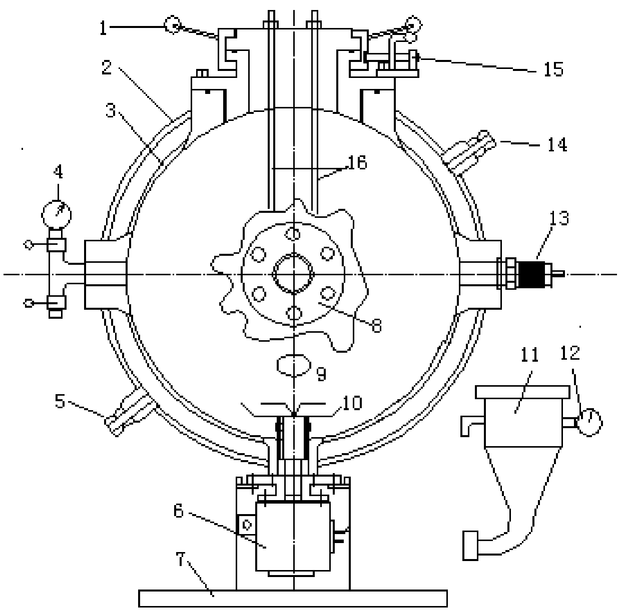

Figure 2 The 20L spherical explosion chamber

1 Handles 2 Outside layer 3 Inside layer 4 Vacuum gauge 5 Inlet of recycling water 6 Dust/air multiphase valve 7 Stand 8 Inspect window 9 Inlet of fuel gas/air 10 Dispersion valve 11 Dust sample vessel 12 Gauge with signal output

13 Pressure sensor 14 Outlet of recycling water 15 Safety interlock

2.2 Explosion test mechanism

2.2.1 Dust explosion test

First, the vessel is vacuumed to -0.6MPa (g), then dust sample in the dust vessel is dispersed into the test chamber by compressed air. After a pre-defined ignition delay (normally 60 ms), two pyrotechnical igniters (with energy totally 10kJ) was used to try to ignite the dust cloud. The pressure history in the chamber is recorded by the pressure sensor and data acquisition system. Explosion pressure p_m and normalized rate of pressure rise K_m can be obtained by analysis of the pressure history curve. Explosion tests are carried out at different dust concentration, and p_{max} and K_{max} are maximum value of p_m and K_m respectively.

2.2.2 Gas explosion test

The mechanism of gas explosion test is similar with that of dust explosion test, and the difference is that the way of sample introduction. Fuel gas and air are introduced by fuel gas and air inlet. The dust vessel can be used as a turbulence generation system.

2.3 Mechanism of electrostatic ignition and its limitation

2.3.1 Mechanism of electrostatic ignition

The schematic diagram is shown as Figure 3. The left part of the electrodes is triggering circuit. First, S3 is on to charge the main capacity C2, which store much energy in C2. The voltage of C2 is not enough to discharge. Then S1 is on, C1 is charged to high voltage. Then S2 is on, the gap between electrodes is broken down by C1 because its high voltage. Once the gap is broken down, energy in C2 is discharged by arc sustaining discharge.

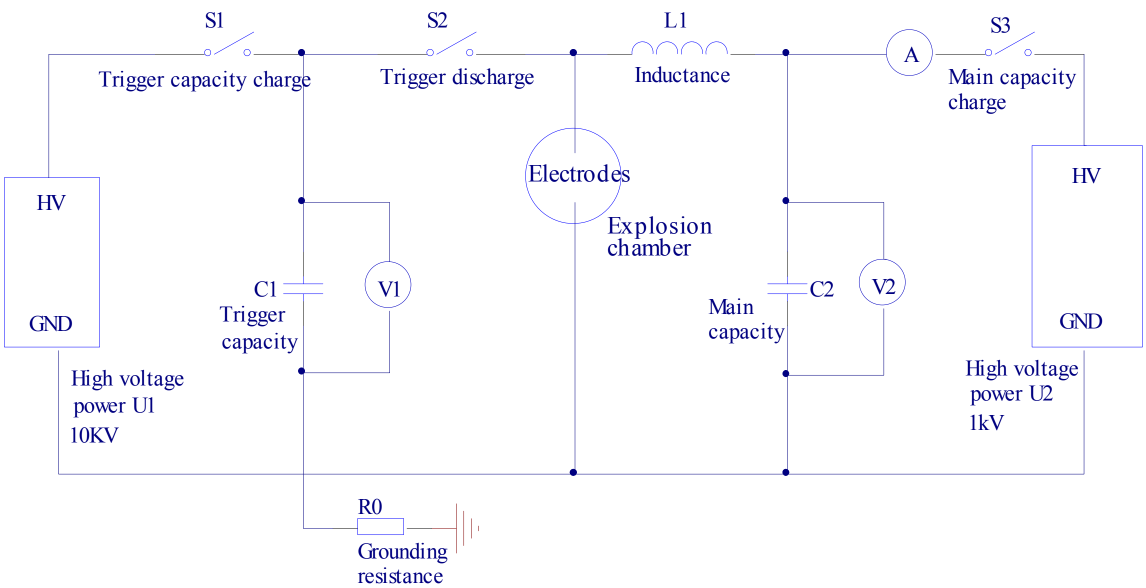

Figure 3 Simplified schematic diagram of electrostatic ignition

The whole system is grounded to earth, and the grounding resistance R0 in Figure 3 is not a real electrical component, but an equivalent resistance because of resistance of grounding cable and contact resistance to earth.

During the process of electrostatic ignition, up to 200A current will be generated in the discharge circuit which is finally directed to the earth. The grounding resistance will raise the voltage of "GND" in Figure 3 and possibly damages other electrical components when R0 is high. Experience proven that grounding resistance less than 2 Ω was acceptable.

Because of the spark generation is an integrated part of the control unit, which share the "GND" with other electrical component. Isolation of GND is not a practical solution.

2.3.2 Limitations of electrostatic ignition

(1) Reliability

The reliability of electrostatic ignition is less than pyrotechnical ignition.

It is possible that the data acquisition system be damaged during electrostatic ignition in the following cases:

(a) poor grounding;

(b) wrong operation of the operator, typically, the high voltage cable is not put into the electrode rods, but to the vessel stand or ground during discharge.

(2) Pressure sensor compatibility

Only ICP type sensor can withstand the noise signal of electrostatic discharge. The charge amplifier type sensor will have a sharp signal rise at triggering of the discharge.

(3) Range of use

Electrostatic ignition can't be used in determination of p_{max} and K_{st} (K_g). In determination of LEL/MEC, 3~5 kJ electrostatic ignition yields similar result obtained by 2kJ or 2.5 kJ pyrotechnical ignition. However, electrostatic ignition is not recommended in related standards.

However, the electrostatic ignition has been used in 6 institutions in China already. We need more time to observe the reliability.

Generally ETD-20L DG is only sold in mainland of China considering after sale service. If customers that are not in the mainland of China would like to buy ETD-20L DG (the electrostatic ignition supported version), we can only provide repair service in the mainland of China, and the cost of transportation in after sale service has to be paid by the final user.

3 Advantages

(1) The hardware was designed according to international standards;

(2) The fast action valve is from Adolf Küller AG, which is worldwide used as a standard dust dispersion system;

(3) Both pyrotechnical and electrostatic ignition methods are supported;

(4) The test software named ExTest 2010 support curve analysis, database management and

report.

4 Packing List

Table 2 Packing list

Items	Quantity
20L explosion test chamber, ETD-20L DG	1
Control unit, ETC-20L DG	1
Connection pipe, Pipe-20L	1 suite
Control cable, Cable-20L	1suite
High voltage cable, Cable-HV	1
Explosion test software - ExTest 2010	1

5 Requirement for installation

Table 3 Requirement for installation (prepared by the final user)

Requirement	Description
Dimension of field	3m×4m
Power supply	220V, 50 Hz, 10A
Grounding terminal	With grounding resistance less than 4 Ω for ET-20L DG, and less than 2Ω for ET-20L DGS.
Fume hood	Fume hood with flexible duct, designed according to drawing provided by IEPI, NEU.
Compressed air supply, 2MPa	Two 40L compressed air steel bottles, maximum pressure 15 MPa. 1 bottle is used for pneumatic driving of multiphase valve, and the other is used for dust dispersion media (carrier). Two pressure reducing valves, 15 MPa to 5 MPa, operated at 2 MPa.
Air compressor	Maximum pressure: 0.8MPa; Volume: 35L; Flow rate: 120 L/min.
Vacuum pump	4L/min
Movable dust collector	
Pyrotechnical igniter	5kJ, 1kJ

6 Related pictures

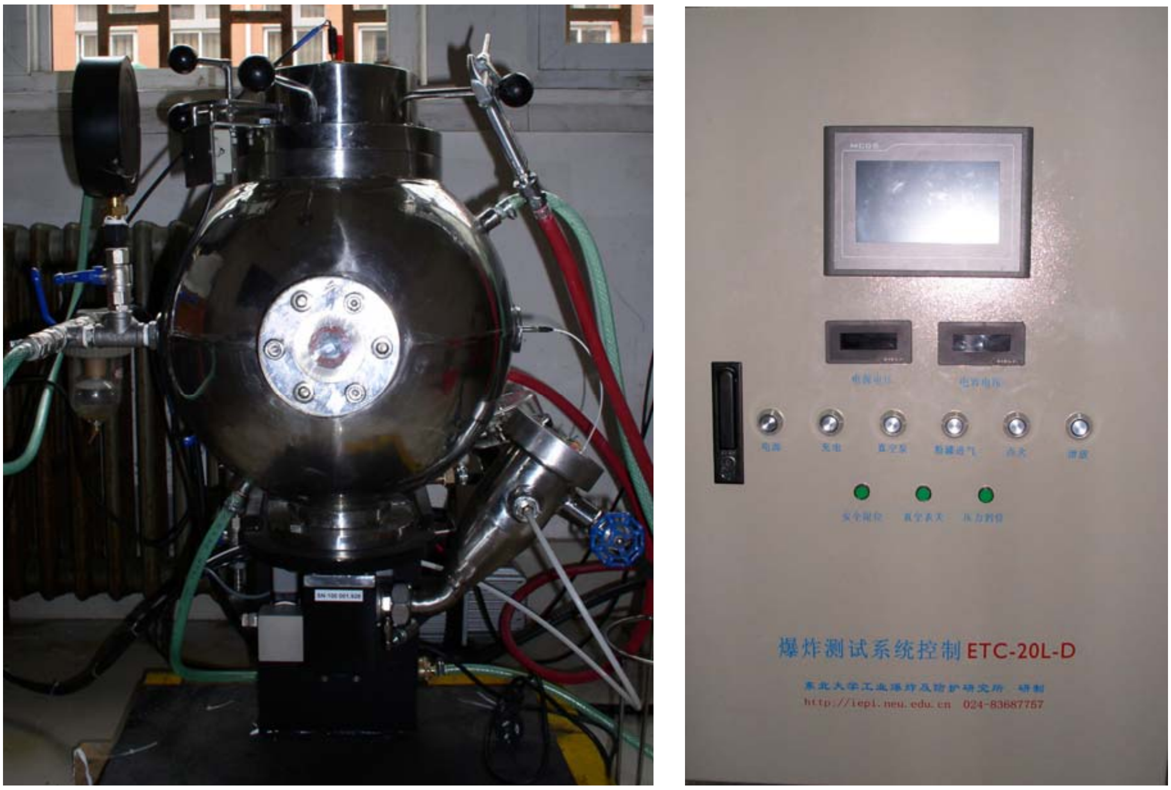

Figure 4 Explosion chamber and control box

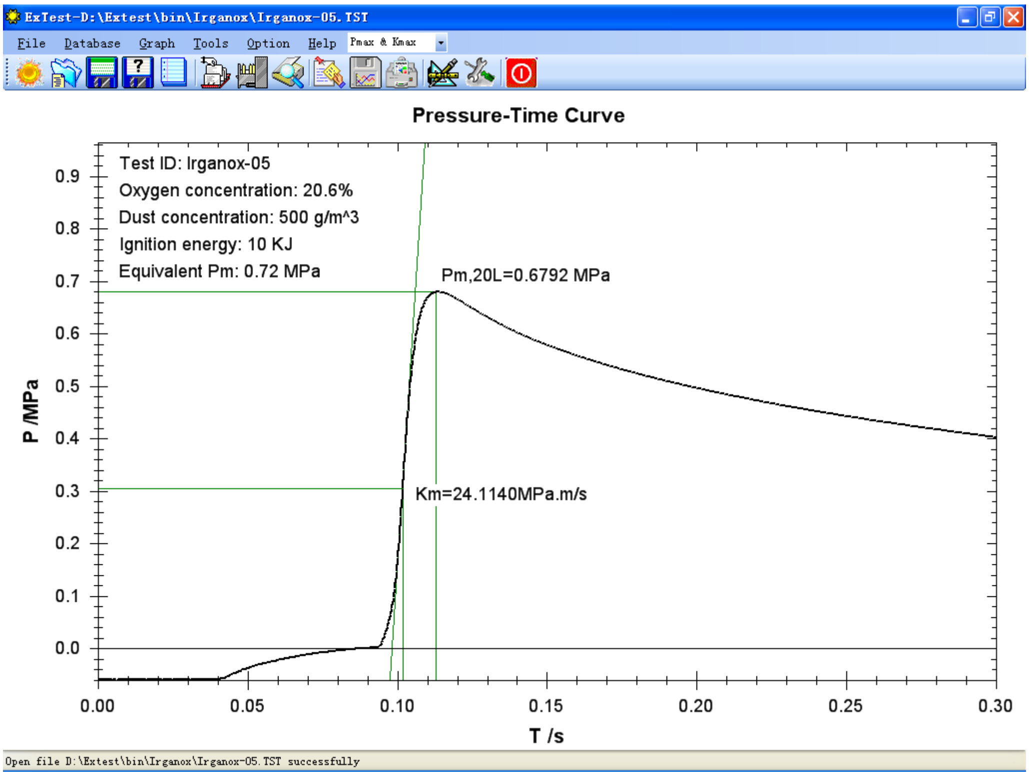

Figure 5 Typical pressure history curve

7 Contact us

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