DEPT OF HIGH VOLTAGE AND INSULATION ENG， CHONGQING UNIVERSITY

Part I- Chapter 1: Electrical Breakdown in Gases

1.6 Factors influencing breakdown voltages of gases

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1.6.1 Influences of field non-uniformity

1. Breakdown voltages of gases in uniform and quasi-uniform fields

- **No polarity effects**
- **Processes from initiation of ionization to final breakdown are very quick.**
- **Under AC, DC, and impulse voltages, breakdown voltages are same.**
- **Empirical formula of breakdown voltage:**

$$U_b = 24.22\delta d + 6.08\sqrt{\delta d} \qquad \text{kV}$$

- **δ - relative density of air**
- ***d* – length of air gap**

U_b is a function of (δd), which satisfies the Paschen's law.

1.6.1 Influences of field non-uniformity

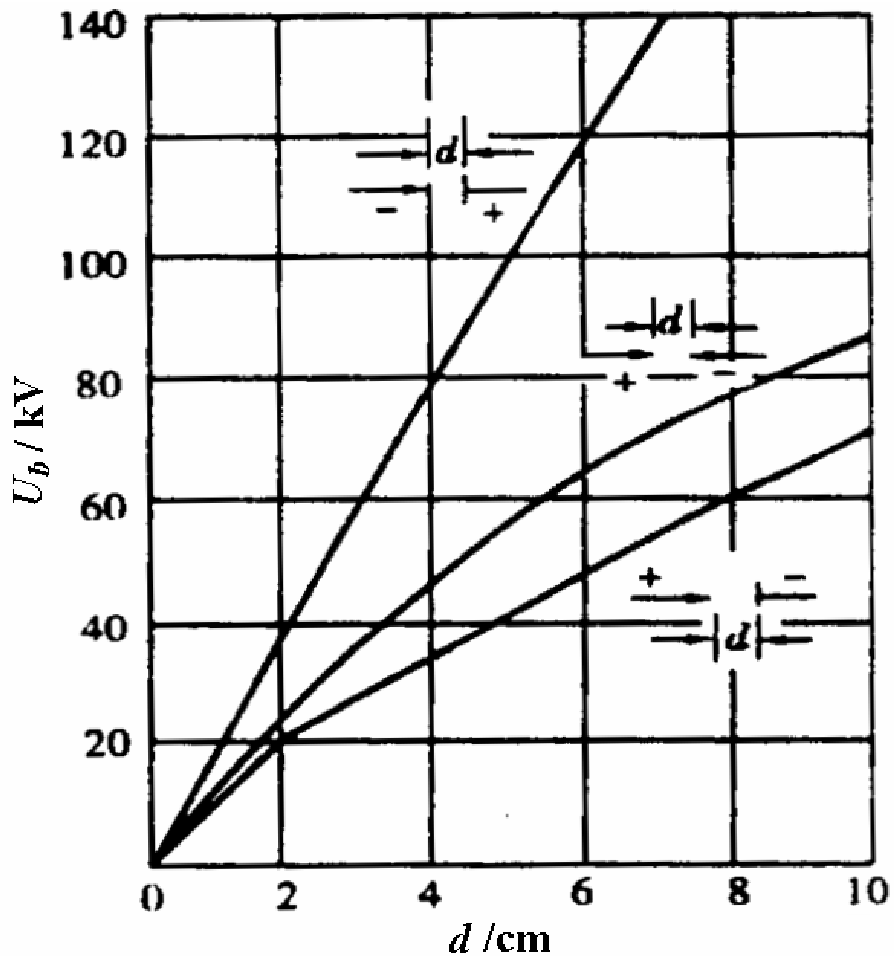
2. Breakdown voltages of gases in strongly non-uniform fields

- **In power transmission application, breakdown voltages of rod-to-rod and rod-to-plane arrangements are used to determine insulation distances in cases of symmetric and asymmetric electrode arrangements, respectively.**
- **Results of breakdown voltages are scattered and polarity effect is significant.**

$$U_b(+) < U_b(-) \quad \text{and} \quad U_c(+) > U_c(-)$$

1.6.2 Influences of waveforms of applied voltages

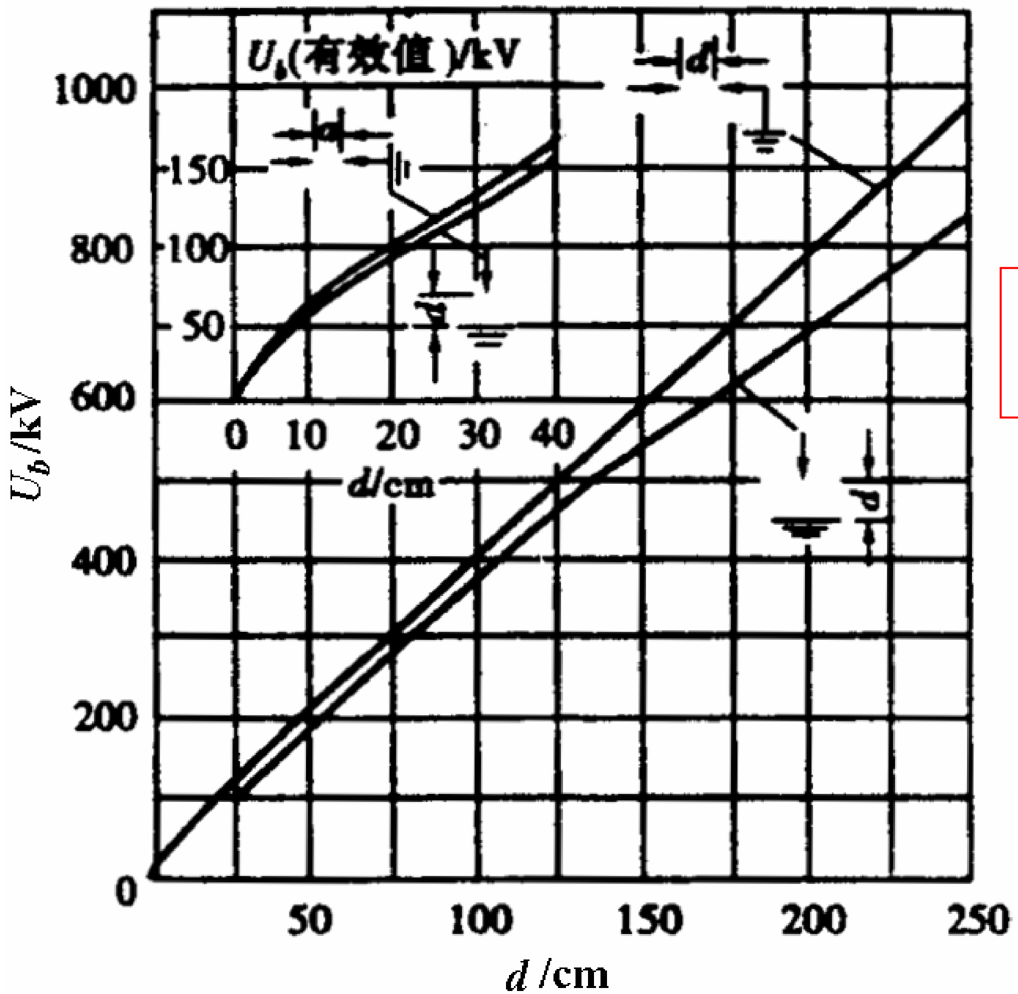
- **DC breakdown voltages of gas gaps**



Breakdown voltages of rod-rod and rod-plane air gaps via gap distance

1.6.2 Influences of waveforms of applied voltages

- **AC breakdown voltages of gas gaps**

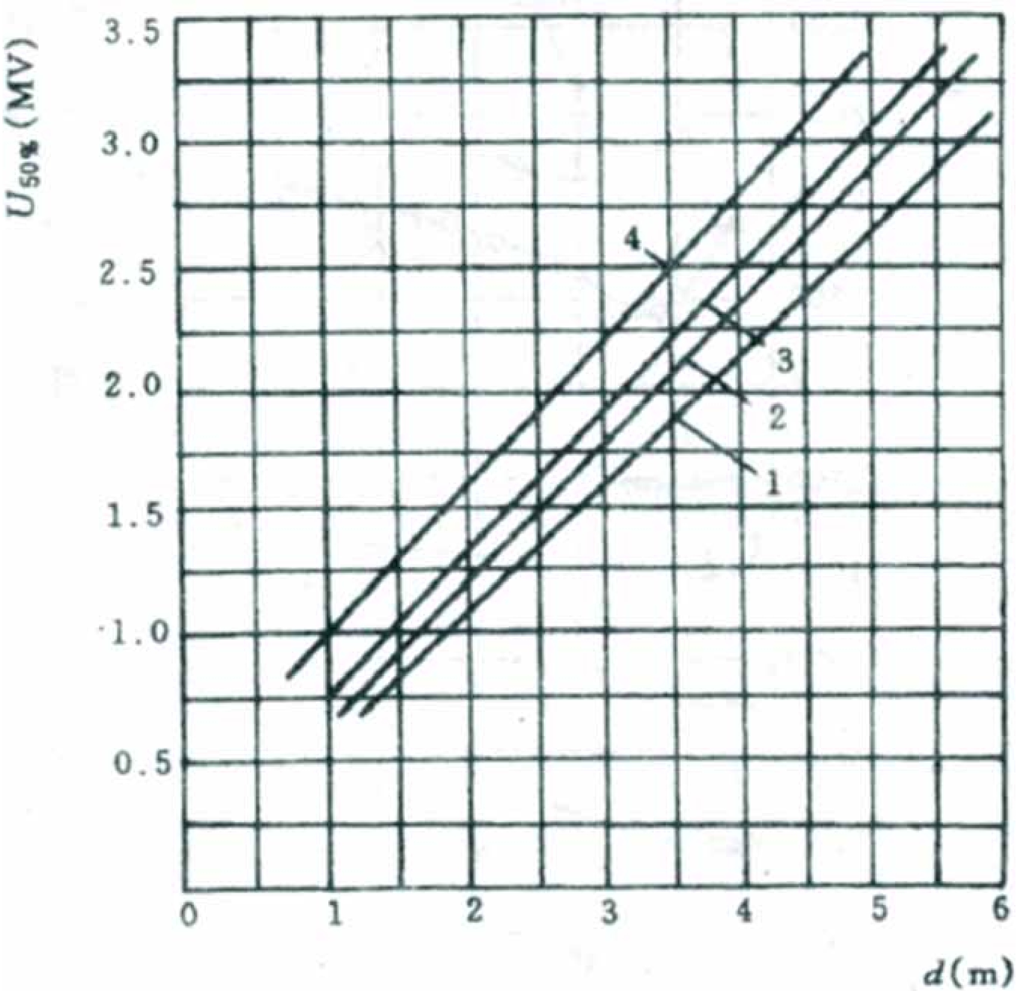


Breakdown always occurs at positive half cycles

Breakdown voltages of rod-rod and rod-plane air gaps via gap distance

1.6.2 Influences of waveforms of applied voltages

- **Breakdown voltages of gaps under 1.2/50 impulse voltages**

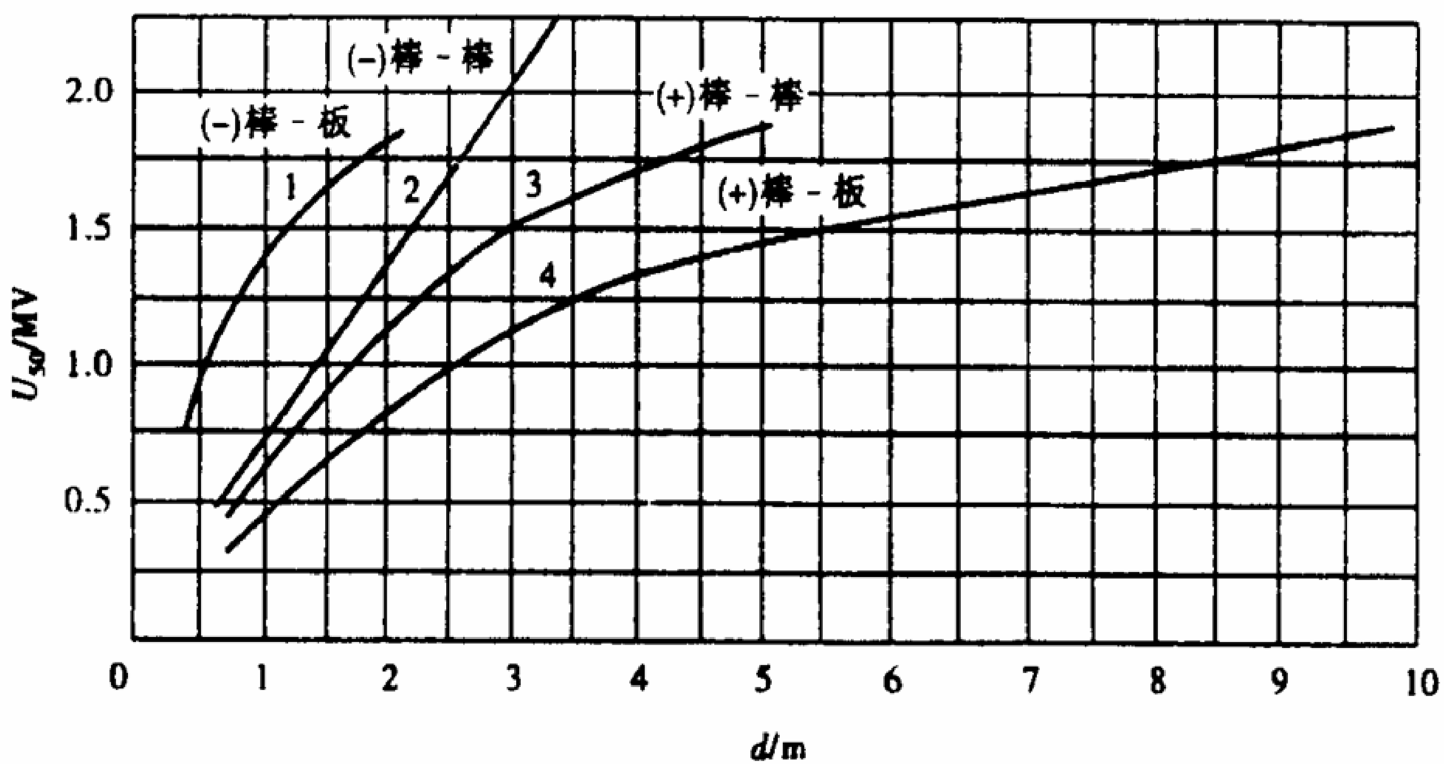


$$U_{50}(+) < U_{50}(-)$$

- **1- rod-plane, positive**
- **2- rod-rod, positive**
- **3- rod-rod, negative**
- **4- rod-plane, negative**

1.6.2 Influences of waveforms of applied voltages

- **Breakdown voltages of gaps under switching impulse voltages**



Relationship between breakdown voltage and gap distance under switching impulse voltage (500/5000 μs)

1.6.2 Influences of atmospheric conditions

- **Pressure (P), temperature (T), and humidity (h_c) of air influence density of air, free paths of electrons, collision ionization, and attachment of electrons. Therefore, atmospheric conditions influence breakdown voltages of air gaps.**
- **Breakdown voltages measured in different atmospheric conditions have to be transformed into values in standard atmospheric conditions for comparison.**
  - **Standard atmospheric conditions: P=101.3 kPa; T=293 K; h_c=11 g/m^3**
- **Breakdown voltages of air gap decrease with increasing altitude, because density and pressure of air decrease with increasing of altitude.**
  - **Altitude correction for breakdown voltages**

$$U = \frac{K_d}{K_h} U_0$$

U - *breakdown voltage in actual atmospheric condition.*

U_0 - *breakdown voltage in standard atmospheric condition.*

K_d - *correction coefficient of air density*

K_h - *correction coefficient of altitude*

1.7 Approaches to improve electric strength of gas gaps

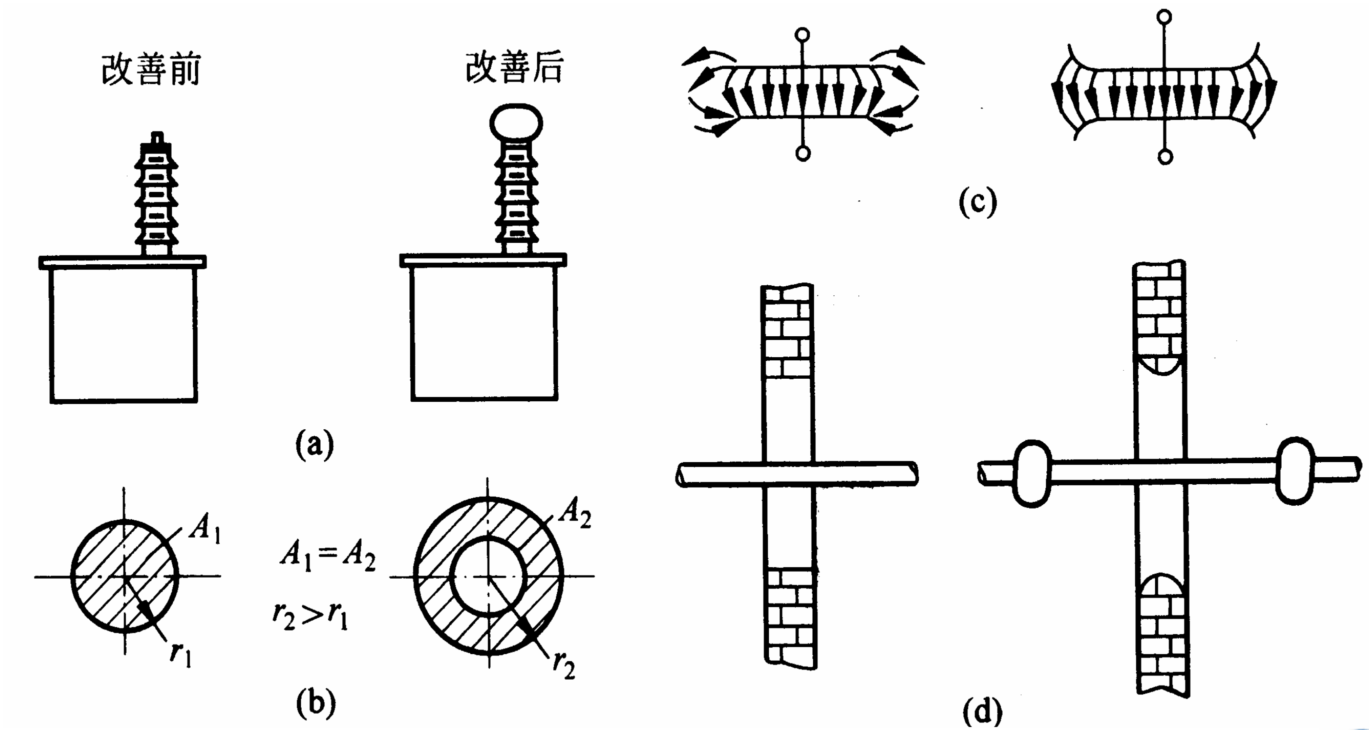
Basic approaches

- The approaches are classified into two groups:
  - To improve electric field homogeneity in gas gaps.
    - To improve configuration of electrodes.
    - To generate field distortion by space charge.
  - To weaken ionization in gas gaps.

1.7.1 Improvement of electric field homogeneity

1. Improvement of electrode configuration

- To increase radiuses of curvature of electrodes.
- To smoothen the surfaces of electrodes
- To eliminate the sharp edges of electrodes



1.7.1 Improvement of electric field homogeneity

2. Field distortion by space charge

- **Corona discharges occur before complete breakdown in gas gaps.**
- **Space charge generated by corona discharges may improve field distribution in gas gaps and thereby enhance breakdown voltages.**
- **Breakdown voltages of gas gaps between two conductor lines may increase with decreasing diameters of conductor lines in a certain range.**

“细线效应 ”

雷电冲击电压下不存在“细线效应”

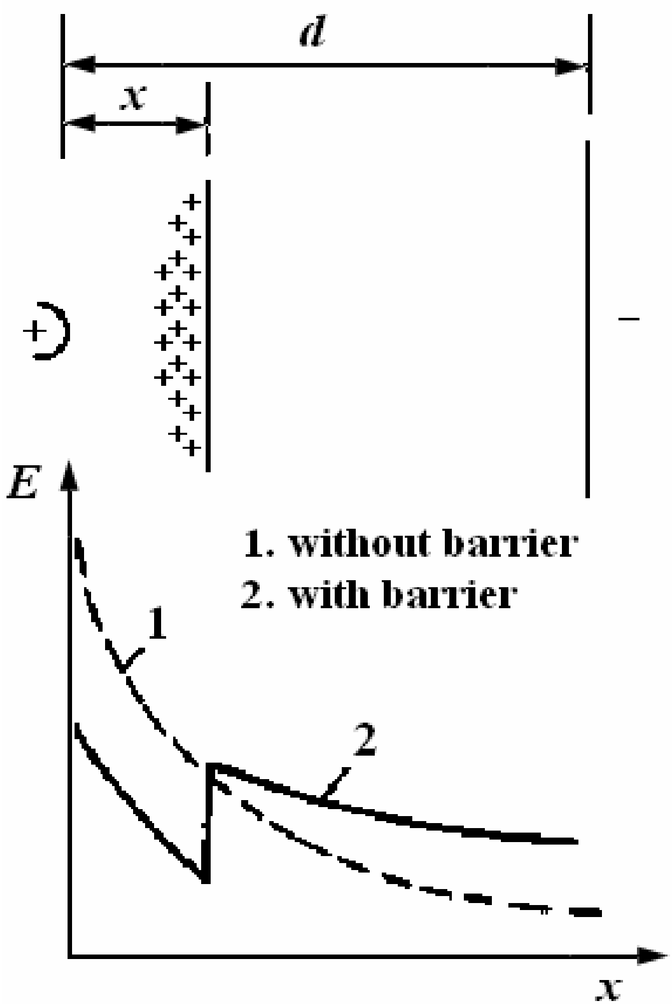
1.7.1 Improvement of electric field homogeneity

3. Barriers used in strongly non-uniform fields

- **In strongly non-uniform fields, thin insulation boards used as barriers can improve field distribution.**
- **Breakdown voltages of gas gaps in strongly non-uniform fields can be enhanced by using barriers.**
- **The function of a barrier is to retard ions with the same polarity as the electrode where corona starts.**

1.7.1 Improvement of electric field homogeneity

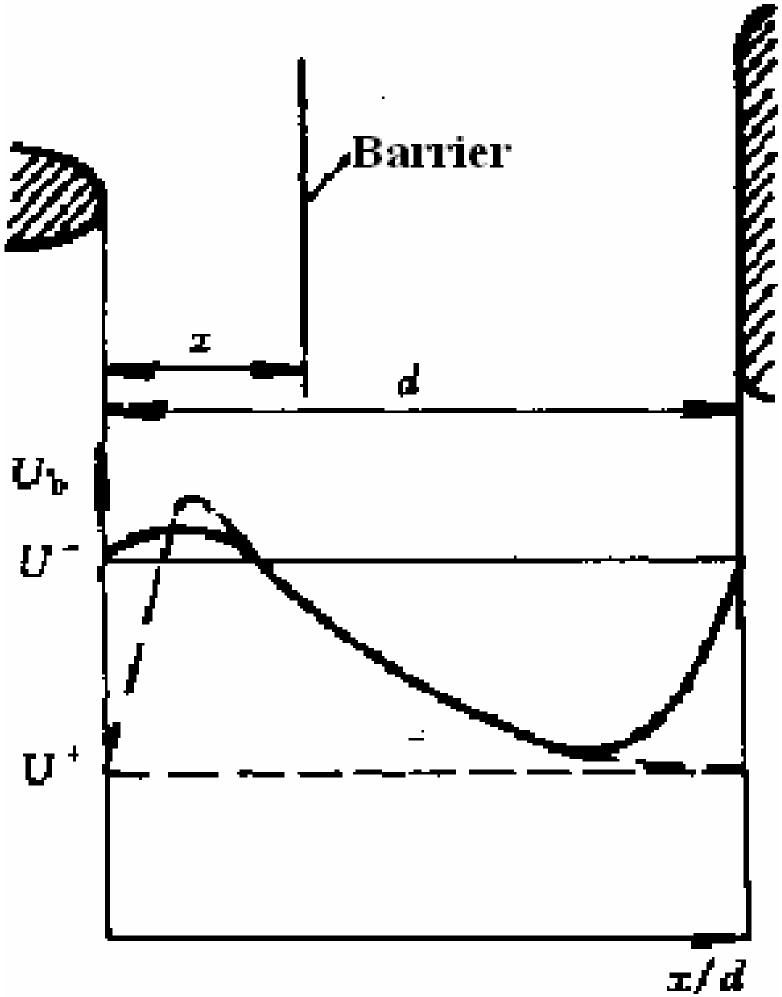
- **Example of barrier in positive rod to negative plane**



- **Positive space charge is retarded by the barrier.**
- **Positive space charge stays and distributes on the barrier uniformly because of electrostatic repulsion.**
- **The field between the barrier and the positive rod is reduced and between the barrier and plane become more uniform.**
- **Breakdown voltage of the gap is improved by the barrier.**

1.7.1 Improvement of electric field homogeneity

- **Breakdown voltages via barrier position under DC voltages**



- **Breakdown voltages of positive rod to plane gap are significantly enhanced by barriers.**
- **Barrier with well selected position may improve breakdown voltages of gas gaps.**

1.7.2 Approaches to weaken ionization

1. Increase of gas pressure

- **Free paths of electrons are reduced by increasing gas pressure and thereby collision ionization is weakened.**
- **Field homogeneity influence more on breakdown voltages in high-pressure gases than in low-pressure gases.**
  - **Breakdown voltages decrease sharply in high-pressure gases when field homogeneity decreases.**
- **Surface conditions of electrode influence more on breakdown voltages in high-pressure gases than in low-pressure gases.**
  - **Roughness of electrode surface.**
  - **Contamination of electrode surface.**
  - **Humidity**

1.7.2 Approaches to weaken ionization

2. Vacuum gaps

- **Free paths of electrons are greater than gap distance in vacuum. Collision ionization is impossible. Breakdown voltages are significantly improved.**
- **Field emission is a principle ionization in vacuum. Cathode material and its surface conditions mainly influence breakdown voltages of vacuum gaps.**
- **If solid and liquid dielectrics are used in vacuum, they may release gases so that breakdown voltages decreases sharply.**
- **Application: vacuum breakers.**

1.7.2 Approaches to weaken ionization

3. Uses of high-electric-strength gases (SF_6)

- **Some gases of halogen family have greater electric strength than air, such as SF_6.**
- **Gases with great Electro-negativity**
- **Used mainly for gas-insulated breakers.**
- **It is not environment friendly.**
  - **A type of greenhouse gas**