YAKIN DOĞU ÜNİVERSİTESİ
UZAKTAN EĞİTİM VE BİLİŞİM TEKNOLOJİLERİ MERKEZİ

EE 475 HIGH VOLTAGE TECHNIQUES I

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UNIT-5
GIS

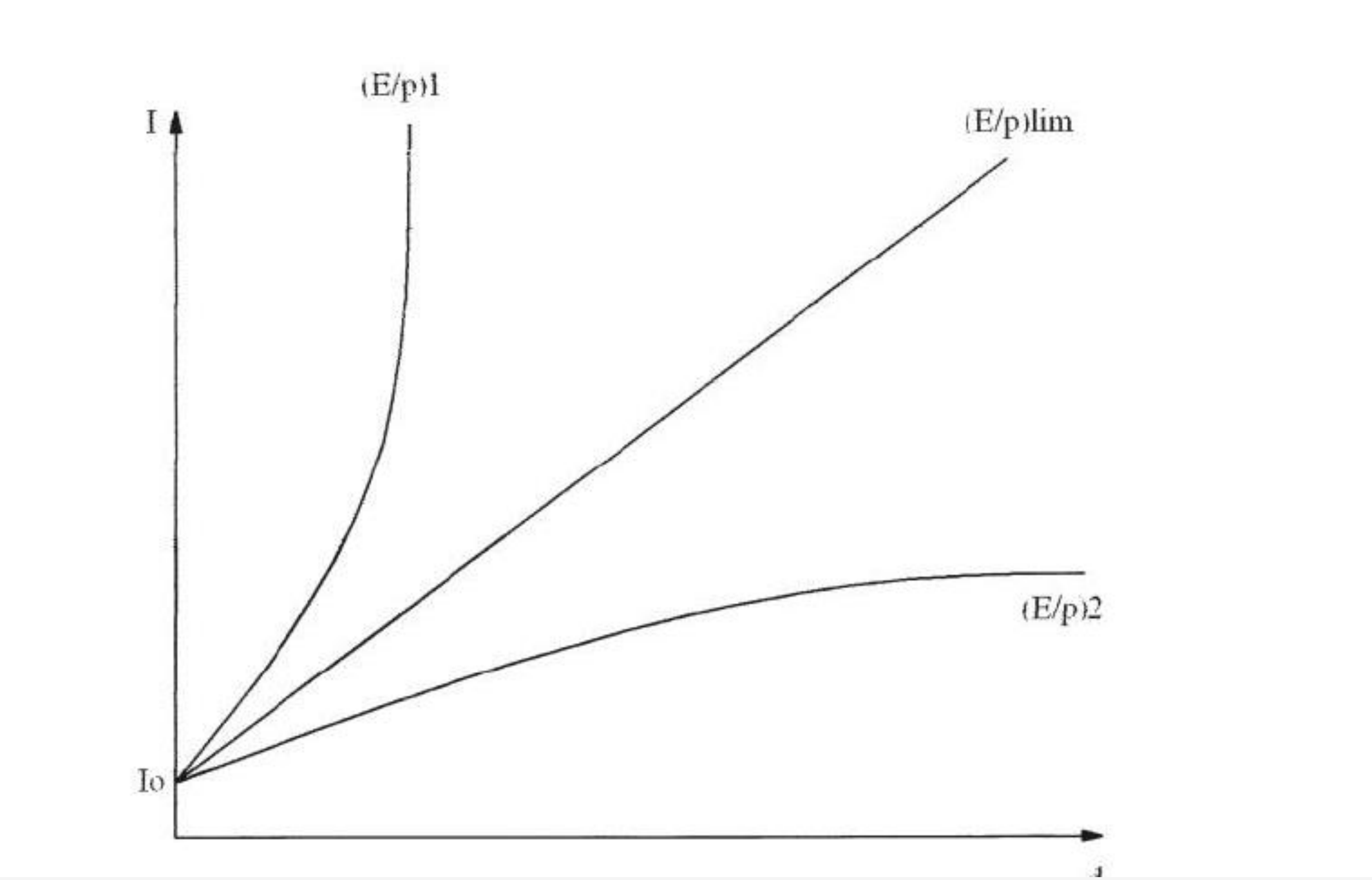
Ionization Growth at the Limiting E/P

$$n_-(d) = n_0 + \eta n_0 d$$

$$n_-(d) = n_0(1 + \eta d)$$

Total number of particles arriving the anode

$$I = I_0(1 + \eta d)$$

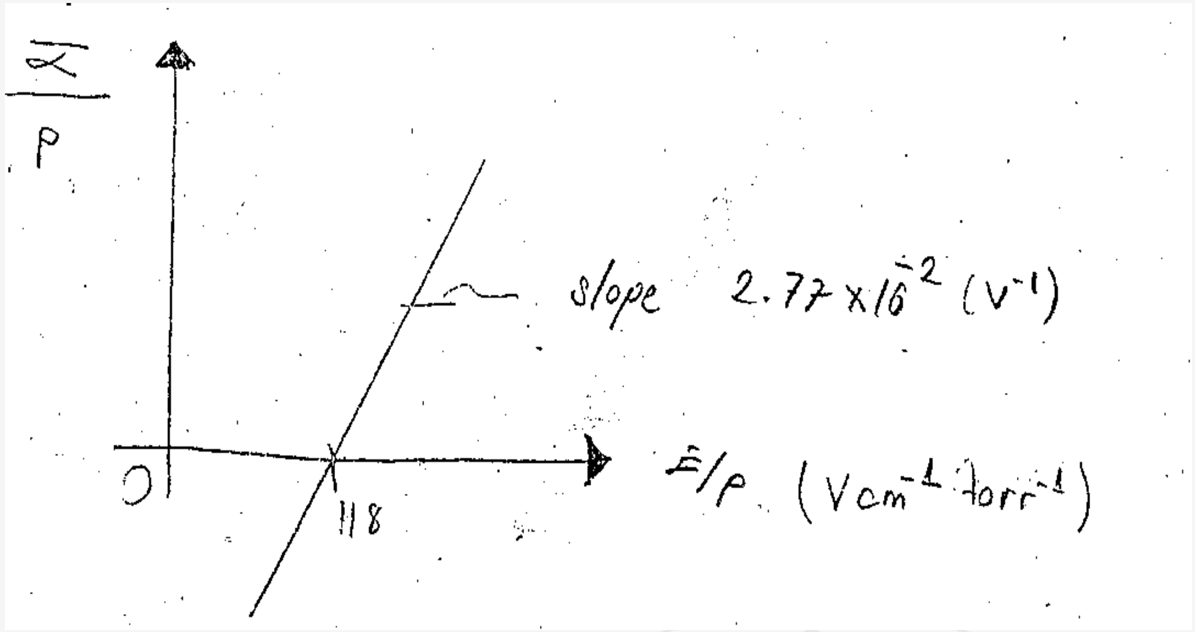


Effective ionization Coefficient in SF6

$$\frac{\bar{\alpha}}{p} = \frac{\alpha - \eta}{p} = C\left[\left(\frac{E}{p}\right) - \left(\frac{E}{p}\right)_{\lim \alpha = \eta}\right]$$

C= 27.7 kV^{-1}

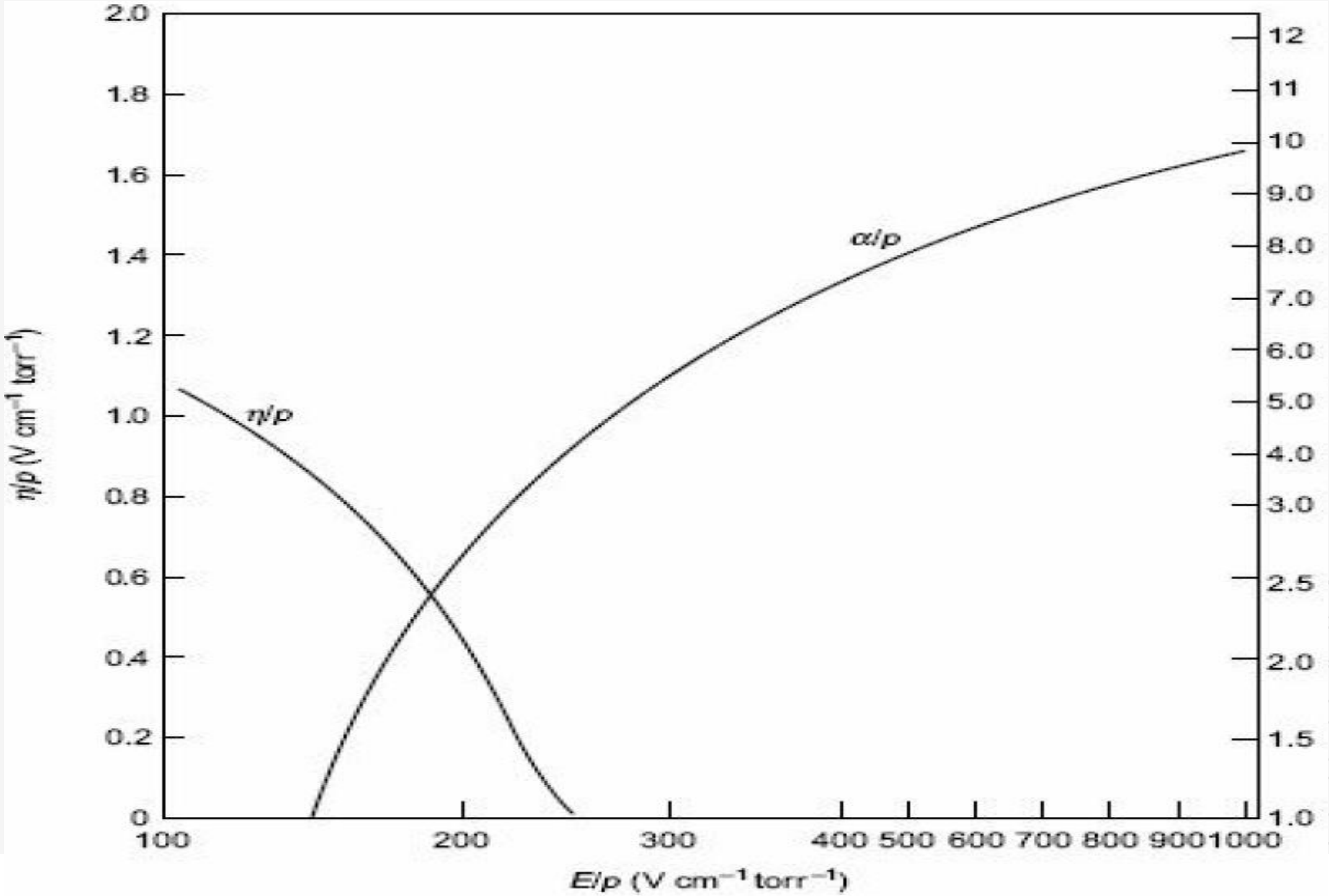
$$(E/p)_{\lim \alpha=\eta} = 88.5 kV/(cm bar) = 118 V/(cm torr)$$



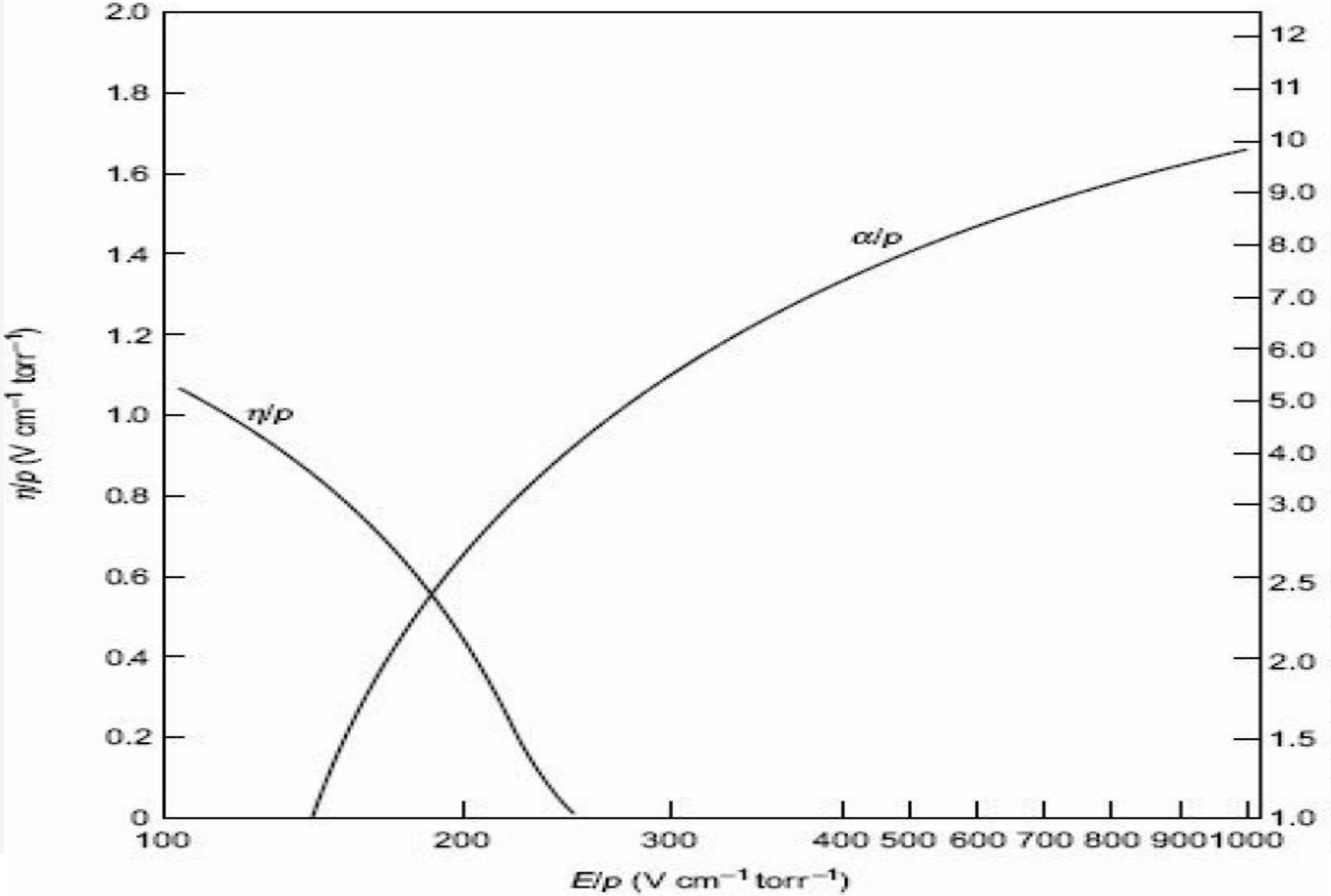
$$\frac{\bar{\alpha}}{p} = \frac{(\alpha - \eta)}{p}$$

→ effective ionization coefficient

Ionization and attachment coefficients in SF6

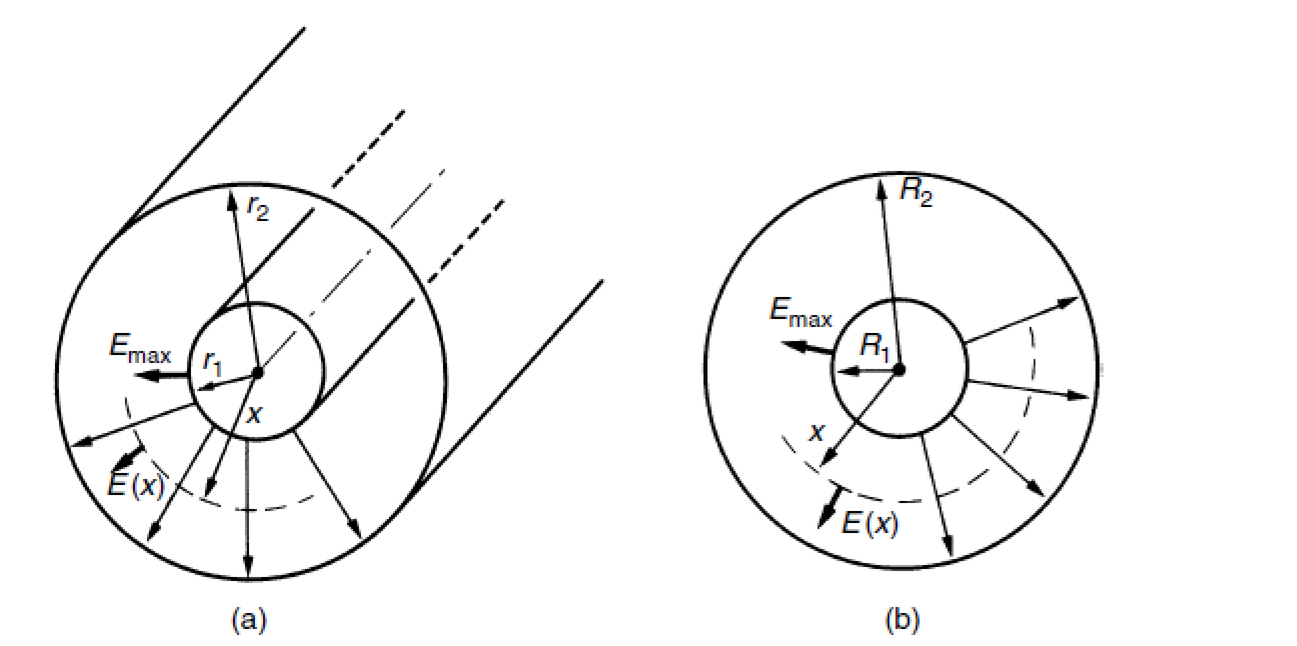


Ionization and attachment coefficients in SF6



Coaxial cylindrical and spherical fields

Electrode configurations providing cylindrical or spherical fields are used in h.v. equipment as well as in laboratories for fundamental research or field stress control. a) cylindirical b) spherical



Coaxial cylindrical and spherical fields

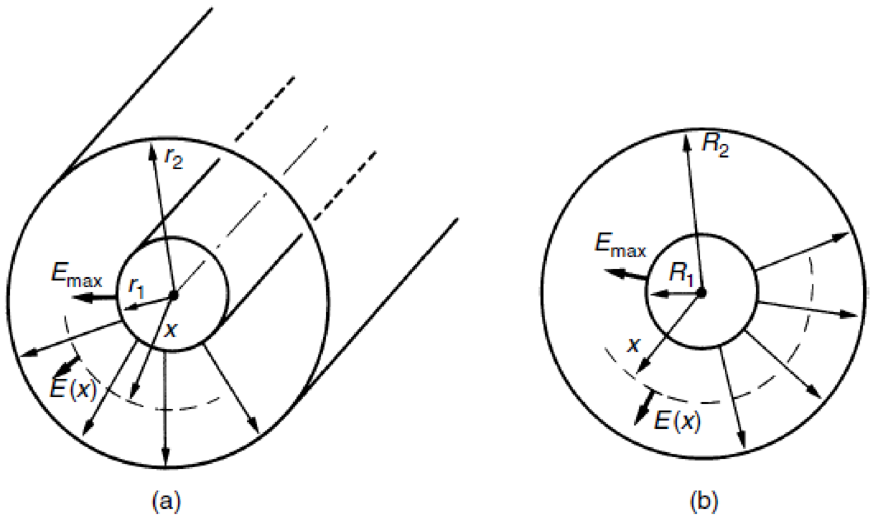
- Coaxial cylinder:

$$E(x) = \frac{Q/l}{2\pi\varepsilon}\frac{1}{x} = \frac{V}{\ln(r_2/r_1)}\frac{1}{x},$$

- Coaxial spheres:

$$E(x) = \frac{Q}{4\pi\varepsilon}\frac{1}{x^2}$$

$$= \frac{V}{(R_2 - R_1)/R_1R_2}\frac{1}{x^2},$$



Coaxial cylindrical and spherical fields

- Coaxial cylinders:

$$E_{\max} = \frac{V}{r_1 \ln(r_2/r_1)}.$$

- Coaxial spheres:

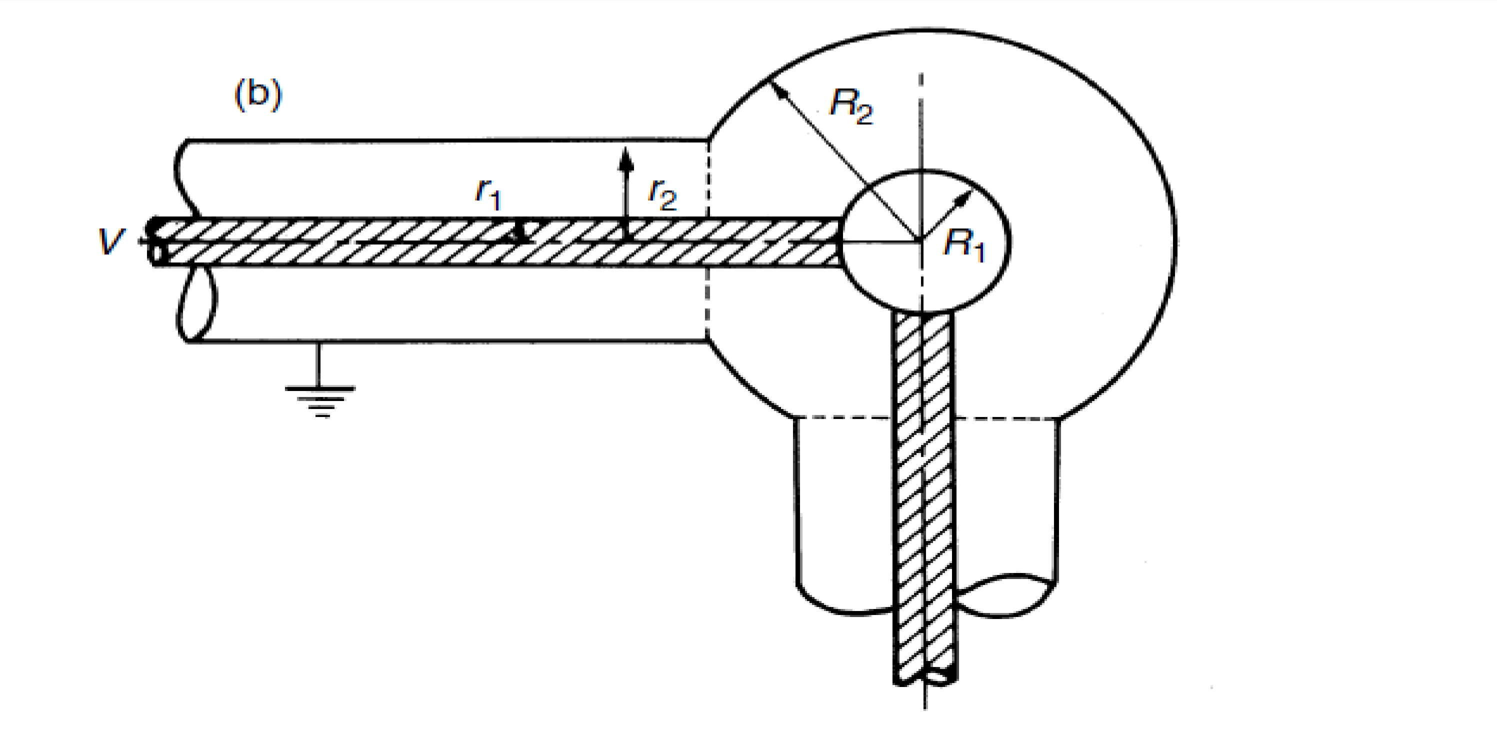
$$E_{\max} = \frac{V}{R_1(1 - R_1/R_2)}.$$

$E_{\max}$ is reached for $x = r_1$ or $x = R_1$

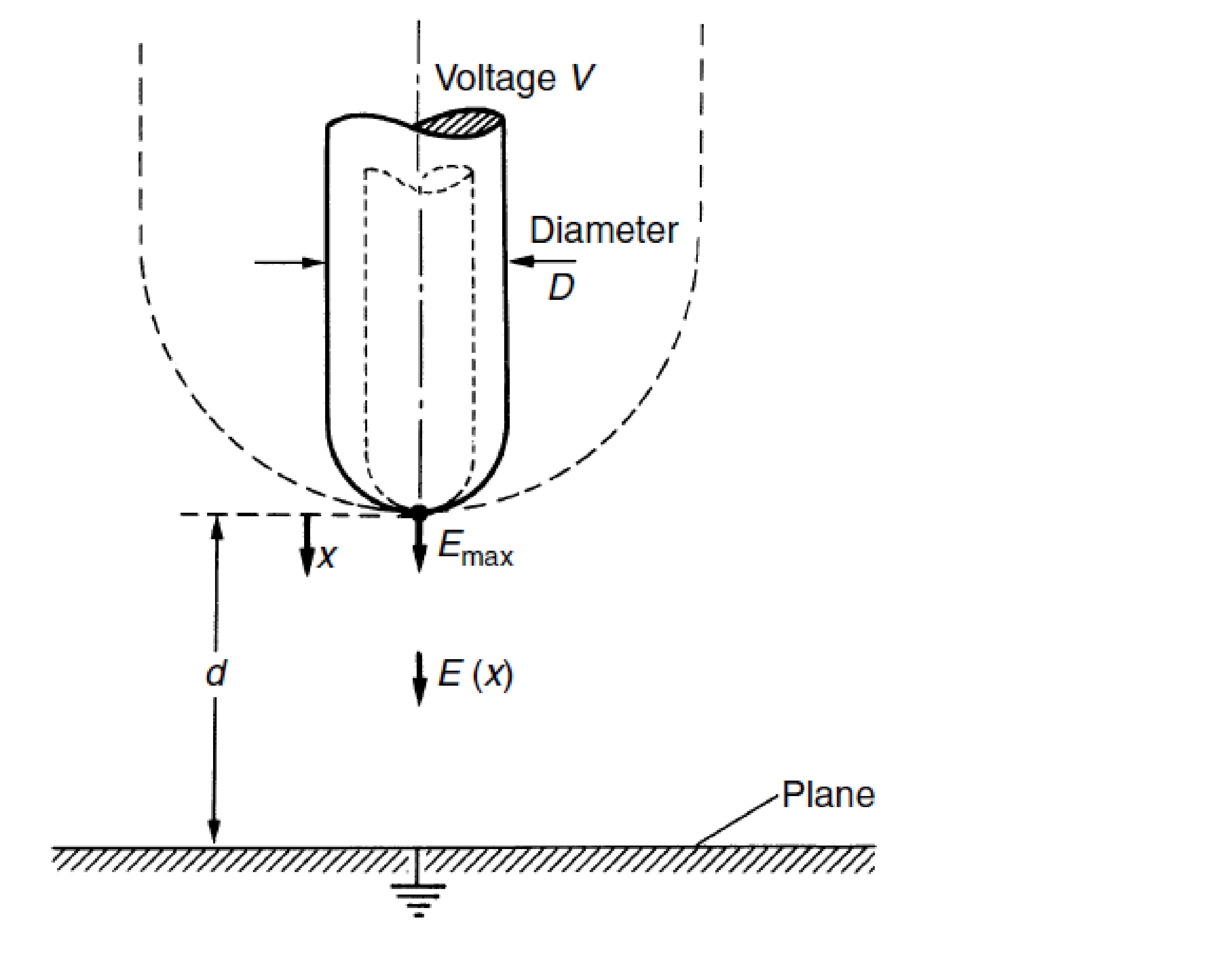
380 KV GIS

GIS geometry

Busbars for SF6-insulated, metal-enclosed equipment (GIS) are typical coaxial cylindrical arrangements. If the busbar must change the direction, a ‘knee’ or elbow will be necessary, as shown in Figure



Field factor f for a non-uniform geometry



$$f = \frac{E_{mean}}{E_{max}} = \frac{V}{dE_{max}}$$

Vb = E*max* d f = E*b* d f

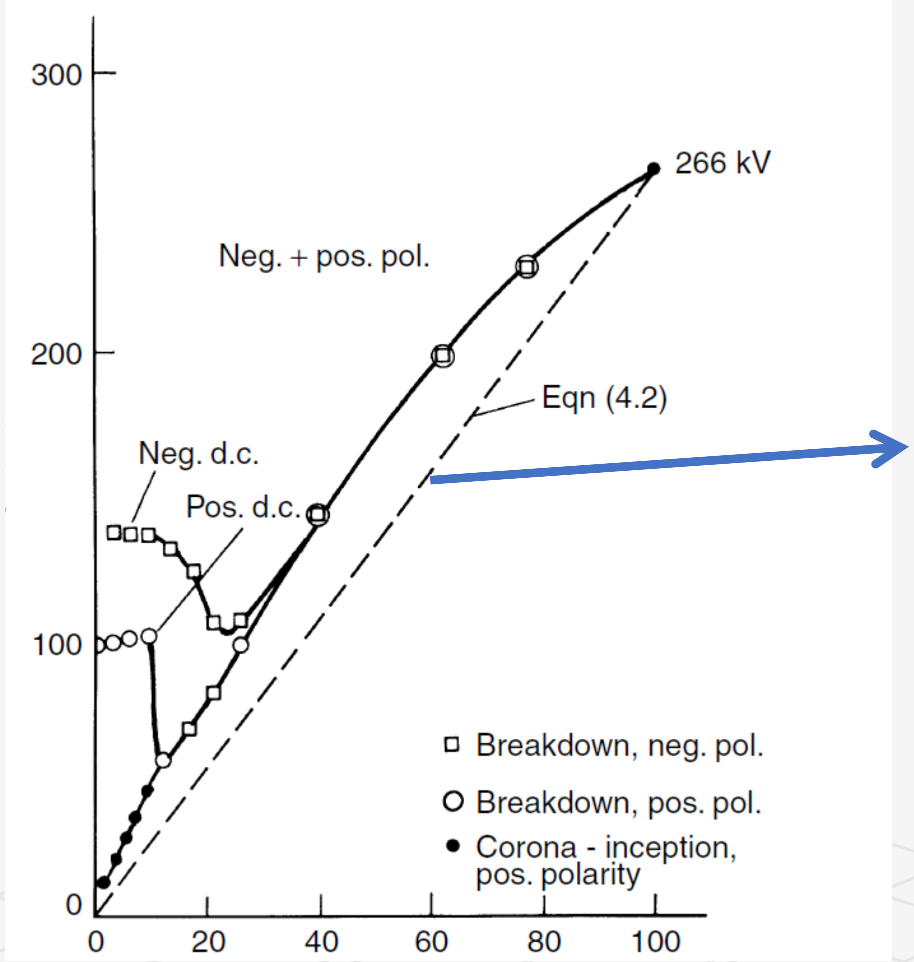
(Emax = Eb)

Breakdown Stresses in Non- Uniform Geometries

In general, breakdown stresses are dependent upon the field distribution within high field regions,

Thus, models representing only those regions in which high stresses occur are, in general, sufficient; this offers definite advantages ,as the models can be reduced in size using electrode configurations in which the low field regions are absent

Breakdown Voltage of Air atmospheric pressure wrt Field Factor with d= 10 cm



F %

Vb = *Emax* d f = E*b* d f

Field factor for coaxial and spherical geometry

$$f = \frac{1}{\left(\frac{r_2}{r_1} - 1\right)} \ln\left(\frac{r_2}{r_1}\right).$$

coaxial

$f = E_{mean} / E_{max}$

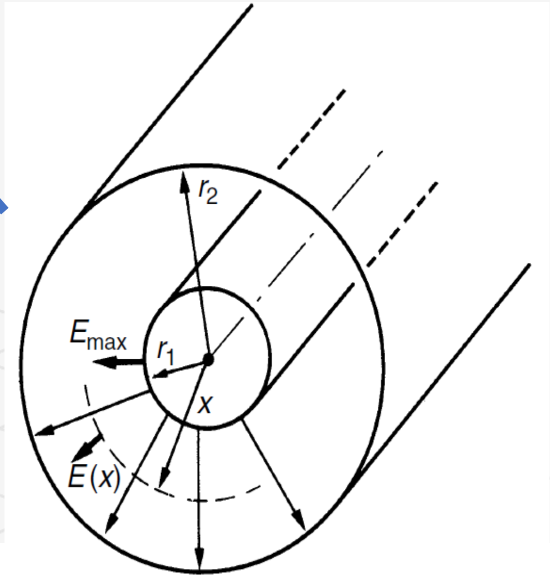
$E_{mean} = V / (r_2 - r_1)$

$$E_{max} = \frac{V}{r_1 \ln(r_2/r_1)}$$

Vb = E_{max} d f = E_b d f

Breakdown Voltage

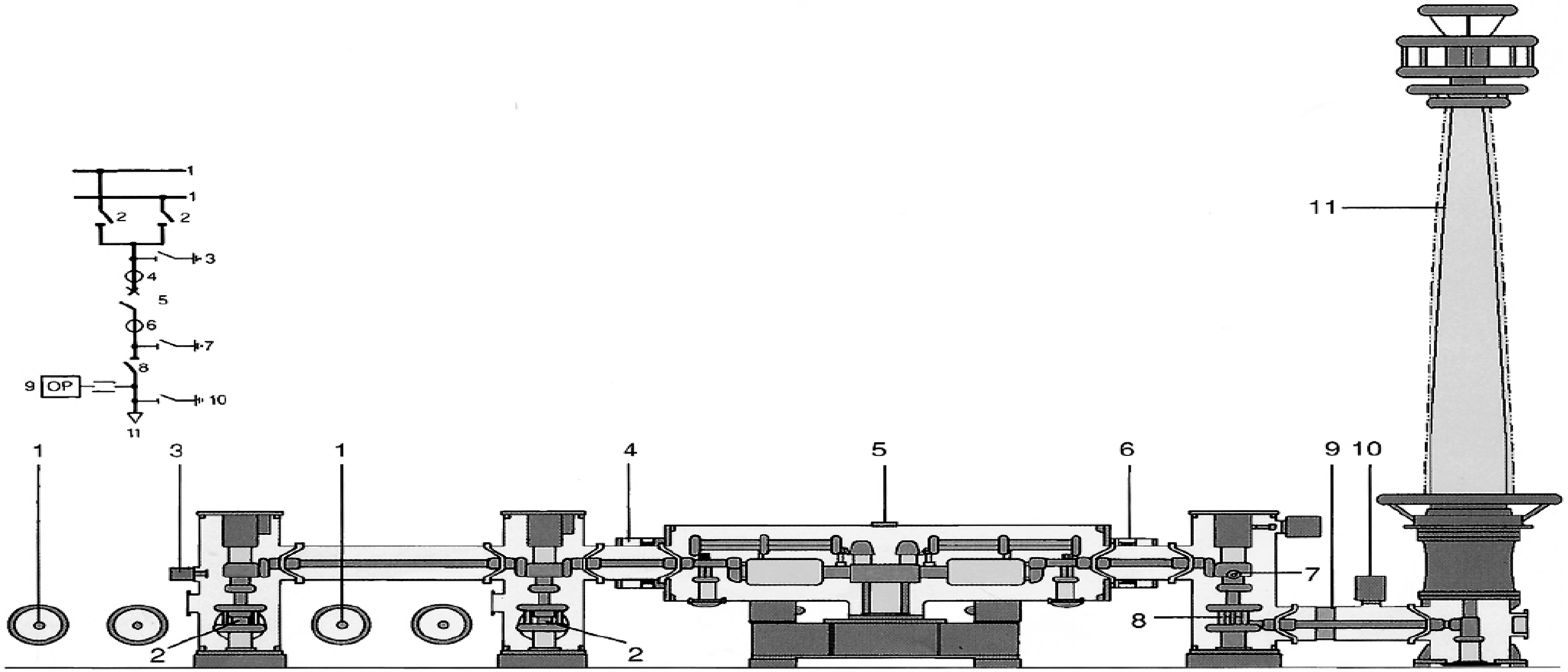
f = R1 / R2 spherical



1100 kV SF 6 gas insulated substation (GIS), courtesy Toshiba, Japan.

(a)

1100 kV GIS Sectional View (Toshiba, Japan)



1: Busbar
2: Busbar disconnector
3: Maintenance earthing switch
4: Current transformer
5: Circuit breaker
6: Current transformer
7: Maintenance earthing switch
8: Disconnector
9: Optical potential device
10: Earthing switch
11: Bushing

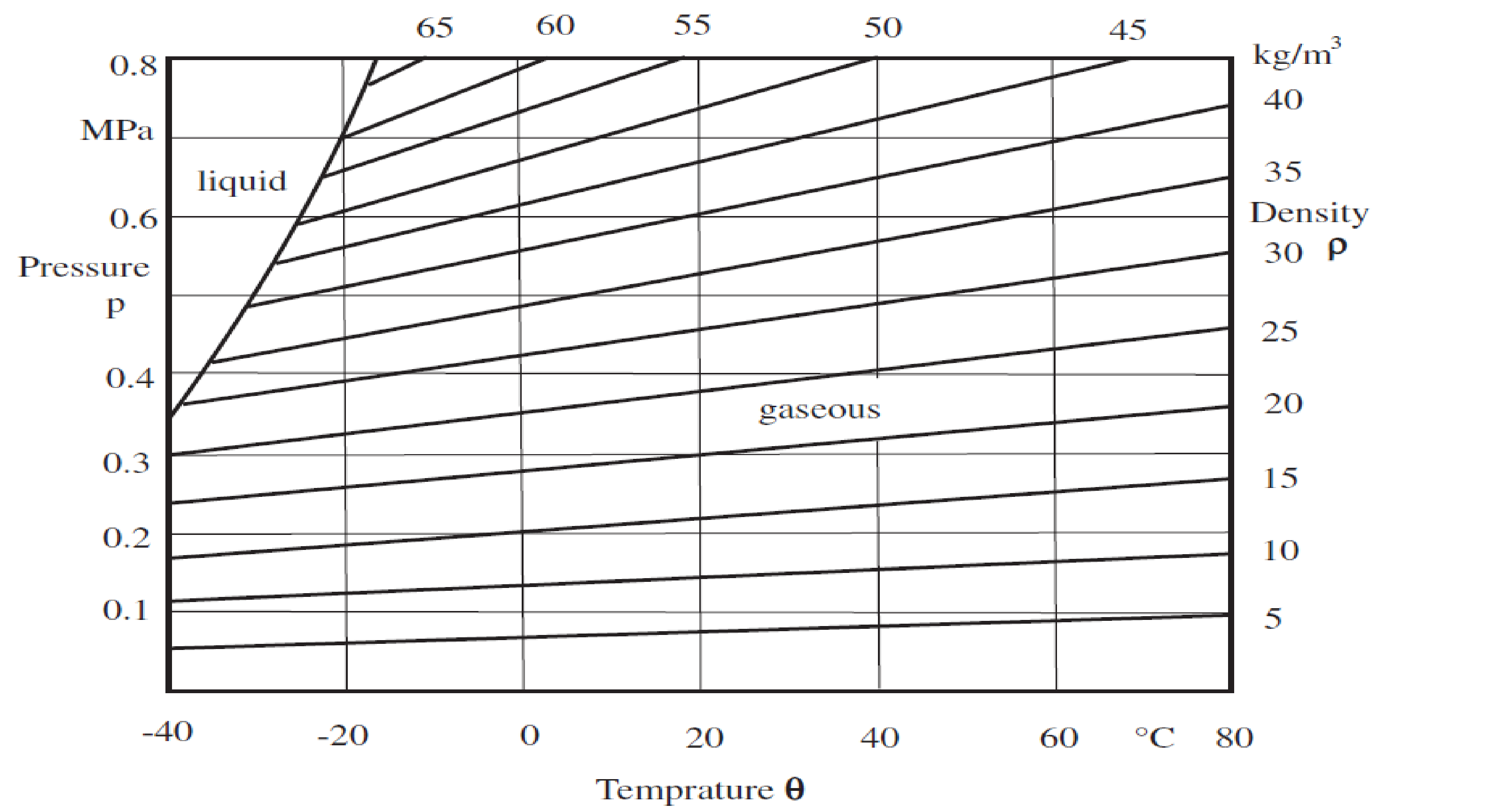
SF6 gas
Insulators
Live parts
CT/PT
Eathed parts

1,100 kV GIS Sectional view of a bay with double busbar system

SF6 LOADING PRESSURE

Over the working temperature range of – 30 ° to + 60 ° C and design pressure conditions, liquefaction of the gas should not take place. Liquefaction of the gas reduces the gas pressure in the enclosed volume, considerably affecting the dielectric strength.

1 megapascal = 10 bar



Calculation of Breakdown Voltage in Air

$$\alpha d = \ln\left(\frac{1}{\gamma}+1\right) = K$$

Breakdown Criteria

$$\frac{\alpha}{p} = \frac{1}{pd}\ln\left(\frac{1}{\gamma}+1\right) = \frac{K}{pd}$$

$$\frac{K}{pd} = C\left[\frac{E}{p} - \frac{E_c}{p}\right]^2$$

$$\frac{E}{p} = \frac{E_c}{p} + \sqrt{\frac{K/C}{pd}}$$

Thus the expression for breakdown voltage in uniform fields can be given as,

$$\frac{\alpha}{p} = C\left[\frac{E}{p} - \frac{E_c}{p}\right]^2$$

$$V_{\textbf{breakdown}} = \left(\frac{E_c}{p}\right)pd + \sqrt{\frac{K}{C}}\sqrt{pd}$$

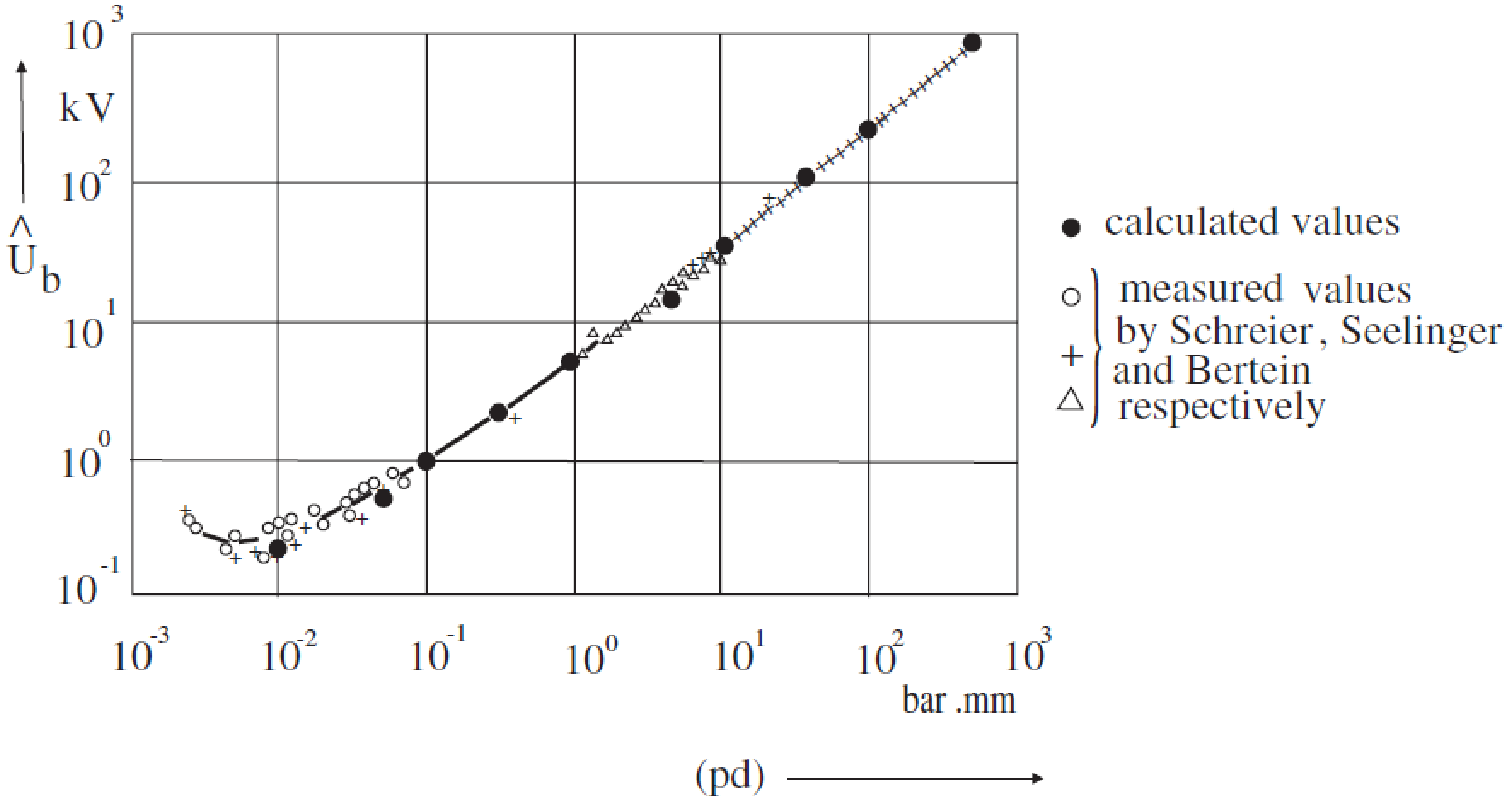
For Air over a wide range of E/P

$$\widehat{E}_c = 24.36 \text{ kV/cm}$$
$$K/C = 45.16 \text{ (kV)}^2/\text{cm}\cdot\text{bar}$$

$$V_{\textbf{breakdown}} = 6.72\sqrt{pd} + 24.36(pd) \quad \text{kV}$$

where p is given in bar and d in cm, therefore pd in bar.cm.

Paschen Curve in Air



External Insulation correction for ambient conditions

Correction for the variation in ambient conditions of air can be made by introducing the factor of " relative air density " defined as,

$$\delta = \frac{p}{760} \cdot \frac{293}{273+t} = 0.386 \frac{p}{273+t}$$

where p is in Torr and t in ° C.

At normal temperature (t = 20 *degrees C*) and pressure (p = 760 Torr), δ is equal to one.

The breakdown voltage at standard conditions multiplied by this factor gives the breakdown voltage corresponding to the given ambient conditions approximately

$$V_b(\delta) = \delta V_b(\delta = 1)$$

Reference

High voltage and electrical insulation engineering / Ravindra Arora, Wolfgang Mo

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