Wuhan University of Technology

《Blasting Engineering》
Excellent course

Chapter 3 Initiation materials and initiation methods

Main content

3.1 Basic conception

3.2 Method of ordinary detonator initiation

3.3 Method of detonating cord initiation

3.4 Method of Nonel detonator initiation

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3.1 Basic conception

initiation power

Although the explosive belongs to the unstable chemical system, it can detonate only under an certain outside energy, which is called initiation power.

Initiation materials ——used to initiate the explosive。

Type of initiation materials:

The initiation materials in blasting engineering including: detonator, safety fuse, detonating cord, Nonel, connector of Nonel, detonating relay and initiation charge, etc.

- **Initiation material（detonators）**
- **Propagation material of detonation（safety fuse、Nonel ）**

（detonating relay、detonating cord）

Industrial detonator

blasting cap

The blasting cap enclosed the primary explosive shelled initiates the explosive by its explosion detonated by ignition device.

There are 10 grades of blasting cap based on charge amount, the higher the number, the stronger .

Common：No. 8 blasting cap and No.6 blasting cap

No. of blasting cap	Ingredient						
	Primary explosive			Secondary explosive			
	Charge amount/g						
	DDNP	Mercury fulminate	Lead azide	Hexogen (or passivation hexogen)	Tetryl	Hexogen-TNT	Tetryl-TNT
No. 6	0.3±0.02	0.4±0.02	0.1±0.02 0.21±0.02	0.42±0.02	0.42±0.02	0.5±0.02	—
No. 8	0.3~0.36 ±0.02	0.4±0.02	0.1±0.02 0.21±0.02	0.7~0.72 ±0.02	0.7~0.72 ±0.02	0.7~0.72 ±0.02	0.7~0.72 ±0.02

Common blasting cap

The common blasting cap in engineering blasting: plain detonator, electric detonato and non-electric detonator.

Electric detonator, Electromagnetic detonator, Electronic detonator

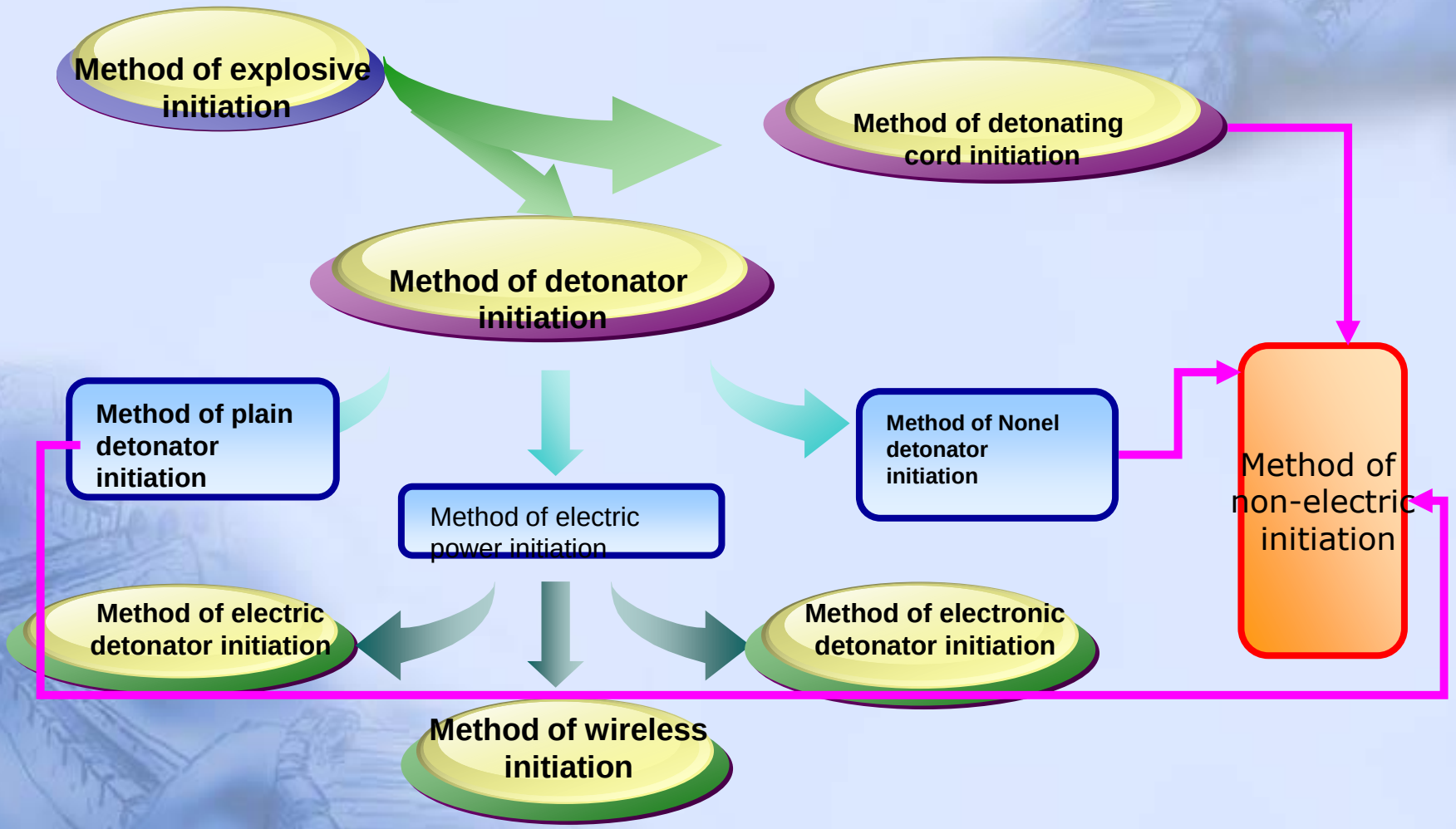
Instantaneous electric detonator,
Second or half-second delay detonator,
Millisecond delay detonator

Two aspect requirements

（1）aspect of technology condition

（2）aspect of manufacture and economy condition

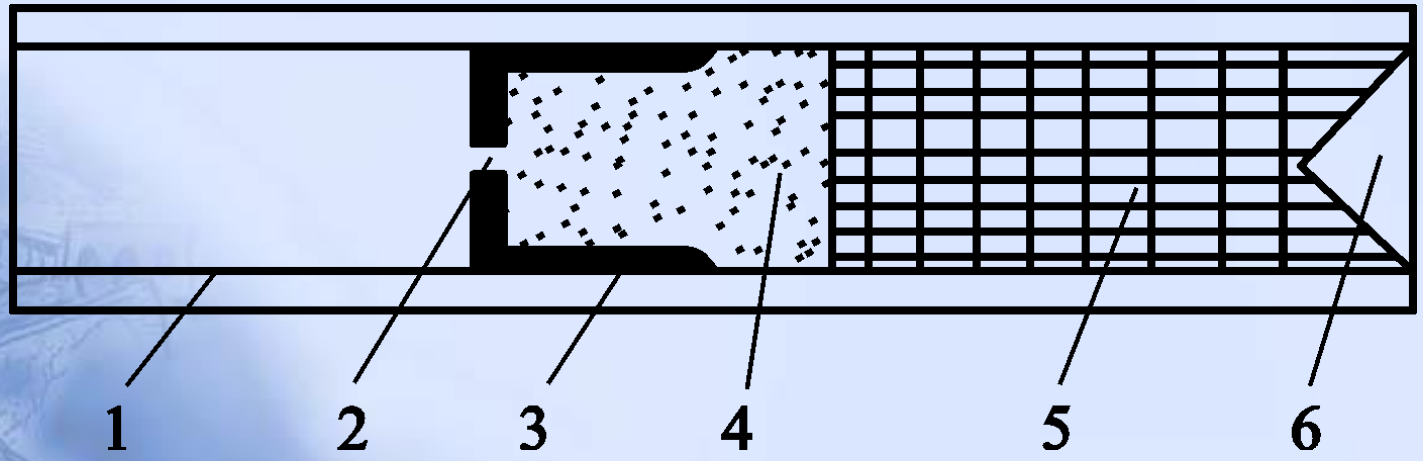
Classification of initiation method



3.2 Method of plain detonator (Ordinary detonators) initiation

The method of plain detonator initiation is the plain detonator detonation by means of a safety fuse.

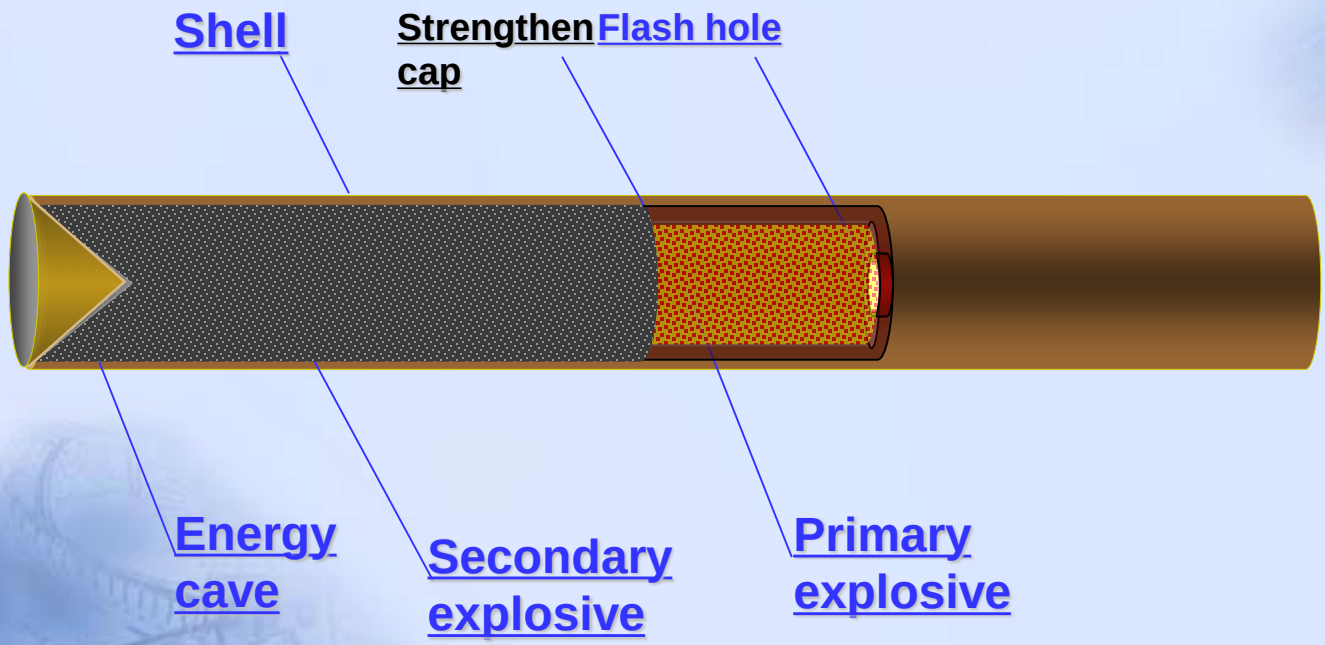
Three parts of method of plain detonator initiation is safety fuse, plain detonator and ignition material .



Plain detonator

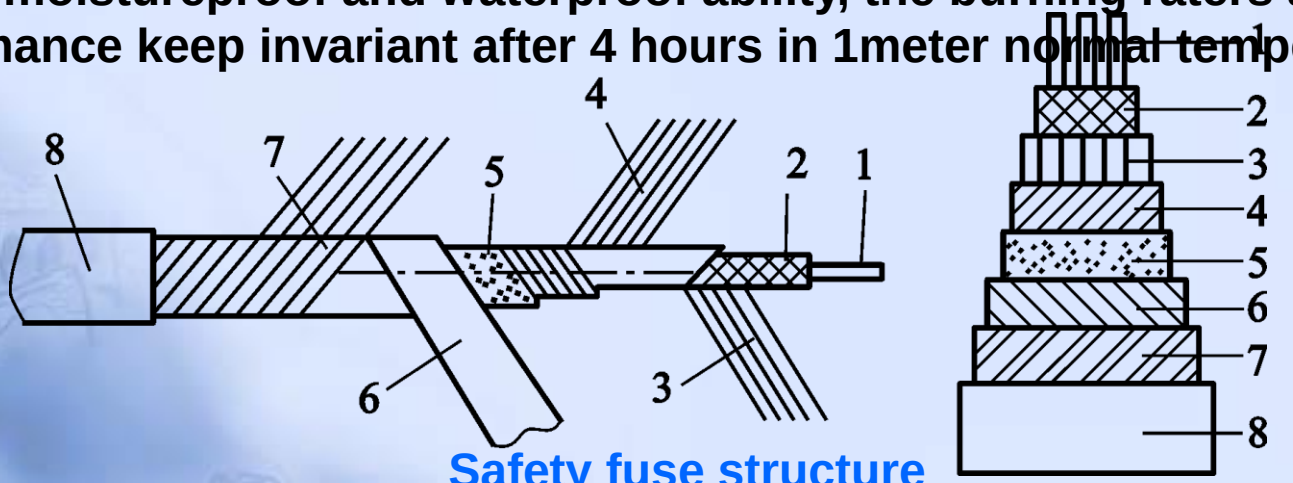
1- cap shell; 2-flash hole; 3-sealing cap; 4- primer charge; 5-base charge; 6- energy cavity

Plain detonator



Safety fuse

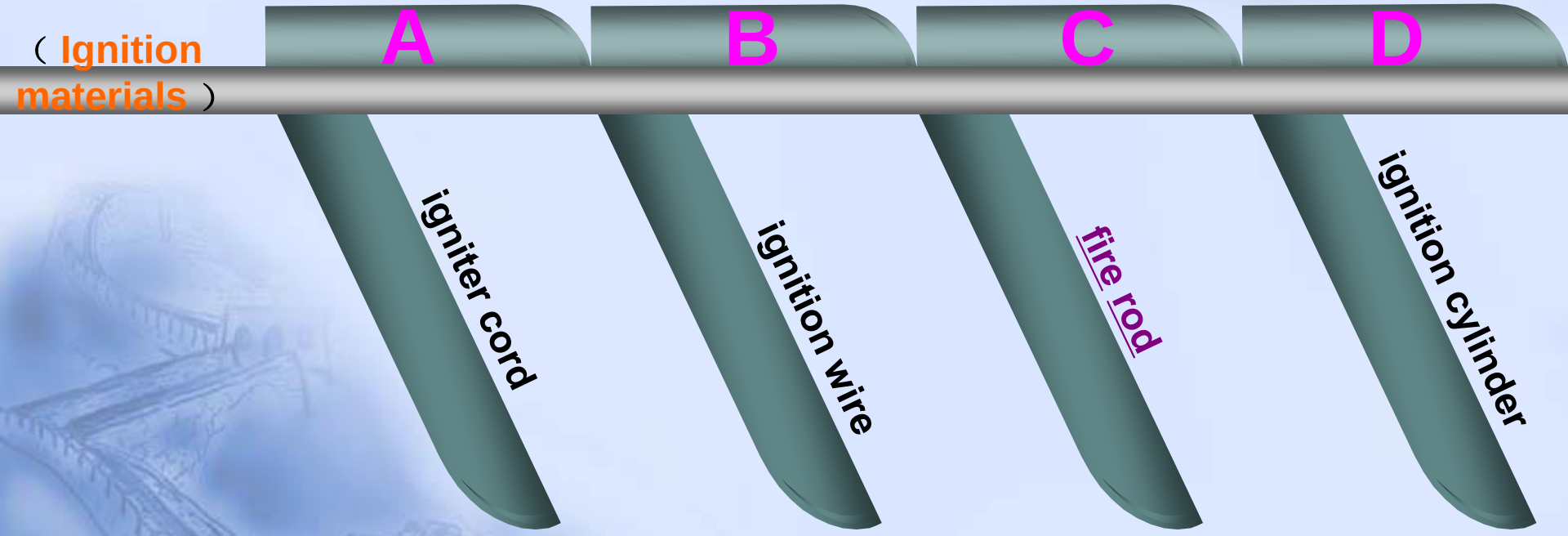
The safety fuse is visually white, and its outer diameter is the range of 5.2 to 5.8mm, the core load is 7~8g/m. the burning rates for fuses are in the range of 100 to 125s/m. For assuring initiate the plain detonator, the flaming of fuse is no less than 40mm. The fuse should be no cutoff, fire reveal, combustion of outer shell, quick burning and deflagration during the combustion process. The burning rates and the performance of furs are two important marks of quality. The safety fuse should be a certain moistureproof and waterproof ability, the burning raters and performance keep invariant after 4 hours in 1meter normal temperature water.



Safety fuse structure

1-corewire; 2-powder core; 3-innerwire layer; 4-mid-layer; 5-waterproof layer; 6-scrip layer; 7- outerwire layer; 8-dope layer

Ignition materials



Construction technology of plain detonator initiation

- **A Making of plain detonator**
- **B Making of igniting primer cartridge**
- **C Construction technology during ignition process**

1. when solo igniting, the number (groups) of fuse ignited by one person: no more than 5 under ground blasting, and no more than 10 in open blasting.

2. the length of safety fuse should assure the personnel remove to safety place after igniting all of fuse, but the shortest should shouldn't shorter than 1.2m.

3. the checker just enter into the blast site after more than 5 min from the last charge detonation.

4. if it can't affirm existing misfire, the checker could enter the blast site after 15min .

3.3 Method of detonating cord initiation

Detonating cord

Detonating cord is a narrow core of single high explosive Hexogen and pentaerythrite tetranitrate enclosed in a woven cover of polymer yarns and extruded plastics.

The detonating cord strong to initiate the commercial explosive, the circuit of detonating cord could initiate group charges, but it should be ignited by detonator firstly. This method is non-electric initiation method.

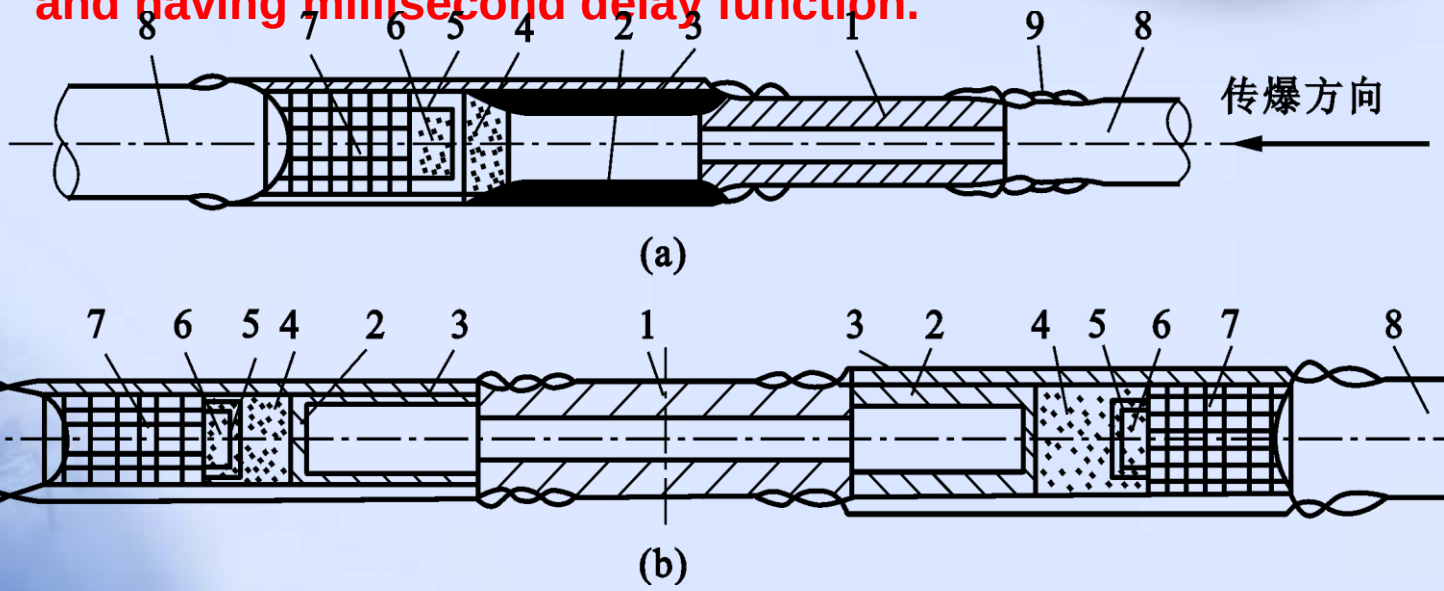
Classification of detonating cord

1. Common detonating cord
2. Safety detonating cord
3. Oil well detonating cord
4. Lead-antimony tube detonating cord
5. Seismic cord

Detonating relay function and structure

Detonating relay

The detonating relay is used cooperatively with detonating cord and having millisecond delay function.



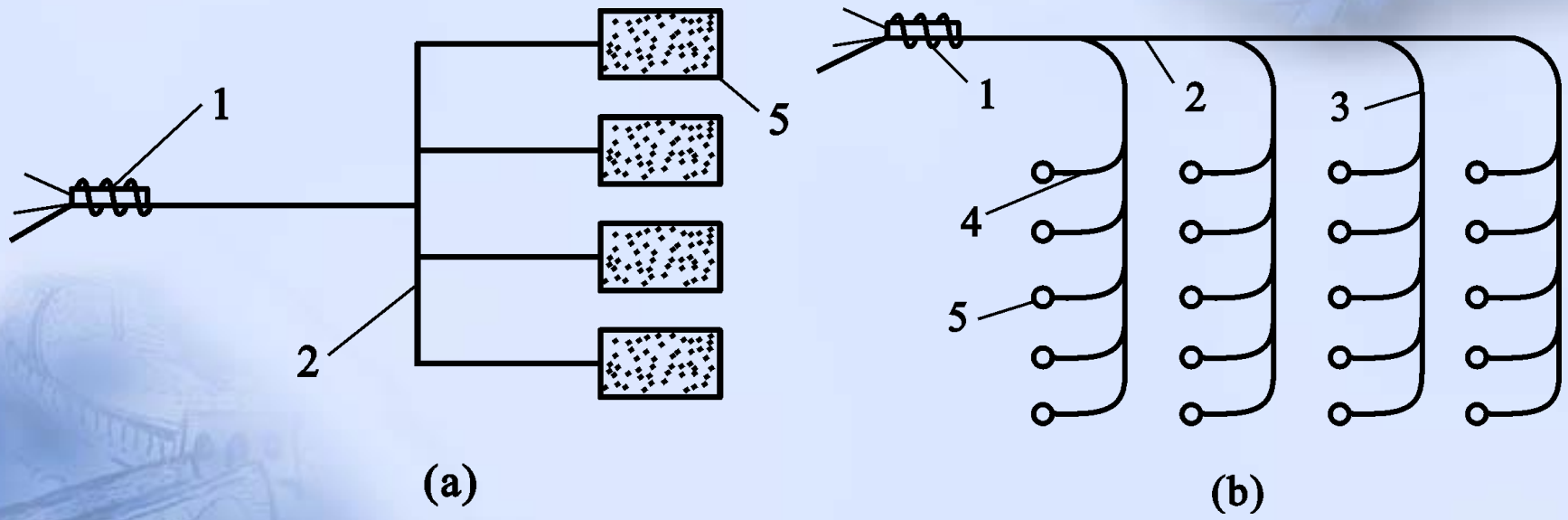
Detonating relay structure

a **Uni-directional relay** ； b **Bi-directional relay**

ation-subside tube；2—big inner tube；3—outer sleeve；4—delay charges；5—strengthe

6—primary explosive；7—secondary explosive；8—detonating cord；9—connecting tube

Initiation circuit of detonating cord（1）

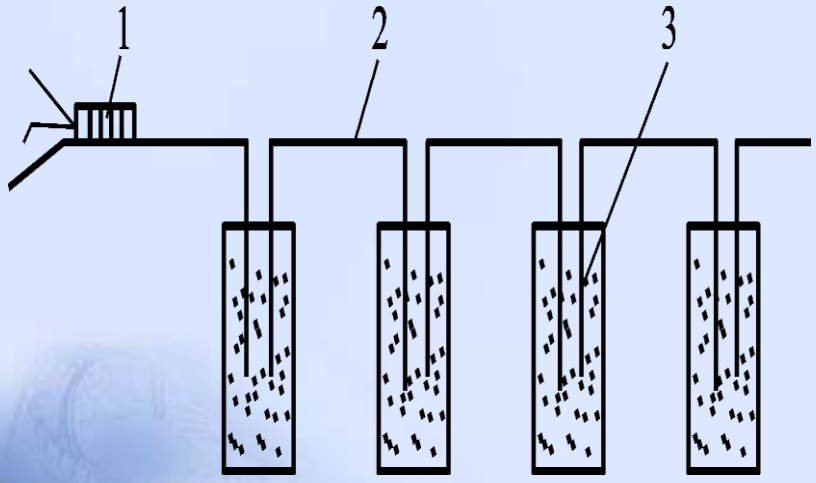


Parallel circuit of detonating cord

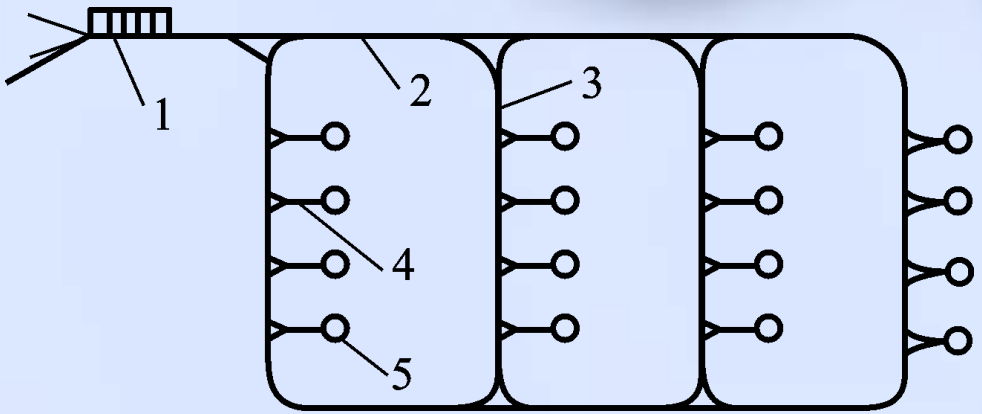
（a）Parallel-bunch; （b） Segmentation-parallel

—detonator； 2—trunkline cord； 3—downline cord； 4—in-hole cord； 5—cartridg

Initiation circuit of detonating cord （2）

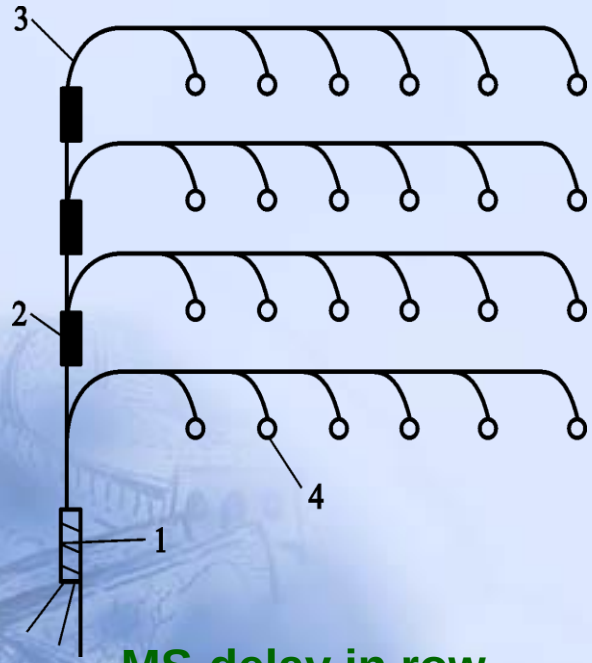


Series of detonating cord
1—detonator； 2—detonating cord；
3—cartridge



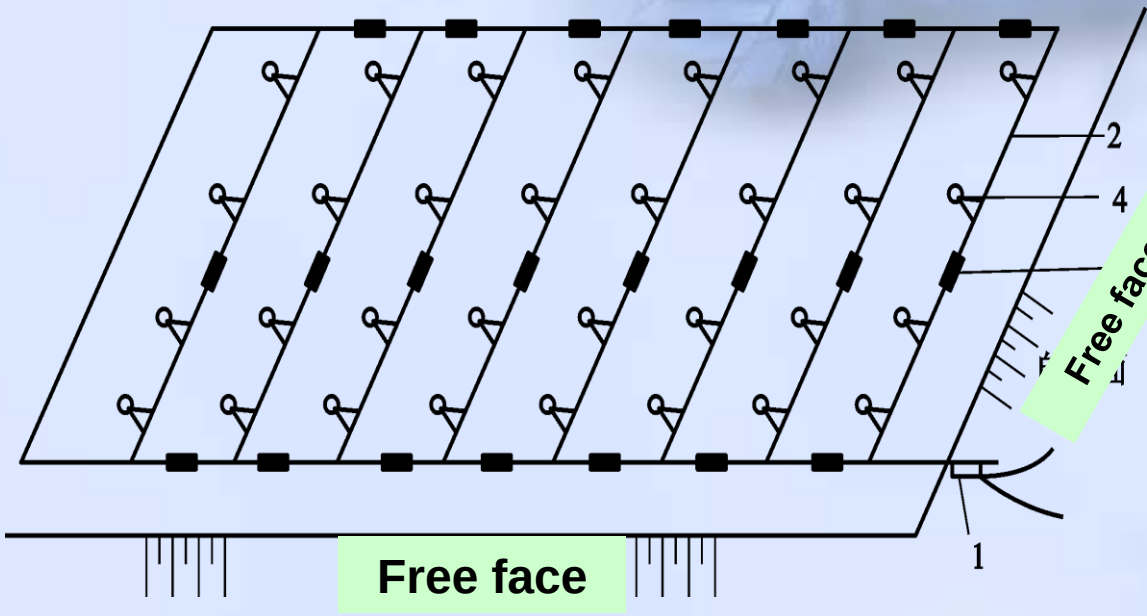
Segmentation-parallel of bi-direction
1—detonator； 2—trunkline cord；
3—downline cord；
4—initiated cord； 5—cartridge

Initiation circuit of detonating cord （3）



MS-delay in row

1—detonator 2—detonating relay
3—detonating cord 4—cartridge



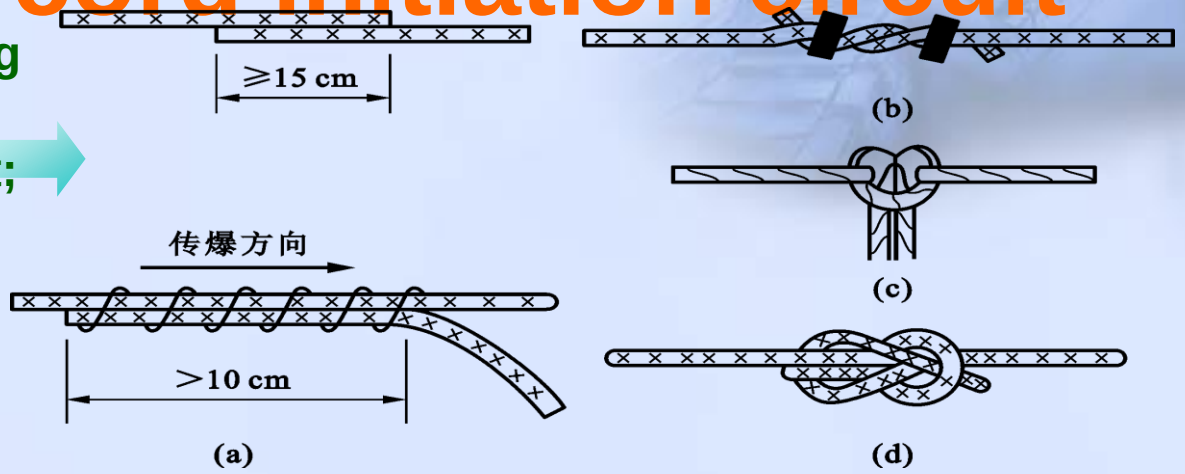
Detonating cord- detonating relay circuit

1—detonator； 2—detonating cord；
3—bi-directional detonating relay 4—cartridge

Construction technology of detonating cord initiation circuit

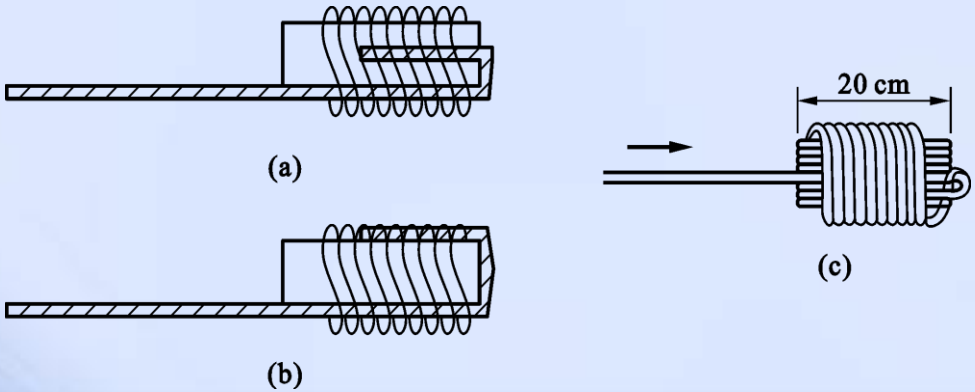
1.Connection type of detonating cord

a）overlap joint；b）twist joint;
c）T-joint； d）sailor's knot



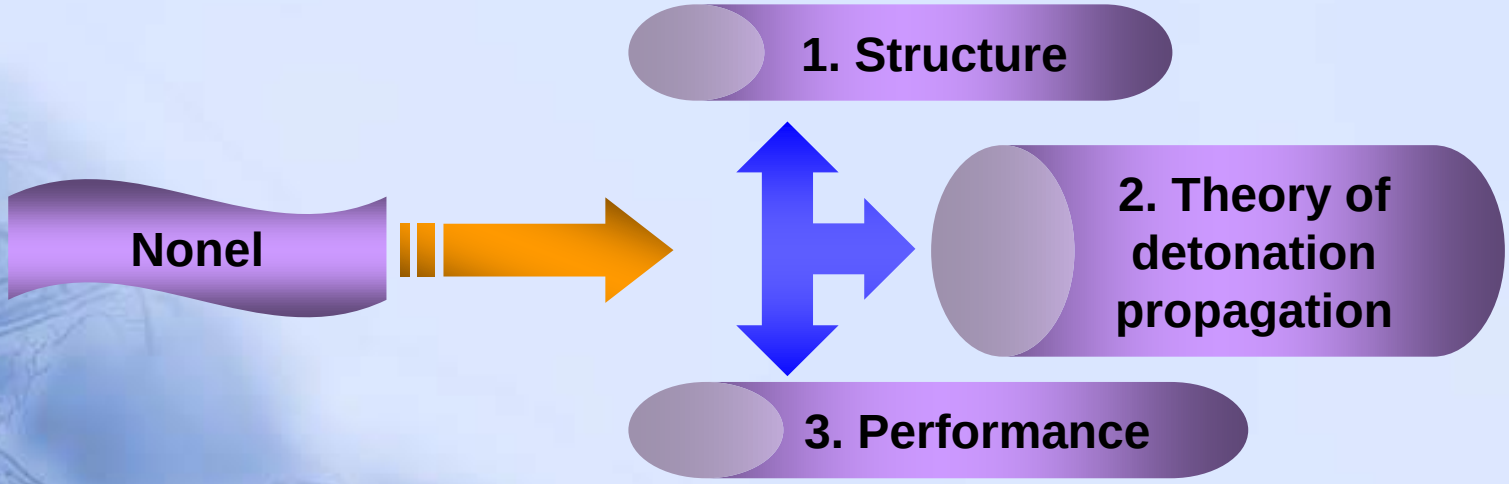
2.Connection technology of detonating cord

3.Connection of detonating cord with cartridge

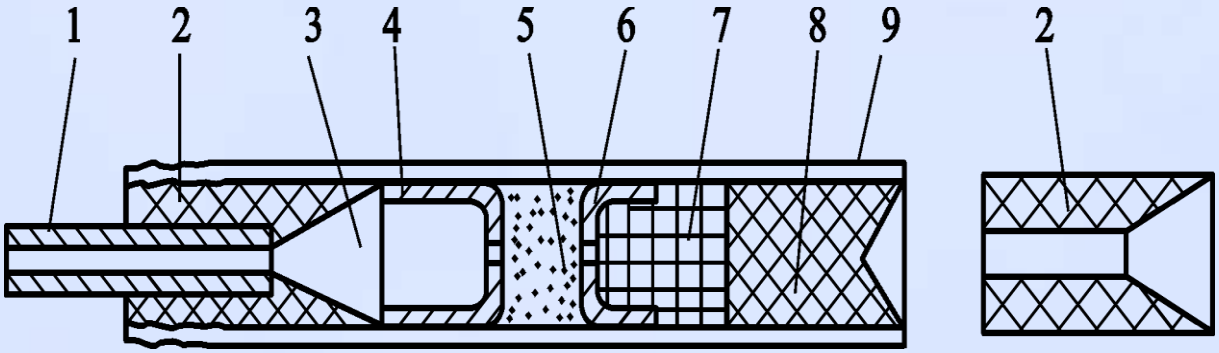


3.4 Method of Nonel detonator initiation

The Nonel detonator initiation system transmits the reaction-supported air shock wave in Nonel tube which ends in a detonator, then initiates the detonating cord or commercial explosive. It is non-electric initiation method.



Nonel detonator

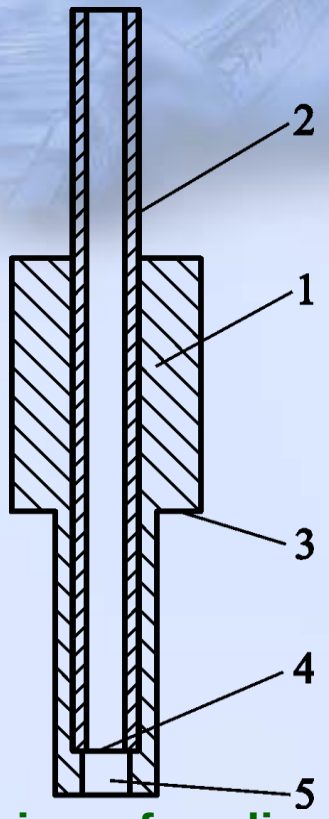


a. non-electric millisecond detonator structure

1-Nonel; 2-sealing plug; 3-cavity of detonation subside; 4-empty cap 5-delay charges；6-strengthen cap;7-primary explosive; 8-secondary explosive; 9-metal shell

c. Nonel detonator in hole and it's delay segments

（6）is MS 6



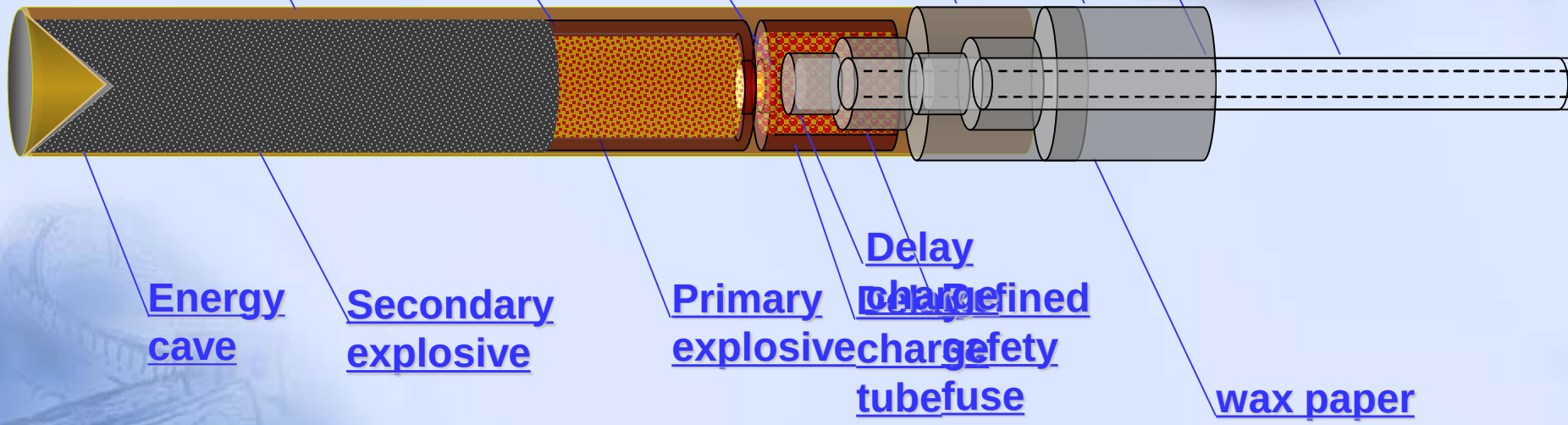
b. Enlarged view of sealing plug

1-communicating pipe;2-Nonel

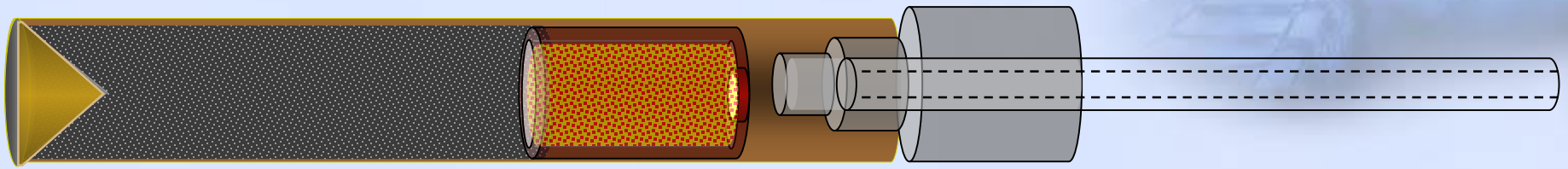
3- limit step of shell

4-limit step of Nonel5-nozzle hole

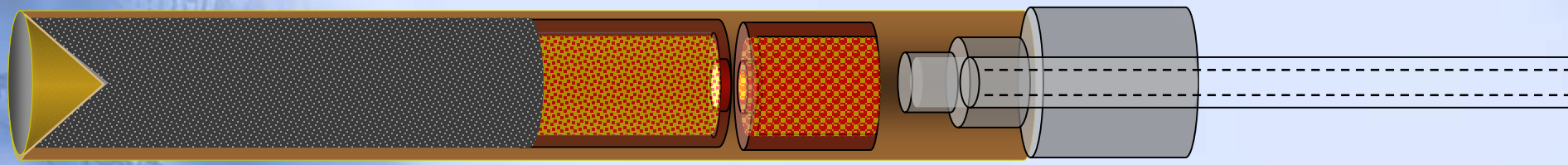
Plain detonator Instantaneous detonator Nonel short delay detonator Nonel detonator



Instantaneous Nonel detonator

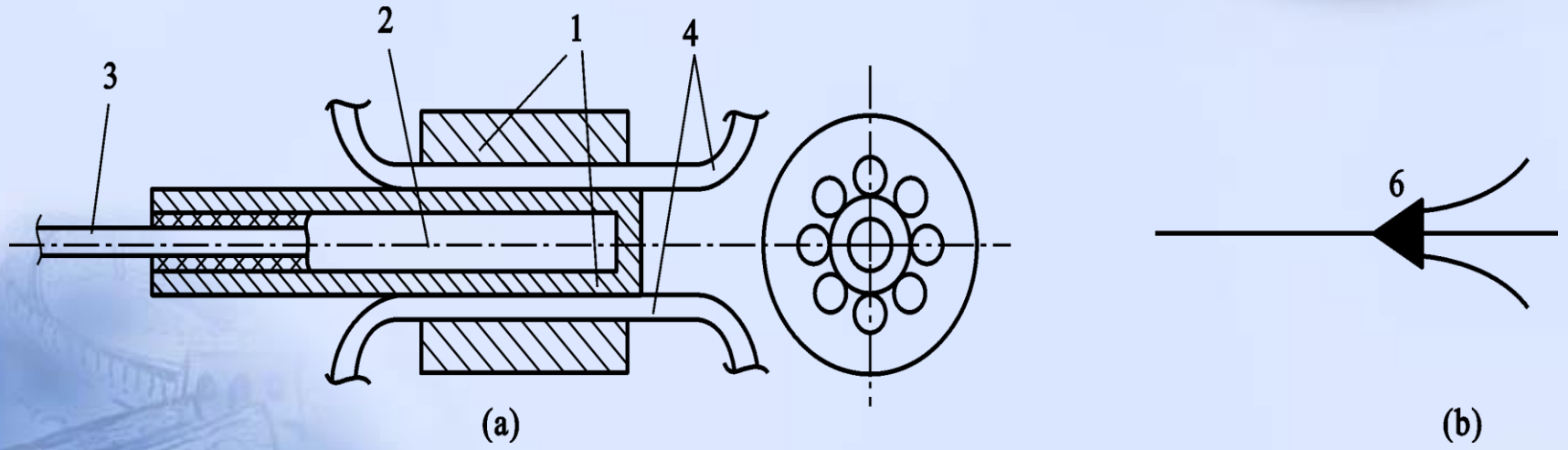


Nonel short-delay detonator



Connection elements of Nonel（1）

1. Link block



Link block with blasting cap

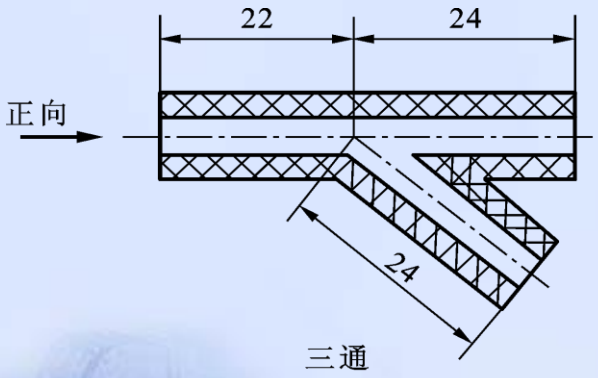
(a)Link block and Nonel assembled **(b)** Graphic method of joint with blasting cap

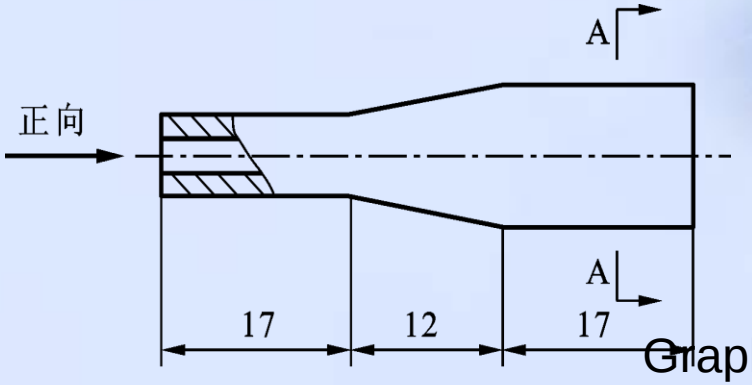
1—main part of plastic link block；**2**—blasting cap for propagation；

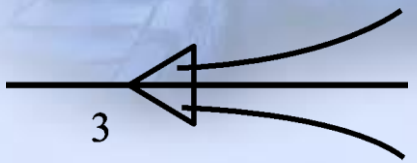
3—detonating Nonel ； **4**—detonated Nonel

Connection elements of Nonel （2）

2. connector

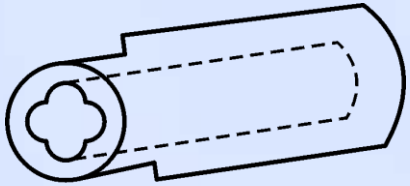






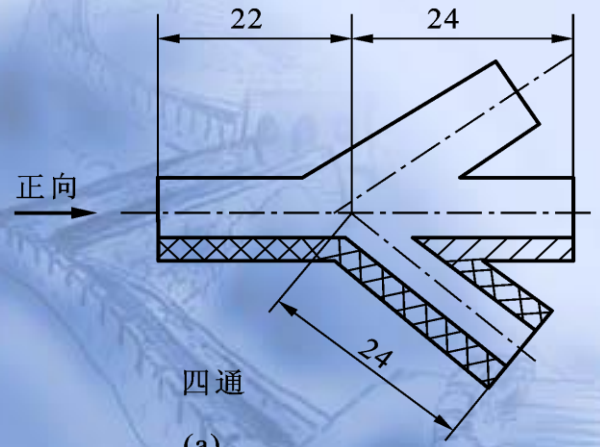
(c)

Graphic method of fork connec



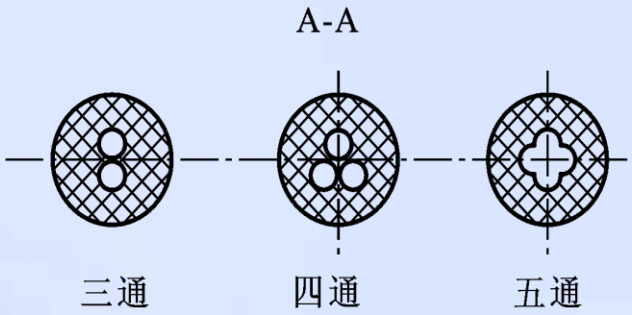
(d)

Regular reflection four away



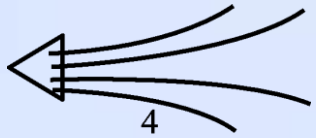
(a)

Fork connector



(b)

Cluster connector



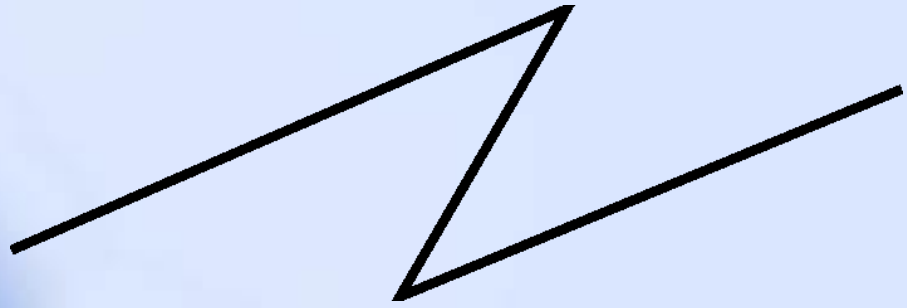
(e)

Graphic method of regular reflection joint

Ignition element of Nonel

Ignition elements are the devices for igniting the Nonel.

The ignition elements are usually marked in detonation position in Nonel blasting circuit. The mark as follow:



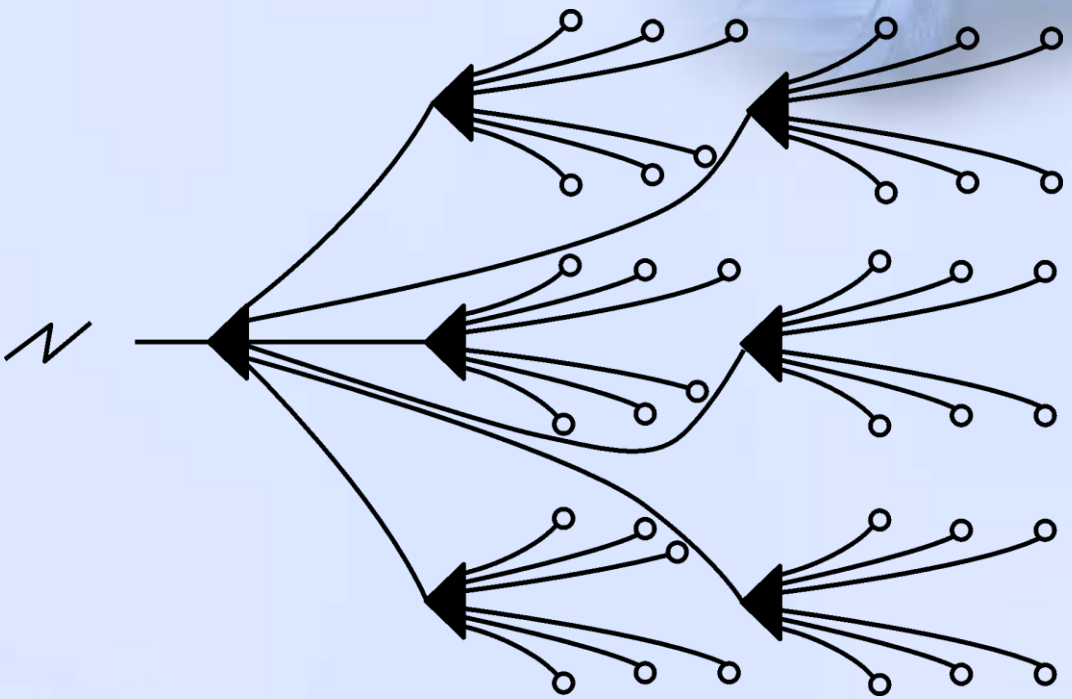
Graphic method of ignition position

Connection form of Nonel initiation circuit（1）

1. Cluster connecting

2.Parallel series connecting

3. Closed network connecting



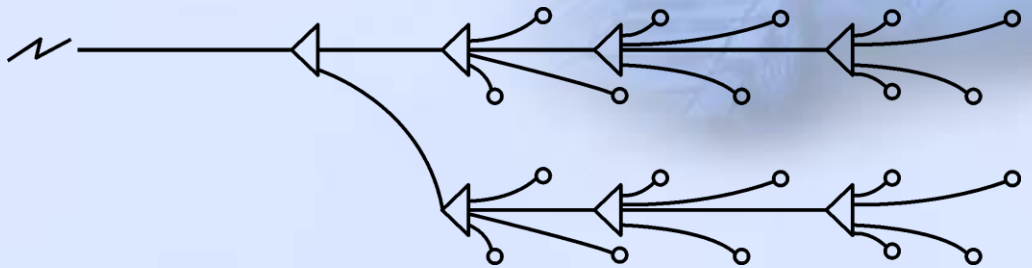
1. Cluster connecting of Nonel circuit

Connection form of Nonel initiation circuit （2）

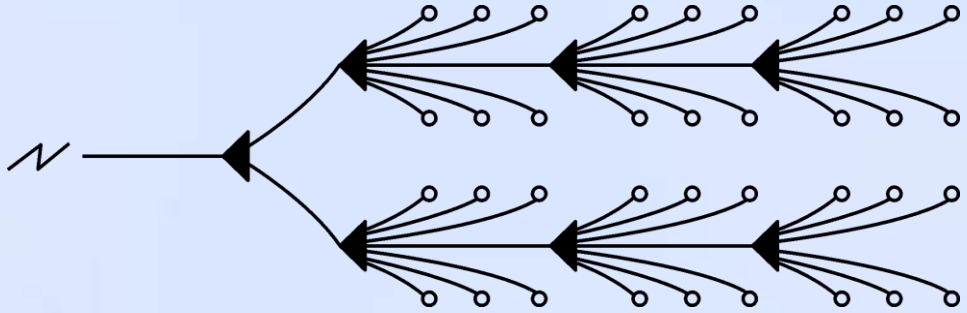
1. Cluster connecting

2.Parallel series connecting

3. Closed network connecting



2.1 Parallel series circuit of Nonel initiation with connector



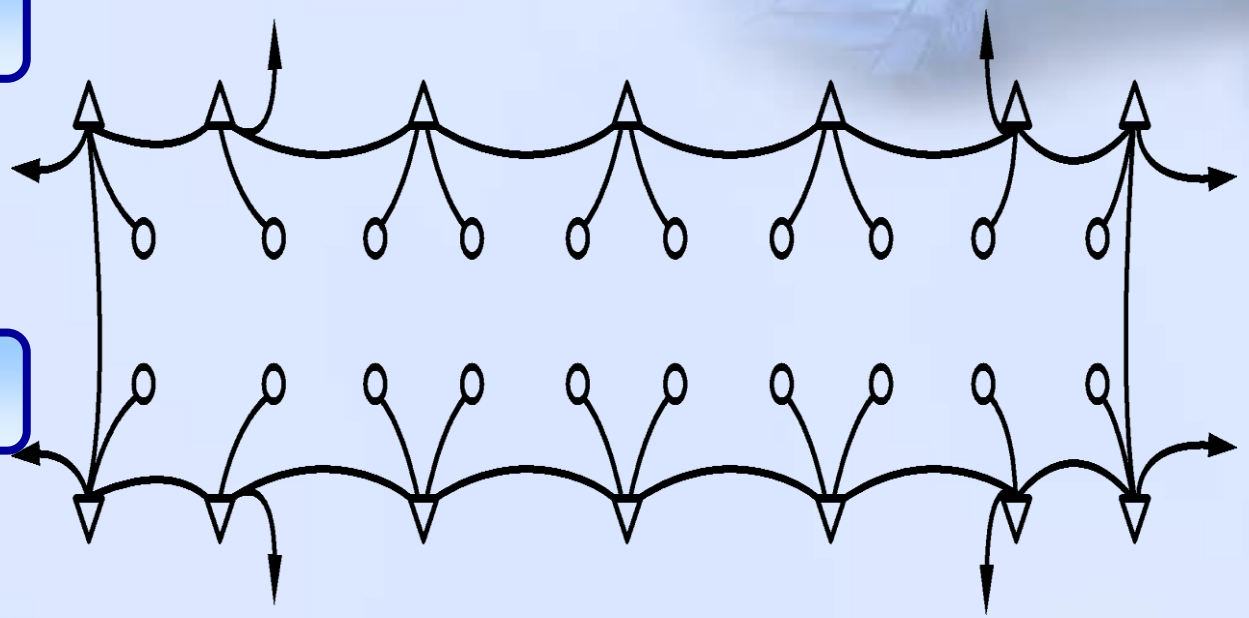
2.2 Parallel series circuit of Nonel initiation with link block

Connection form of Nonel initiation circuit （3）

1. Cluster connecting

2.Parallel series connecting

3. Closed network connecting



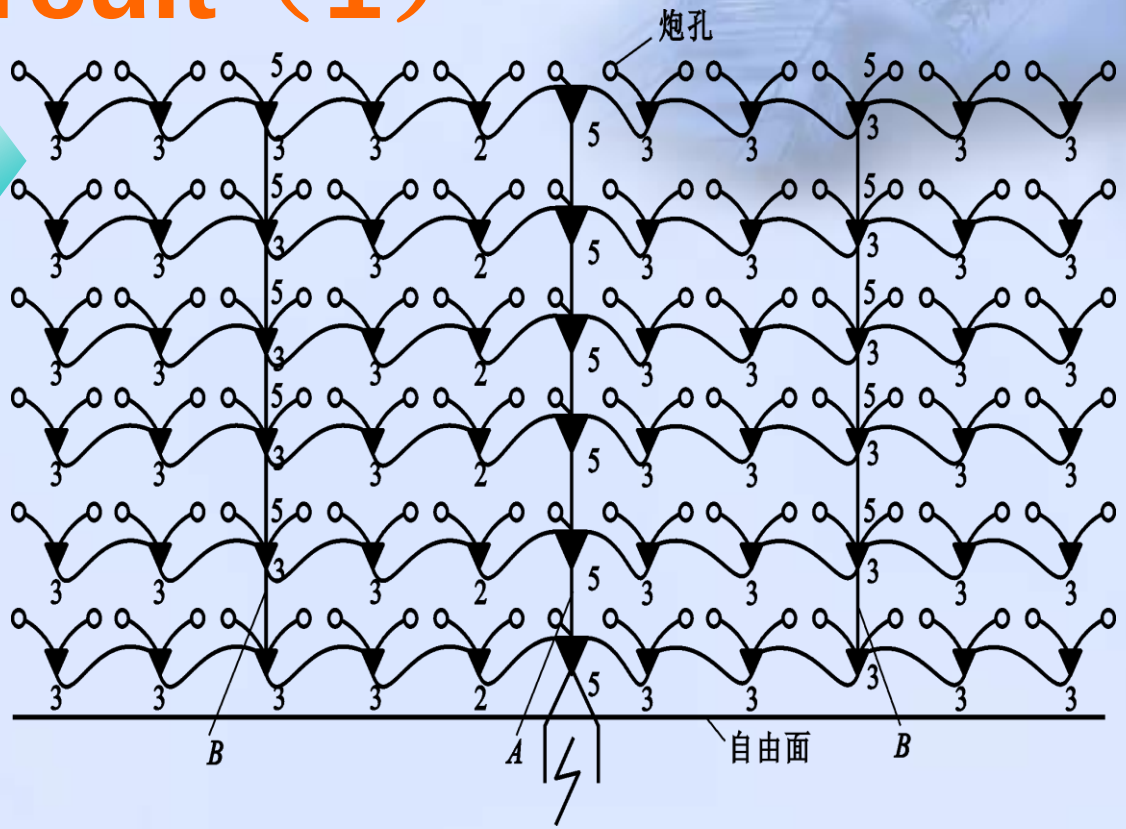
3. Closed network connecting with regular reflection four away

Nonel millisecond delay blasting circuit（1）

1.Outer hole delay blasting circuit

2.Inner hole delay blasting circuit

3.Inner and outer hole delay blasting circuit



Outer hole delay blasting circuit

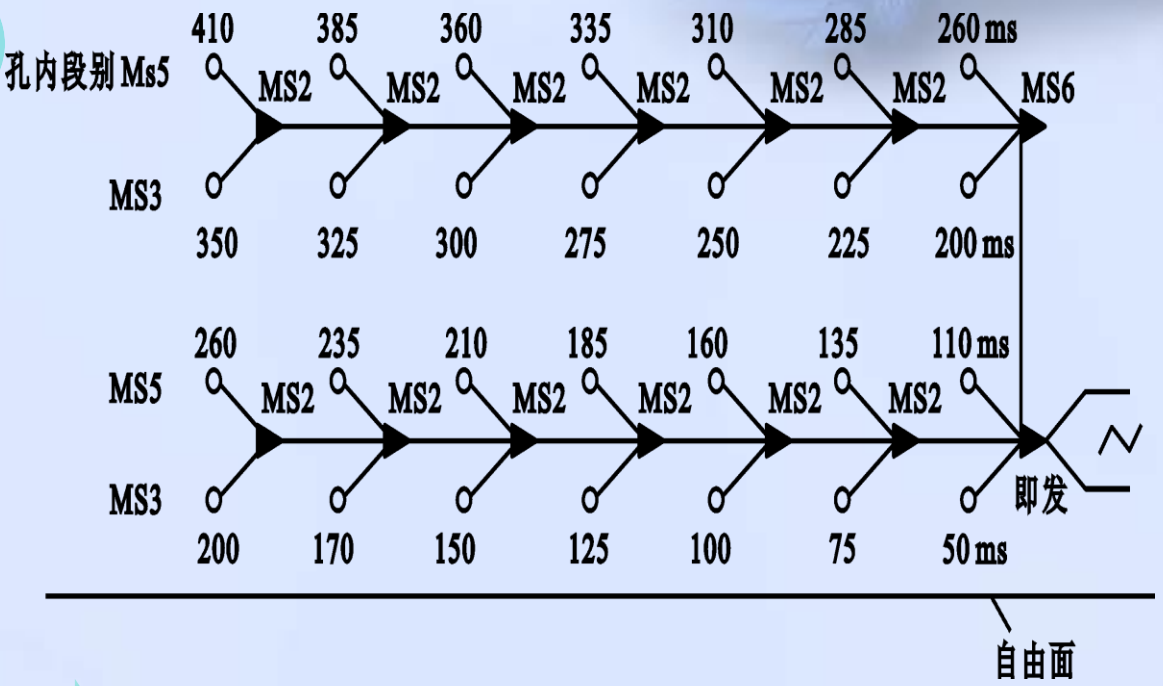
A—trunkline；**B**—branchline；MS10 in holes

Nonel millisecond delay blasting circuit （2）

1. Outer hole delay blasting circuit

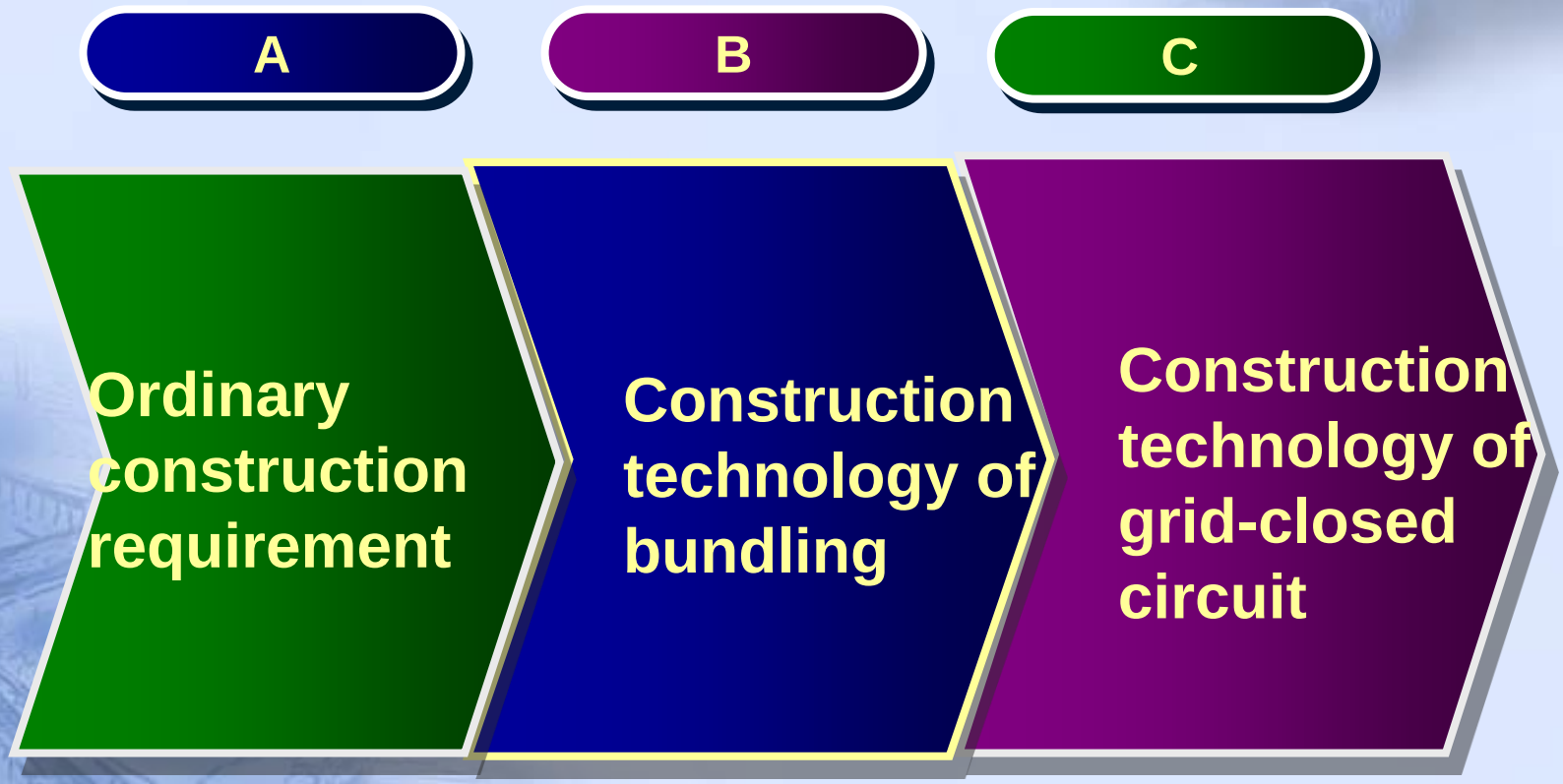
2.Inner hole delay blasting circuit

3.Inner and outer hole delay blasting circuit

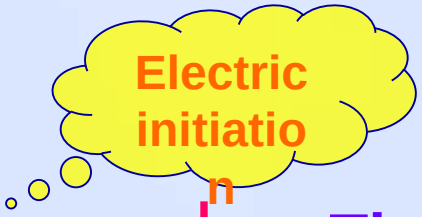


Different delay inner and outer hole blasting circuit

Construction technology of Nonel initiation circuit



3.5 Method of electric initiation



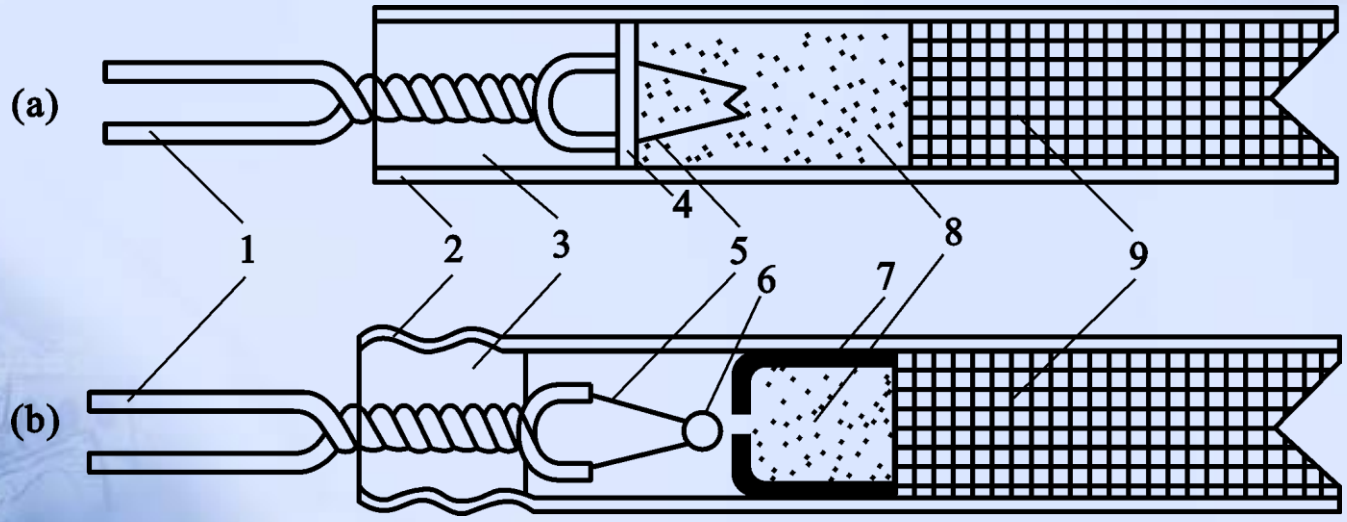
The method of electric initiation uses the electric energy igniting the blasting cap and then initiating the explosive directly or other way indirectly initiating explosive.

Compositions of electric initiation system:

electric detonator, wire, ignition power source and measuring meter

Classification of electric detonator（1）

1. Instantaneous electric detonator

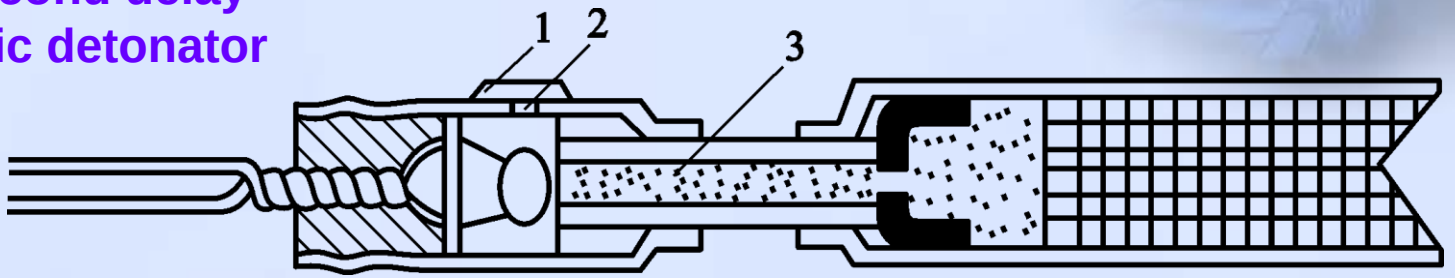


Instantaneous electric detonator

1-legwire;**2**-shell；**3**-sealing plug；**4**-paper pad；**5**-bridge wire；**6**-fuse head；**7**-strengthen cap;**8**-DDNP；**9**-primary explosive；**10**-secondary explosive

Classification of electric detonator（2）

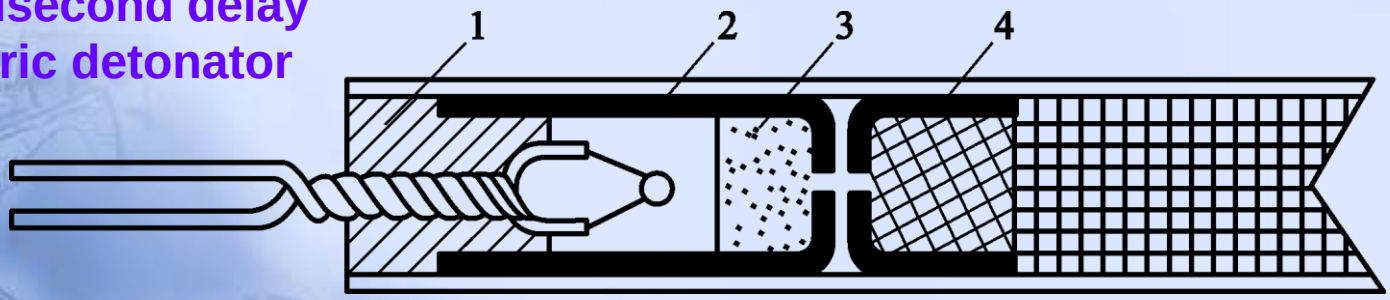
2. Second delay electric detonator



Second delay electric detonator structure

1-wax paper; **2**-gas vent; **3**-refined safety fuse

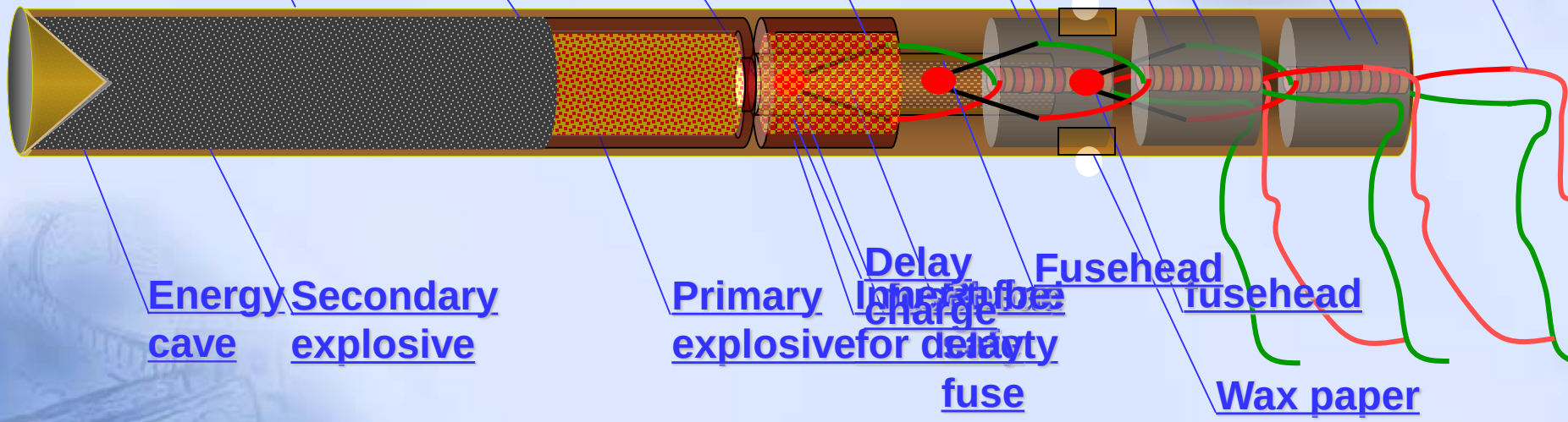
3. Millisecond delay electric detonator

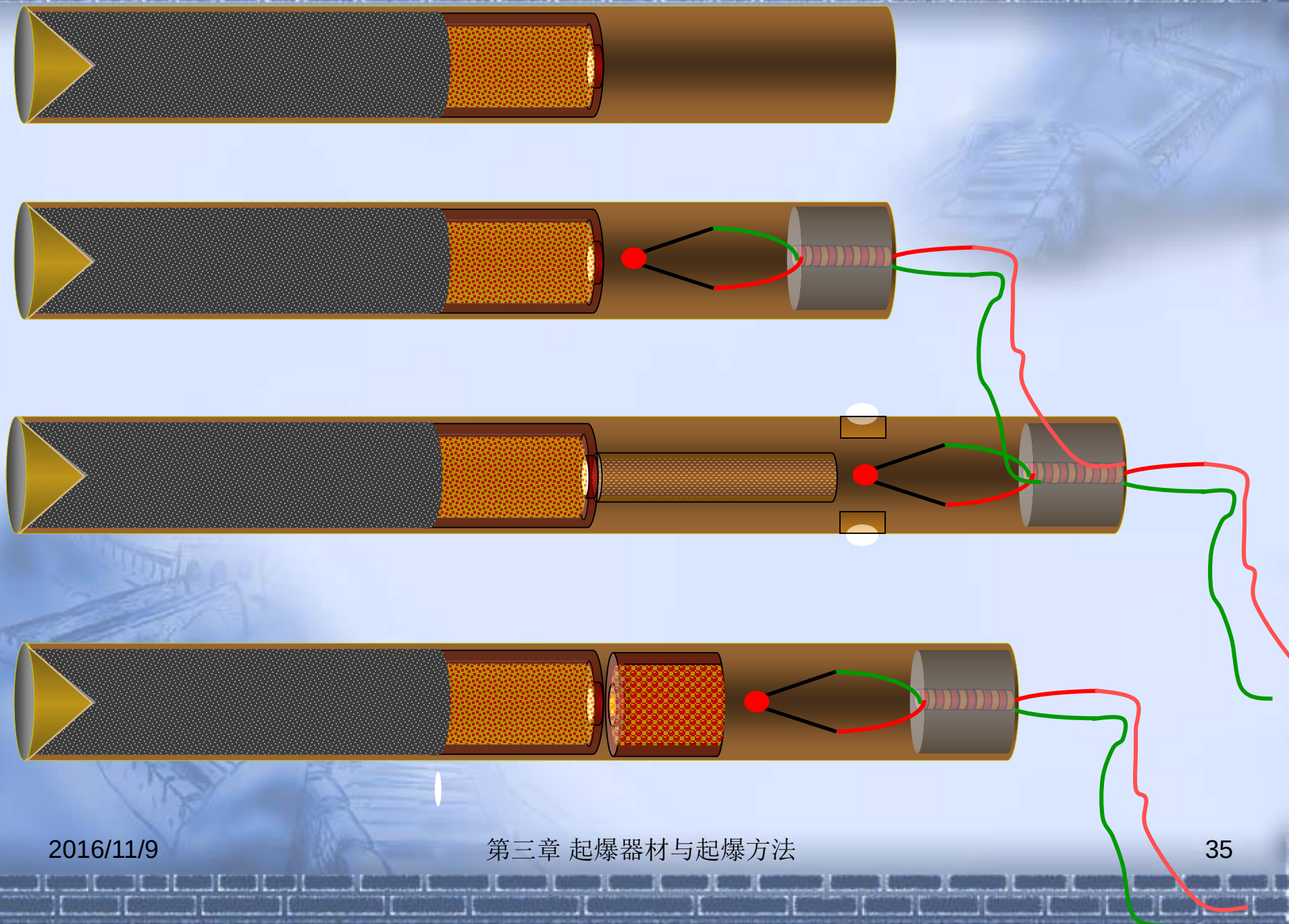


Millisecond delay electric detonator structure

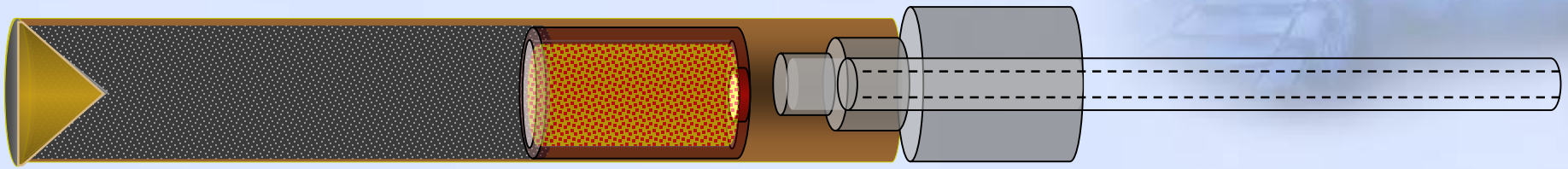
1-plastic plug; **2**-inner tube with delay charge; **3**-delay charge; **4**-strengthen cap

Millisecond delay electric detonator

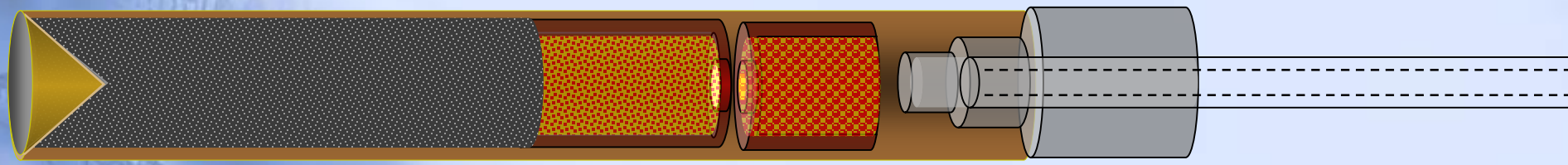




Instantaneous None detonator



Millisecond delay Nonel detonator



Classification of electric detonator（3）

4. anti-stray current electric detonator

（1）Millisecond delay electric detonator without bridge wire

（2）Electric detonator with low resistance bridge wire

（3）Electromagnetic detonator

5. Safety electric detonator

6. Electronic detonator

Main performance parameters of electric detonator（1）

（1）Resistance The total resistance is sum of bridgewire resistance and legwire resistance.

（2）Highest safe current

The highest safe current of electric detonator is the highest current which all of 20 detonators not ignite electrified constant direct current respectively after 5 min.

The meaningful of highest safe current assures the safely carry out of the blasting work; it is also base of choosing output current of instruments when designs the special blasting meter. The 30 mA is the required highest safe current based the safety regulation for blasting, so the output current all the measuring meter of electric detonator not more than this value.

（3）Minimum ignition current

the minimum ignition current is the minimum current which all of 20 detonators ignite electrified constant direct current respectively after 5 min.

（4）Ignition time t_d 和transmission time t_c

The ignition time t_d is the time from the birdgewire electrified to the fuse heat ignition.

The transmission time t_c is the time from the fuse heat ignition to detonation of electric detonator.

The time of electric detonator exposed to the heat $t_f = t_d + t_c$

Main performance parameters of electric detonator （2）

（5）Ignition energy k_d

The ignition energy (ignition impulse) is the minimum current energy which makes the fuse heat of electric detonator igniting.

$$K_d = I^2 t_d$$

（6）Ignition condition of series bunching-detonators

For assuring the ignition of the electric detonator, the requirement as follows:

$$t_{d\min} + t_{c\min} \geq t_{d\max}$$

$$t_{d\max} - t_{d\min} \leq t_{c\min}$$

Main performance parameters of electric detonator （3）

（7）Ignition condition of bunching detonators applied in engineering

① When the bunching detonators initiating together, the current through each electric detonator is : the alternating current no less than 2.5A and the direct current no less than 2A in general blasting, but in chamber blasting, the alternating current no less than 4A and the direct current no less than 2.5A. This is the minimum ignition current I_s of signal electric detonator in electric blasting circuit.

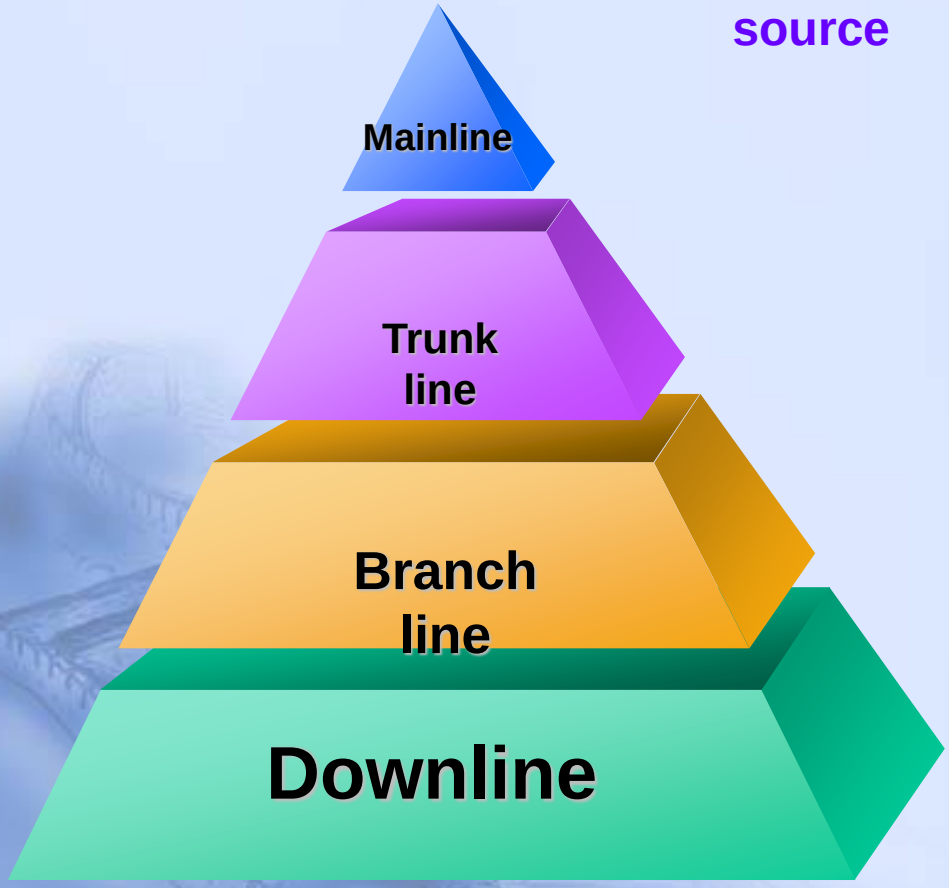
② All the electric detonators in electric blasting circuit should be the same factory, same batch, same specification, and the resistance scatter must be less than the set of product manual, that is to say, the resistance of each electric detonator is equal or similar.

The resistance scatter value of each electric detonator is not more than 0.25Ω generally.

③ The resistance scatter value of each series resistance in circuit is not more than 5% generally. That is to say, the number of electric detonator in each series should be equal, the electric detonators are visually in rows in any case during the design and construction.

wire、 ignition power source

1.wire



2. ignition power source

A **Battery**

Dry battery and storage battery, direct current

B **Alternating current power supply**

Alternating current (ac) power frequency, 220V and 380V

C **Blasting machine**

direct ignition power source, including hand generator blasting machine and capacitive blasting machine

$R_{总} = R_m + \frac{R'}{m}$

Formulae for Electric Circuit（1）

1. Series Circuit

$$R_o = R_m + nR'$$

$$i = \frac{V}{R} = \frac{V}{R_o + nR'} \geq I_s$$

2. Parallel Circuit

$$R_o = R_m + \frac{R'}{m}$$

$$I = \frac{V}{R'} = \frac{V}{R_m + R'/m}$$

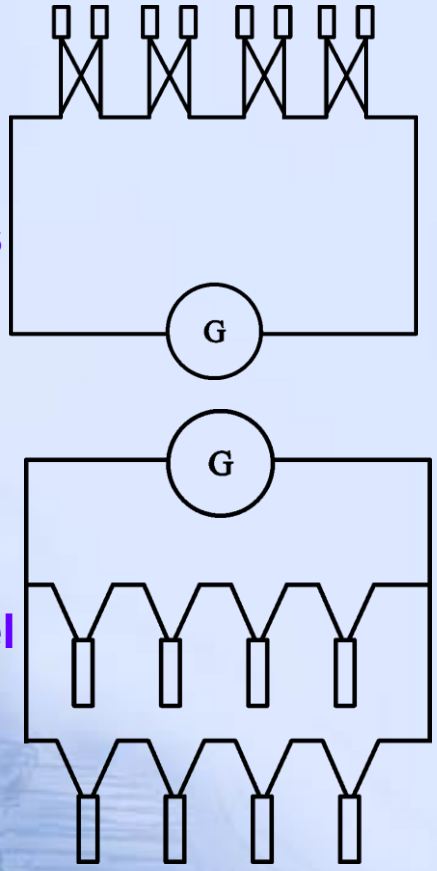
$$i = \frac{I}{m} = \frac{V}{mR_m + R'} \geq I_s$$

Formulae for Electric Circuit （2）

3. Hybrid Circuit

a. parallel-series circuit

b. series-parallel circuit



$$R_o = R_m + \frac{nR'}{m}$$

$$I = \frac{V}{R_m + \frac{nR'}{m}}$$

$$i = \frac{I}{m} = \frac{V}{mR_m + nR'} \geq I_s$$

Formulae for Electric Circuit （3）

4. Maximum numbers of Detonator and Optimal Circuit

A、 Maximum numbers of Detonator in hybrid circuit

$$n = \frac{V}{I_s R'} - \frac{mR_m}{R'}$$

Total numbers of detonator：

$$N = nm = \frac{Vm}{I_s R'} - \frac{R_m m^2}{R'}$$

Then：

$$\frac{dN}{dm} = \frac{V}{I_s R'} - \frac{2R_m m}{R'}$$

if $\frac{dN}{dm} = 0$ **then** $m = \frac{V}{2R_m I_{准}}$

The same as $n = \frac{V}{2R' I_s}$

Formulae for Electric Circuit （4）

4. Maximum numbers of Detonator and Optimal Circuit

B、 Optimal Circuit

$$i = \frac{V_m}{m^2 R_m + NR'}$$

Then：

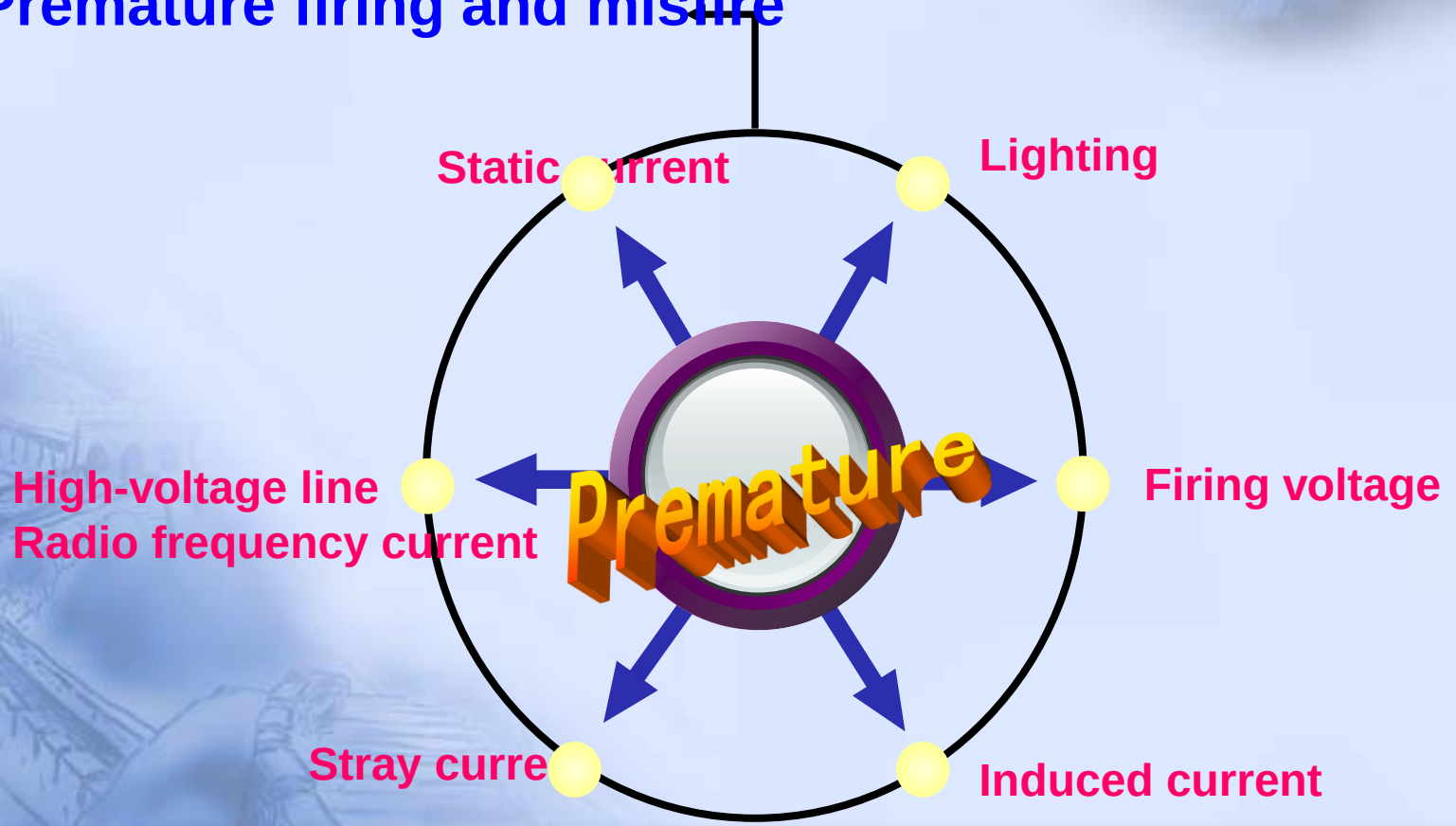
$$\frac{di}{dm} = \frac{V(NR' - m^2 R_m)}{(m^2 R' + NR')^2}$$

if $\frac{di}{dm} = 0$ **then** $m = \sqrt{\frac{NR'}{R_m}}$

The same as $n = \sqrt{\frac{NR_m}{R'}}$

Electric initiation circuit

1. Construction Technique
2. Premature firing and misfire




Thank You !
Wuhan University of Technology