報　文

導火線の改善に關する研究委員會記事

本篇は昭和22年1月～6月にわたり，日本産業火藥會が行つた導火線の改善に關する研究委員會の研究事項概要であつて，同年11月14日連合軍火藥監督官 Mr. Morand に提出した寫である．　山本諦德

Report of the Committee for the Improvement on Safety Fuse.

Introduction—In Japan, the powder train of the safety fuse has been prepared of, not grain but dusty powder. At pre-war time, as the coating material, jute yarn from India was used properly, but since its import has ceased, it is replaced with paper thread mainly. The particularities of jute yarn are as follows. (1) While the tensile strength is somewhat weak than that of cotton or hemp yarn, it is sufficient to wrap the powder train tightly enough. (2) Softness, toughness and elastic property as well as fine fur-like cillia and waterproof behavior join together, holding good quality of safety fuse. On the contrary, paper thread, even from good mulberry genus fiber, has little cillia and is inferior to jute yarn in tensile strength, toughness, elastic property, etc.

We had already heard and read on "Flash-over and Hang-fire"—very quick burning and so slow combustion of safety fuse—but not recognized them as plausible facts. On Jan. 19, 1947 it was reported that three men were killed by the premature explosion of a blasting shot, caused by flash over, in the Jyôban Coal Mine. That fuse burnt some 2 meters long in about 70 seconds. "What are the causes of flash over?" is the serious problem pushing on us.

There are various types of machines for making safety fuse. But for the first grade fuse (mainly used in coal mines), the processes are operated similarly in different works. A number of threads (ordinary 13) pass through a fine orifice whilst they are rotating, and at the same time a fine current of powder falls into the tube thus formed, and is held as a fine powder train by the cord. The cord thus formd is tightly stretched downward, and is passed through a second orifice similar to the first. In this place, some 8 threads are rotating in the opposite direction and wrap a second layer of covering. Then the fuse is drawn through a batch of tar and wrapped by paper tape, over which coated by the devil's tongue paste (in Japanese 'Konnyaku-nori') and finally wound by fine cotton threads (about 6). The finished fuse is painted by white kaolin pigment.

Résumé of the Investigations.

1°. Inquiry on the false fuse which caused the accident.

The appearance of that fuse is somewhat small in diameter (5.5 mm.) and weight (18.6 g/m) than ordinary one. We loosen the wrappings, collect and weigh the powder, so get 1.085 g/m. Ordinary fuse is about 5.6 mm in diameter, weighs 22–23 g/m and contains 4–4.5 g of powder per meter. The smaller is the content of powder per unit length, the looser is the covering, and there may occur some clearance between powder train and wrapping. If any clearance or air gap appears, the combustion by parallel layers may transform into the inflammation—quick burning followed by the flow of flame.

2°. Inflammation of gunpowder.

Mixing fine meal of gunpowder with water and fastening the thick paste on three cotton threads, we furnish quick matches. In the air open, the quick matches burn in about 32 sec/m, but in a glass tube of 3 mm diameter very quickly in 3–5 sec/m. Between the tube wall and the powder, as there is air gap, flame reflects at the wall and inflammation propagates very quickly like as flow of flame. This phenomenon causes in safety fuse the flash over.

3°. Experiment on small bored fuse.

We prepare a special fuse by using a copper wire (B.S. 24) in stead of a central cotton thread, drawn out the wire and get small bored fuse. When it is ignited by a piece of ordinary fuse, it burns off instantaneously quickly with loud detonating sound. That is the behavior of a quick burning fuse.

4°. Powder train.

In microscopic stand point, black gunpowder is a heterogeneous mixture of fine ground meal of saltpeter, sulphur and charcoal, and the components may separate from one another by the shaking owing to the transportation, handling or fuse making. After conveyance the composition of meal powder shows the very iirregularity on chemical analysis.

The powder train of the fine ground meal is easily affected by the atmospheric moisture. As grain powder is more uniform in its composition and less sensitive with moisture, in the future we must use grain powder to make safety fuse.

5°. The characteristic features of jute yarn.

Jute is cheaper in cost than other fibrous materials such as cotton, hemp, linen, ramie, etc. Amongst many particularities of jute yarn, the fine fur-like cillia are most important for making fuse to fasten powder train tightly, without any air gap. Therefore we cannot replace all inner jute winding with paper thread. As to our safety fuse, inner winding has generally thirteen threads. Now we leave three or four of jute threads as they are, and use nine or ten of paper threads in place of jute. But if grain powder is used for central core, the thirteen threads must be all jute yarn. Otherwise air gaps take place through the powder and along the winding.

A trial sample wound by 13 jute threads has 4.84 g of grain powder and 1.4 mm of powder diameter, burns normally in 74 sec/m, while the other one wound by 3 jute and 10 paper threads (grain powder 4.97 g/m, powder diameter 1.8 mm) burns off only in 36 sec/m.

6°. Necessity of roller yokes.

As soon as the first wrapping pass through the orifice, it will get loose again. So it is recommended to put a pair of roller yokes beneeth the orifice. Use of roller yokes make the burning of fuse slow and steady. Without them the rate of burning of fuse alters in large range over 20 seconds per meter, but after compression by yokes the difference becomes narrow within about 10 seconds.

7°. Fuses with small powder contents.

We choke the mouth piece of charge funnel by pitch, and prepare some kinds of fuses with small powder contents. Their rate of combustion become irregular.

Dia. of mouth piece	Mean power content g/m	Remarks
0.5 mm	0.5	Powder is too little to ignite.
1.0	0.75	Burning stops in the midway.
1.5	1.0	5 in 21 stop their burning.
2.0	1.2	One in 21 stops its burning in the midway.
2.5	1.8	
2.9	3.9	Ordinary combustion occurs.
3.6	5.6	

These samples are prepared by using the roller yokes, and do not happen quick burning.

8°. Effects of wrapping materials.

The following materials are used for inner covering, and the state of burning is observed.

Materials:—A. Indian jute yarn (good quality),
B. Inland jute yarn (bad quality),
C. Paper thread (with long and soft fiber),
D. Paper thread (short and hard).

Fuse with A burns slowly and steadily at a rate of about 120 sec/m, and the difference among some samples are very small (1–2 sec/m). B also burns steadily, but somewhat fast (100–110 sec/m). The burning of C is also steady and faster (about 85 sec/m), but D burns irregularly and quickly in 70±10 sec/m.

9. Effects of dryer and drying methods.

Drying of gunpowder can get about all right in the direct sun shine, because there is no spontaneous decomposition. In Japan usually safety fuse is also dried in the sun shine. As the drying of safety fuse is need only to take out the wetness of the outer white painting, strong heating is not only unnecessary but somewhat harmful. At high temperature even in short time, safety fuse with paper thread becomes very quick

burning. The reason is considered as follows. Paper thread emits the contained moisture (about 10% by weight) by sudden heating, and as it has little elasticity, gaps are posssible to form at places owing to the weight loss. Naturally quick burning is caused by the air gap between thread and powder train. But if we dry safety fuse at high temperature for long time, the heat is likely to melt the waterproofing material, causing it to penetrate to the powder and making it less inflammable.

On experiments of drying, we have observed few false fuses, but safety do not permit even million to one. Therefore, temperature of drying must be kept below 40°C.

10°. Pitch tank or tar batch.

Safety fuse is usually treated by molten asphalt pitch to make waterproof. Supposing that the temperature in the pitch tank is high or the time of treatment is prolonged, the fuse should be affected by the hot pitch. Molten pitch heats the fuse by outside and penetrate into powder train through coverings. Heating effect is similar to drying, and causes quick burning.

Condition of expeirment:—Temperature varies from 110° to 150°C, and time of heating is about 10 minutes. Time of burning per meter is measured.

Temp. °C	room temp.	110	120	130	140	150
Time of burning	121 sec	91.8	75.5	65	46.8	34.5

Fuse cord passed through pitch tank is scraped away the excess pitch by means of small mouth piece. If the cord stay some time in the mouth piece, it may be given compression and heating. Consequently, pitch penetrates to thread covering and even into powder train and tightens the fuse, so the burning may stop at the place.

Time of heating with mouth picce (about 120°C)	2 min	3	4	5	6
No. of half burnt	2/10	6/10	8/10	9/10	10/10

11°. Wetting and drying up.

When fuse is wetted, it becomes somewhat fast to burn, because the swelling of coverings results pressing action to the powder train. But if water absorbed is dried up speedily, then coverings more or less deform and fuse burns irregularly. By the penetration of water to powder core, change occurs in the composition of powder causing half burnt.

Time of dip in water	Temp. of dryer	Time of drying	Sample	Burning rate, obsd. (sec/m) Quick	Slow	mean
Moment	90°C	5 min	53	70	121	116
"	"	10	55	14	121	106
"	"	15	53	56	121	108
30 min	"	15	25	45	122	98
"	"	30	26	30	122	87
"	"	60	27	57	124	91
15 hr	"	3 hr	3	half burnt		
17	"	"	"	not ignite		

12°. Strength of coverings.

Covering materials in hand are examined their physical strength and evaluated the adaptability to wrap safety fuse. Of course, jute yarn has the best quality but some paper threads show reasonable values. Samples on test, except No. 1 and 7, are over 4 kg in tensile strength, and of practical use. Tensile strength of paper thread mainly depends upon its nature of fiber, the width of paper tape and number of twist. So we must keep in mind the selection of materials as well as the operation of twisting.

Paper threads.

No.	Paper mill	Brand	Twist. work	Fuse maker
1	Oji, Fuji	Roll No. 3	Iino	Teikoku-Kakohin K.K.
2	Oji, Ochiai	Wrap No. 2		
3	Oji, Fuji	Roll No. 3	Shôji	Mita-Dokasen
4	Odawara	Cent coin No. 2	Chûgai	Nihon-kayaku
5	Unknown	,, No. 1	Unknown	Iwahana
6	,,	,, No. 2	,,	,,
7	,,	Wrap No. 1	,,	,,
8	,,	,, No. 2	,,	,,
9	,,	Unknown	,,	Kanto-Denki-Kogyô
10	Yamato	,,	,,	Kayaku-Kogyô-Kai
11	Unknown	,,	,,	Mita-Dokasen
12	,,	,,	,,	Kanto-Dokasen

No.	Tensile streng h	Elongation	Weight
1	2.2(1.2- 3.6)kg	2.5(2.0–2.8)%	509(502–515)mg/m
2	4.8(4.4- 5.0)	3.6(3.0–4.2)	499(497–501)
3	4.6(4.1- 5.0)	3.8(3.4–4.2)	753(746–763)
4	4.1(4.0- 4.2)	4.6(4.2–4.8)	524(517–532)
5	9.6(9.0–10.1)	7.4(7.0–7.8)	782(774–792)
6	4.7(4.1- 5.1)	5.3(4.4–6.2)	425(419–432)
7	1.6(1.2- 2.6)	3.9(3.0–5.2)	545(536–562)
8	4.3(4.1- 4.4)	4.1(3.4–4.4)	576(568–588)
9	6.2(5.0- 6.5)	3.0(2.8–3.5)	601(592–610)
10	6.7(6.4- 6.9)	3.9(3.6–4.2)	682(672–691)
11	5.4(5.0- 5.7)	4.1(3.4–4.7)	797(790–805)
12	6.0(5.6- 6.4)	7.6(7.2–8.4)	482(475–495)

In No. 1 tensile strength is increased from 2.2(1.2–3.6) kg to 3.1 (3.0–3.2) kg, owing to the number of twist from 30/30 cm to 45/30 cm.

Jute yarn.

No. 13 (stocks of the Kanto-Denki-Kôgyô K.K.) is of good quality from Indian nature. No. 14 (Mita-Dôkasen) and No. 15 (Iwahana) are from home-grown weeds, and the former is better than the latter.

No.	Tensile strength	Elongation	Weight
13	12.7(11.2–14.7)kg	3.0(2.2–4.0)%	502(494–510)mg/m
14	8.5(8.0- 9.0)	4.3(4.0–4.8)	740(725–750)
15	5.4(4.4- 7.6)	3.6(3.0–4.2)	481(460–495)

Recently special Japanese paper thread (manufactured at Odawara Paper Mill, Nippon Shigyô K.K. and twisted by Chûgai Shikô K.K.) has been made trials to wrap fuse. Results are very reasonable, but the thread is not sufficient in quantity and is of very high cost.

Summary.

(1) To improve the uniformity of powder composition, we recommend to mix powder again just before use.
(2) Impurities in powder choke the charging hole of powder funnel. Powder must be sieved and removed impurities, then it can hold a good quantity in the central core.
(3) Covering material must be so soft, tough and of reasonable strength that it can hold the powder core tightly enough. Indian jute is the most recommendable, special Japanese paper thread is in the next place.
(4) Fuse cord must be pressed by roller yokes after first and second wrapping.
(5) Temperature of pitch tank should be held below 100°C, and do not stay fuse cord at the temperature over one minute.
(6) Drying of finished fuse may be done in the sun shine. If drier is used, temperature in it is normally below 40°C and not raised over 60°.
(7) Rate of burning must be examined at about 10 points in 1000 meters.
(8) Look at the section of fuse before making primer, and if the diameter of powder core is small (less than 1.0 mm) do not use it without testing.
(9) Do not store safety fuse in hot or wet place. Fuse once wetted must not be used.

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