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Hazard Assessment for Manufacture of Combustible Cartridge Cases using Picrite

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ABSTRACT

A systematic study of the effect of impact, friction, flame and electric spark sensitivity, was carried out on the samples of combustible cartridge case (CCC) withdrawn at different stages of manufacture. These are Stage I - dried, felted CCC; Stage II - CCC from Stage I and gelatinised with solvent, pressed and dried; Stage III - CCC from Stage II coated with nitrocellulose (NC) coating. Based on the results obtained from various experiments, the CCCs can be classified for handling, storage and transportation as Group 3, for safety distance category as UN 1.3 and for fire fighting as Class 2. Further, it is concluded from hazard analysis study that the CCCs are safe to handle but these should be protected from naked flame.

1. INTRODUCTION

Current combustible cartridge case (CCC) technology offers a realistic alternative to conventional metal (brass) cartridge case, because it possesses numerous advantages, such as reduction in weight of the cartridge case, cost-effectiveness in manufacture, minimisation of salvage problems, generation of less toxic gases in the crew chamber after firing, adaptability to automatic loading, supplementation to the energy of propellant used and enhancement of barrel life.

The CCCs are manufactured from a mixture of 60 per cent nitrocellulose (NC), containing 12.6 per cent N_2, 20 per cent nitroguanidine and 14 per cent inert cellulose fibre, while 1 per cent diphenylamine and 6 per cent dibutylphthalate are used as stabiliser and plasticiser, respectively. Since the composition contains about 80 per cent of energetic materials, viz., NC and nitroguanidine, the manufacture of CCCs falls in the category of explosives.

The manufacture of CCC presents many potentially hazardous situations during its processing and handling by workers. Lack of safety data leads to accidents. To prevent any casualty and severe material damage associated with loss of production, it was decided to generate safety data for CCCs to enable the manufacturer or user to achieve acceptable level of safety in their operations. The following tests were therefore carried out on CCC to generate the required data: (i) impact test, (ii) friction test, (iii) electric spark sensitivity test, (iv) measurement of deflagration temperature, (v) ignition test by Bickford fuse, (vi) naked flame ignition test, and (vii) measurement of static charge.

2. PROCESS FOR MANUFACTURE OF CCC

The CCCs used in these tests were made by the High Energy Materials Research Laboratory (HEMRL) technology[1]. The process of CCC manufacture starts with the preparation of slurry, which is prepared by mixing NC, picrite and beaten cotton along with DBP and DPA in a water medium. The homogeneous slurry is deposited on a rotating mandrel. A vacuum line is attached to this tool. The felting mandrel is then lowered into the felting tank and vacuum applied. After the predetermined time, the tool is raised from the felting tank, while vacuum continued to remove the water. The vacuum is then cut off and the CCC is dried with hot

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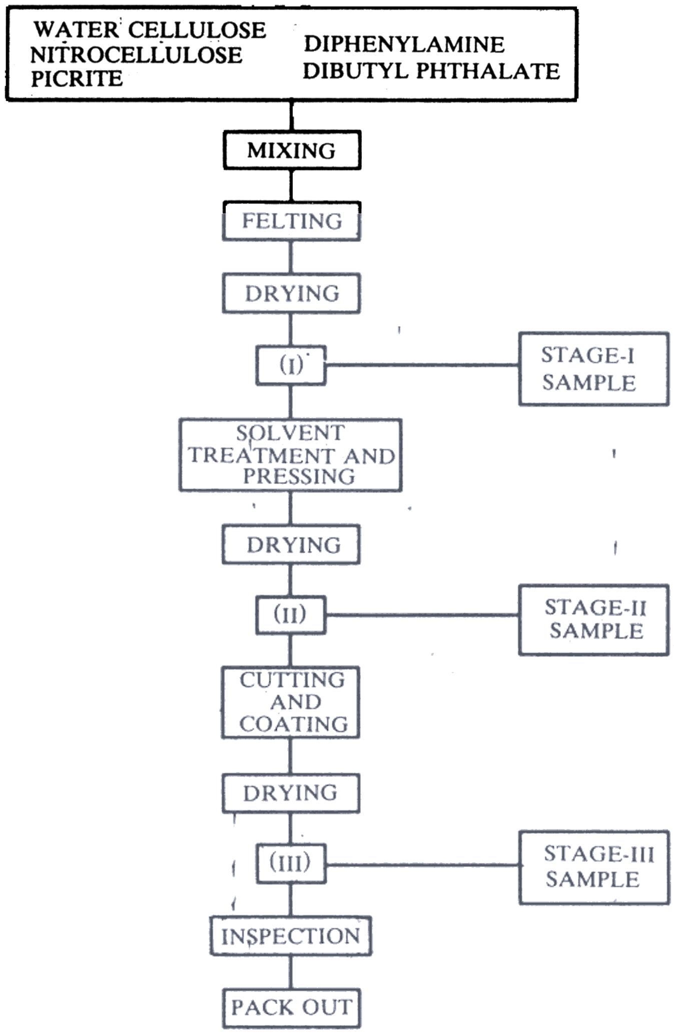

Figure 1. Combustible component manufacturing flow diagram.

air. The dried CCC is treated with solvent and pressed. Solvent is removed with hot air. Finally, it is trimmed, coated and packed. The flow diagram of the complete process is shown in Fig. 1.

3. MATERIALS & METHODS

3.1 Samples

During the process of manufacture of CCC, three different stages are susceptible to hazardous explosive conditions. These are :

Stage I Dried felted combustible liner.

Stage II Combustible liner from Stage I, but gel-atinised with solvent, pressed and dried.

Stage III Combustible liner from Stage II, but coated with titanium dioxide, copal and NC varnish.

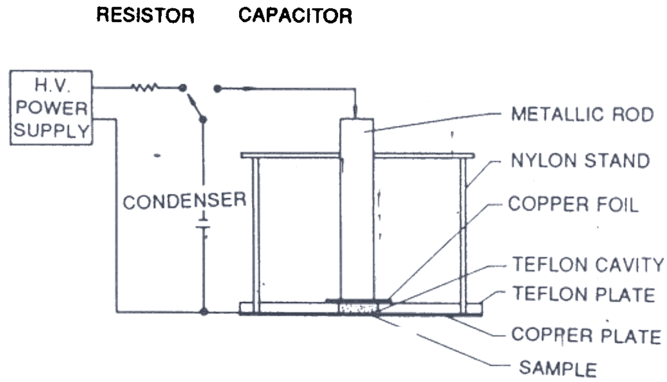

Figure 2. Schematic diagram of instrument for spark sensitivity test.

Samples were drawn and prepared at these three stages of manufacture, as per the requirement of test.

The CCC composition is almost similar to that of the propellant. Hence standard tests are employed for assessing the sensitivity towards impact, friction, heat and shock[2].

3.2 Impact Sensitivity

Impact sensitivity of the samples was measured on standard Rotter impact machine, with 2 kg drop weight and 50 mg of sample of size 5 mm x 3 mm x 2.5 mm. The height given in Table 1 refers to 50 per cent probability of the explosion of CCC at the three different stages of manufacture. Results are compared with standard sample of CE (composition exploding, 52/100 BSS).

3.3 Friction Sensitivity

Friction sensitivity of CCC was measured by (i) Mallet friction test and (ii) Julius Peter apparatus. In the first test 50 mg of sample, each passing 18 BSS, was taken on various anvils. Mallet weighing 700 g was struck 10 times. Results shown in Table 1 indicate zero ignition.

In the second test, 15 mg of sample, each passing 18 BSS, was taken and variable load was applied on moving surface. Maximum load up to 36 kg was applied. Table 1 includes also these results on samples at different stages showing that they did not ignite.

3.4 Spark Sensitivity

Sensitivity to spark was measured by ZARAN - 10 kV static charge unit (Fig. 2), using 0.3-0.4 g sample of CCC passing 18 BSS.

Table 1. Impact, friction and spark sensitivity of CCC

Test sample	Impact: Impact 50 % explosion height (cm)	Impact: Fall energy (kg m)	Figure of insensitivity	Friction a: Standard wooden mallet wt 700 g on York stone anvil	Friction a: Hard wood anvil	Friction a: Soft wood anvil	Friction b*: Friction load (kg)	Spark: Spark Sensitivity (J)
Stage I	164	3.28	145	0	0	0	36	0.02
Stage II	120	2.40	106	0	0	0	36	4.5
Stage III	132	2.64	117	0	0	0	36	4.5

* No explosion up to 36 kg.

3.5 Deflagration Temperature

Deflagration temperature was measured by Julius Peter apparatus[3], using two types of samples for all the three stages. Sample X was in powder form passing 18 BSS weighing 15 mg in each case, while sample Y was in the form of pieces of 5 mm x 5 mm x 2.5 mm weighing 50 mg each. Temperature at which puff of smoke or decomposition is observed is recorded as deflagration temperature. The values are listed in Table 2.

Table 2. Temperature of deflagration of CCC

Sample	Weight (mg)	Stage	Temp (°C)
X (powder) (passing 18 BSS)	15	I	
		II	
		III	
Y (pieces) (size : 5 mm x 3 mm x 2.5 mm)	50	I	184
		II	177
		III	179

3.6 Ignition Tests

3.6.1 Ignition by Bickford Fuse

Three grams each of CCC samples in the form of powder (passing 18 BSS) and in the form of cut pieces (5mm x 5 mm x 2.5 mm) were taken in the test tube. These were subjected to the burst of flame emitted from the end of a length of Bickford fuse. The results are shown in Table 3.

3.6.2 Ignition by Naked Flame

Samples of CCC, each of 10-20 g in three different forms, viz., in the powder form (passing 18 BSS), in small pieces (5 mm x 5 mm x 2.5 mm) and in long pieces (300 mm x 12.5 mm x 2.5 mm), were ignited at one end by naked flame in an unconfined train. The type of burning observed is reported in Table 4.

Table 3. Ignition of CCC by Bickford fuse

Sample	Weight (g)	Stage	Result
Powder	3		Ignites & burns quietly
(passing 18 BSS)	3	II	Ignites & burns quietly
	3	III	Ignites & burns quietly
Pieces	3		Ignites & burns quietly
(size : 5 mm x	3	II	Ignites & burns quietly
3 mm x 2.5 mm)	3	III	Ignites & burns quietly

Table 4. Ignition of CCC by naked flame

Sample	Weight (g)	Stage	Result
Powder	10	II	Supports train steadily
(passing 18 BSS)	10	III	Supports train steadily
Pieces	20	I	Supports train steadily
(size in mm	20	II	Supports train steadily
5 x 3 x 3.2)	20	III	Supports train steadily
Strips	8	I	Supports train steadily
(size in mm :	8	II	Supports train steadily
300 x 12.5 x 2.5)	8	III	Supports train steadily

3.7 Static Charge

Samples (100 mm x 25 mm x 2.5 mm) at Stages I, II and III were taken and rubbed 10 times on woollen cloth, and static charge thus developed was measured with Keithley-616-digital static charge measuring system, where static detector model 2503 was used. The results are shown in Table 5.

Table 5. Development of static charge on CCC

Sample	Stage	Charge developed (Coulombs)
Strips (size in mm		Nil
100 x 25 x 2.5)	II	Nil
	III	Nil
Standard teflon		5.6

4. RESULTS & DISCUSSION

4.1 Impact Sensitivity

Drop-weight impact test methods are based on the response of a group of test specimens subjected to an impact load of known energy. The drop-weight test most commonly used in reporting data is the Bruceton stair-case method (ASTM D 3029). The impact height for 50 per cent probability of explosion was determined by Bruceton staircase technique[3,4].

These values and corresponding fall energies are compiled in Table 1. The results show that the sample at Stage I has comparatively higher figure of insensitivity than those at Stages II and III. This is due to soft and spongy nature of the sample at Stage I, which has a tendency to absorb the kinetic energy imparted by the falling hammer; hence lower frequency of explosion. The lower figure of the insensitivity at Stages II ahd III in comparison to Stage I is due to compact nature of sample which has a tendency to develop hot spot due to impact of falling mass. The results of figure of insensitivity of CCC at all stages when compared with figure of insensitivity of standard CE which is 70 indicates that the sample of CCC is comparatively more insensitive.

4.2 Friction Sensitivity

The results in Table 1 indicate that the CCC at Stages I, II and III is comparatively insensitive as it does not crack, spark or flash when wooden mallet was struck. The results obtained by Julius Peter apparatus indicate that CCC at Stages I, II and III does not explode up to 36 kg load.

4.3 Spark Sensitivity

The experimental results show that the sample of CCC at Stage I is of sensitive class, as low (0.02 J) energy is required to ignite the sample. Thus, it needs utmost precaution from electric spark during processing, handling and storage. This is due to the NC constituent of the CCC which is in virgin form and makes it more susceptible to electric spark. On the other hand, samples of CCC at Stages II and III are solvent-treated and compressed. These require higher energy of 4.5 J for their ignition.

4.4 Deflagration Temperature

Table 2 summarises the data on temperature of deflagration of CCC when heated. Samples in Y form at all the three stages, have lower temperature of deflagration than the samples in X form. It may be due to the physical form of the samples. When the sample is in piece form, there is uniform and continuous maintenance of thermochemical decomposition. On the other hand, the sample in the loosely packed powder form has higher time for temperature of deflagration due to fast conduction and radiation of heat taking place from the sample.

4.5 Ignition Tests

Results in Table 3 indicate that samples of CCC in any form burn quietly from incendive spark of Bickford fuse which indicates that the CCC is susceptible to any non-electric spark and will ignite and burn. The results of the effect of naked flame on the CCC samples show that the CCC, in all forms, burns and supports the train of burning steadily.

4.6 Static Charge

Table 5 gives the static charge developed on rubbing the CCC on a woollen cloth. The results show that CCC is safe from the development of static charge on friction.

5. CONCLUSION

Based on the results obtained from various experiments, the CCC can be classified as follows :

	Stage I	Stage II	Stage III
1. Sensitivity	Insensitive	Insensitive	Insensitive
2. Classification			
a) Explosive group for handling, storage and transport	3	3	3
b) Safety distance category	Y (UN 1.3)	Y (UN 1.3)	Y (UN 1.3)
c) Fire fighting class for storage	2	2	2

It is concluded from the results of safety tests that CCCs are quite safe for handling, storage and transport. However, these should be carefully isolated and protected from any source of naked flame, spark, flash, etc. to avoid any accidental ignition.

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