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Research on the Most Appropriate Method for the Pyrotechnic Industry To Determine the Sensitivity of Compositions

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SUMMARY

Those of us who work in the pyrotechnic industry have three requirements to obtain data concerning the sensitivity of mixtures:

1) establish the starting point of no-ignition

2) understand the possibility of propagation of the ignition to combustion or explosion

3) clarify the variation of the sensitivity, which is dependent on the materials that we have used for tools

The methods used up to now have not satisfied our requirements.

The sensitivity was determined with a drop test using a steel ball onto a sample placed on an anvil. The sample used was molded as a thin round disk. This method was used to establish the propagation of ignition.

Initially, the experiment was conducted using the up-and-down method so as to compare with that described below. The data obtained on a salute composition did not indicate a normal probability distribution. This method does not give an exact result, without having some prior test data.

The experiment was then conducted using the descending-method, which I use regularly at the factory. The height of no-ignition was determined on 50 trials with the salute composition and with the composition CuO–Al.

It was possible determine the influence of the material of the anvil on the sensitivity of the mixture and substituting aluminum for the steel.

1. Introduction

This report concerns the test method used to determine the sensitivity of pyrotechnic compositions. We who work in a pyrotechnic factory have three requirements to obtain the sensitivity data on compositions.

1) establish the point of no ignition

2) understand the possibility of propagation of the ignition to explosion

3) clarify the variation of the sensitivity, which is dependent on the materials that we have used for tools

Up to now, no methods have satisfied the requirements.

2. Equipment

The sensitivity was determined with a drop test using a steel ball onto a sample. The ball has a diameter of 76 mm and a mass of 1.8 kg. A small amount of pyrotechnic composition was placed on an anvil (Figure 1). This method permitted us to determine the propagation of the ignition to combustion, to explosion, or to non-propagation.

3. Testing

3.1 By the Up-And-Down Method

The first series of tests were performed using the up-and-down method. A description of this method follows.

Place the ball at an initial height and allow it to fall on the sample on the anvil. If the sample does not ignite, the ball is dropped from a higher, predetermined level. If the composition does ignite, the ball is dropped from a shorter, predetermined level. The process is then repeated.[1]

The sample of salute composition consisted of 64% potassium perchlorate, 23% aluminum and 13% sulfur and is more sensitive than the usual compositions.

Using a manual method,[2] one establishes the level for the next test by basing it on the

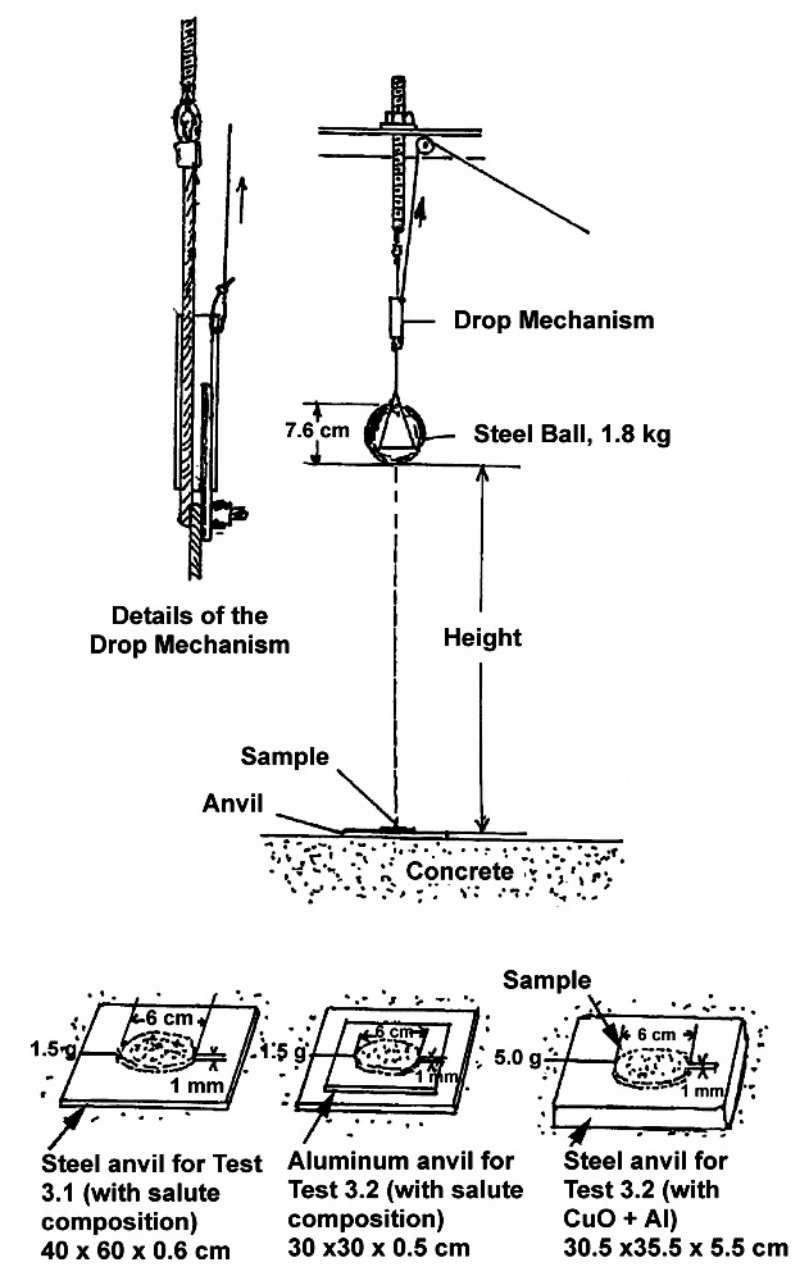

Figure 1. Equipment for the tests.

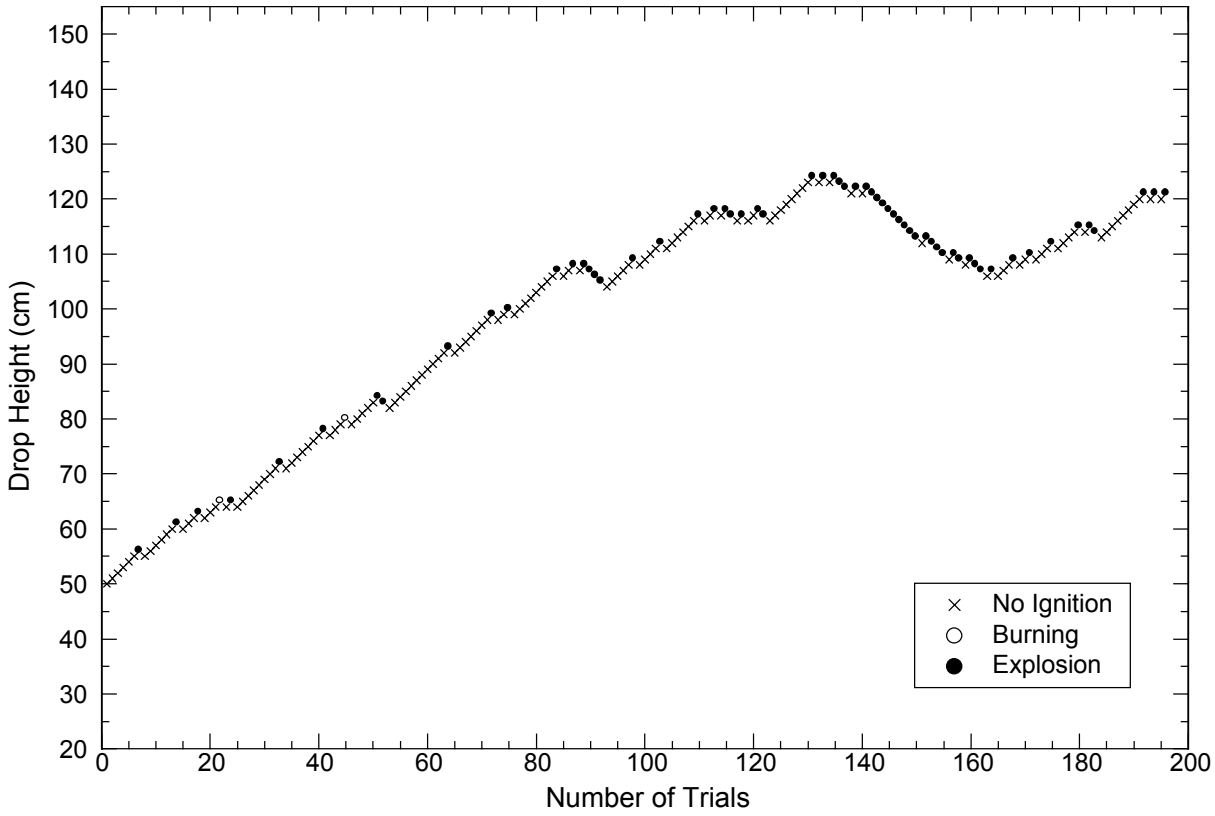

Figure 2. Test results for the up-and-down method with the salute composition.

results of the previous one. However, it was impossible to do this since I did not have the first data point nor could I obtain it using this method. I, therefore, chose a value of 1 cm. The results are shown in Figure 2.

As indicated by the curve, the data does not define a normal distribution, which is essential to obtain the exact, 50% height for ignitions.

That is to say that the up-and-down method does not give exact results, if we do not have sufficient previous test results.

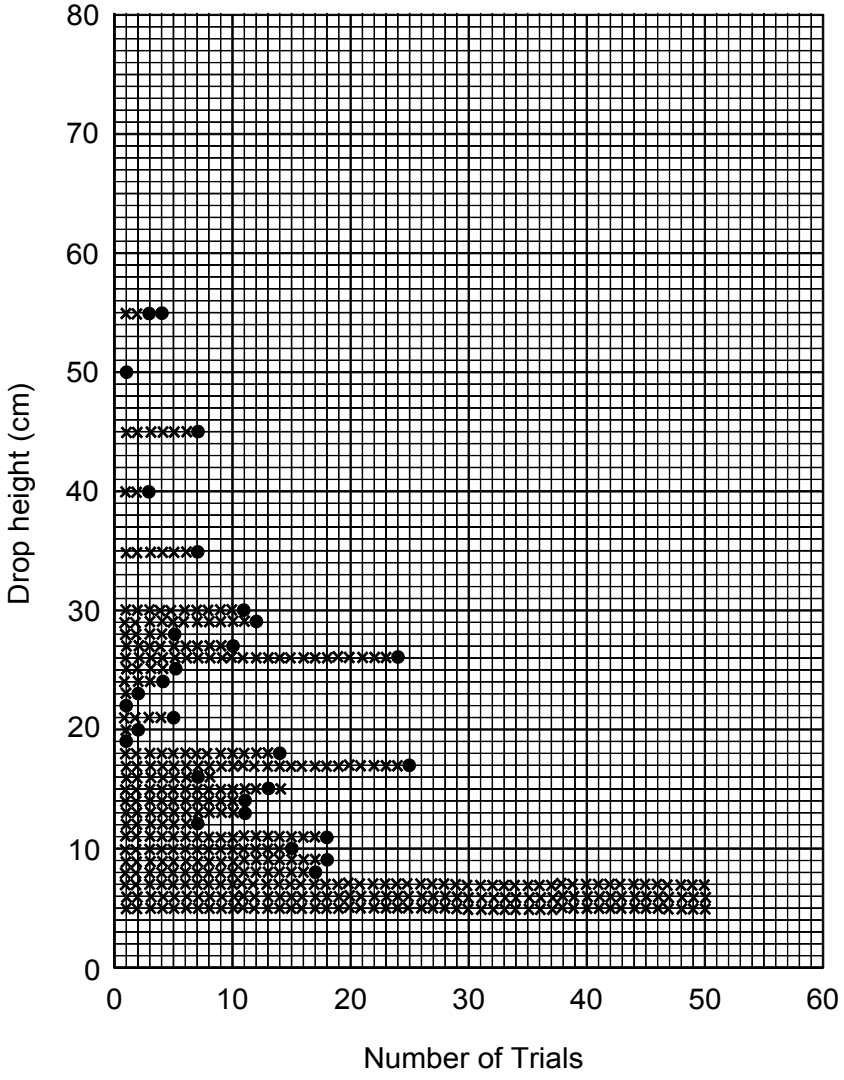

Figure 3. Test results for descending method with salute composition.

3.2 Descending-Method

The testing process was performed by using the descending-method, which I have used successfully. We place the ball at a first height and we drop the ball many times until an ignition occurs. After, we decrease the height from which the ball is dropped and we repeat the process.

One test was performed using this method with the same sample of salute composition. The results are shown in Figure 3. With 50 trials, a height of 7 cm was obtained as the no-ignition value.

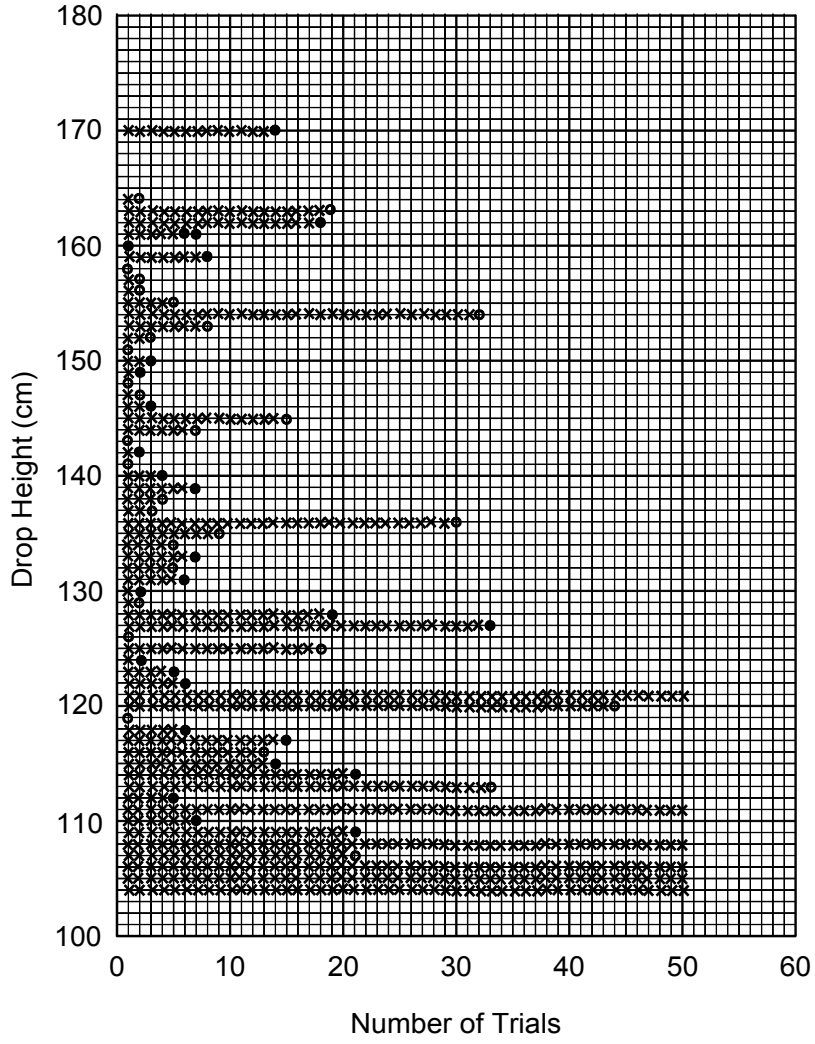

Figure 4. Test results for the descending method with the CuO + Al composition.

Figure 4 shows results for a recent composition, 80% CuO + 20% Al (atomized, Yamaishi VA 2000).[3] This composition is very efficient as a bursting charge for firework shells.

The height for no-ignition, determined with 50 trials, was determined as 106 cm.

The same tests with the salute composition was repeated on an aluminum anvil instead of the one of steel. The 50 trials at a height of 170 cm did not result in any ignitions.

4. Discussion

The effect of the propagation is indicated as a no-ignition (×), ignition without propagation (Δ), combustion (○), or explosion (•). This can be seen with the symbols in Figure 2, 3, and 4. The effect of ignition without propagation was not demonstrated by our compositions, but I have frequently seen it with other compositions. The salute composition has always given an explosion, but the CuO–Al composition sometimes results in combustion and sometimes in explosion. It seems to be due to the strong shock waves created by the ignition. We can obtain the effects of the propagation of the ignition by this method.

As indicated by the curve in Figure 2, the 50% height for ignition was not obtained because the results are not normally distributed. Certainly, the initial test height was incorrectly

chosen. It is believed that it is not possible to obtain good results by the up-and-down method without prior experience with the method, the composition, and the test apparatus.

Also, this method cannot provide the height of no-ignition that we fervently require at our factory. Moreover, even if we have obtained good results by this method, we could not determine this height with sufficient precision because of insufficient trials. This is why the up-and-down method is inadequate for our factory.

We find from Figure 3 that it is possible to obtain the height of the no-ignition using the descending method. This height was determined from the no-ignition of 50 trials at each of three, adjacent, descending heights. This method assumes that testing begins at an arbitrary height. Furthermore, the distance between test levels is chosen according to the precision desired. Another advantage of the descending method is that the number of times that a trial results in combustion or explosion are very few. This reduces the amount of damage to the equipment. The height of no-ignition for the salute composition using this method, was found to be 6 cm.

Figure 4 gives a result of the mixture CuO–Al using the same method, which finally will give us an acceptable method. The results are shown in the following Table 1.

Table 1. Number of Non-Ignitions at Various Heights.

Sample	Height(cm)	Number of Non-Ignitions
a)	121	50
	120	43
	119	0
b)	111	50
	110	6
c)	108	50
	107	20
d)	106	50
	105	50
	104	50

It is not possible to determine the no-ignition height of a), b) or c) with 50 trials at the same test height. Confirmation of the results at three adjacent heights, such as those in d), is necessary. These tests have resulted in a no-ignition height of 106 cm for the composition.

It is possible to establish the effect of the anvil material by changing it. As already mentioned, using the descending method, the no-ignition height for the salute composition was 7 cm for the steel anvil and 170 cm for the aluminum anvil.

5. Conclusions

A simple method was evaluated, whereby, a steel ball was dropped onto molded, thin disk sample placed on an anvil. Using this method it is possible to determine the point of no-ignition, ignition, or the propagation of ignition to combustion or to explosion. Moreover, it is possible to establish the sensitivity of the composition as a function of the anvil material.

The up-and-down test method does not provide useful information for our factory. It is very difficult to obtain a good normal distribution.

The descending method have given us good results, which can be used in our factory. However, confirmation of the effect at three different height with 50 trials at each height is necessary to obtain exact results.

6. References

1) W. J. Dixon and F. J. Massey, Jr., *Introduction to Statistical Analysis*, McGraw Hill (1969).

2) Yoshida et al, *Safety for Reactive Substances and Pyrotechnic Compositions*, Taisei Shuppan Co. (1988) (Japanese).

3) Private communication with D. Allen, (USA) and T. Yoshida (Japan), *Manual of Dangerous Substances*, Marzen Co. (1987) (Japanese).