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CARTRIDGE FIRING DEVICE DESIGNED FOR
ATTACHMENT, RELEASE AND EJECTION OF A SATELLITE

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1 - ABSTRACT

The under presented device has been manufactured by A.M.D.-B.A. for attachment , release and ejection of a small dimension satellite.

The device is of interest in that the above-mentioned functions are performed by a one-piece unit with resulting performances which are of interest regarding the satellite attachment and the accuracies of the path and velocity during separation and ejection.

A gain in weight may be obtained relative to the conventional device used, i.e. maintenance belt, belt unlocking device, pusher spring, cartridge fired pusher.

This expose specifies the tests conducted to demonstrate the device efficiency showing the development specific cases.

2 - GENERAL

The hereunder described device has been developed and manufactured by A.M.D.-B.A. as a contractor for CENTRE NATIONAL D'ETUDES SPATIALES (C.N.E.S.).

It was succesfully used by C.N.E.S. to orbit a 30 kilogram satellite.

The main C.N.E.S. requirements were :

- accurate path with a deviation along the various axis lower than 1°/second
- ejection velocity 1.05 m/s ⁺0.5
- correct tightness of the system during and after release.

3 - DESCRIPTION OF THE DEVICE

This assembly is shown on photograph N° 1.

Photograph N° 2 shows the device after release, with the upper part attached to the satellite and the lower part attached to the launcher.

Diagrams 1 through 5 show the device operation during flight, release and ejection phases.

Analysis of diagram N° 1 shows the main parts of the device, i.e. :

- an attachment plate (A) fitted to the launcher
- a comparatively light (B) main body
- a center assembly distributed between plate A and body B and ensuring attachment, release and ejection. This center assembly is briefly described hereunder.

3.1 - Diagram N° 1

The device is shown in its flight phase.

The satellite, through part B, is attached to plate A by means of the C ball-type lock.

This conventional ball-type lock is shown on diagram 4.

The D lock piston retains the balls within the E fixed part. Spring F inhibits ball unlocking.

Nut G applies a pre-stress to the locking unit. It eliminates all plays and, with spring F, ensures perfect strength when launching occurs (namely strength during vibrations generated during launching).

Let us specify that the whole device is installed and adjusted in the factory. It then only requires to attach B to the satellite and to attach A to the launcher.

3.2 - Diagram N° 2

The device is shown in its unlocking phase. The two small H gas generators have produced a comparatively high pressure (100 bars) in the I chamber. This pressure causes a comparatively high force which pushes the J unlocking piston (this force has to be important to overcome the ball locking force due to pre-stress of G nut).

The D locking piston plunges and allows balls withdrawal which free B part from A plate.

As soon as the balls are no longer maintained by piston D, an associated device causes pressure drop in chamber I. See diagram 5.

Once unlocking piston J has moved to allow action on piston D, an opening is caused on the piston face by the relative motion of pin K which discloses the L gas transfer part. The gases expand in the M annexed chamber.

3.3 - Diagram N° 3

The device is shown in its post-ejection phase.

The ejection velocity is obtained by the action of reduced gas pressure on piston J.

The piston tightness is obtained by conventional addition of O-rings to the piston head.

4 - DEVELOPMENT AND TESTING

As the specification requirements concerning the device should mainly be path accuracy and comparatively reduced ejection velocity, the hereunder mentioned tests specify the main steps cleared to prove correspondence with technical specifications.

4.1 - Checking the path accuracy

Because the satellite thrust during ejection is ensured by piston J centered relative to the satellite, and because the thrust axis passes through the gravity axis of the satellite, no specific difficulty was expected.

The path accuracy has been verified using the test set-up described hereunder and shown on diagram 6.

A model of the satellite was fitted to the device. The satellite axis of the device was horizontal. Plate A was attached to a rigid support. The satellite and its B plate was retained by a 5-meter long vertical wire. The hanging wire was attached to the satellite at a point such that the wire direction was passing through the gravity center of the B part satellite assembly.

The movement of the satellite was filmed by two cameras : one along the fore and aft center line and one for sideways filming.

The film analysis has shown on the basis of the first five tests that no parasite motion existed about the thrust axis over a distance of approximately 50 cm (later on, disturbances were found due to the presence of the gas generator supply wires).

4.2 - Adjustement and substantation of ejection velocity

This is the most interesting point to examine because the velocity required was very low ($1.05 \text{ m/s} \pm 0.15$) and because the various parametres summarized below affected this ejection velocity.

The test set-up used was identical to that specified in preceding paragraph, i.e. the satellite was hanged by means of a 5-meter long wire. The ejection velocity was measured by a test set-up shown on diagram 7.

4.2.1 - Test set-up for velocity measurement

Diagram 7 shows the test set-up for velocity measurement. The test set-up includes a graduated transparent scale including opaque lines spaced by two millimeters, with the width of each line being two millimeters. This scale is a conventional device which is called rake.

A punctual light source sends a light ray which goes through the rake and excites a photodiode whose reactions are recorded on a magnetic recorder.

The internal pressure in the I gas expansion chamber was also measured.

4.2.2 - Parameters affecting the ejection velocity

The following parameters had to be examined and adapted :

- gas pressure due to cartridge firing
- value of pre-stress caused by nut G
- tightness and friction of piston J
- gas pressure drop caused by pin K and M expansion chamber.

4.2.2.1 - Gas pressure of cartridge fired generators

- The generator powder charge was rapidly determined from the first tests (see table 1).

To obtain the 1.05 m/s velocity, the main powder charge was 55 mg.

- Following this series of tests, the device has been operated using one gas generator. The test velocity has been 0.53 m/s, which has confirmed that the device was operating with a single squib.

4.2.2.2 - Value of the G nut pre-stress

Further checking tests have shown too high a variation in the ejection velocity. This velocity was increasing with the number of tests.

An analysis of the piston effect has shown that, due to the variation of the locking force, the gas pressure obtained in chamber I prior to motion of piston J was varying substantially with tightening of G nut.

It was necessary to determine accurately a method of application of the G nut tightening torque. This tightening has been lightly increased in order to decrease the force dispersion, which has caused a requirement for higher pressure in I chamber and the powder charge of the gas generators has been increased from 55 mg to 65 mg.

The velocity values recorded are shown on table 2. . The results obtained were not perfectly satisfactory. The dispersion was too high and the velocity recorded was very often lower than the average wanted.

4.2.2.3 - Tightness and friction of piston J

Following the additional tests, light gas leakages between piston J and body B were found to affect velocity substantially.

The requirements for installation of the seal into the piston and for greasing in piston B have been rapidly established and a better regularity has been obtained in the velocity recorded.

4.2.2.4 - Effect of pressure maintenance in chamber M

The best accuracy was obtained after establishment of the means to find the effect of :

- the expansion volume in chamber M
- the diameter of pin K, i.e. gas through the L part (in actual practise a variable pressure maintenance when the gas expand in chamber M)
- the setting of the known part of pin K which was adjusting, in the ejection first phase, the velocity of the gas expansion through part L.

After approximately thirty tests, all these parameters have been perfectly determined and the results specified in table 3. show that the velocity required was practically obtained very faithfully.

5 - CONCLUSION ON THE ADJUSTMENTS CARRIED OUT

The summary report of the tests specified here-above shows that the device used allows the performance required as far as accuracy is concerned for such a low ejection velocity.

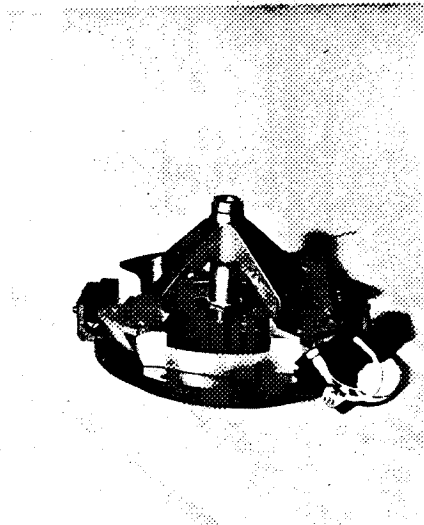
By analysing systematically the records and various parameters, it was possible to define an assembly procedure likely to allow obtaining the velocity required : $1.05 \text{ m/s} \pm 0.15$.

It is clear that if the ejection velocity was higher, the various parameters specified here above would have a far more negligible effect and that, for instance, for a 3 m/s ejection velocity, the device could be much more easily adjusted.

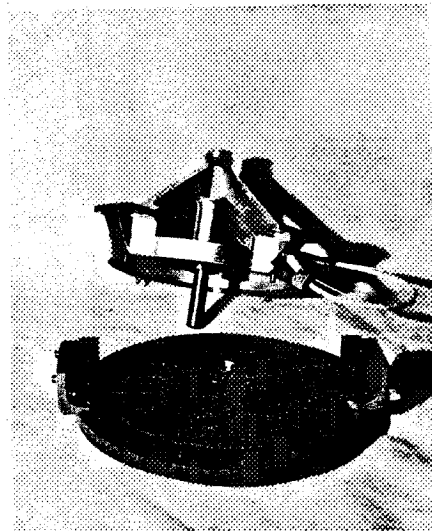
Let us recall that the device is of interest in that all the devices required for carriage, release and ejection of a satellite are formed in the one-piece unit. The complete device as it is shown can be fitted to the satellite in the factory, which prevents any setting or specific operation later on.

Another interest can also be stressed : indeed no expandable part is used as compared with the problem of retaining the connection belt used in other devices.

Photograph N° 1



Photograph N° 2



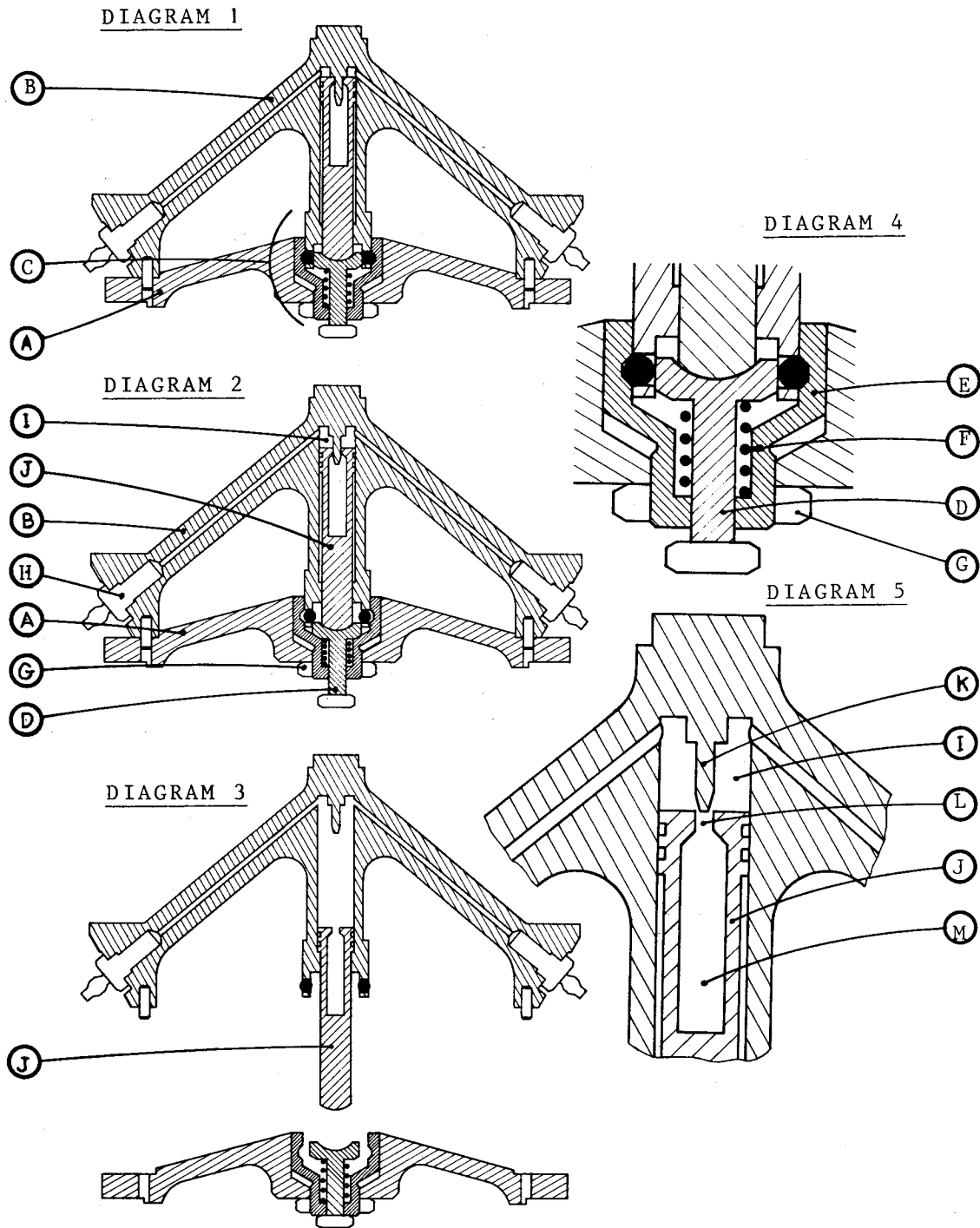


Figure 1. Release and Ejection Phases During Flight

DIAGRAM 6

Checking the Path Accuracy

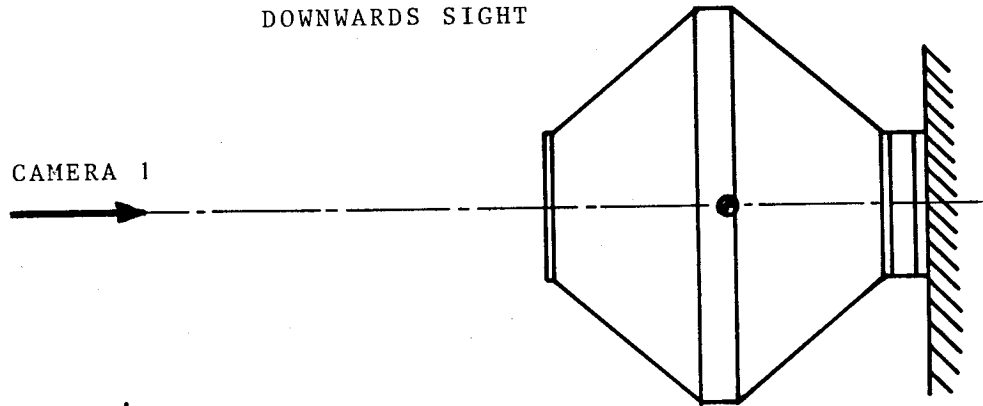


DIAGRAM 7

Velocity Measurement

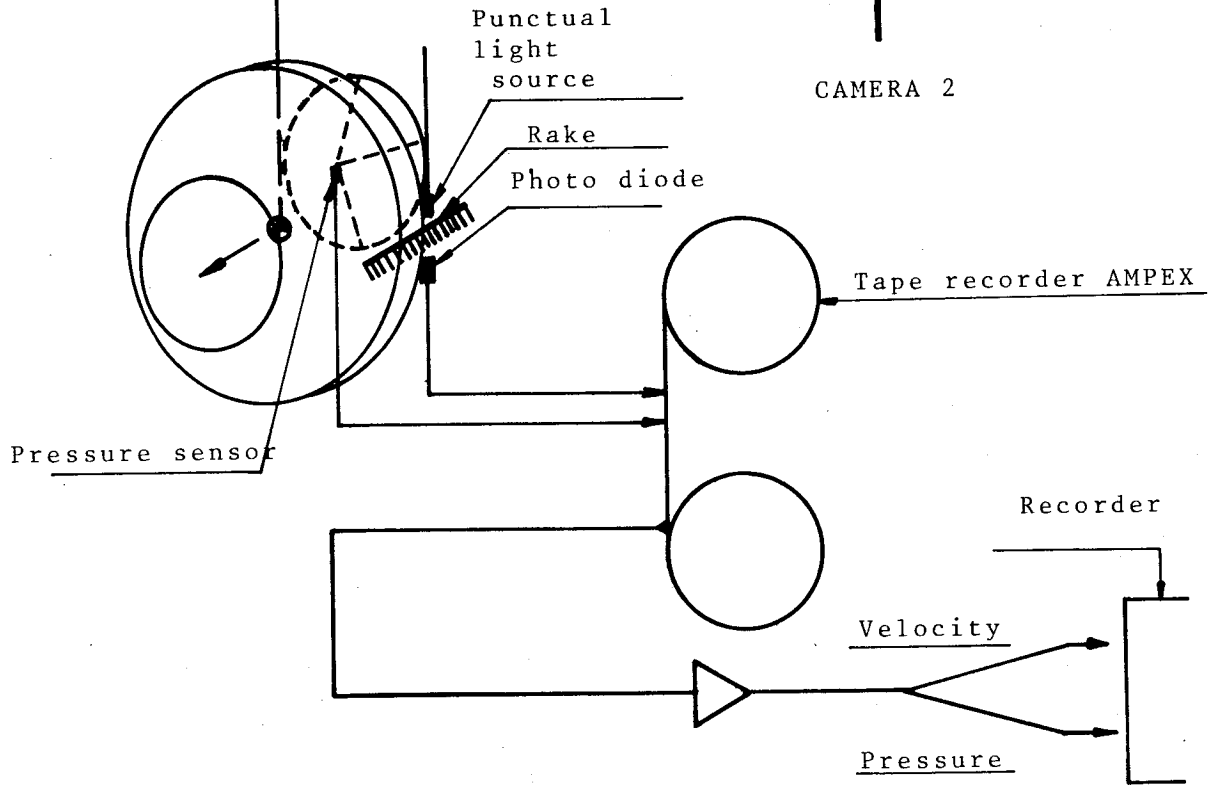


Figure 2. Test Set-up

TABLE 1

GBSe powder charge	Velocity
2 x 120 mg	2.15 m/s
2 x 100 "	1.7 "
2 x 60 "	1.15 "
2 x 50 "	1.00 "
2 x 55 "	1.05 "

TABLE 2

Firing	Velocity	Remarks
1	1.08 m/s	
2	1.02 "	
3	0.9 "	
4	1.03 "	
5	0.98 "	
6	0.836 ")
7	0.815 ") 3 firings made
8	0.815 ") in presence of
9	0.768 ") C.N.E.S.
10	0.795 "	
11	0.83 "	

TABLE 3

Firing	Velocity	Remarks
1	1.066)	
2	1.02)	
3	1.15)	Average :
4	1.04)	1.07 m/s
5	1.087)	
		Real gas generators.