MECHANISMS AND PYROS SUBSYSTEM FOR THE METEOSAT SECOND GENERATION[1]

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ABSTRACT

Two covers protect the sensitive surfaces of the MSG satellite against possible contaminants. Once the peril of contamination ceases, the covers must be jettisoned, allowing the satellite to operate. Their failure to provide isolation or the failure of their jettisoning leads to mission failure.

The mechanisms responsible for the ejection must face severe requirements: only one pyrotechnic is allowed for the baffle cover, the acoustic environment reaches levels of 146dB, the allowed mass is very low. These requirements have led to the use of preloaded supports such as the "flexible hinge", which is capable of supporting the cover and releasing it passively, without the use of telecommand.

1. INTRODUCTION.

The MSG (Meteosat Second Generation) requires protection for its optical surfaces against contaminant particles during ground operations, transportation, launch and ascent to the satellite final orbit. Two independent covers provide this protection.

The covers isolate the inner cavities of the satellite preventing any contaminant from entering, and allowing the venting of the gas inside while the external pressure decreases. Once the peril of contamination ceases, the covers must be jettisoned, allowing the satellite to operate.

Their failure to provide tightness or the failure of their jettisoning leads to the loss of the mission.

2. REQUIREMENTS AND SOLUTIONS.

The most challenging requirements were:

- Only one pyrotechnic was allowed for the baffle cover. This requirement limits the number of supports for the cover, since these supports must be detachable in order to jettison the cover in orbit.
- The acoustic level, and the mechanical environment in general, were very severe for a high stiffness and barely supported structure.

SEVIRI ENTRY BAFFLE COVER	
SURFACE TO BE COVERED:	APPROX. $0.7m^2$
TELECOMMAND:	1 PYROTECHNIC
VENTING: INNER CAVITY	$1.2m^3$ MAX(PINT-PEXT)=170PA
JETTISONING SPEED:	> 1.5 M/S
MASS	≤ 4 KG
MECHANICAL ENVIRONMENT	35G QUASISTATIC 25G SINE $27.3G_{RMS}$ RANDOM 146dB
THERMAL ENVIRONMENT	-60ºC TO +60ºC
STIFFNESS	FIRST MODE AT F>140HZ

SEVIRI PASSIVE COOLER COVER	
SURFACE TO BE COVERED:	APPROX. $1.9m^2$
TELECOMMAND:	3 PYROTECHNICS
VENTING: INNER CAVITY	$0.94m^3$ MAX(P_{INT}-P_{EXT})=170PA
JETTISONING SPEED:	> 1.5 M/S
MASS	≤ 10 KG
MECHANICAL ENVIRONMENT	15G QUASISTATIC 4G SINE $17.3G_{RMS}$ RANDOM 146dB 80G DURING 0.8ms
THERMAL ENVIRONMENT	-60ºC TO +60ºC
STIFFNESS	FIRST MODE AT F>60HZ

[1] The mechanisms & pyros subsystem for MSG is a project developed under a European Space Agency / EUMETSAT contract. The prime contractor of the MSG is Alcatel Space (Cannes).

2.1 Preloading.

The easiest way to support a detachable cover is fixing it with several pyrotechnically removable joints. But in this case, the number of pyrotechnic devices was limited to one (baffle cover) or three (cooler cover) and these were not sufficient unless additional non-pyrotechnical supports were added. The solution chosen to solve this problem was using support points where contact was ensured applying a constant preload.

SEVIRI cooler protective cover.

The cooler cover is supported at six points: three preloaded points and three pyrotechnically detachable support points. The cover is round and all the support points are distributed symmetrically on the perimeter: between each two pyrotechnic mechanisms there is one preloaded intermediate hard support point.

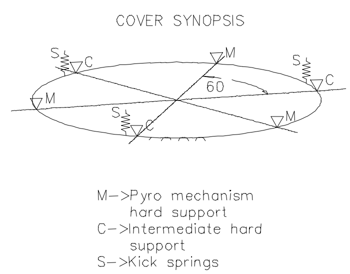

Figure 1. Cover support points and distribution.

The preload in the intermediate hard support points is produced deforming the cover (sandwich panel). The deformation of the cover is produced joining the two parts of the pyro mechanism: the gap between these two parts is calculated to produce the desired preload (see Figure 3).

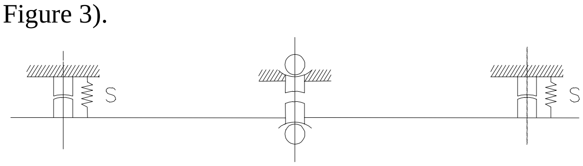

Figure 2. SEVIRI cooler cover preloading.

SEVIRI entry baffle protective cover.

The baffle cover is supported at five points: four preloaded support points and one pyrotechnically detachable support point. The design of the preloaded support points ensured that if the pyrotechnic was activated, the cover would detach completely.

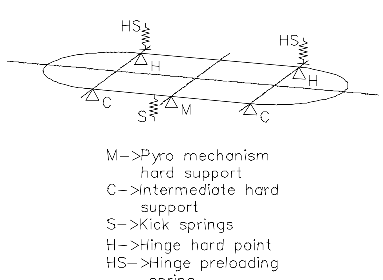

Figure 3. Cover support points and distribution.

For this preloaded support joints to work properly, the following requirements must be necessarily fulfilled:

- The joined parts must be easily detached without interference and with the lowest friction possible.
- The joined parts must be kept together by the action of an external force (preload). This force must be higher than the maximum separation effort that may be caused by the thermal or mechanical environments (vibration, acoustic, thermal loads).
- Cold welding must be avoided.

The preload, in these covers, is applied deforming some elements of the cover. The work sequence is 1)"flexible hinge" preloading, 2)"kick spring" preloading, 3)panel preloading, 4)launch and ascent, and 5)jettisoning.

This sequence is simpler for the cooler cover. The cooler cover is jettisoned perpendicularly to the mounting plane of the cover. After being jettisoned the cover moves parallel to itself as it distances from the satellite.

This is not the case of the baffle cover. The baffle cover, once the pyrotechnic cutter releases the cover, rotates around the hinge support. Once a critical angle is achieved, the cover gets disengaged from the hinge and distances freely. Therefore, in addition to the translational motion of the cooler cover, the baffle cover has a rotational motion.

Figure 4 shows this process schematically.

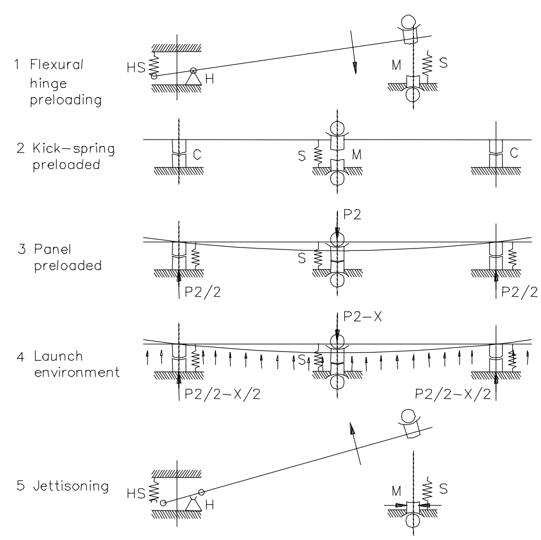

Figure 4. Structural and functional concept of the SEVIRI entry baffle cover.

1) "Flexible hinge" preloading. The flexible hinge is a very simple titanium piece that allows supporting the cover at one point preloading the joint. There are two of these pieces, both of them at the same side of the cover. Once the cover is engaged at the flexible hinges, it is

turned until the contact is stabilised with the "kick spring".

2) Kick spring preloading. The function of the kick spring is to provide the initial separation speed once the cover is jettisoned. During the mounting of the cover, this spring must be compressed.

3) Panel preloading. The panel is the flat surface of the cover. The panel has some flexibility: when it is deformed to allow the bonding of the two parts of the pyro mechanism, which together are shorter than the lateral support points, it produces a joining preload at these lateral support points that prevents the cover from separating.

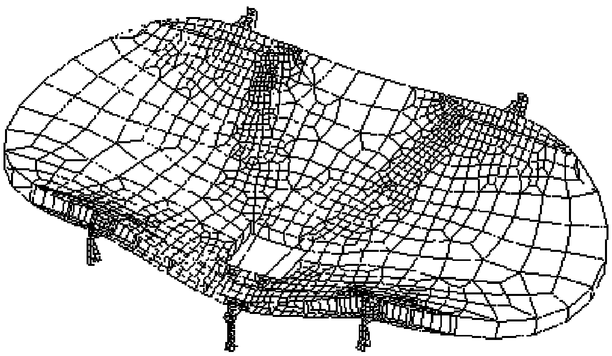

Figure 5. Baffle cover panel deformation FEM analysis (view out of scale).

4) Launch and ascent. Once all the support points are preloaded, the cover is ready for the launch environment.

5) Jettisoning. The jettisoning operation is activated firing the pyrotechnic cutter. Once the pyro bolt is cut, all the preloads of the rest of the support points are discharged and the cover is released.

- The first preload to disappear is the preload at the hard points (points C in Figure 3): when this preload is discharged the cover loses contact with the hard points.
- The kick spring will continue pushing the cover apart for some distance. Lost the contact between the cover and the spring, the baffle cover will still continue rotating around the hinge for a small angle.
- The critical rotation angle is achieved and the cover is disengaged from the hinge. The cover distances freely.

Calculation.
A detachable preloaded support can be treated analytically as a bonded piece if the preload is sufficient. The maximum external load must always be higher than the preload. Following this statement, calculating the preload is easy for static loads (or quasi-static). For sine and random loads it is also easy although a criterion must be defined: the preload is a constant force while the sine or random loads are not.

2.2 The preloaded supports.
Hinge.
The flexible hinge, of the SEVIRI entry baffle cover, was designed to fulfil the following main requirements:

- Maximum allowable volume: $60 \times 35 \times 124$ mm.
- It must provide one point of support for the cover during all the phases of the mission prior to arriving at the final orbit.
- It must passively allow, without interference and with limited friction (a friction budget must be performed) the correct release and jettison of the cover.

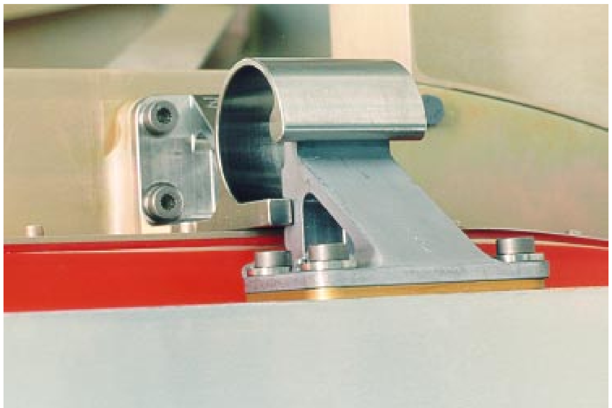

Figure 6. Flexible hinge mechanism.

Figure 7. Flexible hinge mechanism, lateral view.

The most outstanding problems that were faced during the design of the hinge were:

- The allowable volume.
- The high preload required in order to overcome the acoustic environment.
- The hinge must allow the jettisoning of the cover without interference.
- Manufacturing with very tight tolerances to achieve the required stiffness and strength.
- Cold welding due to high preloads and dynamic environment.
- The friction caused by the sliding of the two contact surfaces when the cover turns during the first stage of the jettisoning.

Figure 8. Hinge characterisation test.

In order to avoid the cold welding or similar undesired effects that could have an impact on the correct release of the covers, the detachable pieces were coated with TiC (titanium carbide) applied using the Physical Vapour Deposition (PVD) process[2]. Unlike other processes, this process may be carried out at a temperature which maintains the properties of the structure of the titanium.

The contact surfaces must be designed performing a trade-off between these two points:

- The contact surface cannot be a flat surface against another flat surface, since this kind of contact surface cannot withstand forces in a plane (or only by friction).
- The contact surface cannot be a cone against a cone or sphere if the aperture of the cone is small and causes bonding due to friction.

The conclusion of this trade-off must be the aperture angle of a cone:

- Closed enough so that every lateral or axial load is withstood without the surfaces detaching (for a given preload).
- Open enough so that the contact surfaces do not get stuck due to friction (for any preload).

From the hinge standpoint, the functional sequence of the jettisoning is:

- Once released, the cover loses contact with the hard points and the kick spring. Up to this point, the cover has turned around the hinge.
- The cover continues rotating around the hinge up to the critical angle. During this rotation there is friction between the two surfaces in contact. The preload produced by the flexible hinge itself causes this friction. Nevertheless, since the preload decreases as the angle is changing, the friction also decreases.
- There is an angle, between the "loss of contact with kick spring" angle and the critical angle for which the preload is zero.
- The cover loses contact with the hinge and disengages.

Hard points.

Figure 9. Hard points.

Hard points, located in front of the flexible hinges, are composed of two detachable parts: on the cover side a cone and on the satellite side a sphere. This kind of contact provided the support of all the loads caused by the thermal and mechanical environment and at the same time made it possible for the cover to separate without interference or friction. The aperture of the cone is designed by performing a trade-off, in the same way as for the flexible hinge support (explained above).

This trade-off, performed for the hard points, concluded that there was no angle that fulfilled both conditions at the same time. The angles that are open enough not to cause friction problems during detachment were not enough to absorb the external lateral loads. This problem was solved using two aperture angles (two different cones with two different aperture angles) at the same time.

One of the angles was calculated such that it would be open enough to prevent sticking during the detachment, while the other one was calculated such that it was closed enough to prevent detachment due to the environmental loads.

[2] SENER qualified the PVD process for the Silex LEO LLD project.

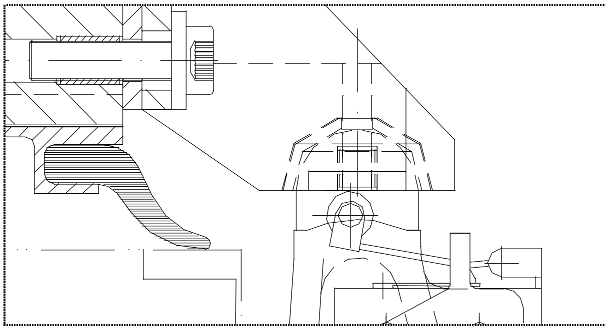

Figure 10. Hard points, contact surfaces.

Therefore, the cover contact surface, as shown in Figure 10, is not a pure cone.

2.3 Pyrotechnic support.

The fifth support point, is mainly composed of a double pyro cutter and a rod. The rod is cut to jettison the cover.

During the integration of the cover, and after supporting it by the two hinges and the two hard points, a gap exists between the fixed and jettisonable parts. This gap is absorbed deforming the panel, and therefore applying a preload to the rest of the supports (especially the hard points).

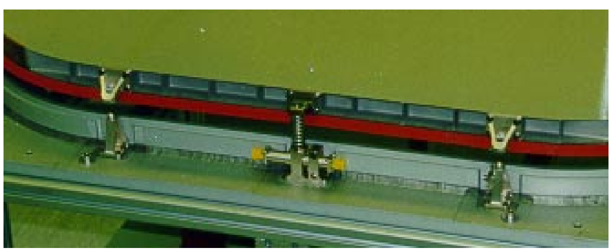

Figure 11. Pyro mechanism and hard points.

2.4 Jettisoning.

Once the covers are not needed (after transfer orbit), they must be ejected. The main requirement of the ejection is not causing damage to the satellite. For this to happen a minimum ejection velocity is required and the ejection direction must be such that no interference exists with any other part of the satellite.

Since the release of the covers is very important for the mission of the satellite, this operation has been designed with redundancy. In the case of the baffle cover the level of redundancy is up to three: the pyro cutters are fully redundant and the separation is produced by three different forces: the spin of the satellite, the deformation of the cover itself and the kick spring located next to the pyrotechnic.

All the jettisoning process has been simulated using SENDAP[3] software.

Figure 12 shows the evolution of the separation velocity and distance between the baffle cover and the satellite.

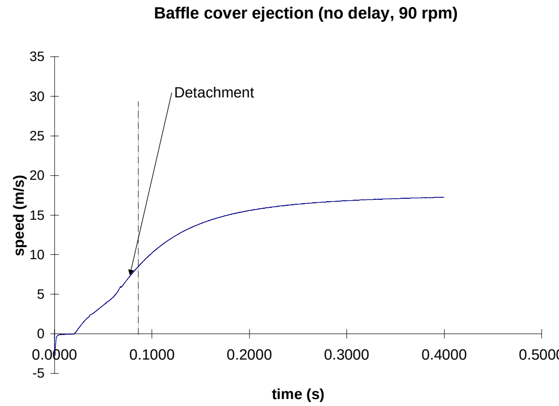

Figure 12. SEVIRI baffle cover ejection simulation.

Figure 13 shows the evolution of the separation velocity for the cooler cover. In this case, one pyrotechnic failure has been considered.

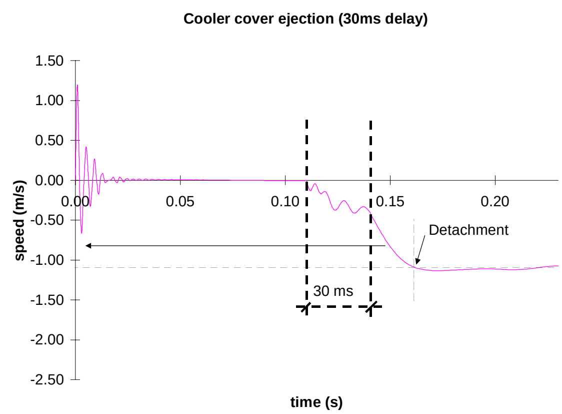

Figure 13. SEVIRI baffle cover ejection simulation.

The simulations demonstrated that the jettisoning fulfilled all the requirements, namely absence of interference and minimum jettisoning speed. The tests confirmed this fact during the qualification stage.

2.5 Other requirements.

Tightness.

So as to avoid the contamination of the inner cavities of the satellite due to the external dust, the cover provided effective isolation. A seal made of silicone rubber was designed specifically for this function: it absorbed high displacements with low sealing pressure variations.

Venting.

Since the external pressure decreases during the ascent of the satellite to its first orbit, the inner pressure must be released. For this to happen, preventing at the same time the contamination of the inner satellite elements, a

[3] SENDAP stands for SENER dynamic analysis program. This software is capable of simulating very complex dynamic situations: it was designed to simulate the docking / berthing of spacecraft and it was qualified for the HERMES space plane program.

filtering device was built and a simulation of the venting process was performed (Figure 14).

The filter provides a large filtering surface (pliable supported PTFE membrane), which was folded several times for compactness. The entire filter was sealed to avoid undesired leakage.

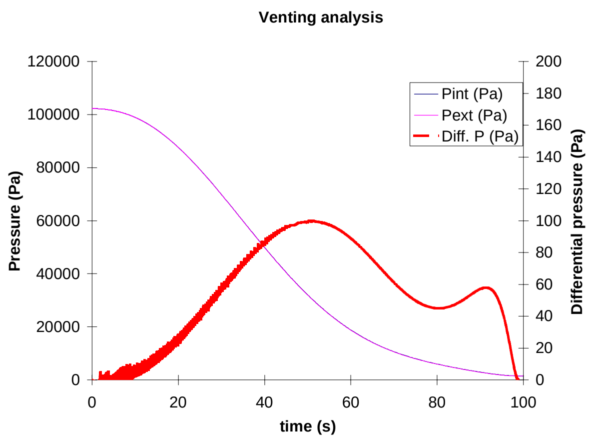

Figure 14. Venting analysis.

3. VERIFICATION.

The most important tests performed during the qualification stage of the mechanisms were:

- Environmental tests: testing the vibration, thermal and acoustic environments.
- Functional tests: the most remarkable test was the jettisoning test where the jettisoning speed was measured and the ability to release the covers without interference was proved. Another functional test proved tightness of the cover and the sealing system to be adequate.

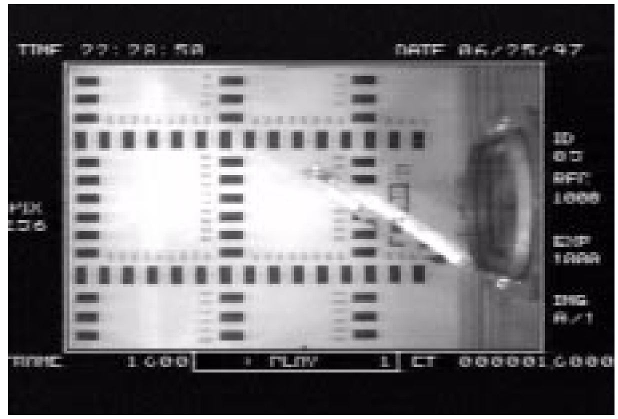

Figure 15. Baffle cover jettisoning test.

All the tests were successful, and in some cases the results measured were better than required.

4. CONCLUSIONS.

Major improvements provided are:

- The design, analysis and test of a support concept for low-mass structures (such as protective covers), including the mechanisms to release or jettison them once they are no longer needed.
- The design, analysis and test of a hinge, capable of supporting high external lateral and axial loads (support), allowing relative rotation motion between the parts (hinge), and of eventually disengaging the parts for a predefined angle (release mechanism).
- The design, analysis and test of a sealing and filtering device, capable of isolating parts and allowing at the same time quick controlled air flow between them. This device was not commercially available.

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