METEOSAT SECOND GENERATION REFOCUSING MECHANISM

B.C. Braam, H.A. van Mierlo,

TNO Institute of Applied Physics (TNO-TPD), P.O.Box 155, 2600AD Delft, The Netherlands
phone: +31-15-2692000; fax: +31-15-2692111

G. Buvril

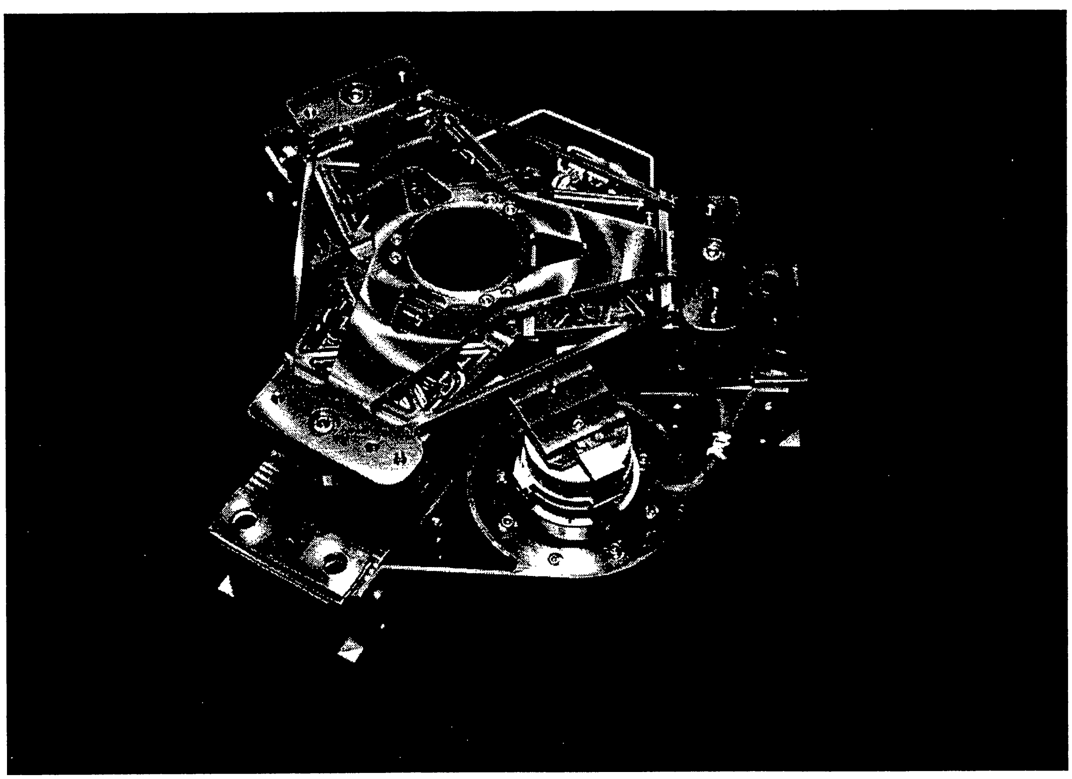
SKF Transrol, 73024 Chambery Cedex, France
phone: +33-479757975; fax: +33-479757979

S. Gill

AEA-ESTL, Warrington, United Kingdom
phone: +44-1925-252114; fax: +44-1925-252415

ABSTRACT

A refocusing mechanism has been developed for the SEVIRI telescope, the imager in the Meteosat Second Generation satellite. The purpose of the refocusing mechanism is to provide a linear displacement capability for the secondary (M2) and tertiary (M3) mirror assembly of SEVIRI.
This function is realized in two modules. A guide module provides the required stroke within the strict requirements on lateral deviation and tilt.
An actuator module provides the force for translation of the mirror unit.
Main drivers for the design were that no launch lock was allowed and the available volume was limited.
The mechanical design is based on an elastic elements guide system and an actuator system with a motor, a planetary gear box, a recirculating roller screw and a lever arm.
Presently the Engineering Qualification Model has been built and tested successfully.



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1. INTRODUCTION

The Meteosat Second Generation (MSG) programme is being implemented by the European Space Agency (ESA), in cooperation with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). Prime contractor for the MSG spacecraft is Aerospatiale in Cannes (Fr). The Imager of the MSG satellites, called Spinning Enhanced Visible and Infra-Red Imager (SEVIRI), is developed by Matra Marconi Space France (MMS-F).

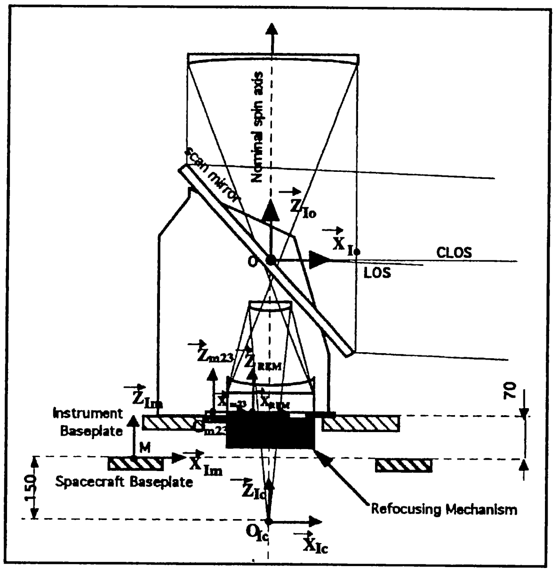

Figure 1 SEVIRI configuration.

The SEVIRI configuration is schematically presented in Figure 1. The part of the Earth surface that can be monitored instantaneously is a few square kilometers. A complete image of Europe is realized by scanning. The East-West direction is covered by rotation of the satellite and the North-South direction is covered by the scan-mirror. The SEVIRI entrance beam (diameter: ~1 m) travels via the scan-mirror to the primary mirror and then via the secondary (M2) and tertiary (M3) mirror system to the focal plane unit. The optical beam travels through the center of the REfocusing Mechanism (REM). The function of REM is the translation of the M2/M3-mirror-system along a straight line. In this manner defocusing in SEVIRI due to changes in environmental conditions after launch can be corrected.

REM consists of the following components:

- The mechanical interface with the SEVIRI instrument (baseplate).
- The mechanism itself, including motor, transmission and sensors (temperature, end stops).
- The mechanical interface with the M2/M3-mirror-system.

The main functions of REM are:

1. Support the 3.9 kg M2/M3-mirror-assembly (CoG 110 mm above REM) and maintain its position, at µm accuracy, during launch **without a locking device** and without using power.
2. Provide a controlled linear motion of the M2/M3-mirror-assembly for a stroke of +/- 1 mm (lateral deviation/decenter: < 25 µm; spurious rotations/tilt: < 25 µrad).
3. Maintain the M2/M3-mirror-assembly in a fixed position (stability 10 µm) during its life time.
4. Allow the passage of the optical beam from the primary mirror to the telescope focal point.

2. REQUIREMENTS AND CONSTRAINTS

The most relevant requirements of REM are presented in Table I.

Table I Requirements refocusing mechanism.

Item:	Value:	Remark:
dimensions	ϕ280 mm x 123 mm	
mass	< 7.9 kg	
power	< 14 Watt	peak
stroke	+/- 1 mm	functional
endstops	+/- 1.1 mm	electrical
	+/- 1.2 mm	mechanical
eigenfrequencies	130 Hz	perpendicular on motion direction
	180 Hz	in motion direction
lateral motion	< 25 µm	
rotations	< 25 µrad	all axes
resolution	1.4 µm (+/- 30%)	over entire stroke
operational time	120 hrs	in 7 year
storage	12 years	on-ground

The environmental conditions are given in Table II.

Table II Main environmental constraints.

Item:	Value:	Remark:
quasi-static loads	+/- 16 g	lateral directions (launch)
	+/- 30 g	axial directions (launch)
interface loads	+/- 270 N, 10 Nm	with baseplate
	+/- 10 N, 3 Nm	with M2/M3-mirror-syst.
temperature	+13 to +43 °C	operational
temp. gradient	+/-4 °C	operational

3. DESIGN

The REM design consists of two modules which are related to two main functions: guiding and actuation. The Guiding Module guides the M2/M3-mirror-system and provides adequate lateral stiffness, which is of primary importance during launch.

The Actuator Module provides the actuator function, the holding force and the axial stiffness in the actuation direction during launch.

Hereafter the key features in the design are further elaborated.

3.1. Guide Module

Systems based on elastic elements can be applied as guide system for low stroke applications. The Guide Module is a system on the basis of six folded leaf springs. The concept is presented in Figure 2 which shows the configuration of the leaf springs and the direction of motion of the rigid body that connects the leaf springs.

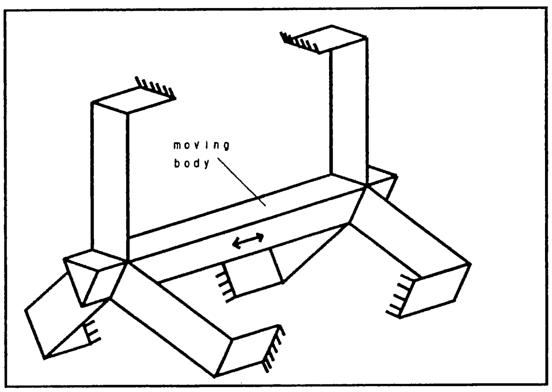

***Figure 2** Six folded leaf springs.*

Each folded leaf spring constrains one degree of freedom. This is illustrated in Figure 3[1], showing the folding leaf spring as two separate springs. A single leaf spring can constrain three degrees of freedom. In the folded leaf spring only the z-direction (degree of freedom) is constrained at the end of the system. Leaf spring B cannot pass on the constraints x and rot y as provided by leaf spring A.

The six folded leaf spring configuration provides six constraints while only five are needed for a guide system. As a result the moving body is overconstrained once. The sixth leaf spring is needed to provide sufficient stiffness and strength to the design. Analyses showed that this did not affect significantly the performance of the system.

Alternatives such as a membrane approach were extensively studied, but appeared to be not suitable. Especially the many over-constraints in a membrane system are the cause of tilts beyond the specifications.

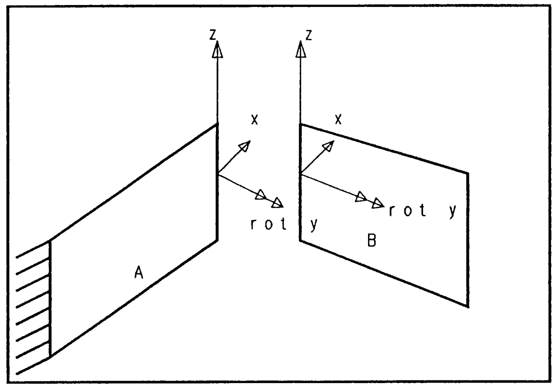

***Figure 3** Constraint realized with folded leaf spring.*

Due to the symmetry, the configuration is insensitive for thermal effects. Changes in temperature have practically no effect on the performance because the thermal center (axis which maintains its position during temperature change) in the REM design coincides with the geometrical center[1]. Analyses showed that thermal gradients cause a lateral displacement of less than 1μm in the REM configuration, which is an effect that can be neglected.

The selected leaf spring configuration facilitates the beam passage and the realization of a minimum volume. The Actuator Module could be accommodated practically inside the Guide Module envelope. The realized design is presented in Figure 4. The figure shows the six folded leaf springs as they are realized in three monolith blocks. The applied material is the $TiAl_6V_4$-alloy which was machined by spark-erosion. The mass was kept at a minimum by FE-modelling.

In more detail the design of the leaf spring configuration fulfills the following design criteria:

1. The dimensional stability meets the requirements.
2. A low mass design.
3. The maximum stresses, both during launch and at the end of the stroke, are about 200 MPa which is sufficiently below the proof stress of 900 MPa.
4. Adequate lateral stiffness and strength.

The force required to move the moving body from its zero to its 1 mm position is ~500 N.

The M2/M3-mirror-system and its interfaces are located outside the REM volume, while the REM moving body is located inside. In order to provide a mechanical interface, the moving body is extended with a top bracket. This bracket is connected to the moving body via three rods, thus keeping the volume and mass within the requirements.

The central cylinder was made of black anodized Aluminium and acts as straylight/radiation baffle.

3.2 Actuator Module

The Actuator Module consists, besides a housing, of the following components:

1. A stepper motor.
2. A transmission that amplifies the motor torque.
3. A screw/spindle system that transforms a rotation into a linear motion and a force.
4. A lever arm that connects the Guide Module and the Actuator Module.
5. A mechanical end stop.

Figure 5 shows in which manner the Actuator Module fits within the REM design. Details of the Actuator Module are presented in Figure 6. The Module has a compact concentric design with a volume of ϕ100 mm x 123 mm in extended position. The housing has a triple labyrinth seal to restrain possible debris of coatings and materials. Titanium was used for the Actuator Module for low mass and CTE match.

A stepper motor, with redundant windings, of a series especially developed by SAGEM for space applications, is used. The motor is optimized for maximum torque. A planetary gear was selected as transmission because of its compact volume in combination with a low mass.

The applied screw/spindle is an SKF (Transrol) 'recirculating roller screw' as presented in Figure 7. The rollerscrew was selected for its heritage, its good mechanical properties and its relative simplicity. This spindle is especially suitable because of the high forces it can sustain in combination with a low pitch.

The Module axial stiffness is achieved by the high axial stiffness of the rollerscrew (> 10^8 N/m) and the relatively high axial stiffness of the selected bearings. The stroke of the spindle is ±7 mm and is limited by the available volume.

Backdriving of the rollerscrew is prevented by the unpowered holding (detent) torque of the stepper motor which is amplified by the gearbox. With this increased holding torque the recirculating rollerscrew is able to maintain the position of the REM, even under high launch loads.

Figure 5 shows the lever arm. Important tasks of the arm are the reduction of the loads on the Actuator Module during launch and the amplification of the actuator force. The lever arm is connected to the frame via a Haberland hinge and to the moving body via leaf springs. In this manner no high lateral forces are exerted on the moving body during actuation.

For the recirculating rollerscrew the lubrication system was selected in cooperation with ESTL. The selected lubrication is Ion-plated Lead, applied to all the screw components, plus Braycote 601 grease. The two lubricants act in a synergistic manner to enhance the lubricant lifespan, since the Ion-plated Lead effectively delays the onset of polymerization of the PFPE oil-based grease. The gear box bearings are standard Ion-plated Lead lubricated and the gear-wheels are a self-lubricating combination, Vespel SP3 vs. Titanium. In the actuator a Vespel lever arm is introduced as a mechanical endstop which acts directly on the stepper motor.

4. PERFORMANCE

The performance of the roller screw has been tested at ESTL. The REM-EQM has been tested at TNO-TPD and fulfills practically all requirements. The lateral motion during actuation is < 2 µm. The tilt performance (around y) depends on the stiffness of the base-plate interface and the manufacture accuracy of the folded leaf springs. In the ideal case (stiffness: high; manufacture error < 5 µm) the tilt is < 1 µrad. The actual tilt will be about +\- 50 µrad, which is acceptable in the MSG program. The realized lateral eigenfrequency, including the mounted M2/M3-mirror-system, is 128 Hz. The axial eigenfrequency is 209 Hz.

The realized actuator force is >1200 N while 500 N is needed. The resolution is ~1.33 µm.

An over view of the realized performance is presented in Table III.

Table III Requirements versus realized performance.

Item:	Required:	Realized:
dimensions	ϕ280 mm x 123 mm	ok
mass	< 7.9 kg	6.8 kg
power	< 14 Watt	ok
stroke	+/- 1 mm	ok
endstops	+/- 1.1 mm	ok
	+/- 1.2 mm	ok
eigenfrequencies	130 Hz (rad)	128 Hz
	180 Hz (axial)	209 Hz
lateral motion	< 25 µm	2 µm
rotations	< 25 µrad	+/- 50 µrad
resolution	1.4 µm (+/- 30%)	1.33 µm +/- 10%
operation	120 hrs	ok
storage	12 years	ok

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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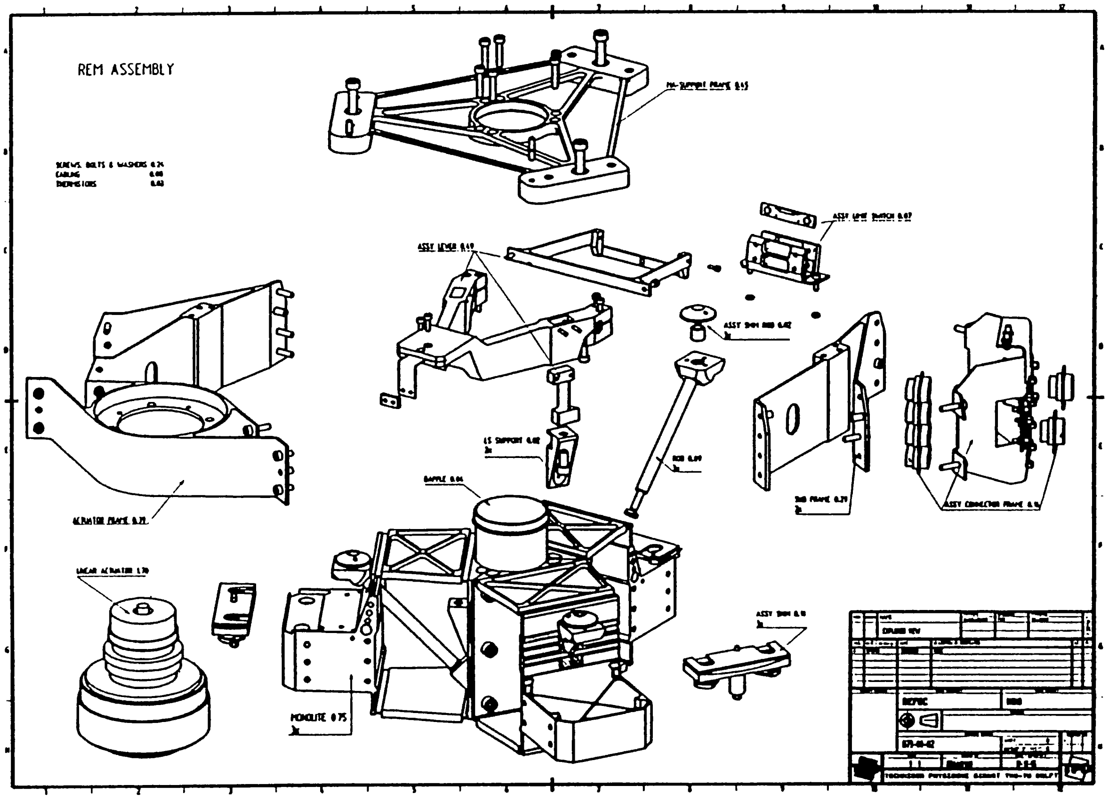

Figure 4 REM exploded view.

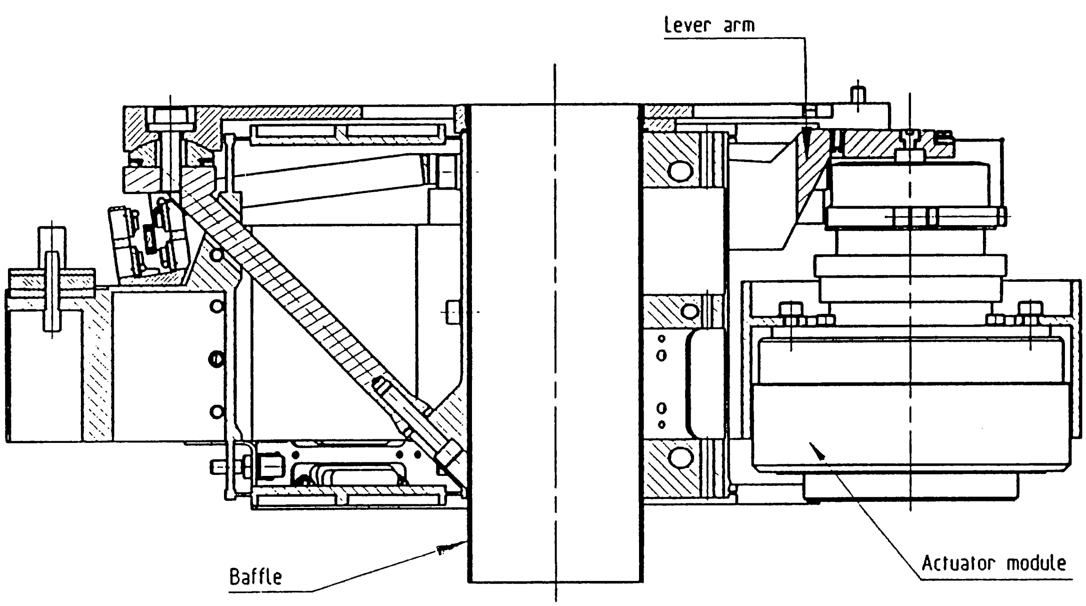

Figure 5 Accommodation of Actuator Module in REM.

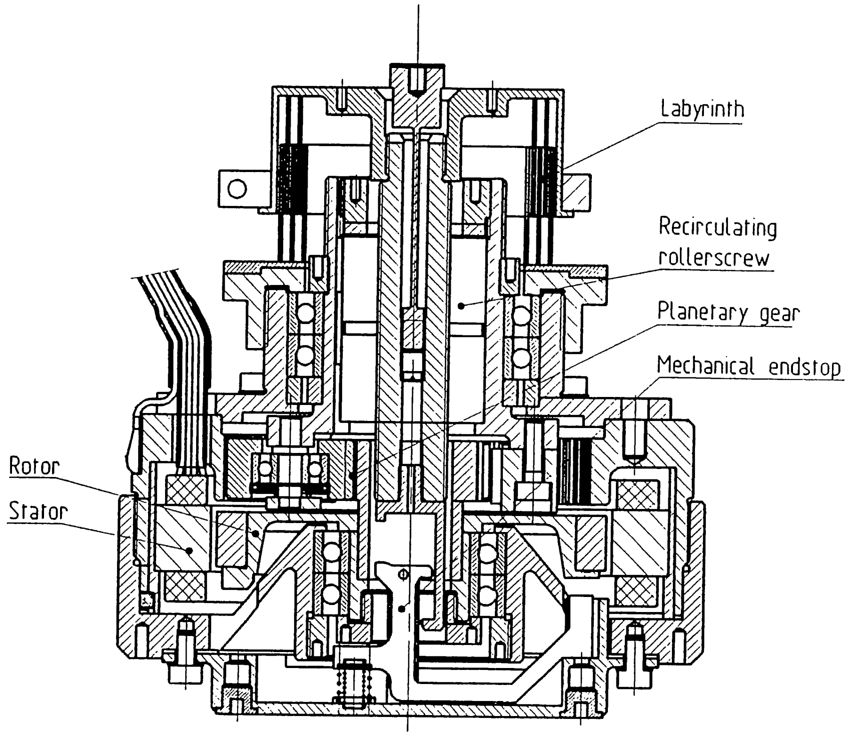

Figure 6 Actuator Module.

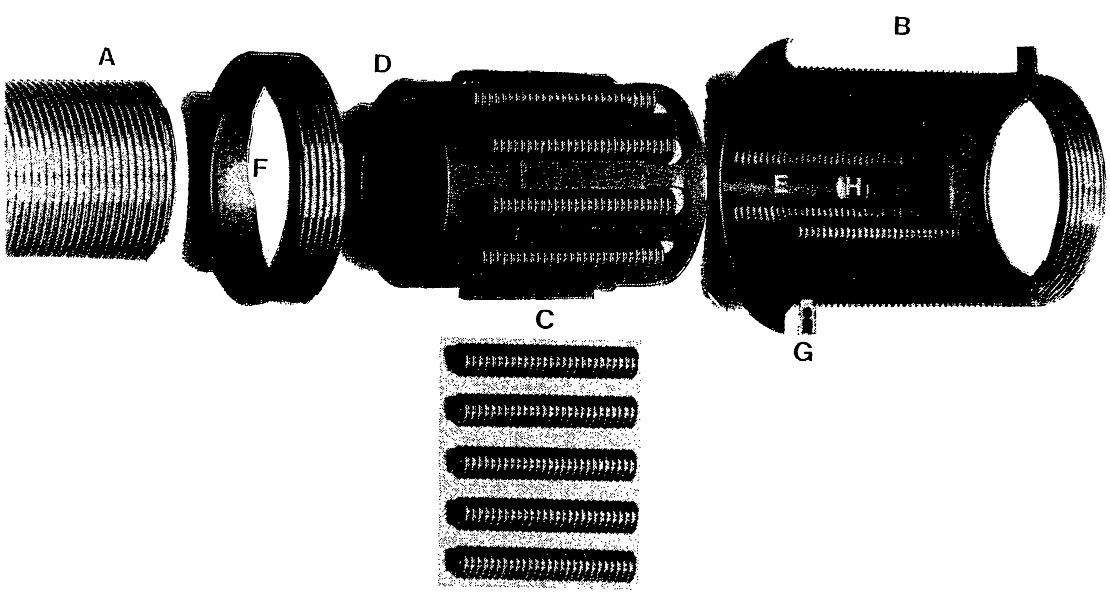

Figure 7 SKF recirculation roller screw.

Session 3

Deployment Mechanisms

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