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## Remote Manual Operator for Space Station Intermodule Ventilation Valve

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### Abstract

The Remote Manual Operator (RMO) is a mechanism used for manual operation of the Space Station Intermodule Ventilation (IMV) valve and for visual indication of valve position. The IMV is a butterfly-type valve, located in the ventilation or air circulation ducts of the Space Station, and is used to interconnect or isolate the various compartments. The IMV valve is normally operated by an electric motor-driven actuator under computer or astronaut control, but it can also be operated manually with the RMO. The IMV valve RMO consists of a handle with a deployment linkage, a gear-driven flexible shaft, and a linkage to disengage the electric motor actuator during manual operation. It also provides visual indication of valve position. The IMV valve RMO is currently being prepared for qualification testing.

### Introduction

The IMV valve RMO has often been described as “just a handle”, but in fact it has several stringent, and sometimes conflicting, requirements and constraints that have made it into a rather sophisticated and complex mechanism. The IMV valve RMO consists of several interrelated mechanisms in one unit. These different mechanisms are used to deploy and stow the RMO handle, to actuate the IMV valve, to disengage the electric motor-driven actuator, and to provide visual valve position indication.

### Requirements and Constraints Driving the Design

The requirements imposed on the IMV RMO are the reasons for its existence, but some of them contributed substantially to the resulting complexity of this mechanism. As with requirements, constraints caused the mechanism to be more complex. Constraints are sometimes described as the designer’s friend, but some were anything but friendly.

#### Requirements

The RMO must provide for manual operation by either an EVA-suited astronaut or a regulary clothed astronaut functioning in a zero-gravity environment. The EVA suit is bulky, and an astronaut can exert only limited force when restricted by the EVA suit and/or zero gravity. The RMO should rotate in the “logical” direction — i.e., clockwise to open the valve and counterclockwise to close the valve. It should also require a limited angle of rotation to avoid excess motion and ambiguity. In addition to providing visual indication of valve position without consumption of additional electric power and with minimal increase in IMV electric power use, the RMO must be visible in low light. The RMO must stow flush with or below the surface of the close-out panel. In addition, it should have a good “feel” or adequate stiffness to give confidence in both actuation

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and position indication. This also requires any detents to be adequately positive, but not “too” positive. The RMO must withstand the push-off loads imposed by an astronaut moving around the Space Station.

### Constraints

The IMV valve is located in the duct work and behind close-out paneling, thus preventing convenient or direct access to the valve and its actuator. The IMV valves are used in pairs — one located on each side of each hatch. This requires both “right-hand” and “left-hand” installations of both the IMV valve and the RMO. The logical location for the RMO is on the close-out panel as close as possible to the IMV valve. In the end cone of a module, this area is very crowded. This requires the RMO to be as compact as possible, especially in the stowed position. The available location puts the RMOs very close to the hatch track. A limited number of spare RMO and IMV units will be carried on the Space Station, and any spare must be useable in any location.

### **Detailed Description Of The Mechanisms**

The IMV RMO is actually several different mechanisms closely connected together. Each has its own purpose and unique characteristics. Making them work together in minimum space was the real challenge of this design.

#### Deployment and stowage. inverted slider-crank mechanism

To go from the stowed to deployed position, the RMO handle pivots on its handle mount and rotates about an axis parallel to the surface of the close-out panel. A spring-loaded detent mechanism holds the handle in either the stowed or deployed position. This presented some problems since the detent must be stiff enough to keep the handle stowed during launch vibration and yet permit deployment by an astronaut under zero-gravity conditions.

The RMO handle mount rises out of its housing by approximately 4.3 cm (1.7 in) during deployment. This allows the handle to rotate over the hatch track with adequate clearance for the astronaut’s fingers. Although this rising action is needed in only half of the installations since only the right-hand installation needs to rotate over the hatch track (in the left-hand installation, the rotation is away from the track), it is provided in all units for commonality. This rising action is accomplished with an inverted slider-crank mechanism driven by a pinion and sector gear. The pinion is part of the rotating handle and rotates with the handle about a pivot axis on the handle mount. The pinion engages a sector gear that is the crank of the slider-crank. The sector and crank also pivot on an axis on the handle mount. The handle mount is the slider. A connecting link connects the moving end of the sector gear/crank and a [pivot] connected to the hub. The hub is “ground,” or a fixed point, with respect to the deployment mechanism.

In more detail, as viewed from the side (Figure 1), the handle rotates counterclockwise approximately 147° from the stowed position to the deployed position. The pinion, which is directly connected to the handle, makes this same rotation about the handle pivot axis, which is fixed to the handle mount. The sector, which is part of the crank of the crank-and-slider linkage, is engaged with the pinion and rotates approximately 79° clockwise about an axis that is also fixed to the handle mount. The gear ratio between

the handle/pinion and sector-crank is 15:28. The other end of the sector-crank is pinned to the upper end of the connecting link. The lower end of the connecting link is pinned to a bracket attached to the hub. The hub is the fixed link, and the handle mount is the slider of this inverted crank-and-slider mechanism.

Stowage is just the reverse of deployment. The handle is rotated about the pinion axis, the pinion rotates the sector-crank which now pulls up on the connecting link, and the handle mount slides back down to its stowed position.

#### Valve actuation, geared flexible shaft

With the handle deployed, the astronaut can rotate the handle, handle mount, sector-crank, connecting link, etc., as a unit to actuate the IMV valve. The bracket, which connects the connecting link to the hub, also acts as a key to transmit torque from the handle mount to the hub. A gear, attached to the hub, engages a pinion which drives a flexible shaft. The gear-to-pinion ratio is 3:1 (i.e., the flexible shaft turns three times as fast as the handle). This speed-up makes the relatively small-diameter flexible shaft appear three times as stiff in torsion and reduces the torque that it is required to transmit.

#### Actuator motor and gear train disengagement, flexible shaft as push link

The IMV valve electric motor driven actuator has a high reduction ratio and is therefore hard to back-drive. This makes it necessary to disengage the motor and gear train of the actuator to permit manual operation. As the RMO handle is deployed, the handle mount slides up relative to the hub and the RMO housing. A U-shaped link, attached to the lower end of the handle mount and prevented from rotating by guides attached to the housing, pushes upward on two rocker arms pivoted on the housing. The other ends of these rocker arms push downward on a yoke that, in turn, pushes on a flange on the flexible shaft core. This exerts an axial force on the flexible shaft core, making it act as a compression link.

At the IMV valve actuator, the core of the flexible shaft pushes on a pin extending through the input pinion of the right-angle gear set. The pin pushes on a rocker link that moves the face gear clutch out of engagement. This disengages the motor and gear train from the actuator output shaft and allows the RMO to turn the actuator output shaft without back-driving the gear train and motor.

This disengagement of the electric motor driven actuator by RMO deployment also has the effect of defeating any automatic or electrical remote control of the IMV. This is a good news/bad news situation. It keeps the deployed handle from flailing about unexpectedly, but it also prevents the IMV valve from working normally if the RMO is inadvertently left in the deployed position.

### Visual position indication. RMO always turns with valve

Whether the RMO handle is deployed or stowed, it remains connected to the valve by the flexible shaft and rotates whenever the valve moves and through twice the angle the valve moves. A pointer, attached to the RMO hub, points to legend marks on the flange of the RMO housing to indicate valve position. The pointer is in the plane of the RMO housing flange to permit viewing from a wide angle without confusion.

### Overload protection, flexible shaft as torsion spring

The RMO must withstand an astronaut "push-off" load of up to 222 N (50 lbf) in any direction. If this load is imposed horizontally with the handle deployed and in a direction that would further open an open valve or further close a closed valve, it imposes torque that is a potentially damaging overload on the IMV valve actuator. There are positive limit stops in the IMV actuator at both extremes of travel that establish the fully open and fully closed valve positions. Positive rotation stops in the RMO limit handle travel to approximately 25° beyond the actuator stops with the flexible shaft allowed to deflect torsionally. This over-travel is sufficient to allow for tolerances and to ensure that the RMO or the actuator can always move the valve to either the open or closed position, as defined by the actuator limit stops, and is small enough to keep the torque below damaging levels. The torque is limited by the torsional stiffness or spring rate of the flexible shaft.

If this "push-off" load is imposed in a direction that would open a closed valve or close an open valve, it is permitted to do so. If the "push-off" load is in the direction to further deploy the deployed RMO handle, the handle and mechanism are strong enough to sustain it.

### Rigging, common units used in different locations

To achieve the commonality requirement (i.e., that an IMV valve and a RMO be useable in either the "right-hand" or "left-hand" installation), some special "rigging" is required at installation. The upper portion of the IMV valve actuator can be rotated around the valve shaft to make the flexible shaft connection face either "right" or "left." Six clamp screws must be loosened, and the upper gear housing must be rotated into proper position before the RMO flexible shaft is connected to the actuator. After the RMO flexible shaft is connected, the upper gear housing can be rotated a small amount in either direction until the visual position indicator pointer matches up to the legend marks. Tightening the six clamp screws finishes the "rigging."

## **Lessons Learned**

### Work with customer to define requirements as early as possible.

Well into this program, the specific requirements were not clearly defined. The customer was not completely sure what was needed, and early specifications for the IMV only indicated that it “provide for manual operation.” Only after many conversations with the customer and several visits to the customer’s facility were the real requirements established.

### Build development or prototype hardware early.

The proper detent stiffness was not determined until after hardware was built. The original detent was much too stiff, and the detent ball made deep grooves in the hardened detent cam. This problem had not been predicted by calculations. A larger diameter detent ball and softer spring solved the problem.

Several parts had “rattle” or lost motion, thus resulting in damage during early vibration tests. Some re-design was necessary to constrain all the parts and avoid vibration-induced damage. The RMO does not experience much vibration in service, but the in-transit or launch vibration is quite severe.

## **Conclusion**

The IMV valve RMO started out to be “just a handle,” but its stringent, and sometimes conflicting, requirements and constraints resulted in a rather sophisticated and complex mechanism. We tried to avoid or reduce this complexity, but complexity appears necessary for the RMO to accomplish its functions.

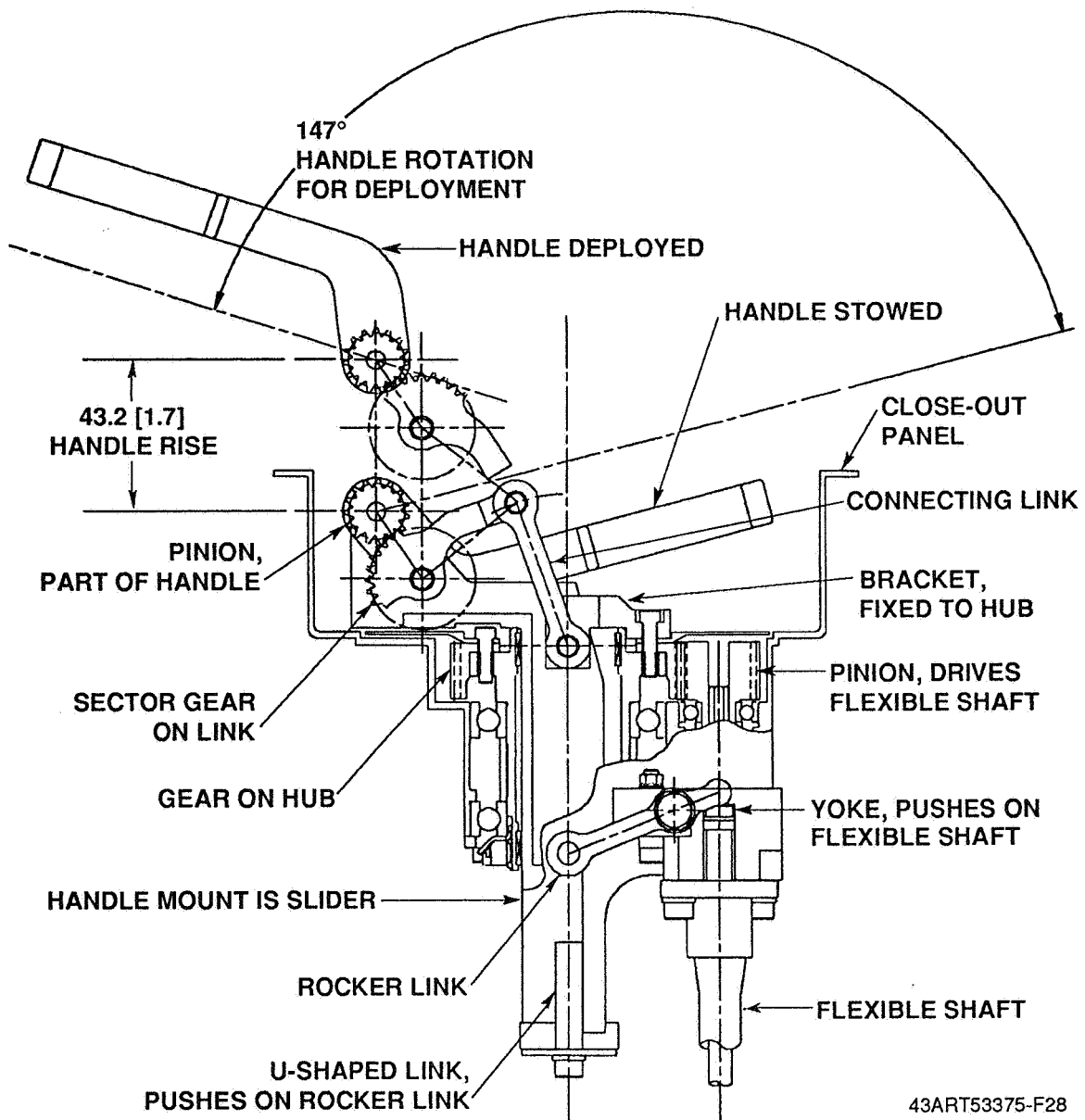


Figure 1. Side View of Remote Manual Operator Mechanism