# CVS AIRCRAFT LIFTS

BY

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ABSTRACT

After consideration of the design requirements and constraints, the essentials of the design are described. The liability of the lift platform to tilt severely was due to a design weakness in the synchronizing system. An automatic platform level sensing and shut-down facility has been designed, and an interim method of emergency stopping has been fitted. In-service experience also showed design shortcomings in keeps and latches and their interlocks, the fulcrum seal, trunnion blocks, and the hydraulic oil cooler; the resulting modifications are described.

## Introduction

Traditionally aircraft lifts in R.N. aircraft carriers have been of counterbalanced design carried by multiple chains on two or more sides of the lift platform, and driven by electric motors. The advent of the INVINCIBLE Class into service, however, introduced a radical change in lift design that utilizes a non-counterbalanced platform driven by an electro-hydraulic system designed and manufactured by Mactaggart Scott & Co Ltd.

As with most new design equipments, initial teething problems were to be expected. Since its introduction into service the CVS aircraft lift has been beset by problems. Most of these have been of a minor nature, but early operating experience revealed a more serious shortcoming in design that on several occasions resulted in near catastrophic failure of the lift machinery with serious operational implications. Poor material and documentary support exacerbates the situation and adds to the frustrations of the equipment maintainers.

This article seeks to clarify the issues surrounding the aircraft lift design and outlines the measures that have been and are being taken to overcome the known shortcomings in design and support.

## BACKGROUND

### Design Evolution

The evolution from traditional aircraft lift design to the present electro-hydraulic system stems from stringent design parameters in the lift well area of the CVS Class. The major design requirements were:

(*a*) Clear access to be provided to three sides of the lift platform at hangar deck level and a flush platform at flight deck level, together with severe limitations on the loading that could be transferred to the hangar bulkhead on the fourth side. This precluded traditional lifting chains and guides.

(*b*) A target weight for the complete lift assembly of twice the platform weight and a restricted space envelope. This precluded the use of counterbalance weights and the raising gear had to be capable of lifting the platform together with the payload.

(*c*) Power requirements to be kept to a minimum.

(*d*) The lift must fail safe at all times, irrespective of the failure mode, and the platform should then have the capability of being immediately raised to close the flight deck aperture.

(*e*) The lift must function within shipborne environmental conditions and comply with specified load and speed duties.

(*f*) The lift operating mechanism must collapse and be housed in the lift well within a height of about one-third of the lift stroke.

**Primary and Secondary Functions**

The primary functions of the lift are to maintain the integrity of the flight deck for flying operations with interruptions not exceeding two minutes, and to transport aircraft from the hangar to the flight deck.

Its secondary functions are to transport aircraft from the flight deck to the hangar and to close the opening in the flight deck in the event of NBC attack. The system is also required to complete a given number of cycles in a specified time.

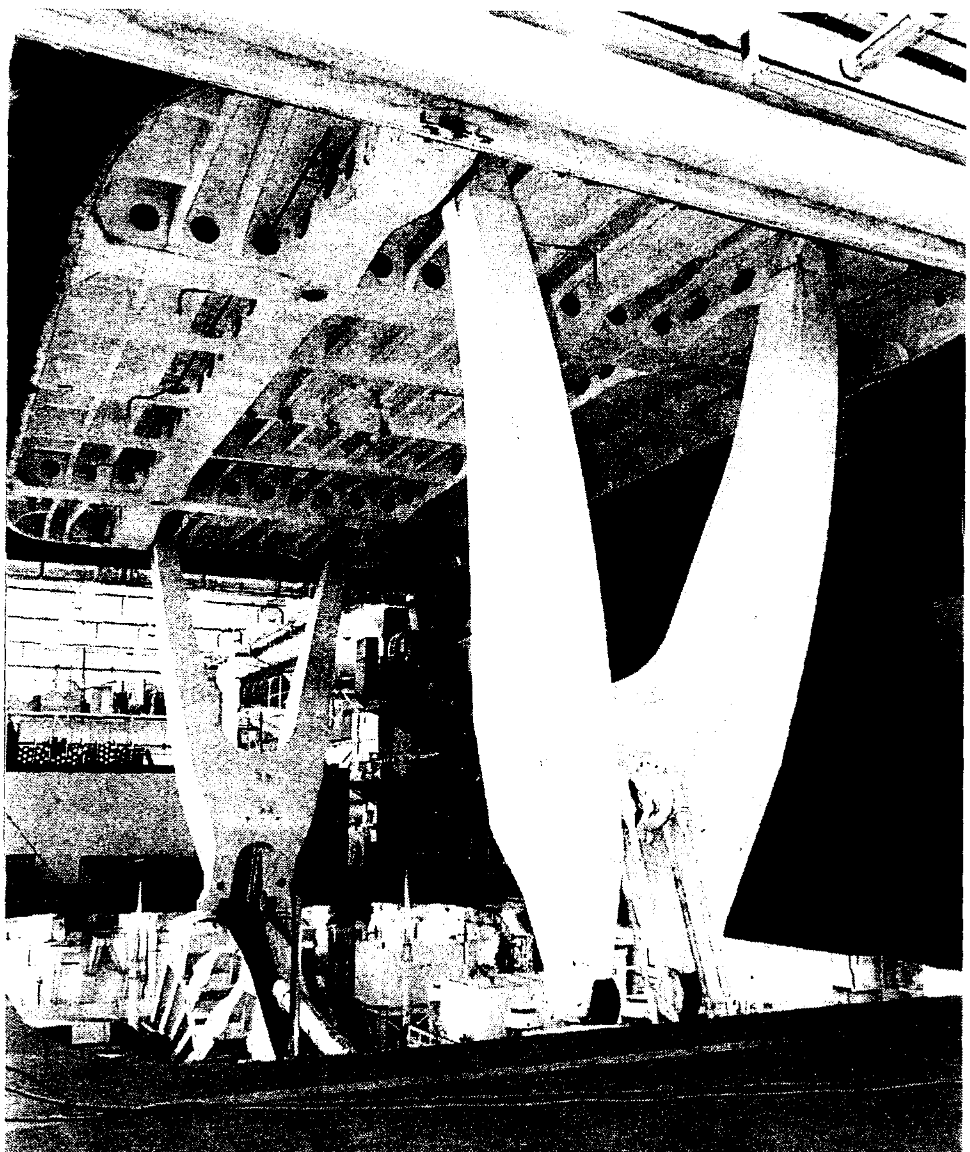


FIG. 1—CVS AIRCRAFT LIFT, SHOWING 'Y' STRUTS AND ROLLERS

**The Lift Design**

Two identical electro-hydraulic operated aircraft lifts (FIGS. 1 and 2) are fitted in each of the CVS Class. The lift platforms are 16.75 m long by 9.75 m wide with corners of parabolic form. They move at a constant velocity irrespective of payload weight distribution and have a creeping characteristic at the extremities of travel. The lift platform is a fabricated construction consisting of four main load-carrying box girders stiffened by tee sections, and it is of sufficient strength to sustain aircraft landing loads, since the platform becomes an integral part of the flight deck. The platform weighs about 70 tonnes and is supported on two 'Y' struts which have their upper ends trunnion mounted to the platform and the lower ends fitted with rollers that run on a profiled cam track.

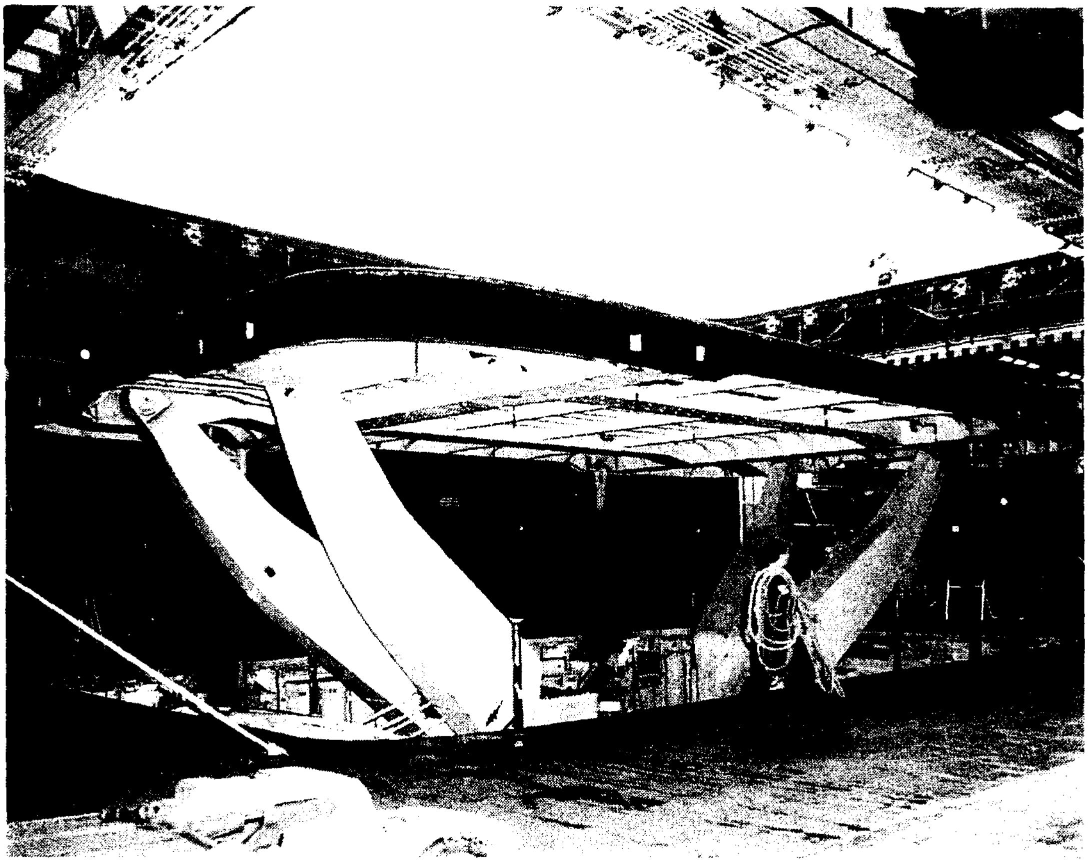


FIG. 2—LIFT PLATFORM AND 'Y' STRUTS

Each strut is attached by drag links to a hydraulic cylinder crosshead which runs on a secondary cam track (FIG. 3). The two opposed hydraulic cylinders oscillate about a single fulcrum pin through which hydraulic fluid is fed to the cylinders; in consequence the piston rods move, pulling the bottom rollers of the struts along the cam track. The profile of the cam track is such that throughout the working travel the pressure in the cylinders remains constant and the platform moves at constant velocity. Thus the power supply is constant, without peak demands.

The main hydraulic control valves (FIG. 4) are fitted directly to the main ram fulcrum bracket, there being no interconnecting pipes.

Fore and aft location of the platform is provided by two vertical guides attached to the port bulkhead (just visible in FIG. 2). These guides only carry the relatively small longitudinal loads resulting from ship motion and eccentric

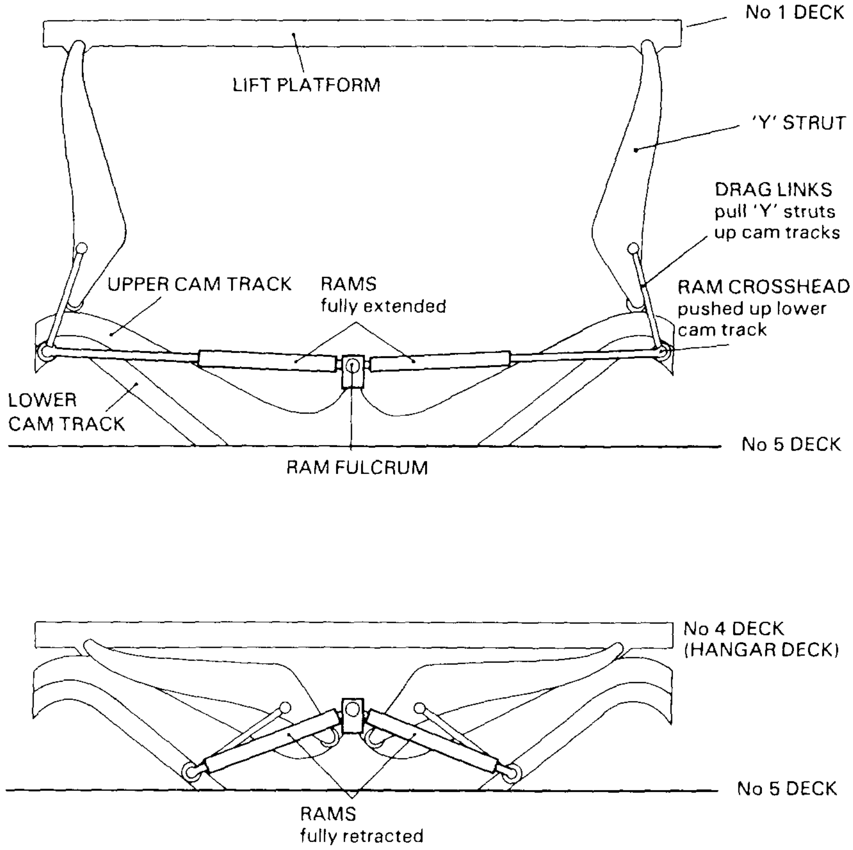



FIG. 3—LIFT OPERATION, SIMPLIFIED

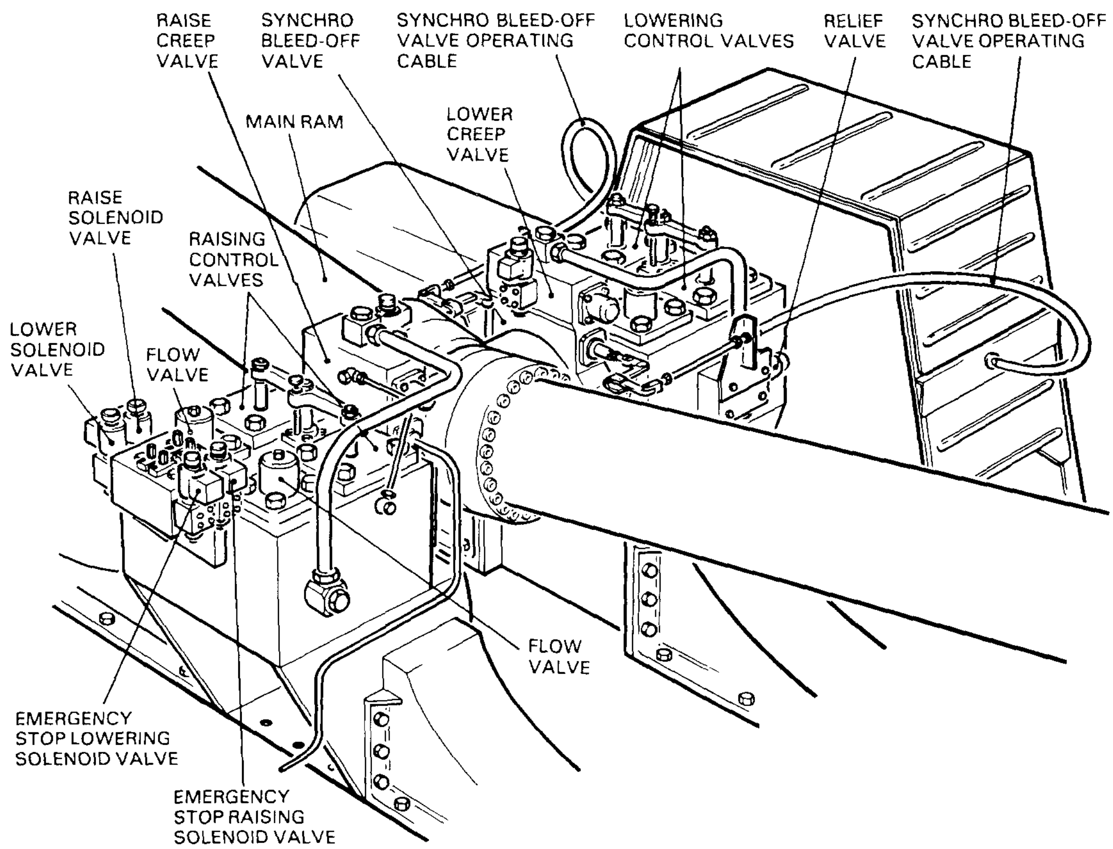



FIG. 4—RAM HYDRAULIC CONTROL VALVES

platform loading. The larger athwartships movement is carried principally by the cam structure. Buffer cylinders are fitted to provide additional lift during the initial acceleration from the hangar deck and also for cushioning on arrival at the hangar deck.

Platform alignment at each deck level is provided by a keep and latch arrangement sited around the lift openings in flight and hangar decks. Thus, when the platform is secured by these, it becomes an integral part of the deck structure and no external load, due to aircraft landing or ship movement for instance, is transferred to the lift operating mechanism.

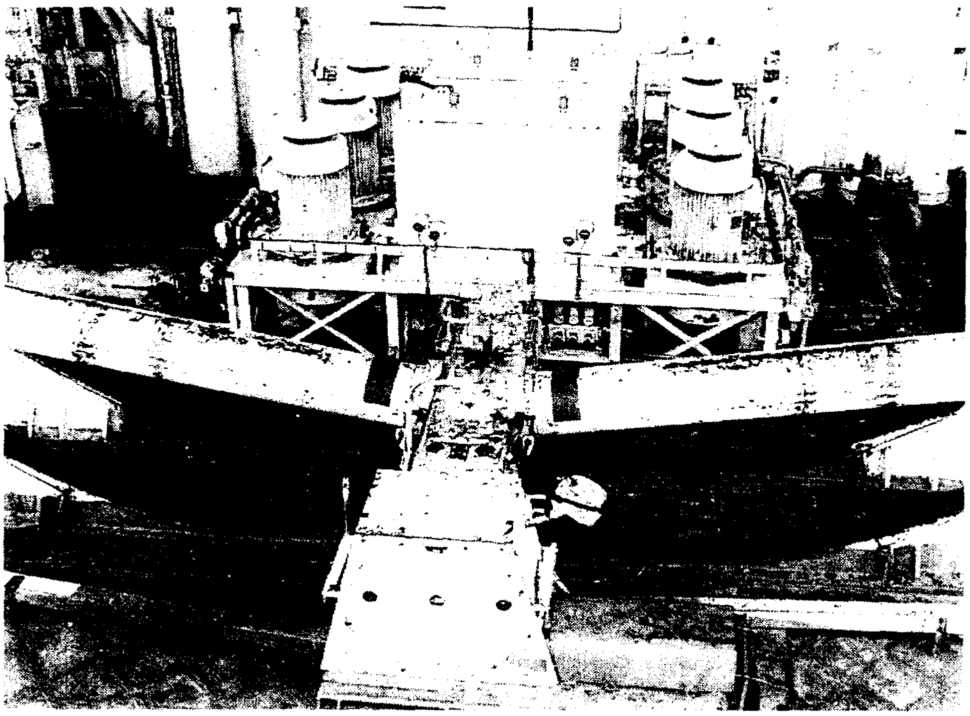


FIG. 5—LIFT MACHINERY

Hydraulic power is provided to each lift by three 115 litre/min fixed delivery pumps (FIG. 5). Each pump is driven by a 37 kW electric motor. The pumps run in an open loop circuit (FIG. 6) where they suck from a reservoir and deliver into three air-loaded accumulators of sufficient capacity to power one complete platform cycle. Pump demand is controlled by differential pressure switches which actuate hydraulic by-pass valves to maintain a system pressure of 145–173 bar.

The lift is controlled by an operator travelling on the platform, using a control rod running the length of lift travel. The entire sequence of events from selection of raise or lower is automatic. All limit switches associated with lift control are sited on or around the cam track area thereby permitting easy access and giving reasonable environmental protection.

Indication of various lift states and latch positions is provided on the lift control panel in the lift control room, enabling maintainers readily to identify any tilt condition. Remote indication is also provided at the Aircraft Control Room (ACR) and Flyco positions. Additional safety features include emergency stop push buttons and synchronizing gear interlocks to stop the lift should platform horizontal lift exceed design parameters.

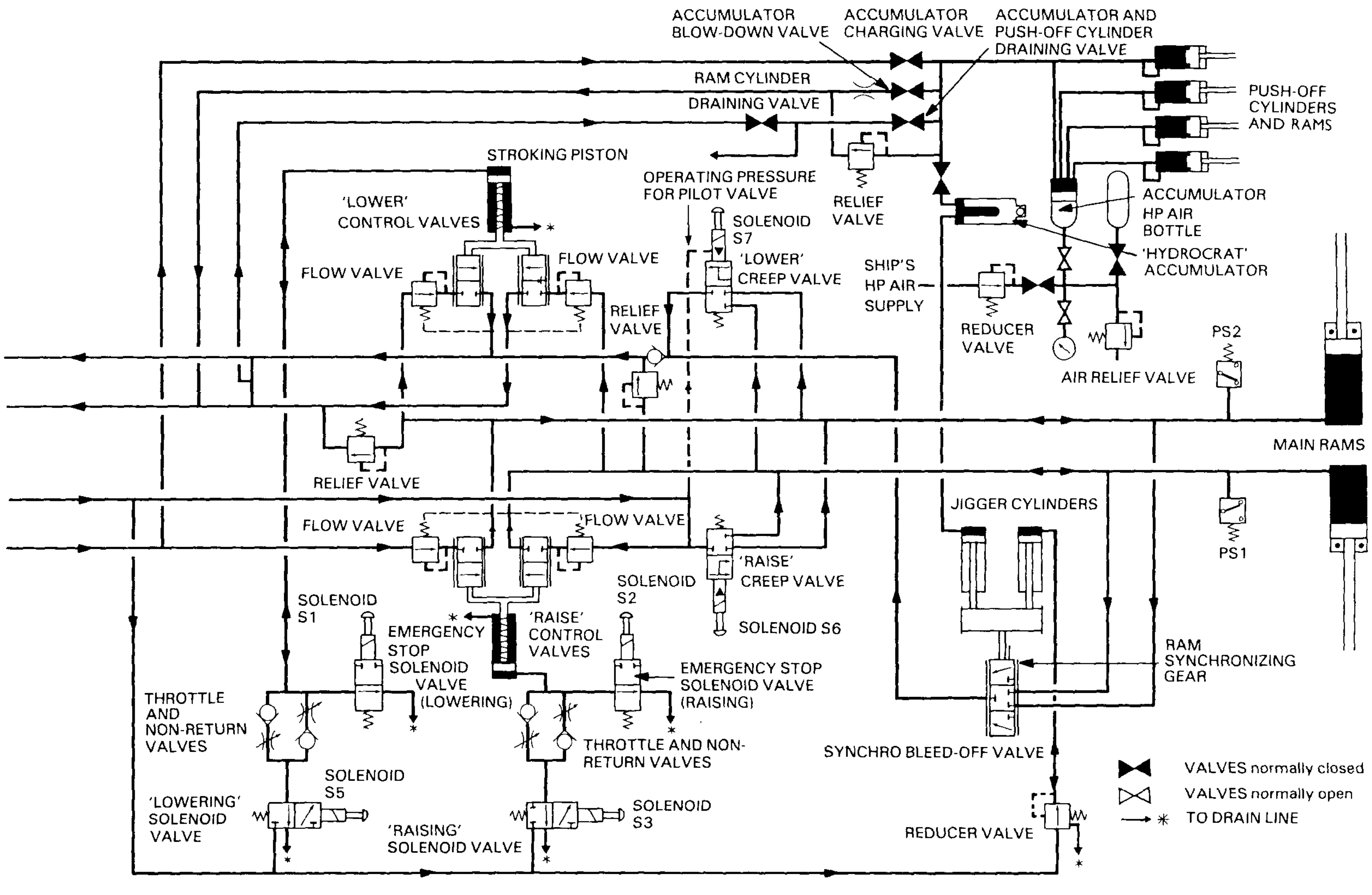



FIG. 6—LIFT HYDRAULIC SYSTEM

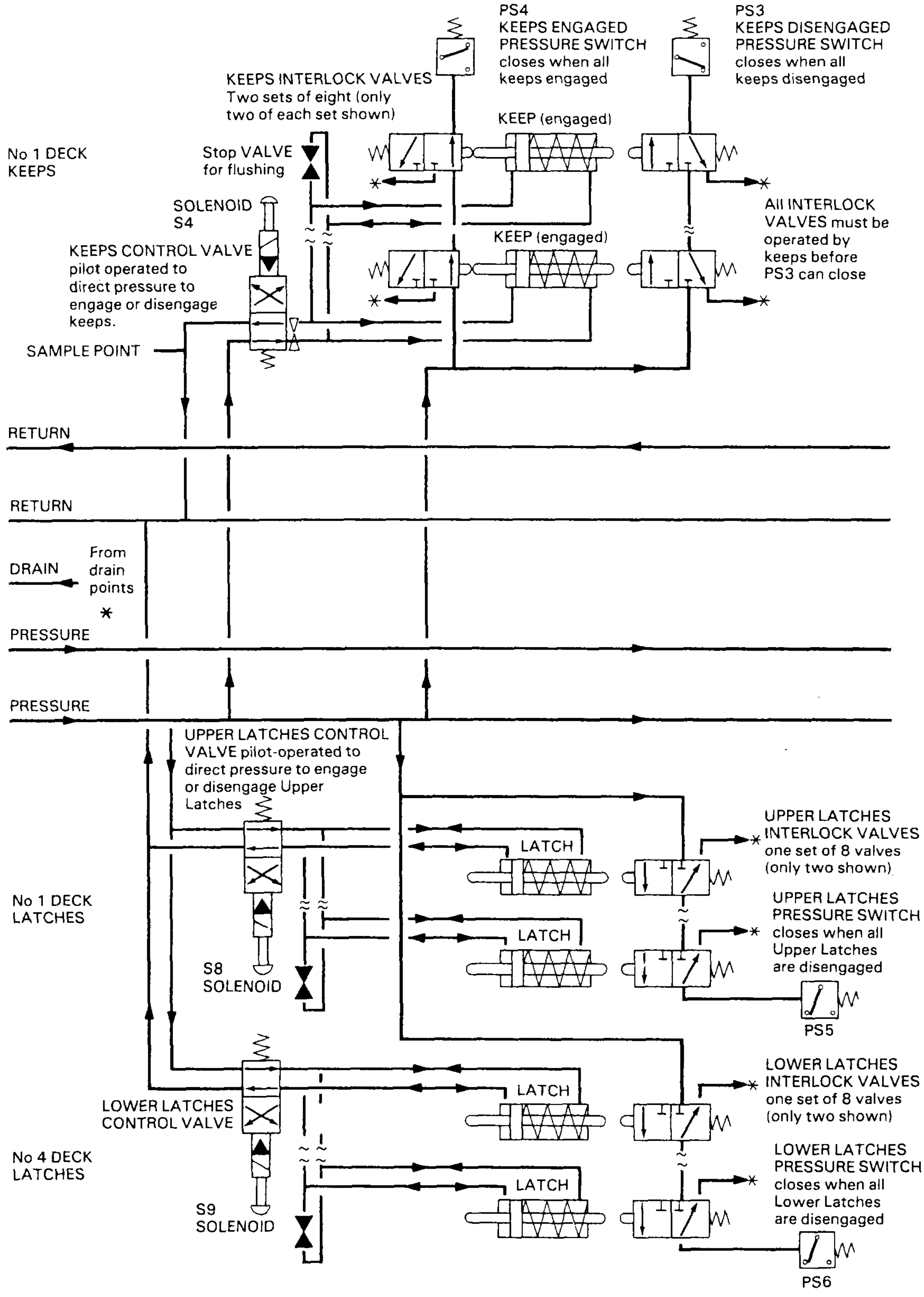



FIG. 7—KEEP AND LATCH HYDRAULIC SYSTEM

*Keeps and Latches*

Hydraulically operated keeps and latches fitted around the deck openings are designed to lock into the platform and effectively make it an integral part of either the hangar or flight deck.

A hydraulic interlock system (FIG. 7) ensures that all locks are engaged, or disengaged, before platform movement.

So that the locks engage and disengage smoothly, the platform initially rises 25 mm above the flight deck level; the keeps then engage and the platform sits down on them, and finally the latches engage to secure the platform in all directions. The sequence is reversed when lowering the platform.

*Platform Level Control*

Since there are no load-bearing guides, and the platform sits on two separate columns of hydraulic oil and is thus sensitive to eccentric loading, the platform level must be controlled by synchronizing the movement of the two main hydraulic cylinders. This is achieved by a mechanical hydraulic feedback system (FIG. 8).

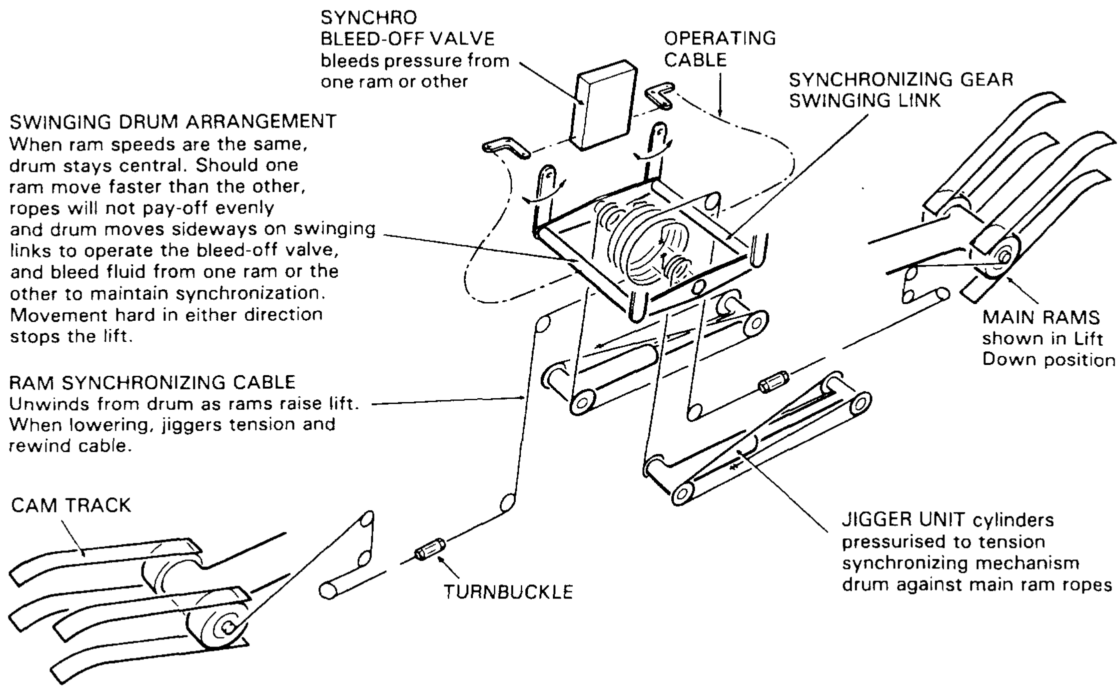
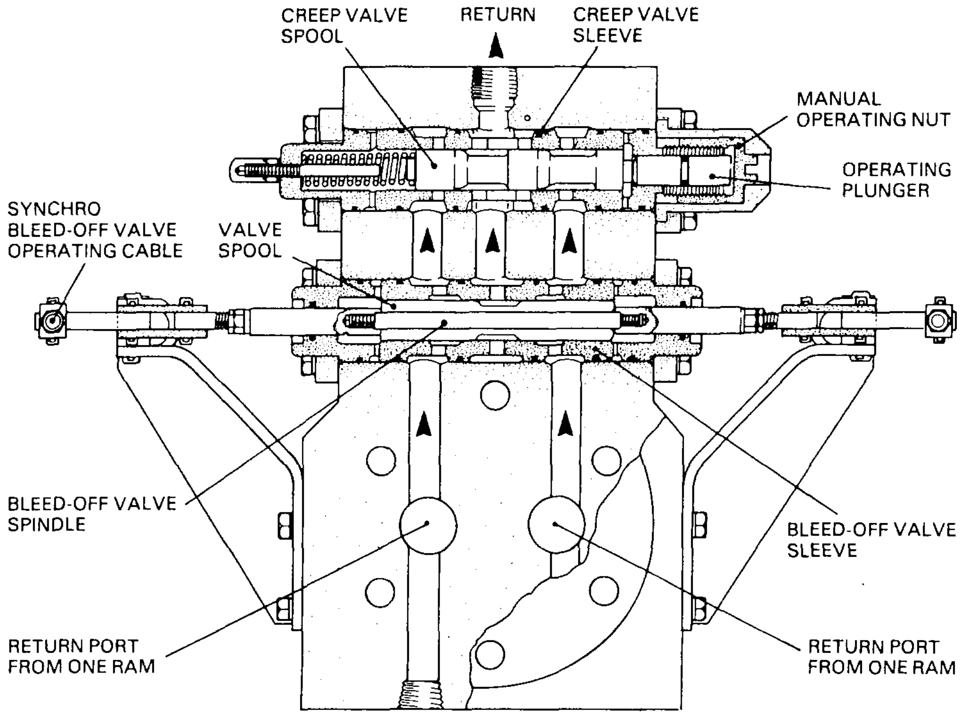



FIG. 8—RAM SYNCHRONIZING GEAR

The control valves for the two opposed cylinders are mounted directly on the common fulcrum assembly (FIG. 4). The movement of each cylinder is controlled independently by pressure-compensated flow valves which are pre-set to provide as nearly similar cylinder velocities as possible irrespective of platform load distribution. Accurate synchronization is obtained by attaching a constant tensioned wire to each cylinder crosshead. The other end of each wire is attached to a hydraulically loaded constant tension drum which is free to swing if more wire is demanded from one crosshead than the other.

The swinging drum is attached to a synchro bleed-off valve (FIG. 9) mounted on the fulcrum block at the base of the rams. The synchronizing mechanism functions by mechanically sensing any difference in axial movement between the two ram crossheads and then actuating the synchro bleed-off valve in the leading ram, so bleeding oil from that ram direct to the reservoir until they become synchronous. By this means the platform is maintained level throughout its stroke.




LOWER CREEP AND SYNCHRO BLEED-OFF VALVES

FIG. 9—SYNCHRO BLEED-OFF VALVE

## IN-SERVICE EXPERIENCE

Since its introduction into service the CVS aircraft lift has suffered many minor defects resulting from shortcomings in material or design. Of more concern have been a series of failures leading to uncontrolled tilting of the platform to extreme angles due to a fundamental weakness in the design of the synchronizing system. However, through increased on-board experience and regular meetings between the Ministry of Defence, Mactaggart Scott, and the staff of C-in-C Fleet, progress continues to be made in improving the reliability and availability of this vital 'weapon' system.

## Minor Design Shortcomings

*Keeps and Latches*

Hydraulically operated keeps and latches (FIG. 10) are installed to secure the platform at flight deck level; at hangar deck level only latches are fitted. Experience has shown that the hydraulic seals in both the keeps and the latches are prone to leakage. Not only does this result in an unacceptable spillage of oil but the efficiency of the hydraulic circuit and the smooth operation of the keeps and latches is eventually degraded. Rectification of this defect entails removal of the keep/latch cartridge from its housing. The cartridge weights 280 lb and, due to inaccessibility, particularly at flight deck level, the task is often extremely difficult and can take even an experienced maintenance crew between four hours and two days to complete. In order to limit interference with operational flying commitments the task is regularly completed overnight often in arduous weather conditions.

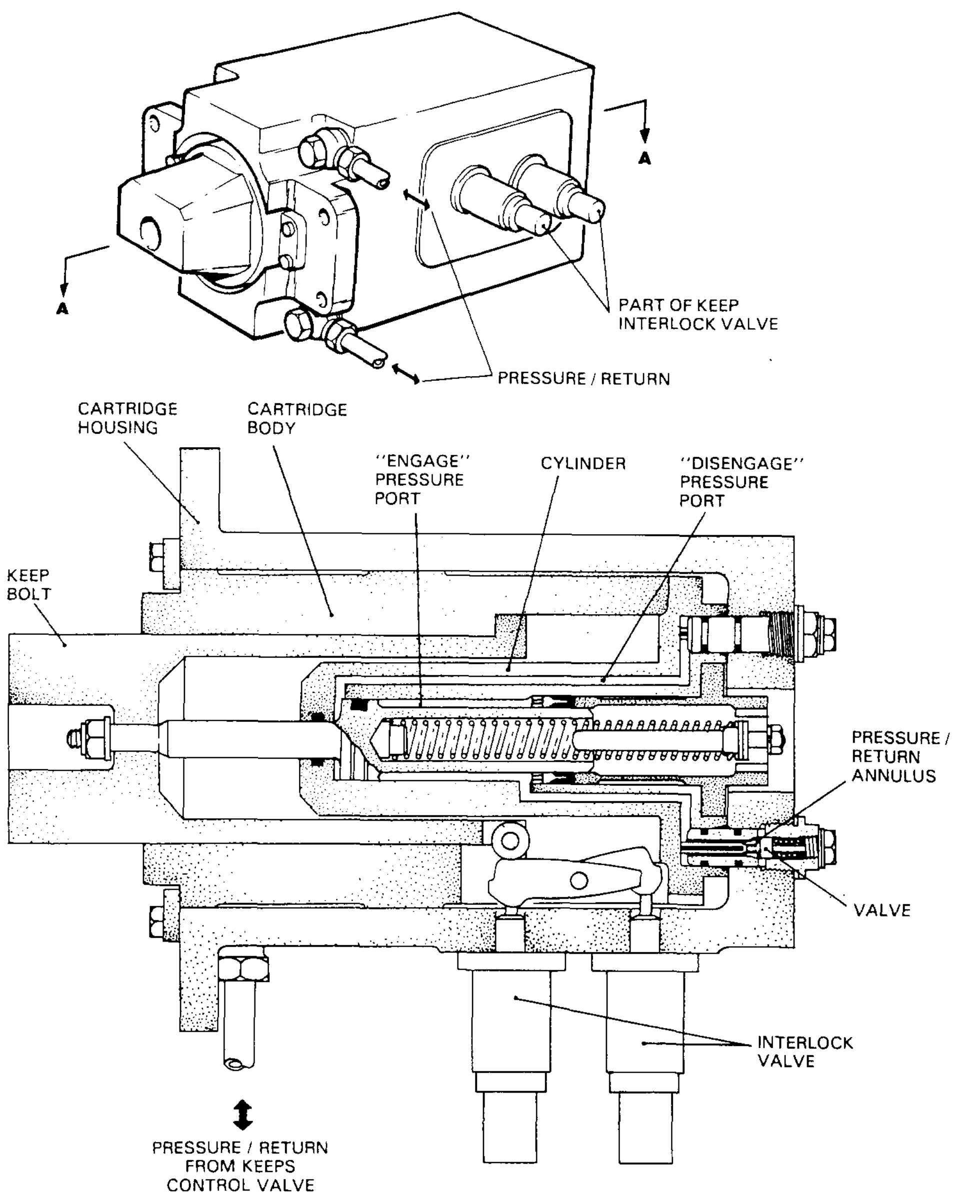



FIG. 10—KEEP; LATCHES ARE SIMILAR

To overcome these problems a modified keep/latch has been designed. It incorporates a much improved valve arrangement with the hydraulic supply and return pipework moved to the front of the cartridge, thus avoiding the need to remove the cartridge from its housing in the event of leakage.

*Interlock Valves*

The hydraulic interlock system is designed to ensure that all keeps and latches have correctly engaged/disengaged before platform movement. The interlock valves are connected in series and therefore all must operate before the control circuit can initiate platform movement. Interlock valves (FIG. 11) have been prone to failure, either from leaking seals or more usually from valve seizure due to corrosion, particularly prevalent at flight deck level. Failure of an interlock valve causes a lift hang up. The lift operator has no way of identifying which interlock valve has failed, and accurate diagnosis can only be achieved by the maintainer taking the lift in hand control and physically disconnecting the hydraulic system from each interlock in turn until the defective valve is identified, a tedious and time-consuming task.

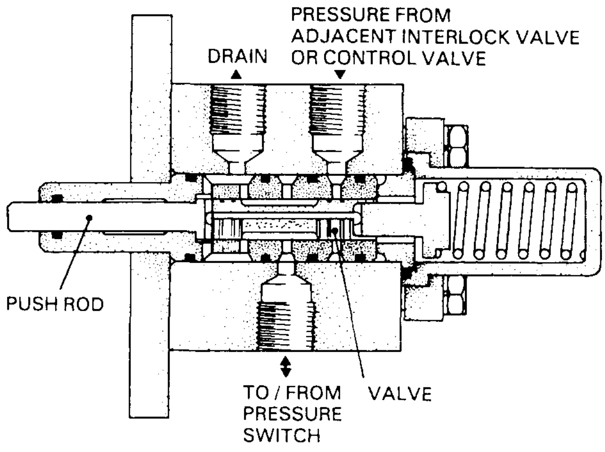



FIG. 11—KEEP AND LATCH INTERLOCK VALVE

To remedy this situation the hydraulic interlock system has been replaced by electrically operated proximity switches mounted in the keep/latch cartridge. The system incorporates a mimic board (FIG. 12) mounted in the lift machinery control room, providing a visual display of the position of the keeps/latches and so enabling the maintainer to identify the position of each keep/latch.

The new system of modified keeps/latches and proximity switches has undergone extensive trials in one ship and has proved very reliable. It will now be installed as an A & A in all ships of the Class.

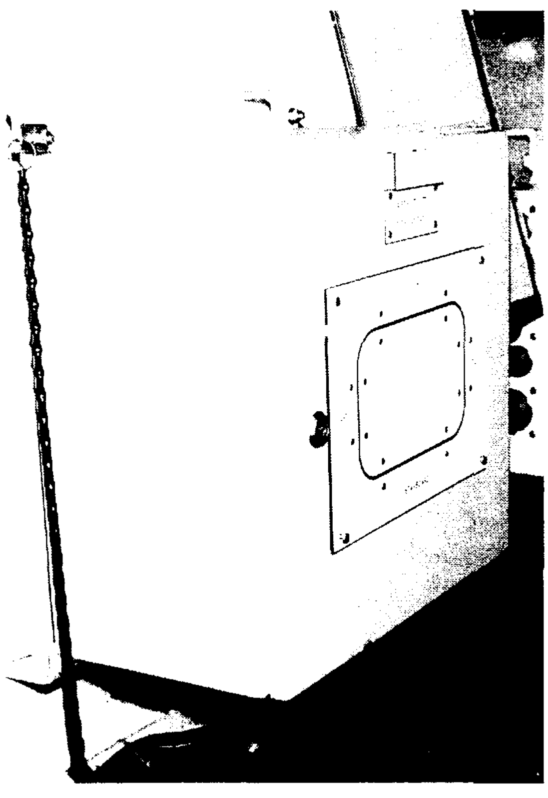


FIG. 12—KEEP/LATCH MIMIC BOARD

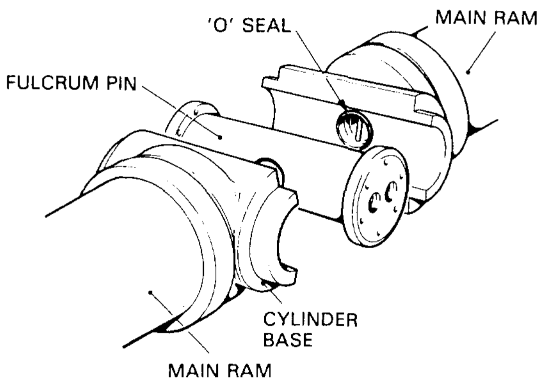



FIG. 13—CONNECTION OF MAIN RAMS TO FULCRUM

*Fulcrum Seal*

Hydraulic oil is transferred to and from the hydraulic cylinders via drilling in the fulcrum pin. Each pin sits in two half bearings and an oil seal achieved by an 'O' seal in each half bearing (FIG. 13).

These seals have tended to leak and have required regular replacemen Seal replacement is a major evolution, taking an experienced team up t eight hours to complete, with an obvious penalty to operational availabilit Various designs and material of seal were tried, all meeting with varyin degrees of success although none have achieved a tight seal for any apprec able length of time. However, success has at last been achieved with a ne seal designed and produced by Mactaggart Scott and Shamban. The ne seal has been tested over a protracted period and will now be fitted in a ships of the Class.

*Accumulators*

The hydraulic system is so designed that, in the event of a total electric power failure with the lift at hangar level, the 3×6 cu ft accumulators wi raise the platform to flight deck level. Whilst meeting the design requiremen on build the accumulators have proved to be incapable of achieving th after a period in service. This is being overcome by installing an extr accumulator.

*Structural Integrity*

In 1984 H.M.S. *Invincible* reported that both aircraft lifts were less tha smooth in operation and that the bolts securing the cam track sections wer shearing at regular intervals. The ship further reported that the lift pedest securing nuts and bolts were working loose to such an extent that 90% c the fastenings required re-securing on completion of each days flying prc gramme. As a result of the concern expressed by the Marine Engineer Office MOD commissioned a study into the structural integrity of both aircra lifts. The study was carried out in the ship by YARD Ltd. The study di not identify any serious shortcomings in the design of the lift structure, bu several modifications to the securing arrangements were recommended an will be incorporated by A & A action.

Since the study was completed *Invincible* entered refit at Devonport wher following removal of the lift machinery, significant misalignment of bot lifts was identified. The lifts will be properly re-aligned on re-assembly an this re-alignment, together with the modified securing arrangements, shoul produce tighter, smoother-operating lifts.

*Trunnion Blocks*

A CVS recently reported surface cracking of the 'Y' strut trunnion block on both lifts, discovered during regular preventive maintenance inspection An immediate Class inspection identified similar cracks in all trunnion block A full destructive inspection was therefore carried out on the worst affecte block. The laboratory report revealed that the blocks had been manufacture from steel of the incorrect material specification. Fortunately the report als revealed that the blocks had not suffered any stress and that the cracks wer formed during the casting process and had not propagated since installation

At the time of the incident much shuffling of trunnion blocks occurre between ships to enable operational programmes to be met. Replacemen blocks are now being procured for gradual installation throughout the Class

*Hydraulic Oil Cooler*

It appears that we never learn from past mistakes. The hydraulic oil coole is supplied with salt water at a much higher pressure than that of the o system. Only one case of salt water contamination has been reported; but avoidance of further failures will stem more from good engineering management of the system rather than from sound engineering design.

## Major Lift Failures

Since introduction into service there have been several serious and near catastrophic aircraft lift failures due to uncontrolled tilting of the lift platform (FIG. 14). In each case ships have had to withdraw from operational commitments and expensive and manpower-intensive base support has been required to return the lifts to normal operation. In the majority of failures the prime cause of loss of control of the platform has been centred around the synchronizing system.

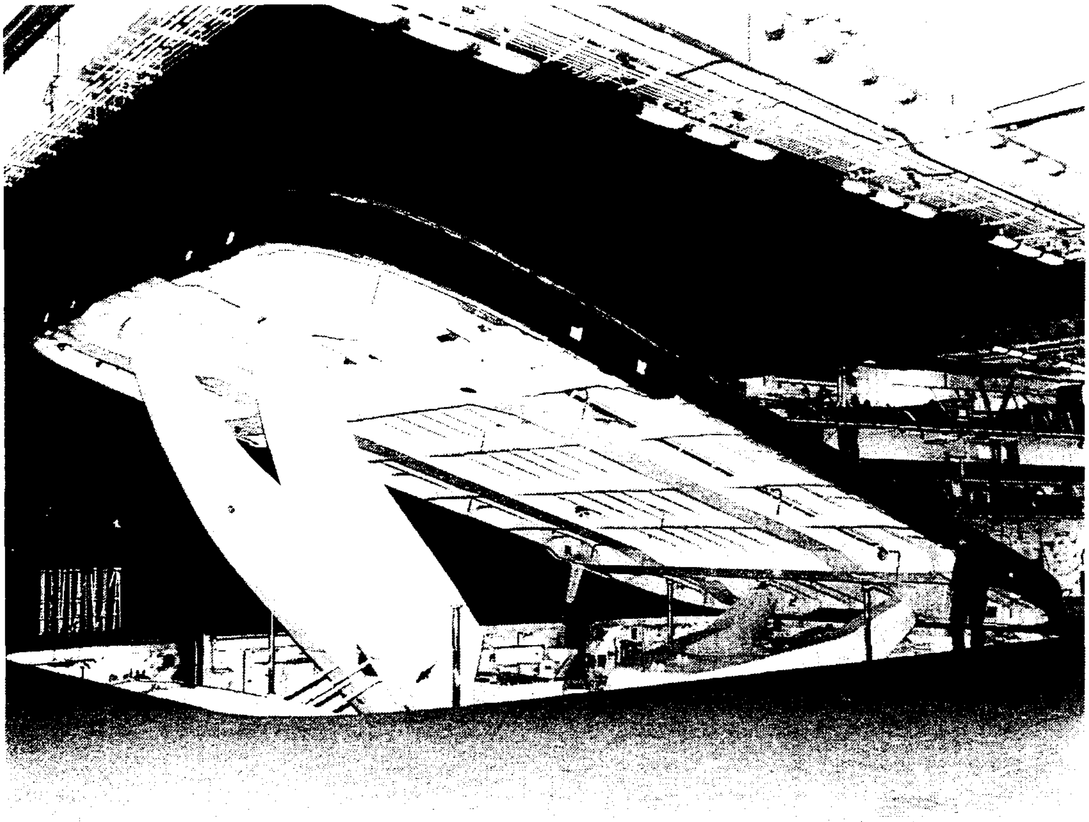


FIG. 14—MAJOR LIFT FAILURE

*Synchronizing System*

As described on pp. 552–553 platform level control is achieved by the synchronizing gear operating the synchro bleed-off valve. The system is designed so that if one of the wires attached to either ram breaks, the synchro bleed valve will be forced hard over under the action of the hydraulically tensioned swinging drum. With the synchro bleed valve hard over to either side a hydraulic lock will be achieved stopping any further movement of the lift. Should a synchro wire jam in one of its pulleys the swinging drum will be pulled towards the side that has fouled; however, in this failure mode, with the opposite ram synchro wire still intact, the synchro bleed-off valve is prevented from being pulled hard over to a hydraulic lock position. The result is that the fouled side ram is bled away to the reservoir and the platform tilts out of control until it is prevented from tilting further by a mechanical stop, usually jamming of the skate guides.

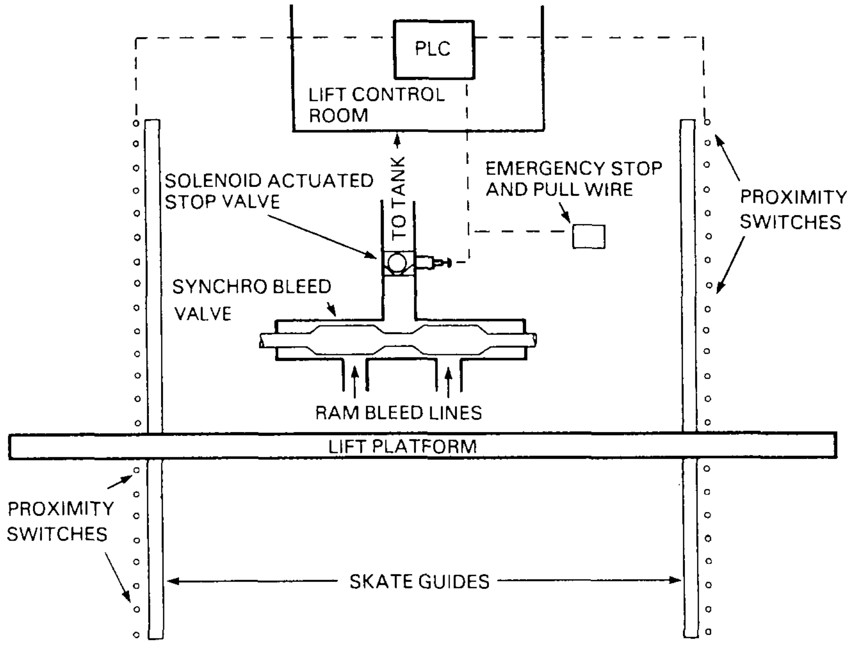



FIG. 15—SYNCHRONIZING SYSTEM MODIFICATION
PLC: Progammable Logic Controller

To overcome this, Mactaggart Scott Ltd. has proposed a modification package that provides an automatic platform level sensing and shut-down facility (FIG. 15) that is complementary but separate to the synchronizing system. The proposal incorporates the fitting of a solenoid-operated stop valve in the synchro bleed line and a series of proximity switches fitted in parallel and adjacent to the skate guides. The system is controlled through a programmable logic controller (PLC) fitted in the Lift Control Room. The stop valve is actuated by energizing the solenoid by any of four methods:

- From the platform by a pull wire accessible throughout platform travel. The wire activates a switch, so energizing the solenoid and closing the valve.
- By operation of existing emergency stop buttons.
- By manual override at the solenoid.
- Automatically by sensing platform tilt.

Whilst the full implications of this modification are being assessed in MOD, immediate short-term action has been taken by C-in-C Fleet's staff and Mactaggart Scott to fit solenoid-actuated stop valves to both lifts in *Illustrious* and *Ark Royal.* Whilst there is no automatic facility, the valves can be operated by the pull wire, the emergency stops, and the existing tilt limit microswitch fitted to the swinging drum. This interim installation proved to be very effective on trials where all modes of synchro wire failure were simulated.

Nevertheless the latest failure of an aircraft lift through uncontrolled tilting of the platform occurred after installation of the modification. It was caused by human error.