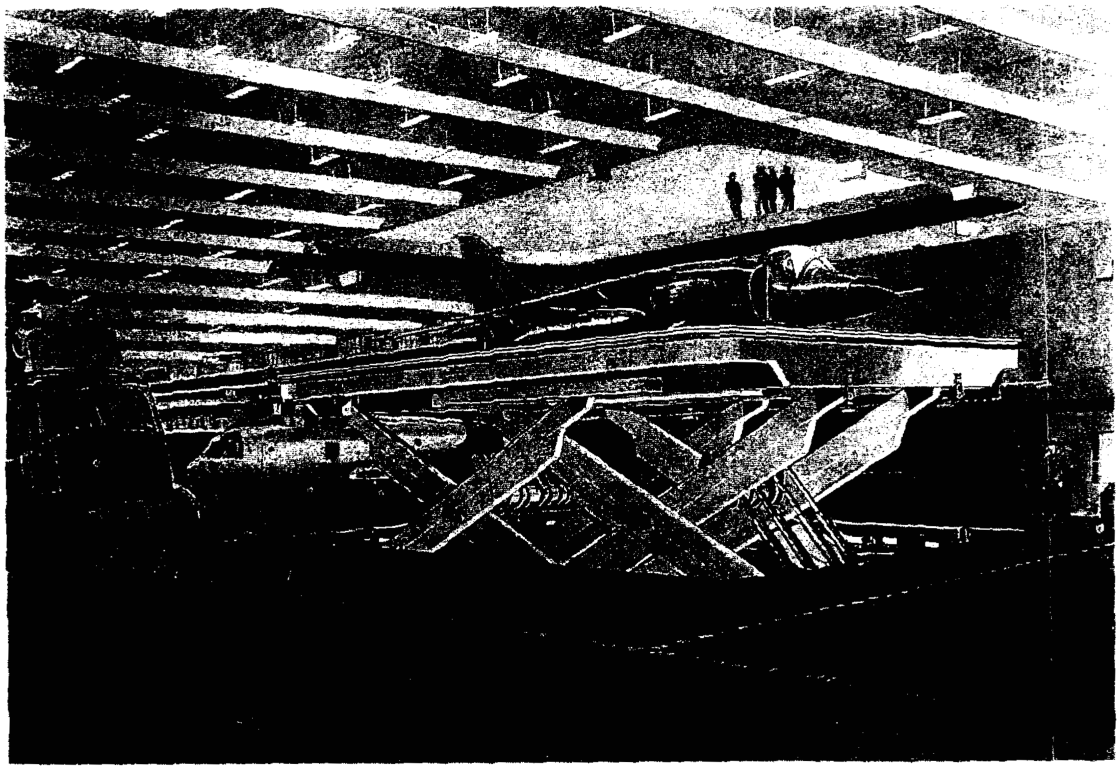
CVSG AIRCRAFT LIFT REPLACEMENT PROJECT

BY

M. LOCK
(Senior Mechanical Engineer—Strachan & Henshaw)
AND
LIEUTENANT COMMANDER P. C. KING MSC MCGI RN
(Director General Fleet Support (Equipment and Systems—ES221)

ABSTRACT

Strachan and Henshaw Ltd are developing and manufacturing a new aircraft lift for the CVSG class under contract from DGFS(ES)/ES221. The background to the decision to replace the aircraft lifts is given. The article details progress made to date on the key aspects of the prototype design and manufacture.



ARTISTS IMPRESSION OF CVSG REPLACEMENT LIFT

Introduction

An aircraft carrier's primary weapon system is its aircraft. The ability to transfer these to their launch positions from the hangar, depends on a highly reliable lift system which is safe to operate and easily maintained. The Carrier Vertical Strike Guided (CVSG) aircraft lift, as fitted at build in all 3 vessels, was a revolutionary design, *circa* 1972, which was heavily constrained by the specification. This required clear access on 3 sides, with low:

- Weight.
- Power requirement.
- Volume when lowered.

The low load capacity of the hangar bulkhead made traditional solutions difficult to engineer. The resulting lift design solved all these problems and appeared at first to be capable of meeting all its requirements. As with all new equipments the usual teething problems were to be expected, however the lift did not settle down as envisaged and it was beleaguered by many minor defects caused by shortcomings in material or design. More importantly, early in the life of the design it became clear that the control system integrity was poor, which resulted in several occasions when near catastrophic failure occurred. Some of the key areas which led to the final decision to investigate a new lift design are given below.

Background

By far the most onerous failure mode was the occurrence of uncontrolled tilting of the platform, with obvious implications for the safety of personnel and equipment. This fault was attributed to a weakness in the design of the ram synchronising gear, which could lead to a hydraulic lock safety feature not operating. This resulted in ram pressure being bled away on one side of the lift and therefore uncontrolled tilt of the platform (FIG. 1). A solution has been derived which uses a programmable logic controller which detects tilt and closes a stop valve. Despite this there has been a further incident which resulted in a lift tilt and although this was eventually attributed to human error, it could not be said that the possibility of tilt had been completely removed.

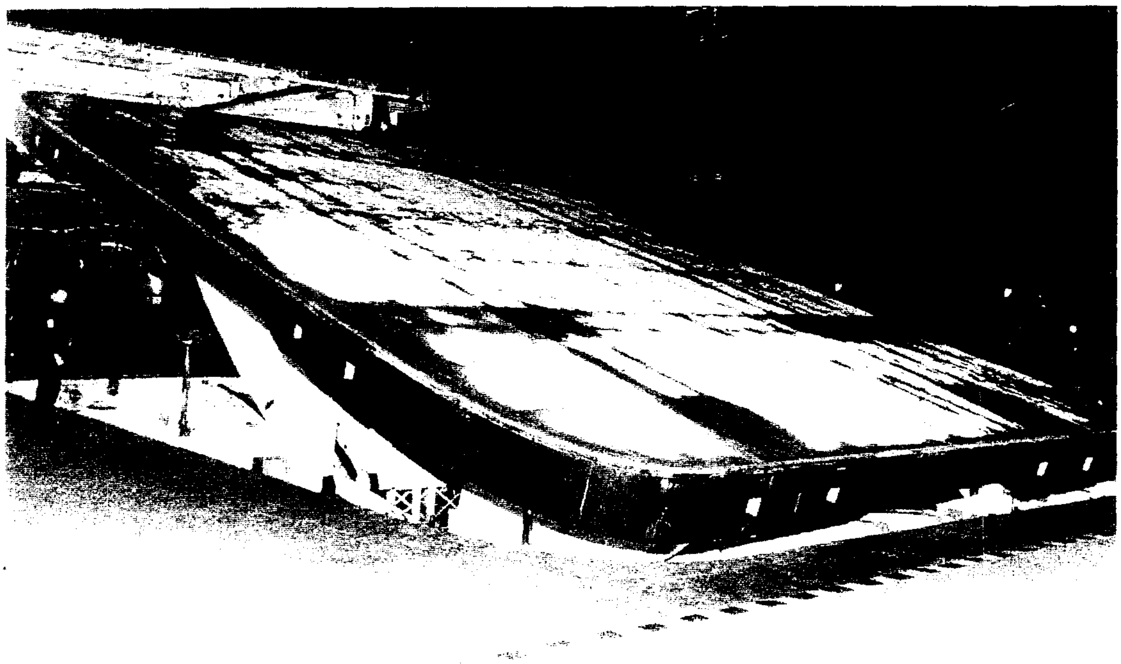


FIG. 1—UNCONTROLLED TILT OF THE PLATFORM

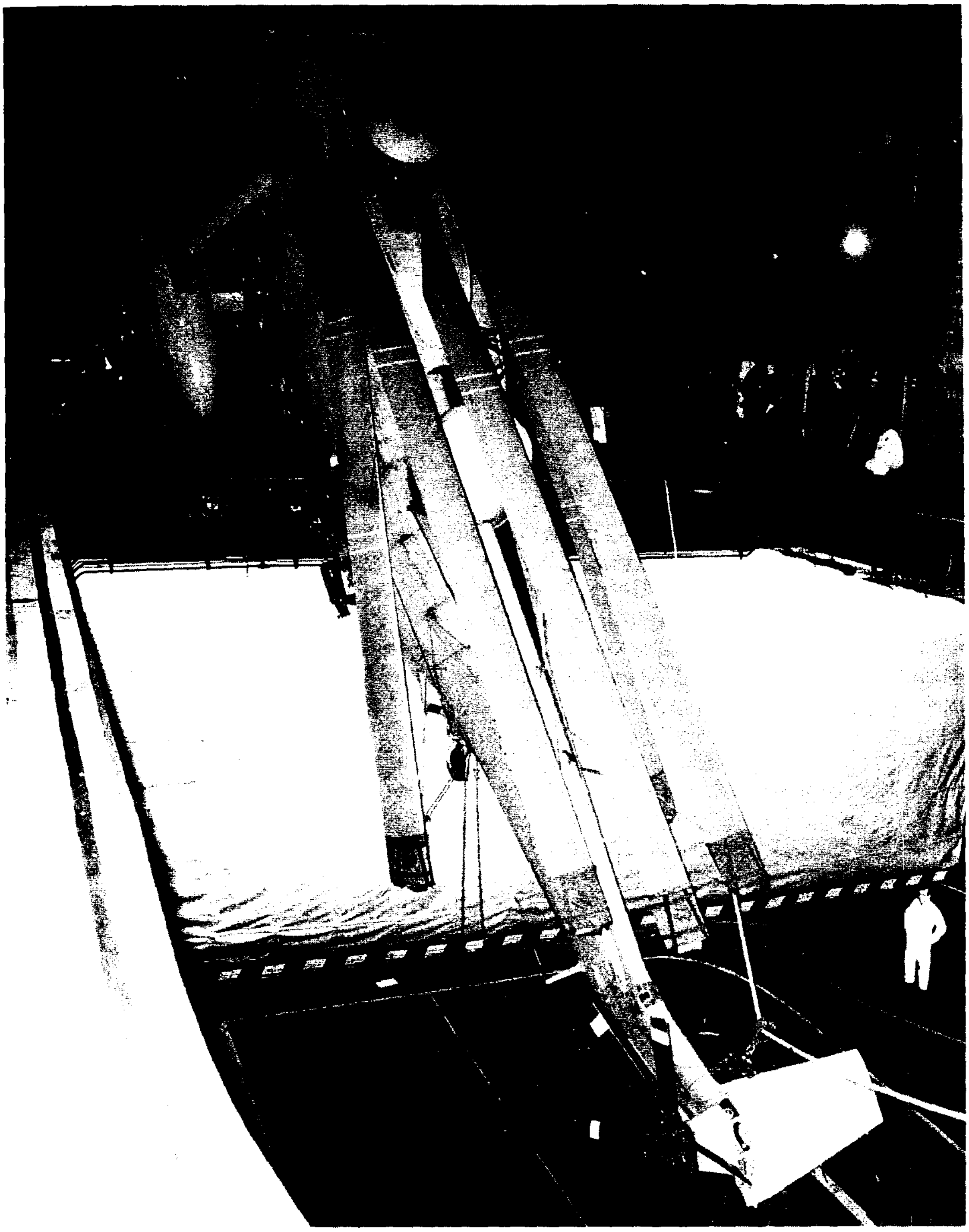


FIG. 2—SEA KING ON BOARD H.M.S. 'ILLUSTRIOUS'

In 1987 a SEA KING on board H.M.S. *Illustrious* was damaged, when the lift started to move without demand while the aircraft was being loaded onto the platform (FIG. 2). This was traced to a single point failure in the operating key control system design. Fortunately there was no loss of life but an expensive asset was badly damaged.

The majority of the defects reported were due to minor design shortcomings which have been improved over the years. It is these more frequent minor faults which consume maintenance time and irritate the operators. The most frequently reported defect is the poor performance of the lift weather seal. Water entering the hangar hampers helicopter maintenance in the vicinity of the lift and causes slipping hazards for personnel. Consequently time is wasted in cleaning spillages which is a thankless task. The latter is further complicated by the frequent hydraulic oil leaks from the fulcrum pin oil seals, which have required much re-design effort.

Having identified the weather seal as a problem, maintainability of these areas becomes a significant factor. By sighting the weather seal on the periphery of the aperture, the maintainer is forced to try to repair the item whilst in the relatively poor environmental conditions of the upper deck and with the safety implications of working aloft with the platform partially lowered. This applies equally to the lift retention equipment. While in engineering terms it is simpler to provide the keeps and latches on the aperture structure, thereby negating the need to transfer hydraulic power to the platform, the task of maintaining these items is more difficult, uncomfortable and time consuming.

Another area of concern was the reliability of the static and moving structures, which have required considerable work during refits and tend to be expensive.

Way forward

Despite much hard work to try to improve the design and its safety, there was always the possibility of another tilt which could result in loss of life. In 1988, the Director General Surface Ships commissioned an investigation into the control system problems with the aim of fitting a new control system which would fail safe in all failure modes and could be installed in the ships operational time. This report concluded that although there were improvements that could be made to the control system, the requirement to fail safe could not be guaranteed. However, a more extensive redesign was put forward which could meet the requirement, but not within the installation time scale. This involved a new control system and also large changes to mechanical structure. In view of the costs involved, it made sense to open the study up to allow industry to put forward other solutions, which could be assessed to ensure overall value for money.

The procurement strategy was to select two solutions for project definition studies. This would reduce project risk in terms of time scale and performance and to retain a competitive environment within the project. Project Definition (PD) contracts were placed in September 1990, against a Statement of Technical Requirements (STR) formulated after wide consultation with MoD agencies and operators. The first solution was essentially an enhancement of the existing design to include mechanical synchronization of the lift legs and the second being a scissor lift design. After assessment, it was concluded that both solutions should be tendered for full development. After an extended clarification period and negotiation, tenders were submitted in May 1992. The full development contract was finally placed with Strachan & Henshaw (S&H) in June 1992. The following paragraphs describe the winning scissor lift design and progress made to date.

Design philosophy

The design philosophy was one of a 'low risk' concept, achieved by designing around a tried and tested commercial scissor lift design, and where necessary upgrading to meet specific MoD requirements. The tandem scissor configuration (two scissors end to end), enhances the scissor lift concept of a non tiltable platform even in the event of a catastrophic failure such as a structural failure of a scissor leg during an operating sequence. One set of scissors are narrower than the other set enabling them to partially cross on lowering, thus achieving the required 2.5m closed height. The difference between the closed height and the lift well depth, being filled with a stiffening structure designed to distribute the new lift load pattern to the existing No.5 deck strong points, without having to carry out extensive underdeck strengthening.

It was recognized during PD that a new seal design, to overcome the sea water ingress problems, would require a development period, to establish a preferred design and to prove its capability. A test rig was proposed which would reproduce the elliptical corner section of the platform. To improve maintainability of the seals, keeps, latches and associated actuators it was decided to mount this equipment on the platform, enabling all maintenance to be carried out at hangar deck level and improve safety during maintenance. Efforts were also made in the design to simplify and reduce the amount of maintenance required.

The lift operating sequence is controlled in normal mode by electrical control of hydraulic valves and by manual operation of the same valves in emergency mode. Normal operation will be by a control key inserted into a socket situated on the platform. A reversionary control panel is mounted on the bulkhead in the hangar, adjacent to the lift, should the normal operating position not be available.

A surveillance system is provided which monitors correct operation of the control system and is an aid to fault diagnosis. Failure of the surveillance system does not prevent the continued operation of the lift.

Both the control and surveillance systems have been designed around solid state logic with no recourse to software, a pre-requisite by the MoD on safety and reliability grounds.

The need identified at PD to uprate the commercial lift design to meet the very high static and dynamic loads likely to be experienced by the lift and the STR requirement to use the existing hydraulic power pack, led to a significant design effort to reduce the revised weight. Finite element analysis was used extensively in this process. The weight saving programme that followed changed the scissor design significantly from the commercial lift concept but retained all the features from the PD study. The changes will be more fully discussed later.

S&H will be required to demonstrate, following prototype testing, that the STR and contract requirements have been met. Running in parallel with the design programme a full Availability, Reliability and Maintainability (ARM) and safety programme was specified as part of the contract. An Independent Safety Auditor (ISA) was appointed to oversee the project

The scissor lift (FIG. 3), consists of four major fabrications:

1. Base.
2. Wide scissor.
3. Narrow scissor.
4. Platform.

Added to these fabrications are the various sub assemblies that comprise the four main assemblies, together with:

- Hydraulics.
- Electrical control system.
- Pneumatic pipework for the Nuclear Biological Chemical Defence (NBCD) seal.
- Pipework for the water spray system.

Base assembly

The base frame is a fabricated steel structure that performs two main functions:

(*a*) It positions the scissor legs within the lift well, providing both fixed pivot positions and location for the sliding legs.

(*b*) When bolted to the lift well deck it forms part of the reinforcement of that deck, helping to spread the loads into the ship structure strong points.

Four maintenance props are mounted to the outer base structure, which when raised hydraulically to their vertical position and locked into the underside of the

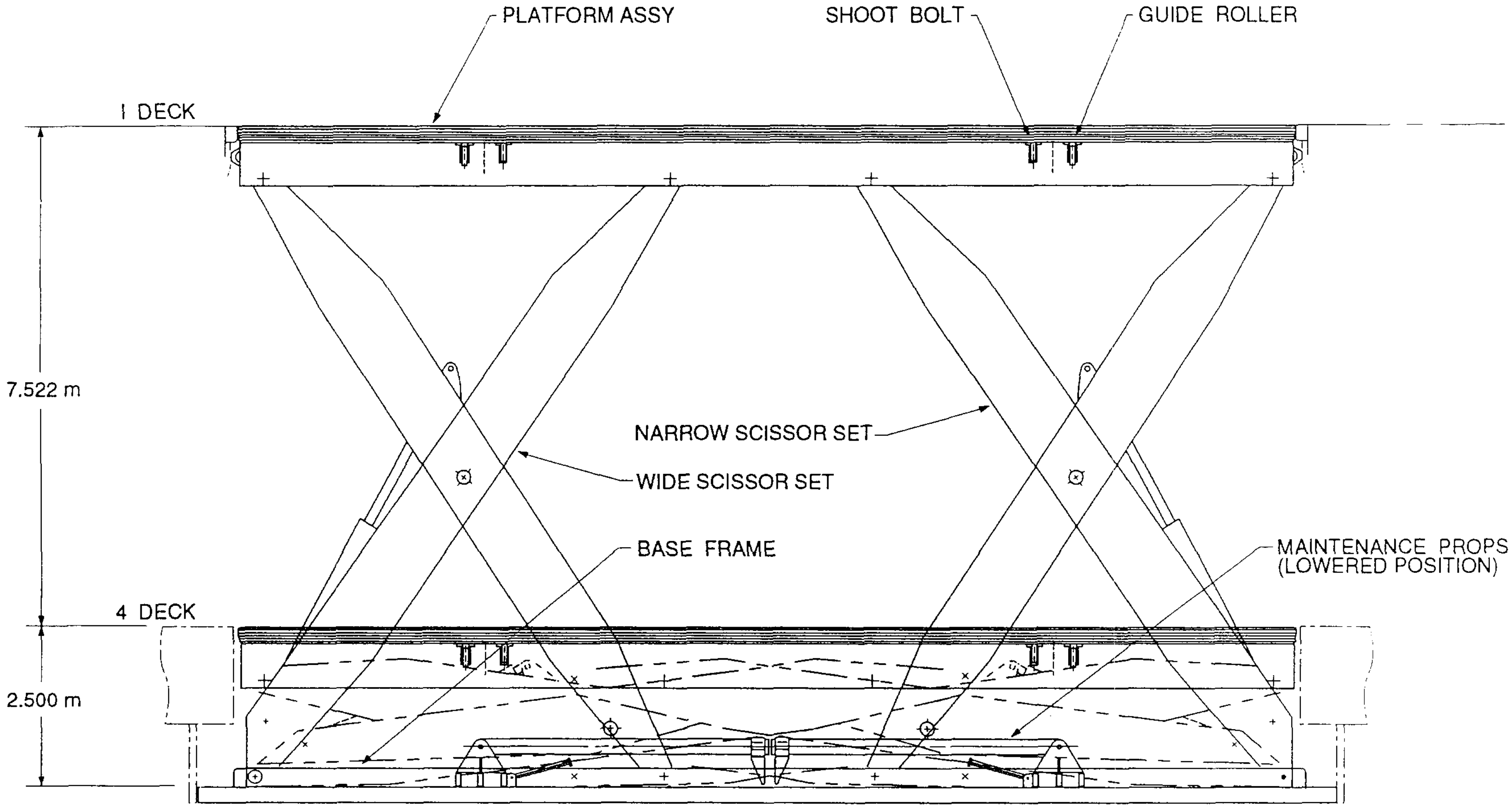


FIG. 3—THE SCISSOR LIFT

platform allow the hydraulic pressure to be relaxed and maintenance tasks to be carried out in safety. Oleo buffers are also mounted on the base structure which assist in the deceleration of the lift when approaching the hangar deck and provide lift off assistance when raising to the flight deck.

Scissor assembly

The scissor legs (FIG. 4) were the major target for the weight saving investigation, the back to back box section commercial configuration, whilst being simple to construct, had obvious weight penalties. The single fabricated box section was more expensive to construct, but was as strong and considerably lighter. Extensive computer modelling was used to ensure that in the event of shock, the legs and their associated torque tubes and slider blocks would not fail. The iterative exercise of designing to strengthen the weak areas identified by the finite element analysis, whilst maintaining the lightest possible structure was a very testing exercise and a large amount of design time was expended in this area. In addition the potential construction difficulties posed by the strengthening requirements, was taken into account.

Attached to the moving ends of the scissor legs (FIG. 5) are low friction slide blocks which are contained within slider guides mounted to the base and platform fabrications. The scissor movement is generated by hydraulic rams mounted between torque tubes. There are four rams per scissor assembly. Control of the rams is described in the hydraulic section.

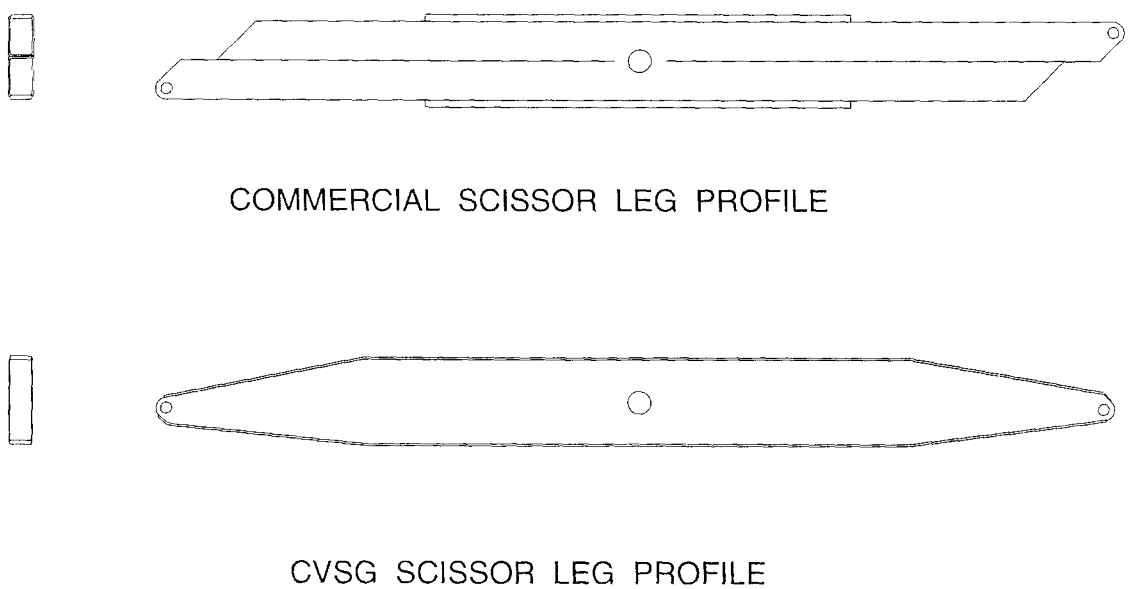


FIG. 4—SCISSOR LEGS

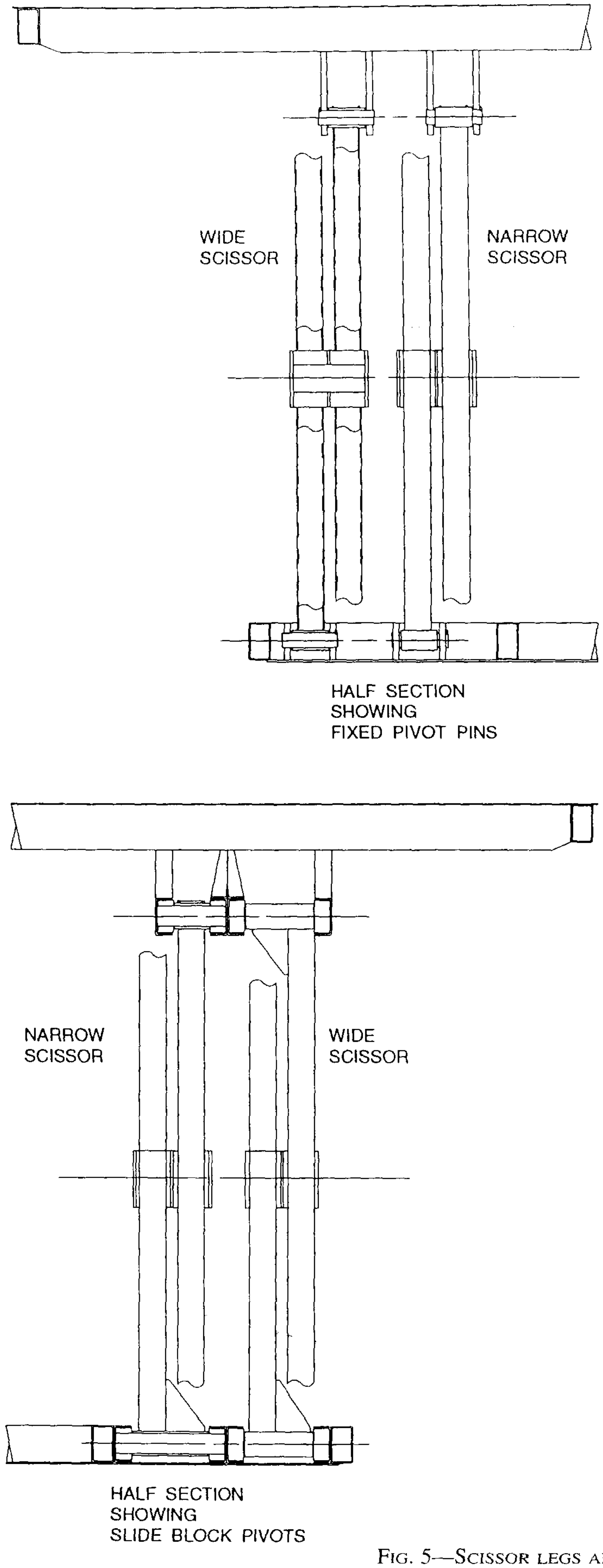


FIG. 5—SCISSOR LEGS AND SLIDE BLOCKS

Platform

The platform (FIG. 6) was also subjected to modification from its commercial equivalent. The major factor governing the design being the requirement to land an aircraft at any position on the platform surface without causing permanent deformation. In addition it has to withstand shock loading when locked into the flight deck and having survived, be able to continue operating.

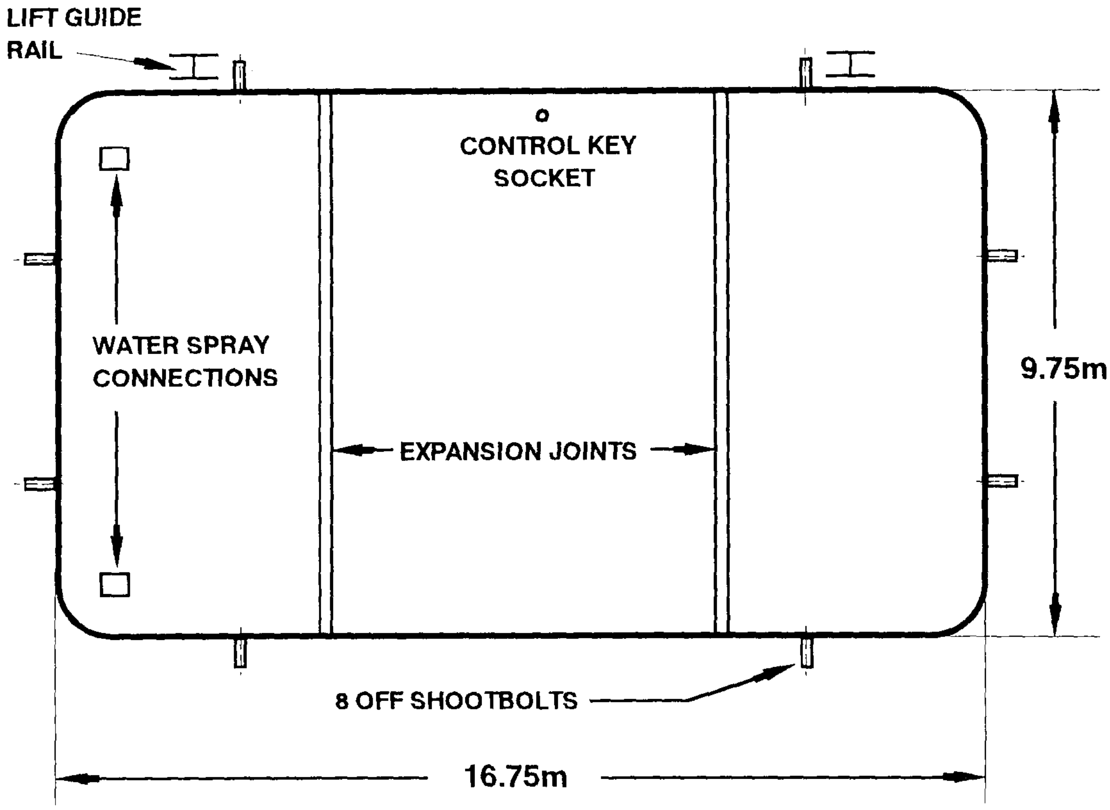


FIG. 6—PLAN VIEW OF LIFT PLATFORM

To remove the present tendency for the platform, in hot climate conditions, to distort and jam on its latches, the new design includes expansion joints which allow the platform deck plating to expand and contract. The resulting design was a platform assembly consisting a skeletal spine on top of which are mounted three platform sections, each section consisting of stiffening members, a box section skirt and deck plating. A gap is left between the three sections of sufficient width to allow for the expansion. A sealing compound together with protection plates prevents the ingress of water etc.

The skeletal structure is the backbone of the platform from which are mounted the upper scissor guides, the eight off shootbolts and the eight platform guide rollers. Attached around the skirt are the weather and NBCD seals.

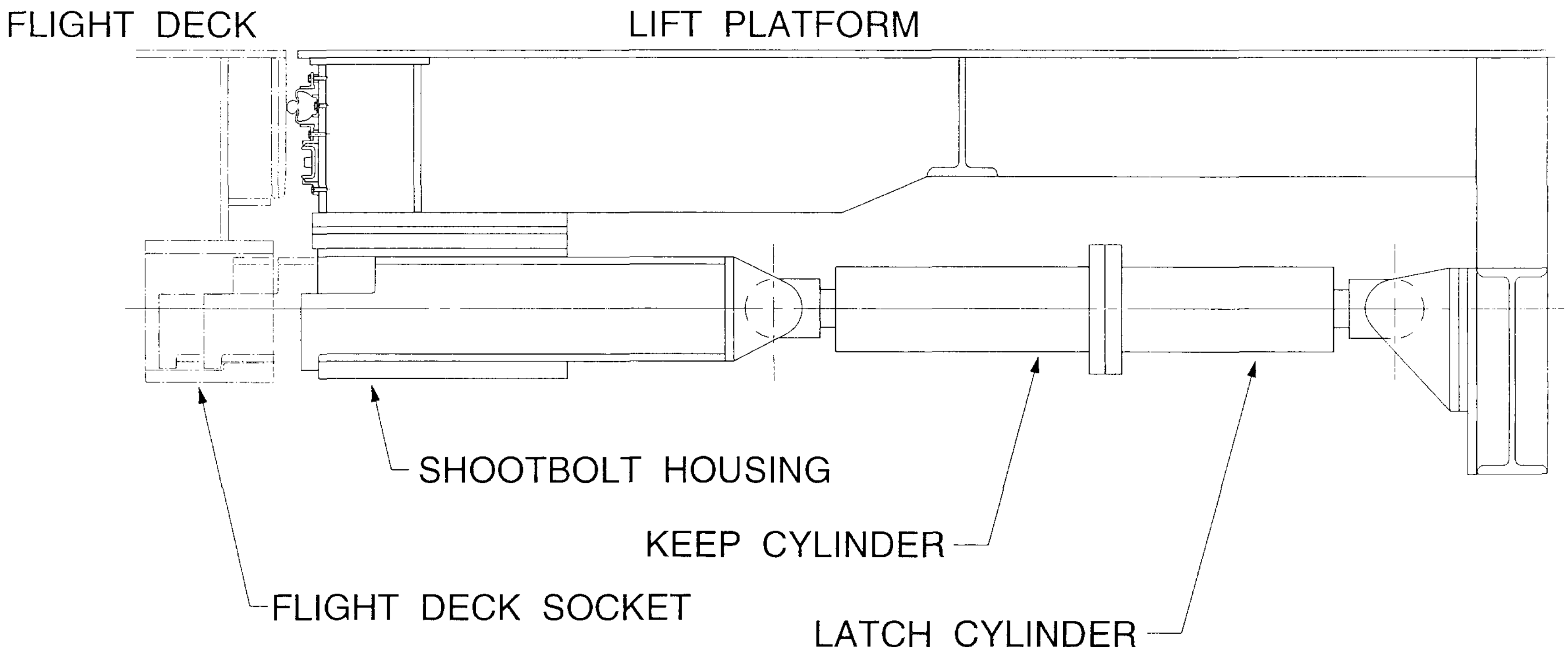


Fig. 7—Platform shootbolts arrangement

Shootbolts

Each of the eight shootbolts (FIG. 7) act as both 'keep' and 'latch', and being mounted on the platform, the same bolts operate at both flight and hangar deck positions. This feature reduces the number of bolts from the existing configuration of twenty four, greatly improving the reliability and maintainability figures.

At both flight and hangar decks the bolts are driven into suitably constructed housings within the ship structure. Low friction pads are attached to the steel bolt and housing mating surfaces to aid movement. However, at the flight deck, a mechanical stop is also fitted which prevents the bolts creeping back beyond the keep position.

Guide wheels

Eight adjustable guide wheels are used to centralize and maintain the platform within the flight deck aperture, to ensure that the seals are able to exert the correct compression around the whole perimeter of the platform. This will prevent misalignment damage to the seals which is a known problem with the existing lift. Guide strips will be attached to the flight deck structure to ensure that the guide wheels centralize the platform prior to the seal contacting the seal plate.

Vertical guide skates

The scissor configuration is inherently stable along the line of the scissor leg but will flex slightly when subjected to athwartship movement i.e. 'roll'. Whilst not critical to the lift operation, the availability of the longitudinal bulkhead on one side of the lift enables two vertical guide rails similar to the existing arrangement to be used.

Hydraulic system

As well as meeting the ARM requirements laid down in the STR, the design of the hydraulic system had to take account of the capacity provided by the existing power pack and the resultant power to weight ratio analysis already briefly discussed. A hydrodynamic computer model was produced to evaluate all hydraulic characteristics required to operate the lift in the permitted time, the weight to be lifted and the scissor geometry. In addition assumptions had to be made as to the performance losses attributable to hydraulic losses through the pipework and manifolds and friction in the slider blocks and bearings.

A sensitivity analysis was conducted using values for both friction and flow losses from the optimistic, i.e. values claimed by the manufacturers of low friction materials and hydraulic manifolds, to more pessimistic values gained from past engineering experience. From the data, predictions of the pressure needed to lift the platform from hangar to flight deck and flows required to meet the cycle time were produced, taking the pump supply as a constant and a variable accumulator charge state at the start of the cycle.

From this data calculations were carried out to select the optimum ram piston size and the reserves available within the existing system. The calculations indicated that whilst there was a reasonable margin of error available when the friction coefficient was 0.05, it became marginal when the friction coefficient was predicted at 0.15.

The solution was to improve the efficiency of the accumulators during their period of decay. By adding additional air reservoirs, the pressure applied to the system was increased throughout the platform travel. But more significantly, it improved the margin when nearing the flight deck position. This also means that a lift carrying a safe working load could be raised from hangar to flight deck without the pumps running and with the accumulators only charged to the relief pressure. (FIGS. 8 & 9) show the effect the additional air reservoirs have on the lift operability.

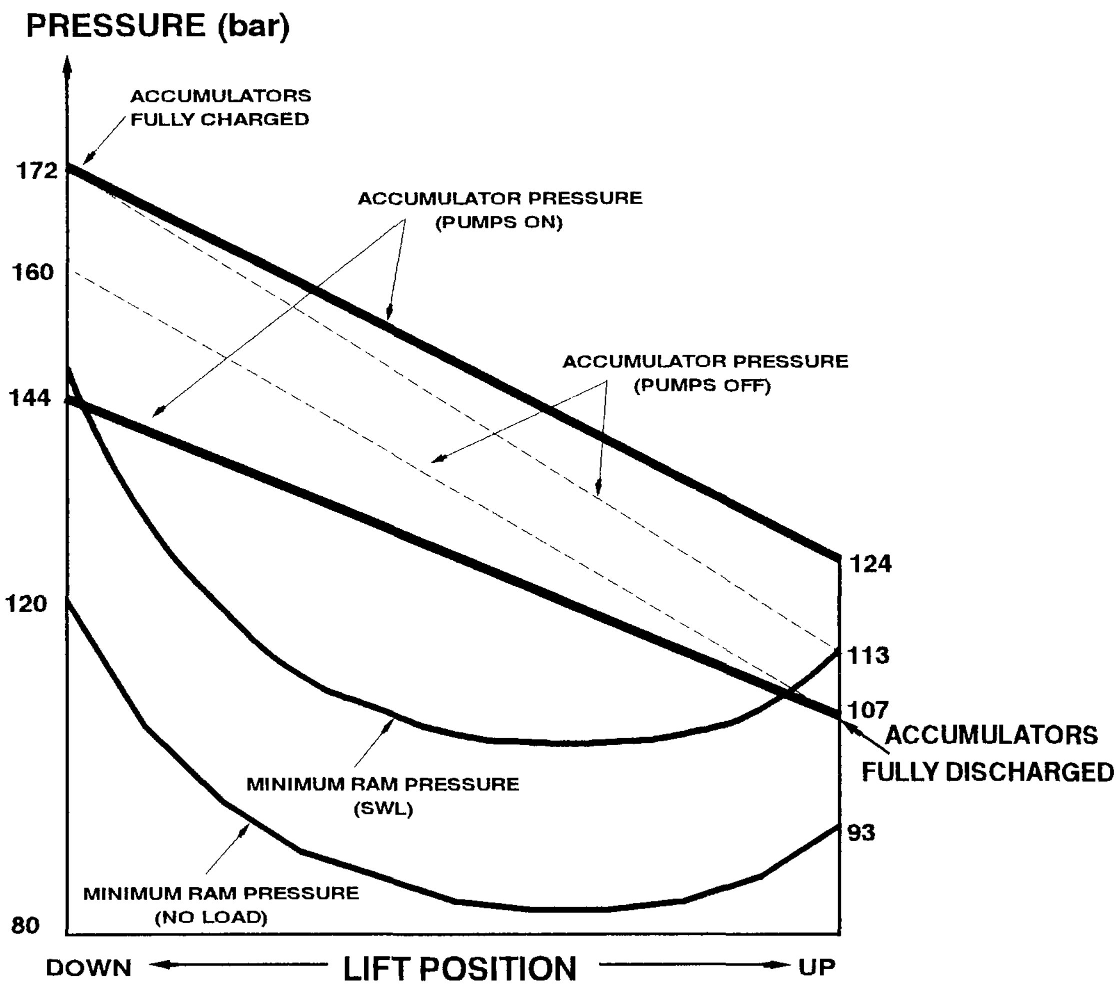


FIG. 8—MINIMUM RAM PRESSURE (9 RECEIVERS)
ACCUMULATORS—5
FRICTION COEFFICIENT—0.05
RAM DIAMETER—210 MM

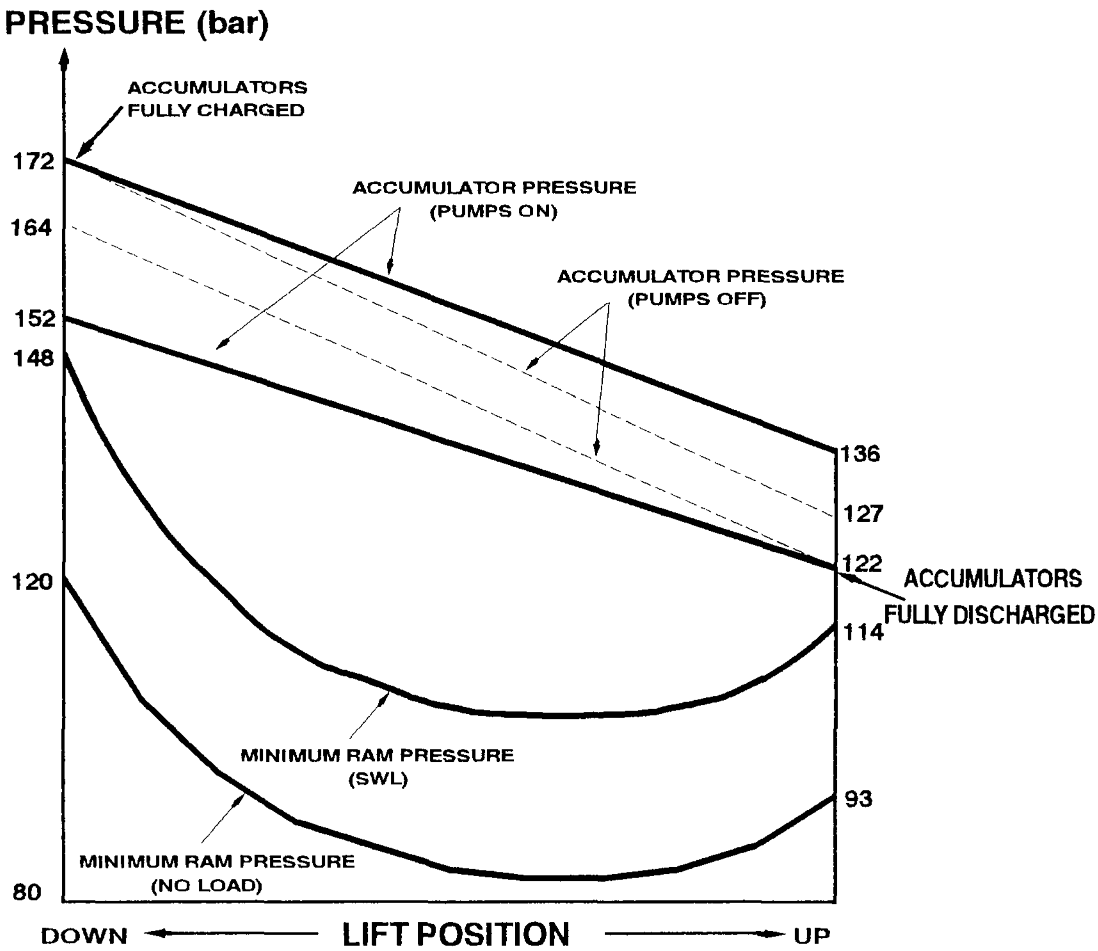


FIG. 9—MINIMUM RAM PRESSURE (13 RECEIVERS)
ACCUMULATORS—5
FRICTION COEFFICIENT—0.05
RAM DIAMETER—210 MM

A simplified block diagram of the hydraulic circuit is shown in (FIG. 10). New valve manifolds are added to existing ship equipment. The existing pressure manifold is replaced to improve the flow rate to the new lift.

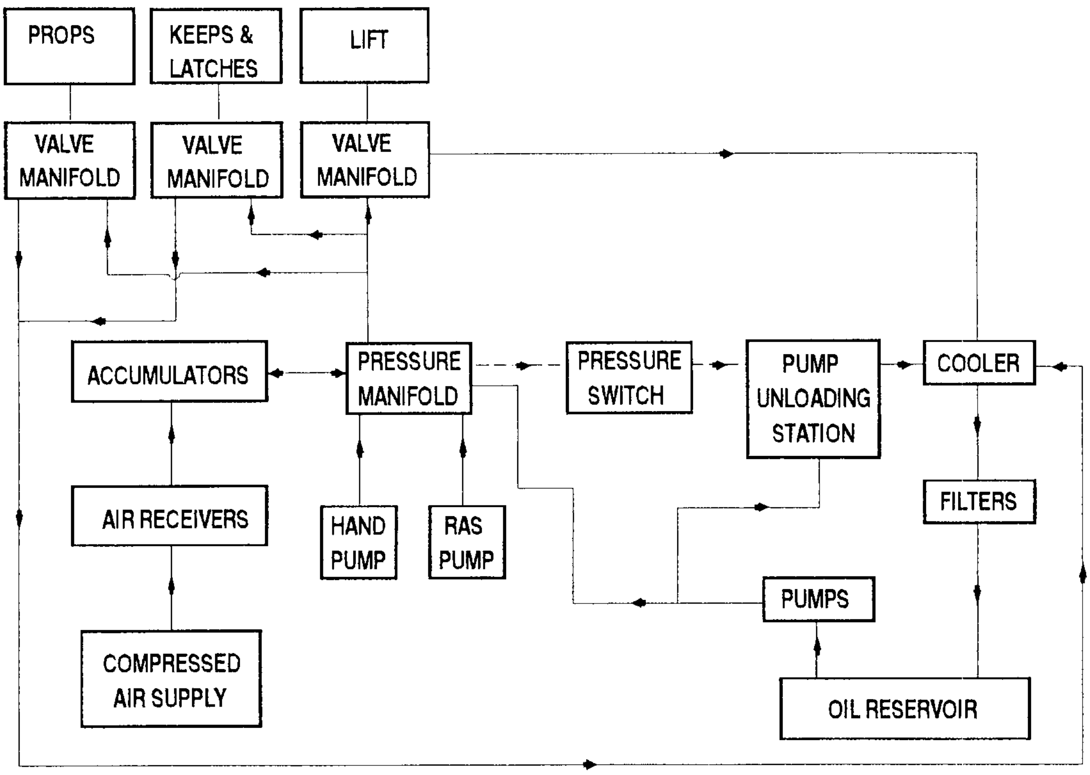


FIG. 10—HYDRAULIC CIRCUIT BLOCK DIAGRAM

Lifting circuit

Platform movement is achieved via eight hydraulic rams acting on torque tubes fixed across the scissor legs. There are four rams in a split circuit configuration attached to each of the scissor assemblies. The split circuit ensures that in the event of a hose rupture, the remaining active circuit supplies two rams on each scissor. The pressure overload thus being evenly distributed, the lift coming safely to a stop and being held in position until emergency measures can be taken. When lowered, flow control valves ensure a controlled and safe lowering procedure.

Considerable design resources were allocated to the design of the manifolds to ensure minimum flow losses. Cartridge valves were selected for their ability to accept high flow rates, ease of fitting and the small number of components. The latter played a significant part in the ARM analysis.

In addition to its capacity to accept high flows, the valves are very simple to maintain and replace. The valve body is pushed into the manifold bore, a cover being fixed to the manifold face onto which is attached the solenoid valve, which can be removed without disturbing the valve itself. Replacement of the cartridge is a simple matter once the oil flow is stopped and the cover removed. (FIG. 11) is a simplified lift circuit showing the valve arrangement. Valves A, B, D and the isolation valve are solenoid operated with a manual override facility. Their operating sequence will be described later.

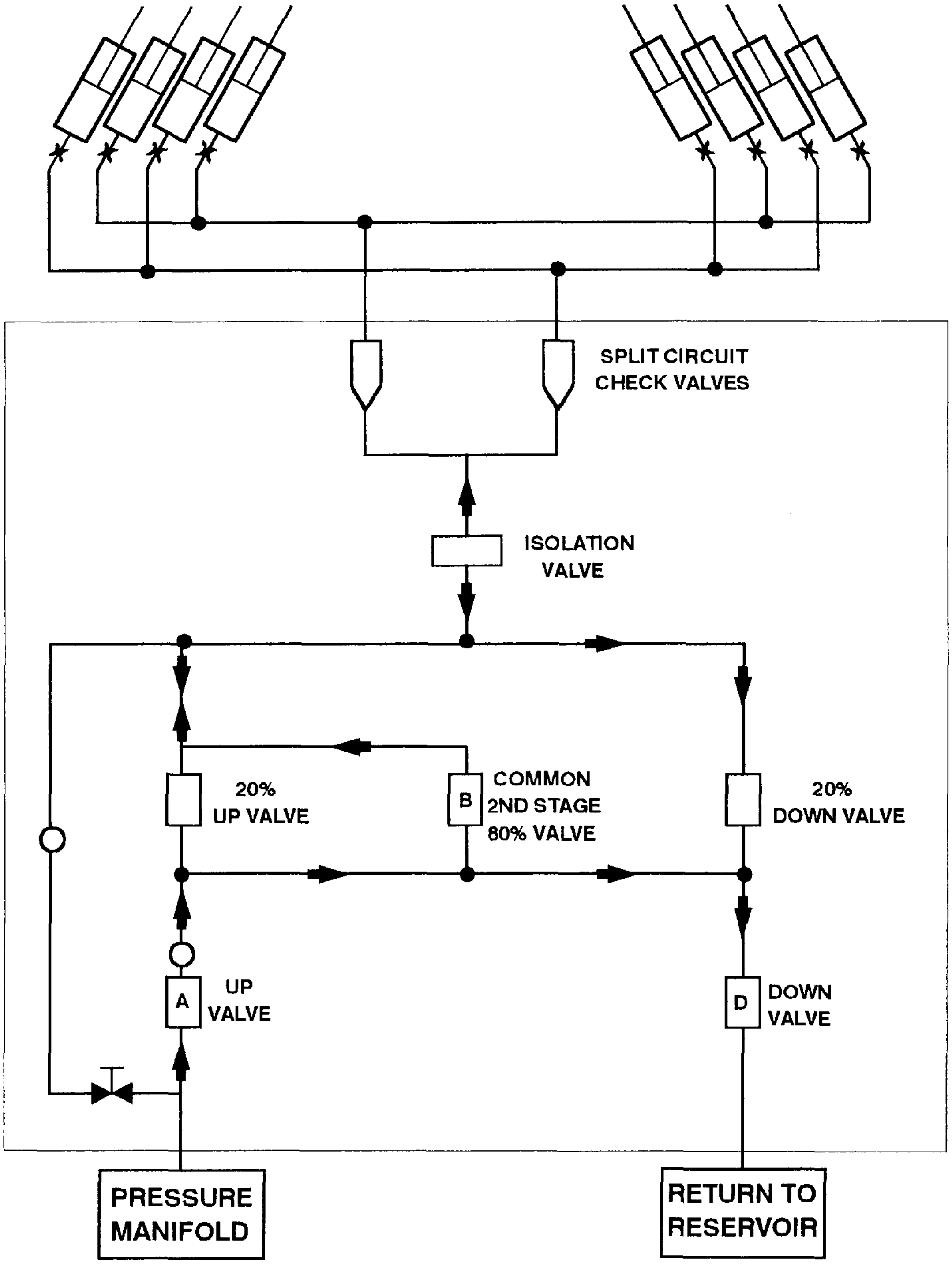


FIG. 11—SIMPLIFIED LIFTING AND LOWERING CIRCUIT

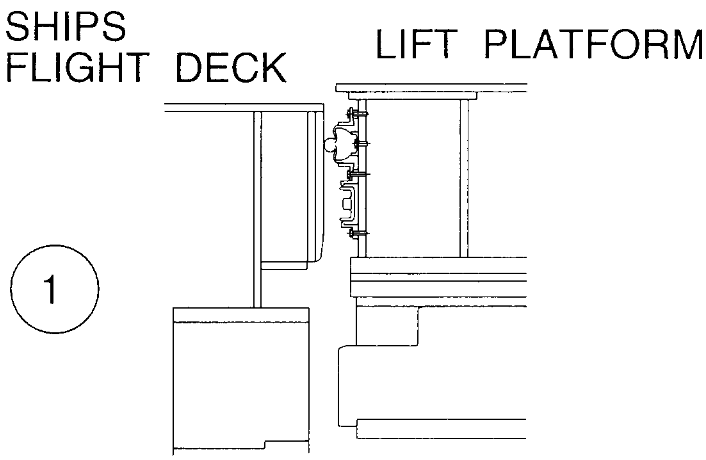
Lift operating sequence

The lift sequence starts with the lift locked at the flight deck.

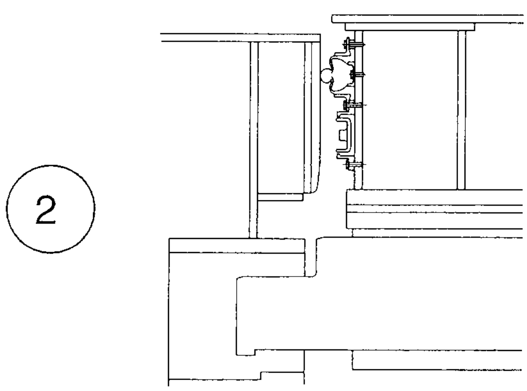
Lowering

When lift 'LOWER' is commanded the shootbolts retract from the 'latch' to the 'keep' position. The lift then raises to a height 30 mm above the flight deck and the shootbolts (FIG. 12) fully retract. The 30 mm raise allows the lockbolt to pass the mechanical lock.

With the lockbolt fully retracted, the lift descends initially at 20% speed, in the control system 'upper zone', then full speed until it reaches the control system 'lower zone' when it again returns to 20% speed. Shortly before this the platform contacts the 'Oleo' buffers, which further reduce its speed, until it is stopped by the mechanical stops mounted on the base. When stopped the shootbolts drive fully out to the latch position.



PLATFORM RISES ABOVE FLIGHT DECK



BOLT EXTENDS TO KEEP POSITION

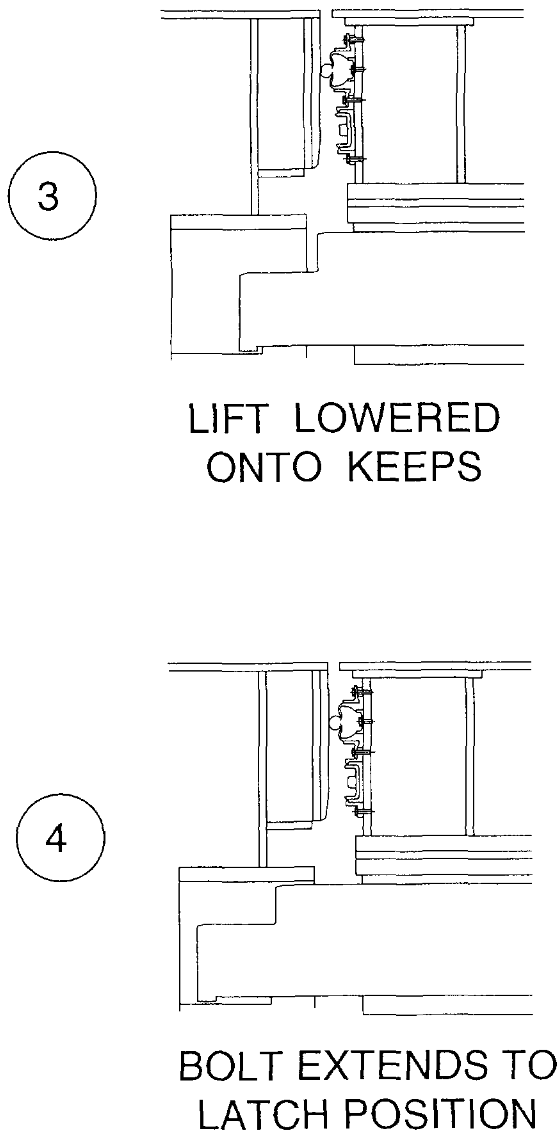


FIG. 12—LIFT LOCKING SEQUENCE

Raising

To return to the flight deck lift 'RAISE' is commanded. The shootbolts are fully retracted, there are no mechanical locks at the lower position. When fully retracted the platform raises at 20% speed, lift off being assisted by the stored energy in the 'Oleo' buffers, in the control system 'lower zone' then at full speed until it enters the 'upper zone' when it again reduces to 20% speed. At a position 30 mm above the flight deck, the lift stops. When stopped the shootbolts move to the 'keep' position, i.e. half extended, the platform then lowers onto the keeps and the shootbolts are fully extended to the 'latch' position and the hydraulics relaxed.

The electrical control system (Fig. 13)

The STR requirement for the new control system was very exacting and specific in its operating, environmental and ARM requirements. In addition to the lift operating in the manner described in the previous paragraphs it must also be capable of coming to a controlled stop at any position between the two decks. At these positions the shootbolts would not be operative.

All operator controls that result in lift movement are 'dead man' type and emergency stop buttons are placed at strategic positions in the immediate vicinity of the lift. The lift can be controlled from various positions and modes of operation:

1.	Normal	Key operation at a station on the platform.
2.	Reversionary	From a control panel mounted on the bulkhead adjacent to the lift in the hangar.
3.	Maintenance	From the same panel as 2. but with special features required for maintenance.
4.	Manual	Operation of the lift by direct operation of the solenoid manual overrides at the hydraulic manifolds in the lift well. To prevent unauthorized lift movement in this manner, during which time all electrical interlocks will be inoperative, the manifolds are mounted within a locked cabinet.

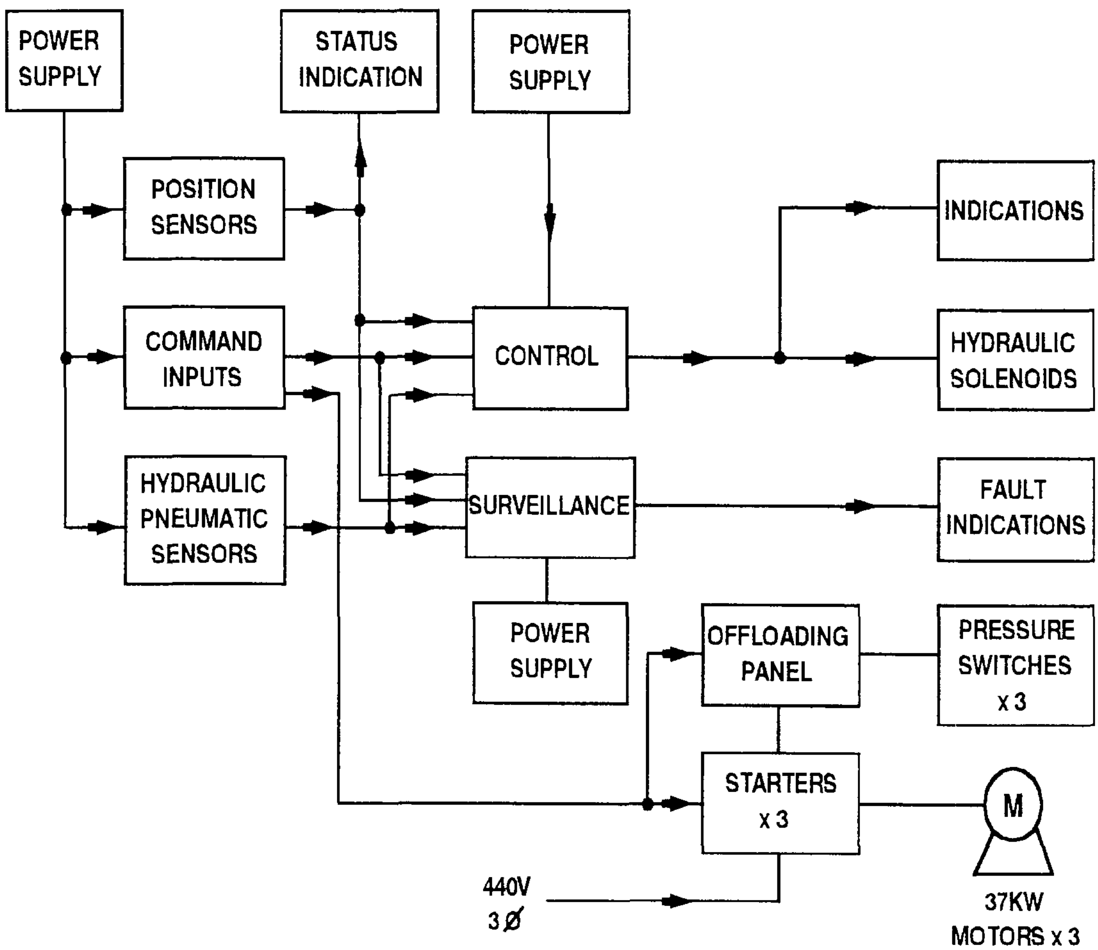


Fig. 13—Electrical control system

During normal or reversionary mode operations, electrical interlocks prevent lockbolt operation at any position between the flight and hangar decks. A maintenance zone has been designated, however, which does permit lockbolt operation within the zone for maintenance purposes, but only when the lift is not moving and with maintenance mode selected.

A lift inhibit switch is available to the control officer in the Aircraft Control Room (ACR). Lift inhibition can be preselected at any time in the operating cycle, but will only inhibit when the lift returns to the flight deck and is locked in position.

The control circuit is designed to prevent incorrect or unsafe operation and in addition to the control and interlocking circuits, a surveillance system that monitors control inputs is incorporated, to give warning of actual or imminent failures.

The control system main design drivers are:

(*a*) *Safety*

- Error detection of inputs from sensors and selectors.
- Error detection of operating times and outputs.
- Interlocking to ensure only one control station is available at one time.
- Audible warning of movement.

(*b*) *Reliability*

- Use of high quality components selected from DEF STAN 59–59/ British Standards or the Cenelec Electronic Component Committee.
- Solid state components used wherever possible.
- Use of the minimum number of components in achieving the STR requirements.
- De-rating of components where possible.

(*c*) *Maintainability*

- All electrical/electronic components are designed to be quickly replaceable, some boards being interchangeable.
- A surveillance system, independent of control, monitors actual/ imminent failures and reports their existence and location to enable accurate and speedy rectification to be carried out.
- An override feature included to enable continued operation in the event of the failure of one or more shootbolts up to a specified number.

(*d*) *Environmental parameters*

During the development phase, the control system must prove that it can withstand a range of environmental conditions including:

- Temperature and humidity.
- Ruggedness and vibration within specified values.
- Watertight integrity.
- Atmospheric pressure.
- To withstand a range of contaminants including atmospheric, oils, lubricants, aviation fuels, etc.
- Electro magnetic compatability requirements in line with current naval standards.

Main Control Panel

(FIG. 14) shows the cover of the main control panel which is within the electrical distribution room. The majority of the controls on this panel are self explanatory. The fault code cancel push-button is used when system faults have been repaired and therefore no longer valid, the fault code increment push-button when operated will initiate the next fault code to be displayed. All illuminated indicators are Light Emitting Diodes (LED).

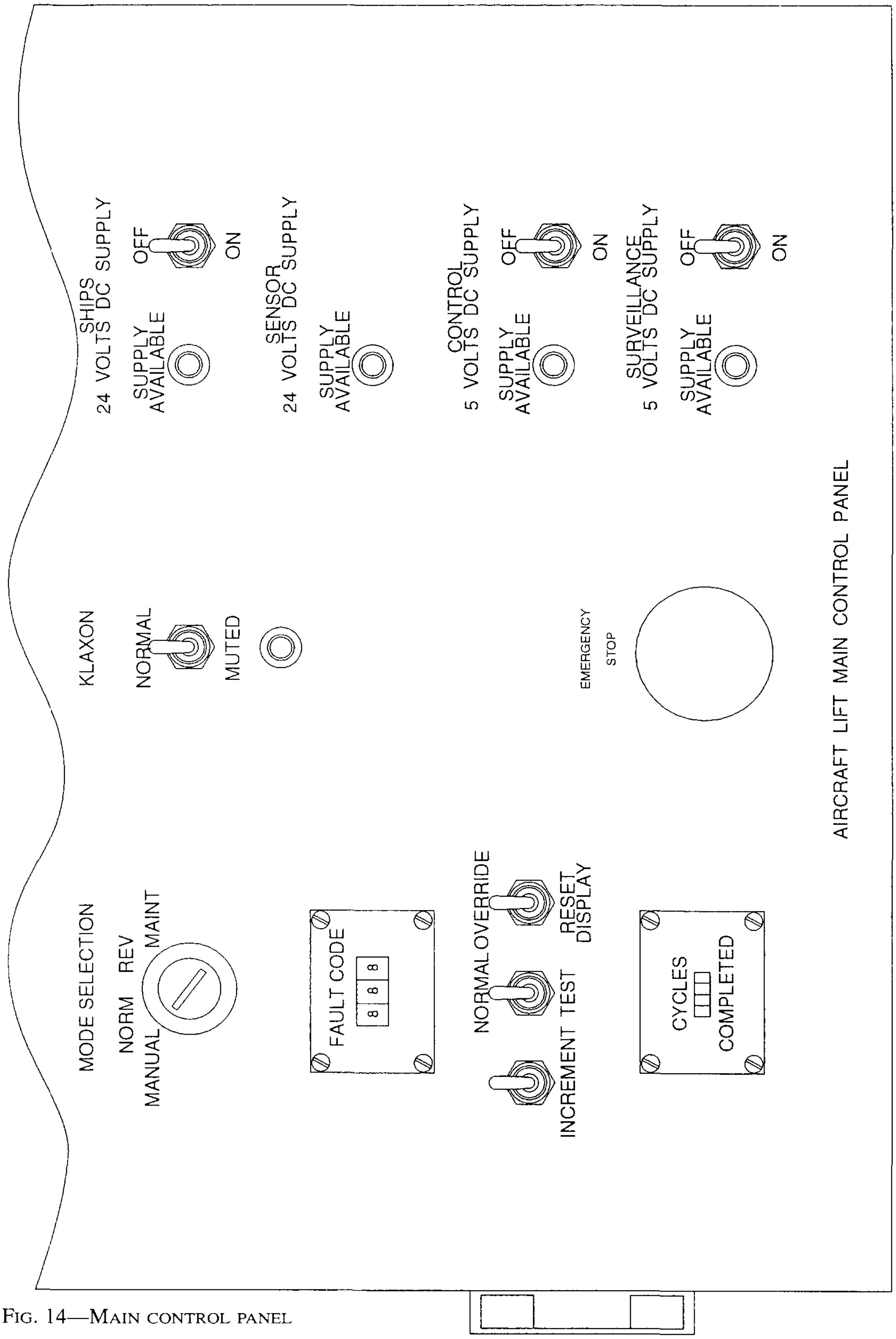


FIG. 14—MAIN CONTROL PANEL

Normal mode operation

In this mode the operator controls the lift movement by turning a key in an operating socket (FIG. 15) mounted on, and flush with, the platform surface. Each

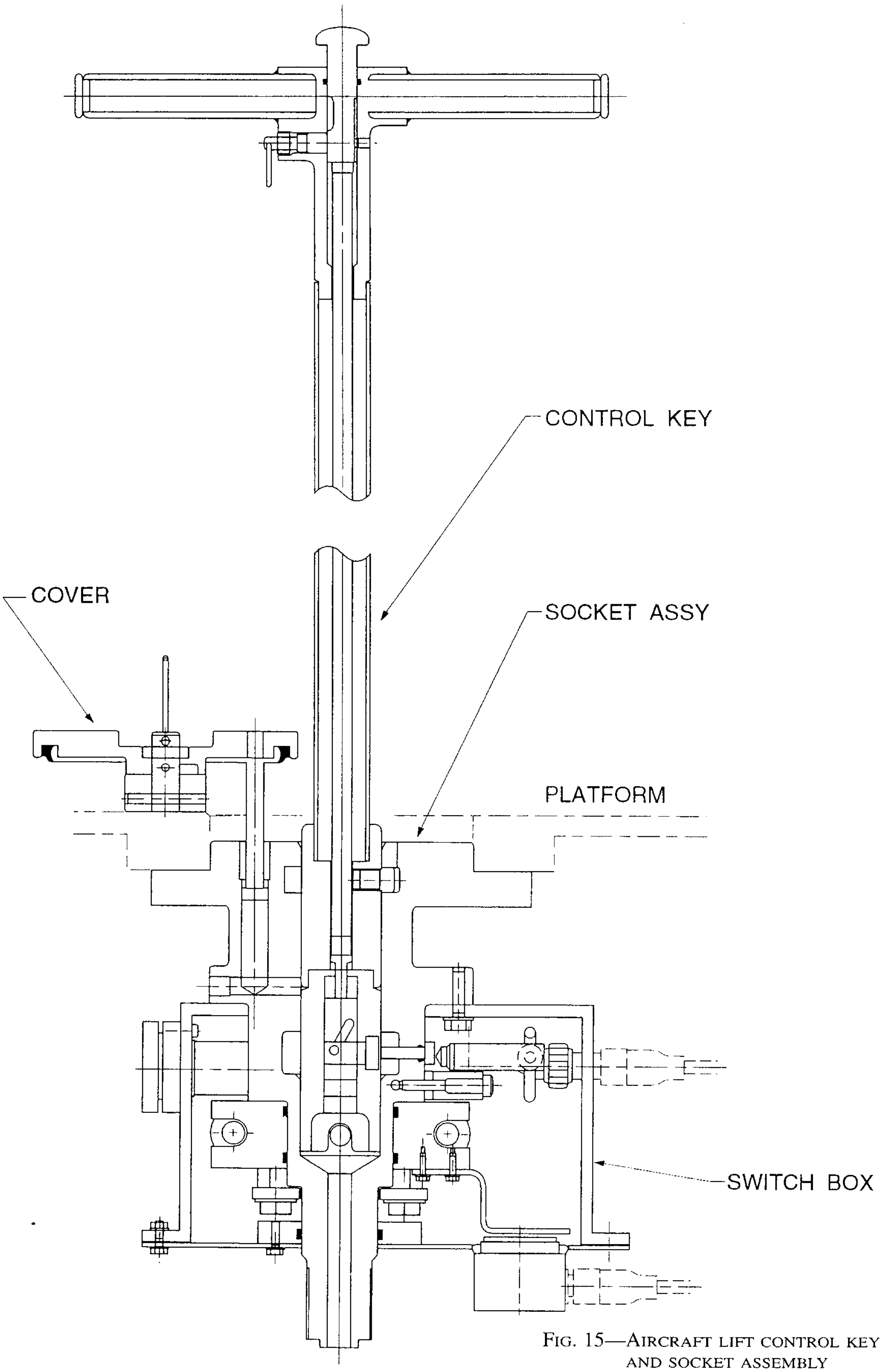


FIG. 15—AIRCRAFT LIFT CONTROL KEY AND SOCKET ASSEMBLY

key is unique to its own lift. The operator collects the key from the ACR and inserts it into the socket turning it in one direction for 'Raise' and the other direction for 'Lower', the mid position being 'Off'. The key is a 'dead man' arrangement returning to the off mid position if released. On top of the handle is an emergency stop button. The construction of the key is rugged being designed after consultation with the user. The socket arrangement has a number of sensors and switches which are protected from the elements by a watertight box construction. Access for maintenance is via a removable cover on the underside of the platform.

Reversionary mode

The reversionary controls share the same panel as the maintenance controls, reference FIG. 16. When the reversionary mode is selected on the main control panel, the lift will operate in the same manner as normal mode, but will be controlled from this panel mounted in the hangar on the bulkhead adjacent to the lift well. As with the key the switch is a 'dead man' type which will return to the central stop position if released.

In addition to the two sets of controls this panel also displays, by way of LED's, the platform positions and the lockbolt status. In addition LED's inform the operator of the mode status as selected on the main control panel.

Maintenance mode

In the maintenance mode (FIG. 16) lift speed can be selected by the maintainer, lift direction being controlled from the same switch as in the reversionary mode. Lockbolt operation can also be selected in isolation of the platform position as long as that position is within the maintenance zone and the lift stopped.

Surveillance, System test and fault display

The surveillance system has been briefly discussed within the context of the electrical control system. The system is independent of the lift control system, ensuring that surveillance failure does not in any way affect the operation of the lift. In the event of a surveillance system shut down, fault/failure indications to assist the maintainers will be restricted, although position indication will continue.

When operating, the surveillance system will monitor a range of control system inputs and when detecting a fault will indicate the source of that fault by a fault code.

Two types of fault will be detected:

1. Category '1' fault.
   Will appear if the lift has stopped at any other time than when commanded to do so, the system sensing that safety has been compromised and therefore stopping all movement.
2. Category '2' fault.
   Where the fault detected is deemed not safety critical, thus allowing lift movement to continue.

The surveillance system monitors a range of control system parameters including error detection of:

(*a*) Inputs to control logic from selector switches.
(*b*) Inputs to control logic from position sensors.
(*c*) Outputs from the control logic.

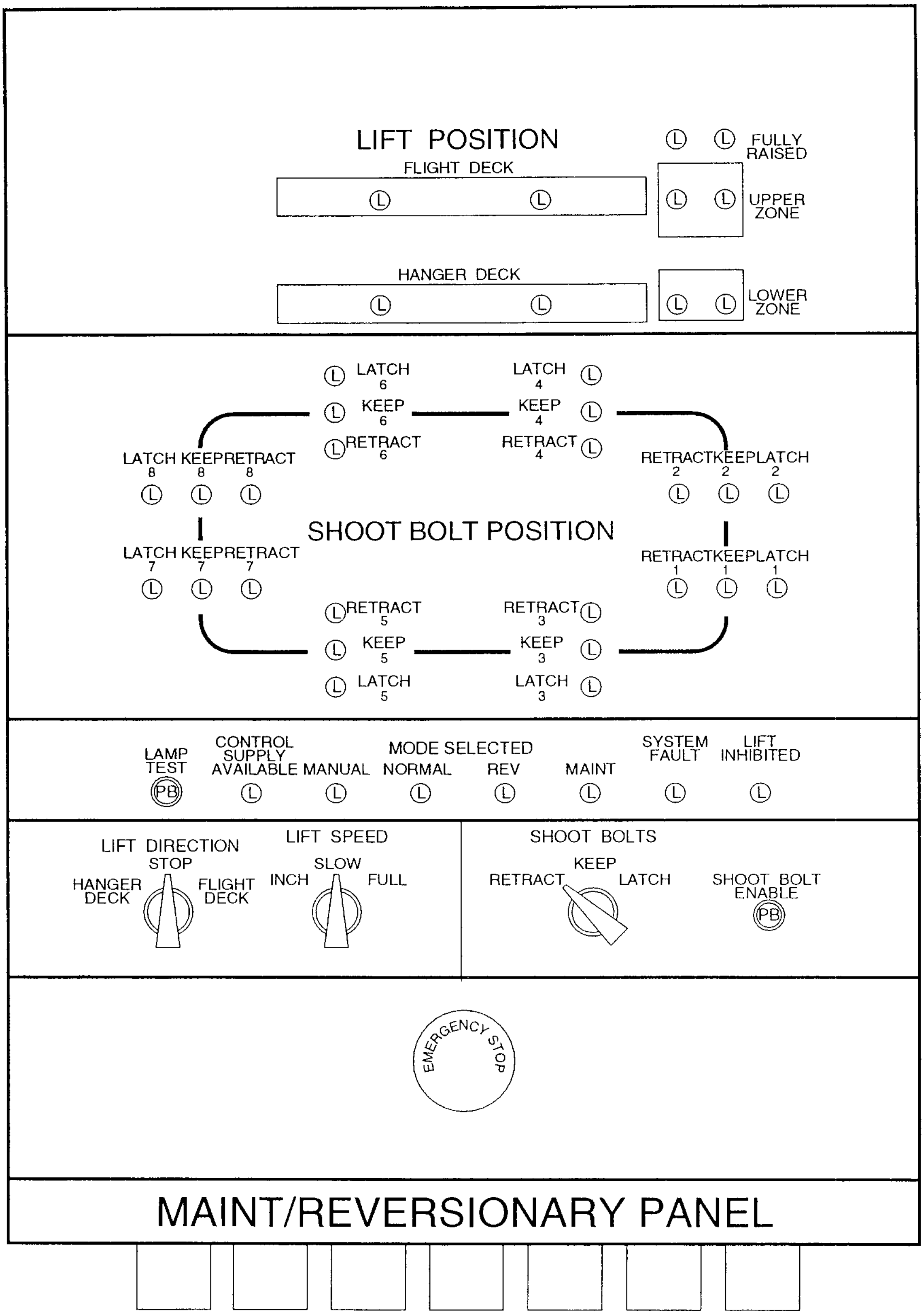


FIG. 16—MAINTENANCE/REVERSIONARY CONTROL PANEL

The fault, when detected, causes a discrete number to be displayed in the three window fault code display, the:

First —Identifies the fault category, i.e. 1 or 2.
Second—General area of the fault identified, in a look up table.
Third —Specific fault type.

Safety, ARM and Risk

These three elements have played and will continue to play an important part of this project, given the past problems of the existing lift.

Safety

A safety analysis in line with the requirements of DEF STAN 00-56 is being carried out. Following the writing and acceptance of a safety plan at the start of the project and the selection of an ISA, safety work has continued on two fronts; one to produce a comprehensive hazard log to track progress of hazard mitigation and secondly to influence the design to ensure that safety features are incorporated within the design philosophy and the design itself.

The first safety driven decision was in choosing the scissor lift design to remove the tilt problem. Having done that it was then necessary to ensure that all the controls and operating parameters were carefully thought through, so as not to compromise that basic safety feature.

As stated previously in this article, in the event of a hydraulic failure, the lift will stop at the position the failure occurs and will remain there until it is decided to lower the platform to its lower position in a controlled descent. Even in the unlikely event of a rupture to both hydraulic pipe systems simultaneously, the lift will only descend at a controlled speed until reaching the platform lowered position.

The control system, if it detects or receives a Category 1 fault, will immediately stop lift movement and will not permit restart until the fault has been rectified and the system reset.

All of these events will have to be proven to the satisfaction of the safety committee during the prototype testing phase of the project. To this end computer modelling has been carried out by the electrical design team to simulate possible errors and to monitor the control system response.

In addition to meeting the specific requirements of the STR and DEF STAN 00-56 it is also necessary for the equipment to meet the requirements of the Health and Safety at Work Act (1974). (FIG. 17) shows the CVSG lift safety activities flow diagram.

ARM

It is intended that the new lift will require substantially less maintenance and will be more available and reliable than the existing lift. To summarize the STR requirements, the new lift must have:

1. Intrinsic (mission) availability of not less than 99.8%.
2. Reliability—Have a probability of surviving a specified mission time without any faults of not less than 37%.
3. Maintainability (mission)
   (*a*) *Corrective maintenance:*
   Mean Active Repair Time (MART) not greater than 2 hours.
   (*b*) *Preventive maintenance:*
   MART less than 20 mins
   MART total less than 30 hours

An ARM plan was produced at the start of the project and the analysis is being carried out by the S&H ARM group. Maintenance task analysis for both planned and corrective maintenance has been undertaken as well as ARM modelling and predictions. This work has had considerable influence on the design. A full upkeep evaluation will be conducted during prototype testing.

The main attention of the ARM team, like that of the safety committee, has been directed to the control system both hydraulic and electrical, mainly because

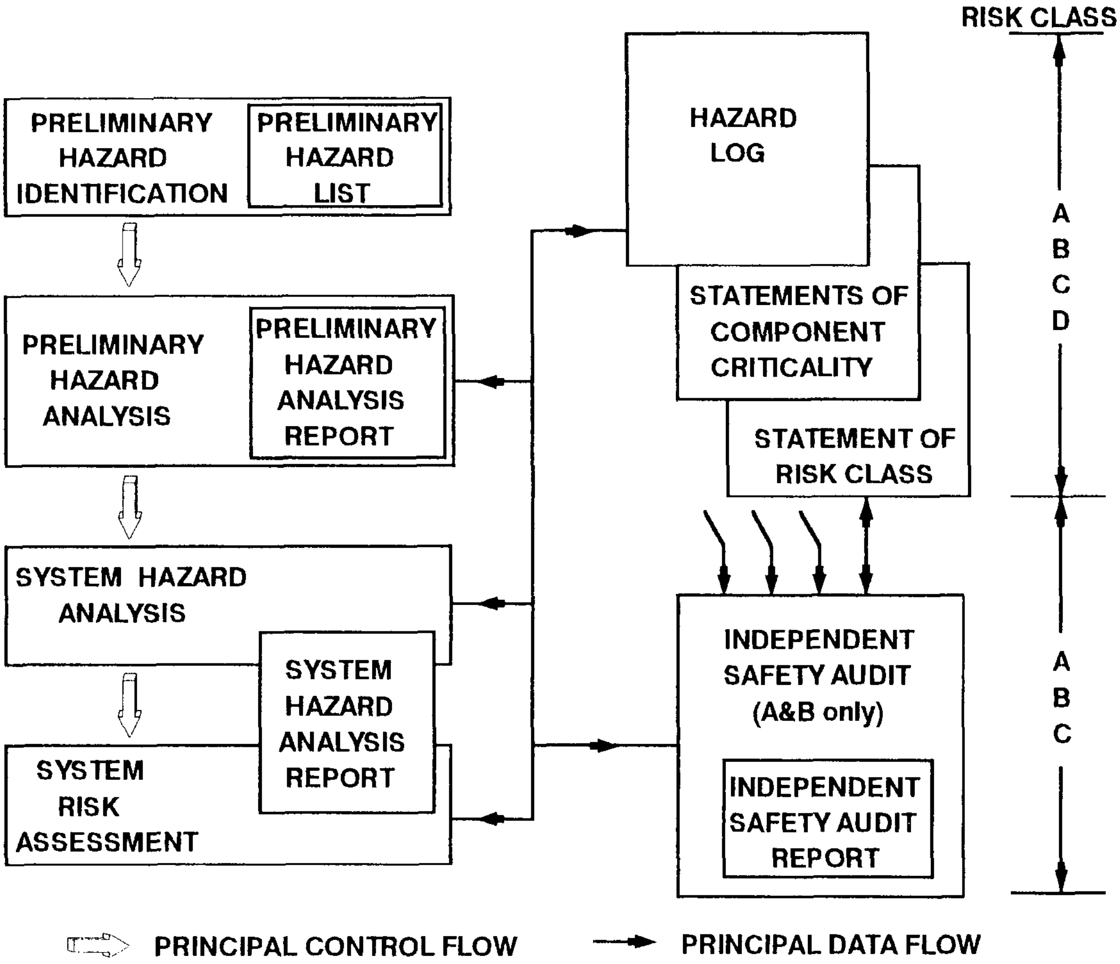


FIG. 17—SAFETY ACTIVITIES AND DOCUMENTATION FLOW DIAGRAM

they contain components which, if they fail, will have the greatest influence on the availability of the lift. Much work has been carried out to identify components with high reliability or reconfiguring the design to replace unreliable components, for example the replacement of microswitches with sensors.

There have been changes made to the mechanical design of the lift as a result of safety and ARM, for example:

- Retention of the maintenance props within the platform retention sockets was improved.
- The lockbolt configuration was modified with the introduction of a mechanical latch to prevent creep in the event of decaying hydraulic pressure
- Low friction wear plates were moved from difficult access faces to more accessible surfaces
- Items containing perishable 'lifed' items, such as 'O' seals, have been made easily accessible.

At the present time preliminary ARM predictions indicate that the STR requirements will be met. Again prototype testing will verify the predictions.

Risk

Project risk is monitored constantly at regular risk meetings which address both commercial and technical risks. A risk register has been raised which is used by the risk committee for evaluation purposes. At the risk meetings each risk is addressed and when deemed to have been eliminated will be removed from the live register. If new risks are identified, they are evaluated and added to the register. Risks which cannot be eliminated are monitored with the aim of reducing the risk to a minimum.

One major change where ARM played a significant part in the decision making, and where as a result risk was affected, was in the decision to mount the shootbolts and seals onto the platform. Whilst this improved the ARM requirement by making these items more accessible for repair etc., it did have the effect of increasing an already delicate balance between the weight of the equipment and the power available from the existing power pack. At one stage the risk was outweighing the ARM, but as described previously, the fall back position of being able to increase the pressure by the addition of air reservoirs enabled the risk level to be reduced and the ARM predictions improved.

Seals

In addition to the safety and ARM difficulties experienced by the existing lift, another source of concern expressed by the users and maintainers of the equipment, was the inability of the weather seal to perform adequately. There were, in addition to the human irritation this caused, also safety and ARM implications.

The only proposed changes to the NBCD seal were to move it onto the platform which meant piping for the LP air had to be attached to the lift and designing a better seal retention. Both these changes were seen as minimal risk. The weather seal however was to be a completely new design, which was seen as a high risk to the project. The risk reduction exercise concluded that the present seal manufacturer should be consulted at an early stage and that a test rig be produced where testing of the new seal proposal could be satisfactorily carried out. (FIG. 18) shows the seal test rig general arrangement, the rig being a corner section of the platform together with seal plates representing the flight and hangar deck apertures. All aspects of the proposed design that could influence the seal capability and wearability were included, for example at the hangar deck slots have to be inserted to allow the guide rollers to pass through and at the flight deck drain holes. To allow for ship build tolerances the seal plates are adjustable to simulate probable variations in width of the gap between platform edge and seal plate position.

The development seals produced thus far by the seal manufacturer have met the S&H design with varying degrees of success and testing has proved that whilst the design has major improvements over the existing lip seal, it requires further development before it can be accepted as totally satisfactory. The ability to continue testing development seals without affecting the progress of the prototype lift considerably reduced the risk element of the seal development programme.

To date major improvements have been made to the seal retention and the seal has proved that in almost every case it will continue to provide a watertight seal up to 15,000 cycles, approximately three years service. The main areas still to be addressed are wear rate to survive 30,000 cycles and its ability to seal where a sharp undulation in the seal plate face occurs. To overcome these problems, both the seal profile and the material compound are being evaluated. The rig will also be used to assess and refine seal repair techniques for the new seal.

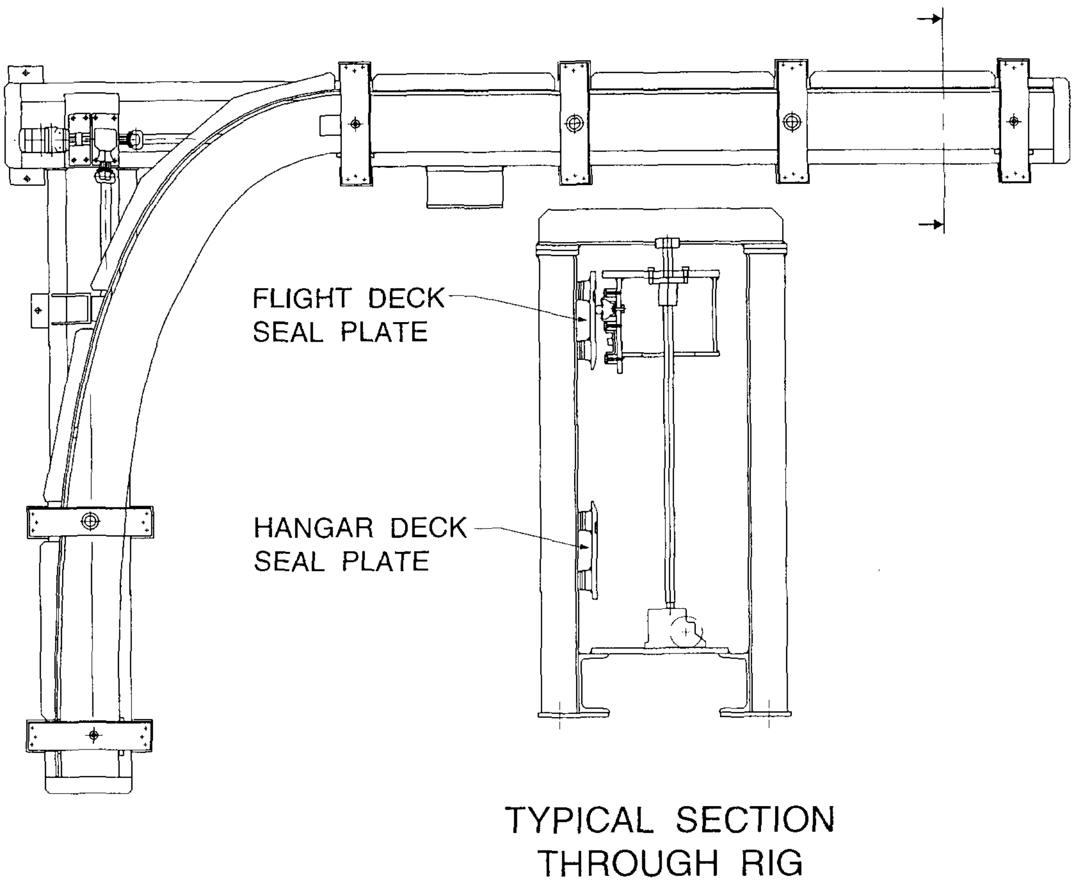


FIG. 18—SEAL TEST RIG

Prototype testing

The contract requires a prototype lift to be manufactured to test and evaluate its capability to perform and meet the requirements of the STR. To factory test a piece of equipment weighing some 120 tonnes, which is 16.75 m long, 9.75 m wide, being 2.5 m closed and 10.1 m fully raised, requires careful planning.

A test rig has been designed to carry the floor loadings and to simulate the ship structure in the areas of the lockbolt pockets. In addition, structures have to be manufactured for mounting the hydraulic manifolds and the control system panels. As it is not possible to use a ship power pack, commercially available equipment has to be obtained and adapted. The test programme will take account of the variations in performance between the commercial and ship systems.

The factory testing, as well as proving the lift capable of meeting its operating requirement, will enable, as previously stated, the safety and ARM predictions to be put to the test and conclusions drawn prior to the lift being installed in a ship. Only after successful proving tests will the go ahead for production be given, thus reducing the risk of problems when installing and use when in a ship.

Having satisfactorily tested each of the production units, the modular construction permits the lifts to be delivered in the tested condition, rather than dismantling and thus increasing the risk of problems during re-assembly. This has required much advance work, liaising with the police, highway authorities, and to produce a satisfactory shipping plan with a competent haulage firm.

Ship interfaces

In parallel with the lift design, work has been carried out to establish all the interfaces with the ship. To ensure that all the ship requirements are fully understood and complied with, S&H have enlisted the support of Devonport Management Services Ltd (DML) who have many years of experiences in refitting the CVSG's. They have been tasked with producing the level 1, 2 and 3 Alteration & Addition guidance information, together with the test forms. This includes defining the interfaces of the existing equipment that will be retained and the repositioning of that equipment within the lift well to permit access for the new lift. A joint exercise was carried out between S&H and DML in devising a well deck strengthening structure (FIG. 19) which could be sandwiched between the well deck and the lift base, thus eliminating expensive and difficult under deck strengthening.

Expectations

The work done to date suggests that the new design is meeting all its requirements. A great deal of effort has been expended in ensuring that the reliability and safety issues are key considerations in the design process and that they are implemented early in the project. The need for safety has not been allowed to compromise operability and it is expected that lift operation will degrade gracefully in the event of a fault. The development of the seal test rig early in the project will ensure that a seal which is fit for purpose will be produced. It is expected that the prototype lift will be accepted by the end of 1994 and that the next phase of refurbishment and production will be authorized. Subject to design acceptance, it is intended that the first lift set will be fitted to H.M.S. *Ark Royal* at her first refit, when she will be modified for MERLIN aircraft operations.

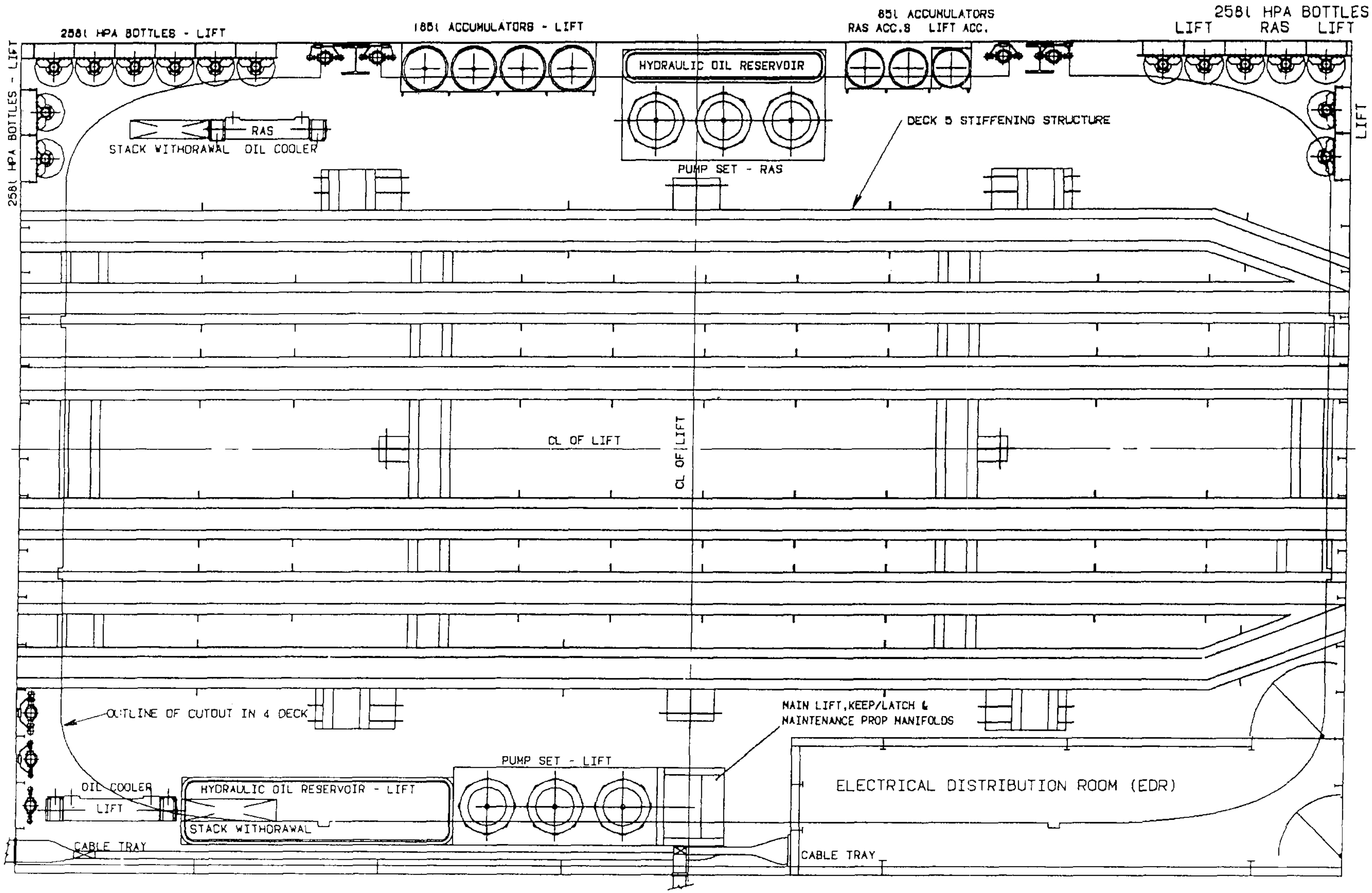


FIG. 19—PLAN VIEW OF THE AFT LIFT WELL REVISED LAYOUT