THE BOMB LIFTS IN 'EAGLE'

BY

A. T. G. COLEBORN.

' The constant distraction caused by these bomb lifts, with their impracticable design and shoddy engineering, bears a substantial responsibility for *Eagle* being unable to achieve as much progress in gunnery as might have been hoped for, considering the excellent standard of so much of the other equipment.'

This was the comment of the Flag Officer, Heavy Squadron on *Eagle's* bomb lifts in November, 1953. Needless to say it was viewed, officially, with some concern and, as the new equipment officer responsible for such lifts in the Naval Ordnance Department, with personal dismay, which became, in the ensuing months, quickened by such criticisms as ' unworkable' ; ' unmaintainable ' ; ' unsuitable ' ; ' limiting the operational efficiency of *Eagle* '. Everybody in the gunnery world, and many outside it, seemed to know about *Eagle's* bomb lifts, and mournfully shook their heads at the evidently hopeless situation.

But why so disastrous a blunder, if blunder it was ? The lifts, together with those for the *Ark Royal*, cost over £900,000 ; design and manufacture took eight years, and the equipment had been in service for two years.

Design Considerations

One has to go back a long way—to 1943, in fact. It appears that the lifts were conceived on the basis that each should be capable of raising a 4,000 lb bomb from the bomb room to the flight deck every 90 seconds or less ; a vertical height of approximately 100 feet and a horizontal traverse of about 20 feet. The time cycle was deduced from the original staff requirements, which required that a given number of aircraft could be bombed up with 2,000 lb or 500 lb bombs in a specified time, making no mention of 4,000 lb bombs or the sixty-odd types of ammunition and boxes which were casually introduced later. The latter resulted in the expedient of tray service, referred to later, with all its incredible electrical complication.

With the 15 in shell handling arrangements in mind, it was decided that the lift should be electro-hydraulic and of the ' combing ' type. This resulted in a lift that is relatively inefficient for anything but the 4,000 lb bomb (which incidentally did not materialize) and perhaps, is incapable of handling modern missiles should they be supplied to *Eagle*. On the score of efficiency, it certainly does seem ludicrous that, when the lift cradle complete with its gantries rises ponderously though rapidly, it should hold only some Bofors or small arms ammunition, 3 in. rockets or even depth charges ! This is, however, inevitable when such a specialized piece of equipment is called upon to do these mundane jobs. The fact is that the lifts could be made much more efficient when handling miscellaneous stores, if they were designed less specifically for one store. With regard to the modern missiles, it would have been quite ridiculous to have prejudiced the design of the lifts and the surrounding magazines to accommodate ammunition which might not have become available during the life of the ship, if at all. The alternative is probably a general purpose platform lift involving larger trunking and bulkhead openings, and to accept the difficulties associated with portable handling gear such as trucks, bomb skids, etc.

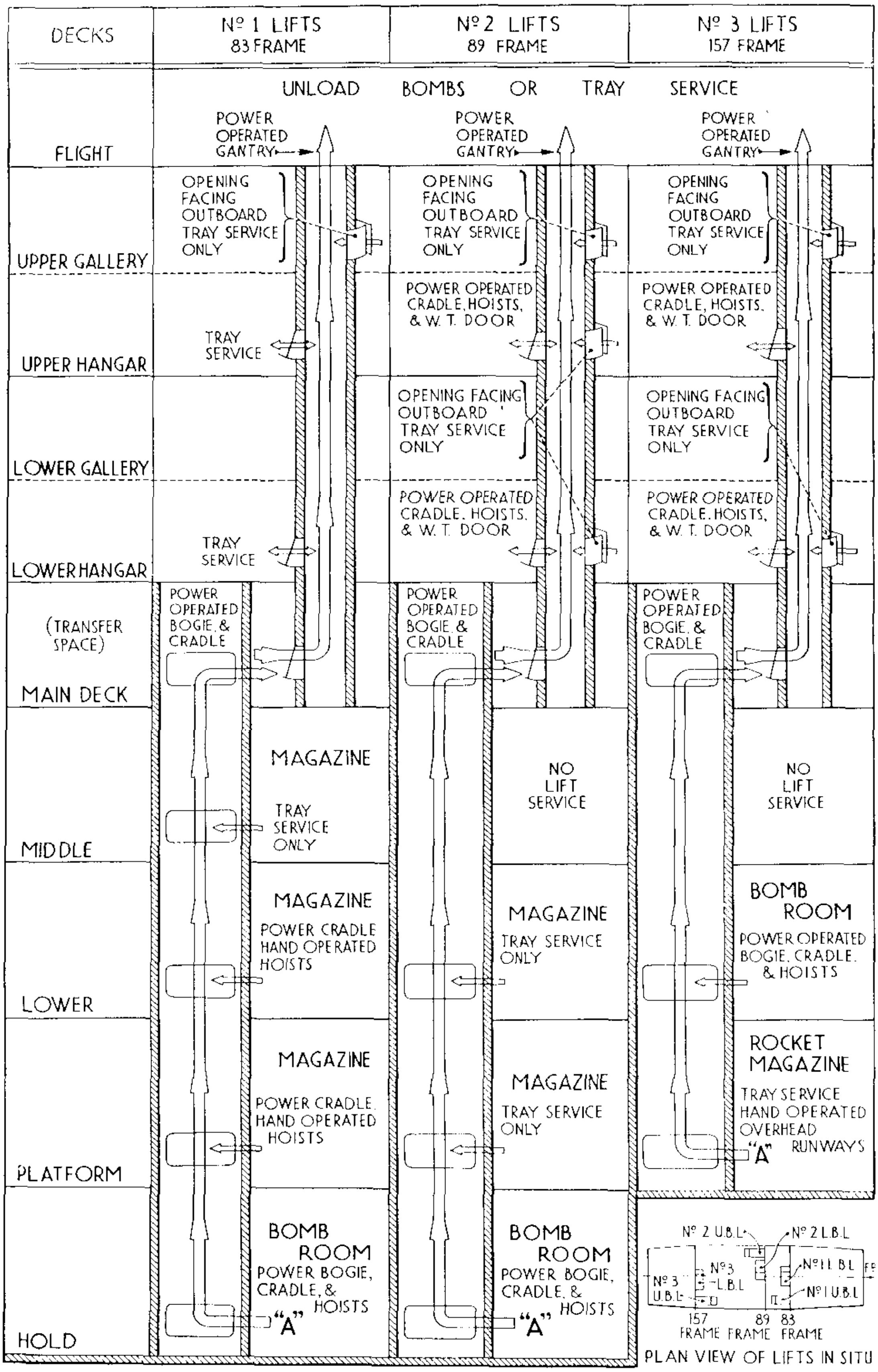

FIG. 1—DIAGRAMMATIC LAYOUT OF BOMB LIFTS

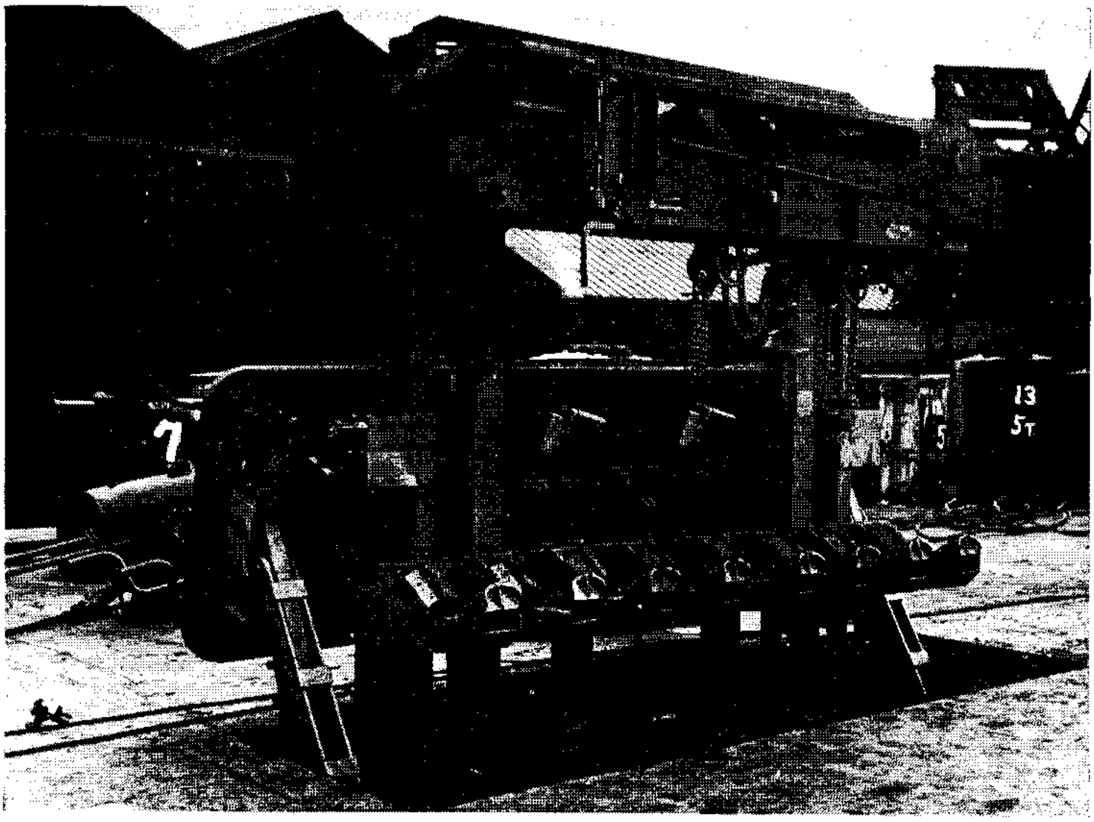

FIG. 2—UPPER LIFT PROTRUDING THROUGH THE FLIGHT DECK HATCH

Description of Lifts

At this stage, it may be desirable to give a general description of the lifts. There are, in fact, three pairs of bomb lifts in the ship (FIG. 1). The lower lift trunks, from the bomb rooms to the main deck, are arranged near the centre line of the vessel and with the major dimension athwartships, while the upper lift trunks, from main deck to flight deck, are longitudinal and arranged to clear the hangars. This arrangement is obviously necessary when the appropriate athwartship sections of the vessel, together with the relative positions of the bomb rooms and the hangars, are considered. In consequence, the load has to be transferred from the top of each lower lift to the bottom of the corresponding upper lift by a power operated transfer bogie. In the case of the two forward lifts, the bogies move across a compartment which is so labyrinthine and cluttered up with equipment, ranging from a hull and fire pump to an emergency operating theatre, that the space is known throughout the ship as ' hell's kitchen ' !

Each lift incorporates a fabricated steel platform of vee-shaped arms in which the load is carried (FIG. 2). The platform, guided in the trunk by vertical steel rails, is raised by a single wire rope which passes over a sheave at the top of the trunk, through sheaves mounted in the crosshead of an hydraulic ram, and secured to the cylinder. The hydraulic cylinder, ram and crosshead, which together is called the ' lifting jigger ' and is capable of a static force of 60 tons, raises the platform 6 feet for every foot the ram is extended (FIG. 3). Each upper lift platform is fitted with hydraulically operated gantries, ratchet operated chain blocks and quick action bomb grippers which transfer the bombs to the bomb trolleys for transport to the waiting aircraft.

The hydraulic fluid supply, at between 1,000 and 1,250 lb/sq in, is taken from the ship's miscellaneous hydraulic mains through a master stop valve, provided

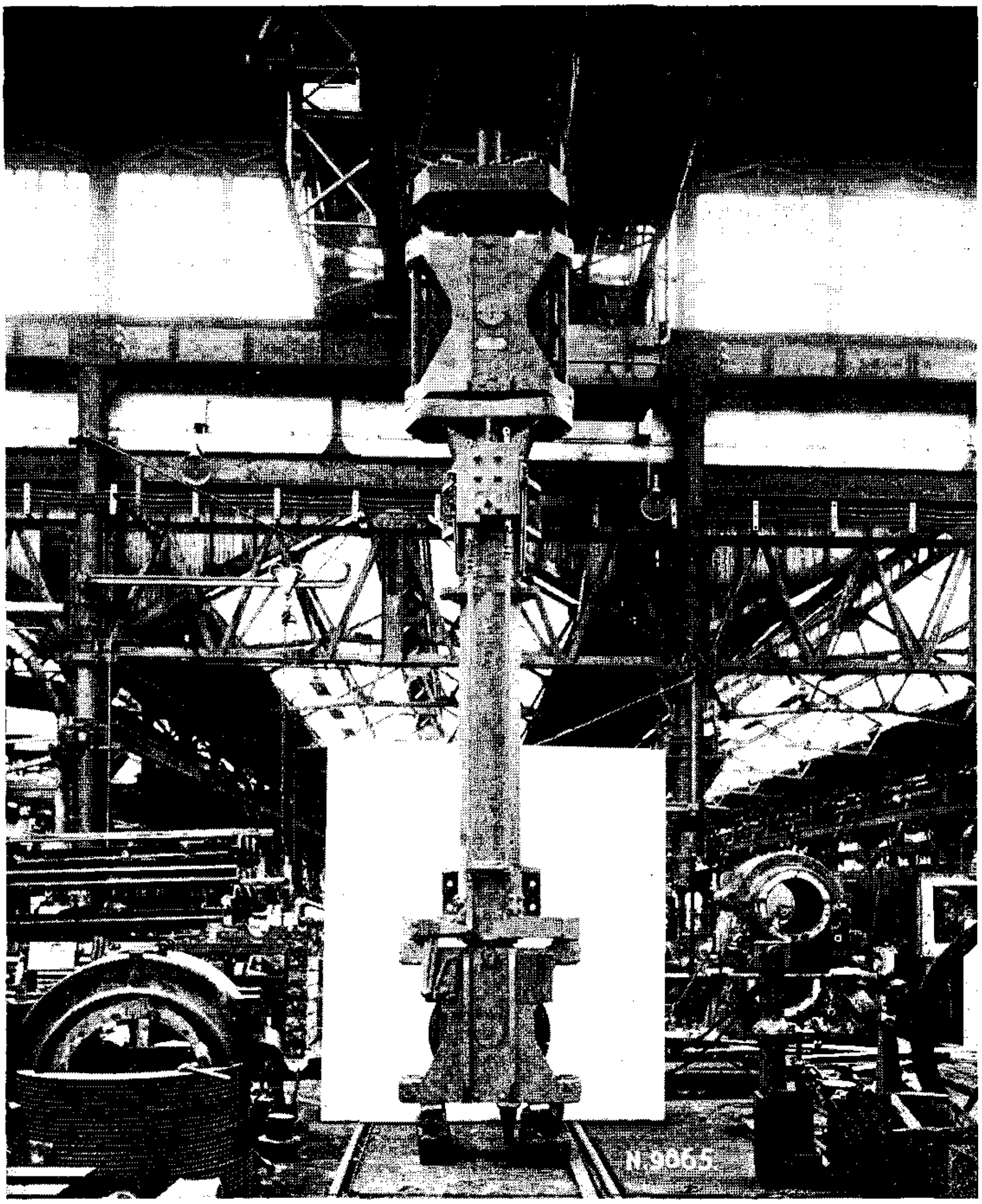

FIG. 3—MAIN LIFTING JIGGER IN THE ERECTING SHOP

for each lift, to the servo-operated main working valve which controls the supply to the jigger and thus the upward movement of the lift platform. Downward movement is governed by similar valves opening to the exhaust main. Supply leads are also taken from the main stop valve to all control standards ; solenoid operated servo-valves controlling the main working valve, flight deck hatch and gantry operating cylinders, bomb room lifting and traversing gear and to the constant pressure cylinders, which are provided instead of springs, to return the valves to the off position and assist the return of the hydraulic rams.

Two emergency auxiliary pumps are provided for each pair of lifts, one in the bomb room, to clear the lower trunk and allow the watertight door to be

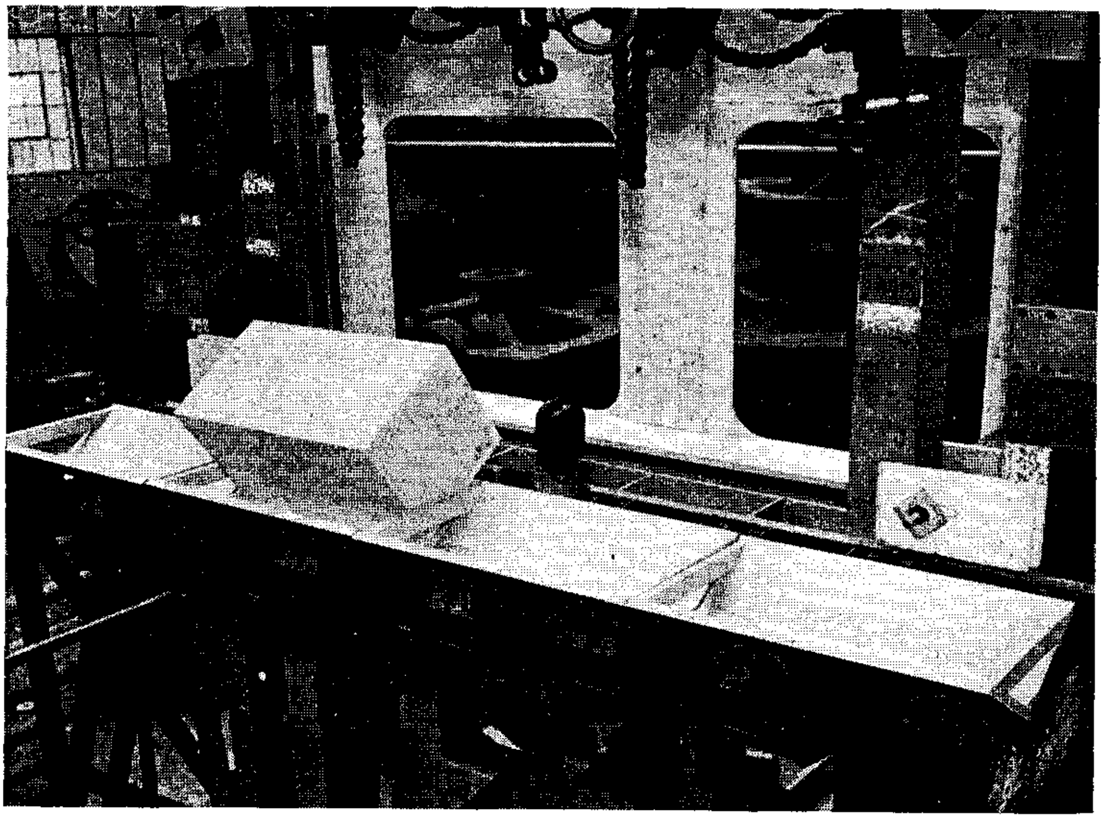

FIG. 4—MOCK UP OF TRAYS FOR LIFTING SMALL ARTICLES

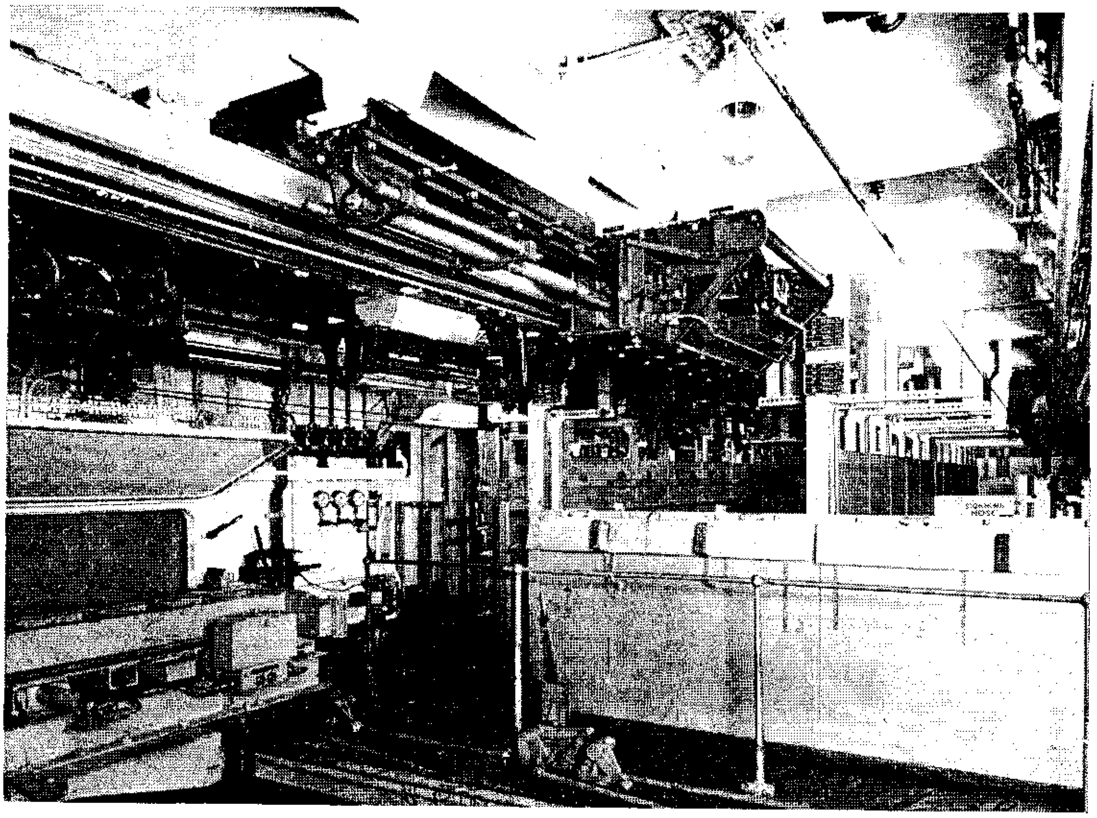

FIG. 5—A BOMB ROOM SHOWING STOWAGE BINS, TRAVERSING GEAR AND THE TRUNK OPENING

closed and the load and equipment stowed ; the other on the upper gallery deck, to lower the lift platform and allow the flight deck cover to be closed and clear the flight deck.

Electric power for operating the switchgear, solenoids and indicator panels is taken from the ship's 220 volt D.C. main power supply system through double-pole switches, which energize or isolate the lift systems. The master control of each pair of lifts rests in the pre-selector panels, one for the lower and one for the upper lift. The panels contain the switches which govern the decks between which the lifts will operate, and the service selector switches. When the required decks have been selected, the rotation of the handwheel on the control standard of the appropriate deck will automatically operate flash-tight or protective shutters, the lift platform, and will ram and withdraw the cradle. Bogie traversing is effected by means of a hand lever fitted to the control standard. The control standards are fitted at each opening into the lift trunks except at the flight deck, in which case, controls are fitted to the hatch cover.

Small stores are carried in steel trays which rest on the arms of the lift platform. The original arrangement was for one tray (in halves so that it could be manhandled) with its load to be sent to the receiving deck and returned empty to the despatch deck. This proved to be very slow and cumbersome since the whole system remained idle until the tray returned to the appropriate magazine. The revised arrangement uses a lighter tray in three nesting sections which, with its load, is raised to the flight deck as if it were a bomb (FIG. 4). After several loads have been delivered, the empty trays are stacked on the lift platform and returned. The lifts can be used for striking down ; the sequence of operations for supplying ammunition being reversed.

A Supply Cycle

A description of the operations connected with the supply of bombs from a bomb room to the flight deck may be of interest. The necessary crew consists of a petty officer and seventeen ratings. On receiving instructions to supply bombs to the flight deck, the pre-selector panel switches are moved to their appropriate positions and the watertight doors and flight deck hatch cover are opened. The control standards at the selected decks are energized. The bomb is taken from the stowage bin by hydraulically operated lifting and traversing gear (FIG. 5) and deposited on the cradle arms of a traversing bogie, which is then moved hydraulically to the lift opening by operating a lever on the control standard. Rotation of the handwheel then opens a flashtight shutter, locks the bogie to the deck, unlocks the cradle from the bogie undercarriage and rams the cradle, and bomb load into the trunk. Another step rotation of the handwheel raises the lift platform by a predetermined amount called 'zoning' ; because the arms of the platform are constructed to pass between the arms of the cradle the bomb is lifted or 'combed' clear of the latter. Further steps of the handwheel withdraw the cradle, lock it to the bogie undercarriage, unlock the bogie from the deck and close the flashtight shutter. Completion of this sequence signals the main deck that the lift platform is free to be 'called'. In every case the lift platform must be called by a 'receiving' deck ; it cannot be 'sent' by a 'despatch' deck.

At the main deck, the lower lift control standard takes control of the lift and, by another series of step movements, transfers the bomb load on to another traversing bogie (FIG. 6). This bogie is called across the transfer space by the upper lift control standard, which, operated in a similar way to the one in the bomb room, deposits the bomb load on to the arms of the upper lift platform, closes the flashtight shutter and passes a signal to the flight deck that the lift is free and can be called by that deck. The bombs, when they reach the flight deck, are transferred to the bomb skids by using the lift gantries and chain blocks.

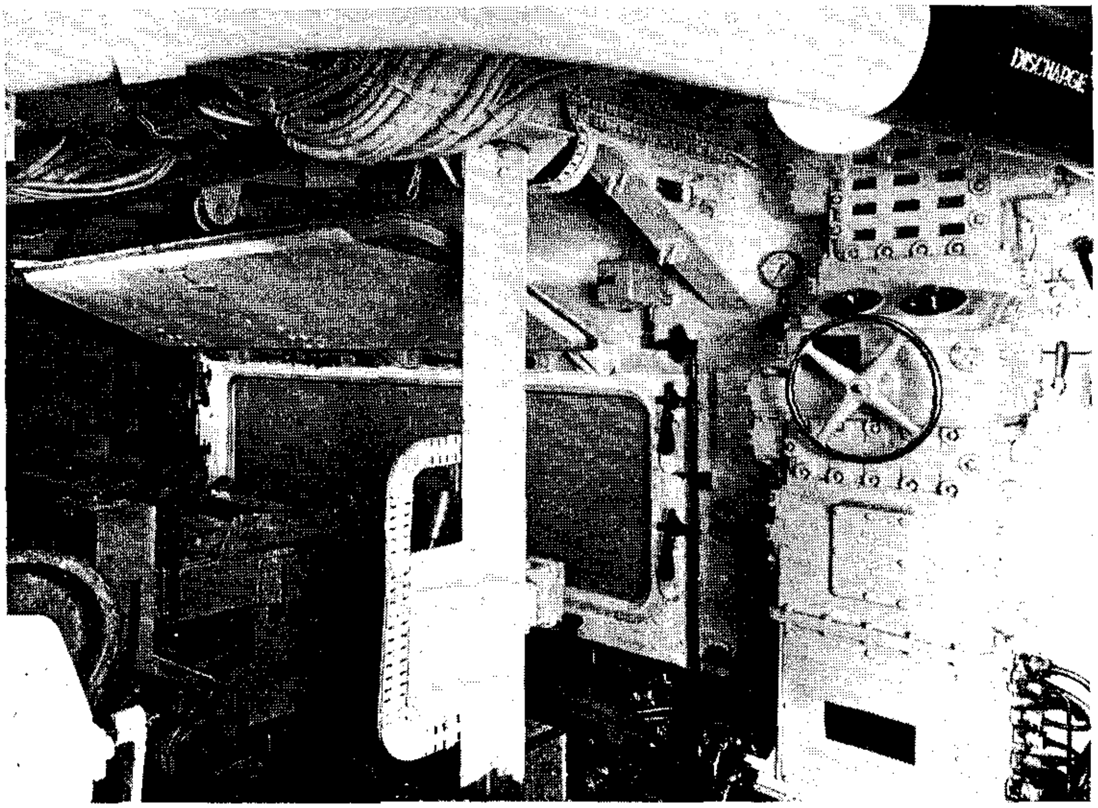

FIG. 6—A TRANSFER BOGEY AND CONTROL STANDARD

The Contractor's Difficulties

The contract for the design, manufacture and installation of the lifts was awarded to Messrs. Fraser and Chalmers, a firm with ample experience both of lifts and naval requirements but not necessarily of the highly specialized practices required for naval ordnance work. Neither the firm nor D.N.O. appreciated the magnitude of the job in its final form, and the many demands for interlocks and other refinements necessitated considerable alteration to the original conception. Furthermore, requirements for such items as hangar service gear and tray service were revised very late in the development. The enormous number of drawings for approval overwhelmed the inadequate staff in N.O.D. and at one time approval took nine months ! Installation, which appears to have been started in good time, was delayed by all manner of troubles, mainly from the hydraulic fluid system. These resulted in the replacement of all leathers by synthetic seals, increasing clearances and fitting ' O ' rings, with all the consequent dismantling, machining and refitting. It must be remembered, too, that these lifts were prototype and could not be erected in the shop. Correction of teething troubles had to be carried out during erection and test in the ship. Small wonder that the installation took a long time !

Doubtless the firm suffered much heartbreaking frustration and, despite their efforts, the job was incomplete when the ship commissioned in late 1951, for the ship's staff to ' work-up '. Every time the ship returned to port, however, the firm sent men on board until the lifts were taken over in August, 1952.

Sea Experience

The ship's Ordnance Engineer Officer was therefore faced, not only with the usual operational requirements and maintenance, which in the new carrier were particularly onerous, but with the problem of making the vast lift mechanism work. His principal troubles were associated with dirt in the 15,000 feet of piping which joined the bewildering array of solenoid and control valves, jiggers and cylinders. Bursting joints and valves flooded electrical interlock switches and great quantities of fluid were lost. The job was made more difficult by obscure faults in the electrical system, in which the original tray service wiring remained, and the lack of adequate drawings, fault-finding charts, and instruction books. Loss of fluid can have serious consequences outside the bomb lift systems, since they share their pressure supply with the flight deck machinery, and a major burst is likely to put the flight deck out of action.

Fortunately, in spite of the frustration and worry connected with these temperamental monsters, there were many lighter moments. The amusement of the ship's company can be imagined when No. 2 flight deck hatch started, for its own good reasons and quite unattended, slowly and inexorably to open under the forward end of an aircraft which was waiting to taxi forward to one of the catapults. The Flight Deck Officer, who was a heavy man, rushed forward and with great presence of mind stood on the hatch. Unfortunately, the hatches are armoured and weigh two tons ; they are raised by two 4-in diameter cylinders with a working pressure of 1,250 lb/sq in and so was the Flight Deck Officer. Meanwhile the pilot of the aircraft, disturbed by the unusual engine vibration, was fascinated by the sight of the spinning disc of his propeller gradually decreasing in diameter as it was neatly turned off by the hatch cover.

There was also the airman who, looking down the 70-foot shaft of one of the upper lifts, and seeing water which accumulates from condensation, leaks and bursts, swilling about at the bottom, said, ' Good heavens, I didn't know they went straight through ! '

Hand Control

After a seemingly endless succession of breakdowns, *Eagle* in desperation devised a method of operating the control valves by hand when electrical faults occurred. This enabled important operational functions, like arming a strike, or topping up the ready use Bofors magazines during the brief gaps in the flying programme, to be completed quickly. As the bomb lifts carry every item of ammunition for both ship and aircraft, except that for the 4·5-in guns, it also ensured that ammunitioning and de-ammunitioning programmes were not disrupted. Hand control had, however, among others, the not inconsiderable disadvantage that when the electrical control system was inoperative, so were most of the interlocks and, since there was then some danger of damage or accident, it was necessary to man the lifts entirely with ordnance artificers and to proceed with considerable care. It is, for instance, possible in hand control, to hold the lift platform at the flight deck with the keeps, which are used to steady the platform while the load is being removed, close the jigger, thus slackening the main lifting wire, and then remove the keeps. The result is as Newton predicted, but with a generous addition of drama ; the lift platform, projecting eight feet out of the deck, disappears abruptly and should there be only a little slack, disconcertingly bounces back to view by the resilience of the wire.

In spite of the disadvantages and dangers, however, approval was given for the use of hand control when it was operationally necessary, with the object firstly of getting as much operational value out of the lifts as possible, and secondly, of allowing further experience to be gained. The Captain reported that, during one cruise, it was necessary to use hand control for half the ammunition embarked or supplied. He also said that his ordnance staff were fully occupied in day-to-day repair and maintenance, while the ship's electrical staff found it impossible to carry out the endless maintenance essential for gear which operates in such perpetually damp conditions ; as an example, it took the latter 200 man-hours to locate a short circuit ! As a result, proposals for hand control and recommendations for mechanical interlocks to make it safe and reasonably foolproof were forwarded. These were received at the Admiralty with the Flag Officer's forthright remarks which constitute the opening paragraph of this article.

Improvement of Performance

D.N.O. was now faced with the problems of improving the performance of the lifts and of obtaining some indication, during the spring cruise, of what to do during the 1954 refit. During the Christmas leave period an effort was made, with Devonport Dockyard assistance, and through the good offices of firms who supplied material, for which they got contracts afterwards, to :—

(*a*) convert No. 2 lift arrangements to an experimental form of hand control;

(*b*) overcome the principal causes of failure in No. 3 lift (by replacing the hydraulic joints and electrical interlock switches).

Unfortunately, the official machine is not geared to cope with a job of this nature and, in consequence, the ship left with very little done, leaving the ship's staff to finish the outstanding items. This they did, with the help of Gibraltar Dockyard, using equipment sent out from home. It was hardly fair, however, to expect a report on the effectiveness of (*a*) and (*b*), giving the relative merits of hand versus electrical control, in the spring of 1954. By this time, moreover, it had become painfully obvious that if *Eagle's* bomb lifts were to be made satisfactory during the forthcoming refit period, August, 1954 to February, 1955, action had to be initiated immediately. A meeting between representatives of D.N.O., D.E.E., H.M.S. *Excellent* and Messrs. Fraser and Chalmers decided that :—

(*a*) Every effort should be made to bring the existing equipment, as designed for full automatic control, up to maximum efficiency.

(*b*) For full automatic operation of the lift, all 85 interlocks are necessary

(*c*) Hand control should be developed for emergency operation.

(*d*) With emergency hand operation and on a basis of ' major material safety', or to avoid wrecking the equipment but not to protect the personnel, all interlocks could be dispensed with except those for flash-tightness in the lower lift, the necessary safety being attained by meticulous attention to drill.

(*e*) Fourteen alterations and additions should be submitted for approval, the largest of which were to cut pipework to easily portable lengths with screwed connections, replace all existing Yorkshire Copper soldered joints with their brazed type of joint, replace diamond copper joint rings by ' O ' rings, fit additional isolating valves and provide filters in the hydraulic supply lines. On the electrical side, all interlock switches were to be replaced by an improved pattern and protected with drip guards, all wiring associated with the original tray service to be isolated, all remaining wiring to be colour coded to facilitate fault-finding, all indicator lamp box covers replaced to ease lamp changing and the contactor panels raised above possible flood level. Finally, to make provision to operate all lifts by hand under emergency conditions.

The lift makers agreed to provide all the necessary drawings, running into many hundreds, and the replace parts, thus relieving the dockyard of all but the work of refitting.

A Note on Hydraulics

It should be noted here that the hydraulic joints which gave so much trouble were the soldered type (97 per cent tin, 3 per cent silver—240°C melting point) supplied by the Yorkshire Copper Company. These were different from the firm's standard fittings as supplied for domestic systems, in that tin-silver solder was used instead of tin-lead solder and the fittings were 50 per cent longer. The joints were fully tested on behalf of the Admiralty at Messrs. Vickers-Armstrongs' works at Elswick and their use officially approved. Although the system in the ship was tested satisfactorily to twice the working pressure, many joints failed in service for reasons which are obscure, and the manufacturers recommended replacement by their high duty brazed fittings (brazing metal, 55 per cent silver, 21 per cent copper, 22 per cent zinc, 2 per cent tin—650°C melting point) which incidentally were not commercially available when the type of pipe joint to be used in *Eagle's* lifts was decided.

In any case the soldered type was preferable because of its relatively low cost and the fact that it is theoretically possible to remake a joint with the use of a specially designed soldering iron, thus avoiding a naked flame in the magazines. The adoption of the brazed fitting has meant that the pipe systems have had to be broken up into easily portable lengths, by the plentiful use of screwed connections.

The hydraulic fluid now used consists of 49 per cent distilled water, 49 per cent glycerine and 2 per cent soluble oil. It is maintained slightly alkaline by small additions of caustic soda or caustic potash. The amount of caustic soda previously recommended (10 lb per 100 galls of fluid), is now considered excessive, and may have been a contributing factor in the failure of the soldered joints, by stress corrosion. It was reported that the hydraulic fluid originally used resulted in disintegration of hydraulic leathers and formation of sludge, the latter being attributed to bacterial fermentation. Hydraulic leathers had to be replaced by synthetic seals. The sludge and dirt left or collected in the system, which is difficult if not impossible to clean because of the number of dead ends, caused many stoppages. The chief difficulty encountered was sticking of the piston type control valves, due to particles of foreign matter in the fine clearances, which the solenoids failed to overcome. To rectify this, clearances were increased, necessitating the use of ' O ' seals, the effectiveness, but not the life, of which has been proved in these small reciprocating mechanisms.

Originally it was considered unnecessary to fit permanent filters in the supply lines from the ship's hydraulic main to the lift, but the need for such filters has now been demonstrated in the light fleet carriers in which it has been found that it is necessary to clean filters at least every month. Furthermore, the original interlock switches, although watertight to normally accepted standards, were vulnerable to the mixture of glycerine and soluble oil of the hydraulic fluid from burst pipes. It appears that the choice of the constituents of the hydraulic fluid had a substantial bearing on the poor performance of the lifts and may indeed have been the principal cause of most of the troubles experienced.

A Note on the Electrics

In the meantime the ship's remarks regarding electrical maintenance had been strongly challenged by D.E.E. A study of a register of electrical troubles during the spring cruise indicated that this had not been as bad as represented. There was no doubt, however, that the many switches, which were vulnerable to the hydraulic fluid, without sufficient wiping action and arranged in series, caused a great deal of trouble, since failure of any one of these switches paralysed its associated lift. As a result of these investigations, and because the dockyard was definitely unable to undertake the work, and the growing realization that the lifts could be made to work as designed, the proposals for hand control were abandoned without much reluctance.

The 1954 Refit

After some discussion between D.N.O. and D. of D. the dockyard undertook to complete or progress all the mechanical alteration and additional items with the exception of ' hand control ', and D.E.E. arranged for Messrs. Harland and Wolff to do the necessary electrical work.

The ship duly arrived at Devonport in August, 1954, and de-ammunitioned in four days without hitch, all bomb lifts, except No. 2 upper, working perfectly under power control. The exception performed its full share with the emergency hand gear. Here was a poser ; had the ship at last succeeded in overcoming the many defects and made all the necessary repairs ? Should the work of tearing out all the hydraulic piping, electrical switches and surplus wiring be proceeded with, knowing that there was barely time to do it, let alone to retune to test the lifts before the ship returned to active service ? The decision was made to go ahead ; materials were available to start the re-piping and and, promises of delivery of other replace items, together with the necessary drawings, looked good though optimistic.

It is difficult to write an end to this article before the work has been completed and the lifts have passed their official tests and given some months of service under sea conditions. It is touch and go all the way but relying on the goodwill of all concerned, in particular Messrs. Fraser and Chalmers, The Yorkshire Copper Company, Messrs. James Walker and the Dockyard, there is hope that the work will be brought to a successful conclusion. Despite the fact that some of the modifications required will not have been carried out, the future performance is viewed with restrained optimism. Perhaps the ship's officers will write the epilogue!

Conclusion

Looking back, it would appear that, had the dreadful caustic fluid, which flowed through the veins of the great robots insidiously attacking the myriad leathers and joints, not been used ; and had fortune been better served in the selection of joints and interlock switches, so liberally dispersed throughout the systems, there is no doubt that, beyond the usual teething troubles, the lifts would have given vastly less trouble.

Messrs. Fraser and Chalmers showed great ingenuity and engineering skill in devising and manufacturing the various mechanisms to meet Admiralty requirements and criticism of ' impracticable design and shoddy engineering ' may be less well founded than at first appeared. D.N.O.'s contribution in the design was not inconsiderable, but he should not, perhaps, have allowed the ' user ' so great a latitude in the introduction of requirements and refinements. Perhaps he should have been more forceful in expressing his views of their cost in terms not only of expense but of complication and maintenance. On the credit side, lessons have been learnt, and much experience gained, which has already been incorporated in other lifts in the Service ; the way is clear for *Eagle's* ' modernization' in due course ; ample design and manufacturing experience for building bigger and better hydraulic lifts in future carriers is available.

The Flag Officer, Heavy Squadron, was justifiably infuriated in 1953 : there should be no rude messages from sea in 1955.

(The photographs were supplied by Messrs. Fraser and Chalmers of Erith, Kent.)