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by

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STUDY OF SOLID STATE REMOTE CONTROL TECHNIQUES AS APPLIED TO THE REDESIGN OF THE ELECTRICAL SYSTEM IN A LARGE CIVIL AIRCRAFT

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SUMMARY

This Report describes how the electrical power distribution system of a large civil aircraft might be redesigned to employ remote power controllers, embodying solid state protection, in conjunction with solid state logic, to operate circuits remotely through lightweight signal wires. An assessment of the masses of a conventional and a remotely controlled system, based on a VC 10 installation in which it is assumed that the latest lightweight cables and switchgear are used indicates that the remotely controlled system would be about 90kg lighter. Additional saving might result from equipment specifically designed to be compatible with solid state remote control techniques.

The effect on both systems of resiting the electrical compartment from the forward to a mid-aircraft position has been examined and it is concluded that a further saving of 36 kg would result with remote control.

The redesigned system lends itself to, and has been arranged for, easy conversion to multiplexed data transmission. Although a multiplexed system has not been assessed, the mass of cables and fittings that would be replaced has been evaluated as 42 kg, or 77 kg if analogue circuits were included. This indicates the allowances within which the multiplexed data transmission should be designed.

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* Replaces RAE Technical Report 72238 - ARC 34764

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1 INTRODUCTION

It has been shown[1] that cables form a substantial proportion of the total mass of aircraft electrical installations and it appears that this area provides the greatest potential for reducing installed mass. The smaller sizes may account for some 70% of the mass of all cables installed in modern aircraft but these, of 20 gauge and lighter, are often poorly utilized in carrying currents much lower than their rated capacities and for very short periods. Typical duties are the transmission of low powered switching signals and the operation of indicators. The amount of cabling installed could be reduced in such cases by using multiplexed data transmission, and a study[2] has already indicated that about 170 kg might be saved in the electrical system of a VC 10 by this means. For that study the relay logic and contactors were in existing form and position and no attempt was made to produce a system more compatible with multiplexing techniques except the use of remote bus bars for light loads.

The present study examines an alternative method of reducing the quantity of power distribution cable, based on the application of solid state devices as recently developed in the USA for the protection and remote control of circuits, known as remote power controllers (RPCs), and on experience at RAE with experimental remotely controlled devices of advanced design which it is believed could be developed readily for production (Ref.3, and later work to be reported). Study entails the redesign of the electrical system, using dispersed bus-bars, fed by sub-feeders, such that much of the present distribution wiring could be shortened and replaced by small, lightweight signal cables to operate the RPCs through solid state interlocking logic. Ultimately the number and mass of signal cables could be reduced by using multiplexing techniques, and the redesigned system has been specifically arranged to involve the minimum of modification for a change to multiplexed data transmission. The necessary components could be placed in enlarged versions of the control or logic boxes and the multiple signal wires reduced to a few screened twisted pairs. No attempt has been made to estimate the mass of a multiplexed system, but the mass of cables and fittings that would be replaced has been established in Appendix B, and forms the allowance within which the multiplexed system would have to be designed with maximum saving the aim. Analogue data could also be transmitted through the multiplexed channels, but at a cost of considerably increased complexity. The mass of existing analogue data transmission wiring has therefore been established and forms the added allowance for including this feature.

The assessment has been based on the VC 10 electrical installation, but for the datum case, the most up-to-date cables, switches, circuit breakers and relays available have been substituted for the existing items, so that a fair comparison might be made with the latest techniques employed in solid state remote control. As a result of these changes, the system mass would be reduced considerably and would no longer represent the VC 10. For this reason there can be no direct comparison with the results of the earlier study[2].

2 FACTORS AFFECTING THE CHOICE OF CABLE SIZE

The size of cables chosen for individual circuits depends on at least one of the following factors

(a) current carrying capacity,

(b) rating and performance characteristics of the circuit protection,

(c) voltage drop, limited by BS 3G100 part 3[4] to 2 volts for 28 volts dc and 4 volts for 115-200 volts ac, except in special cases,

(d) mechanical strength.

These factors could be greatly affected by the introduction of solid state remote control methods.

For a conventional system, the continuous current rating of a cable when installed in a loom depends on loom size, cable position and the heat generated within the loom, and may be reduced to about one third of the value for a single cable in free air. The main fuselage looms in the proposed system would consist mainly of signal cables, carrying currents so small that their ratings would be unaffected by close packing while the power cables from the dispersed bus-bars would run, mainly locally, to wings or to engines in smaller looms, if indeed looms were necessary. In this study no benefit has been assumed from increased current carrying capacity due to these changes.

A fuse or thermal circuit breaker can carry from 150% to 200% of full rated current for several minutes before rupturing a circuit, the exact rupturing current varying considerably from fuse to fuse of given rating. The time lag of the circuit breaker is particularly affected by ambient temperature. Furthermore, in some circuits, large surge currents occur at switch-on, and the protective devices sometimes have to be uprated to cover this. For these reasons cable size must often be chosen to match the protective device rather than the nominal load current to avoid fire risk. With a solid state protective device, however, the operating envelope can be made closer to the load characteristics and thus give better protection to both load device and cable without having to uprate the latter.

In a large proportion of circuits the allowable voltage drop governs the size of cable used. Run lengths of 30 metres and over are common in large aircraft as the VC 10, and to keep within the 2 volts drop specified for dc circuits, a 22 gauge wire of this length, for example, would be limited to carrying about 1 ampere, whereas its maximum current capacity is about 11 amperes. By adopting remote control, many run lengths could be reduced, which would not only save cable directly, but might also permit the use of smaller cables without exceeding the voltage drop limit.

The VC 10 is wired mainly with Nyvin cable, of which the smallest size is 22 gauge. Recently, very small cables have been developed with cores of copper alloy for added strength, permitting 24 gauge wire to be introduced into new aircraft, including Concorde. Wires smaller than 24 gauge, although mechanically acceptable, might be limited in their application in a conventional system, because of high resistance and the difficulty of selecting suitable protection. However, in a system designed specifically to be controlled by solid state devices which require low voltages and currents only, resistance would present no problem and fuses or circuit breakers are not the best means of protecting the signal cables. For this study, it is proposed that 26 gauge cable be used for all low powered control circuits, while 24 gauge should be used, where practicable for power circuits. The latter cable has also been substituted for 22 gauge, where suitable, in the existing VC 10 installation. The cable masses in both installations have been calculated from BICC Kapton insulated cable (KP150) data for sizes up to 12 gauge, and Nyvin cable data for larger sizes for which Kapton is not available.

3 ARRANGEMENT OF CONVENTIONAL AND PROPOSED REMOTELY CONTROLLED SYSTEMS

3.1 Conventional system

In the VC 10, four main, 3-phase, ac feeders of Nyvin 4 cable, transmit power from the engine mounted generators at the rear of the fuselage to the four main ac bus-bars, which are installed together with the main ac and dc electrical equipment in an electrical bay, zone F7, Fig.1. This bay also contains four main dc bus-bars and special bus-bars mainly to supply 28 volt ac power, and ground power. Sub-feeders (12 gauge for ac and 10 gauge for dc) transmit power forward from the main bars to sub-bus-bars at the engineer's position in zone F1, Fig.1. The sub-bus-bars consist of two three phase ac bars, two single phase ac bars and four dc bars from which the majority of circuits, directly switched by the crew, are supplied. All heavy power loads are indirectly switched *via* contactors or relays from the main bus-bars in zone F7.

3.2 Remotely controlled system (scheme 1)

The principal object of employing remote control is to reduce installed mass, replacing much of the under utilized distribution wiring by a few sub-feeders which share both intermittent and continuous loads. It is proposed for this system to retain the main ac feeders and the position of the main equipment and bus-bars exactly as in sub-section 3.1 above, but to employ sub-feeders to carry power from the main bars in zone F7 to sub-bus-bars in zones F1, F8 and F4, Fig.1. Loads would be supplied and controlled remotely from the nearest bus-bar zone, except for continuous loads larger than 10 amperes which would be fed and controlled from the main bus-bars in zone F7; since it is lighter to supply such loads by individual cables rather than by a larger common feeder, due to the superior heat dissipation of the former method. This is especially true where lightweight KP150 cables would be used rather than the heavy duty Nyvin. The proposed layout is depicted in Fig.2, which illustrates the combination of sub-bus-bars, feeders and logic boxes for controlling the remote switching.

3.3 Alternative arrangements of power transmission (scheme 2)

It will be seen from the descriptions in sub-sections 3.1 and 3.2 that power is transmitted forward from the rear of the aircraft, and much of it is distributed back again to the loads. In a system where circuits are directly switched by the crew, this undesirable feature is largely unavoidable, whatever bus-bar layout is adopted. But for remotely controlled circuits there are alternative positions for the main bus-bars and electrical equipment which could virtually avoid this objection. Changes to the siting of the electrical bay are discussed in Appendix A, where an alternative arrangement (scheme 2) is suggested in which the electrical bay would be moved from zone F7 to F8, without greatly affecting the aircraft cg position.

4 DESCRIPTION OF PROPOSED SYSTEM EMPLOYING REMOTE CONTROL

4.1 General features

Methods of using solid state techniques, with their low power requirements, to achieve reductions in installed mass have been outlined. The proposal is to operate the whole of the control system from a 5 volt, dc, power source and to limit the actuating current of each remote power controller (RPC) to about 10 milliamperes. This would permit solid state logic to replace conventional relay logic for control and interlocking purposes, while 26 gauge would be adequate for the signal wiring indicated in Fig.4.

Two forms of RPC have been suggested (a) all solid state and (b) electro-magnetic with solid state amplifier and protective circuits. The former would be employed to switch currents up to 15 amperes in dc and single phase ac circuits or up to 6 amperes in 3-phase ac circuits, while the latter type would switch heavier currents. The division between the two has been chosen arbitrarily, with the object of keeping losses in solid state devices low and thus avoiding the use of heavy heat sinks. This objective could also be aided where several RPCs are mounted on the same heat sink by interspersing continuously rated with intermittently rated RPCs. It might well prove that the chosen limits for these devices could be raised, since the estimated losses for each zone, see Table 9 and section 5.3, are fairly modest. The use of advanced cooling techniques such as evaporative cooling or heat pipes might have a powerful influence. Solid state remote power controllers have not yet been developed in this country; all information about these devices has been extracted from an American specification MIL-P-81653(AS)[5]. The electro-magnetic RPC would utilize a relay or contactor and built-in solid state protection. Should the latter prove too complex or expensive for general use in the ratings required, the existing arrangement of relay and fuse or circuit breaker protection could be retained. In either arrangement the relay or contactor would incorporate a solid state amplifier to trigger it from the 5 volt supply. An experimental electromagnetic RPC having such an amplifier has recently been explored at RAE[3].

It is intended that the control wiring should be kept separate from that of power distribution, to avoid electro-magnetic interference from this source producing spurious signals. Fig.2 shows the intended layout and indicates the number of logic boxes, wires and connectors required.

Each box would provide a 5 volt, dc, power source for the control and logic components, obtained from internal, duplicated, transformer-rectifier units, each supplied from an adjacent ac bus-bar. The TRU outputs would be paralleled, but each would be capable of providing the full requirements of its box. In order to prevent possible spurious pulses causing inadvertent operation of the solid state RPCs, their control current would be fixed at a minimum level of, say, 10 milliamperes and anti-interference measures could be built into the triggering circuit should this be found necessary.

Based on this figure, the estimated rating of the power units would be 8.5 watts for zone F1 boxes and 4 watts for other boxes.

The current level would be limited to 10 milliamperes for each individual circuit by a resistor, which could form part of a printed circuit, connected within the boxes to the power source. External wiring could not therefore become overloaded and present a fire risk, should a short circuit occur. Some signals would originate from 115 volts ac or 28 volts dc sources and need similar resistors. For convenience, these are included in the logic boxes, but in practice, it would be preferable to position them within equipment or at bus-bars producing the signals.

It is proposed that all warning lights and indicators should be operated by the 5 volt control system, through transistor amplifiers built into the light or indicator body.

The system voltage would be regulated at the main bus-bars, consequently a sub-feeder becomes part of the total resistance of a circuit. For dc circuits, with a sub-feeder carrying its full continuous load, the voltage drop has been divided between it and the distribution cables in the ratio of 1.3 volts to 0.7 volt respectively, while for ac circuits the ratio would be 2.5 volts to 1.5 volts. The sizes of cables used for sub-feeders and power distribution have been selected to meet these figures, subject to their current rating being adequate. In general the effect of circuit protection on cable selection has been ignored, since it is considered that in most situations voltage drop would predominate when sizing.

Some important circuits in the present system are protected by manual circuit breakers which enable the engineer to reset rapidly a tripped circuit. Where the same circuits would be protected by RPCs this facility has been retained, by installing warning lights and reset buttons at his station. To save cable in less important circuits, group resetting could be provided at accessible positions close to the various bus-bars. Should it prove possible to reset a tripped RPC by opening and closing the crew's operating switch, then the reset button and associated wiring could be deleted.

Remote control methods are neither necessary nor suitable for some circuits, for example, those operating gauges, position indicators and parts of the interior lighting. Such circuits would remain unaltered and could retain their existing protection, transferred, where necessary, to the most suitable of the new bus-bars.

4.2 Details of control and logic

Full details of the control system, including the appropriate Boolean logic expressions, are given in Tables 1 to 4. Each table quotes all of the components and connections for the zone. These should be divided equally between right and left hand boxes, unless an item is marked by R or L, which denotes right or left hand only. Tables 5 and 6 contain details of the connections and solid state logic required to replace the existing relay logic for the flying control and master warning systems on panel B.

A control circuit is initiated when a positive voltage (or logic 1 signal) is applied to an RPC or to a portion of the solid state logic. If a circuit contains interlocking logic, this is represented in the appropriate table by an expression formed from discrete letters of the alphabet, where each letter represents a logic 1 signal produced by the contacts, when closed, of each switch or sensor in the circuit. Where a logic 1 signal is required from open contacts, this can be achieved by inverting the normal logic 0 signal and is represented by the symbol $\bar{A}$ or $\bar{B}$, etc.

The symbol (M) in a logic expression denotes a memory and is prefixed by a letter representing the setting signal and suffixed by a letter denoting the resetting signal. Thus A(M)B indicates that contact A initiates a logic 1 signal, which would remain until reset to logic 0 by a signal from contact B. When a prescribed logic expression has been fulfilled, an amplified logic 1 signal is produced to actuate the appropriate RPC.

Fig.4 illustrates a typical circuit in its conventional and remotely controlled forms, indicating the reduced cable mass associated with the latter arrangement. The additional complication arising from the use of more components in the case selected should not be overlooked.

5 COMPARISON OF THE MASSES OF CONVENTIONAL AND REMOTELY CONTROLLED SYSTEMS

The masses of those parts of the two systems which differ are compared in Tables 7 and 13 and the following observations amplify or explain details in the tables.

5.1 Cables and connectors

5.1.1 Scheme 1 (refer to section 3.2)

It can be seen from Table 7, that, whereas the total length of cable for the remotely controlled system is greater by 2181 metres, partly due to the extra wiring needed for warning and reset purposes, the cable mass has been reduced by 73.7 kg. The estimates for both installations are based on the modern cable data quoted in section 2. The 26 gauge, KP150, cable is not yet available, but its specific mass has been estimated from other cables and is assumed to be 2.0 g/m.

The input connectors required at boxes and panels are assumed to be the latest high density types to an American specification MIL-C-0081511D (Navy)[6]. The quantities quoted are the minimum required, as indicated in Fig.2 and Table 10, but alternative combinations might be preferred in practice; these should not significantly increase the total mass.

5.1.2 Scheme 2 (refer to section 3.3)

Table 13 shows that moving the electrical bay from zone F7 to F8 gives a reduction in cable mass of 19 kg for a conventional system and 36 kg for a remotely controlled system: a clear advantage of 17 kg for the latter.

5.2 Protection, relays and switches

In the remotely controlled system, fuses would be retained to protect those circuits not operated by RPCs, while heavy duty, bolted type, fuses are required for sub-feeder protection only. The mass of the solid state RPC has been extracted from specification MIL-P-8163(AS). No firm information exists about solid state protection as applied to an electro-magnetic RPC; therefore the specific mass assumed in the table for a given rating comprises that of an equivalent relay or contactor, a fuse or fuses, and 4.0 g for the solid state amplifier. The latter figure represents components weighed at RAE, where samples of both ac and dc relays have been modified to contain a triggering amplifier.

The specific masses of circuit breakers, switches and relays quoted for the existing system, in Table 7, refer to modern designs as installed in Concorde. The relatively large difference in mass between the manual switches of the two installations results from the existing switch having to be sufficiently robust to make and break inductive currents up to 10 amperes, while the lightweight type for remote control has only to switch resistive currents of 10 milliamperes. Although the lightweight switches, reset buttons and warning lights weighed at RAE were not approved aircraft types, they are considered reasonably representative of what could be achieved for these applications.

5.3 Logic boxes and equipment panels

Details of the logic boxes and the solid state logic for the central warning systems on panel B are given in Table 8. The internal masses have been calculated from standard discrete components, weighed at RAE, while the power units and box shells have been estimated from typical laboratory samples. For production equipment, large scale integrated circuits could be employed to reduce the mass of internal components, but it is doubtful whether the power units or boxes could be made much lighter, especially as the latter would have to accommodate the connectors for incoming cables.

Because of the totally different layout required when a system employs remote control, many of the existing equipment panels would have to be modified. For example, the present fuse and bus-bar panels, C(zone F1) and J,K,U,Z (zone F7) would be split between zones F1, F7, F8 and F4 to carry the revised protection detailed in Table 9. This table shows the numbers of solid state RPCs for either intermittent or continuous operation, the latter producing a total of 348 watts of heat. Table 11 gives the total mass of panels C, J, K, U and Z as 74.6 kg. In the revised system, about 45% of the protective devices would be solid state RPCs mounted directly on heat sinks. If 45% (33 kg) of the total panel mass be allotted for these heat sinks, then a modest continuous heat dissipation of 10.5 watts/kg would result. Typically, RAE experimental RPCs have been mounted on finned aluminium heat sinks, which under laboratory conditions, have a dissipation of about 80 watts/kg. Elaborate cooling methods, therefore, appear unnecessary and the 74.6 kg allowance for installation mountings has not been changed. It should be noted that little weight would be added to the near compartment (zone F4), since the total mass of protective devices and logic boxes mounted here (Tables 7 and 9) is 6.54 + 3.69 = 10.23 kg only, which would be partly offset by the elimination of relays from panels V and S.

Table 11 lists the existing electrical panels, their masses and the estimated reduction in size and mass made possible by the elimination of relays mounted on them.

5.4 Installation fittings

The introduction of remote control affects the cable runs and dusting only within the fuselage. In the VC 10 this ducting, for Nyvin type cables, has a mass of 110 kg, but for smaller cables the ducting could be reduced in proportion to the square roots of the areas occupied, assuming tubular or rectangular ducting of a similar shape and length. Table 12 gives the numbers of each cable size and the areas occupied to interzone runs, from which the ratios for calculating trunking masses have been derived. Thus, by substituting KP150 cables into the VC 10, trunking could be reduced to 110 × 0.72 = 79.2 kg, and with remote control further reduced to 79.2 × 0.89 = 70.5 kg.

6 SYSTEM INTEGRITY AND RELIABILITY

In order to obtain maximum system integrity, the installations considered in this Report, whether basic VC 10 or exploiting remote control techniques, depend on the same philosophy of separate and independently operated circuits so protected that a fault on one would not affect the correct functioning of another. Most aircraft electrical systems, including the VC 10, employ some sub-feeders and a fault on one of these would cause the loss of several circuits. With the increased number of sub-feeders needed for remote control, the potential risk of failure would be greater, but the number of circuits affected by a single fault would be reduced. In practice, substantial cables would be used for sub-feeders, and given careful installation the risk of faults occurring would be slight as is confirmed by experience in service. The provision of 5 volt control power would be an extra requirement associated with the use of RPCs and solid state logic: it would be arranged as two paralleled power units in each of eight boxes. Double failure in a single flight, causing the loss of several circuits, is regarded as unlikely. If thought advisable, however, a dc fed standby unit could be installed, for a total penalty of about 1.5 kg, to be switched manually or automatically to any box suffering a complete power failure. By careful design of equipment and installation the overall integrity should be substantially the same as for the existing system.

As remote power controllers have not yet been developed in this country, there is no statistical evidence of their reliability and at this stage, only general comments can be made on possible trends. The fuse is the simplest and potentially the most reliable form of protection, although it can be very difficult to choose a rating that will protect equipment in all circumstances. Military aircraft continue to employ fuses, but the latest trend in modern civil aircraft, such as Concorde and A300B airbus, is towards the exclusive use of manual circuit breakers. These are also thermal devices but having mechanical movements. It therefore appears that there would be some prospect of achieving higher reliability by using solid state protection. The electromagnetic RPC, with solid state protection and control, if successfully developed for general use, would replace the existing combination of fuse and relay and should have comparable reliability.

Where solid state components replace relays in control logic, reliability should improve but the accompanying change from point-to-point wiring in VC 10 to interconnected control boxes, using multi-pin connectors might be more susceptible to faults, particularly with the proposed use of 26 gauge wire. This form of installation was chosen in the study to keep the control system self-contained and for easy conversion to multiplexed data transmission. The crew's control switches could be directly coupled to the RPCs in many circuits to reduce the number of connections, although installation breaks would still have to be provided at the various zones. A growing application of solid state techniques to control aircraft systems would tend to increase the use of equipment boxes with multi-pin connectors, and reliability would depend increasingly on the latter's satisfactory performance.

The study has indicated that although cable mass would be considerably reduced, the lengths of small diameter cables used in the various remotely controlled systems would be greatly increased. At the same time, because of the minute currents involved - about 10 mA to actuate an RPC, cables would be reduced from the smallest size now used in the VC 10 (22 gauge) to 26 gauge. Inevitably, this would set the designer installation problems to maintain the present standard of freedom from cable mechanical failure and to provide satisfactory end connections.

7 CONCLUSIONS

The comparative assessment for a VC 10 aircraft indicates that an electrical power distribution system employing remote power controllers, embodying solid state protection in conjunction with solid state logic, should be some 91kg lighter than a conventional system modified to incorporate the latest equipment and cables. Reduced cable mass accounts for 73 kg of this saving. The total mass of the modernised system was not evaluated, only those parts directly compared in Table 7, but BAC figures for the existing installation are given as 677 kg of cable in a total of 2256 kg, which indicates that the above savings would be *in excess of* 11% for cable and 4% for the total in a modernised system.

There are potential savings beyond the 91 kg quoted above, since some equipments have internal relays or sensors which could be reduced in size or even eliminated because of the very much smaller control currents used. No attempt has been made to estimate a figure for this, but some future equipment could be made lighter if designed specifically to operate in conjunction with solid state devices.

The foregoing results depend on two assumptions being substantiated. One is that 26 gauge cable, with a copper alloy core, as yet untried for general aircraft wiring, would prove sufficiently robust to cause no problems at terminations. An enforced increase in size to 24 gauge would be electrically wasteful and would reduce the saving by about 20 kg. The second is that the specified mass and reliability of solid state remote power controllers can be met in fully developed models to production standards, that they can be mounted on efficient heat sinks with little weight penalty, and that the electro-magnetic form of RPC can be produced with a mass similar to that of a relay and fuse of equivalent rating.

The comparison between the two systems has been based on the existing power transmission layout in VC 10, but a remotely controlled system might offer a further advantage if the main electrical equipment bay were resited. A position in the rear fuselage would allow the most favourable distribution of power, involving the least amount of cable, but would be unacceptable in this aircraft because to move heavy equipment to the rear would adversely affect its cg. An alternative mid-position has therefore been assessed and the results show a saving of 19 kg for a conventional system and 36 kg for remote control, due to this modification alone. A centrally positioned electrical bay would benefit equally an aircraft with either rear or wing mounted engines, provided of course, there were no physical or mechanical penalties resulting from repositioning.

Further large reductions in the specific masses of small cables are unlikely, unless a range with aluminium alloy conductors is developed. Whether a 26 gauge cable in this material would be sufficiently strong for use in general wiring is not known, but to substitute a larger size of light alloy conductor would give little advantage over 26 gauge, copper alloy. Feeders and power distribution cables would benefit by employing aluminium alloy conductors which at present are confined to sizes of 8 gauge and larger; but beyond this, additional saving is only likely to come from introducing multiplexed data transmission.

Since insufficient information is available to make a reliable estimate of the mass of a multiplexed system, this has not been attempted, but the allowance within which a system would have to be designed has been assessed. This allowance is established as the mass of the 26 gauge signal cables and installation fittings which would be replaced by multiplexing and would amount to 42 kg approximately for a system transmitting on-off signals only, with an additional allowance of 35 kg for including analogue data in the same channels. It is quite probable that a useful proportion of these masses could be saved.

Development work has not yet started in this country on either solid state remote power controllers or multiplexed data transmission for use with aircraft electrical systems, although laboratory work at the RAE using experimental controllers has reached a sufficiently advanced stage for equipment specifications to be written. Integrity and reliability studies would be the essential first step in any programme aimed at equipping aircraft with these controllers, particularly if multiplexed signalling were contemplated.

Appendix A

THE EFFECT ON INSTALLED MASS OF RESITING THE ELECTRICAL BAY (SCHEME 2)

As mentioned in sub-section 3.3, resiting the electrical bay might reduce the mass of either type of installation. The most direct power distribution would come from mounting the electrical equipment and main bus-bars in the rear fuselage, close to the generators, with feeders running forward to the centres of load concentration. However, repositioning some 340 kg of equipment in the rear fuselage would be unacceptable, because of the undesirable effect on aircraft cg, and the loss of accessibility. For these reasons this change has not been considered. An alternative, which might be more acceptable, would be to resite the electrical bay in mid-aircraft by interchanging the positions of bays 7 and 8 (see Fig.1). This could be of equal benefit to either a rear or a wing mounted engine installation and forms the basis of scheme 2.

By applying scheme 2 to either conventional or remotely controlled installations, the main feeders, sub-feeders and cables running aft or to the wings would be shortened by 8.25 metres, while forward running cables and sub-feeders would be lengthened by 8.25 metres. The longer sub-feeders would also have to be increased in size to counteract voltage drop, while a few of the shortened feeders could be made smaller. Fig.3 shows the remotely controlled system (scheme 2), in which bus-bars and logic boxes of zones F7 and F8 could be combined to eliminate the feeders and cables linking them. However, in order to save much re-estimation of cable lengths, it has been decided for scheme 2 to retain the sub-bus-bars of zone F8 (scheme 1) and link them to the main bars, within the repositioned bay, by short feeders, 4 metres long.

Table 13 indicates how the lengths and masses of cables have been changed in both types of installation by resiting the electrical bay F7. It shows that scheme 2 is lighter than scheme 1 in both cases, but that remote control has an advantage of 17.04 kg. The useful saving of 36.02 kg of cable with the latter system would depend on the possibility of re-siting the bay, without incurring direct or indirect mass penalties.

This saving is additional to the saving achieved by system redesign for remote control.

Appendix B

MASS ALLOWANCES FOR THE INTRODUCTION OF MULTIPLEXED DATA TRANSMISSION

As stated in the introduction, the remotely controlled system has been purposely arranged, possibly with some small penalty, to enable multiplexed signal transmission to be introduced without further alteration to the basic system concept. Referring to Fig.2, the necessary components could be included in enlarged control boxes, which would be joined by transmission lines, composed of screened twisted pairs, in place of the existing control wiring. In the present lack of development, it is not possible to estimate the mass of the enlarged boxes, but tabulated below are the masses of those items which would be replaced or reduced by multiplexing the control signals. The total mass sets the limit within which a system incorporating built-in redundancy to maintain an acceptable standard of overall integrity, would have to be designed.

Control wiring, 26 gauge, length 14180 metres	=	29.62 kg
Negative wiring, 24 gauge, length 403 metres	=	1.17 kg
Connectors 24 off (various, as shown in Fig.2)	=	2.32 kg
Ducting reduction due to eliminating 26 gauge wires. See estimate below (case 1)	=	8.74 kg
Total		41.85 kg

To include analogue data in a multiplexed transmission system would mean introducing the extra complexity of analogue to digital conversion and subsequent reversion, as well as enlarging the address and data registers. In order to establish the mass saving against which the extra complexity must be balanced, the existing analogue data transmission wiring has been estimated as follows.

24 gauge cable, length 8816.3 metres	=	25.57 kg
22 gauge cable, length 672.8 metres	=	2.85 kg
Ducting reduction due to eliminating above cables. See estimate below (case 2)	=	6.49 kg
Total		34.91 kg

The estimates of reduced ducting used in the above evaluations are calculated below from information given in Table 12.

Case 1. The elimination of 26 gauge cable

(delete area of 26 gauge from Table 12)

Zones	Total area (A) mm^2	Side $\sqrt{A}$ mm	Proportion of total length (ℓ)	$\ell\sqrt{A}$ per zone	Total $\ell\sqrt{A}$
F1 to F7	320.4	17.9	0.208	3.72	32.15
F7 to F8	1474.5	38.4	0.375	14.4	
F8 to F4	1132.0	33.8	0.417	14.03	

$$\text{ratio of } \frac{\text{multiplex(1)}}{\text{remote}} = \frac{32.15}{36.68} = 0.876.$$

Ducting mass = 70.5 × 0.876 = 61.76 kg

Case 2. The elimination of analogue data transmission wiring

(delete areas of 22, 24 and 26 gauges from Table 12)

Zones	Total area (A) mm^2	Side $\sqrt{A}$ mm	Proportion of total length (ℓ)	$\ell\sqrt{A}$ per zone	Total $\ell\sqrt{A}$
F1 to F7	122.1	11.05	0.208	2.3	28.74
F7 to F8	1265.4	35.6	0.375	13.35	
F8 to F4	984.1	31.4	0.417	13.09	

$$\text{ratio of } \frac{\text{multiplex(2)}}{\text{remote}} = \frac{28.74}{36.68} = 0.784.$$

Ducting mass = 70.5 × 0.784 = 55.27 kg

List of abbreviations for Tables 1 to 6

F1C, F7J, etc.	-	zone F1 panel C, zone F7 panel J (see Fig.1)
sw	-	switch
transtr	-	transistor
pressr	-	pressure
LP	-	low pressure
HP	-	high pressure
RPC	-	remote power controller
o/heat	-	over heat
tempr	-	temperature
norm	-	normal
auto	-	automatic
Indr	-	Indicator
Lt	-	light
W/L	-	warning light
o/ride	-	over ride
emergy	-	emergency
TRU	-	transformer rectifier unit
c/o	-	change over
Hydl	-	hydraulic
Refrig	-	refrigerator
u/c	-	undercarriage
dv	-	direct vision
CSD	-	constant speed drive
GCB	-	generator control breaker
BTB	-	bus tie breaker
SSB	-	split system breaker
GPB	-	ground power breaker
ELRAT	-	electrical ram air turbine
UVV	-	unpressurised vent valve
mod	-	modulating
A, B, C, etc.	-	letters refer to switching operations as described in section 4.2. (These are allocated to switches in the detailed wiring diagrams for a VC 10 aircraft, which are not reproduced in this Report.)

TABLE 1

ZONE F1 DETAILS OF REMOTE CONTROL CIRCUITS UP TO BUS-BARS

Item No.	Equipment and location	No. of wires	F1 Logic boxes: Limiting resistors	F1 Logic boxes: Connections	F1 Logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
1	F1C 1 to 4ac bus-bars 3amp fuses 12 off	12 in		To T.R.U.s for	5 volt rail for logic operation				1
2	F1B Transistor switches for oil low pressure warn/light 4 off	4 out		4 through		4 in	F4	Table 4, No.2	2
3	F1B Low pressure cock switches A shut, D open	4 out 8 return	4(5V)	Signals A, D					3
4	F1D High pressure cock switches B shut, E open	4 out 8 return	4(5V)	Signals B, E	D.E open field; A + (D.B.C) close field: No.1 logic for fuel cocks (four identical)				4
5	F1A Fire switches C shut	4 out 4 return	4(5V)	Signal C		No 1 logic 8 out	F8	Table 3, No.4	5
6	F1B Inter engine valve switches A shut, B open	2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.5	6
7	F1B Transistor switches for fuel cock indicators (open/close) 12 off	12 out		12 through		12 in	F8	Table 3, No 6	7
8	F1C reset button 2 off warning light for RPCs 2 off	2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.7	8
9	F1B Transfer valve switches A shut, B open	4 out 8 return	4(5V)	8 through A, B		8 out	F8	Table 3, No.8	9
10	F1B Jettison and cross feed switches A shut, B open	2 out 4 return	2(5V)	4 through A, B		4 out	F8	Table 3, No.9	10
11	F1B Transistor switches for transfer valve indicators (open/close) 12 off	12 out		12 through		12 in	F8	Table 3, No.10	11
12	F1C reset button 2 off warning light for RPCs 2 off	2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.11	12
13	F1B Fuel pump switches 10 off	10 out 10 return	10(5V)	10 through		10 out	F8	Table 3, No.12	13
14	F1B Transfer valve switches A shut, B open	2 out 4 return	2(5V)	4 through A, B		4 out	F8	Table 3, No 13	14
15	F1B Engine switches speed/temperature control	4 out 4 return	4(5V)	4 through		4 out	F4	Table 4, No.4	15
16	F1B Transistor switches for low pressure indicators 4 off	4 out		4 through		4 in	F4	Table 4, No 5	16
17R	F1B Transistor switch for low pressure indicator 1 off	1 out		1 through		1 in	F8	Table 3, No.15R	17R
18	F1B Tank transfer valve switches	4 out 4 return	4(5V)	4 through		4 out	F8	Table 3, No 16	18
19	F1B Transistor switches for tank valve indicators 4 off	4 out		4 through		4 in	F8	Table 3, No.21	19
20	F1B No.1 to 4 valve switches A switch closed	4 out 4 return	4(5V)	4 through A		4 out	F8	Table 3, No.22	20
21	F1, EA No.1 to 4 power drain switches B switch closed	4 out 4 return	4(5V)	4 through B		4 out	F8	Table 3, No.23	21
22	F1B Centre transfer valve switches	2 out 2 return	2(5V)	2 through		2 out	F8	Table 3, No.26	22

Table 1 (continued)

Item No.	Equipment and location	No. of wires	F1 Logic boxes: Limiting resistors	F1 Logic boxes: Connections	F1 Logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
23	F1B Master valve switches C norm. A, B jettison	4 out, 6 return	4(5V)	6 through A, B, C		6 out	F8	Table 3, No.27	23
24	F1B Transistor switches for master valve indicators (open/shut) 4 off	4 out		4 through		4 in	F8	Table 3 No 28	24
25	F1C reset button 2 off, warning light 2 off	2 out, 4 return	2(5V)	4 through		4 out	F8	Table 3 No 29	25
26	F1B Ignitor relay, master switch (G) and engine start switches	5 out, 8 return	5(5V)	8 through		8 out	F4	Table 4, No.6	26
27	F1B Transistor switches for ignitors 'on' 2 off	2 out		2 through		2 in	F4	Table 4, No.7	27
28	F1B Master switch contacts D, E, H, J	4 out, 4 return	4(5V)	4 through D, E, H, J		4 out	F4	Table 4, No.8	28
29	F1B Master switch contacts F, H; Starter switch contacts A1, A2, A3, A4, A5, A6	2 out, 6 return	2(5V)	6 through F.A1, F.A2, F.A3, F.A4, H.A5, H.A6		6 out	F4	Table 4, No.9	29
30R	F1B Transistor switch for start running indicator 1 off	1 out		1 through		1 in	F4	Table 4, No 15R	30R
31	F1A, F1B Transistor switches for reverse thrust indicators 8 off	8 out		4 junctions		4 in	F4	Table 4, No 16	31
32	F1B Transistor switches for engine overheat and oil low pressure indicators 8 off	8 out		8 through		8 in	F4	Table 4, No 17	32
33	F1, EA Test switch	1 out, 2 return	1(5V)	2 through		2 out	F4	Table 4, No.18	33
34	F1A Transistor switches for fire warning lights 4 off	4 out		4 through		4 in	F7	Table 2, No.4	34
35L	F1A Test switch for fire detectors	1 out, 1 return	1(5V)	1 through		1 out	F7	Table 2 No 5	35L
36	F1B Engine anti icing valve switches	4 out, 4 return	4(5V)	4 through		4 out	F4	Table 4, No.19	36
37	F1C reset button 2 off, warning light 2 off	2 out, 4 return	2(5V)	4 through		4 out	F4	Table 4, No.20	37
38L	F5 Stn 60 left ice detector switch A shut	1 out, 1 return	1(5V)	Signal A	No.2 logic for ice warning (one only) A(M)B				38L
39L	F1B Wing anti-icing valve stop switch B (valve open)	1 in		Signal B					39L
40L	F1A Transistor switch for ice warning light 1 off	1 out		From logic 2					40L
41L	F1A Illuminate/deice switch	1 out, 2 return	1(5V)	Diode between leads					41L
42L	F1C No.1 non essential dc bus 3 amp RPC 1 off, 20 amp RPC 1 off	2 out							42L
43	F1E Pitot head heater switches	4 out, 4 return (43–44)	4(5V)						43
44				4 through		4 out	F7	Table 2, No.6	44
45	F1C Reset button and warning light 4 off each	4 out, 4 return	4(5V)	4 through		4 out	F7	Table 2 No.7	45

Table 1 (continued)

Item No.	Equipment and location	No. of wires	F1 Logic boxes: Limiting resistors	F1 Logic boxes: Connections	F1 Logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
46	F1C Ground power 115V supply (V2 alive)	2 in	3(5V) diodes and 3(115V)	V1, V2, $\overline{V2}$ A from 230	No.3 logic (three identical, two right hand, one left hand) A.V1.$\overline{V2}$				46
47	F1C No.2, 3 and 4 ac bus-bars phase C 3 amp RPC; F1E High/low temperature selector switches — 3 off	6 out; 3 return		From logic 3 signal A					47
48	F5X Windscreen controller overheat switch (B, overheat); F1B Transistor switches for overheat warning light — 3 off	3 out; 3 return; 3 out	3(5V)	Signal B; 3 through B	No.4 logic for windscreen heat control: A.$\overline{B}$ operates RPC in phase B; C.$\overline{B}$ operates RPC in phase C (Three identical)				48
49	F5X Windscreen controller, norm heat SW C Low temperature	3 in	3(115V)	Signal C					49
50	F1C 2, 3 and 4 ac bus-bars phase B 15 amp RPC 3 off; phase C 15 amp RPC 3 off	3 out; 3 out		From logic No.4					50
51	F1 Windscreens 1 to 4 and dv thermostats — 5 off	5 out; 5 return	5(5V), 5(115V)	V1 and V2 from 46, A from 230, logic No.5 out	No.5 logic V1.$\overline{V2}$.A (five identical)				51
52	F1C 1 and 4 ac bus-bars phases B and C 5 amp RPC 4 off; 2 and 4 ac bus-bars phase A 5 amp RPC 2 off; 1 ac bus-bar phase A 10 amp RPC 1 off	5 out		5 through					52
53L	F1E Demist fan switch	1 out; 1 return	1(5V)	1 through					53L
54L	F1C No.1 ac bus-bar, three phase 5 amp RPC — 1 off	1 out							54L
55	F1B High pressure stop valve switches C shut	4 out; 4 return	4(5V)	4 through C*		4 out	F4	Table 4, No.22	55
56	F1A Fire switches (A + B) shut	2 out; 2 return	2(5V)	2 through (A + B)		2 out	F4	Table 4, No.23	56
57	F1, EA High pressure stop valve reset switch (R, reset)	2 out; 2 return	2(5V)	2 through R		2 out	F4	Table 4, No.25	57
58	F1B Transistor switches for high pressure stop valve position indicator — 4 off	4 out		4 through		4 in	F4	Table 4, No.26	58
59	F1B Start master switch and pressure reducing valve switches	2 out; 4 return	2(5V)	4 through		4 out	F4	Table 4, No.27	59
60	F1B Start master switch and wing anti icing stop valve switches	2 out; 4 return	2(5V)	4 through		4 out	F8	Table 3, No.31	60
61	F1B Start master switch and tail anti icing stop valve switches	2 return		2 through		2 out	F4	Table 4, No.28	61
62	F1B Transistor switches for pressure reducing valve indicators — 2 off	2 out		2 through		2 in	F4	Table 4, No.29	62
63L	F1B Transistor switches for tail anti icing stop valve indicator — 1 off	1 out		1 through		1 in	F4	Table 4, No.30L	63L
64	F1B Transistor switches for wing anti icing stop valve indicator — 4 off	4 out		4 through		4 in	F8	Table 3, No.32	64
65	F1B Transistor switches for hot air duct overheat warning light — 2 off	2 out		2 through		2 in	F4	Table 4, No.31	65
66L	F1B Transistor switches for main duct interskin pressure warning light — 1 off	1 out		1 through		1 in	F8	Table 3, No.34L	66L

Table 1 (continued)

Item No.	Equipment and location	No. of wires	F1 Logic boxes: Limiting resistors	F1 Logic boxes: Connections	F1 Logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
67	F1B Transistor switches for wing ducts pressure warning lights 2 off	2 out		2 through		2 in	F8	Table 3, No.35	67
68	F1B Thrust augmenter switches, (A1, A2 open) (C1, C2 shut)	2 out 4 return	2(5V)	4 through A1, A2 / C1, C2		4 out	F7	Table 2, No.8	68
69R	F1C Reset button and warning light 1 off each	1 out 2 return	1(5V)	2 through		2 out	F7	Table 2, No.11R	69R
70L	F1C Reset button and warning light 1 off each	1 out 2 return	1(5V)	2 through		2 out	F4	Table 4, No.34L	70L
71L	F1B Transistor switches for thrust augmenter rear indicators 2 off	2 out		2 through		2 out	F4	Table 4, No.35L	71L
72R	F1B Transistor switches for thrust augmenter forward indicators 2 off	2 out		2 through		2 out	F7	Table 2, No.12R	72R
73L	F1B Louvre boost fan switch	1 out 1 return	1(5V)	1 through		1 out	F8	Table 3, No.36L	73L
74L	F1B Humidification switch (select one, both)	1 out 2 return	1(5V)	2 through		2 out	F8	Table 3, No.37L	74L
75L	F1B Forward and rear discharge valve switches	2 out 2 return	2(5V)						75L
76L	F1C No.1 essential dc bus-bar 3 amp RPC 1 off	1 out		2 through		1 out	F4	Table 4, No.36R	76L
77	F1B 1 to 4 mass flow control switches	4 out 16 return	4(5V)	16 through		16 out	F4	Table 4, No.37	77
78	F1B Transistor switches for blower fail warning lights 4 off	4 out		4 through		4 in	F4	Table 4, No.38	78
79	F1B Transistor switches for 'auto off' warning lights 4 off	4 out		4 through		4 in	F4	Table 4, No.39	79
80L	F1B Unpressurised vent valve switch (H open, A shut)	1 out 2 return	1(5V)	1 through A, H		2 out	F8	Table 3, No.38L	80L
81L	F1B Transistor switches for uvv indicator (open, shut) 2 off	2 out		2 through		2 in	F8	Table 3, No.40L	81L
82L	F5 Stn 137 left radio rack cooling valve (open E, L, shut F, N)	2 in	2(28V)	2 through L, N L and junction with N		1 out	F8	Table 3, No.41L	82L
83L	F1B Transistor switches for RRCV indicator (open, shut) 2 off	2 out							83L
84L	F1C No.1 non essential dc bus-bar. 5 amp RPC 2 off	2 out		2 through		2 in	F8	Table 3, No.43L	84L
85L	F1C No.1 reset button and warning light 2 off each	2 out 2 return	2(5V)	2 through		2 out	F8	Table 3, No.44L	85L
86R	F1B Transistor switches for non return valve warning lights 2 off	2 out		2 through		2 in	F4	Table 4, No.40R	86R
87	F1B Spill valve control switch, A norm, B shut, C spill	2 out 6 return	2(5V)	6 through A, B, C		6 out	F4	Table 4, No.41	87
88	F1C Reset button and warning light 2 off each	2 out 4 return	2(5V)	4 through		4 out	F4	Table 4, No.45	88
89L	F1B Flow balance switch (increase, off, decrease)	1 out 2 return	1(5V)	2 through		2 out	F8	Table 3, No.45L	89L
90	F1B Normal/overheat switch (overheat reset, A)	2 out 2 return	2(5V)	2 through A		2 out	F8	Table 3, No.46	90

Table 1 (continued)

Item No.	Equipment and location	No. of wires	F1 Logic boxes			No. of wires	Circuit continuation		Item No.
			Limiting resistors	Connections	Boolean logic expressions		Logic box	Identification	
91	F1B Transistor switches for overheat warning light (55°C) 2 off	2 out		2 through		2 in	F8	Table 3, No.50	91
92	F1B Transistor switches for overheat warning light (120°C) 2 off	2 out		2 through		2 in	F8	Table 3, No.51	92
93	F1B Temperature control switch (off, A auto, B decrease, C increase)	2 out 6 return	2(5V)	6 through A, B, C		6 out	F7	Table 2, No.13	93
94	F1B Selector switch (norm modulation isolation H, choke overide N)	2 out 4 return	2(5V)	4 through H, N		4 out 4 out	F4 F8	Table 4, No.51 Table 3, No.53	94
95	F1C Reset button and warning light 4 off each	4 out 8 return	4(5V)	8 through		4 out 4 out	F8 F4	Table 3, No.57 Table 4, No.49	95
96	F1B Refrigerator master switch (A norm, off, G isolate)	2 out 4 return	2(5V)	4 junctions G, out A, G		2 out 4 out	F4 F8	Table 4, No.52 Table 3, Nos.54 and 60	96
97	F1B Recirculating fan SW (E norm, off, F, on)	2 out 4 return	2(5V)	4 through E, F		4 out	F7	Table 2, No.16	97
98	F1B Transistor switches for refrigeration failure warning light 2 off	2 out		2 through		2 in	F8	Table 3, No.62	98
99	F1B Reset button and warning light 2 off each	2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.67	99
100	F1B Flying control switches (A norm, off, B isolate) 11 off	11 out 22 return	11(5V)	22 through A, B		4 out	F7	Table 2, No.18	100
101	F1B Transistor switches for hydraulic pressure warning lights 11 off	11 out		11 through		4 in 7 in	F8 F4	Table 3, No.68 Table 4, No.58	101
102	F1D Tail trim switches (A down, B up, X,Y autopilot)	2 out 6 return	2(5V)	6 through A, B, X,Y.		6 out	F4	Table 4, No.59	102
103	F1B Re-arming push (normally closed J)	2 out 2 return	2(5V)	2 through J		2 out	F4	Table 4, No.60	103
104	F1B Transistor switches for overrun warning lights 2 off	2 out		2 through		2 in	F4	Table 4, No.63	104
105	F1B Artificial feel pump switches (norm, isolate)	2 out 2 return	2(5V)						105
106	F1C No.4 ac bus-bar 3 phase 7 amp RPC 1 off Auxiliary bus 3 phase 7 amp RPC 1 off	2 out		2 through					106
107	F6 Nose wheel bay hydraulic pressure switches and over-heat thermostat	4 out 4 return	4(5V)	4 through to 108					107
108	F1A Transistor switches for pump and motor overheat warning lights 2 off F1B Transistor switches for feel failure warning lights 2 off	2 out 2 out		through. See 107					108
109L	F1C No.1 non essential dc bus-bar 3 amp RPC 1 off	1 out		1 through		1 in	F8	Table 3, No.69L	109L
110L	F1C Reset button and warning light 1 off each for 109 L	1 out		1 through					110L
111L	F1A u/c selector switch (down A, up B)	1 out 2 return	1(5V)	2 junctions and 2 through A, B					111L
112L	F1C No.1 essential dc bus-bar 3 amp RPC 2 off	2 out				2 out	F8	Table 3, No.70L	112L

Table 1 (continued)

Item No.	Equipment and location		No. of wires	F1 Logic boxes			No. of wires	Circuit continuation		Item No.
				Limiting resistors	Connections	Boolean logic expressions		Logic box	Identification	
113L	F1A u/c selector SW and emergency switch (up C,D, norm E)		1 out 2 return	1(5V)	2 junctions C,D, E and 2 through		2 out	F8	Table 3, No.71L	113L
114L	F1C No.1 and 2 essential dc bus-bar 3 amp RPC	2 off	2 out							114L
115	F1C Reset button and warning light	2 off each for 112L & 114L	2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.72	115
116R	F1A u/c selector switch (down, up)		1 out 2 return	1(5V)	2 junctions and 2 through, 1 diode in 'up', 1 diode in 'down'		4 out	F8	Table 3, No.73	116R
117R	F6 Nose wheel up lock and down lock-switches		2 out 2 return							117R
118R	F1A Transistor switch for u/c indicator 'nose unlock'	1 off	1 out							118R
119R	F6 Nose wheel down lock switch		1 out 1 return	1(5V)	1 through					119R
120R	F1A Transistor switch for u/c indicator 'nose lock'	1 off	1 out							120R
121R	F6 Nose wheel door lock switch		1 out 1 return	1(5V)	1 through					121R
122R	F1A Transistor switch for nose door warning light	1 off	1 out							122R
123	F1A Transistor switch for u/c indicator 'main wheels unlock'	2 off	2 out		2 through		2 in	F8	Table 3, No.74	123
124	F1A Transistor switch for u/c indicator 'main wheels lock'	2 off	2 out		2 through		2 in	F8	Table 3, No.75	124
125	F1A Transistor switch for main wheels door lock indicator	2 off	2 out		2 through		2 in	F8	Table 3, No.76	125
126R	F1, EA Test switch (norm open, test shut D)		1 out 1 return	1(5V)	Signal D	No.6 logic for warning horn (one only)				126R
127R	F6 Nose wheel down lock switch (shut C)		1 out 1 return	1(5V)	Signal C					127R
128R	F1B Throttle micro-switches (closed E,F + G,H)		1 out 1 return	1(5V)	Signal (E,F + G,H)	(A + B + C + D). $\bar{J}$. (E,F + G,H)				128R
129R					Signal J, $\bar{J}$		1 in	F7	Table 2, No.25R	129R
130R	F1C No.2 essential dc bus-bar 5 amp RPC	1 off	No.6 logic 1 out		Signal (A + B)		1 in	F8	Table 3, No.77R	130R
131R	F1C Reset button and warning light	2 off each for 130R	1 out	1(5V)						131R
132	F1D Flap selector switches (up, 20°, 30°, down)		2 out 8 return	2(5V)	8 through		8 out	F8	Table 3, No.78	132
133	F1C Reset button and warning light	2 off each	2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.80	133
134	F1B Overide switches (norm E, overide $\bar{E}$) Isolate switches (norm B, isolate A)		2 out 5 return	2(5V)	2 junctions (A) with 137 / 3 through A, B, C		5 out	F8	Table 3, No.81	134
135	F1B Transistor switches for flap isolate warning light	2 off	2 out							135

Table 1 (continued)

Item No.	Equipment and location	No. of wires	F1 Logic boxes: Limiting resistors	Connections	Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Identification	Item No.
136	F1B Transistor switches for selector valve indicators (up, down) 4 off	4 out		4 through		4 in	F8	Table 3, No.83	136
137	F1B Transistor switches for flap isolate indicators 2 off	2 out		2 junctions with 134/135 2 through		2 in	F8	Table 3, No.86	137
138	F1C Reset button and warning light 2 off each	{ 2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.87	138
139	F1D Slat control micro switches (in A, out B)	{ 2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.89	139
140	F1C Reset buttons and warning lights 2 off each	{ 2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.91	140
141	F1B { Transistor switches for slat indicators and isolate indicators 6 off	6 out		6 through		6 in	F8	Table 3, No.97	141
142	F1B { Transistor switches for hydraulic fluid overheat warning light 2 off	2 out		2 through		2 in	F4	Table 4, No.64	142
143R	F1B Ferry link switch (norm A, linked B)	{ 1 out 2 return	1(5V)	2 through A, B		2 out	F4	Table 4, No.65R	143R
144L	F1B Emergency steering switch (norm A, emergency B)	{ 1 out 2 return }	1(5V)	2 through A, B					144L
145L	F1C No.1 essential dc bus-bar 5 amp RPC 2 off	2 out }							145L
146R	F1C Reset button and warning light 2 off each	{ 2 out 2 return	2(5V)	2 through		2 out	F4	Table 4, No.66R	146R
147	F1B Hydraulic off load switches No.1 to 4	{ 2 out 4 return	2(5V)	4 through		4 out	F4	Table 4, No.67	147
148	F1C Reset button and warning light 2 off each	{ 2 out 4 return	2(5V)	4 through		4 out	F4	Table 4, No.68	148
149	F1B Transistor switches for ferry link actuator indicators/2 off	2 out		2 through		2 in	F4	Table 4, No.69	149
150	F6 { Stn 197 emergency steering actuator limit switches (open, shut)	2 in }	2(28V)	2 through					150
151	F1B Transistor switches for emergency steering indicator 2 off	2 out }							151
152R	F1E Ground hydraulic pump switch	{ 1 out 1 return	1(115V) (V2 from 46)	1 through		1 out	F7	Table 2, No.28R	152R
153	F1B Spoiler isolate switches, one pole earthed (norm, isolate)	{ 3 out 6 return	3(5V)	6 through		6 out	F8	Table 3, No.98	153
154	F1C Reset buttons and warning light 2 off each	{ 2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.99	154
155	F1B Hydraulic isolation valve switches (shut A, open B)	{ 4 out 8 return	4(5V)	Signals A, B	{ No.7 logic for hydraulic isolation valves B.D = open, A + B.C = shut } four identical				155
156	F1A Fire control switches (C emergency, D norm)	{ 4 out 8 return	4(5V)	Signals C, D		No.7 logic 8 out	F4	Table 4, No.70	156

Table 1 (continued)

Item No.	Equipment and location	No. of wires	F1 Logic boxes: Limiting resistors	F1 Logic boxes: Connections	F1 Logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
157	F1B { Transistor switches for hydraulic isolation valve indicators 8 off	8 out		8 through		8 in	F4	Table 4, No.71	157
158	F1C Reset button and warning light 2 off each	2 out 4 return	2(5V)	4 through		4 out	F4	Table 4, No.72	158
159	F1C Auxiliary ac bus-bar phase B (alive V4)	2 in	Diodes and 2(115V)	Signal V4	No.8 logic for standby gyro horizon A.V4.$\overline{V2}$ (one only)				159
160L			1(115V)	Signal A from 230 Signal V2 from 46					160L
161L	F1C Auxiliary ac bus-bar phase B 3 amp RPC 1 off	No.8 logic 1 out							161L
162L	F1C Auxiliary ac bus-bar phase A 3 amp RPC 1 off	No.9 logic 1 out	2(115V)	Signal V4, signal V2 Signal A from 230	No.9 logic for turn and slip indicator A.V4.$\overline{V2}$ (one only)				162L
163R	F6 Nose wheel steering pressure switch	1 out 1 return	1 (5V)						163R
164R	F1B Transistor switch for steering pressure indicator 1 off	1 out		1 through					164R
165	F1E Landing/taxi lamp switch (wings)	2 out 8 return	2(5V)	8 through		8 out	F8	Table 3, No.100	165
166R	F1E Landing/taxi lamp switch (nose)	1 out 4 return	1(5V)						166R
167R	F1C No.2 non essential dc bus-bar 15 amp RPC 2 off 5 amp RPC 2 off	2 out 2 out		4 through					167R
168R	F1E Turn off lamp switches	1 out 2 return							168R
169	F1C No.2 non essential dc bus-bar 10 amp RPC 2 off	2 out		2 through					169
170	F1C Reset button and warning light 3 off each for 167R and 169	2 out 4 return	2(5V)	4 through		4 out	F8	Table 3, No.101	170
171	F1E Navigation lights and rotating beacon switches	2 out 2 return	2(5V)	2 through		2 out	F8	Table 3, No.102	171
172R	F1C Servicing lights switches (on, B)	1 out 1 return	1(5V) 1(115V)	V2 from 46 B	No.10 logic for nose wheel bay servicing lights B + V2 (one only)				172R
173R	F1C 28 Volt ac bus-bar No.1 3 amp RPC 1 off	No.10 logic 1 out							173R
174R	F1C 28 Volt ac bus-bar No.1 3 amp RPC 1 off	1 out	1(115V)	V2 from 46	Nose bay servicing lights (one only)				174R
175R	F1B { ground crew call button (closed C) reset button (closed R)	1 out 2 return	1(5V)	Signals C, R	No.11 logic for warning horn (one only) C + B				175R
176R	F6 Nose wheel bay { call button aircrew (closed A) nose wheel micro switch (closed B)	1 out 2 return	1(5V)	Signals A, B	No.12 logic for ground crew call (one only) A(M)R				176R
177R	F1C No.2 essential dc bus-bar 5 amp RPC 1 off	1 out		From No.11 logic					177R
178R	F1B Transistor switch for ground crew call light 1 off	1 out		From No.12 logic					178R

Table 1 (continued)

Item No.	Equipment and location	No. of wires	F1 Logic boxes: Limiting resistors	F1 Logic boxes: Connections	F1 Logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
179R	F1C Reset button and warning light 1 off each for 177R	1 out	1(5V)						179R
180R	F1E Steward call button (closed A, B)	1 out 2 return	1(5V)	2 through A, B		2 out	F7	Table 2, No.42R	180R
181R	F1C No.2 essential dc bus-bar 3 amp RPC 1 off	1 out		1 through D		1 in	F7	Table 2, No.43R	181R
182R	F1C Reset button and warning light 3 off each	3 out 4 return	3(5V)	4 through		2 out 2 out	F7 F4	Table 2, No.51R Table 4, No.91R	182R
183R	F1E Warning sign switches	2 out 2 return	2(5V)	2 through		2 out	F7	Table 2, No.52R	183R
184R	F1C Reset button and warning light 1 off each	1 out 2 return	1(5V)	2 through		2 out	F7	Table 2, No.53R	184R
185	F1B Galley control switches	4 out 4 return	4(5V)	4 through		4 out	F7	Table 2, No.54	185
186	F1C Water heating switches	5 out 5 return	5(5V)	5 through		2 out 3 out	F7 F4	Table 2, No.55 Table 4, No.92	186
187	F1C Water pump control switches	2 out 2 return	2(5V)	2 through		2 out	F8	Table 3, No.115	187
188R	F1B Throttle switch (shut, C)	1 out 1 return	1(5V)	Signal C	No.13 logic for warning horn (one only)				188R
189R	F1D Spoilers micro switch (shut, G)	1 out 1 return	1(5V)	Signal G					189R
190R				Signal (E + F + H)	C.D. (A1 + B1 + E + F + H + G)	1 in	F8	Table 3, No.117R	190R
191R				Signal D		1 in	F8	Table 3, No.119R	191R
192R	F1B Flying control central warning (warning A1 + B1)	1 in		Signal (A1 + B1)					192R
193R	F1C No.2 essential dc bus-bar 5 amp RPC 1 off	1 out		From logic No.13					193R
194R	F1C Reset button and warning light/1 off each for 193R & 196R	1 out	1(5V)						194R
195R	F1B Flying control warning (warning A2 + B2)	1 in		1 through (A2+ B2)					195R
196R	F1C No.2 essential dc bus-bar 3 amp RPC 1 off	1 out							196R
197R	F1A Warning system cancel button (cancel-X)	1 out 1 return	1(5V)	1 through X					197R
198R	F1B Flying control central warning	1 out							198R
199	F1B Transistor switches for door shut warning lights/3 off	3 out		3 through		3 in	F4	Table 4, No.94	199
200	F1B Transistor switches for door shut warning lights/3 off	3 out		3 through		3 in	F8	Table 3, No.120	200
201	F1B Transistor switches for door shut warning lights/3 off	3 out		3 through		3 in	F7	Table 2, No.56	201
202L	F5 Nose access door switch	1 out 1 return	1(5V)	1 through					202L
203L	F1B Transistor switch for door shut warning lights 1 off	1 out							203L

Table 1 (continued)

Item No.	Equipment and location	No. of wires	F1 Logic boxes: Limiting resistors	F1 Logic boxes: Connections	F1 Logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
204L	F1A Cancel button for master warning light (cancel X)	1 out 1 return	1(5V)	1 through X					204L
205L	F1B Master warning system	1 out							205L
206L	F1B Master warning system (warning signal)	1 in		1 through					206L
207L	F1A Master warning buttons	1 out 1 return							207L
208L	F1C No.2 essential dc bus-bar 3 amp RPC 1 off	1 out		1 through					208L
209L	F1R No.1 radio supplies switches (for ac and dc)	2 out 4 return	2(5V)	4 through		4 out	F7	Table 2, No.57L	209L
210R	F1R No.2 radio supplies switches (for ac and dc)	2 out 4 return	2(5V)	4 through		4 out	F7	Table 2, No.58R	210R
211	F1B No.1 and 2 radio rack fan switches (No.1.A, B, No.2,C, D)	2 out 4 return	2(5V)	4 through A, B, C, D		4 out	F7	Table 2, No.59	211
212	F1B Transistor switches for fan failure warning light (via switch)	2 out		2 through		2 in	F7	Table 2, No.62	212
213	F1B Disconnect switch for csd (one pole earthed)	4 out 8 return	4(5V)	8 through		8 out	F4	Table 4, No.95	213
214	F1B { generator trip switches overheat trip switches generator close switches }	8 out 16 return	8(28V) generator control bus	16 through		16 out	F7	Table 2, No.63	214
215	F1B { split system breaker trip switches ground power breaker trip switches DC 1 and 2 systems switches (close) }	2 out 3 return	2(28V) ancillary control bus	3 through		3 out	F7	Table 2. No.65	215
216R	F1B Split system breaker close switch	1 out 1 return		1 through		1 in	F7	Table 2, No.66R	216R
217R						1 out	F7	Table 2, No.67R	217R
218R	F1B Transistor switches for GCB, BTB, SSB, GPB indicators/10 off	10 out		10 through		10 in	F7	Table 2, No.68	218
219	F1B Transistor switches for { TRU input isolate non essential dc isolate } indicators 4 off	4 out		4 through		4 in	F7	Table 2, No.69	219
220	F1B Transistor switches for battery bus isolate indicators 2 off	2 out		2 through		2 in	F7	Table 2, No.70	220
221	F1B { Transistor switches for 1 and 2 dc system failure warning light } 2 off	2 out		2 through		2 in	F7	Table 2, No.71	221
222	F1B dc system isolate switches	2 out 2 return	2(5V)			2 out	F7	Table 2, No.72	222
223	F1B { Power on/battery isolation switch Power on/battery isolation switch (on C) }	2 out 2 return 2 return	2(28V) battery bus-bar	Signal C	No.14 logic for non essential contactor A.C (two identical) No.15 logic for battery contactor B (two identical)	2 out	F7	Table 2, No 73	223
224	F1D ELRAT micro switch (norm A, operated B)	2 out 4 return	2(28V) battery bus-bar	Signals A, B		No.14 & 15 logic 4 out	F7	Table 2, No.74	224

Table 1 (concluded)

Item No.	Equipment and location	No. of wires	F1 Logic boxes: Limiting resistors	F1 Logic boxes: Connections	F1 Logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
225	F1B { Transistor switches for 1 and 2 standby relay indicators — 2 off	2 out		2 through		2 in	F7	Table 2, No.78	225
226R	F1B { Standby changeover switch and transistor switch for ac input indicators — 1 off	1 out		1 through		1 in	F7	Table 2, No.79R	226R
227	F1B Standby changeover switch for contactor control	2 return		2 through		2 out	F7	Table 2, No.80	227
228R	F1B Standby changeover switch for ac input contactor	{ 1 out 1 return	1(115V) from V4 No.159	1 through		1 out	F7	Table 2, No.81R	228R
229R	F1B Transistor switch for auxiliary bus-bar indicator — 1 off	1 out		1 through		1 in	F7	Table 2, No.82R	229R
230	F1C Ground/flight switch (ground $\bar{A}$, flight A both to earth)	2 in		2 junctions A, $\bar{A}$	(for use in F1 and F7 logic boxes)	2 out	F7	Table 2, No.83	230
231R	F1, EA ELRAT test switch	{ 1 out 1 return	1(5V)	1 through		1 out	F7	Table 2, No.85R	231R
232	F1B { Transistor switches for generator overheat warning/lights — 4 off	4 out		4 through		4 in	F4	Table 4, No.96	232
233	F1C { No.1 and 2 essential dc bus-bar 3 amp RPC — 3 off No.1 and 2 non essential dc bus-bar 3 amp RPC — 3 off	6 out	6(5V)		Supplies for transistor switches at panels A and B				233
234	F1C { No.1 and 2 essential dc bus-bar No.1 and 2 non essential dc bus-bars } reset button & warning light for 233 — 4 off	4 out	4(5V)						234

TABLE 2

ZONE F7 DETAILS OF REMOTE CONTROL CIRCUITS UP TO BUS-BARS

Item No.	Equipment and location	No. of wires	F7 Logic boxes			No. of wires	Circuit continuation		Item No.
			Limiting resistors	Connections	Boolean logic expressions		Logic box	Identification	
1	F7 1 to 4 ac bus-bars 3 amp fuses 12 off	12 in		To TRU's for	5V rail for logic operation				1
2	F7 Ground power supply (alive V2)	2 in	4(5V) 4(115V)	Signals V1 Signals V2	No.1 logic for fuel rate of flow A.V1.$\overline{V2}$ } four identical				2
3	F7 1 to 4 ac bus-bars 3 phase 3 amp RPC 4 off	4 out		Signal A from 83 from logic No.1					3
4	F7 PA Fire detector units	4 out 4 return	4(5V)	4 through		4 out	F1	Table 1, No.34	4
5 L	F7 PA Fire detector units (test)	1 out		1 through		1 in	F1	Table 1, No.35L	5
6	F7 { No.1 and 2 non essential dc bus-bar 20 amp RPC 2 off No.1 and 2 essential dc bus-bar 2 off	4 out		4 through		4 in	F1	Table 1, No.44	6
7	F7 { No.1 and 2 non essential dc bus-bar reset and warning No.1 and 2 essential dc bus-bar light for 6	4 out		4 through		4 in	F1	Table 1, No.45	7
8				Signals A1, A2, $\overline{A1}$, $\overline{A2}$, C1, C2	No.2 logic for thrust augmentors (Total) A1 (open field), C1 + Y (M) $\overline{A1}$ close field A2 (open field), C2 + Y (M) $\overline{A2}$ close field	4 in	F1	Table 1, No.68	8
9				Signal Y		2 in	F8	Table 3, No.49	9
10R	F7 No.2 essential dc bus-bar 5 amp RPC 2 off	2 out		From logic 2 (A1)		Logic 2(A2) 2 out	F4	Table 4, No.33L	10R
11R	F7 No.2 essential dc bus-bar reset and warning light for 10R	2 out		2 through		2 in	F1	Table 1, No.69R	11R
12R	F7 Stn 230 thrust augmentor actuator switches (open, close)	2 in	2(28V)	2 through		2 out	F1	Table 1, No.72R	12R
13	F7H Temperature control box (less heat A.D, more heat A.E)	2 out		2 through A 4 junctions B and C		6 in	F1	Table 1, No.93	13
14		4 return		A.D, A.E	Signals (A.D+B) out (A.E+C)	4 out 4 out	F8 F4	Table 3, No.52 Table 4, No.50	14
15R	F7 PA Altitude switch (H closed, $\overline{H}$ open)	1 out 1 return	1(5V) 2 diodes	Signals H, $\overline{H}$	No.3 logic for recirculating fan F + A.D.E.$\overline{H}$ (Two identical)				15
16				Signals E, F		4 in	F1	Table 1, No.97	16
17	F7 No.2 and 3 ac bus-bars 3 phase 30 amp RPC 2 off	No.3 logic 2 out		Signals A.D, A.B		2 in	F8	Table 3, No.61	17
18	F7 No.1 and 4 ac bus-bars 3 phase 20 amp RPC 6 off	12 out		12 through, signals A, B, $\overline{B}$	No.4 logic for flying controls (five identical)	22 in	F1	Table 1, No.100	18
19	F7 No.2 and 3 ac bus-bars 3 phase 20 amp RPC 5 off	No.4 logic 10 out			A.$\overline{C}$ - norm (or reset) } Main RPCs				19
20	F7 Auxiliary switches on RPCs No.19 (trip T)	5 in		Signal T	{B + V3.$\overline{B}$} or {B + V3d.$\overline{B}$} - isolate (or trip)				20
21	F7P Emergency ac bus-bars 3 phase 20 amp RPC 5 off	No.5 logic 5 out			No.5 logic for emergency flying controls (five identical)				21
*22	F7P Emergency ac bus-bar (V3 alive)	2 in	2(115V) 4 diodes	Signal V3 instant	{V3.T.$\overline{B}$ (M) $\overline{V3}$} or {V3d.T.$\overline{B}$.(M) $\overline{V3d}$} - close emergency RPCs				22
**23	F7P Emergency ac bus-bar time delay (V3d, alive delay)	4 in	2(115V) 4 diodes	Signal V3d, delay					23
24	F7P Auxiliary switches on RPC No.21 (closed C)	5 in		Signals C, $\overline{C}$					24

* V3 alive instantaneously for left inner elevator

** V3 delayed for four other flying controls

Table 2 (continued)

Item No.	Equipment and location	No. of wires	F7 logic boxes: Limiting resistors	F7 logic boxes: Connections	F7 logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
25R	F7PA Airspeed switch (closed, lowspeed J)	1 out 1 return	1(5V)	1 through J		1 out	F1	Table 1, No.129R	25R
26	F7G Flap asymmetrical circuit X and Y	2 in		2 through X, Y		2 out	F8	Table 3, No.88	26
27	F7G Slat asymmetrical circuit X	2 in		2 through X		2 out	F8	Table 3, No.95	27
28R	F7 Ground power bus, 3-phase 20 amp RPC 1 off	1 out		1 through		1 in	F1	Table 1, No.152R	28R
29	F7Z Battery bus-bar (alive V5)	2 in	2(28V) battery	Signal V5	No.6 logic for F7 bay lights. Normal (one only) B.(A + V2)				29
30R	F7RR Servicing lights switch (on A), emergency switch (normal B)	1 out 1 return	1(5V)	Signals A,B	No.7 logic for F7 bay lights. Emergy (one only) C.V5				30R
31R	F7RR Emergency switch (standby C)	1 out 1 return	1(5V)	Signal C					31R
32R	F7 {28 volt ac bus bar No.1 3 amps RPC 1 off (No.6 logic) Battery bus-bar 3 amp RPC (No.7 logic) 1 off}	2 out	1(115V)	Signal V2 from 2 from logic 6 and 7					32R
33L	F7 Rear bulkhead. Servicing lights switch (on F)	1 out 1 return	1(5v)	1 through F		1 out	F8	Table 3, No.107L	33L
34L			1(5V) 1(115V)	signal V1 signal V2 from 2					34L
35L	F7 {No.1 ac bus-bar phase C 3 amp RPC(a) 1 off ground bus-bar phase C 3 amp RPC(b)}	2 out		from logic 8(a) and (b)	No.8 logic for entrance and ~~step~~ lights (one only) V1 = RPC(a), V2.$\overline{V1}$ = RPC(b)				35L
36R	F2L Forward cabin roof lights switch (on A)	1 out 1 return	1(5V) 1(115V)	Signals V1, A, Signal V2 from 2	9 logic for cabin roof lights (one only) V1.A = RPC(a), V2.A.$\overline{V1}$ = RPC(b)				36R
37R	F7 {No.1 ac bus-bar phase C 3 amp RPC(a) 1 off ground bus-bar phase C 3 amp RPC(b) 1 off}	2 out		From logic 9(a)&(b)					37R
38R	F2L Aft cabin roof lights switch (on B)	1 out 1 return	1(5V)	1 through B		1 out	F8	Table 3, No.110R	38R
39L	F7 {No.1 ac bus-bar phase C 3 amp RPC(a) 1 off ground power bus phase C 3 amp RPC(b) 1 off}	No.10 logic 2 out	1(5V) 1(115V)	Signal V1 Signal V2 from 2	No.10 logic for toilet lights (one only) V1 = RPC(a), V2.$\overline{V1}$ = RPC(b)				39L
40R	F2L Cabin Cove lights switch (on A)	1 out return	2(5V) 1(115V)	Signal V1, A Signal V2 from 2	No.11 logic for Cove lights (one only)	Signal A 1 out	F8	Table 3, No.112R	40R
41R	F7 {No.4 ac bus-bar phase phase B 5 amp RPC(a) 1 off ground power bus phase B 5 amp RPC(b 1 off}	2 out		From logic 11(a)&(b)	V1.A = RPC(a), V2.A.$\overline{V1}$ = RPC(b)				41R
42R				Signals A,B	No.12 logic for steward's buzzer (one only) A + C	2 in	F1	Table 1, No.180R	42R
43R	F2L Stn.276 {Galley call button (closed G) Pilot call button (closed D)}	1 out 1 return	1(5V)	2 through D,G	No.13 logic for pilot call (one only) B(M)R1	Signal G 1 out Signal D 1 out	F4 F1	Table 4, No.88R Table 1, No.181R	43R
44R	F2 Right, left passenger call button (closed right E) (closed left F)	2 out 2 return	2(5V)	Signals E,F	No.14 logic for right toilet call (one only) E(M)R2				44R
45R	F2L Stn.276 reset buttons (reset R1, R2, R3)	1 out 3 return	1(5V)	Signals R1, R2, R3	No.15 logic for left toilet call (one only) F(M)R3				45R
46R	F2L Stn.276 Transistor switches for for'd toilet call lights 2 off	No.14 and 15 logic 2 out		Signal C		1 in	F4	Table 4, No.84R	46R
47R	F2L Stn.276 Transistor switch for pilot call light 1 off	No.13 logic 1 out			No.16 logic for forward toilet call (one only) E(M)R2 + F(M)R3	No.16 logic 1 out	F4	Table 4, No.87R	47R

Table 2 (continued)

Item No.	Equipment and location			No. of wires	F7 logic boxes: Limiting resistors	F7 logic boxes: Connections	F7 logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
48R	F2L	Stn.276 Transistor switches for rear toilets call lights	1 off	1 out		Signal H(M)R4 + J(M)R5 + K(M)R6		1 in	F4	Table 4, No.89R	48R
49R	F2L	Stn.276 Transistor switches for steward's buzzer	1 off	1 out		From logic 12					49R
50R	F7	No.2 essential dc bus-bar 3 amp RPC	1 off	1 out	1(5V)	(Supply for transistor switches in F2L)					50R
51R	F7	No.2 essential dc bus-bar reset and W/L for 50R		2 out		2 through		2 in	F1	Table 1, No.182R	51R
52R	F7	No.2 non-essential dc bus-bar 7 amp RPC W/L for 52R	2 off	2 out		2 through		2 in	F1	Table 1, No.183R	52R
53R	F7	No.2 non-essential dc bus-bar reset and W/L for 52R		2 out		2 through		2 in	F1	Table 1, No.184R	53R
54	F7	Nos.1 to 4 ac bus-bars. 3 phase 30 amp RPC	4 off	4 out		4 through		4 in	F1	Table 1, No.185	54
55	F7	Nos.1 and 4 ac bus-bars. Single phase A. 3 amp RPC	2 off	2 out		2 through		2 in	F1	Table 1, No.186	55
56	F2 F2 F7	Front passenger door switch Front galley door switch Electrics bay access door switch		3 out 3 return	3(5V)	3 through		3 out	F1	Table 1, No.201	56
57L	F7	No.1 ac bus-bar. 3 phase 10 amp RPC (latched) No.1 non-essential dc bus-bar 15 amp RPC (latched)	1 off 1 off	4 out		4 through		4 in	F1	Table 1, No.209L	57L
58R	F7	No.4 ac bus-bar. 3 phase 15 amp RPC (latched) No.2 non-essential dc bus-bar 35 amp RPC (latched)	1 off 1 off	4 out		4 through		4 in	F1	Table 1, No.210R	58R
59						Signals A,B,C,D	No.17 logic for cooling fans (one only)	4 in	F1	Table 1, No.211	59
60	F7	Stn.187 Fan motor thermostats Nos.1&2 (closed No.1-F) (closed No.2-E)		2 out 2 return	2(5V)	Signals E,F	No.1 C+E.D No.2 A+F.B				60
61	F7	Nos.1&4 ac bus-bars. 3 phase 10 amp RPC	2 off	2 out		From logic 17 (Nos.1&2)					61
62	F7	Stn.187 Fan motor thermostats Nos.1&2 (for overheat warn)		2 out 2 return	2(5V)	2 through		2 out	F1	Table 1, No.212	62
63	F7J&K	Generator control panel Auxiliary control panel		8 out 8 out		4 junctions with 64 12 through		16 in	F1	Table 1, No.214	63
64	F7J&K	Generator circuit breaker, trip coil		4 out		4 junctions with 63					64
65	F7J&K	Split system breaker. Trip coil Ground power breaker. Trip coil Auxiliary control panel		1 out 1 out 1 out		3 through		3 in	F1	Table 1, No.215	65
66R	F7K	Auxiliary control panel (SSB close)		1 in		1 through		1 out	F1	Table 1, No.216R	66R
67R	F7J&K	Split system breaker close coil		1 out		1 through		1 in	F1	Table 1, No.2[illegible]R	67R
68	F7J&K	GCB,BTB,SSB,GPB contacts for indicators		10 out 10 return	10(28V) ancillary bus	10 through		10 out	F1	Table 1, No.218	68
69	F7U&Z	ac input contactor contact non-essential contactor contact		4 out 4 return	4(5V)	4 through		4 out	F1	Table 1, No.219	69

Table 2 (concluded)

Item No.	Equipment and location	No. of wires	F7 logic boxes: Limiting resistors	F7 logic boxes: Connections	F7 logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
70	F7U&Z Battery contactor contact	{2 out 2 return	2(28V) battery	V5 from 29 2 through		2 out	F1	Table 1, No.220	70
71	F7U&Z Undervoltage unit	2 in		2 through		2 out	F1	Table 1, No.221	71
72	F7 Nos.1&4 ac bus-bar. 3 phase 20 amp RPC 2 off	2 out		2 through		2 in	F1	Table 1, No.222	72
73	F7U&Z Battery contactor coil (via non-essential contactor)	2 out		2 through		2 in	F1	Table 1, No.223	73
74	F7U&Z Battery contactor coil (direct)	(signal B) 2 out		Signals A.C, B	No.18 logic for non essential dc contactor	4 in	F1	Table 1, No.224	74
75	F7 Auxiliary ac bus-bar phase A (alive V4)	2 in	2 (115V) and diodes	Signal V4	A.C.D (Two identical)				75
76	F7U&Z Standby contactor switch (closed D)	{2 out 2 return		From V4 No 15 Signal D					76
77	F7U&Z Non-essential dc contactor coil	2 out		From logic 18					77
78	F7U&Z Standby Nos.1&2 relay contacts	{2 out 2 return	2(115V)	From V4 No.75 2 through		2 out	F1	Table 1, No.225	78
79R	F7U&Z Standby ac input contactor contacts	{1 out 1 return	1(115V)	From V4, No.75 1 through		1 out	F1	Table 1, No.226R	79R
80	F7U&Z Standby Nos.1&2 relay coils	2 out		2 through		2 in	F1	Table 1, No.227	80
81R	F7P Auxiliary bus-bar. 3 phase 20 amp RPC 1 off	1 out		1 through		1 in	F1	Table 1, No.228R	81R
82R	F7P Auxiliary bus contactor contact	{1 out 1 return	1(115V)	From V4, No.75 1 through		1 out	F1	Table 1, No.229R	82R
83				Signals A, $\bar{A}$	For use in the logic of this box	2 in	F1	Table 1, No.230	83
84	F7 {Nos.1&4 ac bus-bar phase A. 15 amp RPC (a) 2 off ground power bus phase A. 15 amp RPC (b) 2 off	Logic 19(a)(b) 4 out	2(115V) 2(5V)	Signal V2 from 2 Signal V1	No.19 logic for 28 volt ac supplies (two identical) $V1.\overline{V2}$ = RPC(a), $V2.\overline{V1}$ = RPC(b)				84
85R	F7P ELRAT test control relay	1 out		1 through		1 in	F1	Table 1, No.231R	85R

Table 3

ZONE F8. DETAILS OF REMOTE CONTROL CIRCUITS UP TO BUS-BARS

Item No.	Equipment and location	No. of wires	F8 logic boxes			No. of wires	Circuit continuation		Item No.
			Limiting resistors	Connections	Boolean logic expressions		Logic box	Identification	
1	F8 1 to 4 ac bus-bars 3 amp fuses 12 off	12		To TRUs for	5 volt rail for logic operation				1
2	W4 and W5 Oleo switches A1, A2, B1, B2	4 out 8 return 11 *	4(5V) 24(5V)	4 positive, 4 negative *cross connections between left and right hand boxes.	For details of logic using the 24(5V) resistors. See under individual circuits.				2
3					No.1 logic from 2 (four identical) $\overline{A1}.\overline{A2}$	4 out	F4	Table 4, No.3	3
4	F8 Nos.1 and 2 essential dc bus bars. 5 amp RPC 8 off	8 out		8 through		8 in	F1	Table 1, No.5	4
5	F8 Nos.1 and 2 essential dc bus-bars. 5 amp RPC 4 off	4 out		4 through		4 in	F1	Table 1, No.6	5
6	W4 and W5 Fuel cock limit switches (open, close)	12 in	12(28V)	12 through		12 out	F1	Table 1, No.7	6
7	F8 Nos.1 and 2 essential dc bus-bars reset and W/L for 4 and 5	4 out		4 through		4 in	F1	Table 1, No.8	7
8	F8 Nos.1 and 2 essential dc bus-bars. 5 amp RPC 8 off	8 out		8 through		8 in	F1	Table 1, No.9	8
9	F8 Nos.1 and 2 essential dc bus-bars. 5 amp RPC 4 off	4 out		4 through		4 in	F1	Table 1, No.10	9
10	W3, 4 and 6 transfer and cross feed valve limit switches (open) (close)	12 in	12(28V)	12 through		12 out	F1	Table 1, No.11	10
11	F8 Nos.1 and 2 essential dc bus-bars resets and W/L for 8 and 9	4 out		4 through		4 in	F1	Table 1, No.12	11
12	F8 1 to 4 ac bus-bars. 3 phase 10 amp RPC 10 off	10 out		10 through		10 in	F1	Table 1, No.13	12
13	W3 and W6 Stn.717 vent tank float switch (shut C)	2 out 2 return	2(5V)	Signals B,A,C	No.2 logic for fuel pump (two identical) B + A.C	4 in	F1	Table 1, No.14	13
14	F8 2 and 3 ac bus-bars. 3 phase 10 amp RPC 2 off	2 out		From logic 2					14
15R	W5 Stn.950 transfer low pressure switch	1 out 1 return	1(5V)	1 through		1 out	F1	Table 1, No.17R	15R
16	W5 Stn.120 Fuel load control unit	4 out 8 return		4 through		4 in	F1	Table 1, No.18	16
17	W1, W8 and WR float switches (8 off)	8 out 8 return		8 through					17
18	F8 Nos.1 and 2 essential dc bus-bars. 3 amp RPC 8 off	8 out		8 through					18
19	W5 Stn.120. Fuel load control unit	8 in		8 through					19
20	F8 Nos.1 and 2 essential dc bus-bars. 3 amp RPC 8 off	8 out							20
21	W5 Stn.120 Fuel load control unit	4 in	4(28V)	4 through		4 out	F1	Table 1, No 19	21
22				Signal A	No.3 logic for fuel jettison valves	4 in	F1	Table 1, No.20	22
23				Signal B	(four identical)	4 in	F1	Table 1, No.2'	23
24	W3,4,5,6 Low level switches (shut C)	4 out 4 return		Signal C	B + A.C				24
25	F8 Nos.1 and 2 essential dc bus-bars. 3 amp RPC 4 off	4 out		From logic 3					25
26	F8 Nos.1 and 2 non-essential dc bus-bars. 3 amp RPC 2 off	2 out		2 through		2 in	F1	Table 1, No 22	26
27	F8 Nos.1 and 2 essential dc bus-bars 5 amp RPC 4 off earthing transistor switches in actuator negative 2 off	6 out		6 through A,B,C	Signals A and C operate RPC Signal B operates negative transistor switch	6 in	F1	Table 1, No.23	27

Table 3 (continued)

Item No.	Equipment and location	No. of wires	F8 logic boxes			No. of wires	Circuit continuation		Item No.
			Limiting resistors	Connections	Boolean logic expressions		Logic box	Identification	
28	W4 and 5 Stn.166 master valve limit switches (open, shut)	4 in	4(28V)	4 through		4 out	F1	Table 1, No.24	28
29	F8 Nos.1&2 essential dc bus-bars reset and W/L for 27	4 out		4 through		4 in	F1	Table 1, No.25	29
30L	F8 {No.3 ac bus phase B 3 amp RPC 1 off; 28 V ac bus single phase 3 amp RPC 1 off}	2 out		{$\overline{A1}$ to No.3 bus; A1 to 28 V ac bus}	No.4 logic from 2 (Total) A1,$\overline{A1}$ (left), A2,$\overline{A2}$ (right)	2 out	F4	Table 4, No.21L	30L
31	F8 Nos.1&2 non-essential dc bus-bars. 5 amp RPC 4 off	4 out		4 through		4 in	F1	Table 1, No.60	31
32	WR Stn.698 Wing anti-icing stop valve switches (open) (close)	4 in	4(28V)	4 through		4 out	F1	Table 1, No.64	32
33L				Junction with 34		1 in	F4	Table 4, No.32L	33L
34L	WR Stn.83C interskin pressure switch	{1 out; 1 return}	1(5V)	Junction with 33L		1 out	F1	Table 4, No.56L	34L
35	W1&8 slat Stn.736 wing duct pressure switch	{2 out; 2 return}	2(5V)	2 through		2 out	F1	Table 1, No.67	35
36L	F8 No.1 ac bus-bar. 3 phase 10 amp RPC 1 off	1 out		1 through		1 in	F1	Table 1, No.73L	36L
37L	F8 No.1 non-essential dc bus-bar 3 amp RPC 2 off	2 out		2 through (with linking diode)		2 in	F1	Table 1, No.74L	37L
38L	F8 Stn.659 left.UVV pressure switch ($\overline{B}$ open, B closed)	{1 out; 1 return}	1(5V)	Signals B, $\overline{B}$, A, H	No.5 logic from 2 (Total) A1 + A2 = G right, B1 + B2 = G left	1 in logic 5	F1	Table 1, No.80L	38L
39				Signal G	No.6 logic for UV valve (one only)	2 out	F4	Table 4, No.42	39
40L	F8 UVV actuator limit switches (open C,J; closed D,K)	2 in	2(28V)	Signals C,J,D,K	H.B (open) Signals C,D	2 out	F1	Table 1, No.81L	40L
41L				Signal N	A.$\overline{G}$ + A.G.N (shut)	1 in	F1	Table 1, No.82L	41L
42L	F8 No.1 nonessential dc bus-bar 5 amp RPC 2 off	2 out		From logic 6	No.7 logic for RRC valve (one only) H.B.J.G (open)	logic 7			42L
43L					$\overline{G}$ + A.G (shut)	2 out	F1	Table 1, No.84L	43L
44L	F8 No.1 non-essential dc bus-bar reset W/L for 42L	2 out		2 through		2 in	F1	Table 1, No.85L	44L
45L	F8 No.1 ac bus-bar phase C. 3 amp RPC 2 off	2 out		2 through		2 in	F1	Table 1, No.89L	45L
46				signal A	No.8 logic for overheat warning (two identical)	2 in	F1	Table 1, No.90	46
47	F8 Stn.639 duct overheat thermostat 55°C (D = low temperature) (B = high temperature)	{2 out; 4 return}	2(5V)	Signals B,D,E,C	B + $\overline{D.E}$ = warning light 55°C; C + $\overline{D.E}$ = warning light 120°C	4 in	F4	Table 4, No.46	47
48					(B+C)(M)A = overheat signal Y	2 out	F4	Table 4, No.44	48
49					signal Y	2 out	F7	Table 2, No.9	49
50					W/L 55°C	2 out	F1	Table 1, No.91	50
51					W/L 120°C	2 out	F1	Table 1, No.92	51
52				Signals A.D+B, A.E+C	No.9 logic for compressor speed modulating valve (two identical)	4 in	F7	Table 2, No.14	52
53				Signals H,N,$\overline{H}$,$\overline{N}$	(A.E + C).$\overline{G}$ = Increase (open)	4 in	F1	Table 1, No.94	53
54				Signals G$\overline{G}$ (2 junctions with No.60)	(A.D + B).$\overline{N}$.W.$\overline{H}$.V.$\overline{G}$ + (A.D + B).N.$\overline{H}$.V.$\overline{G}$ + (A.D + B).$\overline{N}$.W.H.$\overline{G}$ } Decrease (shut)	see No.60	F1	Table 1, No.96	54
55		Logic 9		Signal W		2 in	F4	Table 4, No.47	55
56	F8 No.1&4 ac bus-bar phase C. 5 amp RPC 4 off	4 out		Signal V		2 in	F4	Table 4, No.48	56
57	F8 No.1&4 ac bus-bars phase C, reset and W/L for 56	4 out		4 through		4 in	F1	Table 1, No.95	57
58	W8 inner wing. Compressor speed mod. sensor (open J,T)	2 in	2(115V) and diodes	2 through J,T		2 out	F4	Table 4, No.53	58

Table 3 (continued)

Item No.	Equipment and location	No. of wires	F8 logic boxes: Limiting resistors	F8 logic boxes: Connections	F8 logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
59				Signal C	No. 10 logic from 2 (Total) A1+A2 = C right, B1 + B2 = C left				59
60				Signals A,G (G,2 junctions with No.54)	No.11 logic for turbine compressor control valve (two identical)	4 in	F1	Table 1 No.96	60
61	W1 and W8 compressor speed sensor SW (A.B open, A.D closed)	2 out 4 return		Signal A from No.60 Signal A.B,A.D	A.B+C	2 out	F7	Table 2 No.17	61
62	W1 and W8 amplifier warning light switch (closed P)	2 in	2(28V)	2 through, P	No.12 logic for amplifier 'on' (two identical)	Signal P 2 out	F1	Table 1 No.98	62
63	F8 No.1 and 2 non essential dc bus bars. 3 amp RPC 2 off	2 out		from logic 12	A.D No.13 logic for condenser control valve (two identical)				63
64	F8 No.1 and 2 non essential dc bus bars. 3 amp RPC 2 off	2 out		from logic 11	A.D.C				64
65	F8 No.1 and 2 non essential dc bus bars. 3 amp RPC 2 off	2 out		from logic 13	No.14 logic for Table 4 No.43 A.D = X; $\overline{A.D} = \overline{X}$				65
66						Logic 14 2 out	F4	Table 4, No.43	66
67	F8 Nos.1&2 non-essential dc bus-bars, reset and W/L for 63, 64 and 65	4 out		4 through		4 in	F1	Table 1, No.99	67
68	W3 and W6 hydraulic pressure failure switch (ailerons)	4 out 4 return	4(5V)	4 through		4 out	F1	Table 1, No.101	68
69L					No.15 logic from 2 $\overline{B1}.\overline{B2}$ (U/C lock)	logic 15 1 out	F1	Table 1, No.109L	69L
70L	F8 No.1 essential dc bus-bar 3 amp RPC 4 off	4 out		2 junctions A,B		2 in	F1	Table 1, No.112L	70L
71L	F8 No.2 essential dc bus-bar 3 amp RPC 4 off	4 out		2 junctions C,D,E		2 in	F1	Table 1, No.113L	71L
72	F8 Nos.1&2 essential dc bus-bar, reset and W/L for 70L & 71L	4 out		4 through		4 in	F1	Table 1, No.115	72
73	W4 and W5 Main wheels 'up lock' and 'down lock' switches	4 out		2 diodes in 'up' 2 diodes in 'down'		4 in	F1	Table 1, No.116	73
74	W4 and W5 Main wheels 'up lock' and 'down lock' switches	4 return		2 junctions		2 out	F1	Table 1, No.123	74
75	W4 and W5 Main wheels 'down lock' switches	2 out 2 return	2(5V)	2 through		2 out	F1	Table 1, No.124	75
76	W4 and W5 Main wheels doors 'lock' switches	2 out 2 return		2 through		2 out	F1	Table 1, No.125	76
77R	W4 and W5 Main wheels 'down lock' switches (shut A,B)	2 out 2 return		one junction (A+B)		1 out	F1	Table 1, No.130R	77R
78	W4 left, flap limit switches	8 out 4 return		8 through		8 in	F1	Table 1, No.132	78
79	F8 Nos.1&2 essential dc bus-bars. 5 amp RPC 4 off	4 out		4 through					79
80	F8 Nos.1&2 essential dc bus-bars, reset and W/L for 79	4 out		4 through		4 in	F1	Table 1, No.133	80

Table 3 (continued)

Item No.	Equipment and location	No. of wires	F8 logic boxes: Limiting resistors	Connections	Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Identification	Item No.
81				Signals A,B,E,$\bar{E}$	No.16 logic to energise isolate valve (two identical) $\overline{A + B.(C.G + D.F + E.X + E.Y)(M)\,\bar{E}}$	5 in	F1	Table 1, No.134	81
82	W4 and W5 flap overtravel limit switches (down F, up G)	2 out 4 return	2(5V)	Signals F, G					82
83	W4 left flap up/down micro switches (down D, up C)	2 out 4 return	2(5V)	Signals C,D	No.17 logic for selector valve indicator (two identical) B.C (up), B.D (down)	Logic 17 4 out	F1	Table 1, No.136	83
84				Signal (X+Y) from logic No.19	No.18 logic for isolate W/L and indicator (two identical) $B.(C.G + D.F + E.X + E.Y)(M)\bar{E}$				84
85						Logic 18			85
86	F8 Nos.1&2 essential dc bus-bars. 5 amp RPC 2 off	2 out		from logic 16		2 out	F1	Table 1, No.137	86
87	F8 Nos.1&2 essential dc bus-bars, reset and W/L for 86	4 out		4 through	No.19 logic for asymmetric control (two identical) X+Y for 84 above	4 in	F1	Table 1, No.138	87
88				Signals X,Y		2 in	F7	Table 2, No.26	88
89	WR slat limit micro switches (in A, out B)	4 out 4 return		4 through A,B		4 in	F1	Table 1, No.139	89
90	F8, Nos.1&2 essential dc bus-bars. 5 amp RPC 4 off	4 out		4 through					90
91	F8, Nos.1&2 essential dc bus-bars. Reset and W/L for 90, 91	4 out		4 through		4 in	F1	Table 1, No.140	91
92	W1 and W8 slat protection micro switches (A system A, B system B)	4 out 4 return	4(5V)	Signals A,B	No.20 logic for slat control (two identical) $\overline{(A + B + E.C + D.F + X)(M).\overline{V1}}$				92
93	WR slat overtravel switches (C in, D out)	2 out 4 return	2(5V)	Signals C,D					93
94	WR Stn.688 slat selector valve switches (E in, F out)	2 out		Signal E,F	No. 21 logic for isolate indicators (two identical) $(A + B + E.C + D.F + X)(M).\overline{V1}$				94
95		4 return		Signal X		2 in	F7	Table 2, No.27	95
96					No.22 logic for slat selected indicators (two identical) E-in; F-out	Logic 21&22			96
97	F8 Nos.1&2 essential dc bus-bars. 5 amp RPC 2 off	2 out		from logic 20		6 out	F1	Table 1, No.141	97
98	F8 Nos.1&2 essential dc bus-bars. 5 amp RPC 3 off F8 Transistor switches in negative of solenoids 3 off 5 amp	3 out 3 out		6 through		6 in	F1	Table, No.153	98
99	F8 Nos.1&2 essential dc bus-bars, reset and W/L for 98	4 out		4 through		4 in	F1	Table 1, No.154	99
100	F8 Nos.3 and 4 ac bus-bars phase C. 15 amp RPC 2 off F8 Nos.1&2 non-essential dc bus-bar 5 amp RPC 4 off W1 and W6 landing lamp control	2 out 4 out 2 out		8 through		8 in	F1	Table 1, No.165	100
101	F8 Nos.3 and 4 ac bus-bars / Nos.1&2 non-essential dc bus-bars reset and W/L for 100	4 out		4 through		4 in	F1	Table 1, No.170	101
102	F8 28 V ac bus-bar No.2 3 amp RPC 1 off No.3 ac bus-bsr phase A 3 amp RPC 1 off	1 out 1 out		2 junctions with 103		2 in	F1	Table 1, No.171	102
103				2 junctions with 102		2 out	F4	Table 4, No.73	103
104	F8 No.2 non-essential dc bus-bar. 10 amp RPC 2 off	2 out		2 through		2 in	F4	Table 4, No.74	104
105	F8 Ground power supply (alive V2)	2 in	diodes and 2(115V)	V2	No.23 logic ror main U/C bay servicing lights V2 (one only)				105
106R	F8 28 volt ac bus-bar No.2 7 amp RPC 1 off	1 out		From logic 23					106R

Table 3 (concluded)

Item No.	Equipment and location	No. of wires	F8 logic boxes			No. of wires	Circuit continuation		Item No.
			Limiting resistors	Connectors	Boolean logic expressions		Logic box	Identification	
107L	F8 28 volt ac bus-bar No.1 5 amp RPC 1 off	Logic 24 1 out	1(115V)	V2 from 105 Signal F	No.24 logic for for'd freight bay F8 servicing lights F + V2 (one only)	1 in	F7	Table 2, No.33L	107L
108L			1(5V) 1(115V)	Signal V1 Signal V2 from 105	No.25 logic for entrance and stop lights (one only) V1 = RPC(a); V2.$\overline{V1}$ = RPC(b)				
109L	F8 {No.1 ac bus-bar phase B 3 amp RPC(a) 1 off ground power bus-bar phase B 3 amp RPC(b) 1 off}	2 out		From logic 25					
110R			1(5V) 1(115V)	Signal V1, signal B Signal V2, from 105	No.26 logic for cabin roof lights (one only) V1.B = RPC(a); V2.B.$\overline{V1}$ = RPC(b)	1 in	F7	Table 2, No.38R	110R
111L	F8 {No.1 ac bus-bar phase B 3 amp RPC(a) 1 off ground power bus-bar phase B 3 amp RPC(b) 1 off}	2 out		From logic 26					
112R				Signal A 1 junction with 113L	No.27 logic for cove lights (one only)	1 in	F7	Table 2, No.40R	112R
113R				1 junction with 112L(A)	V1.A = RPC(a); V2.A.$\overline{V1}$ = RPC(b)	1 out	F4	Table 4, No.82R	113R
114R	F8 {No.4 ac bus-bar phase B 5 amp RPC(a) 1 off ground power bus-bar phase B 5 amp RPC(b) 1 off}	Logic 27 2 out	1(5V) 1(115V)	Signal V1 Signal V2 from 105					114R
115	F8 Nos.1&4 ac bus-bars. 3 phase 3 amp RPC 2 off	2 out		2 through		2 in	F1	Table 1, No.187	115
116R	WR Stn.719 slats micro switch (shut E)	1 out 1 return	1(5V)	Signal E junction with 117R and 118R					116R
117R	W5 Stn.89 flaps micro switch (shut F)	1 out 1 return	1(5V)	Signal F junction with 116R and 118R	Signal E + F + H out	1 out	F1	Table 1, No.190R	117R
118R				Signal H junction with 116R and 117R		1 in	F4	Table 4 No.93R	118R
119R				Signal D	No.28 logic from 2 $\overline{B1}$ + $\overline{B2}$ = D (one only)	Logic 28 1 out	F1	Table 1, No.191R	119R
120	{F2 rear passenger door switch F8 front hold door switch F8 water filling door switch}	3 out 3 return	3(5V)	3 through		3 out	F1	Table 1, No.200	120

Table 4

ZONE F4. DETAILS OF REMOTE CONTROL CIRCUITS UP TO BUS-BARS

Item No.	Equipment and location	No. of wires	F4 logic boxes: Limiting resistors	F4 logic boxes: Connections	F4 logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
1	F4 Nos.1 to 4 ac bus-bars 3 amp fuses 12 off	12 in		To TRUs for	5 volt rail for logic operation				1
2	M1 to M4 CSD oil low pressure switches	4 out / 4 return	4(5V)	4 through		4 out	F1	Table 1, No.2	2
3	F4 Nos.1 and 2 non-essential dc bus-bars. 3 amp RPC 4 off	4 out		4 through		4 in	F8	Table 3, No.3	3
4	F4 Nos.1 to 4 ac bus-bars. Single phase. 3 amp RPC 4 off	4 out		4 through		4 in	F1	Table 1, No.15	4
5	MS1 and MS2 low pressure switches	4 out / 4 return	4(5V)	4 through		4 out	F1	Table 1, No.16	5
6	F4 Nos.1 and 2 essential dc bus-bars. 7 amp RPC 8 off	8 out		8 through		8 in	F1	Table 1, No.26	6
7	F4 RPC's item 6 (power side)	8 in	8 diodes and 2(28V)	2 through		2 out	F1	Table 1, No.27	7
8	F4 {No.2 essential dc bus-bar. 7 amp RPC 1 off; Nos.1 and 2 non-essential dc bus-bars. 3 amp RPC 2 off}	3 out (H.A5,H.A6)		{signal J; 3 through D,E,H} signals H.A5,H.A6,F.A1 F.A2,F.A3,F.A4,	No.1 logic for engine start valves 'on' (total) (F.A1).$\overline{B1(M)\overline{F.A1}}$ engine No.1	4 in	F1	Table 1, No.28	8
9	F4 No.2 essential dc bus-bar. 3 amp RPC 2 off	2 out			(F.A2).$\overline{B2(M)\overline{F.A2}}$ engine No.2	6 in	F1	Table 1, No.29	9
10	M1 to M4 pneumatic engine speed cut out switches (B1 to B4)	4 out / 4 return	4(5V)	signals B1 to B4	(F.A3).$\overline{B3(M)\overline{F.A3}}$.J = X engine No.3				10
11	F4 Nos.1 and 2 essential dc bus-bars. 3 amp RPC 4 off	4 out		from logic 1	(F.A3).$\overline{B4(M)\overline{F.A4}}$.J = Y engine No.4				11
12R	MS2 combustor pressure switches (C3+C4, closed)	1 out / 1 return	1(5V)	signals H.A5,H.A6 from 9 signals (C3+C4)	No.2 logic for combustor air valve (one only)				12R
13R	F4V time delay switch D closed	1 out / 1 return	1(5V)	signals X and Y from logic 1 signal D,	(H.A5+H.A6).(C3+C4+D).X.Y.				13R
14R	F4 No.2 essential dc bus-bar. 3 amp RPC 1 off	1 out		from logic 2					14R
15R	F4 RPC's item 11 (power side)	4 in	4 diodes and 1(5V)	one through		1 out	F1	Table 1, No.30R	15R
16	M1 to M4 reverse thrust switches	4 out / 4 return	4(5V)	4 through		4 out	F1	Table 1, No.31	16
17	M1 to M4 o/heat warning switches and low pressure oil warning switches	8 out / 8 return	8(5V)	8 through		8 out	F1	Table 1, No.32	17
18	F4S test relays with transistor amplifiers	2 out		2 through		2 in	F1	Table 1, No.33	18
19	F4 Nos.1 and 2 non-essential dc bus-bars. amp RPC 4 off	4 out		4 through		4 in	F1	Table 1, No.36	19
20	F4 Nos.1 and 2 non-essential dc bus-bars, reset and W/L for 19	4 out		4 through		4 in	F1	Table 1, No.37	20
21L	F4 {No.3 ac bus phase B. 3 amp RPC 1 off; 28V ac bus single phase. 3 amp RPC 1 off}	2 out		2 through {$\overline{A2}$, No.3 bus; A2, 28V ac bus}		2 in	F8	Table 3, No.30L	21L
22				signal C	No.3 logic for airframe anti-icing HP stop valves	4 in	F1	Table 1, No.55	22
23				signal A+B		2 in	F1	Table 1, No.56	23
24	MS1 and MS2 pressure reducing valve switch (closed D)	2 out / 2 return logic 3	2(5V)	signal D	(A+B+D)(M)R = memory X (two identical)				24
25	F4 Nos.1 and 2 non-essential dc bus-bars. 3 amp RPC 4 off	4 out		signal R	C.$\overline{X}$ = close valve RPC; $\overline{C}$+X = open valve RPC} four identical	2 in	F1	Table 1, No.57	25

Table 4 (continued)

Item No.	Equipment and location	No. of wires	F4 logic boxes			No. of wires	Circuit continuation		Item No.
			Limiting resistors	Connections	Boolean logic expressions		Logic box	Identification	
26	M1 to M4 high pressure stop valve position switches	4 out 4 return	4(5V)	4 through		4 out	F1	Table 1, No.58	26
27	F4 Nos.1 and 2 non-essential dc bus-bars. 3 amp RPC 4 off	4 out		4 through		4 in	F1	Table 1, No.59	27
28	F4 Nos.1 and 2 non-essential dc bus-bars. 3 amp RPC 2 off	2 out		2 through		2 in	F1	Table 1, No.61	28
29	MS1 and MS2 pressure reducing valve switches	2 out 2 return	2(5V)	2 through		2 out	F1	Table 1, No.62	29
30L	T2 tail anti-icing stop valve switch	1 out 1 return	1(5V)	1 through		1 out	F1	Table 1, No.63L	30L
31	MS1 and MS2 duct o/heat thermostats	2 out 2 return	2(5V)	2 through		2 out	F1	Table 1, No.65	31
32L	F9 Stn.1214 interskin pressure switch	1 out 1 return	1(5V)	1 through		1 out	F8	Table 3, No.33L	32L
33L	F4 No.1 essential dc bus-bars. 5 amp RPC 2 off	2 out		2 through		2 in	F7	Table 2, No.10L	33L
34L	F4 No.1 essential dc bus-bars, reset and W/L for 33L	2 out		2 through		2 in	F1	Table 1, No.70L	34L
35L	F4 Stn.1464 thrust augmenter actuator switch (open, close)	2 in	2(28V)	2 through		2 out	F1	Table 1, No.71L	35L
36L	F4 No.1 essential dc bus-bar. 3 amp RPC 1 off	1 out		1 through		1 in	F1	Table 1, No.76L	36L
37	F4 {Nos.1 and 2 non-essential dc bus-bars. 3 amp RPC 4 off Stn.1300 dual amplifier (auto, increase, decrease)	4 out 12 out		16 through		16 in	F1	Table 1, No.77	37
38	MS1 and MS2 compressor non-return valve switches	4 out 4 return	4(5V)	4 through		4 out	F1	Table 1, No.78	38
39	F4 Stn.1300 dual amplifier auto/off warning lights	4 in	4(28V)	4 through		4 out	F1	Table 1, No.79	39
40R	F4 Stn.1340 right, non-return valve switch	2 out 2 return	2(5V)	2 through		2 out	F1	Table 1, No.86R	40R
41				signals A,B,C	No.3 logic for spill and stop valves (two identical)	6 in	F1	Table 1, No.87	41
42	F4 Nos.1 and 2 essential dc bus-bars. 5 amp RPC (a) 2 off	logic 3 2 out		signals $G,\bar{G}$	$A.\bar{Y}.G.\bar{X}+A.\bar{Y}.\bar{G}+B.\bar{Y}$ for RPC (a)	2 in	F8	Table 3, No.39	42
43	F4 Nos.1 and 2 essential dc bus-bars. 5 amp RPC (b) 2 off	logic 3 2 out		signals $X,\bar{X}$	$A.\bar{Y}.G.X$ for RPC (b)	2 in	F8	Table 3, No.66	43
44	F4 Nos.1 and 2 essential dc bus-bars. 5 amp RPC (c) 2 off	logic 3 2 out		signals $Y,\bar{Y}$	$C.\bar{Y}$ for RPC (c)	2 in	F8	Table 3, No.48	44
45	F4 Nos.1 and 2 essential dc bus-bars, reset and W/L for 42,43 and 44	4 out		4 through		4 in	F1	Table 1, No.88	45
46	F4 Stn.1330 duct o/heat thermostat $120^{\circ}C$ {E, low temperature C, high temperature	2 out 4 return	2(5V)	4 through E,C		4 out	F8	Table 3, No.47	46
47	F4 Stn.1320 choke valve limit switch (open P,W)	2 in	diodes and 2(115V)	2 through W		2 out	F8	Table 3, No.55	47
48	T2 cooling modulating valve limit switch (open S,V)	2 in	diodes and 2(115V)	2 through V		2 out	F8	Table 3, No.56	48
49	F4 Nos.1 and 4 ac bus-bars phase C, reset and W/L for 56 and 57	4 out		4 through		4 in	F1	Table 1, No.95	49

Table 4 (continued)

Item No.	Equipment and location	No. of wires	F4 logic boxes: Limiting resistors	F4 logic boxes: Connections	F4 logic boxes: Boolean logic expressions	No. of wires	Circuit continuation: Logic box	Circuit continuation: Identification	Item No.
50				signals {A.D+B, A.E+C}	No.4 logic for choke valve (two identical) $(A.D+B).\bar{N}$ = decrease RPC (a)	4 in	F7	Table 2, No.14	50
51				signals $H,\bar{H},N,\bar{N}$	$X.\bar{N}$ = decrease RPC (b)	4 in	F1	Table 1, No.94	51
52				signals $G,\bar{G}$	N = decrease RPC (c) dc	2 in	F1	Table 1, No.96	52
53				signals T	$(A.E+C).\bar{G}.T.\bar{H}.U.Y.\bar{N}$ +	2 in	F8	Table 3, No.58	53
54	T2 cooling modulating valve limit switches (shut L,U)	2 in	diodes and 2(115V)	signals U	$(A.E+C).\bar{G}.T.H.Y.\bar{N}$ + } increase RPC (d)				
55	F4 Stn.1335 differential pressure switches (HP = X,LP = Y)	{2 out, 2 return}	2(5V)	signals $X,\bar{X},Y,\bar{Y}$	$(A.E+C).G.\bar{H}.U.Y.\bar{N}$				
					No.5 logic for cooling modulating valve (two identical)				
56	F4 {Nos.1 and 2 non-essential dc bus-bars. 5 amp RPC (c) 2 off; Nos.1 and 4 ac bus-bars, phase C. 5 amp RPC (a,b,d) 6 off}	{2 out, 6 out}		from logic 4	$(A.D+B).\bar{N}.W.\bar{H}$ + $(A.D+B).N,\bar{H}$ } decrease RPC (e)				56
57	F4 Nos.1 and 4 ac bus-bars, phase C. 5 amp RPC (e,f) 4 off	4 out		from logic 5	$(A.E+C).\bar{G}.T.\bar{H}$ + $(A.E+C).G.\bar{H}$ } increase RPC (f)				57
58	T2,3,4 and 6, hydraulic pressure fail switch (elevators and rudders)	{7 out, 7 return}	7(5V)	7 through		7 out	F1	Table [illegible], No.101	58
59				signals A,B,X,Y		6 in	F1	Table 1, No.102	59
60				signal J	No.6 logic for arming valve (two identical)	2 in	F1	Table 1, No.103	60
61	T3 {over run micro switches (G-up+H down); tail trim micro switches (C up,D down)}	{4 out, 4 return}	4(5V)	signals C,D,G+H	$E.F\{\overline{J.(G+H)}\}.(X.Y+A.C+B.D)$				61
62	F4 Stn.1292 hydraulic fault detector (normal E.F, fault K)	{2 out, 4 return}	2(5V)	signals E,F,K	No.7 logic for over run warning (two identical) $J.(G+H)+K.(A.C+X.Y+B.D)$				62
63	F4 Nos.1 and 2 essential dc bus-bars. 3 amp RPC 2 off	2 out		from logic 6		logic 7 2 out	F1	Table 1, No.104	63
64	F4 hydraulic compartment flamestat	{2 out, 2 return}	2(5V)	2 through		2 out	F1	Table 1, No.142	64
65R	F4 No.2 essential dc bus-bar. 5 amp RPC 2 off	2 out		2 through A,B		2 in	F1	Table 1, No.143R	65R
66R	F4 No.2 essential dc bus-bar, reset and W/L for 65R	2 out		2 through		2 in	F1	Table 1, No.146R	66R
67	F4 Nos.1 and 2 non-essential dc bus-bars. 5 amp RPC 4 off	4 out		4 through		4 in	F1	Table 1, No.147	67
68	F4 Nos.1 and 2 non-essential dc bus-bars, reset and W/L for 67	4 out		4 through		4 in	F1	Table 1, No.148	68
69	F4 Stn.1271 ferry link actuator limit switches (open, shut)	2 in	2(28V)	2 through		2 out	F1	Table 1, No.149	69
70	F4 Nos.1 and 2 essential dc bus-bars. 5 amp RPC 8 off	8 out		8 through		8 in	F1	Table 1, No.156	70
71	F4 Stn.1271 hydraulic isolation valve limit switches (open, shut)	8 in	8(28V)	8 through		8 out	F1	Table 1, No.157	71
72	F4 Nos.1 and 2 essential dc bus-bars, reset and W/L for 70	4 out		4 through		4 in	F1	Table 1, No.158	72
73	F4 {No.3 ac bus-bars phase A. 3 amp RPC 1 off; 28V ac bus-bar, No.1 3 amp RPC 1 off}	2 out		2 through		2 in	F8	Table 3, No.103	73

Table 4 (concluded)

Item No.	Equipment and location	No. of wires	F4 logic boxes			No. of wires	Circuit continuation		Item No.
			Limiting resistors	Connections	Boolean logic expressions		Logic box	Identification	
74	F3 Stn.1195 engine intakes inspection light switch	1 out 2 return	1(5V)	2 through		2 out	F8	Table 3, No.104	74
75	F4 ground power supply (alive, V2)	2 in	diodes and 2(115V)	signal V2	No.8 logic for F4 bay servicing lights (one only) D+V2 = RPC (a)				75
76R	F4V servicing lights switch (on, D)	1 out 1 return	1(5V)	signal D					76R
77R	F9 Stn.1208 servicing lights switch (on, E)	1 out 1 return	1(5V)	signal E	No.9 logic for F9 aft freight bay lights (one only) E+V2 = RPC (b)				77R
78R	F4 {28V ac bus-bar No.2 3 amp RPC (a) 1 off 28V ac bus-bar No.1 7 amp RPC (b) 1 off	2 out		from logic 8 and 9					78R
79R			1(5V) 1(115V)	signal V1 signal V2 from 75	No.10 logic for entrance and step lights (one only) V1 = RPC (a); V2.$\overline{V1}$ = RPC (b)				79R
80R	F4 {No.1 ac bus-bar, phase B 3 amp RPC (a) 1 off ground power bus, phase B 3 amp RPC (b) 1 off	2 out		from logic 10					80R
81R	F4 {No.1 ac bus-bar, phase C 3 amp RPC (a) 1 off ground power bus, phase C 3 amp RPC (b) 1 off	logic 11 2 out	1(5V) 1(115V)	signal V1 signal V2 from 75	No.11 logic for toilet lights (one only) V1 = RPC (a); V2.$\overline{V1}$ = RPC (b)				81R
82R				signal A	No.12 logic for cove lights (one only) V1.A = RPC (a); V2.A.$\overline{V1}$ = RPC (b)	1 in	F8	Table 3, No.113R	82R
83R	F4 {No.4 ac bus-bar, phase C 5 amp RPC (a) 1 off ground power bus, phase C 5 amp RPC (b) 1 off	logic 12 2 out	1(5V) 1(115V)	signal V1 signal V2 from 75					83R
84R	F3 LA Stn.1173 galley call button (closed, C)	1 out 1 return	1(5V)	1 through C		1 out	F7	Table 2, No.46R	84R
85R	F3 LA Stn.1173 reset buttons (reset R4,R5,R6)	1 out 3 return	3(5V)	signals R4,R5,R6	No.13 logic for aft right toilet call (one only) H(M)R4				85R
86R	F3 rear toilets call buttons (closed H,J,K)	3 out 3 return	3(5V)	signals H,J,K	No.14 logic for aft centre toilet call (one only) J(M)R5				86R
87R	F3 LA Stn.1173 transistor switches for forward toilet call light 1 off	1 out		1 through E(M)R2+F(M)R3	No.15 logic for aft left toilet call (one only) K(M)R6	1 in	F7	Table 2, No.47R	87R
88R	F3 LA Stn.1173 {transistor switches for aft toilet call lights 3 off transistor switches for galley buzzer 1 off	4 out		from logic 13,14,15,16 signal G	No.16 logic for galley buzzer (one only) G	1 in	F7	Table 2, No.43R	88R
89R					No.17 logic for rear toilet call (one only) H(M)R4+J(M)R5+K(M)R6	logic 17 1 out	F7	Table 2, No.48R	89R
90R	F4 No.2 essential dc bus-bar. 3 amp RPC 1 off	1 out	1(5V)	supply for transtr sws. in F3 LA					90R
91R	F4 No.2 essential dc bus-bar, reset and W/L for 90R	2 out		2 through		2 in	F1	Table 1, No.182R	91R
92	F4 Nos.1,2 and 4 ac bus-bars, phase B. 5 amp RPC 3 off	3 out		3 through		3 in	F1	Table 1, No.186	92
93R	T5 bullet tail trim micro switch (shut H)	1 out 1 return	1(5V)	1 through H		1 out	F8	Table 3, No.118R	93R
94	F3 LA rear galley door switch F9 rear hold door switch F9 Stn.1480 rear ventral door switch	3 out 3 return	3(5V)	3 through		3 out	F1	Table 1, No.199	94
95	F4 Nos.1 and 2 essential dc bus-bars {5 amp RPC 4 off 5 amp negative transtr sws 4 off	8 out		8 through		8 in	F1	Table 1, No.213	95
96	M1 to M4 generator o/heat switches (in negative)	4 in		4 through		4 out	F1	Table 1, No.232	96

Table 5

FLYING CONTROL CENTRAL WARNING ON PANEL B

Connections to logic box F1, Table 1, Item No.	No. of wires	Panel B. Internal details
101	11	In, signals for hydraulic pressure failure warning Ailerons. Right outer J, right inner K, left inner L, left outer N Elevators. Right outer O, right inner P, left inner Q, left outer R Rudders. Upper S, mid T, lower U
108	2	In, signals for hydraulic pressure failure warning Artificial feel No.1, V Artificial feel No.2, W Each signal J, K, O, P, S, U is connected as follows. To { 1 Transistor switch for individual warning light 2 Horn warning signal A1 *via* isolating diode 3 Central warning light signal A2 *via* logic and isolating diode Each signal L, N, Q, R, T is connected as follows. To { 1 Transistor switch for individual warning light 2 Horn warning signal B1 *via* isolating diode 3 Central warning light signal B2 *via* logic and isolating diode Each signal V and W connected as follows. To { 1 Transistor switch for individual warning light 2 Horn warning signal A1(W) or B1(V) *via* isolating diode
192R	1	out, A1 + B1 = J + K + L + N + O + P + Q + R + S + T + U + V + W (warning horn)
198R	1	in, signal X = cancel signal for central warning light logic to cancel central warning light = $X(M)\bar{J} + X(M)\bar{K} + X(M)\bar{L} + X(M)\bar{N} + X(M)\bar{O} + X(M)\bar{P} + X(M)\bar{Q} + X(M)\bar{R} + X(M)\bar{S} + X(M)\bar{T} + X(M)\bar{U}$. logic for $A2 = J.\overline{X(M)\bar{J}} + K.\overline{X(M)\bar{K}} + O.\overline{X(M)\bar{O}} + P.\overline{X(M)\bar{P}} + S.\overline{X(M)\bar{S}} + U.\overline{X(M)\bar{U}}$ logic for $B2 = L.\overline{X(M)\bar{L}} + N.\overline{X(M)\bar{N}} + Q.\overline{X(M)\bar{Q}} + R.\overline{X(M)\bar{R}} + T.\overline{X(M)\bar{T}}$
195R	1	out, logic A2 + B2 (control warning light)

Table 6

MASTER WARNING SYSTEM ON PANEL B

Connections to logic box F1, Table 1, Item No.	No. of wires	Panel B. Internal details
		Generators
2	4	In, signals for CSD oil low pressure No.1-A, No.2-B, No.3-C, No.4-D
232	4	In, signals for generator over heat No.1-$\bar{E}$, No.2-$\bar{F}$, No.3-$\bar{G}$, No.4-$\bar{H}$ (negatively switched)
218	4	In, signals for generator failure No.1-J, No.2-K, No.3-L, No.4-N
221	2	In, signals for dc system failure No.1-O, No.2-P
65	2	In, signals for hot air duct over heat right-Q, left-R
		Each signal A,B,C,D,J,K,L,N,O,P,Q,R is connected as follows To { 1 Transistor switch in positive line for individual warning light 2 Central warning light signal *via* logic and isolating diode
		Each signal $\bar{E}$, $\bar{F}$, $\bar{G}$, $\bar{H}$ is connected as follows To { 1 Transistor switch in negative line for individual warning light 2 Central warning light signal *via* inverter, logic and isolating diode.
205L	1	In, signal X = cancel signal for central warning light Cancel logic = $X(M)\bar{A} + X(M)\bar{B} + X(M)\bar{C} + X(M)\bar{D} + X(M)E + X(M)F + X(M)G + X(M)H + X(M)\bar{J} + X(M)\bar{K} + X(M)\bar{L} + X(M)\bar{N} + X(M)\bar{O} + X(M)\bar{P} + X(M)\bar{Q} + X(M)\bar{R}$
206L	1	Out, signal for central warning light = $A.\overline{X(M)\bar{A}} + B.\overline{X(M)\bar{B}} + C.\overline{X(M)\bar{C}} + D.\overline{X(M)\bar{D}} + \overline{E.X(M)E} + \overline{F.X(M)F} + \overline{G.X(M)G} + \overline{H.X(M)H} + J.\overline{X(M)\bar{J}} + K.\overline{X(M)\bar{K}} + L.\overline{X(M)\bar{L}} + N.\overline{X(M)\bar{N}} + O.\overline{X(M)\bar{O}} + P.\overline{X(M)\bar{P}} + Q.\overline{X(M)\bar{Q}} + R.\overline{X(M)\bar{R}}$

Table 7

COMPARISON OF MASSES OF CONVENTIONAL AND REMOTELY CONTROLLED ELECTRICAL DISTRIBUTION SYSTEMS (SCHEME 1)

Equipment compared	Unit mass	Existing system		Remote control		Totals	
		Quantity	Total mass kg	Quantity	Total mass kg	Existing kg	Remote kg
Sub-feeder cable							
10 gauge	64.5 g/m	30.5 m	1.97	27.4 m	1.77		
12 gauge	29.8 g/m	61.0 m	1.82	338.5 m	10.09		
14 gauge	19.3 g/m	-	-	108.3 m	2.09		
16 gauge	14.8 g/m	-	-	155.6 m	2.3		
18 gauge	10.41 g/m	-	-	347.9 m	3.62		
20 gauge	6.95 g/m	-	-	44.0 m	0.31	3.79	20.18
Distribution cable							
8 gauge	99.4 g/m	5.2 m	0.52	-	-		
10 gauge	64.5 g/m	311.4 m	20.09	226.9 m	14.64		
12 gauge	29.8 g/m	611.8 m	18.23	124.4 m	3.71		
14 gauge	19.3 g/m	1819.6 m	35.12	1518.9 m	29.31		
16 gauge	14.8 g/m	467.3 m	6.92	197.9 m	2.93		
18 gauge	10.41 g/m	2639.5 m	27.48	477.3 m	4.97		
20 gauge	6.95 g/m	6374.8 m	44.31	1361.5 m	9.46		
22 gauge	4.23 g/m	8197.2 m	34.67	1026.3 m	4.34		
24 gauge	2.9 g/m	7182.1 m	20.83	545.3 m	1.58	208.17	70.94
Control signal cable							
26 gauge	2.0 g/m	-	-	22978 m	45.96		
24 gauge (negative returns)	2.9 g/m	-	-	403 m	1.17	-	47.13
Connectors (mated pairs)							
155 way	200 g	-	-	10	2.0		
121 way	164 g	-	-	11	1.8		
85 way	98 g	-	-	5	0.49		
55 way	79 g	-	-	12	0.95		
37 way	64 g	-	-	15	0.96		
12 way	36 g	-	-	12	0.43	-	6.63
Protection							
Fuses and holders 2 to 10 amps	26 g	544	14.14	263	6.84		
Fuses, heavy duty, bolted	32 g	113	3.62	32	1.02		
Circuit breakers	42 g	73	3.07	7	0.29		
RPC solid state	57 g	-	-	287	16.36		
RPC electro-magnetic, single pole	230 to 291 g	-	-	21	4.89		
RPC electro-magnetic, 3 pole	276 to 645 g	-	-	43	15.74		
Reset pushes and W/L	12 g			87	1.04	20.83	46.18

Table 7 (concluded)

Equipment compared	Unit mass	Existing system		Remote control		Totals	
		Quantity	Total mass kg	Quantity	Total mass kg	Existing kg	Remote kg
Relays light duty							
2 amp to 10 amp	19 to 125 g	134	8.55	-	-		
Relays heavy duty							
10 amp to 35 amp	194 to 545 g	64	18.26	-	-	26.81	-
Manual switches							
Single pole 10 amp	41.8 g	153	6.4				
2 pole 10 amp	59.1 g	17	1.0				
3 pole 10 amp	90.0 g	7	0.63				
4 pole 10 amp	110.0 g	12	1.32				
2 pole light duty	7.5 g	-	-	201	1.51	9.35	1.51
Transistor amplifiers for W/L and indicators	1.2 g	-	-	208	0.25	-	0.25
Logic boxes							
In zone F1	see Table 8	-	-	2	5.06		
In zone F7		-	-	2	3.68		
In zone F8		-	-	2	3.76		
In zone F4		-	-	2	3.69		
Logic mounted on Panel B		-	-	1	0.21	-	16.4
Estimated mass of equipment panels	see Table 11	-	125.5	-	102.4	125.5	102.4
Estimated mass of cable ducting	see Table 12	-	79.2	-	70.5	79.2	70.5
						473.65	382.12

difference 91.53 kg

NOTE:- 'Existing system' departs from the VC 10 installation in incorporating the most up-to-date cables and equipment available.

Table 8

ESTIMATED MASS OF LOGIC BOXES AND LOGIC IN PANEL B

Internal components	Unit mass g	Logic boxes F1		Logic boxes F7	
		Quantity	Total mass g	Quantity	Total mass g
Limiting resistors for 5 volts	0.27	268	72.36	42	11.34
Limiting resistors for 28 volts	0.53	18	9.54	17	9.01
Limiting resistors for 115 volts	0.94	20	18.8	18	16.92
Diodes	0.15	80	12.0	72	10.8
Through links and junctions	1.73 g/m	572*	247.0	121*	103.8
Integrated logic circuits	1.96	38	74.5	33	64.7
Transistors	1.18	43	50.7	44	51.92
Resistors for logic	0.27	128	34.6	131	35.4
Mounting cards	26.8	12	321.6	8	214.4
Connectors	18.1	12	217.2	8	144.8
Power supplies 8.5 W and 4 W	-	4 × 8.5 W	1500.0	4 × 4 W	920.0
		Total	2558.3	Total	1583.1
		2 boxes = 2500		2 boxes = 2100	

Internal components	Unit mass g	Logic boxes F8		Logic boxes F4	
		Quantity	Total mass g	Quantity	Total mass g
Limiting resistors for 5 volts	0.27	72	19.44	79	21.33
Limiting resistors for 28 volts	0.53	40	21.2	19	10.07
Limiting resistors for 115 volts	0.94	7	6.58	10	9.4
Diodes	0.15	28	4.2	40	6.0
Through links and junctions	1.73 g/m	211*	91.7	160*	69.2
Integrated logic circuits	1.96	58	113.7	50	98.0
Transistors	1.18	62	73.16	44	51.92
Resistors for logic	0.27	181	49.0	154	41.6
Mounting cards	26.8	8	214.4	8	214.4
Connectors	18.1	8	144.8	8	144.8
Power supplies 4 watt	230.0	4 × 4 W	920.0	4 × 4 W	920.0
		Total	1658.2	Total	1586.7
		2 boxes = 2100		2 boxes = 2100	

Components to be added	Panel B, zone F1		
	Unit mass g	Quantity	Total mass g
Integrated logic circuits	1.96	28	54.9
Transistors	1.18	5	5.9
Diodes	0.15	40	6.0
Resistors for logic	0.27	37	10.0
Mounting cards	26.8	3	80.4
Connectors	18.1	3	54.3
		Total	211.5

Note *. Wire allowance 250 mm per through link.

Table 9

DETAILS OF PROTECTION AT ZONES F1, F7, F8, F4

Protective device	Zone F1		Zone F7		Zone F8		Zone F4	
	dc	ac	dc	ac	dc	ac	dc	ac
Solid state RPC								
Intermittent rating, qty.	17	-	3	-	76	6	54	10
Continuous rating, qty.	10	19	2	20	17	16	18	19
Losses, watts	30	92	14	43	35	63	18	53
Mass, kg	1.54	1.08	0.29	1.14	5.3	1.25	4.1	1.65
Electro-magnetic RPC								
Quantity	3	6	6	34	-	15	-	-
Mass, kg	0.69	1.38	1.44	13.07	-	4.05	-	-
Fuses and circuit breakers								
Quantity, CB	7	-	-	-	-	-	-	-
Quantity, fuses, 2-10 amp	79	39	33	64	2	16	6	24
Quantity, fuses, bolted	-	-	8	24	-	-	-	-
Mass, kg	2.35	1.01	1.11	2.43	0.05	0.42	0.16	0.62
Total mass kg	8.05		19.48		11.07		6.54	

Table 10

CONNECTORS REQUIRED FOR PANELS

	Panel A	Panel B	Panel D	Panel E	Panel EA	Panel FIR	
No. of connections	55	602	37	44	19	12	
No. and type of connector	1 × 55 way	4 × 155 way	1 × 37 way	1 × 55 way	1 × 37 way	1 × 12 way	
Mass	0.079 kg	0.8 kg	0.064 kg	0.079 kg	0.064 kg	0.036 kg	Total 1.12 kg

Table 11

ESTIMATED REDUCTION IN PANEL MASS BY ELIMINATING RELAYS

	Panel B	Panel C	Panel X	Panels G and H	Panels P and PA	Panels U and Z	Panels J and K	Panels RR and RL	Panel L	Panel LA	Panels V and S
Relays deleted	57	–	14	45	13	11*	37*	2	3	3	13
Estimated panel space %	15%	–	50%	85%	20%	–	–	–	15%	15%	85%
Panel mass	15 kg	10.0 kg	5.0 kg	13.2 kg	7.7 kg	17.3 kg	47.3 kg	–	2.3 kg	1.8 kg	5.9 kg
Mass reduction	2.25 kg	–	2.5 kg	11.22 kg	1.54 kg	–	–	–	0.35 kg	0.27 kg	5.0 kg

Total mass of conventional panels = 125.5 kg

Estimated mass reduction = 23.1 kg

* These relays would be replaced by electro-magnetic RPCs.

Table 12

COMPARISON OF CABLE AREAS TO DETERMINE TRUNKING PROPORTIONS

Cable areas

Zones			26 gauge	24 gauge	22 gauge	20 gauge	18 gauge	16 gauge	14 gauge	12 gauge	10 gauge	4 gauge
F1 to F7	Existing VC 10 Nyvin cables	Number off	-	-	578	156	59	26	12	20	15	-
		area mm^2	-	-	1815.8	648.1	289.6	160.1	108.9	215.5	294.5	-
	Modified VC 10 KP150 cables	Number off	-	336	242	156	59	26	12	20	15	-
		area mm^2	-	302.1	287.6	268.4	138.7	80.0	46.8	108.0	294.5	-
	Remote control KP150 cables	Number off	586	165	42	4	2	21	3	6	-	-
		area mm^2	415.4	148.4	49.9	6.9	4.7	64.7	11.7	34.1	-	-
F7 to F8	Existing VC 10 Nyvin cables	Number off	-	-	511	144	54	12	39	13	6	12
		area mm^2	-	-	1605.4	598.3	265.1	73.9	354.1	147.4	117.8	815.2
	Modified VC 10 KP150 cables	Number off	-	314	197	144	54	12	39	13	6	12
		area mm^2	-	282.4	234.1	247.7	126.9	36.9	152.3	73.9	117.8	815.2
	Remote control KP150 cables	Number off	477	177	42	1	2	8	38	20	8	12
		area mm^2	338.1	159.2	49.9	1.7	4.7	24.6	148.4	113.7	157.1	815.2
F8 to F4	Existing VC10 Nyvin cables	Number off	-	-	353	29	23	9	21	13	-	12
		area mm^2	-	-	1109.0	120.5	112.9	55.4	190.7	147.4	-	815.2
	Modified VC 10 KP150 cables	Number off	-	225	128	29	23	9	21	13	-	12
		area mm^2	-	202.3	152.1	49.9	54.1	27.7	82.0	73.9	-	815.2
	Remote control KP150 cables	Number off	248	109	42	9	3	11	23	4	-	12
		area mm^2	175.8	98.0	49.9	15.5	7.0	33.9	89.8	22.7	-	815.2

Trunking proportions

Zones		Total area (A) mm^2	Side $\sqrt{A}$ mm	Proportion of total length (ℓ)	Zone $\ell\sqrt{A}$
F1 to F7	Existing VC 10 Nyvin cables	3532.5	59.43	0.208	12.36
	Modified VC 10 KP150 cables	1526.4	39.07	0.208	8.13
	Remote control KP150 cables	735.8	27.13	0.208	5.64
F7 to F8	Existing VC 10 Nyvin cables	3977.2	63.07	0.375	23.65
	Modified VC 10 KP150 cables	2087.2	45.68	0.375	17.13
	Remote control KP150 cables	1812.6	42.57	0.375	15.96
F8 to F4	Existing VC 10 Nyvin cables	2551.1	50.51	0.417	21.06
	Modified VC 10 KP150 cables	1457.2	38.17	0.417	15.92
	Remote control KP150 cables	1307.8	36.16	0.417	15.08

(a) Existing VC110 Nyvin cables. Total $\ell\sqrt{A} = 57.07$. Ratio $\frac{(b)}{(a)} = 0.72$

(b) Modified VC 10 KP150 cables. Total $\ell\sqrt{A} = 41.18$.

(c) Remote control KP150 cables. Total $\ell\sqrt{A} = 36.68$. Ratio $\frac{(c)}{(b)} = 0.89$

Table 13

EFFECT ON CABLES OF MOVING ELECTRICAL BAY FROM ZONE F7 TO ZONE F8 (SCHEME 2)

Cables	Unit mass	Conventional system		Remote control		Totals	
		Quantity	Total mass	Quantity	Total mass	Conventional	Remote
Main bus-bars shifted to rear by 8.25 m		m	kg	m	kg	kg	kg
Main feeder							
4 gauge	251.9 g/m	-99.0	-24.94	-99.0	-24.94	-24.94	-24.94
New sub-feeders to F1							
8 gauge	99.4 g/m	+63.5	+6.31	-	-	-	-
10 gauge	64.5 g/m	+127.9	+8.19	+63.5	+4.09	-	-
12 gauge	29.8 g/m	-	-	+47.6	+1.42	-	-
14 gauge	19.3 g/m	-	-	+142.7	+2.75	-	-
20 gauge	6.95 g/m	-	-	+47.6	+0.33	+14.5	+8.59
New sub-feeders to F8							
14 gauge	19.3 g/m	-	-	+8	+0.154	-	-
18 gauge	10.41 g/m	-	-	+64	+0.666	-	-
20 gauge	6.95 g/m	-	-	+4	+0.028	0	+0.848
New sub-feeders to F4							
12 gauge	29.8 g/m	-	-	+82.8	+2.47	-	-
14 gauge	19.3 g/m	-	-	+41.4	+0.799	-	-
18 gauge	10.41 g/m	-	-	+62.1	+0.65	-	-
20 gauge	6.95 g/m	-	-	+248.4	+1.73	0	+5.65
Sub-feeders scheme 1						-3.79	-20.18
Distribution cable							
10 gauge	64.5 g/m	+41.2	+2.657	-	-	-	-
12 gauge	29.8 g/m	-98.8	-2.944	-33.0	-0.98	-	-
14 gauge	19.3 g/m	-271.8	-5.246	-321.2	-6.2	-	-
16 gauge	14.8 g/m	-16.5	-0.244	-66.0	-0.98	-	-
18 gauge	10.41 g/m	+8.2	+0.086	+57.6	+0.6	-	-
20 gauge	6.95 g/m	-74.1	-0.515	+6.1	+0.04	-	-
22 gauge	4.23 g/m	+214.1	+0.906	-156.5	-0.66	-	-
24 gauge	2.9 g/m	+189.0	+0.548	-173.3	-0.50	-4.75	-8.68
Control signal cable							
26 gauge	2.0 g/m	-	-	+1578.4	+3.157	-	-
24 gauge	2.9 g/m	-	-	-110.0	-0.319	-	-
less 4 × 12 way connectors	36 g	-	-	-4 off	-0.144	0	+2.69
						-18.98	-36.02

Reduction in mass of 18.98 kg and 36.02 kg respectively for conventional system and remotely controlled system.

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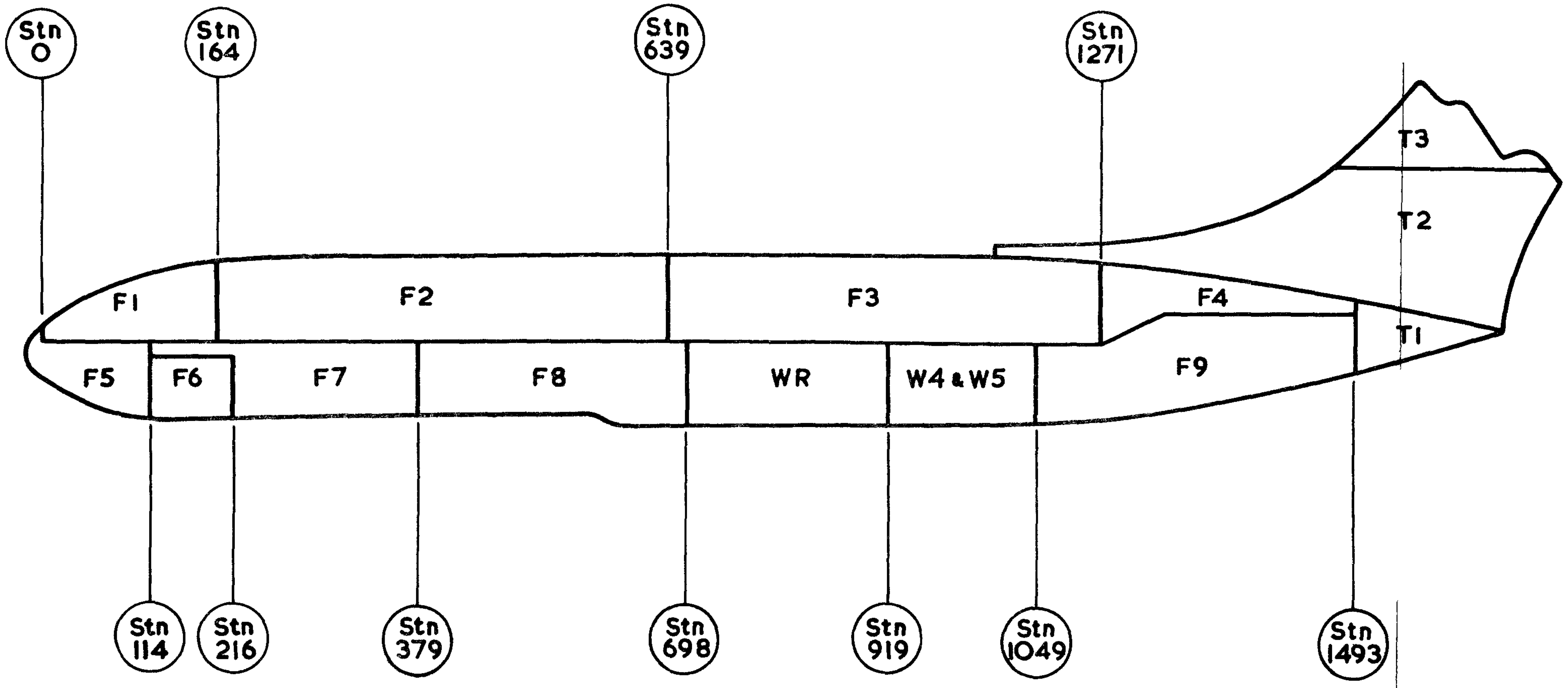

F1 Crew compartment

Existing elec$^{t.}$ panels

	Stn
A - Dashboard	60
B - Engineers	137
C - Distribution	160
D - Centre console	74
E - Roof	85
EA - Maintenance	
EB - Roof equip$^{t.}$	165

Proposed new bus bars & logic box locations — adjacent to Stns 137 to 160

F7 Electrics bay

Existing elec^{t} panels

	Stn
G - Equipment (L)	235
H - Equipment (R)	235
J - ac power (L)	252
K - ac power (R)	252
U - dc power (L)	274
Z - dc power (R)	274
P - ac emergency	216
PA - Equipment (for'd)	216
RL - Radio (L)	348
RR - Radio (R)	348

Proposed new bus bars & logic box locations — adjacent to Stns 252 to 274

F8 For'd baggage

Proposed new bus bars & logic box locations — adjacent to Stn 698

F4 Rear fuselage

Existing elec$^{t.}$ panels

	Stn
V - Rear elec$^{t.}$ (R)	1279
S - Rear elec$^{t.}$ (L)	1279

Proposed new bus bars & logic box locations — adjacent to Stn 1279

Other zones & panels

		Stn
F2 For'd cabin. Elec$^{t.}$ panel	– L for'd stewards	276
	– LB centre stewards	639
F3 Rear cabin. Elec$^{t.}$ panel	– LA rear stewards	1173
F5 Nose bay. Elec$^{t.}$ panel	– X demist/deice	66

F6 Nosewheel bay
F9 Rear baggage
WR Wing root
W4 & W5 L&R landing gear bays
T1 to T3 Fin & tail

Approximate lengths of cable runs

Zones F1 to F7 — 8·24 metres
Zones F7 to F8 — 13·11 metres
Zones F8 to F4 — 15·25 metres
} Between zone bus bars or logic boxes

Zones not shown

T4 to T6 – Tail plane
W1 – Main wing (L)
W2 – Wing tip (L)
W3 – Trailing edge (L)
W6 – Trailing edge (R)
W7 – Wing tip (R)
W8 – Main wing (R)
M1 to M4 Engine bays
MS1 & MS2 Engine stubs

(L) – Left hand
(R) – Right hand

Fig.1 Locations of zones, panels and bus bars on VC10

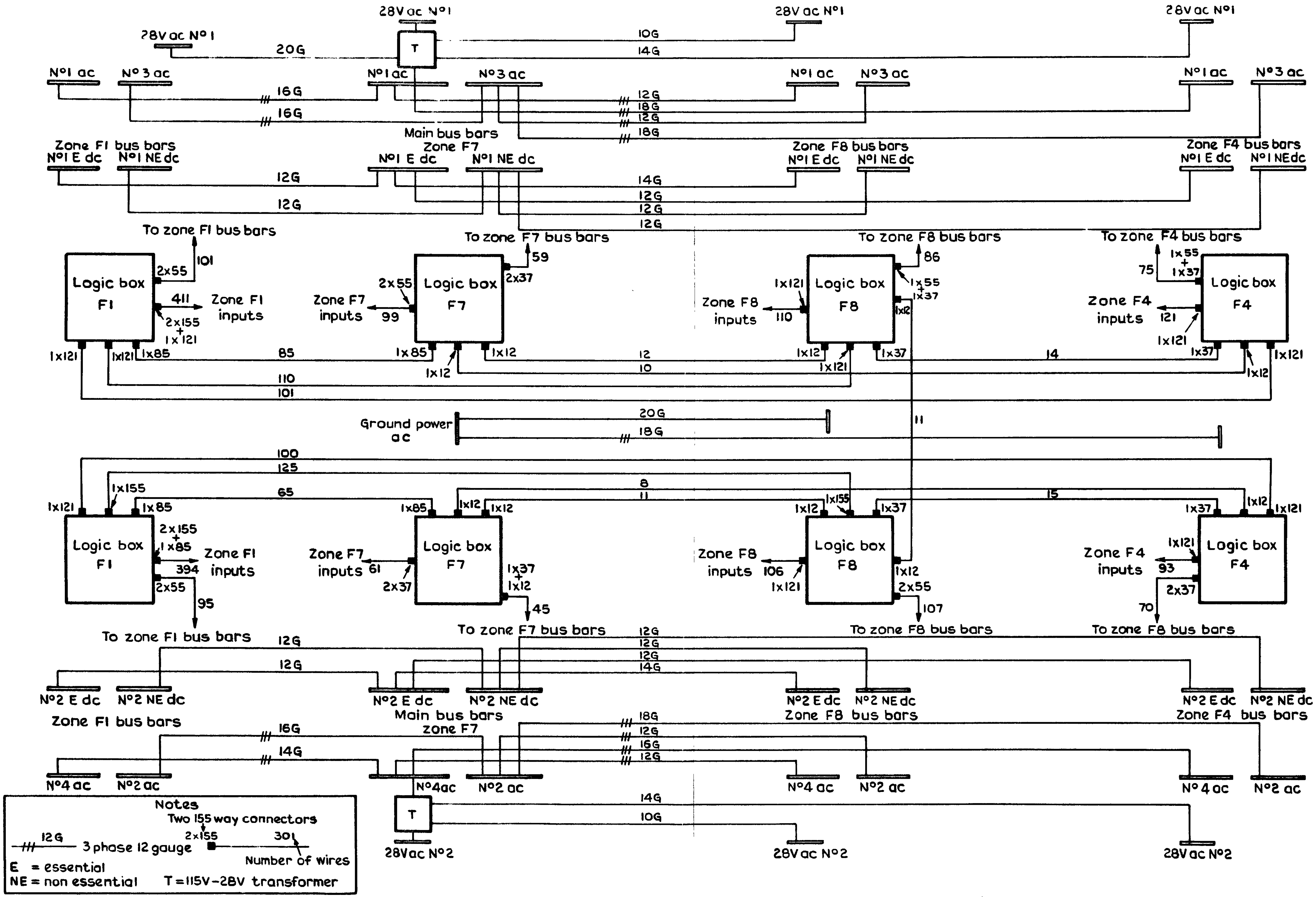

Fig.2 Layout of proposed remotely controlled system (scheme 1)

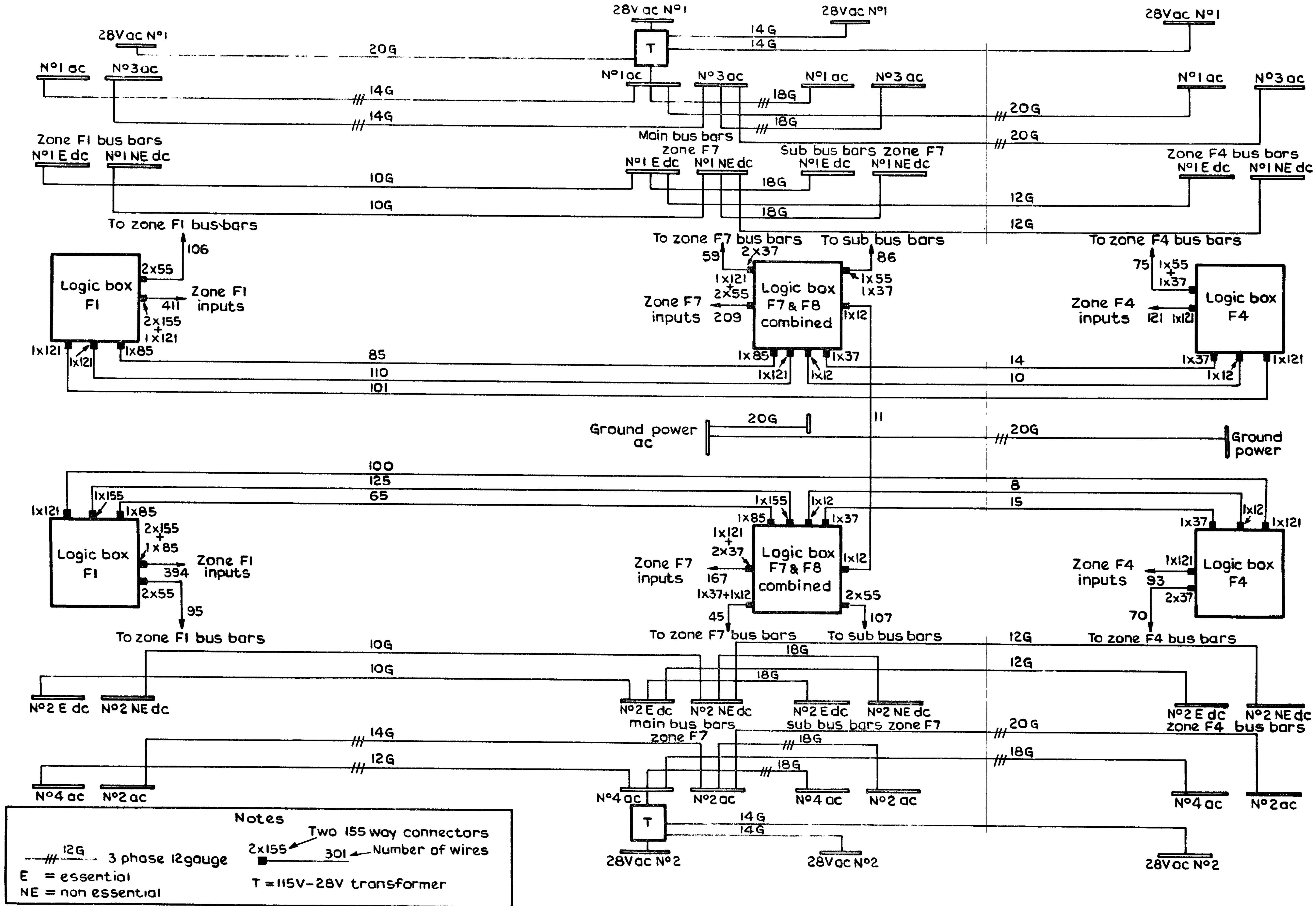

Fig.3 Layout of proposed remotely controlled system (scheme 2)

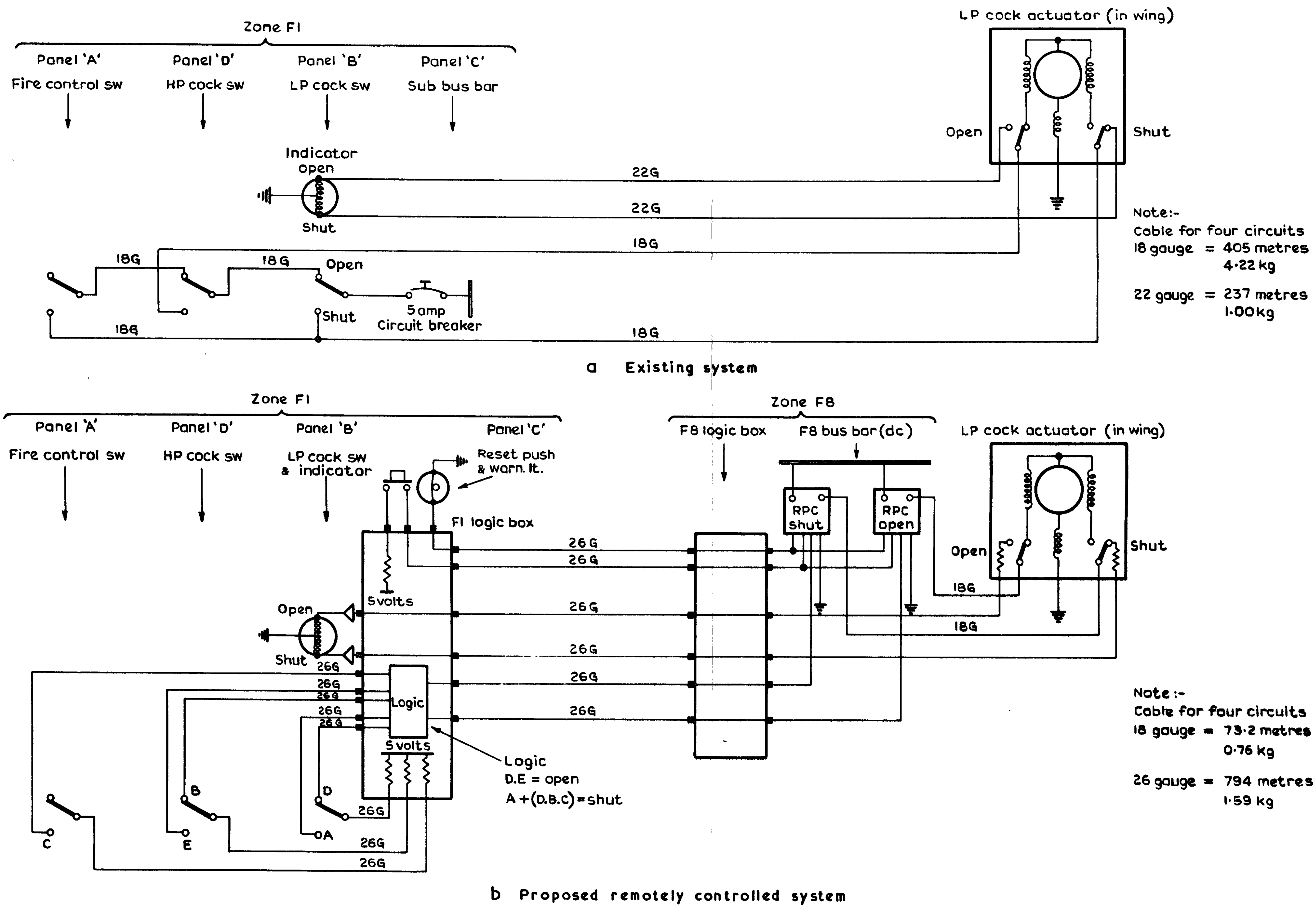

Fig.4a&b Conventional & remote control versions of a typical circuit

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The effect on both systems of resiting the electrical compartment from the forward to a mid-aircraft position has been examined and it is concluded that a further saving of 36 kg would result with remote control.

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