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NIL SINE LABORE

The Design of Martlesham Research Centre

Part 2—Services Provided

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The first part of this article discussed the procedures adopted in the design of the Martlesham Research Centre and described the design of the buildings. This second and concluding part describes the services provided in the Research Centre.

INTRODUCTION

Part 1 of this article* outlined the guiding principles adopted in the design of the Martlesham Research Centre, discussed the production of the Schedule of Requirements and described the overall design of the buildings. This second part describes the services that have been provided in the Research Centre.

THE AIR-CONDITIONING SYSTEMS

Laboratory Block

The air-conditioning plant serving the laboratory block comprises 5 independent similar installations, one on the lower-ground floor of each of the 5 structural zones that make up the building (see Fig. 6, Part 1). Only one of these need be described here.

A dual-duct system is used, in which up to 90% of the returned air can be recirculated after filtering and conditioning; the remainder is made up from fresh-air supplies. The equipment on the lower-ground floor delivers 2 streams of air, one heated and the other cooled, in a quantity to give an adequate rate of change for ventilation purposes (in the range 4–10 air-changes/h), and in the correct proportions in each individual group of rooms to achieve the required pre-set local temperature. With this system, the amount of heat supplied to, or removed from, individual groups of rooms is adjusted by altering the proportion of hot-to-cold air in mixer boxes above the ceiling, under the control of a thermostat.

A block diagram of the laboratory block air-conditioning system is shown in Fig. 8. The air circulation starts in the air chamber (which is divided into 2 compartments shown as intake and exhaust) by a diaphragm wall having an adjustable louvred aperture. Air extracted from the building is returned to the exhaust compartment; the required proportion of it is drawn through the louvre into the intake compartment, where it mixes with not less than 10% of fresh air. Air is drawn from the intake compartment through a filter by a 110 kW centrifugal fan having a through capacity of 47 m^3/s, and, at a pressure of 1·12 kPa, divides into 2 separate air ducts. The first becomes the hot air stream; the second becomes the cold air stream. The dampers controlling the supply air are continuously variable, and adjust the proportions of recirculating and fresh air according to their relative conditions.

The first air stream goes into a heater battery to emerge dry at a controlled air temperature of 32·2 ± 1·1°C. A heater battery is like an enormous car radiator fed with hot water from the main boilers. The hot filtered air is ducted to the vertical hot riser and passes from the lower-ground floor up through the building to be tapped at every floor.

The second air stream goes into the cooler battery, again in principle like a giant car radiator, but cooled by water at 4·4°C from the refrigeration plant. The cold air is humidified by water spray to near saturation, and emerges from the humidifier at a controlled temperature of 10 ± 1·1°C and relative humidity of 98% (that is, just below dew point) and a pressure of 1·12 kPa; it then enters the vertical cold-riser to pass up through the building.

At each floor level, hot and cold horizontal ducts in the ceiling voids tee out from the vertical risers to carry the 2 air streams to an elaborate system of distribution ducts covering the whole ceiling area, each hot and cold pair terminating in a mixer box. About 800 mixer boxes are provided in the laboratory building, located according to laboratory needs and the amount of heat to be moved. Each mixer box has 2 entry points, one taking cold air and the other hot air. The proportion in which mixing occurs is controlled by flap valves which are pneumatically operated under the control of room thermostats. The present standard room temperature is 20 ± 1·1°C. From the mixer boxes, air at the required temperature is ducted into each room through grills in the sides of the fluorescent-light fittings mounted flush with the ceiling. Stale air is drawn from the rooms, over the fluorescent lamps, up into the void above the ceiling; this lowers the lamps' operating temperature, thereby increasing lamp life and raising the temperature of the returning air for recirculation. Heat from the lighting makes a useful contribution to heating the building.

Extracted air is drawn back from the ceiling voids into the return-air shaft running down through the central zone core, the suction being provided by a 55 kW extraction fan in the lower-ground-floor plant room. This fan delivers the stale air to the exhaust-air chamber from which it is drawn for cleaning and recirculation as already described. If it becomes necessary to isolate a zone on the lower-ground, ground or first floors to prevent an undesirable gas entering the air-conditioning system, electro-pneumatically-released safety flaps operate to close the entry to the return-air risers. These flaps, when released by wall-mounted emergency buttons, prevent recirculation of bad air; simultaneously, large fans in the main outer wall are started and these exhaust into the open air.

Although complex, the air-conditioning system is fully automatic once basic adjustments have been made. It is fairly flexible in application and will deal with a wide range of local heat dissipation in the laboratories. It can remove a continuous maximum average heat load of 150 W/m^2 over all floors at any season of the year. Heat from lighting accounts for 50 W/m^2, solar gain can produce up to 50 W/m^2 depending on the sun's elevation, and equipment can produce the

† Mr. Floyd was Head of the Division responsible for the planning of the Martlesham Research Centre and for organizing the move from Dollis Hill, from the beginning in 1964 until his recent retirement

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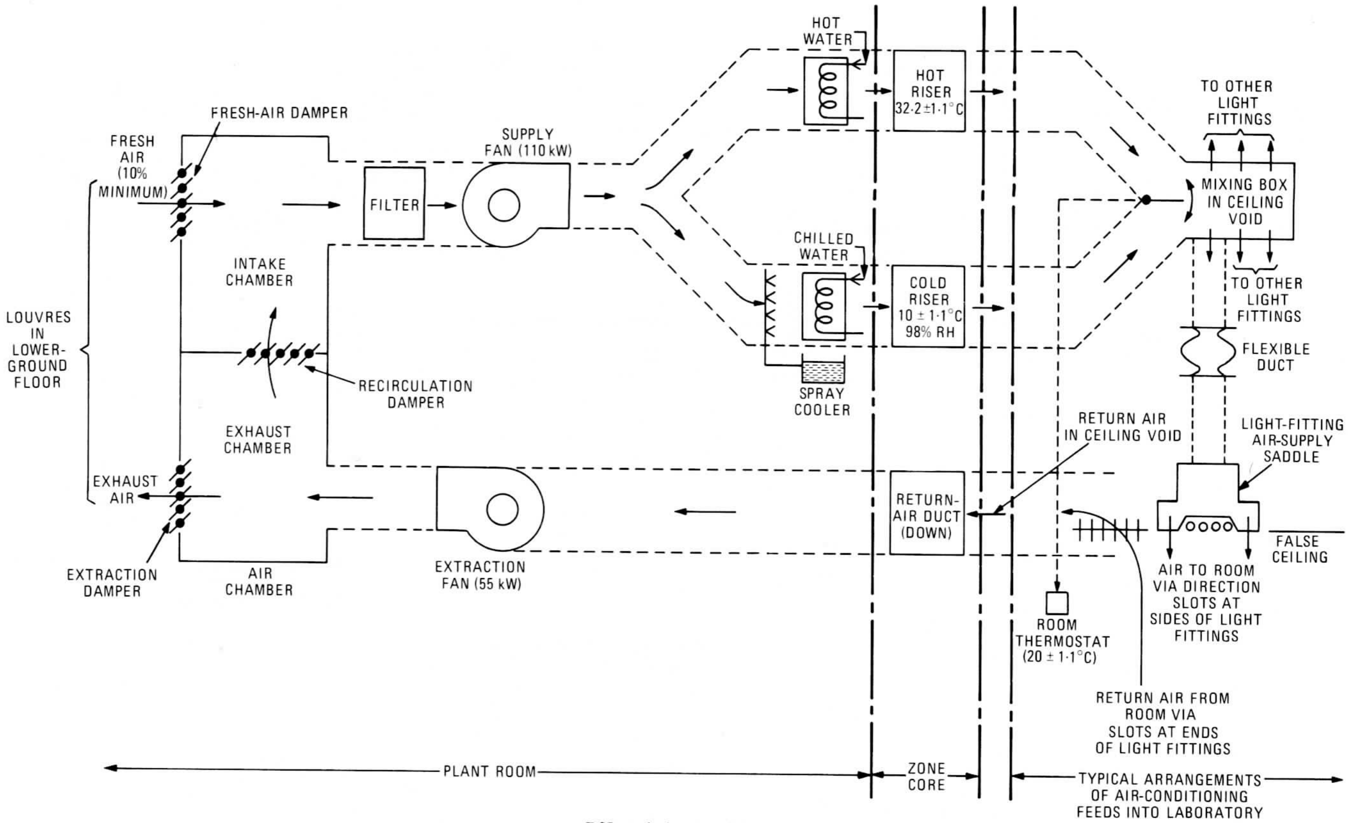


RH—relative humidity

FIG. 8—Block diagram of air-conditioning system for one zone of laboratory block

remainder. Locally, equipment dissipation can be allowed to rise to 100 W/m^2 without causing any disturbance to air conditions. Each of the 5 zones has a humidifier at the main cold-duct output in the basement plant room, and automatic controls ensure that this gives an average relative humidity of 50–70% everywhere in the building. This is not adjustable locally.

Most of the controls in the air-conditioning system are pneumatically operated by compressed air supplied from a centrally-situated air-compressing plant on the lower-ground floor.

The acoustic attenuation between adjacent rooms and the noise level of air emerging from the ceiling units is acceptable for normal laboratory conditions; frequently, the effect of noise from the ceiling units is completely masked by other noise contributions in the room.

To most people, the air noise level is unnoticeable in a laboratory or a laboratory-office.

Administration Block

There are 11 air-conditioning units in the administration building, each serving separate floors or individual rooms; 6 of these units are in the basement, underneath the entrance hall. The remaining 5 small air-conditioning units are in the plant room on the roof; these all serve the top floor, main dining room, coffee lounge, and parts of the kitchen. This multiple-unit system has been remarkably successful in preventing the rest of the building from being aware of the proximity of the kitchen on the top floor.

Some elements of the administration building (for example, the lecture theatres) are used only intermittently, and it would be uneconomical to heat and air-condition them continuously. The multiple-unit air-conditioning system permits selective economy. A block diagram of one of the air-conditioning units in the administration block is shown in Fig. 9. Hot water is supplied from the main boilers and cold water supplied from the refrigeration plant to vary the temperature of the supply air under the control of a wet-bulb sensor at a cold point in the supply duct. This provides "standard air" at a temperature of 10 ± 1·1°C and 100% relative humidity. The room temperatures are jointly monitored by a thermostat in the exhaust duct which controls the reheating of the incoming supply to give the desired average room temperature.

Refrigeration Plant

A large amount of cooling is needed by the air-conditioning plants, and especially by the dual-duct air-conditioning system in the laboratory block. Cold water for all the buildings is produced by 3 refrigeration units, each of 650 short tons refrigeration capacity,† using centrifugal compressors each of which is driven by a 670 kW 3·3 kV 3-phase motor. This commercial cold-store type of refrigerator uses softened water to minimize pipe corrosion, and the total plant can produce a cooling effect equivalent to extracting the latent heat of water to manufacture 1950 short tons of ice in 24 h. The heat produced by the compressing of the refrigerant gas is dissipated in 3 cooling stacks on top of the water tower.

These large refrigerators are very noisy machines because of their enormous centrifugal compressors. Each machine is on isolated mountings on the ground floor on the west side of the cruciform, but air-borne noise enters the main girder-work of the research services block, which was not designed against noise of this intensity. Additional walls are being built on 2 sides of the refrigerator room to increase the sound attenuation in the inward direction. The source of noise is believed to be at the blade tips of the centrifugal compressors which move at a velocity approaching the speed of sound. It is not surprising that, even with a perfectly-balanced rotor, noisy operation is endemic in this type of machine. This is,

† A capacity of 1 short ton refrigeration is the ability to produce 907 kg of ice in 24 h from water at 0°C

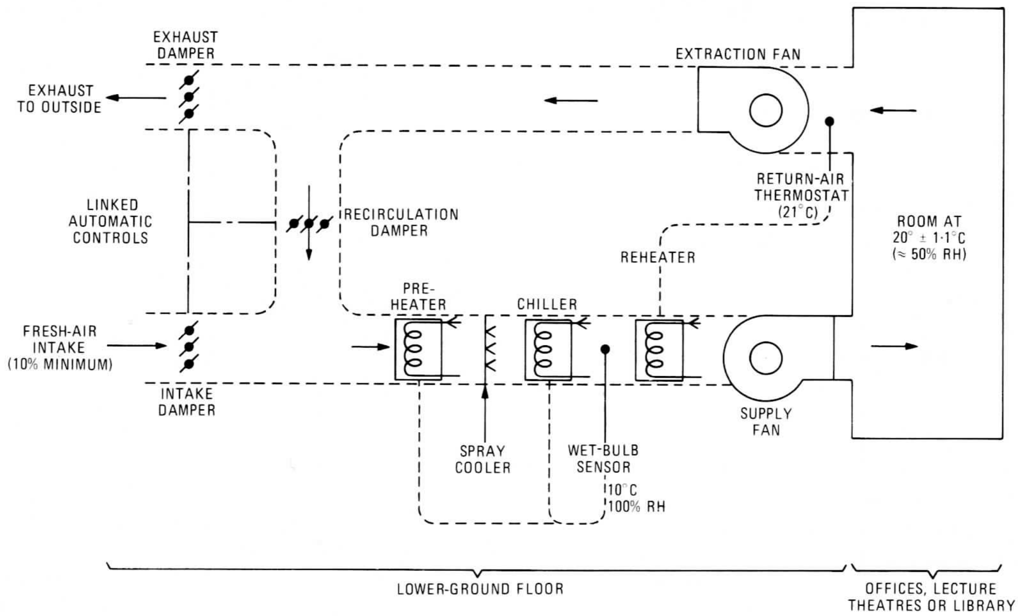
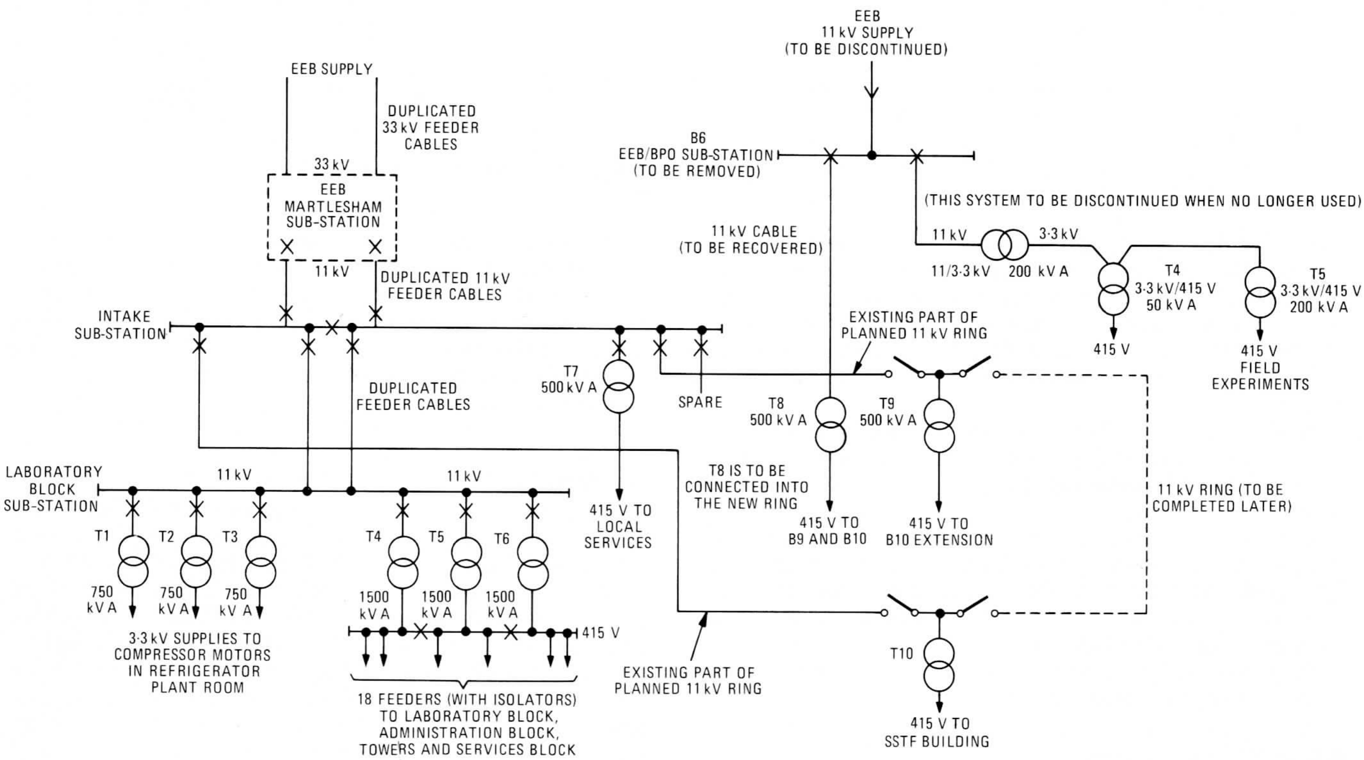


FIG. 9—Block diagram of administration block air-conditioning unit



SSTF—Switching Systems Test Facilities Building
EEB—Eastern Electricity Board

FIG. 10—High-voltage distribution to buildings

however, the most efficient type of large refrigerator, especially when well loaded.

Bench Equipment Cooling System

An additional cooling facility that can be provided at any laboratory bench is a supply of softened chilled water for cooling local equipment. Chilled water tapped from the main refrigerated supply is used as a source and this is connected to a network of 12·5 mm bench feeders that can be connected wherever needed. At present, this system has a maximum total heat absorption capacity of about 15% of one of the large refrigerator machines. It may prove uneconomical to operate this bench service in cold weather when the main refrigerator plant will not need to run for air-conditioning purposes. It could be advantageous to install a small refrigerator unit specifically for bench equipment cooling duties, so that the main refrigerators can be shut down during winter.

Boilers

The heat for all the main buildings is supplied by three 2930 kW (10 MBtu/h) natural-gas-fired boilers, with oil stand-by, accommodated in one large boiler house; there is room for a further two 5860 kW (20 MBtu/h) units in the future. The heat is carried away at 115°C in softened and de-mineralized water at 620 kPa and imparted to air at the many heat exchangers for heating the buildings. It is also used to produce hot water for the washbasins in the 2 tower

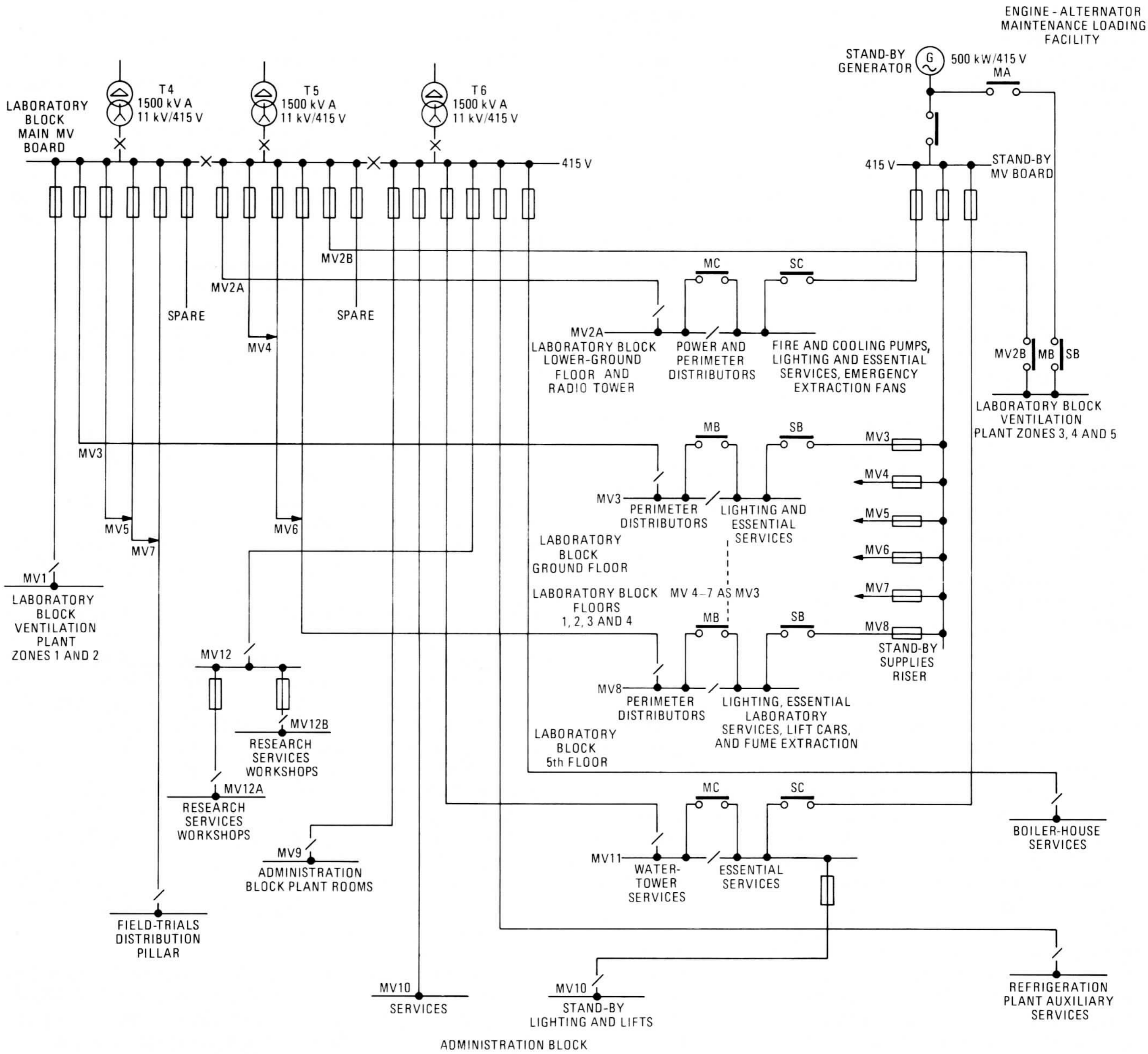


FIG. 11—Medium-voltage (MV) 415/240 V 3-phase network

blocks and the restaurant kitchens. The boiler house is situated on the lower-ground floor in the north wing of the cruciform below the water tower. Pump noise can be troublesome in rooms in the research services block near to the boiler house because it is difficult to damp down this noise at source.

ELECTRICITY DISTRIBUTION SYSTEM

The Research Centre receives its electricity supply from the Eastern Electricity Board (EEB) on duplicated 11 kV feeders from an EEB open-air sub-station just outside the north boundary fence of the site. The maximum design load for the Centre is 7 MW; the normal running load is expected to be about 4·5 MW.

From a main sub-station alongside the gatehouse of the research site, an 11 kV distribution network feeds

(*a*) a sub-station alongside the laboratory block,

(*b*) a 500 kV A transformer feeding the road lighting system and adjacent building, and

(*c*) an 11 kV ring main that is being installed round the whole site.

Fig. 10 shows the 11 kV power distribution to the buildings, and Fig. 11 shows the medium-voltage 415/240 V 3-phase network that carries power into and within the buildings.

The laboratory block sub-station houses 6 oil-cooled distribution transformers, T1–6 in Fig. 10, any 3 of which supply all the new buildings at 415/240 V 3-phase. This sub-station is in an isolated building, located between the laboratory block and the water tower, with the 6 transformers in individual brick cubicles open to the air for ventilation. Three of the transformers, each of 750 kV A rating, provide 3·3 kV 3-phase supplies to the three 670 kW refrigerator motors in the refrigerator plant room. The other 3 transformers are each 1·5 MV A rating and supply 415/240 V busbars, from which 16 circuits radiate to medium-voltage switchboards; 9 of these are in the laboratory block, 2 are in the administration building, 4 in the research services block and one feeds a field circuit.

A medium-voltage distribution system to individual floors was decided upon because a study showed that it would be more economical than a high-voltage system with transformers on each floor. The fire risk is also reduced because the oil-cooled transformers are outside the laboratory building.

Figs. 10 and 11 show that every opportunity has been taken to operate units in parallel so that out-of-service time due to power equipment failure is cut to a minimum. For example, the 11 kV–415 V transformers T4–6, which feed the laboratory block, are paralleled to the busbars from which all the laboratory distribution springs. Two can handle the maximum load; the third acts as a stand-by.

Power for the courtyard single-storey buildings, B9 and B10 on Fig. 2, and the many small buildings on the site is fed from an 11 kV ring main that is being installed round the periphery of the grounds. Spurs can be run to switchboards and step-down transformers wherever necessary, whether in isolated buildings or outdoors. There is no doubt that the ring-main system is technically the best way to provide the flexibility in the power distribution network that is necessary on a complex experimental site such as Martlesham.

The road lighting system uses Ministry of Transport standard mercury fluorescent road lamps on 7·6 m columns, and on 10 m columns in car parks. It operates from a 415 V–240 V transformer in the gatehouse sub-station. At present, each lamp is fitted with its own time switch so that lamps can be selectively operated. This will be changed to a system of batch switching, which is preferred from experience gained over the first whole season.

As is now usual with engineering buildings in the BPO, the Accommodation Services Section of the Operational Programming Department was responsible for the design of the electrical services and lifts in the new main buildings.

Stand-by Diesel-Alternator Set

A 0·5 MW self-starting diesel-alternator set, generating 415/240 V, has been installed as an emergency stand-by supply. This engine set gives full output voltage on full load 25 s after the operation of the NO-VOLTS relay. The question of how best to provide electricity in emergencies presents a problem in this large air-conditioned complex because the water-circulating pumps and the air-circulating machinery are all electrically operated. The lighting load is also large. At least 2 MW stand-by engine capacity will probably be needed to keep the Research Centre functioning under minimal conditions if the EEB supply fails. Such a large capital investment for a rare fault condition was not thought to be justified when the project was in the planning stage and, as a result, electrical circuits are arranged so that only 10% of the lights and a few selected laboratories are connected to the diesel-alternator set when the EEB supply fails. None of the air-conditioning motors is on the emergency supply because the electrical load would be too great for the diesel set. Experience has already shown that a larger stand-by capacity is essential and that diesel-alternator sets to give at least 2 MW capacity may, after all, have to be installed to cover EEB power failures.

LIGHTING

Much attention has been paid to lighting in the laboratory block where deep rooms and windowless laboratories rely on efficient artificial light. An average illumination intensity of 600 lx was specified from the outset, using fluorescent lamps and lighting fittings flush with the ceiling. The spacing of the fittings had to be compatible with the dimensions of the module on which partitions were to be located. A total of 7700 flush ceiling light fittings with a total power consumption of about 1·5 MW is required in the main building.

Ventilation through Ceiling Fittings

It was also decided at the design stage to place all air entry and exit grilles in the ceiling and to combine these with the light fittings, thus ensuring that wherever there was light there could also be ventilation and heating. As a result, the partitions were freed from any complications involving air-conditioning. Not all the flush light fittings had to convey air, but those that did were equipped with an air saddle; this connected the incoming air streams with longitudinal slots on the side of the fittings, and vented the stale air from the room through end slots and over the fluorescent lamps back into the return-air void. The combined air-handling capacity of a saddle and air grilles in the light fittings, estimated at 170 m^3/h, has proved adequate. A sound-absorbing device was incorporated in the air saddle to reduce sound transference from room to room via the air ducts. A test figure of 26 dB attenuation between adjacent laboratories is attained against this source of sound transference. The unusual requirements and large number of fittings needed made it economic to place a development contract for a special design of combined lighting/air-grille fitting for the Martlesham laboratory block.

Low-Voltage Lighting Control

The control of lighting presents problems when demountable partitions are involved, because it is undesirable to have to alter 240 V mains wiring when partition walls are moved. A system of 50 V d.c. control is used, with a relay in every light fitting and all the ceiling light circuits permanently wired to the 240 V supply. Switches operating at a voltage of 50 V can be inserted into wall partitions and can be safely moved when partitions are changed. No light fitting need be touched when partition walls are altered. All the 50 V relay coils and the wall switches are wired back to one of a number of large matrix boards situated in plant rooms on each floor and, by using a system of cross patching, any combination of lights can be wired to any room switch. A diode matrix is arranged so that, in the event of a mains power failure, about 10% of the ceiling lamps operate from the diesel-alternator set as stand-by lighting. This matrix system of lighting control, using 50 V d.c. to operate mains switching relays, has proved satisfactory and flexible in room planning. The lighting intensity measured on test from the new flush fittings is well above that specified, even giving rise to complaint in some laboratories; using the patching matrix, alternate fittings can be cut out of circuit to reduce the intensity if it proves undesirable locally.

It has also been noted that lighting intensity should not be uniform over a large area nor along a corridor, but should vary from place to place. The eye finds uniformity tiring and ultimately objectionable when the lighting is too bright.

LIFTS

An efficient lift service is essential for the smooth running of buildings the size of the Martlesham Research Centre. There are 16 lifts in all: 11 for passengers, 3 for goods and 2 light-load service lifts. Six are in the radio tower, including a 5 t goods lift and one with 22 stations including all mezzanine floors, the tower laboratories and aerial galleries. Six are in the water tower, including a 5 t goods lift and one with stations at all the mezzanine floors in the water tower. Four are in the administration building, including one main passenger lift, one goods lift to the kitchen, a book hoist in the library and a light-load kitchen service lift to the Director's dining room.

Each of the 8 main passenger lifts is driven by a variable-voltage d.c. motor, having a useful power output of 15 kW, and take a load of up to 900 kg (13 passengers) at 1·5 m/s. Each bank of passenger lifts operates on a group control system, whereby selected lifts are brought into operation according to the traffic demand. Every lift has 2 home stations, one at each end of its travel. After its passengers have emerged, a lift continues in the same direction to its home station (usually the top or bottom floors), and waits there until its next instruction from the control unit, which must be in the reverse direction from the last journey.

TABLE 6

Main Performance Features of Lift Installations

Lift Number	Location	Speed (m/s)	Number of Floors Visited	Duty	Maximum Load (kg)	Type of Lifting Motor
A1	Administration building	1·0	5	Passenger	900	Induction motors, 2-speed
A2		0·5	2	Goods	760	
A3		0·15	2	Service hoists	25 each	Induction motors
A4						
R1	Radio tower	1·4	7	Group control, passenger	900 each	DC motors
R2						
R3						
R4						
R5		0·3	8	Goods	5080	Induction motor
†R6		1·0	22	Passenger	680	Induction motor, 2-speed
W1	Water tower	1·4	7	Group control, passenger	900 each	DC motors
W2						
W3						
W4						
W5		0·3	7	Goods	5080	Induction motor
†W6		1·0	11	Passenger	680	Induction motor, 2-speed

† Fireman's facility

The d.c. for the lift motors is supplied by 13 kW motor-generator sets using 3-phase squirrel-cage driving motors. The lift control gear operates at 110 V d.c., supplied by a 3-phase rectifier. Six wire ropes in parallel are used for hoisting each lift cage. The total length of suspension rope used is over 4·8 km. The 5 t goods lifts are much slower than the passenger lifts and are driven by 2-speed induction motors, rated at 18 kW. However, a smaller motor takes over just before the destination floor to give fine control over the stopping level, which is accurate to 6 mm. Loaded trolleys can then easily enter or leave a lift without having to negotiate a step. Table 6 gives the main performance features of all the lift installations.

FUME CUPBOARDS

Many Research Department projects involve chemical processes that use noxious, or even dangerous, gases and this work must be restricted to fume cupboards with efficient ventilation systems. Such gases must not be allowed to leak into the air-conditioning system of the building, and so careful attention has been given to the engineering of the ventilation. Fume cupboards are tools of the trade in the research divisions concerned. They are likely to be used for a variety of purposes and substances, but probably operate intermittently.

For operational reasons, all the chemical work in the laboratory block has been located on the lower floors of the building. Fume cupboards may be needed anywhere on these floors and must, therefore, be treated as movable items, not part of the building.

To prevent exhaust gas from one fume cupboard feeding back through the exhaust flue of another cupboard not in use, every cupboard must have its own independent flue rising to at least 2·4 m clear above roof level. The vertical flues were installed as part of the building contract, and are located over the 5 zones in 10 stacks of 8 (that is, 16 flues per zone). Each permanent vertical flue is then joined as required by a horizontal run below a laboratory ceiling to the fume cupboard in the desired position. The flues are of 230 mm inside diameter plastics-coated asbestos pipe, with sealed spigot-and-socket joints.

For safety reasons, air must be drawn into a fume cupboard, not blown; so substantial 300 mm suction fans with motors having an effective output power of 1·12 kW, and able to create a reduced pressure of 622 Pa at throat entry, are mounted above roof level on each flue. With this low pressure, which is necessary because the flues are over 30 m long, an air input to a fume cupboard approaching 0·38 m^3/s could occur. If this quantity of air were extracted locally from a laboratory, the air-conditioning stability could be upset. So each fume cupboard can be provided with a conditioned fresh-air input, ducted from beneath the nearest balcony by a standard packaged unit consisting of input fan, electric heater, filter and control louvres. This unit is installed unobtrusively underneath the balcony overhang and is easily accessible from below. It is estimated that 70% of air entering a fume cupboard can be drawn from fresh air with considerable saving in air-conditioning costs. A fresh-air intake for each fume cupboard presents no location problem as balconies run continuously round each floor.

It is probable that only about half of the flues will be in use, as fume cupboards are expensive and will be installed only as required.

Since the time of the design of the laboratory building, there has been a considerable increase in the amount of toxic substances used by Research Department, notably in semiconductor research. There is now also a need to increase the amount of clean-room accommodation beyond that envisaged when the Schedule of Requirements was being drawn up. It has, therefore, been decided to convert some of the single-storey buildings B9 and B10 (see Fig. 2) on the north-west part of the site into clean-room accommodation with, close by, a number of special fume chambers in laboratories reserved for highly toxic work. Certain toxic materials are now excluded altogether from the main laboratory air-conditioned building and must be used only in the fume chambers in building B9.

THE ACOUSTICS COMPLEX

A feature of the new laboratories is the specially-designed acoustics block, situated just outside the main laboratory building and with a connecting corridor into it. It is designed to give complete acoustic isolation, with massively constructed double concrete walls on isolated foundations. This complex contains 2 anechoic chambers and a reverberant room with associated control laboratories, and a microphone calibration room.

The anechoic chambers absorb all internal sound on the walls without reflection. This is done by linings of sound-absorbing wedges, over 1 m in depth, completely covering all surfaces; a trampoline-type wire-mesh floor is used to support test equipment. Both rooms, one large and one smaller, have massive double doors to give acoustic isolation, the inner one being trolley mounted and motor operated. Equipment can be controlled from outside these rooms.

The reverberant room, about 200 m^3 in volume, is lined with hard surfaces to reflect all sound. No two surfaces are parallel, and a reverberation time of not less than 5 s has been achieved. Construction is again double-walled, the inner room being on rubber mountings.

FIRE PRECAUTIONS

All the main buildings, especially the laboratories, have a minimum main-structure fire resistance of 2 h, being protected by a Pyroc dry-clad treatment. The laboratory floor duct covers also give 2 h fire protection. The partitions are of steel and give zero flame spread. Smoke doors are provided in corridors as required by the fire authorities to limit smoke and flame spread. Those gas cylinders that must be kept in the laboratory block are held in fire-resistant cupboards.

An extensive fire-alarm system has been installed in all 3 main blocks, the 2 towers and the gatehouse. The operation of an alarm sounds a *clear-out* signal (a loud warble) in the block in which the alarm originates and a *preliminary-warning* signal (short bursts of single-tone pulses) elsewhere. The signal is repeated in the gatehouse with a location indicator, and on mimic panels outside main entrances to blocks.

Alarms can be set off by

(*a*) breaking the glass of a red fire alarm, located on all floors of all blocks,

(*b*) automatic operation of heat detectors,

(*c*) automatic operation of smoke detectors in extract ducts of all the air-conditioning systems, and

(*d*) breaking the glass of a chemical alarm, painted yellow. These are located on the lower ground, ground and first floors of the laboratory block only.

In addition to the audible and visual warnings, operation of the fire alarm in the laboratory block disconnects the power supply to the perimeter trunking of the affected floor.

As stated earlier, the operation of the chemical alarm starts up extractor fans exhausting into the open air in the affected zone and floor, and closes a trap in the air-extraction duct for that floor and zone. This prevents any gases from returning into the air-conditioning system by recirculation. The incoming air continues to flow to give a scavenge effect.

CONCLUSIONS

This article has outlined the principles that formed the basis for the planning of the new Research Centre at Martlesham, and has briefly described the laboratory services provided in the original contract. Some interesting new developments in laboratory design are incorporated, with a view to achieving economy and flexibility when the buildings have to be adapted to future technologies that cannot, at present, be specified.

The engineering design of the Research Centre was a complicated and fascinating task. But, in many ways, the organization behind the move itself, and the Move Committee, by which the unions and staff were kept informed and regularly consulted, was equally important. This more human aspect of the project will be the subject of another article in a future issue of the *Journal*.

ACKNOWLEDGEMENTS

The author wishes to thank the many people who have been engaged in the Martlesham Research Centre project during its 10-year period, and also the colleagues who have assisted in the preparation of this article.

Book Review

Microwave Devices: Device–Circuit Interactions. M. J. Howes and D. V. Morgan. John Wiley & Sons Ltd. 402 pp. 249 ills. £13·00.

As implied by the subtitle of this book, difficulties exist when semiconductor devices are operated at frequencies or speeds that are sufficiently high for the package and circuit parasitics significantly to affect and limit the inherent performance of the basic semiconductor chip. Thus, above about 1 GHz, the combined problems of device physics and technology, and device–circuit interactions, require a new breed of specialist with expertise in both areas. In the past, each of these subjects was tackled by a separate group of scientists, often with little understanding or appreciation of the other's problems. Stemming from this new approach is the tendency for semiconductor manufacturers to provide microwave-amplifier modules rather than individual transistor chips and, in the case of power transistors, to provide input-matching and output-matching networks within the transistor package itself.

This new book, the first of a series, is intended primarily to meet the needs of this new specialism, although the last chapter has an extensive survey of the applications of solid-state microwave devices and brings into context the wide range of solid-state microwave devices that are now available.

The editors are to be congratulated on bridging this gap between basic device physics and device–circuit interaction by bringing together a number of accepted authorities in these areas. Each has dealt admirably with the developments leading up to the current state of the art in his particular subject. However, with such a fast-moving subject as semiconductor research, one cannot hope to publish a definitive work, but this volume manages to update a number of classics in the field. Even in such a well-known device as the bipolar transistor, there are still mechanisms that limit the gain and frequency performance and which are far from being fully understood. High-frequency noise in both bipolar and field-effect transistors is still not adequately described, and even in such basic equations as bipolar noise formulae, there is still confusion over the use of the transition frequency (normally referred to as f_T) and the frequency at which the common-base short-circuit current gain falls to 3 dB below its low-frequency value (normally referred to as f_α).

However, these criticisms do not detract from the general usefulness of the work, and it is to be recommended as being an up-to-date account of the subject.

The level of the text is designed to be suitable for the graduate student or research worker wishing to enter the field. Basic physical concepts in semiconductors and elementary circuit theory are assumed as a starting point, and the text covers such items as Gunn and IMPATT diodes, microwave transistors, and applications such as radar, line-of-sight microwave relay, millimetric-waveguide and optical-waveguide systems.

If further volumes in the series maintain the standard set by this book, they should readily find a place as useful sources of reference.

J. C. H.