*Discussion on Paper No. 6682**

Aircraft fuelling facilities

by

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and

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Mr E. G. Tuch (Resident Engineer, F. S. Snow & Partners), said that he wished to ask a question which did not really come out in the Paper but was concerned with fuelling. As consulting engineers, his firm were involved in the development of many airports and were much concerned with the design of aircraft parking facilities. This obviously involved a multitude of requirements, from nose-wheel turning circles to passenger and cargo-loading systems.

115. In the past, one of their design criteria had been the limiting slope permitted on an apron during fuelling operations. They had been told that with pressure-fuelling, in order that aircraft could accept maximum fuel load, the slope of the apron between main wheel groups must not exceed 1 in 200. When slopes were greater than this, the tanks on the downhill side filled fastest. This aggravated the slope on the aircraft because of the movement of the oleos through the shift of the centre of gravity. The net result was that the aircraft fuel tanks shut down before they were full and, in addition, it became impossible to measure the contents accurately.

116. Although I.A.T.A. recommended that longitudinal slopes could be 1 in 100 provided that transverse falls were not greater than 1 in 200, this was not readily obtainable, particularly where there was a combination of parking configurations including nose-in, parallel and nose-out. When to this was added the difficulty that at a structure such as a terminal building or a pier one generally started with a level base line, plus the fact that fire officers demanded a fall away from a building so that there should be no risk of fire due to fuel spillage, one was obliged to reduce the maximum gradient of the apron to about 1 in 200, at which slope it became impossible to drain the apron.

117. A drainage slope of 1 in 200 was very small indeed, particularly when one considered the surface finish that was frequently used on airfields—for instance, a brushed finish giving very good non-skid qualities, as demanded for towing aircraft and for taxying aircraft. Even when the serrations ran downhill, a slope of 1 in 200 would hold water. With even very mild winds, water could be blown up such a slope. In short, a situation which was unsatisfactory in one respect was being created in order to give satisfaction from the viewpoint of fuelling.

118. Mr Tuch asked whether there were any developments in aircraft fuelling equipment—which was the crux of the matter—which might alleviate the problem so that aprons could be built with what would be considered an adequate drainage gradient of the order of from 1 in 80 to 1 in 120?

* *Proc. Instn civ. Engrs*, vol. 26, October 1963, pp. 193–218.

Mr N. H. Brear (Manager, Distribution Engineering Branch, British Petroleum Co. Ltd) said that he, too, was connected with the problem of providing an aviation fuelling service in the oil industry and was conscious of many of the problems to which Mr Hunter had drawn attention. In all cases of provision of an international aviation fuelling-service in various parts of the world, one of the first concerns, as the Authors had stated, was the provision of a viable installation, a proposition which could be operated economically, efficiently, and with full regard to the standards of safety which were foremost in everybody's mind.

120. Much had been done in recent years to improve the standard of equipment and the type of equipment provided by the manufacturers, both in this country and in other countries in which the oil companies provided fuelling services. Many improvements had been made to keep pace with the rapid developments in aviation itself.

121. Among the developments which had occurred, the fuelling of the super-jet aircraft had, perhaps, presented some of the most interesting problems, not the least of these being the question of dealing with surge pressures arising from the direct connexion to the aircraft, in which the fuelling system and the aeroplane became part of one hydraulic circuit.

122. The Authors had touched on some of the problems involved in dealing with surge and with the control of pressure applied to the aeroplane, which also became extremely important when there was physical connexion to the aeroplane. Pressure-control valve equipment had, therefore, become of the utmost importance.

123. Mr Brear asked the Authors to say a little more concerning developments in this direction which would help to give the required control of pressure at the point of entry to the aircraft, possibly in an easier manner than had been achieved hitherto?

Mr J. L. Rodger (Executive Engineer, F. S. Snow & Partners) had a particular interest in the subject as much of his work was associated with airport planning and his company were pleased to have advised B.P. Petroleum on aircraft parking configurations on aprons. Since the drawings of the nose-wheel guide lines were prepared, modifications had been made, but as these were mainly concerned with movements of the aircraft they did not vary any of the conclusions reached by the Authors.

125. The need for aircraft refuelling facilities was obvious, but some of the difficulties introduced by the provision of such facilities were not apparent. These included, in particular:

(*a*) headroom criteria for tankers;
(*b*) heavy loadings on service roads and large turning circles;
(*c*) fire risks;
(*d*) fuel spillage effect on joint sealers and black top surfaces;
(*e*) tanker parking space on aprons; and
(*f*) allocation of space for fuel storage adjacent to the apron.

As relations between fuel companies were often strained, each company required its own facilities. This could lead to excessive demands on the airport planner.

126. Some of those difficulties were overcome by the installation of hydrant refuelling, but if each company had a number of pipes leading to each hydrant and the spirit of competition was maintained, it could lead to a multiplicity of pipes serving a liberal sprinkling of hydrants on the apron. As the Authors correctly pointed out, when an apron parking layout is altered—and due to the changing pattern of aircraft this could happen frequently—either the hydrants were in the wrong position or the flexibility in apron planning was reduced.

127. Clarification on the following points would be welcome:

(*a*) Were the Authors in favour of hydrant refuelling?

(*b*) Was it correct to assume that the fuel companies paid for the underground installation, since in accordance with § 74 of the Paper they were making financial savings?

(*c*) Was the cost of fuel to the aircraft operator less from a hydrant scheme?

(*d*) Was there a discrepancy between §§ 11 and 48 of the Paper in relation to the output of a 2½-in. fitting?

128. He asked the Authors to say more about the actual time taken for refuelling an aircraft in relation to the overall time taken for an aircraft turn-round. As the planning of an apron was essentially to provide a given number of aircraft stands in the minimum space and as the number of stands required was related to the number of aircraft movements on the runway and the time during which they occupied a parking stand, any significant saving in the turn-round time could make an appreciable saving in the paved area of apron and a consequent reduction in the distance from the terminal building for passengers and baggage vehicles.

Mr G. G. MacAdam (Chief Project Engineer, Aviation Branch, British Petroleum Co. Ltd) said that he wished to make a few comments and queries upon which, possibly, the Authors could enlarge. First, the Paper emphasized hydrants more than fueller operation. This was, perhaps, because hydrants were a more interesting engineering configuration than fueller distribution and, possibly, because hydrants were the engineer's answer to the delivery of the product to the aircraft.

130. To follow up Mr Rodger's remarks, did the Authors feel that a hydrant was the answer when considering: (*a*) pipelines were being buried underneath concrete, and (*b*) the rapid development of aircraft and their changing requirements? If a hydrant was being put in the ground, a 20-year pay-off should be expected, but this was not allowed for in the development of aircraft. They were developing so quickly that apron layouts would change in less than that time.

131. The Authors had mentioned a rate of flow in hydrants of 8000 gal/min. Mr MacAdam asked what their answer would be in arriving at the peak requirement of a hydrant system? As many people knew, an airport attracted aircraft like a flock of birds; they arrived all at one time and then there might be relative inactivity for half the day. Therefore, quite a large number of aircraft had to be fuelled almost simultaneously. The word 'almost' acquired great importance, since if it did not have to be done exactly simultaneously, it would be possible to reduce the primary maximum flow rate required from the hydrant. What were the Authors' views on the maximum flow rate required by hydrant?

132. In discussing fuels for supersonic transport, distinction should be made between the supersonic machine being developed in Gt Britain and France and that being developed in America. Mr MacAdam asked whether the Author agreed that the supersonic aircraft being developed in Gt Britain and France would require facilities not significantly different from those that were now available?

133. Mr MacAdam's next point concerned the designing of airport facilities. It would appear that the function of an airport was to service aircraft as they landed, and one of the services was the provision of fuel. Other services included passenger baggage, toilet facilities, and so on, all of which accumulated at the aircraft itself. The designers of airports appeared to pay insufficient attention to these separate facilities or services and how they could best be co-ordinated. As fuel experts, had the Authors been asked by the designers of airports to sit in on such co-ordination?

134. Looking forward on airport design, and bearing in mind the quick development of aircraft and the aircraft industry—for example, the supersonic aircraft were expected towards the end of the 1960s—Mr MacAdam wondered whether airport designers looked far enough ahead in view of the fact that it took five or six years to build an airport? His own view was that all turning circles and apron layout should already be incorporating the nose-wheel guide lines for the *Concorde* supersonic aircraft and that the development people should be looking further ahead to the

vertical take-off machine. Had any thought been given to airport design for vertical take-off, which was not likely to be far behind the arrival of supersonic machines? It was definitely coming, and it would be worthwhile for people to investigate how it would affect airport facilities.

Mr R. C. Tennant (Senior Development Engineer, British Petroleum Co. Ltd) said that he would like to elaborate on one of the points mentioned in the Paper, i.e. the location of hydrant pits on fuelling aprons. This had always been something of a problem owing to the different location of fuelling points on various types of aircraft. With the conventional shape of aircraft, differing only in size, the problem has been minimized in the past by the sizing of parking bays and optimum pit spacing. With the introduction of supersonic aircraft on to existing parking areas, however, an individual problem might arise, due to the complete alteration of the shape of the aircraft.

136. As would be seen from the Paper, hydrant pits for fuelling had been located under the wings of aircraft or just in front of the leading edge, where the aircraft fuelling points were generally positioned, thus enabling high fuelling rates to be maintained without difficulty.

137. Supersonic aircraft, which would undoubtedly require to be fuelled on existing parking aprons at high rates of flow, would probably require the fuel at the rear of the aircraft in fuselage tanks as well as in the wings. If the fuelling points were not located to suit the fuelling companies and the airport planners, this could present a major fuelling problem.

138. In the past there had been insufficient liaison between aircraft manufacturers, hydrant planners, and the oil companies, which had resulted in operational difficulties for the hydrant operators. Mr Tennant stressed the fact that this liaison should be improved in the future.

Mr W. F. Weppner (British Petroleum Co. Ltd, Holland) said he appreciated that the Paper was probably written some time ago and, therefore, he wished to stress that developments might have taken place in, for instance, the automation part of the hydrant system. Possibly Mr Hunter could elaborate on this point, especially from the viewpoints of higher flow velocities, more aircraft to be fuelled simultaneously, and the saving of labour.

140. Were any figures or experience available about how to express the comparison between the fueller-operated system and the hydrant system on an economical basis? Was there an economic advantage or disadvantage between the two?

141. With the arrival of the supersonic transport, there might be problems of dealing with hot sections of the aircraft on landing after the tremendous speed at which they flew. There was the possibility that the temperature of the outside structure, to which the aircraft coupling was mounted, might be too high to permit the aircraft to be fuelled as soon as it reached its parking position.

142. Could Mr Hunter explain on a broader scale the form and generation of static electricity in relation to the higher flow velocities? Was any means of relaxation at present provided in hydrant systems bearing in mind the higher flow velocities?

Mr J. F. B. Darwin (Senior Engineer, Ministry of Public Building and Works, formerly Air Ministry Works Directorate) said that having responsibility for design of R.A.F. bulk fuel installations, he was very much interested in problems of aviation fuelling.

144. He enquired whether the Authors had any experience of epoxy-lined pipes? It appeared that the cost of these pipes was not significantly greater than for steel, and they seemed to overcome many of the disadvantages experienced on hydrant systems with ferric contamination of the product after it had left the water separator microfilter. In this connexion, possibly the Authors could indicate whether the

pipe was coated internally only or whether it was also coated externally, thus avoiding the cost of covering the pipe to prevent external corrosion.

145. Five or six years ago, the Air Ministry had put in a great number of surge alleviators on various installations with relatively low flow rates. Mr Darwin asked what was the critical flow-rate for which a surge alleviator was required in view of the hose-end controllers which nowadays were on the market, which gave a graduated shut-off, and also the preset meters which were being more and more resorted to and which gave two-stage shut-off, relieving the shock on the system?

146. His third question, which was, perhaps, a new version of the one fired at the Authors by many others, concerned the advantages and economics of the hydrant system. They were all conscious of the high capital cost and of the fact that it was difficult to modify airfields once a hydrant system was installed. On the other hand, refuelling vehicles were now extremely expensive, particularly in the large size, and many of them were required. In addition, their depreciation was rapid.

147. In the early stages of hydrant refuelling, dispensers were simple trolley affairs which were pulled round by a man or were battery-operated. Nowadays they had become more complex and were motor-controlled, their cost tending to be virtually as much as that of a refueller. Perhaps the Authors could give a little information on this, too.

148. The Paper mentioned that aluminium tanks were employed for refueller vehicles. Did the Authors have any experience with corrosion of the aluminium and contamination of the fuel due to anti-icing additives? It had been found in many instances that anti-icing additives caused a rapid corrosion of aluminium, particularly in the presence of other metal, contaminating the fuel massively.

Mr R. T. Davies (Group Engineer to the Borough Engineer of Luton) said that his question concerned the siting of the bulk fuel store. The Paper dealt with where not to site the fuel store, but it did not say very much about where it should be sited. Did the choice of where to have the hydrant system or the fueller system influence the siting of the fuel store in relation to the aircraft apron?

Mr D. A. Fox (Senior Civil Engineer, British Petroleum Co. Ltd) said that underground pipelines in the hydrant fuelling system had come to stay, although some people might not like them. The big question seemed to be whether to use steel pipes with suitable anti-corrosive linings, or what was the cheapest alternative? The best line of attack appeared to be either a thin aluminium or a plastic pipe with concrete encasing.

151. In nearly every case one could expect reasonably well-consolidated ground close to the taxi-ways, close to the aprons and, of course, underneath. Therefore, in situ concrete bedding or casing could offer adequate protection even if it cracked. The impermeability would be provided by the aluminium or plastic pipe. Sufficient strength could be developed even if the encasing concrete should become a two-pinned arch, a three-pinned arch, or even four pinned quadrants, but provided that it was well rammed and tamped in to the sides of the excavation, it should offer the cheapest alternative to steel.

Mr D. A. Sankey (Engineer, Shell International) said that he wished to raise one small point following the remarks of the previous speaker. One always talked about the pipeline being put under the concrete, but was this really necessary? If those pipelines were considered to be immovable once they had been installed, would there be any advantage in installing them in the concrete a suitable distance below the surface, which would seem to offer a cheaper installation and also the possibility of ater removal and a little more flexibility, therefore, in the hydrant system of refuelling?

Mr B. W. Houghton (Head of Aviation Equipment Division, Shell International) asked whether, with the advent of the hose end pressure controllers, the Authors thought it necessary to provide still further pressure control in the dispenser.

Mr P. C. Edwards (Design Engineer, Messrs A. J. and J. D. Harris) said that he wished to take up a point made by several previous speakers about providing facilities for the *Concorde* and various other supersonic aircraft. He wondered whether it would be difficult to get people to pay for installations for aircraft which, for all one knew, might share the same fate as the *Brabazon*. He had no wish to be depressing but this had happened before.

155. A great deal of design time in many engineering fields could be wasted in a detailed examination of facilities and installations for objects that were still on the drawing board. His own experience was that when they actually appeared in service, they were usually much bigger and much more awkward than anything which had been visualized.

156. He therefore suggested that it would be better, for civil engineers at least, to wait and see what the full extent of the problem was before trying to anticipate possible requirements in such detail as had been proposed.

157. In a later written contribution Mr Edwards observed that in §§ 105–112 the Authors had briefly set down some of the problems which were being studied relating to supersonic air transport. Several speakers, in referring to these problems, had made statements which Mr Edwards felt should not go unchallenged.

158. The rapid growth in the use by civil airlines, often for prestige reasons, of increasingly large jet aircraft for passenger transport had *not* resulted in cheaper air travel; nor had it been profitable to airline operators, as the following quotation from the *Guardian* of 19 November, 1963, would appear to indicate: 'Trans World Airlines said competition among the 20 U.S. and foreign carriers flying the North Atlantic was so fierce last year that the equivalent of 40 empty jet airliners crossed the ocean each day.

159. All growth was liable to be followed by decay and the recent decline of the large oceangoing passenger liners might well be followed by a parallel decline in the use of large fast aircraft. (It was perhaps noteworthy that the ships currently tending to increase most rapidly in size were oil tankers.)

160. The greater need of the future would probably be for smaller cheaper aircraft capable of operating with rudimentary airport facilities, from short runways, for both long- and short-haul passenger and freight transport and using methods of propulsion far less wasteful of natural resources than any present-day engine.

161. Although one was told that supersonic transport was imminent, would the Authors not agree that design study programmes for both military and civil aircrafts had frequently been upset by developments, usually in military aviation, which had changed either the direction or emphasis of current research?

162. The grandiose vision of an era of supersonic giants should not occupy one's attention to such an extent that other developments were neglected which, besides contributing to the 'advancement of mechanical science' would also better serve the 'use and convenience' of a greater number of the world's people.

Mr J. Hunter (Joint Author), replying to the discussion at the meeting, said that he would need several hours to get through the thirty questions which he had been asked. He proposed, therefore, to select one or two questions that were, perhaps, of more broad interest to the meeting as a whole and to leave the remainder for a more lengthy reply in writing. Before that, however, he wished to draw attention to an omission from Fig. 1, which did not clearly indicate the overlapping inflammability limits of J.P.4 when compared with aviation gasoline and aviation kerosine. A corrected version of Fig. 1 would be published with the report of the discussion.

Mr Tuch

164. Mr Tuch's first question (§ 118) concerned apron slopes, drainage, and other problems. This had been considered on and off over the years by the Authors, who had found themselves in a dilémma. There were other aspects of aircraft design involved also and it had to be recognized that it was a question of aircraft design and not of apron design. An aircraft was designed to accept fuel in a certain way and while oil company engineers did what they could to influence the aircraft manufacturers in the course of aircraft development, there was inevitably the occasion when an aircraft appeared on the scene which did not incorporate the pooled knowledge of some of the industries associated with, but outside of, the purely aviation industry. It was, however, true to say that this kind of situation happened less frequently now.

165. The Authors were very conscious of the fact that they could help both the aircraft designer and themselves by 'getting on the band wagon' right from the start, and they constantly attempted to do this. Regular meetings were held with aircraft

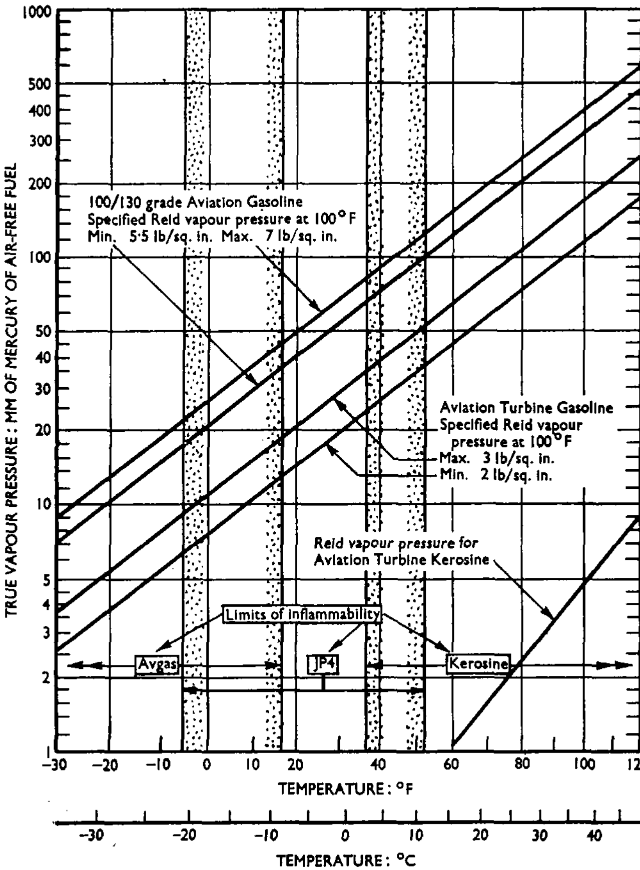

FIG. 1 (*revised*): CALCULATED TRUE VAPOUR PRESSURE/TEMPERATURE RELATIONSHIP FOR VARIOUS AVIATION FUELS designers. This was just as much part of their job as drawing lines on bits of paper and laying down bits of pipe. It was impossible to give a more direct answer than to say that they were endeavouring to do something about it, but it was very long term. It was a matter which presented problems during fuelling operations, too, because not every airport constructor was completely careful and critical in checking his levels when laying the concrete.

Mr Brear

166. In speaking of pressure control, Mr Brear (§ 223) had touched on a subject which, to be truthful about it, warranted a paper on its own. The question of the equipment to fulfil this duty was very involved and had occupied better brains than the Authors' for a long time. Certainly, developments were coming forward steadily.

167. The advent of the hose-end pressure-controller, to which several speakers had referred, was mentioned briefly in the Paper. What the Authors had attempted to do was simply as follows. One of the earlier slides, indicating the pressure gradient across the hydrant, showed that the pressure-control valve was located in the dispenser well away from the actual aircraft skin. Apart from the circuitry in the dispenser, it could therefore be separated from the aircraft by 100 ft of hose.

168. With this valve, they were trying remotely to sense what was going on at that 100 ft distant point on the aircraft skin, to reproduce this condition back in the dispenser, to make the control valve do wonderful things but only after the aircraft valve had started to do its wonderful things and then still beat it to the punch so to speak. They had pondered over this for a long time and Mr Brear had done a great deal of pioneering work on it.

169. They had decided that perhaps they were trying to do the wrong thing in making their pressure-control valve more and more sophisticated and yet keeping it on the dispenser. They had decided to try to produce a piece of equipment which, if located at the right place, would do the job properly—in other words, to cut out all the approximations and simulations inherent in existing systems. They had said that the proper place for pressure control was at the point where pressure required limiting —i.e., at the aircraft skin—and, therefore, the aim should be to design an entirely new piece of equipment which could be accommodated at that position. This, in fact, was what had been done in conjunction with two selected manufacturers.

170. Quite a number of the hose-end control valves were already in service. They could not be said to be in general service as yet because they were still being put into full production but, certainly, a sufficient number of pre-production models had been in service long enough to confirm that they were an answer to the problem.

171. By way of comparison and to indicate the scope of development, the previous type of pressure-control valve on a hydrant dispenser for 500–600 gal/min was a massive affair weighing, perhaps 2 or 3 cwt and costing £400 to £500 with all its associated sense lines, venturi, and so on. In conjunction with specialist manufacturers, the Authors had taken an ordinary self-sealing coupling, as normally used on the end of a hose for linking up to the aeroplane, and into the coupling—weighing normally 15 to 16 lb—had been designed a complete pressure-control valve. A combined control valve and coupling had thus been produced weighing under 20 lb and at a probable unit cost of under £150. A pair of these for £300 would therefore do a better job, at the right place, and at lower cost, than the previous standard equipment mounted on the dispenser.

Mr Rodger

172. Mr Rodger (§ 127(a)) had put what might be classed as the question to end all questions. Were the Authors in favour of hydrant fuelling? To answer this in two minutes would almost qualify one to become Chairman of BP, so involved was the subject. It could also be answered with another question: How long was a piece of string? One's thinking was influenced by many varying factors, depending

on the location, the site, the pattern of the trade involved, the likely life of the airport, the sort of business that could be expected in the future, and whether one could afford to invest the money there, and perhaps, lose out on it in the future. The best thing to do was to skate round the question and simply say that sometimes the Authors were in favour and sometimes they were not.

173. As to whether the oil companies paid for the installation (§ 127(b, c)) the answer certainly was in the affirmative. No instances came to mind of an outside authority having completely financed a fuel system. There might be odd cases when a completely Government-controlled monopoly airport had been established and they had financed the bill for the fuelling system also. In the Middle East, one of the potentates might occasionally feel like spending a good deal of money and would perhaps foot the bill himself. It would, however, be normal to say that the oil companies paid for the fuelling facilities, in the first instance at least, with the investment subsequently being recovered in the fuel charges.

174. Another involved question was whether the cost of fuel to the operator was less with hydrant systems than with mobile fuellers. For example, what size was the hydrant system? Was it operating economically or uneconomically? Had it been designed for a peak condition five or ten years hence but at present was operating at less than 50% capacity. All these factors would influence any answer to the question. Another factor was whether the basic installation, that is the depot and the pipelines, was financed by only one company or was shared between several oil companies. Again, therefore, there was no direct answer to the question. Perhaps a half-answer could be given by saying that if a hydrant was installed, either the company had been obliged to do so by the airport authorities for prestige and other reasons, or it was thought to be a better commercial and operational proposition than the use of fuellers.

175. Replying to questions on the turn-round cycle of aircraft during fuelling (§ 128) it would be true to say that, on average, a big hydrant system would give probably a faster turn-round during peak conditions on the apron, unless of course in the alternative situation, there was an excess capacity of fuelling vehicles, the reason for this being simply that a hydrant system was, in effect, a tank of unlimited size. What one used on the hydrant system were things called dispensers, which were virtually fuellers without a tank. They plugged into the continuously-available fuel-hydrant supply-system and, therefore, simply in terms of possible utilization, there was a greater degree of efficiency in that there was no need for the dispenser to go back to the depot to fill up.

Mr MacAdam

176. Rates of flow had been mentioned by Mr MacAdam (§ 131) who had asked how peak flow rates were arrived at. The subject was a common problem to all the oil companies, and many hours had been spent in trying to work out that kind of thing. It was extremely difficult to lay down a simple yet reliable formula. In effect, what happened was that people with a reasonable amount of experience conducted a traffic study of the airport concerned, that is both current traffic and likely traffic in the future. The total aircraft movements were then plotted in various graphical forms and from the final composite graph arrangement they worked out the probable theoretical peak flow requirement condition. They then applied what might be called an experience factor which was in fact a variable dependent on the number of aircraft requiring fuel simultaneously. The result gave a practical design flow rate and it was therefore not something which was arrived at with mathematical precision; it was merely a blend of factual study and past experience.

177. Mr MacAdam's question (§ 133) on whether or not the oil companies were adequately consulted on the co-ordination of servicing operations on the airport was of considerable interest, and in his introductory remarks at the meeting the Author had attempted to draw people's attention to it. His own firm belief was that although

they were commercial organizations, for which he made no apology, they were also just as interested in the welfare of the passengers and the airlines as were the airport planners, and thus felt they had a contribution to make right from the beginning. He would welcome at any time the opportunity to get together with airport planners in the very early stages of a project, because, being large international organizations, the oil companies had a considerable fund of experience between them, and quite often they had access to experience and information that the individual consulting firms who were normally employed for that kind of job could not always hope to tap.

178. That was, therefore, not only an answer to the question, but also a plea to civil engineers and architects who were planning airports to consult the fuel companies who would always find the time to talk to them about mutual planning and design problems.

Mr Tennant

179. Mr Tennant (§ 135) had mentioned the problem of the location of hydrant pits on aprons. One of the Authors' slides had illustrated a projected supersonic aircraft silhouette located on a typical 80-ft radius nose wheel guideline (see § 204 below and Fig. 23). It was not claimed to be absolutely accurate in terms of the likely manoeuvring path of the aircraft on the guide line, but based on the Author's' limited knowledge of the undercarriage geometry, it was an accurate enough indication for present studies. From the slide it could be seen that having fuelling positions in the rear section of the aircraft could cause difficulties in terms of trying to keep hose lengths down, and so on.

180. It was probably unnecessary to add that it was only one supersonic aircraft configuration and there were several in the offing. Two that were almost certain starters were the *Concorde* (Mach. 2·3) and a possible derivative of the U.S.A.F. *XB.70A*, the *Valkyrie* supersonic bomber (Mach. 3·0) which would be much more difficult to accommodate than the *Concorde*.

Mr Weppner

181. An interesting aspect of supersonic transport operation had been raised by Mr Weppner (§ 141) in referring to residual heat retained in sections of the aircraft after flight. Not a great deal was known about that kind of thing at the moment. However, it was known that during cruise conditions at altitude, a supersonic transport could have skin temperatures at the nose of up to 600°C. The fuselage temperature around the passenger compartment could be up to 450°C. There was no need for any intending passenger to be unduly worried, however, and he himself hoped to travel in these aircraft and he had every confidence it would be fairly safe.

182. Mr Hunter had been told by the experts that the balance of flight-time involving the let-down from cruise altitude of 60 000 to 80 000 ft down to subsonic cruise approaching the airport, down again to 'hold' level at the airport control beacon and on down through the actual landing approach, would give sufficient time in the air for most of the structure to cool down appreciably. In other words, the time spent at subsonic speeds in the air was reckoned to be sufficient to bring down the surface temperature to what was reasonably acceptable on the ground.

183. The Authors were not completely sure of any facts on Mr Weppner's question since most of the information hitherto available was military and therefore difficult to obtain or confirm. They thought, however, that the skin temperature around the fuelling points and other service areas should not be much more than about 50°C, although even this was getting fairly warm for fuel connexions at least.

184. There were other aspects of the heat problem in supersonic transport aircraft such as the possibility of the fuel being overcooked by excess soaking at high temperatures. Such fuel could subsequently be removed during defuelling and after being returned to a depot, possibly be resold in good faith to some other unsuspecting

customer. Again, experience to date and advice from experts like the Bristol Aircraft Corporation appeared to indicate that with Mach 2·3 aircraft trouble was unlikely to be encountered due to the fuel being overheated. A figure recently quoted by B.A.C. was that if they had an incidence of 2% of defuelling as a result of the fuel being overheated in flight, they would consider this as being very high and they would want to investigate the reasons for it.

185. Mr Weppner had also raised what could be a controversial question (§ 142) about static electricity generation and charge relaxation in systems. On that subject, too, while a great deal of work had already been done by the industry there was still a long way to go before it was fully understood. It would suffice to say that the Authors were conscious that there were certain conditions in which the phenomona could give rise to a hazard, and it was their constant policy to be watching for this possibility and to design it out of the system. This was what was meant by the earlier reference to trying to prevent rather than to cure.

186. It was rather unfortunate that essential though microfilters and water separators were, they were also one of the biggest sources of trouble. It was necessary to have them in the system to keep the fuel absolutely clean, and yet their particular way of functioning was such that they generated much more static electricity than one would normally get by pushing a considerable amount of fluid at a very high velocity through an ordinary pipeline. What the Authors attempted to do was to allow an adequate residence time in the system at low fluid velocity, not necessarily in special relaxation tanks, but in the pipelines and the sections following on from the separator or filters, so that the charges had sufficient time to dissipate.

187. In the minds of many people not closely concerned with the problem, there was frequently a confused association of static electricity and lightning conducting and therefore a tendency to run them both together. They were, in fact, two entirely different problems. To put it briefly, lightning conducting required a very low resistance path to earth in order to carry away a very heavy charge as near instantaneously as possible, whereas static dissipation was altogether different in that it could be expected to leak away through a relatively high resistance path of say up to hundreds of thousands of ohms. A practical illustration of the latter would be, for instance, the use of conducting rubber tyres on a vehicle or on an aeroplane, which was considered sufficient to leak away static without the necessity for a separate special (and often unreliable) low resistance path such as an earthing chain.

Mr Darwin

188. One of Mr Darwin's questions (§ 144) concerned the Authors' experience with epoxy-lined pipes and whether the cost was significantly greater than for steel. As would be appreciated, the Authors did not try to solve all their problems themselves, and frequently put them out to specialists. That particular problem was one which they had studied with the corrosion and metal treatment experts for about ten years. Although they were getting a little way along the road, they still had not come to the end of it. Certainly, they had tried out various epoxy resins and many other lining materials and plastics with varied experience.

189. The main problem seemed to be that to get really adequate and reliable lining of a pipe it had to be done under closely-controlled conditions. That led to its being a factory job rather than a field job which, in turn, meant that the pipe had to be treated in shortish lengths, which further led to the fact that joints had still to be made on the site—that was where the big problem arose. To date, they had not been able to find a satisfactory and reliable field jointing-system for that type of pipe. It did not mean that the Authors were not still searching. They were continuing their work, and a number of trial techniques and experimental pipeline sections were at present undergoing tests. They would like to find a solution, because it was one of the obvious answers to the question of minimizing contamination due to internal cor-

rosion and could also lead to operating economies by way of extended microfilter life, etc.

190. They regarded external corrosion as being simply a question of £ s. d. There were other ways of achieving protection against this than surface coating, such as cathodic protection. Their practice was simply to do a few sums and to put in whatever system suited the locality, the ground conditions, and gave the desired combination of economy and reliability.

191. Dispenser design had indeed become very complex and Mr Darwin (§ 147) was quite right in saying that much progress had been made. When talking about the additional complexity of dispensers, however, one had also to relate it to the rather different operating and performance conditions under which they were now called upon to function. The hand-drawn dispenser mentioned by Mr Darwin was generally a fuelling unit of about 50 gal/min maximum capacity. Today, one talked of paired units doing up to 1000 gal/min and also of individual dispensers capable of doing 500, 600, or even 700 gal/min through only two hoses.

192. Other aspects were the weight, volume, and complexity of the equipment aboard. Bearing in mind that since selling a product to an airline was, in effect, a retailing operation, it was necessary to observe certain weights and measures regulations about metering accuracy, and so on as required by H.M. Customs and the Board of Trade. At a guess, up to something like three tons of equipment had to be carried aboard one of the large dispensers. It could be accommodated in a small space, but an attempt was usually made to strike a balance between making it compact and still keeping it a sensible unit from the viewpoint of operational maintenance, so so on. Thus, complexity and cost were directly related to the very considerable increase in operating conditions.

Mr Edwards

193. Mr Edwards had asked whether it was wise to try to plan into existing facilities provision for the supersonic transport. To answer with a question, was it something about which one could afford to wait? Mr Hunter's own view was that one could not afford to wait until events overtook one. A similar situation had arisen in the past and it was not so long ago that people had said of the *Boeing 707* and the *DC8* that they would be completely uneconomic, that the general public would never fly in them, and that they would never be a success. This was far from being true and they had in fact become flying buses operating satisfactorily even in what used to be some of the remotest areas in the world.

194. Who was to say that the supersonic transport would not eventually become similarly successful, particularly if linked with use of the vertical take-off aircraft as the feeder for the longer distance, supersonic, trans-continental type of operation? It was vital to be ready, and, whatever happened, one had to continue studying the problem and be ready when it ultimately made its impact on the planners, the authorities, and the oil companies.

Mr Davies

195. The reply to Mr Davies (§ 149) who had pointed out that the Paper had mentioned where not to put fuel depots, but not where to put them, was that that had been done deliberately when the Paper was written. As had been stated in the introductory remarks, an unfortunate tendency had prevailed in the past for the fuel-supply arrangements to be looked at rather late in the proceedings. Time after time the Authors had found themselves faced with the rather unsatisfactory and often difficult situation where the depot for this essential service was being located a considerable distance away from the apron, resulting in unnecessarily long pipelines, uneconomic installations, heavy fuelling vehicles having to go through tunnels to get to a fuelling apron, and so on. That kind of thing should never happen and if it was possible to get together at an early stage with the authorities, including such local

experts as borough engineers, it should be possible to strike a happy balance between what was an ideal location from the fuel supply company's viewpoint and what was an acceptable location from the point of view of planning aesthetics, public safety, and so on.

196. Later, Mr Hunter observed that, in reviewing the questions answered during the discussion period and those remaining for written reply it would seem that a number either overlapped or were otherwise so closely associated that he could satisfactorily, and, he hoped, without offence to the questioners, adequately reply to them together. The following notes were therefore prepared on that basis.

197. If perchance he had either left unanswered or not satisfactorily answered any aspect then he would, of course, endeavour to rectify his error should the questioner care to pursue the matter further with him in private correspondence.

198. In preparing the following notes he had also taken the opportunity to amplify a little and perhaps phrase more accurately some of the replies given during the meeting.

Mr Rodger

199. Mr Rodger (§ 127) queried an apparent discrepancy between §§ 11 and 48 in relation to flowrates possible through a 2½-in. fitting. In fact on hydrant schemes, Mr Hunter did not design for a flowrate greater than 300 gal/min through a 2½-in. hydrant connexion, and 600 gal/min through a 4-in. hydrant connexion. The reference to up to 600 gal/min being achieved through a single 2½-in. filling point referred to the actual connexion on the aircraft. An example here would be the *Vanguard* which was designed to accept a flowrate of 600 gal/min through a single 2½-in. underwing connexion. That flowrate was achieved by connecting two of the normal discharge hoses, each capable of up to 300 gal/min to a suitable Y-piece adaptor. The hydrant dispenser would of course have to be plugged into the hydrant system via a 4-in. connexion in order to be able to draw off the desired 600 gal/min total fuelling rate.

200. Although current practice in Europe was to provide 4-in. pits for servicing the larger type jet aircraft which required a total fuelling rate of approximately 1000 gal/min, flowrates of up to 500 U.S. gal/min (415 Imperial gal/min) were commonly achieved via 2½-in. pits in the western hemisphere and particularly in the U.S.A. This resulted in considerable pressure-drop across the coupling and necessitated the provision of what the Authors believed to be undesirably high pump/pipeline pressures.

Mr Brear

201. In reply to Mr Brear (§ 123), in the past, pressure-control equipment had normally been installed within the mobile fuelling equipment itself. Although that equipment had been satisfactory in regulating pressure at the aircraft coupling to required limits during normal flow conditions, it had not been entirely satisfactory in limiting surge pressures following rapid closure of the aircraft tank valves. It had been necessary therefore to restrict flowrates in order to ensure that surge pressures should be held below certain acceptable limits.

202. The hose-end pressure-control valves referred to in § 167 et seq. were now an integral part of the delivery-hose coupling and provided the same degree of pressure regulation during flow but with the significant advantage that they also almost completely eliminated the possibility of surge pressures being applied to the actual aircraft fuel systems. The weight of the new controllers, while more than that of the standard international coupling, was satisfactory for use on all aircraft requiring pressure refuelling.

Mr MacAdam

203. Mr MacAdam's question in § 132 could be answered by a simple 'yes' but

the Authors thought it merited some elaboration. In developing the *Concorde* supersonic airliner the B.A.C./S.U.D. organizations had been acutely conscious of the desirability of producing a design which not only met all of the performance and safety requirements called for by its likely operators but which was also capable of operating from existing airfields. The designers had given an assurance that, apart from possibly improved navigational and air traffic control requirements, the existing runways, taxi-ways, parking aprons, etc, could adequately accommodate the *Concorde*.

204. That, of course, was far from being the case with the rival projects from the United States and although it was perhaps a little early to make a detailed comparison (since the American proposals were as yet far from being finalized) the Authors had attempted in Fig. 23 to illustrate some of the problems involved, for example, in parking the *Concorde* and a typical U.S. projected design within existing parking patterns. It was possible to accommodate the *Concorde* and indeed manoeuvre it in and out of any bay with the parking positions on either side occupied by current sub-sonic aircraft type. On the other hand, it was reasonably clear that with the American projects, access to and departure from any given apron parking position would necessitate the allocation of the space equivalent to two adjacent bays to accommodate only one aircraft. Even when thus accommodated, there still remained the problem of the hydrant dispensers being unable to link up with the fixed-position hydrant pits, other than by using long hoses which in turn would result in possibly an unacceptable reduction in the fuelling rate which could be achieved using the existing pumping equipment.

205. Mr MacAdam's question on airport design (§ 134) for vertical take-off machines was of course very much a subject for the airport planner rather than for the oil company. The Authors had no doubt that some study had been, and would continue to be given to it, even though the advent of the vertical take-off airliner seemed not quite so close as had been imagined a year or two previously. Among the studies already carried out on the question the Authors referred Mr MacAdam to a paper presented at the Royal Aeronautical Society in October 1963 which described some very interesting tests carried out on various types of airfield surfaces which were subjected to different levels of jet engine exhaust efflux and temperatures. The Authors believed that the tests included conditions such as a 1600 ft/s impingment velocity and temperatures of up to 600°C. The range of surfaces tested included grass runways, asphalt, and various concrete specifications. The paper also suggested suitable curing techniques for concrete surfaces required to meet such conditions.

Mr Weppner

206. As Mr Weppner had implied in his question (§ 139), the normal processes of engineering development were also applied to hydrant system design. It would therefore be true to say that very few hydrant systems were exact replicas of previous designs since each subsequent installation contained whatever new developments had become available in the meantime. Because the type of service required on airfields was frequently of a spasmodic nature with distinct peaks of extreme activity during any given period, and also in view of the fact that such peaks of activity were often seriously displaced in any time-cycle by factors beyond the control of the airfield operators, such as weather, etc, there was a distinct tendency to design the fuelling system to be as automatic as possible in order to minimize the considerable and ever-increasing costs of employing operating and maintenance personnel. Today it was quite commonplace for the entire reception, storage, and delivery to the fuelling apron system to be fully automatic—particularly in the case of pipeline-fed storage areas. In such a case the only personnel required would be the crew men who operated the hydrant dispensers and a very small single-shift staff to carry out planned maintenance procedures.

207. Such devices as automatic level-controls which simultaneously opened valves

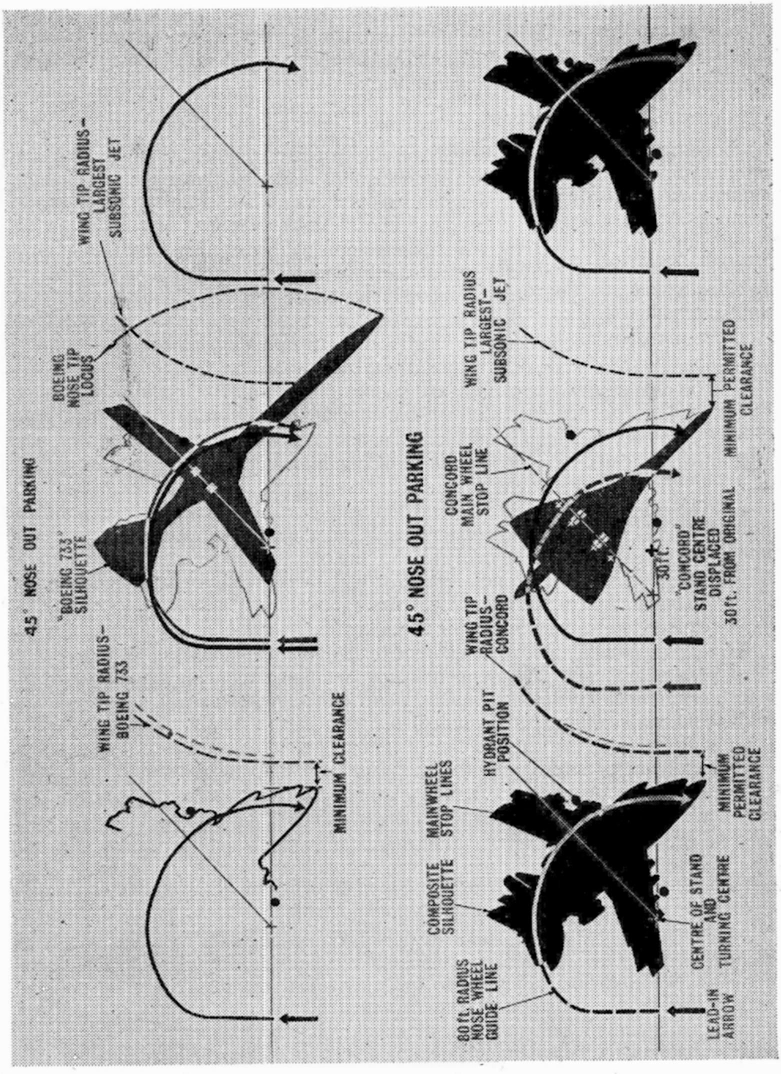

FIG. 23: LOCATION OF PROJECTED SUPERSONIC AIRCRAFT IN A TYPICAL CURRENT PARKING APRON ARRANGEMENT

and started up delivery pipeline pumps, automatic stock-indicating and control devices, automatic sequence-control on hydrant delivery pumps etc., were becoming regular features of any reasonably-sized hydrant system, and it would be true to say that at the time of writing, greater emphasis was probably being laid on developing available equipment to improve reliability under widely varying climatic and operational conditions than on the search for new equipment. Systems were in existence where up to ten pumps could be controlled in any desired sequence, such that they would automatically cut in or out depending entirely on the rate of fuel demanded on the fuelling apron.

Mr Darwin

208. So far as Mr Darwin's question in § 145 was concerned, prior to the introduction of hose-end pressure control valves, there was a need for shock-alleviating equipment in hydrant dispensers or on a hydrant system, because the rapid closure of the vehicle-mounted controller gave rise to high surge pressures in dispenser intake hoses. With the advent of hose-end pressure-control techniques, the factor which would in future govern maximum performance was the surge pressure generated in the dispenser hoses. It had been found that this could not be reduced by the provision of shock alleviators at a point upstream, i.e. in the dispensers, or the hydrant itself. Since performance had to be limited to maintain surge pressures within the physical limitations of the delivery hoses, the peak surge pressures in the intake hose would be accordingly lower, partly due to natural relaxation in the hoses themselves. Consequently, the need for providing shock alleviators also when introducing hose-end pressure-control equipment was overcome. Delivery hoses capable of withstanding higher pressures were necessary however, and the working pressure limits in B.S.3158 were being raised from 150 to 225 lb/sq. in. to meet that condition. In order to obtain maximum performance, the regulation of pressure at the inlet to a dispenser might be desirable, and dispenser input controllers were therefore being developed for this purpose.

209. It was realized that the cost of individual hydrant dispensers, mentioned in § 147, had increased alarmingly over recent years to around £8000 per unit. That had resulted in certain of the major oil companies getting together to review the essential needs of such equipment, and, by a process of design rationalization and inter-company standardization, new designs were being produced incorporating all essential safety and quality control features at a cost of between £4500 and £6000 per unit. Those units would continue to be motorized, but would of course be much more utilitarian in form, with the elimination of much of the decorative and promotional but highly expensive panelling and similar luxuries evident on current equipment.

210. Although the Authors' company's world-wide fuelling fleet included a large number of aluminium tank vehicles they had not experienced any undue trouble in the form of rapid corrosion of the aluminium as a result of the use of anti-icing additives (§ 148). A point worth mentioning was that before the introduction of any fuel or fuelling components, exhaustive tests were carried out in the laboratories in order to ensure that it would not have any adverse effects on the fuel or fuelling system. Apart from concern regarding the company's own equipment, quite obviously the aircraft fuel system itself, which was largely of aluminium alloy, could be adversely effected, thus doubling the necessity to ensure against the possibility by adequate prior testing.

Mr Sankey

211. The Authors felt that Mr Sankey's question in § 152 could perhaps be answered more authoritatively by one of the Institution members rather than by themselves. However, there were two very important reasons which immediately sprang to mind in favour of placing the pipelines underneath the concrete rather than in the mass concrete of the apron. First, it would be recalled that § 45 of the Paper

mentioned that it was necessary to lay all hydrant pipelines with a given minimum slope in order to provide planned low points for drainage and other checks to be carried out. This inevitably meant that at one section of the apron the pipes could be as near as 3 ft to the surface and yet at another they could be perhaps as deep as 8 or 9 ft. A second reason would be the considerable difference in the co-efficient of expansion for concrete and steel. Normally, the average parking apron was constructed in a series of panels each individually insulated from the adjacent panels by a suitably packed expansion joint. The relative movement of those individual but considerable masses of concrete would impose undesirable stresses on the pipeline, and that, in conjunction with possible individual flexing or relative movement of the panels due to heavy aircraft loadings, could eventually result in pipeline damage and even a major fracture.

Mr Houghton

212. Mr Houghton's question (§ 153) had been covered largely in the reply to § 145. The Authors summarized their views as follows. On fuellers, no other form of pressure-control equipment was required when employing hose-end pressure-control valves. Shock alleviators did nothing to reduce the surge pressures generated in the delivery hoses. On hydrant systems, where high pumping pressures were encountered or where large fluctuations in dispenser input pressures occurred, an input controller could be advantageous. When an input controller was employed, shock alleviators mounted either in the hydrant system or at the intake hose would help to reduce shock pressures in the hydrant lines.

Mr Edwards

213. Quite obviously the Authors had to agree with Mr Edwards comments in § 161. However, time waited for no man and it was their belief that one could not afford to stand back and wait for events to overtake one. As planners, the Authors were obliged to analyse all the information available to them at any given time, be they facts, forecasts, or merely opinions, and from this information and to the best of their ability produce a development programme which promised to have at least a reasonable chance of application in the years ahead.

214. Finally, the Authors observed that their reply would be incomplete without some reference being made to the considerable encouragement and pleasure given to them by the wide-searching yet friendly interest shown by the Institution members. As the Authors had mentioned when introducing the Paper, the pleasure was heightened by the fact that they were both non-members. Once again they would like to express sincere appreciation for the privilege of participating in the Institution's activities.