By weather was chiefly meant bad visibility, as this was practically the sole meteorological cause of delays. All their aircraft could fly in bad visibility; it was the pilots who refused to fly, and with existing aircraft, if the pilots did not refuse, he (Sir Sefton Brancker) "would probably have some more items to add to the accidents caused by 'error of judgment.'"

The pilots deserved all sympathy in their struggles with bad visibility conditions. The achievements of some of them in this respect had been wonderful, and they had frequently accomplished feats of air navigation voluntarily, for which orders from a higher authority would not have been justified. It was, therefore, of vital importance that the best brains should be concentrated on the problem of producing aircraft which would not call for such a high standard in piloting, and with which operations in bad visibility could be demanded without injustice to the navigating crew. First and foremost, one must have aircraft of great stability, although whether this stability should be inherent in the design or obtained from some automatic mechanism the lecturer was not prepared to say. The most promising means of obtaining stability appeared at the moment to be the gyroscope. Already a gyroscopic rudder control had been in operation for some weeks with Imperial Airways, and it won high praise from the pilots.

The pilot's lack of confidence in his means of navigation was not, perhaps, so fully justified as his dissatisfaction on other matters. The latest compasses were really very good, if properly placed. Directional wireless, although a little clumsy, worked extremely well. With existing wireless equipment it had already proved possible to bring an aircraft practically over an aerodrome in bad visibility. It then became necessary to evolve means of bringing it down safely. They had tried new systems of landing in fog with some success, and it had been found that the Neon light gave the best results. They had tried in miniature the "leader cable" with satisfactory results, and at Croydon during the coming winter he hoped they would be able to try out on full scale a complete system of landing in fog.

Turning to the second main cause of unreliability, that of mechanical defects in the power plant, it had already been mentioned that this represented the cause of from 21½ to 50 per cent. of unreliable flying, according to the time of the year.

A careful study of the causes of engines being removed before their proper date of overhaul indicated that the real definite sources of trouble were 28 per cent. in the water system, 19 per cent. valve breakage or distortion, and 10 per cent. oil circulation, the three items together accounting for 57 per cent. of the whole. As regards the lesson to be learned from these figures, the first was that lately water-cooling had been their greatest weakness, and the simplest way of curing this trouble would appear to be the employment of air-cooled engines, of which already types of great reliability were in existence, and would shortly be put into regular commercial service. With regard to the 19 per cent. valve trouble, they were developing a sleeve valve engine which should certainly eliminate this source of trouble; but even without this the lecturer felt that something could be done to improve the wear and tear qualities of the valves of ordinary practice, while oil trouble could surely be avoided by more care in detail design. The lecturer therefore arrived at the conclusion that the most prevalent causes of diseases of the standard engines—water, valves and oil—appeared to be comparatively easy to remedy in the future.

Concerning the 23 per cent. of removals, caused by breakage of some part or other, the lecturer said these were mostly minor items, although there were three cases of breakage in the reduction gear which were, of course, very serious items, and pointed to the advisability of using direct-drive engines. Certain new types to be put into service had direct drive, but, generally speaking, aircraft designers were almost unanimous in demanding a geared-down engine.

Multi-engined Machines

The question of multiple engines was then considered as a means of avoiding forced landings, and so eliminating, perhaps, the whole of the unreliability due to mechanical failure. No two-engined machine that the lecturer knew of could be counted on to reach its destination carrying an appreciable load with one engine out of action. In other words, it did not surpass the single-engined machine in reliability, although, as already indicated, it certainly appeared to give a greater measure of safety. The two-engined machine, with its engines in tandem, offered the best endeavour towards reliability, but of this type they did not have much experience in this country.

The three-engined aircraft seemed to deserve consideration next, after the two-engined type. They had as yet had little experience, but on paper the three-engined machine should always be able to reach the end of its stage with one engine stopped. Several such aircraft were under construction, and by this time next year they ought to know whether this was the right solution or not. The most serious item of doubt was the effect of the slipstream from the front propeller on the propellers of the two wing engines. If insuperable difficulties were found there they might have to go to the four-engined machine, with engines in tandem, which system had already been proved to be aerodynamically sound. Personally, the lecturer still believed that it was possible to design and construct an absolutely reliable single-engined aircraft. Summing up the most important subjects for the study of the technical experts in order to better matters, the paper stated :—

"1. Once more, the development of metal construction for every component of the aircraft, and the further investigation into the action of fatigue on all metal structures, particularly those included in the aero engine.

"2. Once more, the provision of an infallible power plant, even at the cost of extra weight and expense. The direct-drive engine is obviously more reliable than the geared engine, and it is for the scientist to endeavour to obtain as good a lift from an ungeared engine as from a geared-down engine.

"3. Once more the design of aircraft of greater stability and ease of handling than those in use today, particularly with a view to flying long distances through cloud without fear of loss of control.

"4. Again, the perfection of wireless navigation equipment.

"5. Again, the elimination of the possibility that snow may choke the engine.

"6. The evolution of some system of guiding an aircraft safely into an aerodrome during fog.

"7. Very close attention to the reliability of all components of the installation.

"8. The development of a satisfactory heavy-oil engine, without exceeding the total weight per horse-power of 'engine plus four hours' fuel' of existing petrol engines.

"It will be seen that several of the most important scientific investigations and items of technical progress necessary to attain perfect reliability are also demanded in the interests of safety, and at no point do these two interests clash in any way: a very satisfactory deduction from every point of view."

Economy

Turning to the real bugbear of air transport—the cost of operation—the paper stated that the history of British air transport in economic progress was a sad one. They had passed through a series of changes in Government policy which had retarded all efforts at steady progress in effecting economies. Finally, they had placed the activities of British air transport within Europe in the hands of a purely commercial organisation, with a clearly defined measure of Government financial assistance promised for a period of 10 years, of which 1½ years had already elapsed. This company had an unfortunate start, and it was now reaping the full harvest of the troubles which were sown through the initial errors of its policy. However, it was hoped that the worst moments were over and that they soon would be given a demonstration of maximum possible efficiency with a minimum of expenditure.

One serious economic difficulty of air transport was that nothing but the best was good enough, and the lecturer thought that air transport must always be expensive when compared with other forms, and he recalled Sir Charles Parsons' statement that air transpert was "always hauling up an inclined plane." The most important items of expenditure on the operation of a service were as follows: (*a*) Cost of fuel and oil; (*b*) the pilots' and mechanics' flying pay; (*c*) engine maintenance and overhauls (man-hours and spares); (*d*) aeroplane maintenance and overhauls (man-hours and spares).

Concerning (*a*), fuel and oil at present accounted for about 30 per cent. of the operating costs. The possibility of an appreciable reduction in the cost of petrol in the near future seemed remote, and they must look to the scientist to obtain the necessary horse-power with a smaller expenditure of fuel: or evolve a means of employing a cheaper form of fuel. Very great progress had been made towards the production of an engine burning heavy oil, and the weight of fuel consumed per horse-power promised to approach something like 20 per cent. less than that of the petrol burnt in existing engines. Taking the cost of heavy oil as about one-fifth of that of petrol, an aircraft of similar horse-power and qualities as the Handley Page W.8 would therefore effect a saving of about 8*d*. per ton-mile by fitting heavy-oil engines. The airship scheme