Altitude test bed

Kuhring, M. S.

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SUBJECT ALTITUDE TEST BED

PREPARED BY M. S. Kuhring

ISSUED TO National Aeronautical Research Committee and Technical Advisory Panel.

LABORATORY MEMORANDUM

ALTITUDE TEST BED

During my recent visit to A. V. Roe, I was asked by Mr. Knowles whether the N.A.E. had any plans for building an altitude test bed for jet engines. He said that the matter had been considered earlier by Avro and a rough design estimate of $75,000 had been mentioned. In their proposal it had been intended to construct a simple altitude chamber in which the engine would be mounted. At the discharge end it was proposed to inject steam from the large Nobel powerhouse and thus induce an air flow through the chamber. An expansion turbine at the entrance would permit the desired depression to be obtained.

Mr. Knowles considered that the time was now near when such facilities would be of considerable value to the Company. In reply to a question, he stated that probably one engine test a year might be required at the present time but that the results of this test would be important to them.

I pointed out that the Engine Laboratory was already short of staff to undertake its present programme and that from personal preference, I should like to avoid the responsibility for such equipment unless there were a real need for it. I agreed to discuss the matter with you.

Upon my return I discussed the proposal with S/L Bridgland but have not as yet heard his final comments.

I believe that there is, or will be, a need for such equipment in the future, although more assurance should be forthcoming that some use will be made of it by A. V. Roe or by the R.C.A.F. before it is built.

If it is decided that such equipment is to be constructed, I believe that it should be built by the N.A.E. so that the facilities will be available to the R.C.A.F. and to manufacturers of other engines used in Canada as well as to the N.A.E. In addition, studies of the operation of any jet engines and accessories and effects of fuels and lubricants could be studied on such equipment. Finally, the icing studies might be extended if tests could also be done under altitude conditions.

If it is decided that such equipment is to be constructed, serious consideration should be given to the size, capacity and method of operating such a test bed.

If an engine is mounted in a cell and permitted to exhaust directly into the atmosphere, the air intake can be throttled and "altitude" conditions may be simulated somewhat in the compressor. However, the compressor inlet will be at altitude condition and the jet nozzle at sea level conditions. Somewhere between the inlet and the jet nozzle, pressures will vary from one to the other and matching of turbine and compressor will be uncertain and combustion will differ from that obtained under normal operating conditions. This simplified form of cell does not fulfill the requirements.

Altitude test beds have been constructed by Rolls-Royce, Hucknell, and they have used jet engines as ejectors to induce a depression in the cell. This is quite a good arrangement for them as they have available engines and spares. These are not readily available to us and some other form of power would be required. Steam nozzles might be used for this purpose, particularly as the fuel required for steam generation need not be too expensive. However, from a rather rapid examination of the problem, it is concluded that the efficiency of the steam ejector is too low for such an application and pumps would probably be required. This would have to be determined later.

The development and construction of a complete altitude test plant for an engine such as Avro are contemplating for development at the present time is a considerable undertaking. Altitudes of 20,000 or 40,000 feet could be considered as design requirements. Simulation of altitude conditions is not complete unless low temperatures are also available. In this regard, while Ottawa winter temperatures would be of some advantage, they are not sufficiently low nor of long enough duration to be very effective.

The desired capacity will also have an important bearing on the requirements for such a test bed. As noted above, Avro are reported to be considering an engine with a thrust of 13,000 lb. Designs should therefore be suitable for this engine and, possibly, for larger engines.

The following table gives a rough idea of the various considerations which would have to be established before design could be started:

TABLE I

Preliminary Requirements for Altitude Test Chamber

Altitude Ft.	Temp. °C.	Mass Air Flow lb./sec.	Refrigeration BTU/Hr.	Water for Cooling Exhaust Gal./Hr.	Power for Compression Exhaust HP
Turbo-jet developing 20,000 lb. thrust at sea level.					
40,000	-40	107	10,800,000	13,000	26,000
20,000	-30	206	17,700,000	24,800	19,700
Turbo-jet developing 15,000 lb. thrust at sea level.					
40,000	-40	80	8,100,000	10,000	19,200
20,000	-30	155	13,300,000	18,600	14,800

No reasonable cost estimate can be given for this equipment at this stage. It can be noted that preliminary design estimates of $75,000 had been considered by Avro some time ago. It may be assumed that both engine capacity and building costs have increased markedly since that time and no provision had been made for refrigeration nor evacuation pumps as the steam plant already available at Nobel was to have been used for the purpose.

For discussion purposes, the following general proposal might be considered:

1. The expansion turbine being purchased for the Gas Dynamics Laboratory is rated at about 2,000 horse-power, but if it were used at the air intake of an altitude test bed, the working conditions and temperatures might permit it to absorb up to 3,000 horse-power.

   The cost of the turbine is estimated at $75,000 but if a second unit were to be purchased for the altitude test bed, the cost would probably be reduced to $50,000.

   While the turbine being installed in the Gas Dynamics Section is being made as flexible an installation as possible, certain changes would have to be made each time the altitude test cell was used. This would entail a considerable loss

of operating time for the turbine and should not be recommended.

2. The expansion turbine would be designed to develop power from the incoming air and it is not likely that it could also obtain maximum air temperature reduction through the unit. Even if this were achieved, it would provide only about half the refrigeration requirements and probably considerably less than this amount, for 15,000 lb. thrust at -40°C. and 40,000 feet (the I.C.A.N. temperature for this altitude is -56°C). Additional refrigeration would therefore be required. No estimate of cost for this is available at this time.

3. The test cell proper would correspond roughly with the proposal that was considered by Avro for $75,000. However, it is anticipated that the size would be increased and that costs will have increased appreciably since that time and this figure is considered to be hopelessly inadequate.

4. The blower or pump required to evacuate the test cell, even under the minimum conditions quoted, would require about 19,000 horse-power and this would increase to 26,000 horse-power under the more severe design conditions.

Of this power, some 3,000 might be supplied by the expansion turbine at the inlet but the remainder would have to be supplied from another source.

No estimate of cost for the blower is available.

Recommendations

The design and construction of an altitude test bed should receive very serious consideration before any work on the project is initiated. A compromise installation providing only for reduced density can give some data but it will be incomplete. Certain data are available on the performance of gas turbine engines under flight conditions and it is likely that, based upon

these results, a calculation may be made which will be quite as accurate as would be tests made under compromise conditions. Reduced temperatures must be considered.

The operation of such equipment is likely to be costly, requiring experienced staff and in view of the altitude test equipment for combustion work being installed by the Gas Dynamics Section, a much clearer estimate of the proposed use of the test bed should be obtained before any decision is reached regarding the construction.