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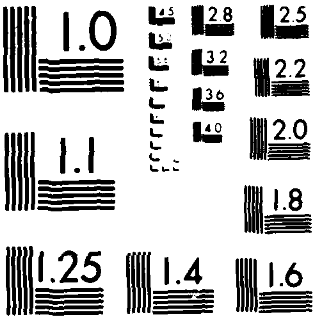
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DESCRIPTION OF A TECHNIQUE TO MEASURE SPRAY DISTRIBUTION IN AN AIR STREAM

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SUMMARY

A technique is described for the measurement of the distribution of introduced liquid mist within an air flow in an annular duct.

These measurements were required as part of a program to develop a system for injecting a mixture of water and methanol into the compressor of a small gas turbine.

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1. INTRODUCTION

Gas turbines suffer a reduction in performance when operated in conditions such as high temperature and high altitude. This reduction in performance can reduce the safety margin of an aircraft with respect to take off run requirements and single engine performance. It is therefore a great advantage to be able to recover this lost performance.

One method of performance recovery is to introduce a spray of a mixture of water and methanol into the intake of the engine compressor, increasing the effective mass flow and power output. In this instance (Ref. 1) the water-methanol mixture was sprayed into the compressor face using an annular array of commercially available nozzles. Because of the bending stresses generated at the blade roots by impact forces, great care had to be taken in this arrangement to ensure that the distribution of the water-methanol spray over the compressor face was such that excessive fluctuating loading of the compressor blades was avoided. To this end a technique was developed to measure the relative distribution of water-methanol mixture at the compressor face.

2. DESCRIPTION OF MODEL

A full scale mock-up of an engine nacelle (Fig. 1) as used in earlier certification tests was used. The model was complete with rotating propeller stubs, variable simulated compressor air flow, and nacelle bleed. The intake was an example as produced for the aircraft in question and the nacelle and cowling were of plywood, but similar in layout to the aircraft installation.

Positioned behind the intake and coupled with a rubber seal were the compressor inlet guide vanes, an actual example as taken from an engine. Air was drawn through the inlet and inlet guide vanes at a mass flow rate of 1.6 kg/s by a 45 kW two stage commercial blower and metered using a venturi.

Forward air speed was simulated by immersing the pertinent part of the nacelle in the exhaust of another 45 kW commercial blower. Parameters measured on this part of the rig were propeller speed, simulated compressor mass flow, simulated forward air speed and atmospheric conditions.

3. DESCRIPTION OF INSTRUMENTATION

A schematic layout of the system used to sample the water-methanol content of the air stream is shown in Fig. 2. An 8-probe sampling rake was situated directly behind the IGV housing, as indicated in Fig. 3. It was free to rotate about the same axis as the compressor hub, and could be indexed to any required position.

Details of the rake are shown in Fig. 4. It was constructed so as to permit isokinetic sampling of the flow (Ref. 2), by positioning an internal static pressure tapping close to the inlet of each probe (Fig. 4(b)). This was achieved by appropriate selection of available hyperdermic tube sizes allowing one tube to sleeve outside the other, thus forming a chamber to measure static pressure. Adjustment of this pressure to a level equal to the local static pressure within the annular duct was taken as an indication that the sampling of the flow was at the same velocity as the surrounding flow.

Each of the 8 sampling probes was connected to a plenum exhausted by a vacuum pump. Depending on the position of a set of eight two-way valves (Fig. 5), the air-water methanol sample was either passed through a set of eight geometrically similar dessicant filled collecting tubes, or otherwise exhausted directly into the plenum chamber.

The dessicant tubes (Fig. 6) were constructed of a glass tube cut to length and fired to achieve a smooth surface and edge. Rubber bungs were inserted into each end of the tubes. One was merely to block the end but the other was drilled to receive two metal tubes, an inlet and an outlet. The inlet tube was arranged to convey the sample to the bottom of the container, so ensuring that the full column of dessicant was active. To avoid loss of dessicant particles, wire gauge was placed at either end of the tubes.

4. DESCRIPTION AND DISCUSSION OF TECHNIQUE

The principle of the isokinetic technique is to have the fluid sample enter the probe without either deceleration or acceleration from its free stream velocity, so that the rate of liquid capture by each probe can be related to a known corresponding flow rate of the conveying medium. This was achieved by adjusting the static pressure at the probe entry to equal the local duct wall static, using a bleed valve on the downstream plenum. To simplify the procedure, all 8 probe entry statics were manifolded to provide a single pressure which was compared with the wall static, When these were of equal value, it was assumed that the probe entry velocity was equal to the duct air stream velocity. After these velocities were matched and set, a period of time was allowed to ensure that stable conditions had been reached. At the appropriate time, the gang of eight valves would be switched from by-passing into a plenum to passing through the dessicant tubes. The same sampling period was used for each probe position.

The assumptions implied in this procedure were:

(a) The local variations in both magnitude and direction of the air velocity over the duct annulus had a negligible effect on the results. It was considered impractical to attempt individual adjustment of the inlet velocity to each probe, (rather than bulk adjustment according to the manifolded value of probe inlet static pressure as was used). In addition to variation in velocity, there was almost certainly variation of local static pressure across the duct, which was unknown. Without resorting to detailed measurement of the static pressure distribution which was thought unjustified, individual probe adjustment would have served little purpose.

(b) Due to geometrical similarity of the eight sample paths, there was negligible variation between the losses associated with each path. This was demonstrated by a run in which the water-methanol mist was sampled across one duct diameter twice, the probe positions in the two cases being 180° apart. Consistency of these results indicated uniformity of the loss characteristics for each path.

(c) The losses associated with flow through the dessicant tubes were insignificantly different from those associated with the by-pass system. The probe entry static pressure was always monitored when switching from by-pass to the sampling mode, and generally there was no noticeable change. On the odd occasion when a small change was observed, this could be quickly corrected by adjusting the plenum suction.

Errors due to water vapour in the atmosphere could be eliminated by sampling the air with no water-methanol flow for a period of time and then noting the amount of moisture collected from the atmosphere. To test the results for self-consistency, the corrected liquid flow distribution was integrated over the complete duct area for isolated cases. The total liquid flow rate so calculated compared well with the measured rate of flow to the injectors.

Repeatability was demonstrated by comparing the results of a number of different runs made under similar conditions.

5. CONCLUSION

An effective and manageable technique was developed for sampling the distribution of liquid spray in the flow entering the annular intake of an aircraft engine. Judged by available criteria, the technique was found to provide reliable and repeatable results.

6. REFERENCES

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G.A.F., Nomad Project Note N3.96,
October 1982.

[2] C.N. KING Fuel/Air Sampling.
A.R.L., Unpublished work.

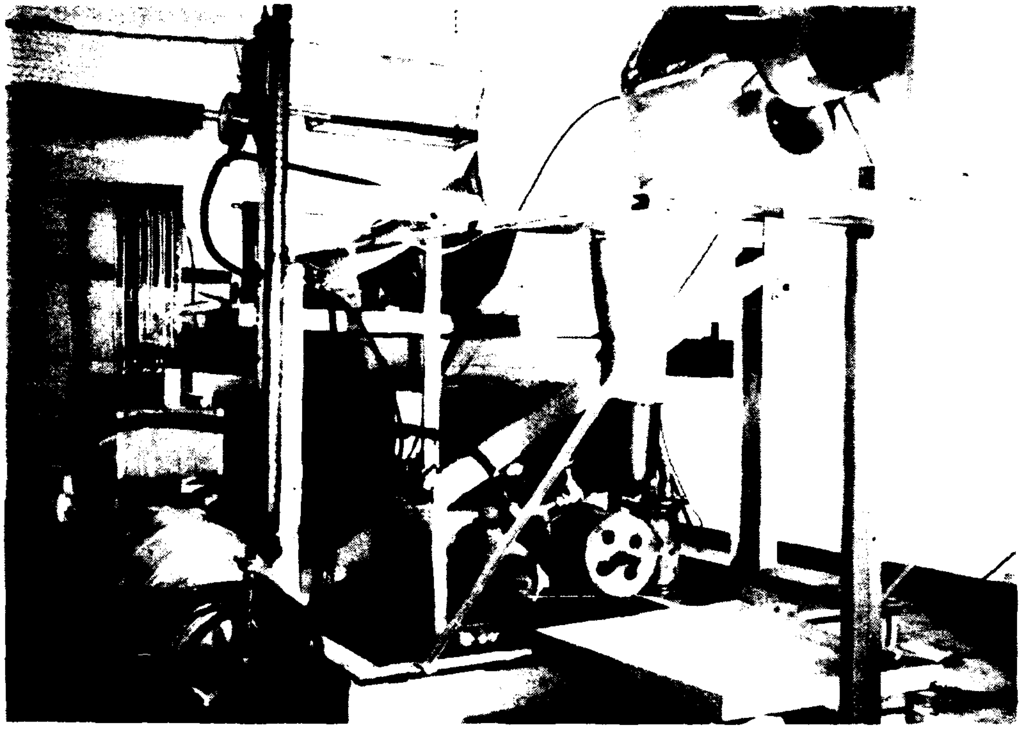


FIG. 1 GENERAL VIEW OF TEST RIG

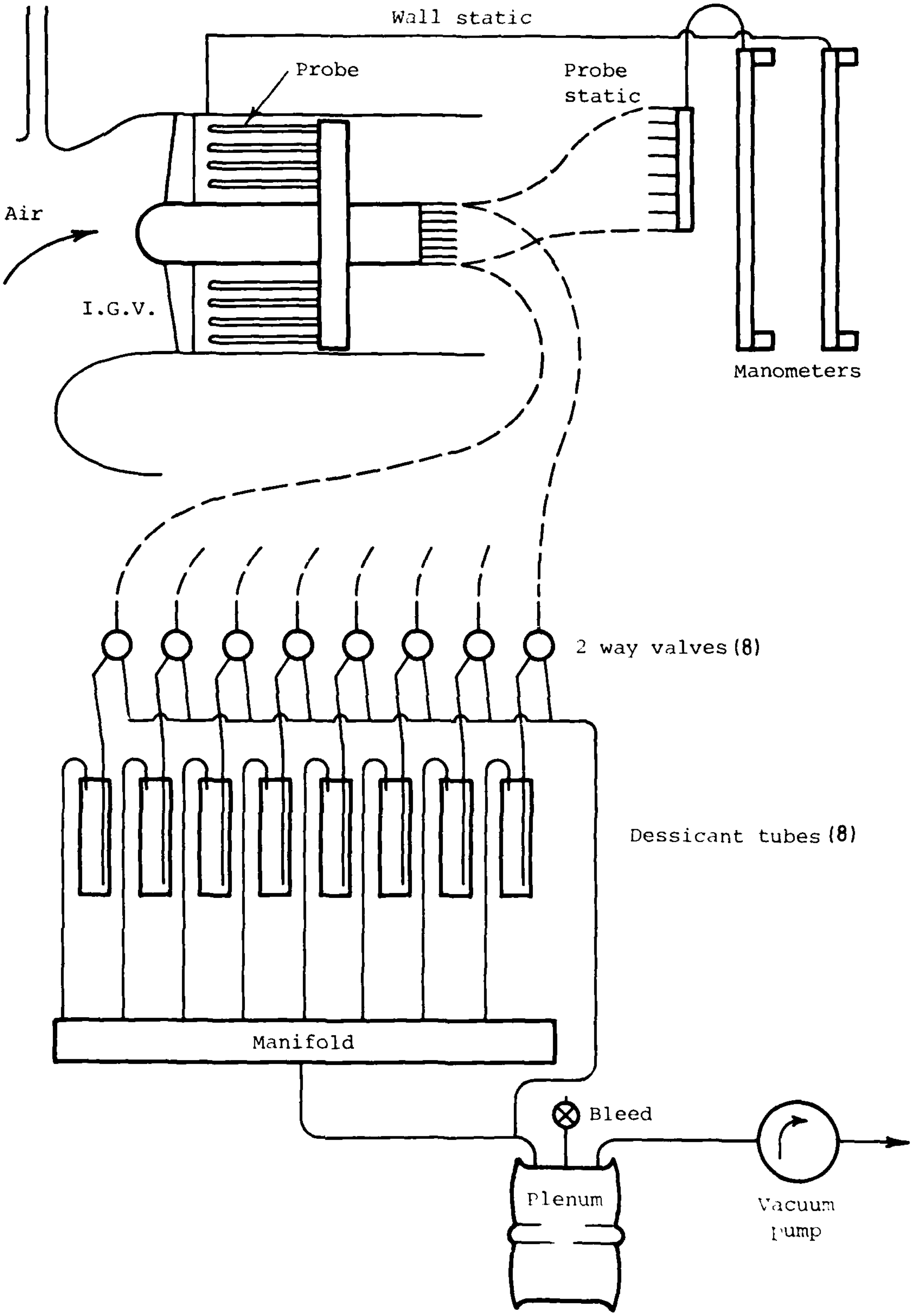


FIG. 2 SCHEMATIC OF SAMPLING SYSTEM

FIG. 3 SAMPLING PROBE ARRANGEMENT

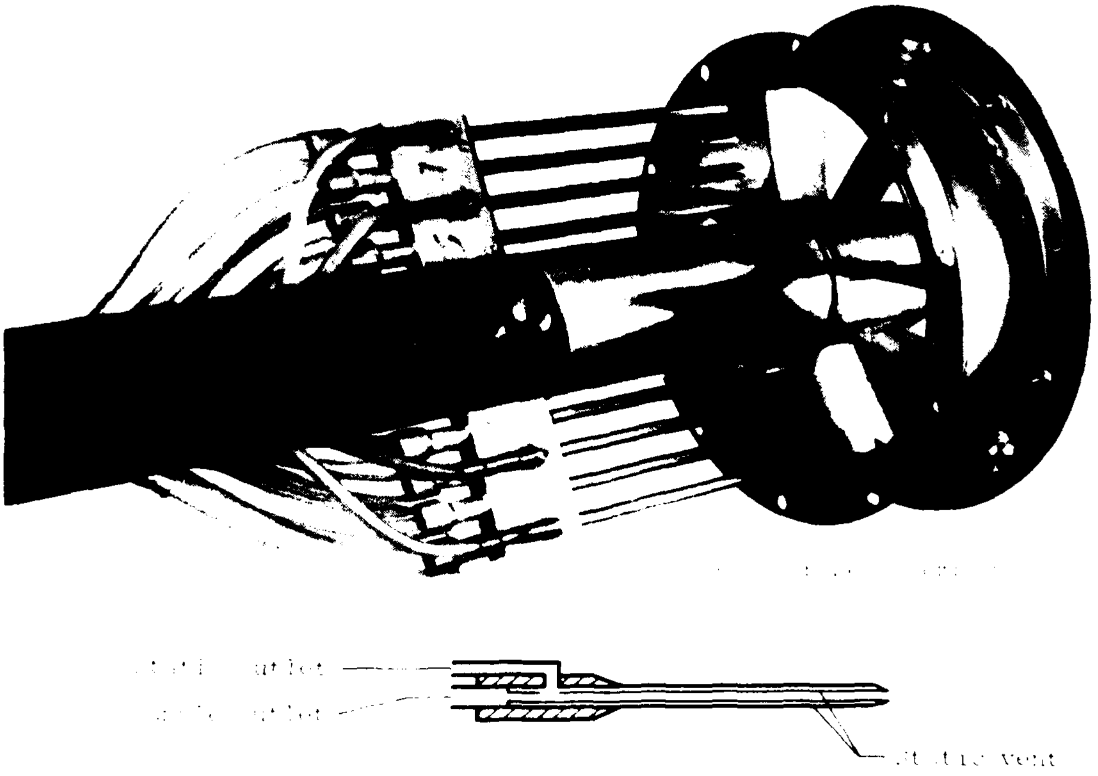
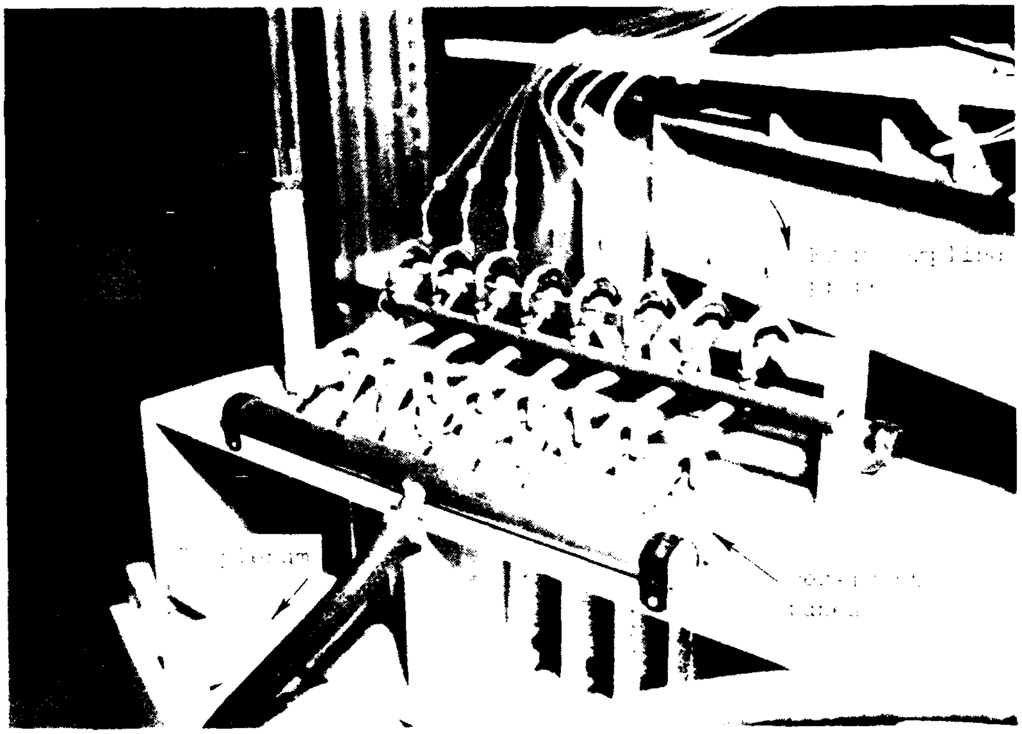


FIG. 4 SAMPLING PROBE DETAILS



(a) Sampling position

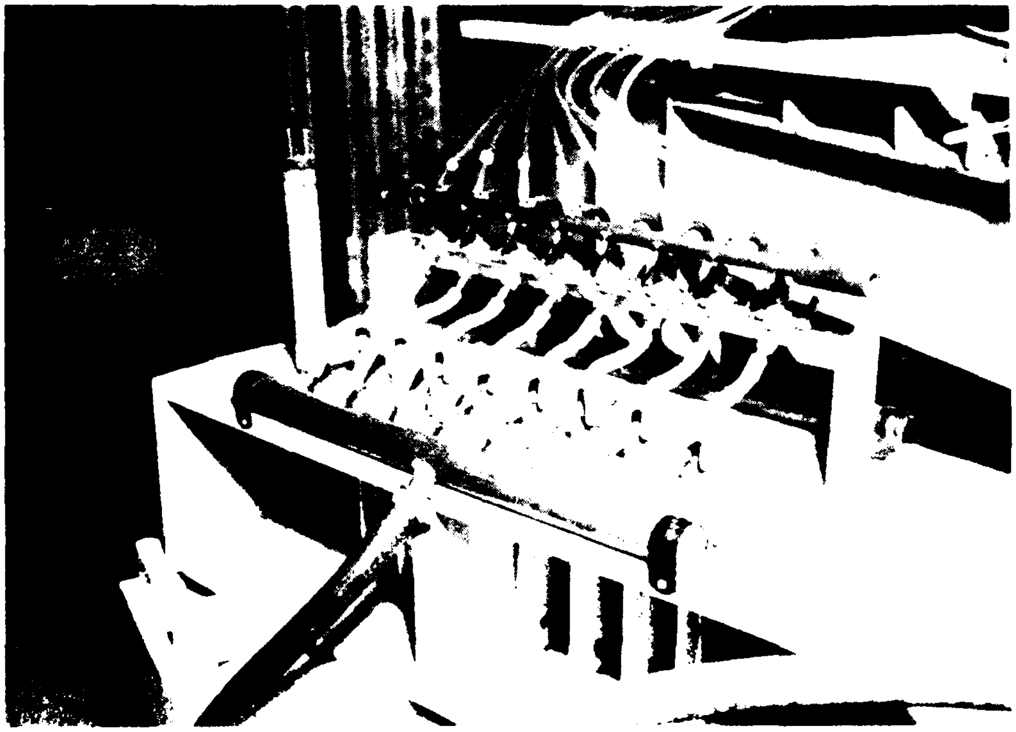


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FIG. [illegible] -WAY VALVE ARRANGEMENT

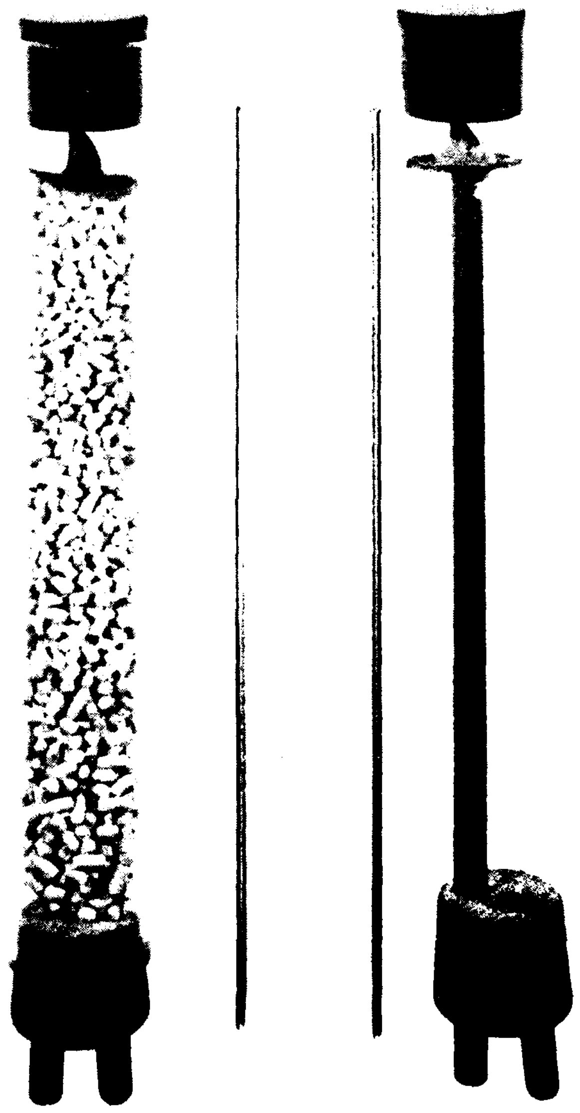

FIG. 6 DESSICANT TUBE ASSEMBLY

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