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To: [redacted] March 7, 1958 25X1

From:

Subject: Report on Meeting with Dr. Hazen, Princeton University, on 4 February 1958

Personnel Present: [redacted] 25X1

Dr. Hazen [redacted] 25X1

[redacted] He has conducted much research in aerodynamics and has a smoke tunnel at the University of Princeton which has proven very useful for qualitative information on flow patterns. He was very interested in the proposed blimp program and stated that immediate and practical results can be obtained in the area of flow separation control. 25X1

Considerable work has been done by Pfenninger on low-drag laminar boundary layer stabilization. A considerable number of flight tests have been made with a B-57 in which 15 or 20 foot length bodies have been mounted in front of the fuselage and measurements of flow made along this body.

Hazen indicated that turbulence and separation problems, particularly at low altitudes, arise mainly because of the waviness and roughness of the skin. Even 0.002 inch particles cause breakdown of the flow. Waviness has been shown to be the major problem, though this has been shown only in the two dimensional case.

At altitudes, the maintenance of flow problems are much reduced. Pfenninger's work, using suction slotted on a section over the after part of the wing, has given laminar flow up to Reynolds numbers of 36×10^6. To obtain 36×10^6 Reynolds numbers, he used 42 suction slots between the 40% chord and the trailing edge of the wing.

In tests made by Amos Smith at North American Aviation, he was able to get laminar flow up to a Reynolds number of 8×10^6 using a slotted configuration with suction.

Hazen pointed out that a slot, unless very carefully made, can in itself cause the breakdown of the flow.

Hazen felt quite optimistic about preventing flow separation on the after portion of a blimp. He was more pessimistic regarding the maintenance of laminar flow on an operational vehicle, although he stated that Dr. Raspet at Mississippi State College has been successful in maintaining laminar flow on a Piper Aircraft.

Apparently, in a Northrup presentation (at WADC) last year, Pfenninger made a lengthy presentation on his scheme of boundary layer and separation control. In order to reduce the wake drag on aircraft, the boundary layer should be kept just on the verge of going through transition. At the trailing edge of the wing, it should just go into turbulence.

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The concept the Reynolds number is misleading when based on frontal diameters or body lengths. The Reynolds number should be based either on the displacement thickness or on the length of run.

Hazen pointed out that the work we have proposed is in an area in which much is unknown and that work certainly needs to be done. Separation control is an area in which immediate and practical results could be obtained. He felt that boundary layer control to achieve laminar flow would require 10 to 100 times as much power as the suppression of separation.

The smoke tunnel at Princeton might be very useful in determining flow patterns on scale models if the concept of crude models which will give only qualitative data is accepted. Such a tunnel shows the gross flow behavior, including such phenomenon as the shedding of vortices. It might be best for preliminary investigations because qualitative information could be obtained for the three dimensional case, which to date has not been solved.

Hazen also discussed some work on submarine periscope oscillations which were reduced substantially through the use of an external perforated (leading and trailing edges) shield surrounding the periscope. Apparently, such an arrangement gave a drag that was pretty much the same as that without the external shield but eliminated the oscillation problem. A flat plate attached to the trailing edge along the axis of symmetry did not offer the same stabilizing influence as the above scheme. In some cases, if the plate were separated from the body by a body diameter, it did have a stabilizing influence.

Boundary layer control on the control surfaces might be effective in giving proper control without putting the control surfaces into the air stream. The work of Lippisch on the "Aerodyne" was discussed. Hazen pointed out that Lippisch used electronic stabilization and that the craft had no natural stability. The effect on stability of power failure, which would eliminate boundary layer suction, should be very carefully considered.

Clauser at Johns Hopkins apparently has been doing considerable work on boundary layer control under adverse pressure gradients and is a foremost authority in this field.

David Taylor Model Basin work has shown that elaborate laminar shapes have not been worthwhile. They have conducted tests of a Goodyear design, with a laminar shape and a single suction slot.

Work now in progress (sponsored by BuAer and ONR) will show where drag improvement is possible on present airships. However, Hazen reiterated that the gains possible through the control of separation would be extremely worthwhile and that this work should be done.

The detection of turbulent flow by the stethoscope method was discussed. The transition of the flow from a laminar to a turbulent condition generates audio frequencies which can be detected from the inside of a blimp by the use of a stethoscope placed to the skin.

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Literature on boundary layer and boundary layer control was discussed. The works of Schlichting and Pfenninger apparently are the best sources of information at the present time. The Princeton series does not have a volume on this subject yet.

The work of Gus Raspet has been done mainly at sea level conditions. He has had no problems in maintaining the laminar flow to Reynolds numbers of 3 or 4 x 10^6. He will have data on full scale blimp flight tests in approximately 12 to 18 months on a currently sponsored ONR program.

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