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NICAL REPORT
T NO. F TR-21 -ND (Preprint)
April 1947

HEADQUARTERS
AIR MATERIAL COMMAND
WRIGHT FIELD, DAYTON, OHIO

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ANALYTICAL INVESTIGATION OF THE COANDA EFFECT

(Project No. FP-186)

Alfred Voedisch, Jr.

April 1947

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TECHNICAL REPORT
REPORT NO. F-TR-2155-ND (Preprint)
DATE: 3 April 1947

HEADQUARTERS
AIR MATERIEL COMMAND
WRIGHT FIELD, DAYTON, O.

ANALYTICAL INVESTIGATION OF THE COANDA EFFECT

(Project No. FP-1[illegible])

Alfred Voedisch, Jr.

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Subject: Analytical Investigation of the Coanda Effect.

Introduction: Great interest has been aroused in a fluid dynamic phenomenon, the so-called Coanda Effect, in respect to a Rumanian, M. Henri Coanda, who claims to have discovered the phenomenon in Paris, France, prior to 1935.

Coanda claims the phenomenon to be applicable to induced flow (thrust augmentation) units; a high-lift, low-drag wing; and various types of prime movers.

A special nozzle or slot with a series of flat lips or surfaces, Figure 1, produces the phenomenon, which is an increase in velocity and mass flow, and the deflection of the issuing stream around a series of surfaces. By employing the proper length and angular placement of the attached lips, a deflection of 180° in the issuing stream may possibly be realized.

Object: In order to aid in bringing about a decision as to the degree of importance of such an effect, and to aid in the present thought, expectation and investigation now active or to be made active on the subject phenomenon, this preprint of a T-2 Analysis Report is deemed necessary, and presented for informational needs.

Bibliography: M. Henri Coanda discovered in the course of his experiments, a device, Figure 1, which produced the following effect. If air was ejected from a rectangular or annular slot or nozzle AB and a series of surfaces C, D and E were attached as shown at increasing angles from the initial axis of flow FG, there was an increase in the velocity and mass flow of the fluid, and it tended to follow around the surfaces C, D and E, entraining some of the free air H. This increase in mass flow was further improved by a straight extension of the other wall JK to JKL.

Coanda adapted this phenomenon to various devices, i.e.; an induced flow (thrust augmentation) device, Figure 2; a wing for high-lift, low-drag characteristics, Figure 3; an exhaust scavenger, Figure 4; a wind tunnel fan, Figure 5; a water propulsion device, Figure 6; and a rotating pump, Figure 7.

Attempts were made by Coanda during 1936 to 1938 to interest the Brandenburg Motor Company, in Berlin, in the Coanda Effect. Since it was not possible to judge the value of the phenomenon from the demonstrations, and Coanda could not show any theoretical calculations, he was advised to have experiments made to show the advantages and usefulness of the device. German engineers saw tests of the exhaust scavenger, Figure 4, in Paris, and no interest was aroused.

A report, "On the Phenomenon of Fluid Veins and Their Application, the Coanda Effect," was presented by A. R. Metral, a professor with the Conservatory of Arts and Trades, Paris in 1939. The report presented a mathematical investigation of this subject phenomenon, which does not truly represent a theoretical analysis of the Coanda Effect due to disregard for the frictional and compressibility effect of fluids; and included results of tests run during 1937 and 1938 on motorcycle, bus and passenger car engines using an exhaust scavenger, Figure 4, to improve the power output of engines.

American interrogations with H. Coanda during 1944 and in early 1945 brought the Coanda phenomenon to light again, and it was learned that a motor car radiator manufacturer, Usines Chasson, had used the Coanda nozzle device, Figure 2, to induce air flow through a radiator, directing the exhaust gas from the engine through the annular Coanda slot. The general manager, J. L. Poitrine, said tests produced a flow augmentation of about 6:1, with a nozzle 150 mm in diameter and a 0.1 mm Coanda slot.

In the book, "Guide to the Study of the Airflow Theory," by Dr. Ludwig Prandtl, 1931, reference is made to a device proposed by NACA which is similar in action to the Coanda induced flow device, Figure 2. This device, Figure 8, was used for evacuating the wind tunnel after high pressure tests by directing compressed air through the annular slot A. A similar device, Figure 9, was proposed and used by the British, for utilizing the compressed air in a large wind tunnel, to operate a small induced wind tunnel, by directing the compressed air through the chamber A, and out the annular slot B.

The Chrysler Corporation was contacted, and it was learned that a Plymouth engine was provided in 1938 for tests mentioned in A. R. Metral's report. Investigation of the progress being made was undertaken and it was decided that no further interest was warranted and all activities of the Chrysler Corporation ceased.

Coanda phenomenon and device:

The Coanda phenomenon consists of the following individual effects as follows:

1. An increase in the mass flow and velocity of a fluid issuing from the exit section of a rectangular or annular nozzle or slot by placing one side of the exit wall at an acute angle to the direction of initial flow, aided possibly by a straight

extension of the other wall. The configuration of the two walls forms an offset divergent nozzle, which it is well-known, produces a greater mass flow than a simple nozzle. Figure 10 compares a regular divergent nozzle and the Coanda type divergent nozzle.

2. Deflection of the mass flow through an angle, by means of a series of surfaces at acute angles to each other. The deflection of a fluid by means of a smoothly curved wall, Figure 11A, is well-known, and various simple and useful applications can be cited and experiments made to show this. By the use of steps, such as in the Coanda device, Figure 1, it is plausible that the total angle of deflection may be greater, since by the use of a sharp corner, such as is formed by two of the surfaces, for example C and D, the mass flow is strongly accelerated, and the slight separation causes a turbulence which produces an augmented mixing, and a renewed boundary layer energy. It might be better, as shown in Figure 11B, to use a smoothly curved surface until just before separation would normally occur, then by means of a corner, renew the boundary layer energy, and allow a greater deflection.

3. Entrainment of additional air by dragging the stationary air along with the primary jet, providing an additional mass flow. It is well-known that a jet of any fluid has the property at its surface to drag stationary fluid into motion by means of frictional forces. Compared to a free jet, Figure 12A, which can cause entrainment on all sides, the Coanda device, Figure 12B, due to the required contact of one side of the jet with the wall, can entrain fluid along only one side.

The Coanda device has inherent energy losses, which are produced by the motion of the device, as follows:

1. Loss due to friction along the series of surfaces while a change in the direction of motion of a fluid occurs.

2. Loss due to boundary layer energy renewal.

These two losses will always be present and since a simple divergent nozzle will produce the useful part of the Coanda Effect which is the increase in the velocity and mass flow of the primary stream, and the entrainment of stationary air, these losses appear to limit the practical use of such a device. Only where it would be necessary to deflect a fluid jet through an angular displacement for application purposes to efficiently utilize the energy of the jet, does it appear advantageous to use the Coanda Effect.

Coanda device applications:

1. An induced flow (thrust augmenting) nozzle, Figure 2. In this nozzle a working fluid A issues from an annular Coanda slot B into a nozzle C, just before the venturi section F. The purpose being to induce a flow D through the nozzle, and produce a flow or thrust augmentation.

Figures 8 and 9 show other proposals for augmenting the fluid flow. Figures 8 and 9 are similar to the induced flow device proposed by Coanda as shown in Figure 2, except in the method of placing the working fluid into action. Since initial mixing of a primary and secondary fluid requires large surface contact between the primary and secondary jet, the surface contact of the device in Figures 8 and 9 could be improved over that shown by cross-section in Figure 13A, by ejecting the fluid in a series of hemispherical portions, the cross-section of which would be as shown in Figure 13B.

Exact calculation of induced flow ejector action is practically impossible, but with a number of assumptions, a close approximation can be made.

There are two methods of ejecting a primary stream into an induced flow nozzle, either by using a central-jet, such as found in standard jet pumps, or by using a ring-jet, such as used in the Coanda nozzle, Figure 2, or in the other induced flow devices shown in Figure 8 and 9. Ring-jet ejectors have been used previously, Figures 8 and 9, with good results; being used in the induced flow tunnel, Figure 9, mainly to avoid the turbulence which would be present were a central-jet employed.

A study of the two types of ejectors has been made, assuming the optimum dimensions and flow conditions of each. Since the Coanda device is merely an ingenious method of utilizing a ring-jet and it has already been shown that there are inherent losses in the use of such a Coanda device, an ideal ring-jet was considered.

In the case of a central and the ring-jet application, there is an optimum size for each. This is shown in Figure 14A which shows the maximum augmentation available from the optimum ring-jet and central-jet nozzles. It can be seen that the optimum diameter is different in each case, due to varying energy losses, and that different thrust augmentation is obtained. For each type application, there is a maximum air speed at which the unit will produce no augmentation. It can be seen, Figure 14B,

that the optimum central-jet will cease to produce thrust augmentation at a lower speed than the optimum ring-jet type.

2. A high-lift, low-drag wing, Figure 3.

Air is blown through a Coanda slot A, over the wing B, the upper surface of which has Coanda steps, D, E, F, etc.

Many ways have been proposed to increase the lift of aircraft wings, and all have shown a good degree of success. Such wings have attempted to control the boundary layer by either blowing it away or sucking it inside the wing for disposal.

A well-known Handley Page wing, Figure 15, uses an interconnecting passage between the upper and lower wing surface, and only at high angles of attack, does the system operate and air blow over the upper surface of the wing.

Wings have been tested which have blowed or sucked air at various positions along the upper and lower airfoil surface. By placing a slot in the forward section of a wing the lift is increased a greater amount due to an increase in the velocity on the upper side of the wing, since the action of the slot tends to increase the negative pressure in front. Slots produce drags which are incompatible with high speed, and their use can only be really advantageous during low speed flight. The use of pressure slots yields lift increments of the same order of magnitude as a Handley Page type slot which passes entirely through the wing. It seems that were pressure slots required, a simple slot would require less energy than a Coanda slot, and the upper surface of the airfoil would not be broken up by the series of Coanda surfaces, Figure 3, which may cause more drag at high speeds.

3. An exhaust evacuator, Figure 4.

The pulsations of the exhaust gas A from an engine are smoothed out by means of a long exhaust pipe, and finally flow from the exhaust evacuator B through the Coanda slots C, around the Coanda steps D. It has long been known that by utilizing an exhaust pipe of correct length, the efficiency of an engine could be improved. If this effect may be further improved by reducing the back pressure to a greater extent, a series of simple divergent nozzles could be used as effectively as the Coanda slots.

4. A wind tunnel fan, Figure 5.

Air is pumped through known slots A, in each corner of the triangular devices shown, and surrounding air is entrained into a stream which follows around the periphery of the walls. Coanda claims the speed is augmented at each corner and a very high speed can be attained. The amount of air admitted to the system is recovered at B and recirculated to the Coanda slots A. Since the only increase in speed can occur as the working fluid goes through the divergent Coanda nozzle, no increase occurs at the corners; and the only final speed disregarding losses could be that of the primary fluid.

5. A water propulsion system, Figure 6.

By using the Coanda device in the nose of a torpedo or ship, and ejecting fluid A through the slot B, the torpedo C will move forward. It is known that by pushing on the thick boundary layer at the rear of such a unit, the propulsion efficiency is greater, than by pushing on the thin boundary layer at the nose of the unit. Placing the propulsion means at the rear would require disregarding the Coanda device, and even if it could be used, inherent losses would give less propulsion efficiency.

6. A rotary pump, Figure 7.

A working fluid A enters the rotor B of the pump D, and issues through several Coanda slots into a pumping chamber C. Using the working fluid as a seal between the rotor B, and the frame of the pump D, fluid may be pumped against a high pressure. Such a pump requires not only a working fluid under sufficient pressure to overcome the working pressure, but also rotation of the Coanda slot rotor. This type of pump requires two different sources of energy to operate it, and since only about 50 - 70% of the fluid pumped is from the required source, it would have a low efficiency. Since water is used as a working fluid, a separation process is required if air or another gaseous material was pumped, since air would not provide a sufficient pumping seal if used as a working fluid. It appears that a simple gear eccentric or piston pump could provide higher efficiencies than the proposed Coanda pump.

It is strongly felt that in all cases where a Coanda device has been proposed, and no doubt many can be mentioned, it can be easily shown that the device is not as practical as Coanda claims it to be

Summary: A partial analytical study has been made of the phenomenon, and the device (hereafter called the Coanda device) needed to produce the phenomena. All suggested applications have been studied, and the relative advantage shown as compared to units now in use. An investigation of the losses prevalent in both the thrust augmenting device and the high-lift low-drag wing are noted, and the relative value of each application is cited in comparison to other well-known methods.

Conclusions:

1. The Coanda Effect is a combination of three separate phenomena which are well-known, and have been utilized in various applications previously, not necessarily in such a combination, but separately.

2. Inherent losses in the phenomena brought about through the use of the Coanda device, places an initial disadvantage on the effect.

3. In many applications, the Coanda device can be shown to be extraneous to the action sought, and/or merely an ingenious arrangement of a mechanism already in use.

4. In all applications of the Coanda device, the action desired is accomplished, but in most cases, with the expenditure of additional energy, which prohibits the use of such a unit.

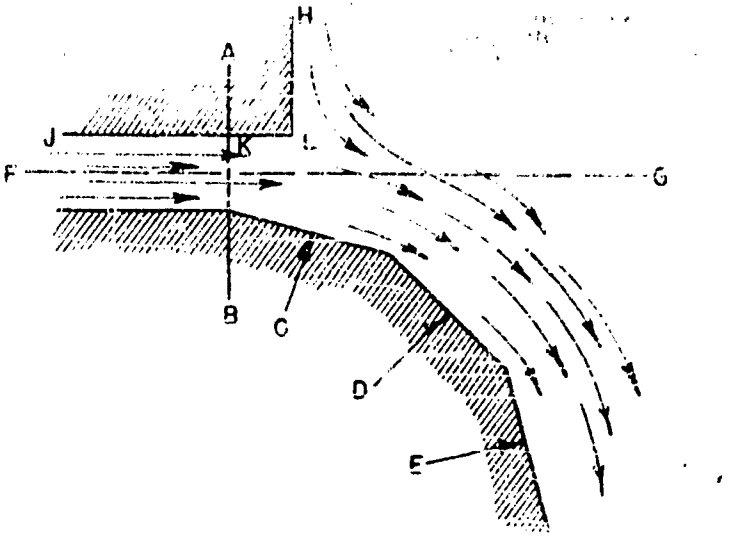

FIGURE 1. COANDA DEVICE

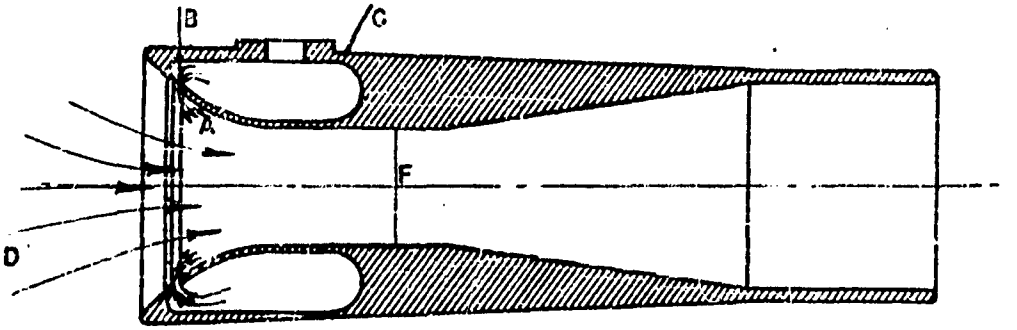

FIGURE 2. INDUCED FLOW, THRUST AUGMENTOR, NOZZLE-DIFFUSER

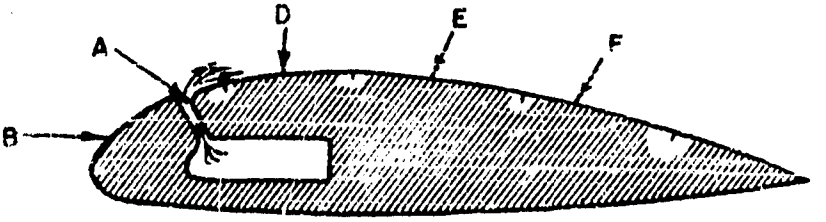

FIGURE 3. HIGH LIFT LOW DRAG WING

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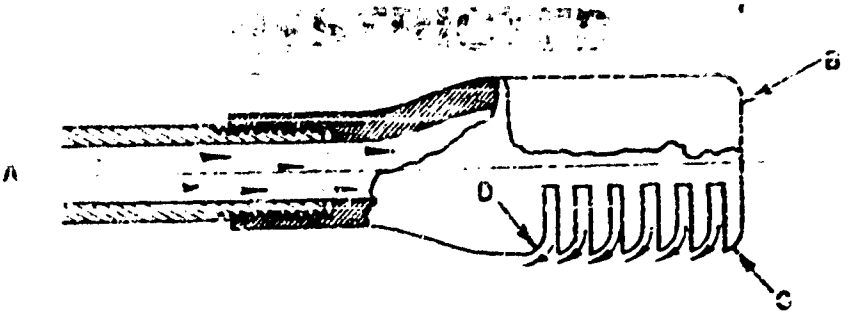

FIGURE 4. EXHAUST SCAVENGER

FIGURE 5. WIND TUNNEL FAN

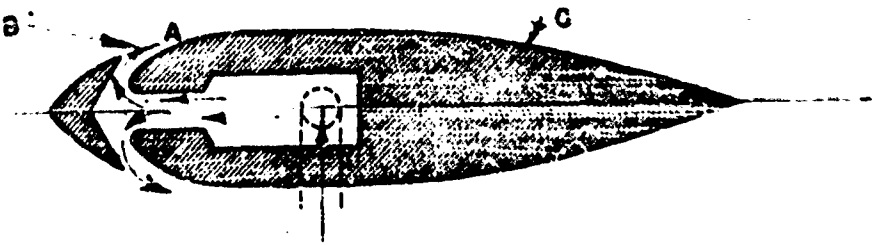

FIGURE 6. WATER PROPULSION UNIT FOR SHIPS AND TORPEDOES

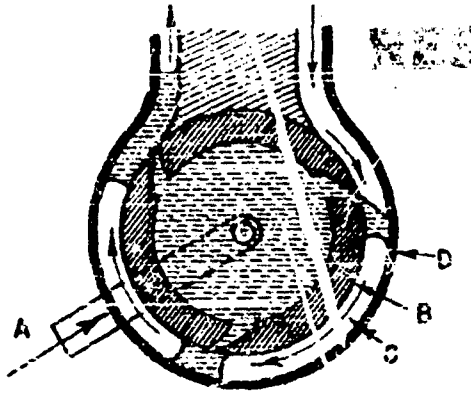

FIGURE 7. ROTARY PUMP

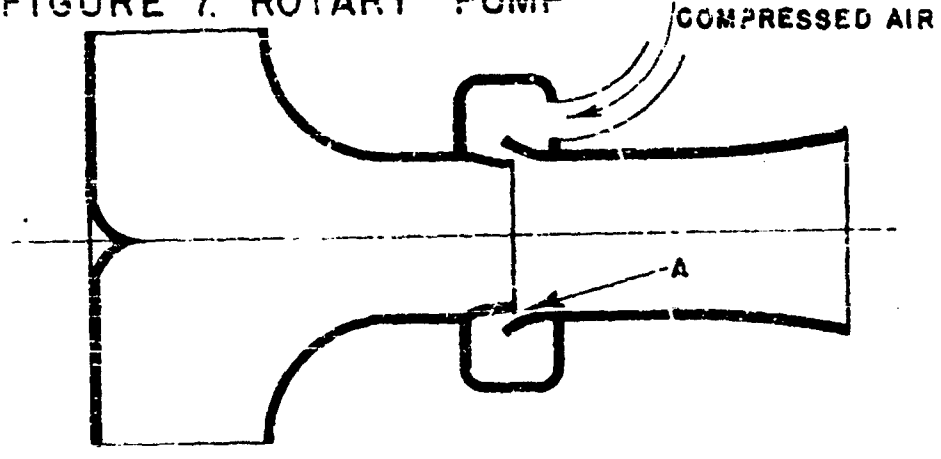

FIGURE 8. PROPOSED NACA WIND TUNNEL EVACUATOR

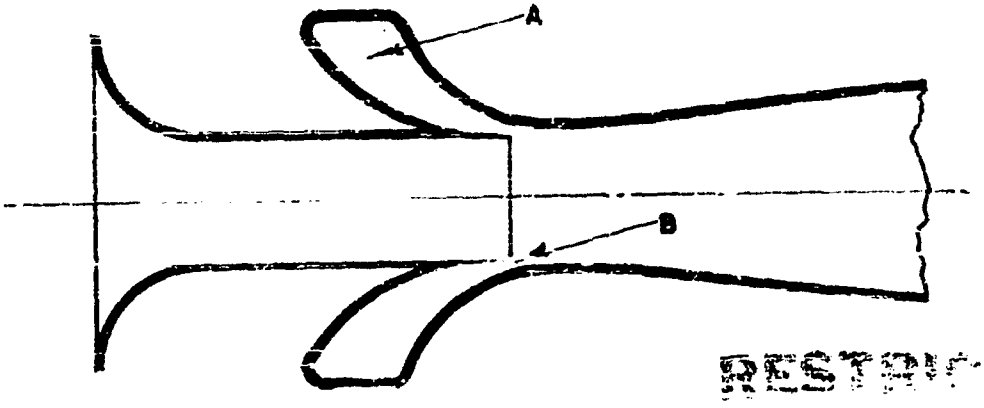

FIGURE 9. INDUCED FLOW WIND TUNNEL

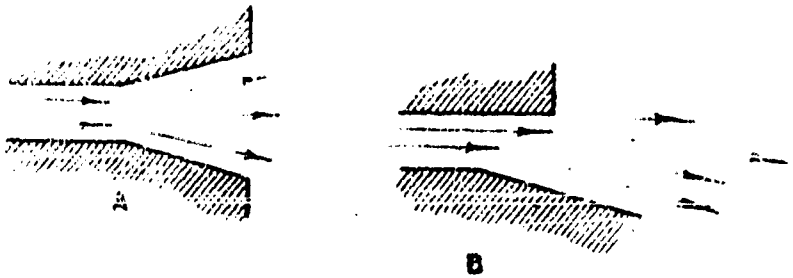

FIGURE 10. COMPARISON OF DIVERGENT NOZZLES

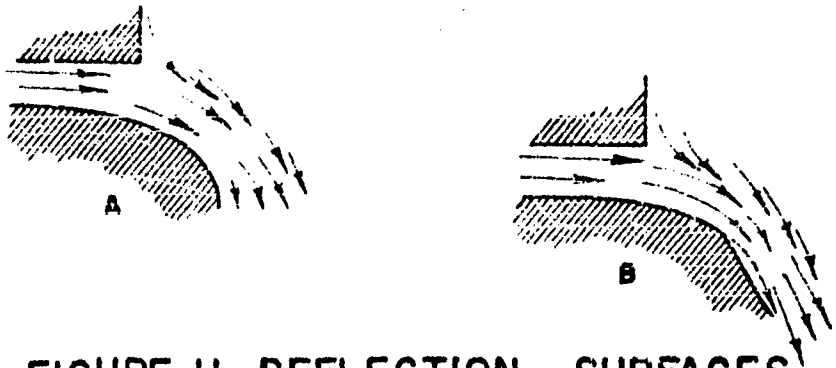

FIGURE 11. DEFLECTION SURFACES

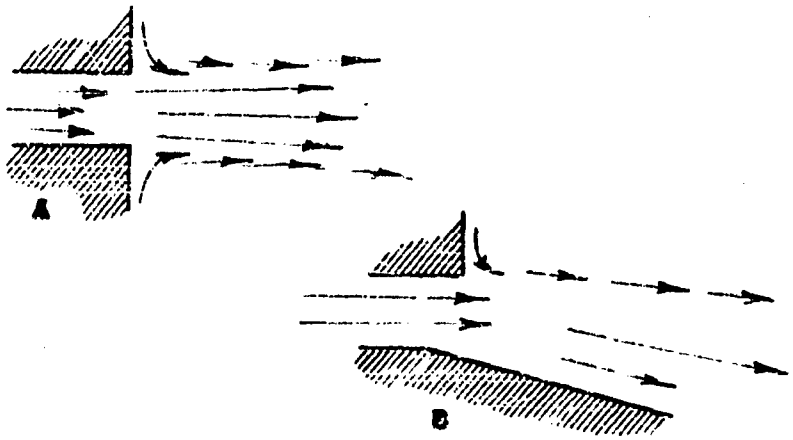

FIGURE 12. COMPARISON OF AIR ENTRAINMENT

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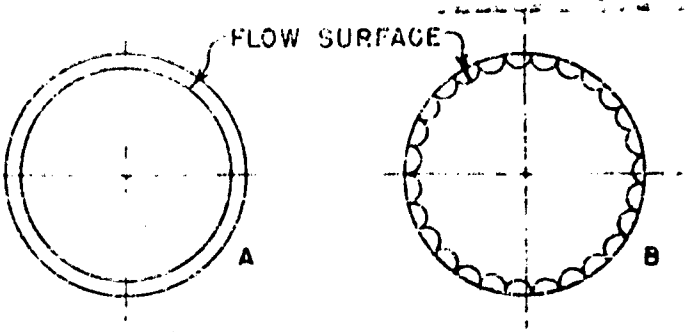

FIGURE 13. IMPROVED INDUCED FLOW SECTION

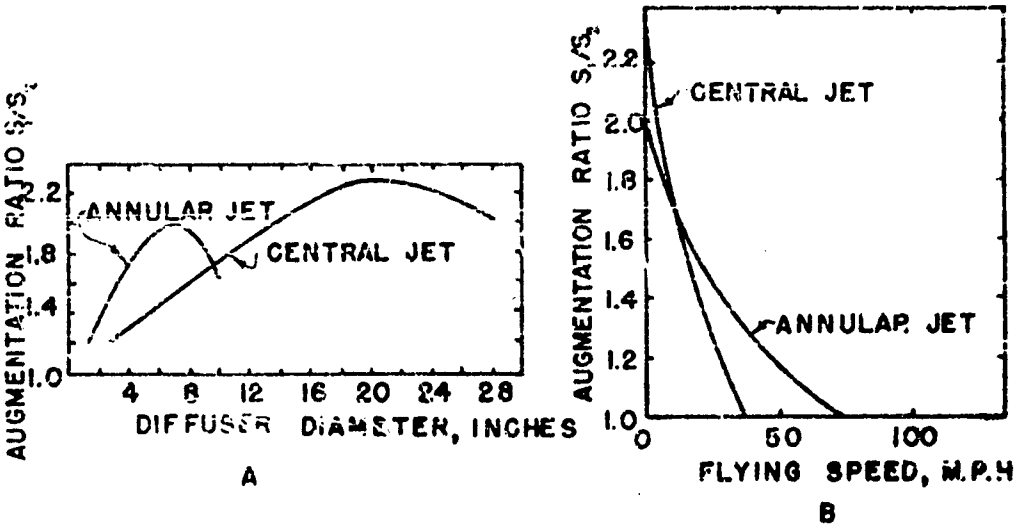

FIGURE 14. AUGMENTATION POSSIBILITIES

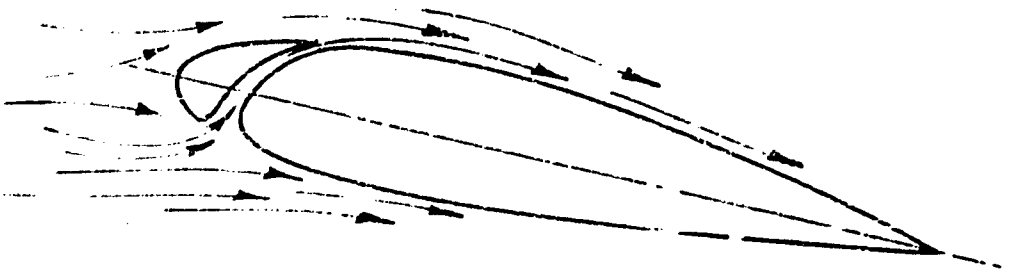

FIGURE 15. HANDLY PAGE TYPE WING SLOT

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Voedisch, A.

AUTHOR(S)

DIVISION: Aerodynamics (2)
SECTION: Wings and Airfoils (6)
CROSS REFERENCES: Flow research - Methods (40950); Flow along surfaces (40200); Coanda (40950)

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ABSTRACT

Analytical study was made of Coanda effect and of a Coanda device. The effect is a combination of three separate phenomena concerning increase in velocity and mass flow a fluid, deflection of issuing stream around a series of surfaces, and entrainment of additional air by dragging stationary air along with primary jet providing additional flow. Coanda claims the phenomenon to be applicable to thrust augmentation units, a h lift, low-drag wing, and various types of prime movers.

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