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THE HALF-MODEL TECHNIQUE IN THE WIND TUNNEL AND ITS EMPLOYMENT IN THE DEVELOPMENT OF THE AIRBUS FAMILY.

H. P. Franz

Translation of " Die Halbmodelltechnik im Windkanal und ihre Anwendung bei der Entwicklung der Airbus-Familie". Deutsche Gesellschaft fuer Luft - und Raumfahrt, Jahrestagung, Aachen, W. Germany, May 11-14, 1981. 38 p. DGLR Paper 81-118.

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16. Abstract The use of the half-model technique in the wind tunnel is very useful particularly during the development of transport airplanes. The slow-flight properties (starting and landing) can be determined and improved to a predominant degree with this technique. VFW uses the half-model technique successfully during the development resp. continued development of all projects for the AIRBUS family and will continue to improve it in the future so that finally absolute accurate results can also be achieved.

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THE HALF-MODEL TECHNIQUE IN THE WIND TUNNEL AND ITS APPLICATION IN THE DEVELOPMENT OF THE AIRBUS FAMILY

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Abstract (technical-scientific neutrally oriented brief summary):

The use of the half-model technique in the wind tunnel is very useful particularly during the development of transport airplanes. The slow-flight properties (starting and landing) can be determined and improved to a predominant degree with this technique. The model expenditures (for nacelle and power plant) are reduced, and the attainable Re-numbers are doubled. Disadvantages of this measuring technique are:

- The absolute accuracy of results is possible only by the use of great technical instrument and analytical expenditures
- The lateral movement cannot be simulated with the half-model technique.

VFW uses the half-model technique successfully during the development resp. continued development of all projects for the AIRBUS family and will continue to improve it in the future so that finally absolute accurate results can also be achieved.

Key words (search terms):

wind tunnel measurements, measurement technique, half-model, transport development

THE HALF-MODEL TECHNIQUE IN THE WIND TUNNEL AND ITS APPLICATION IN THE DEVELOPMENT OF THE AIRBUS FAMILY

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Summary /118-3*

A summary is presented concerning the half-model technique employed by VFW within the framework of the development of the airplanes of the Airbus family. The prinicple of the half-model-technique is demonstrated with the aid of the decision criteria and the alternatives and the limits of this technique are shown.

VFW has consistently pursued, within the framework of the Airbus family development, the step concept of the multiple utilization of suitable half-models in various European wind tunnels. Here we find in the foreground the development of high performance high-lift systems (layout, geometric optimization, performance determination). The essential steps of this concept are:

- o small half-model 1 : 16 in the atmospheric tunnel
  - choice of flaps (system, angle, position)
  - preoptimization of the power plant-integration
- o small half-model 1 : 16 in the high pressure tunnel
  - flap powers at higher Re-numbers
- o correlation full-model - half-model
  - full model 1 : 38 in NLR-HST
  - half-model 1 : 16 in various tunnels
  - full-model 1 : 9.5 in DNW
  - half-model 1 : 9.5 in ONERA-F1
- o large half-model 1 : 9.5 in ONERA-F1
  - flap powers for high Re-numbers
  - power plant interference for high Re-numbers

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* Numbers in margin indicate pagination of orginal foreign text.

The application of this step concept guarantees /118-4

- cost-effective subdivision of the test sections
- broad application spectrum for the model
- relatively high assurance of obtaining results by the use of super-critical Re-numbers even for relatively small wind tunnel test cross-sections
- determination of the power plant influences while using half the number of power plants.

VFW considers the utilization of the half-model technique in the Airbus development to be extraordinarily efficient despite the given limitation to symmetrical flight conditions and will continue to pursue this path even for future derivatives of the Airbus (e.g. A 300-600).

1. INTRODUCTION

The development of civilian transport airplanes for the next few decades demands performances which, to a controlling degree, are determined by the changed cost situation and also by today's awareness of the environment. The development of military airplanes follows other rules; it will not be treated further within the framework of this presentation.

The direct operating costs (DOC) have, as shown in figure 1, increased greatly primarily because of fuel costs. It seems appropriate to make every effort to improve the flight performances of newly to-be-developed transport airplanes and also, within the framework of what is possible, those of already flying commercial airplanes. Here, as shown in figure 2, the development costs amount to about 5% of the total costs of a transport airplane of medium mass production. If one takes into account the fact that already a minor reduction in drag (or an improvement in glide ratio) can reduce the fuel costs appreciably, then it seems appropriate to devote increased interest to the part "Research and Development".

Individually the most important development requirements for modern transport airplanes are:

- transsonic propulsion speed for fuel consumption as low as possible, i.e.: improvement in glide ratio, displacing the rise in the resistance curve to higher Mach numbers and the buffet onsets to higher lifts.
- high start- and climb flight powers for reduced noise levels
- low landing speed (= maximum lift as high as possible).

To satisfy these requirements all transport airplanes which are under development worldwide, are designed on the basis of supercritical profiles which make possible a wing layout of higher

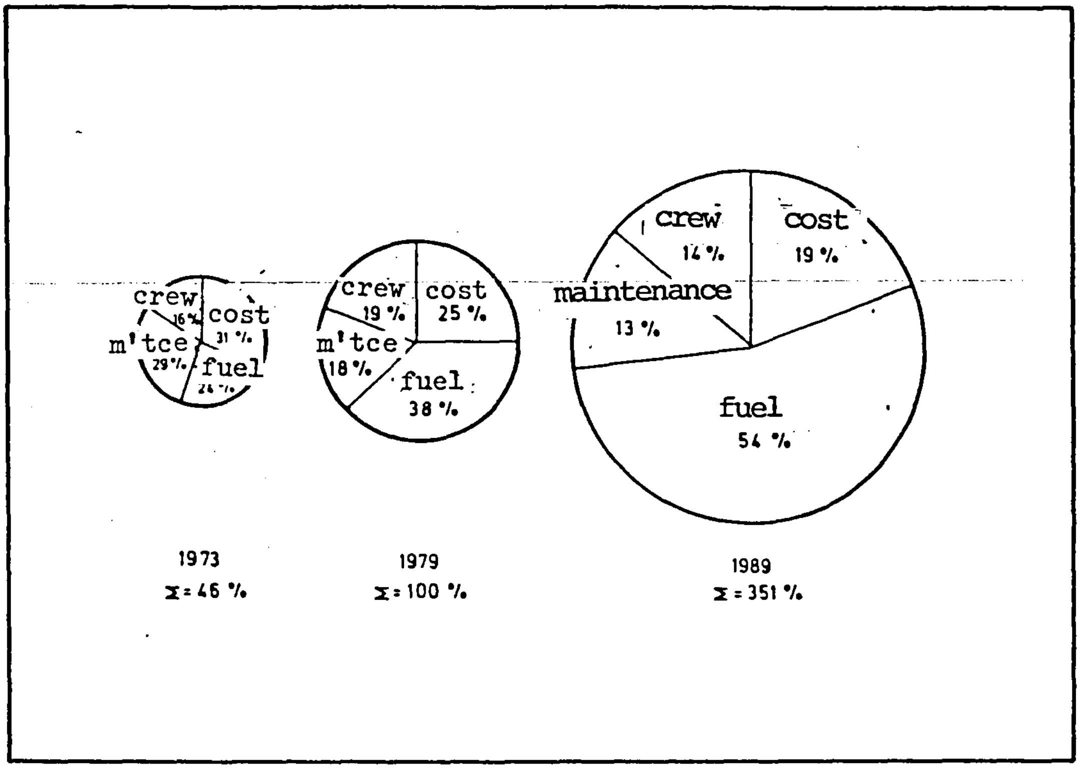

Figure 1: Increase with time of the flight costs and displacement of the relative shares Ref.(1)

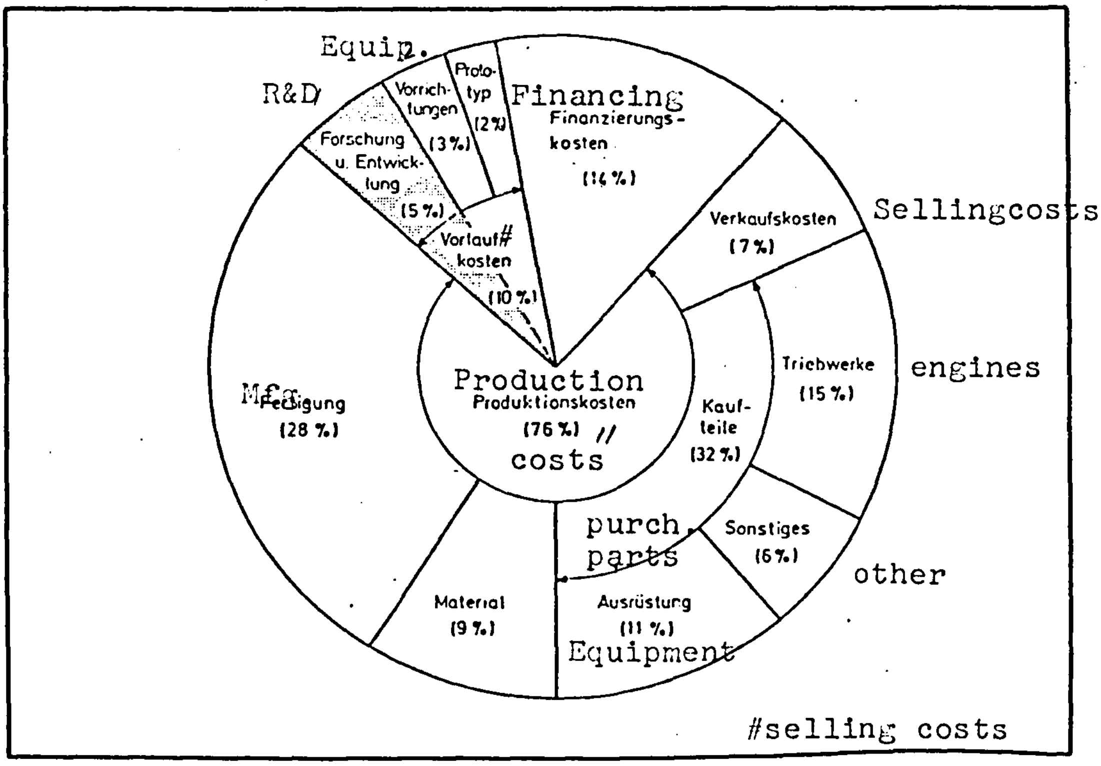

Figure 2: Percentages of total cost for a civilian transport airplane of medium mass production – state 1979/80 Ref.(1)

aspect ratio and greater thickness. Figure 3 shows a plan view comparison between airplanes with conventional and those with modern design [2]. /118-7

As a rule the wings are attached in these progressive designs in a low-wing arrangement. Because of the demanding slow-flight requirements they are equipped with highly-raised flap systems at the leading- and trailing edges. The high thrust, economical double-circle power plants have large diameters because of their high bypass ratios. The required ground freedom causes the power plant to be attached very closely to the wing underside which produces a strong mutual effect between wing and power plant. These typical layout characteristics demand especially careful investigation of local flow conditions for all flight conditions encountered. Most of these tasks are carried out by experiments with a wind tunnel model whereby, because of the required result fidelity, the largest possible approach to the large-scale version must be assumed for external shape and flow conditions.

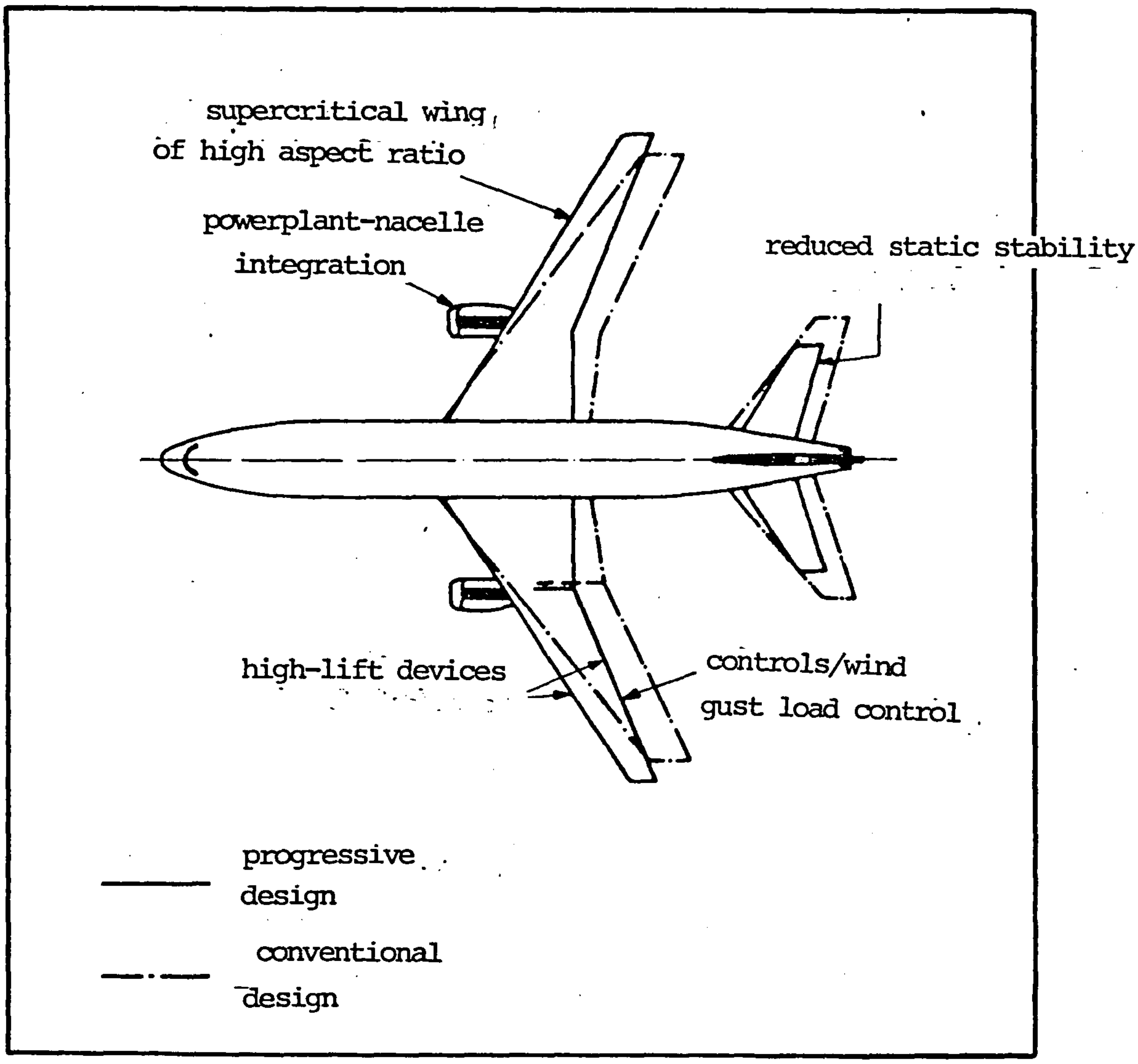

Figure 3: Topview comparison

2. THE HALF-MODEL TECHNIQUE /118-9

2.1 - Application Possibilities

The half-model technique represents a valuable compromise in the experimental aerodynamics. Naturally one can use this technique, out of the entire spectrum of problems in the development of an airplane, only for the investigation of that part which is related to the forward-motion properties; in return, however, it offers advantages compared to the flow-model technique which assure for it a certain domain. The most important advantages are:

- for a given wind tunnel the possible model scale is about twice as great as for the comparable full-scale model. This means a doubling of the Re-number for flow mechanics and thus a strong approximation of the flight Re-numbers
- in the model fabrication the mirror-symmetrical half is eliminated which reduces costs
- the largest half-model parts can be fabricated more simply as a rule and, for equal care, with double the accuracy of the full-model
- the adjustment accuracy of the individual elements with respect to one another is increased considerably. This is of great importance especially with regards to the positioning of individual flaps for highly-developed multiple-flap systems
- for interference measurements with active power plant simulation in the wind tunnel the initial- and the operating expenditures of the model power plant are reduced.

Despite several disadvantages which we will still discuss /118-10
later because of their relation to the arrangement principle, the cited argument in the problem complex

favor the use of the half-model technique. With it one can primarily work on:

- selection of the high lift-flap system
- optimization of flap angles and flap positions (separation geometry)
- optimization of transitions (wing- fuselage, flap end, power plant - Pylon - fore-wing - wing)
- determination of stream effects with active power plant simulation
- optimization of geometric variations with respect to interference effects.

In all the named application possibilities for the half-model no absolutely accurate wind tunnel result is necessary as long as the differences between two conditions to be compared can be measured accurately. Thus a constant disturbing boundary condition can remain in the test result without correction as long as this result serves only as a comparison with one of the referenced data obtained under the same boundary conditions.

Understandably during the use of a measurement technique one will always encounter the desire for improvement; this is also the case for the half-model technique with respect to attainment of absolutely valid wind tunnel results.

Therefore we shall discuss this topic in the next few sections and make a solution proposal.

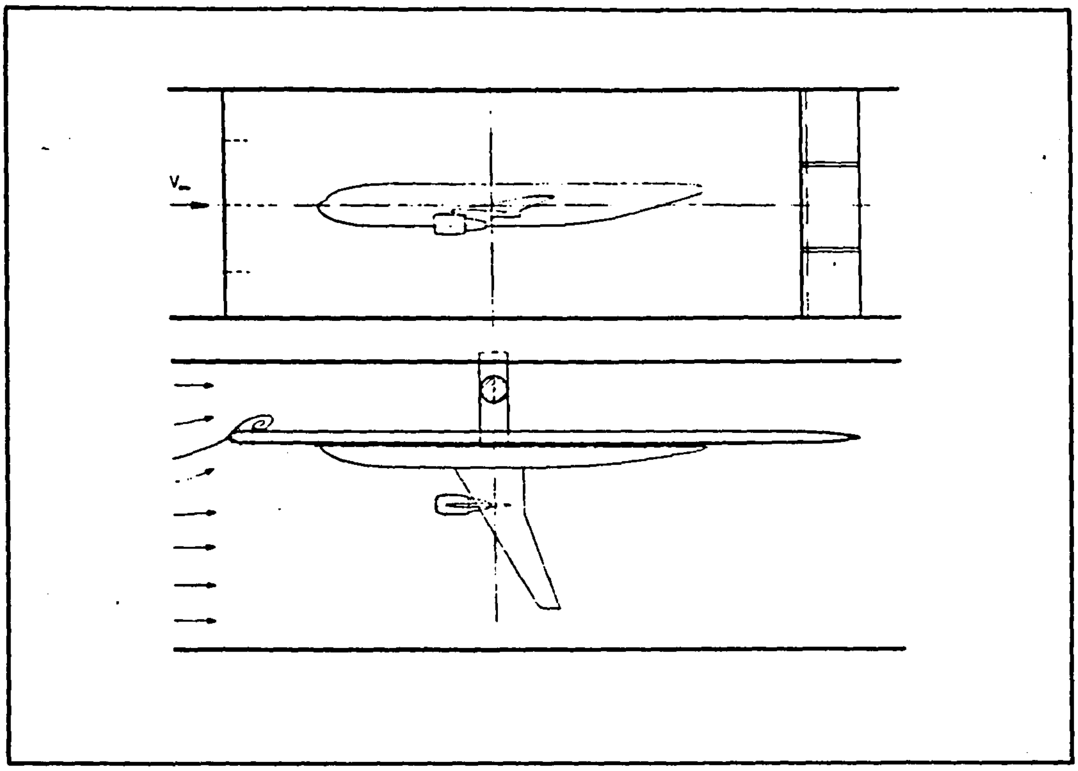

Figure 4: Partition wall installation with free flow division

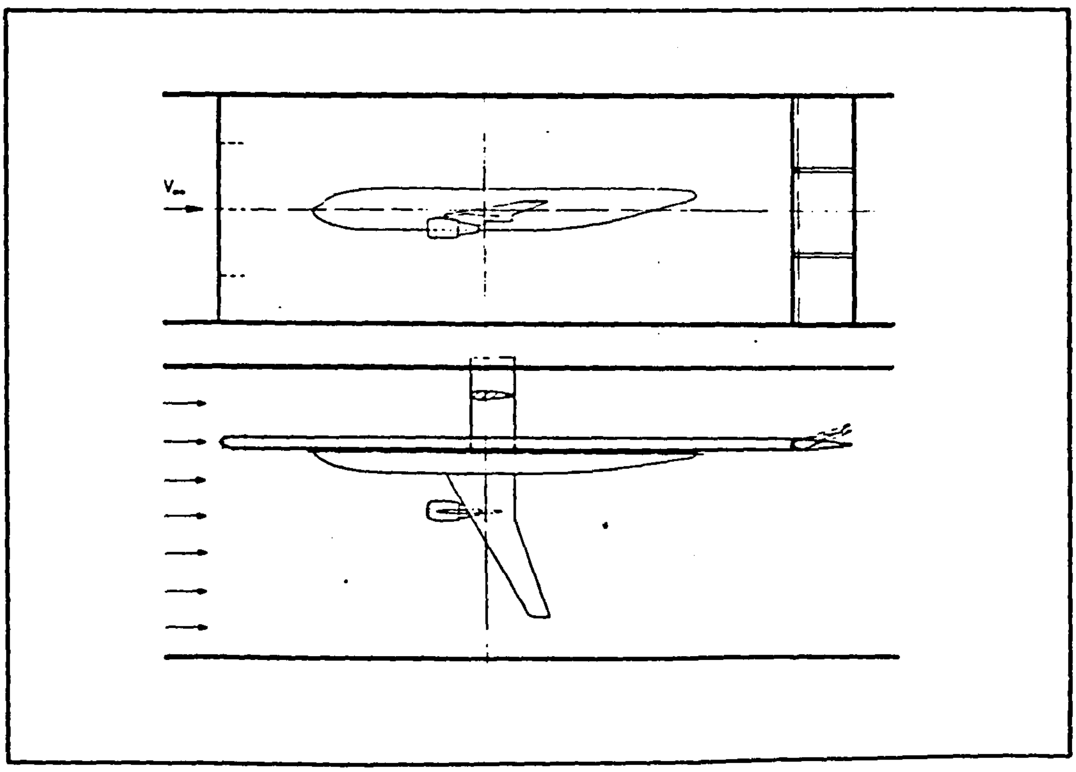

Figure 5: Partition wall installation with controlled flow division

2.2 - Arrangement principles /118-11

A half-model is bounded by one plane which, in the normal case, coincides with the fuselage midsection. The transition from "weighed" model to the fixed-tunnel wall is made here in different ways which all have a common problem, namely difficulty to satisfy the physical boundary conditions in the sectional plane. Additional forces must not be applied to the model, neither by the space between weighed and the tunnel-fixed part of the arrangement nor by an elastic closing of this slot. The flow around the half-model should be as free as possible from the effect of the friction layer of the boundary wall. The individual arrangements for half-models in the wind tunnel attain these goals with varying results.

The most feasible arrangement principles are:

2.2.1 - Partition-wall installation

In this method the half-model is mounted on a partition wall (false wall) and thus the boundary layer of the wind tunnel wall is kept away from it. In general the length of the partition wall upstream and downstream is longer than the model fuselage by about 2 to 3 fuselage diameters each so that we already encounter a new wall boundary layer which must be taken into account. However, typical for this type of arrangement of the half-model in the wind tunnel is the difficulty to divide the initially still undisturbed onflow of the air in the two chambers of the wind tunnel test section in such a way that the mass flow density remains the same in the two chambers under all conditions. Figure 4 makes plain that the angle of attack-dependent, one-sided stream loading in the main channel tries to displace the blockages and thus also the mass flow densities. This produces an oblique flow against the nose of the separating wall which induces a pressure distribu- /118-13
tion at the separating wall. As a rule the pressure distribution

affects the test result to a greater degree than the disturbing wall boundary layer. In the limiting case it can even lead to a flow separation at the nose at the separation wall side of the channel with the weaker loads which makes the test result unusable. However, in any case, for a free flow division in the test section with separating wall, the determination of the exact undisturbed dynamic pressure is impossible in the test section. In order to take care of these grave deficiencies of the separating wall arrangement, the channel flows must be controlled. This can be done, for example, by symmetrically arranged pressure-measuring stations on a semi-elliptical separating wall nose. The thus obtained information of the flow direction can be used for the load-dependent control of the channel flow division. However, to obtain the spatial distribution of the upwind front of the model this pressure measuring station control must be made in most cases in several steps. Figure 5 shows an example in which, in an adjacent channel, a correspondingly large profile goes through the same angle of attack movements of the model. In this profiled fairing it is possible, in addition, to house such necessary things as: model support for pressuredized-air supply for power plants and instrument lines. The fine regulation of the flow divisions can then be made via trailing edge flaps at the separating wall capable of differing openings - with large calibration- and measuring expenditures.

2.2.2 - Tunnel wall installation

In this method the half-model is mounted on the test section wall - without additional separating wall. Then, without the adjacent channel separation, the cross-section of the wind tunnel test section is available in its entirety; however, the friction layer of the channel wall is generally noticeably thicker than the for the above-described partition wall. However, an advantage compared to the "false wall" is the fact that the thickness of the wall boundary layer already has a lower gradient /118-14 because of the longer run which means that the achieved separation wall at the rear of the model deviates to a lesser degree from the required symmetry plane. In order to equalize the higher level of the boundary layer thickness a boundary-layer deflecting measure seems to be unavoidable in the channel wall installation. Therefore, for the fundamental arrangement of the tunnel-wall installation figure 6 already presents a possible solution which consists of a cylindrical separator - using the fuselage midsection as cross-section. For this pedestal the term "peniche" (French: tow barge) has come into use. The fuselage sectional plane and thus also the internal limitation of the "weighed" model parts are thus removed by this device from the friction-afflicted tunnel wall if the height of the pedestal corresponds approximately to the maximum boundary layer thickness at the fuselage rear. Although this method is subject to a typical deficiency which, at first glance, makes it appear to be unsuitable, to provide sufficiently accurate test results for absolute force coefficients, it can still provide usable results if one is interested only either in comparative measurements - in accordance with the reference method -, or if a fuselage correction can be made such as is described in section 2.3. This deficiency is caused by the following: The wall-near flow arriving at the model nose is not divided by the two-dimensional pedestal two-dimensionally into wall-parallel layers, but it flows around the nose three-dimensionally whereby a suction point is formed at the nose directed obliquely upstream which generates a "nose thrust". The axial force and the longitudinal moment are affected noticeably, the normal force only insignificantly in this way.

Here the labyrinth seal (see figure 7, left) between model and the unweighed system (channel wall, turning disc, peniche etc.) prevents the separation flow. However, because of the elasticity /118-16
of the suspension and the balance and the large lever arms at the nose and the rear the load-dependent changes of the two U-profiles relative to each other must be taken into account so that relatively large U-profiles and electrical contact indicators

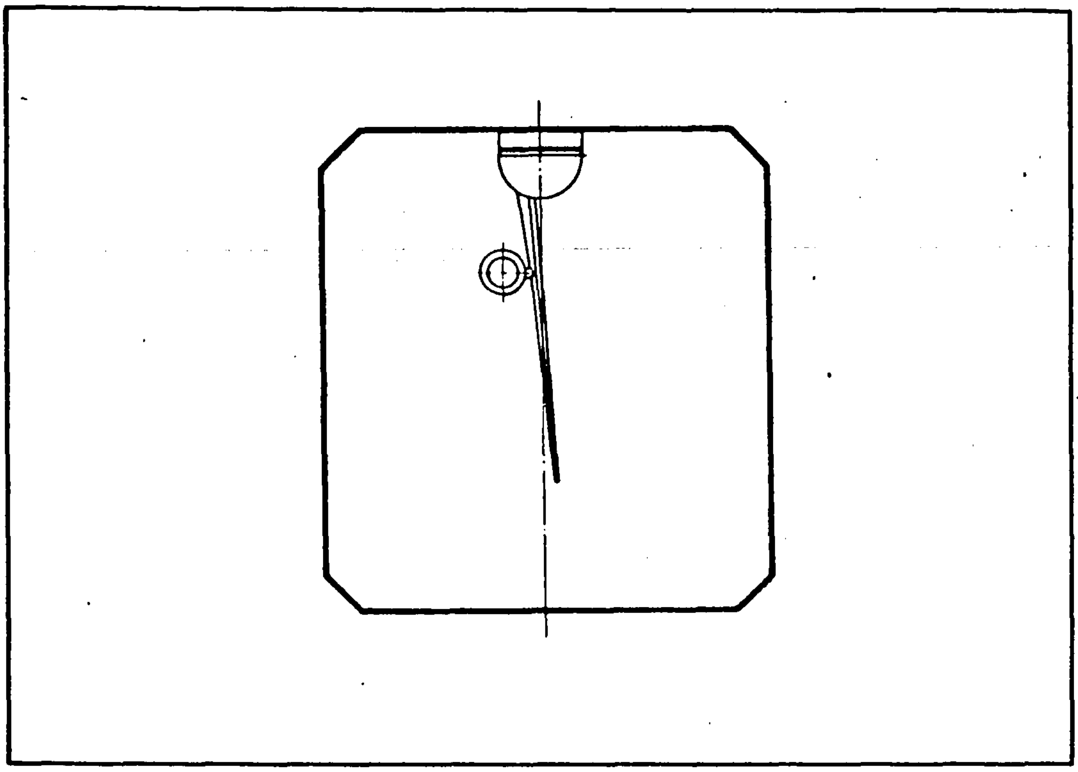

Figure 6: Tunnel wall method, with "peniche"

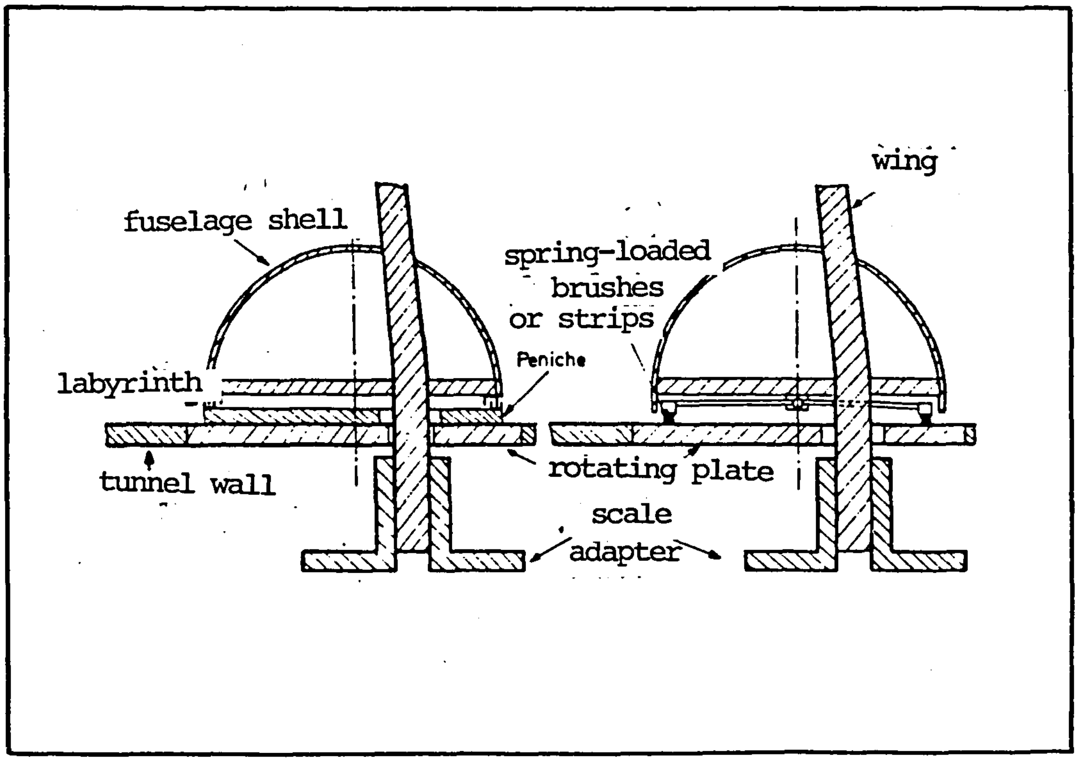

Figure 7: Half-model arrangement

must be attached. Another variation of the half-model arrangement at the tunnel wall is the one shown on the right in figure 7. Here the model is equipped with a spring seal made of brush strips or of an elastic silicon band which provide a seal either directly at the tunnel wall or on the peniche. The reaction forces of these strips can be determined roughly from a static calibration. However a residual hysteresis between dynamic and static measurement cannot be avoided.

A small intermediate step in direction of improved half-model arrangement in the wind tunnel can be attained for the wall mounting by means of a boundary layer fence attached to the upper peniche edge which, however, because of its own boundary layer should have a length only as short as possible so that no "blockage" arises below it. For changes in angle of attack there exists, in addition, the danger of overflow and eddy formation at the outer edge of the boundary layer fence which is the reason why this method did not prevail. A significant advance of the half-model measuring technique is then promised by the boundary layer-suction method if it is done consistently. Although a "simple suction" in front of the model nose would remove the tunnel boundary layer, the larger disturbance at the model caused by the gradients of the newly forming boundary layer would not be avoided hereby. Therefore the suction should consist principally of a perhaps semi-cicular slotted or porous strip which sucks off the "old" tunnel boundary layer, and of a finely-divided device, controllable in sections, for the /118-17
removal of the always newly developing friction layer.

Understandably arrangement and layout of the openings, distribution and controllability of the effective suctions require the most careful preparation, calibration and measurement. The effects of too great, too weak, or falsely distributed suction on the wind tunnel results must be investigated parametrically so that the tolerance width for the adjustment quantities can be determined.

For that reason this method promises, as the only one, that half-model results are valid also as absolute values. Drag and longitudinal moment, which provide valid data in all other methods only as difference methods compared to a reference measurement, thus become independent. This is especially significant for interference measurements with active power plant representation because now, of the undistorted flow around the fuselage rear, the downwind field at the elevator can be measured disturbance-free.

2.3 - Wind tunnel corrections /118-18

Here we shall treat briefly only the half-model-specific wind tunnel corrections. The wall reflection correction according to Prandtl and the blockage correction according to Maskell/ Vaissayre correspond to those for the full-scale model although the reflected model- and tunnel halves must be taken into account.

To this one must add, depending on the type of arrangement of the half-model in the wind tunnel, corrections or correction additions for the shortcomings in the area of the separation plane.

For "false wall" and wall mounting without suction the wall boundary layer effect must be taken into account. VFW has made a start with good partial results in cooperation with NLR with the method: "tunnel wall installation with peniche" which rests on a fuselage comparison measurement. This start is based on the following considerations:

1) The boundary layer-caused errors in the separation plane affect only the fuselage disturbance. The wing is not stressed by the disturbed flow; a simulation of the tail section was discarded in advance because of the disturbed fuselage rear flow.

2) In the reverse direction the interference of the wing with the fuselage flow is negligibly small.

Under the assumption of these boundary condition wind tunnel measurements were conducted with the configuration "fuselage alone" as well as with the full-model - as well as with the half-model-fuselage of this same project and were compared with one another. The force measurements showed the expected large difference; additional pressure distribution measurements made at both fuselages confirmed the prognosis and provided information with regard to the flow physics.

The "fuselage correction" made with these results: /118-19

$$c_{x_{HM,\ corr}} = c_{x_{HM}} + (c_{x_{R;\ GM}} - c_{x_{R;\ HM}})\quad {}^{*)}$$

is no big achievement, but it provides force coefficient which also - on an absolute basis - come surprisingly close to the values for the full models. However, measurements with a tail section present still remain impaired with this arrangement.

However, during the processing of the work package "high lift properties with stream effects" this measurement in particular plays an important role because of the down-wind distribution which is greatly influenced by the power plant. On the other hand it is unsatisfactory to either make only comparative measurements or to make in advance for each project "fuselage alone" - measurements with half- and complete model fuselages.

These reasons led VFW to the decision to develop a separate half-model sidewall mounting with controllable suction which

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*) Here we have

c_x	random force- or moment coefficient
R	fuselage
HM	half model
GM	full model

presumably will be available at the start of 1982.

It is expected that the most important added correction for this arrangement will be the "buoyancy" correction, i.e., the static pressure curves in the test section (and especially at the sidewall for an empty tunnel) must be measured under various suction conditions and must be corrected. Additionally it is necessary, of course, to take into account the suction air removed from the tunnel flow in the impact pressure correction.

3. APPLICATION IN THE AIRBUS FAMILY /118-20

VFW had tested the half-model technique in its own wind tunnel for the first time during the planned continued development of the short-distance transport plane VFW 614 in the year 1974. For, it had been found at that time that the full model adapted to the test section cross-section of 2.1 x 2.1 m^2 at a scale value of 1 : 15 led to laminar flow separation in the outer area of the wing. The critical Reynolds number required for a proper-time reversal could not be attained because of the too low local depths of the outer wing at V_{max} = 60 m/s - even with turbulance screens. The information furnished by these test results with this model thus was limited so greatly, at least in the high lift region, that we were forced to make the test with a correspondingly larger half model. It was built to a scale of 1 : 8.5 and was first measured with different pedestal height in the VFW tunnel using the method of tunnel wall mounting. The pedestal height variation showed for H ≤ 50 mm effects on the coefficients. Then, for about H ≥ 60 mm it appeared that a condition was reached which was no longer influenced by additional pedestal height increases. At that time, because of schedule demands, the discussion regarding the shortcomings of the separation plane-simulation was stopped and the principle was applied as described.

The beginnings of the development of the smaller Airbus A 310 again furnished new light to the half-model technique at VFW, and first, again because of schedule demands, according to the principle: "tunnel wall - installation with peniche".

3.1 - Preliminary development A 310 - IWDT

At the beginning of 1978 VFW built the first half model of the Airbus A 310, to a scale of 1 : 16, with the ZKP wing B10.3V of the IWDT (Integrated Wing Design Team, Bremen).

It consisted of fuselage, wing with slat- and flap/tab /118-21
system and a passive double-circle through-flow nacelle. The first test phase with this model was conducted in the VFW wind tunnel with the goal to determine the optimal positions of all moveable parts of the high-lift system by comparative measurement of various flight conditions. For this purpose a model was equipped with heavy clamp-on hardware pieces for slat- and flap support, which, although poor from a streamlining standpoint, left open all degrees of freedom. Thus flap angles, slot heights, and overlaps could be adjusted without steps within wide limits. The lowering paths were able to lie on conical as well as cylindrical surfaces. After span-width subdivision the flaps could be deflected to various degrees. All these laborious parametric studies could be conducted in the comparably cheaper VFW low speed wind tunnel without the fear that losses in quality would be incurred during the comparative evaluation of the test results although the force coefficients were not absolutely exact because of the disturbance caused by the support.

The optimal flap geometries found in this way were then "fixed" by means of rigid hardware pieces which could be stressed more highly than the clamp-on hardware, and which were still able to be housed in the flap-rail fairings provided in the design. With this

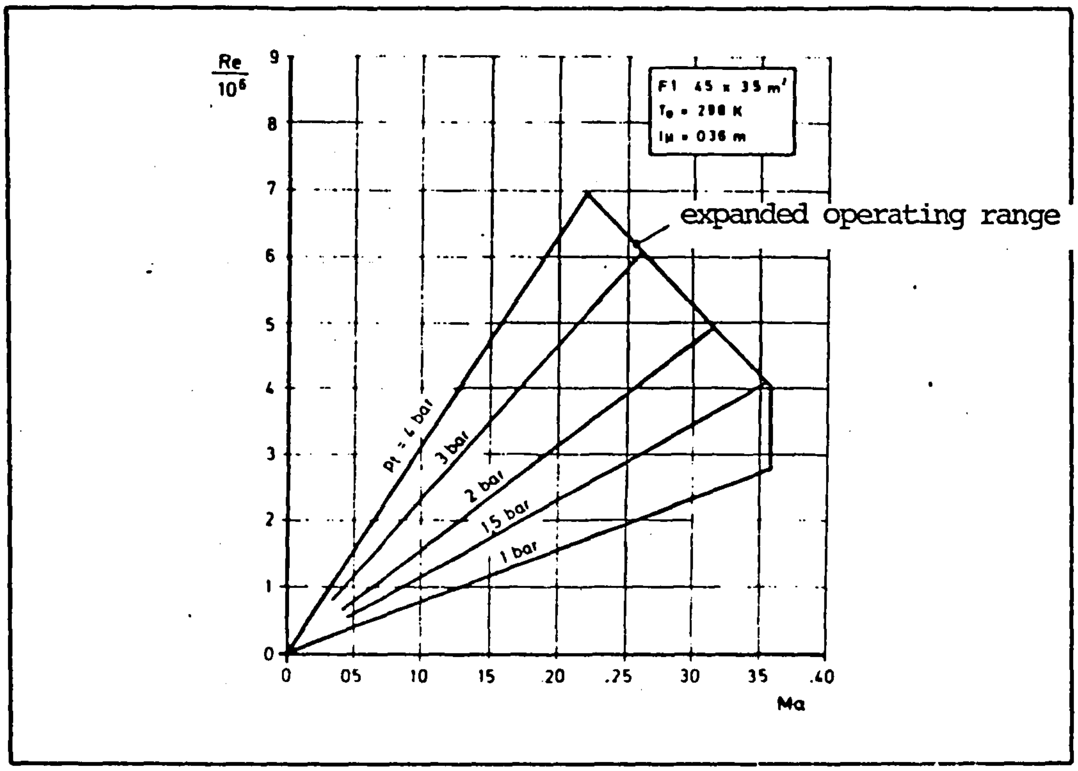

Figure 8: ONERA F1 / Ma-Re - operating range (referenced to A 310 half models)

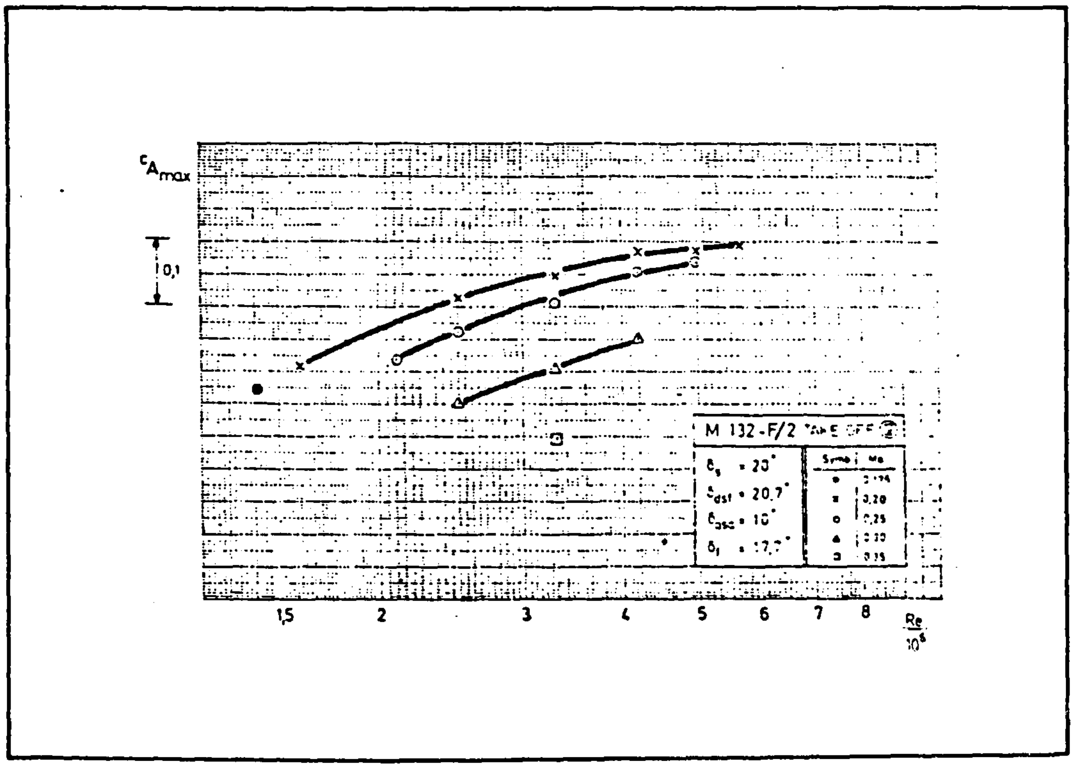

Figure 9: Example for $c_{A_{max}}$ = f (Ma; Re) for a flap drop

model condition we then first made the base measurement in the VFW wind tunnel, which corresponded for V_∞ = 60 m/s to a Reynolds number, referenced to lμ of $\sim 1.5 \times 10^6$.

After that the model was tested in an unchanged condition in the ONERA-F1 high pressure tunnel. This tunnel located near Toulouse had a test section cross-section of $4.5 \times 3.5\ m^2$ and offers, through changes of the pressure in the test section, the independent Mach-Reynolds variation in the limits /118-23

$$0 < Ma \leq 0.36$$
$$0 < Re \leq 6.7 \cdot 10^6$$ (referenced to lμ ≈ 0.36 m of the here discussed half models).

The entire F1-envelope for the A 310 models built at a scale of 1 : 16 is shown in figure 8. Here we list not only the initially named, but also the tunnel limits applying today which result from the pressure- and power limits of the installation. The model-side load limits for wing and moveable parts can bring about, especially for landing, an additional limitation of the test possibilities if a maximum lift coefficient ≥ 3.0 is expected and if a safety factor of 4 is demanded. The requirements for the model resulting from this - typical for the high pressure - problem area require a careful layout of the model, the choice of high strength materials, and a detailed strength determination of the model and its moveable parts.

As an example of the result of the "High Reynolds" measurement in F 1 we showed in figure 9 for a flap drop a typical c_{Amax} - development for Re- and Ma-variation.

In addition to the till now described half model at a scale of 1 : 16 we developed in 1978 an additional one at a scale of 1 : 5.4 - the "ZKP-large scale model". This half-scale model also corresponds to the then IWDT design with the ZKP wing B10.3V.

It was designed for the 8 m transsonic wind tunnel S 1 - Modane of the ONERA and consists of wing (with aileron, but without flaps), fuselage, and single-circle nacelle with variable throttling.

In the year 1979 we conducted with this model in several test phases force measurements and pressure distribution measurements, the latter both stationary and non-stationary, with the following goal formulations: /118-24

- o base measurement, comparability possibilities
- o effect of different seals at the tunnel wall (labyrinth, brushes)
- o aileron effectiveness, stationary
- o power plant-inlet-effect
- o effect of the separately mounted through-flow nacelle on the airplane nacelle
- o nacelle position variation
- o throttling effect
- o wing-fuselage-transition fairings
- o non-stationary effects of ailerons actuated in different ways.

Here the S1-Modane made possible a Mach number range of $0.3 \leq Ma \leq 0.87$ which corresponded to a Reynolds number variation of $6 \leq \frac{Re}{10^6} \leq 11.6$. Because of the atmospheric tunnel operation Ma and Re are coupled, i.e., they cannot be changed separately.

3.2 - Development A 310

With the beginning of the British participation in the A 310-Program toward the end of 1978 the IWDT design was replaced by that of the British Aerospace. A new half model, also at a scale of 1 : 16, was made and was already tested in October 1979 in ONERA-F1 for the first time. This model was equipped with complete pressure distribution at the wing, fore-wing, and double slot flap. For lack of time the positions of the moveable parts were not preoptimized in the VFW wind tunnel - as was the case for its predecessor -, but were selected in accordance with the available information and were fixed directly by means of rigid hardware pieces. Force- and pressure distribution measurements in the ranges /118-25

$$0.1 \leq Ma \leq 0.35$$

$$1.5 \leq \frac{Re}{10^6} \leq 5$$

were conducted for the cruise condition and for various high-lift configurations. Here the condition, mentioned in the previous section, occurred where the model limits were narrower than the tunnel-load limits for the landing configuration. The somewhat more slender profile compared to the IWDT design and the weakening of the cross-section caused by the pressure distribution prevented the attainment of Re numbers of larger than $5 \cdot 10^6$. Figure 10 shows the model in F1. The force measurement results provided a first insight into the high-lift properties of the project, and the pressure measurement showed the load distribution on wings and flaps under the flight conditions tested, and thus also the tear-off behavior in the maximum lift range.

In November 1979 - thus already one month after the measurement phase in F1 - this model was tested in the high flight speed configuration in NLR-HST (high speed tunnel of the National Air- and Space Laboratory of the Netherlands, Amsterdam). This tunnel also can change through pressure variations Ma- and Re- numbers independently of one another, see figure 11. The HST-testing phase had the following goals:

- high speed behavior up to Ma = 0.86
- comparison of the low speed results with those of the F1 (especially effect and correction possibility for extreme differences in tunnel cross-section dimensions).

With that part of the measurements which must be assigned to the last-named goal, there began the work, already mentioned in

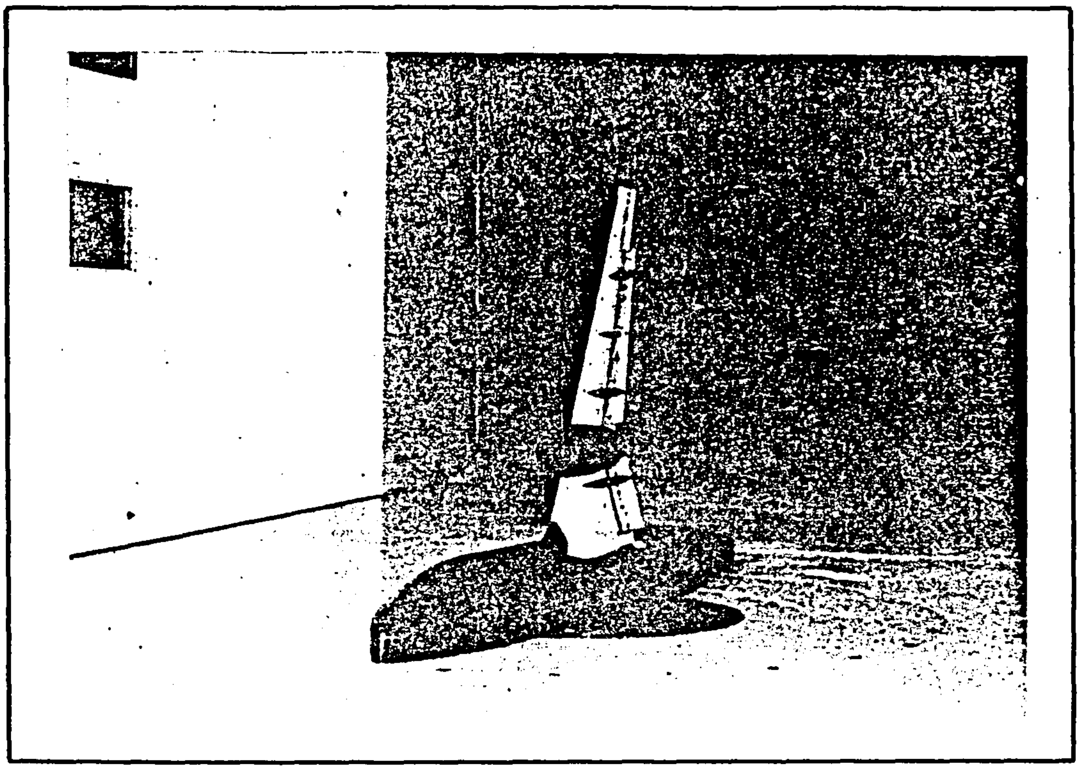

Figure 10: A 310 half model in ONERA F1

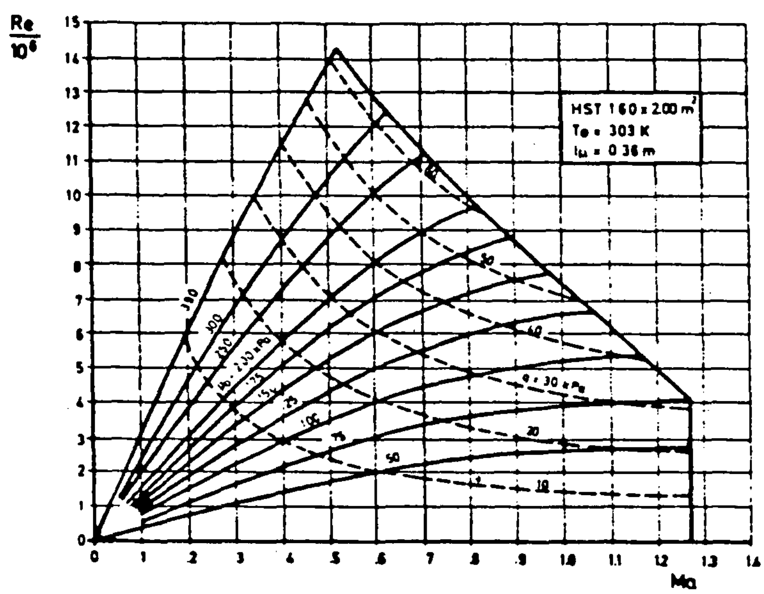

Figure 11: NLR-HST / Ma-Re operating range (referenced to A 310 half models)

section 2.3, for the correction of the error of the separation-plane /118-27
flow by means of fuselage-comparison measurement at the half model and full model. This work has not yet been concluded. Then the A 310 half model was used as of February 1980 for the following investigations in the VFW wind tunnel:

- optimization of the wing inner area (different Krueger flaps and smooth contours)
- flow in the intersection region between Pylon, slat, and wing nose
- effect of different passive model power plants (single-circle nacelle, two-circle nacelle, nacelle with adjustable hub cross-section, nacelle with "eyebrow" as a protection measure against premature tear-off)
- hinge moment measurement on ailerons, spoilers, and airbrakes.

For the last-named measurement the model was equipped with

- the inner aileron ASA (all speed aileron)
- the outer aileron LSA (low speed aileron)
- the 3 spoilers and
- the 4 airbrakes

whose hinge moments, normal forces, and rolling moments were measured each by means of separate three component-strain-gauge balances. Figure 12 shows the partial view of the model with extended airbrakes, figure 13 shows two DMS-balances with the covers removed.

After having been equipped in the wing outer region with a simple-flap system (Fowler) and after having been adapted in many details to the actual project state, this model was then tested in July 1980 again for the determination of the high-lift properties in the ONERA-F1. Despite the expected maximum lift losses the "mixed" flap system (see figure 14) proved to be as the altogether more favorable one because from a construction standpoint it can be

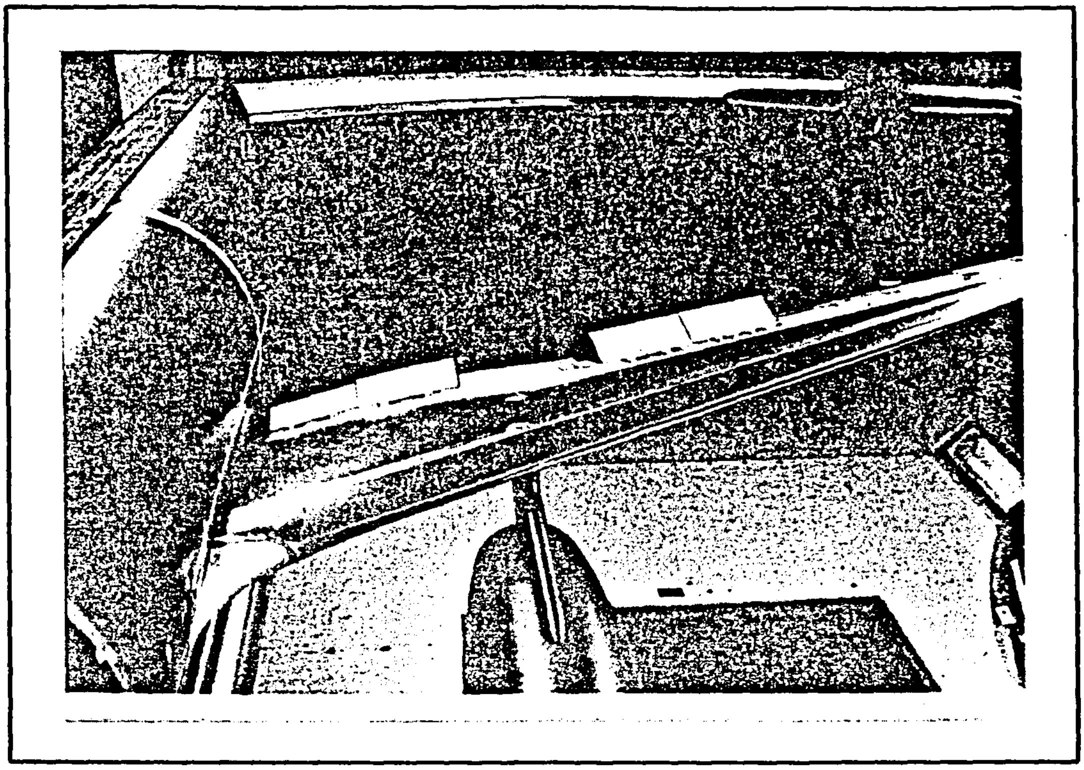

Figure 12: Model with extended airbrakes

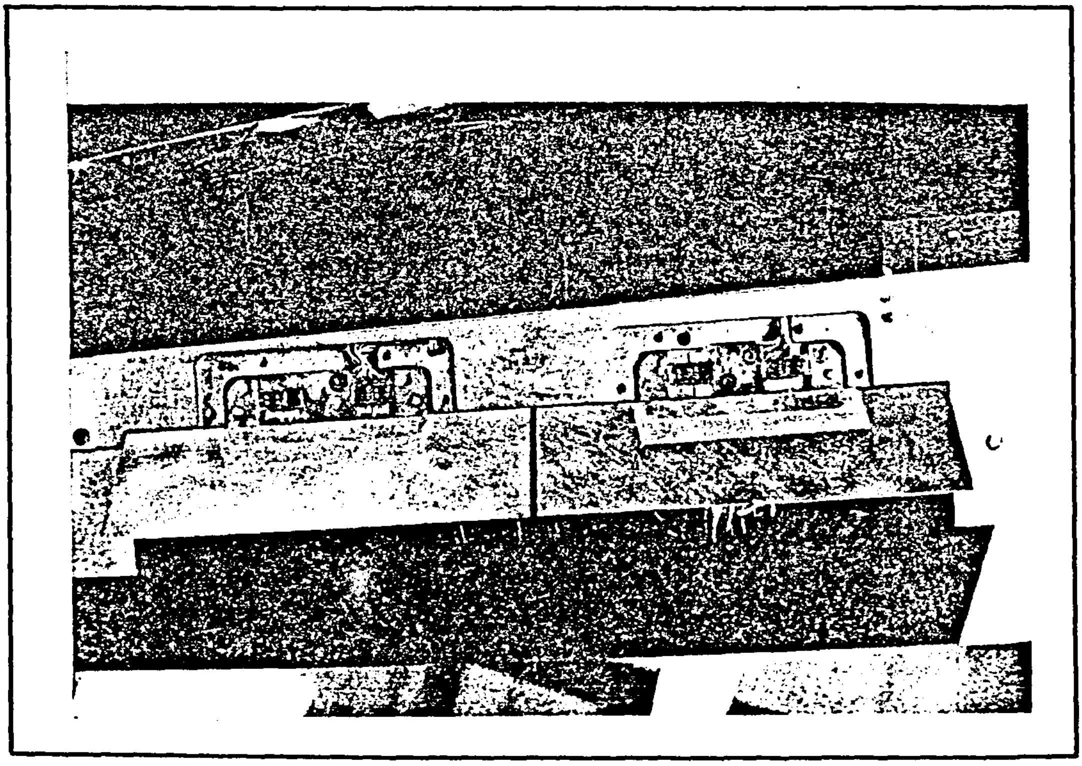

Figure 13: View of the DMS scales (cover removed)

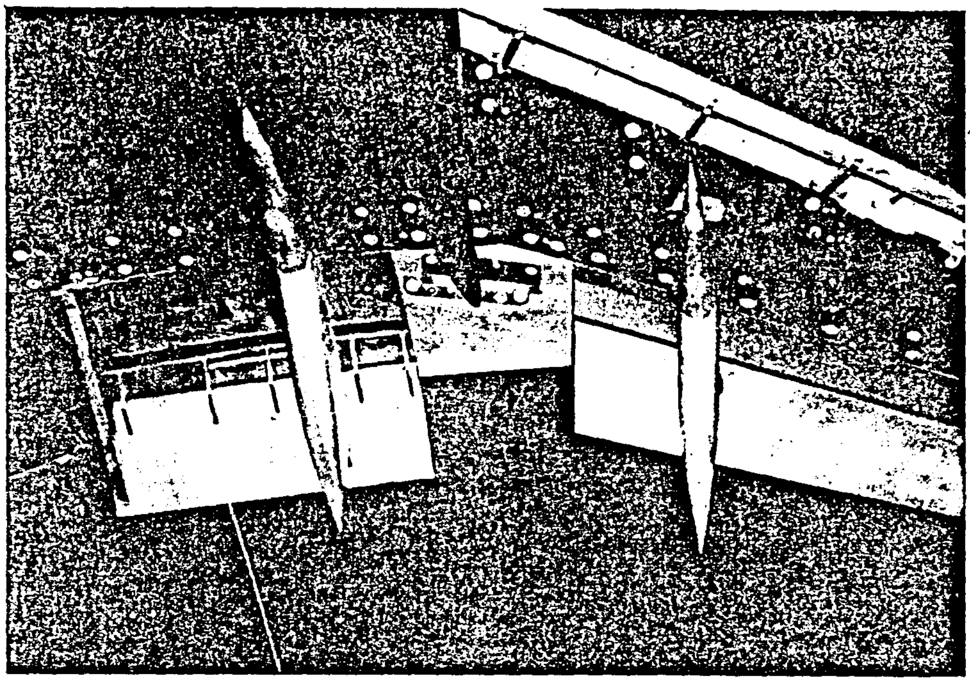

Figure 14: Wing with "mixed" flap system

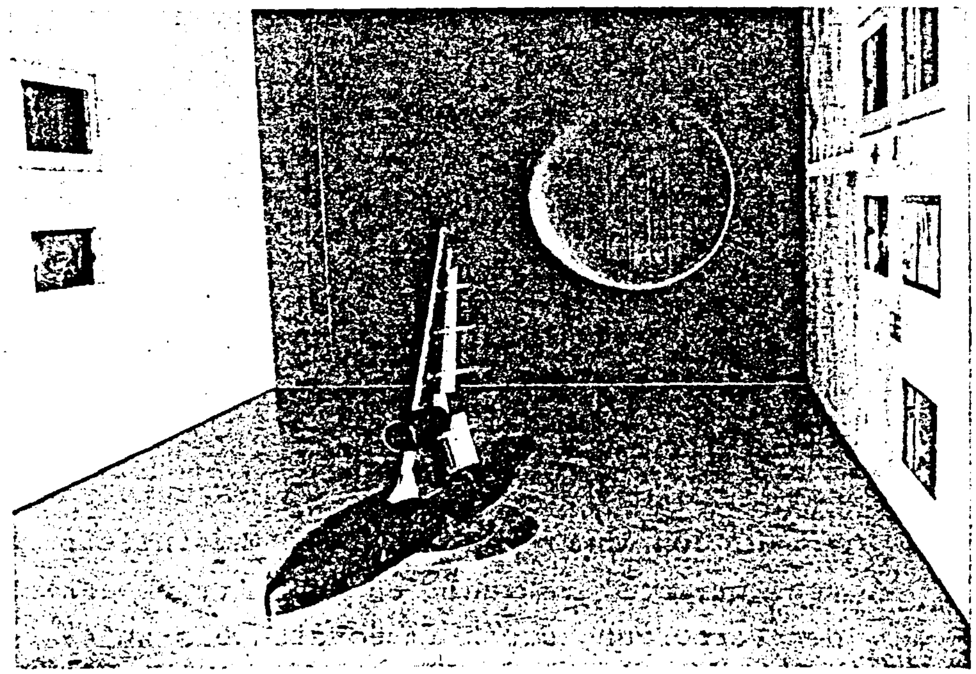

Figure 15: Model, installed in F 1

achieved considerably more easily, and because with it more favorable glide ratios can be obtained during start and climb. Figure 14 shows the elements of the flap system: /118-30

- at the leading edge: on the inside the Krueger flap and, along the entire span width, a slat,
- at the trailing edge: on the inside the double slot flap system with vane and main flap, in the power plant area interrupted by the ASA, in the outer area the simple Fowler flap and in the edge area the LSA.

Figure 15 shows the model in the landing condition, installed ready for test in the ONERA-F1.

3.3 Power plant-nacelle integration

The problem area, already hinted at in section 2.1, of the two-circle power plants of large diameter in their position close to the wing shows clearly that the mutual effect between power plant and wing (including Pylon and high-lift flap) must receive special attention. The passive power plant simulation (figure 16) by means of through-flow nacelle and the active one by means of ejector-power plants or blowout nacelles simulated the flow conditions around the power plant fairing and at the edge of the stream only very incompletely. A considerably better simulation of the power plant flow was attained by the TPS model power plants (TPS = Turbine Powered Simulator) developed in the USA by Tech Development. Figures 17 and 18 show the principle and a photograph of a TPS model power plant. A compressed-air turbine drives the fan whose exit flow corresponds exactly to that of the large version. The fact that the primary circle flow consists of very cold expansion air rather than of hot combustion gases, has only little effect on the simulation because the fan stream responsible for the interferences with the nacelle encloses the inner primary circle and thus shields it. The rotational speed of the model propulsion system can be regulated by means of the supplied pressure within a range of up to 40 bar.

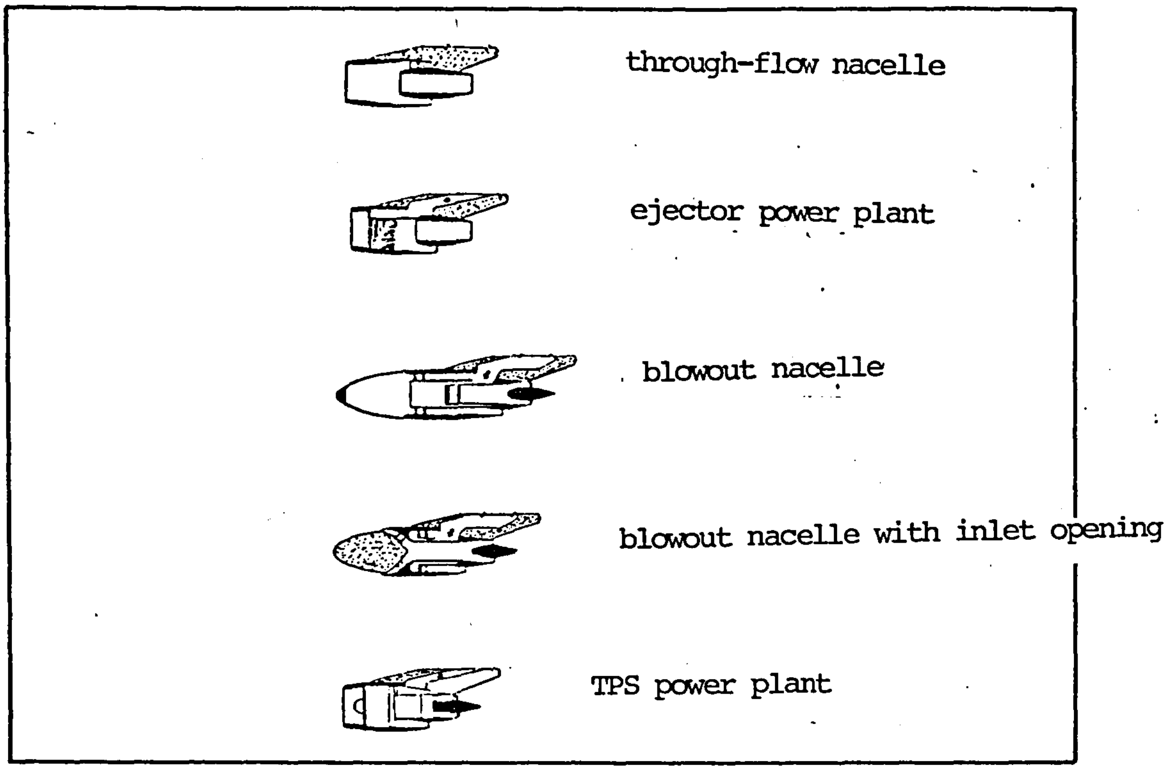

Figure 16: Variations of the power plant simulation

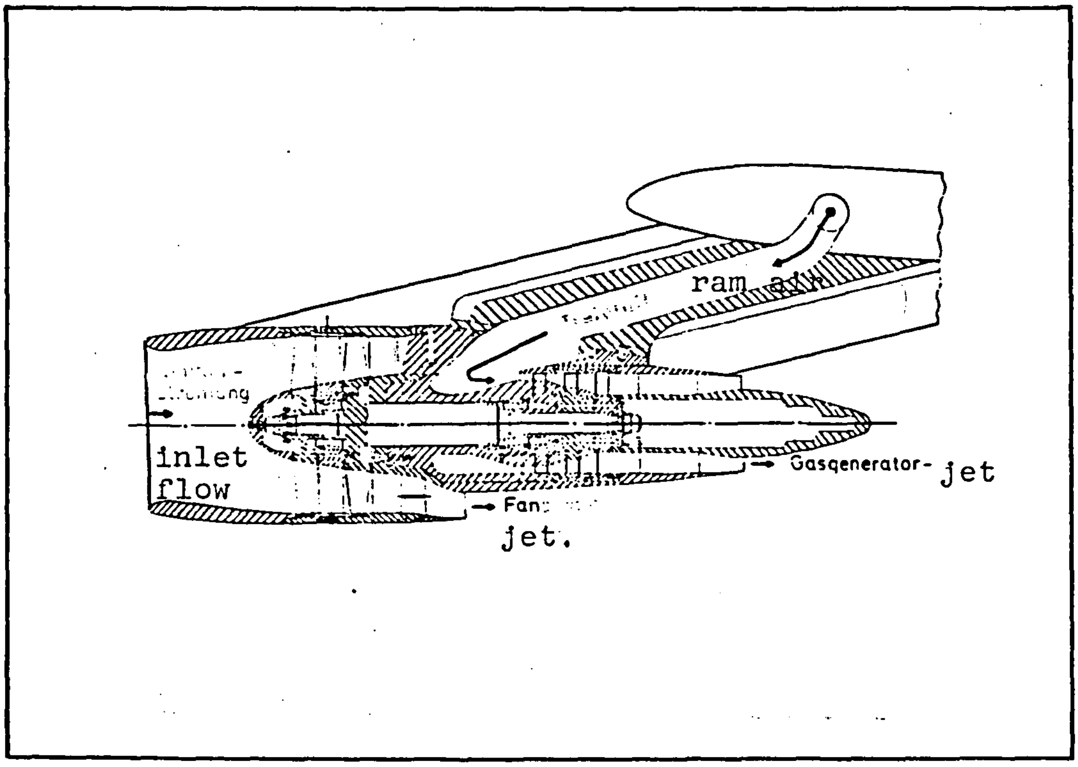

Figure 17: Fundamental buildup of a TPS (cross-sectional view)

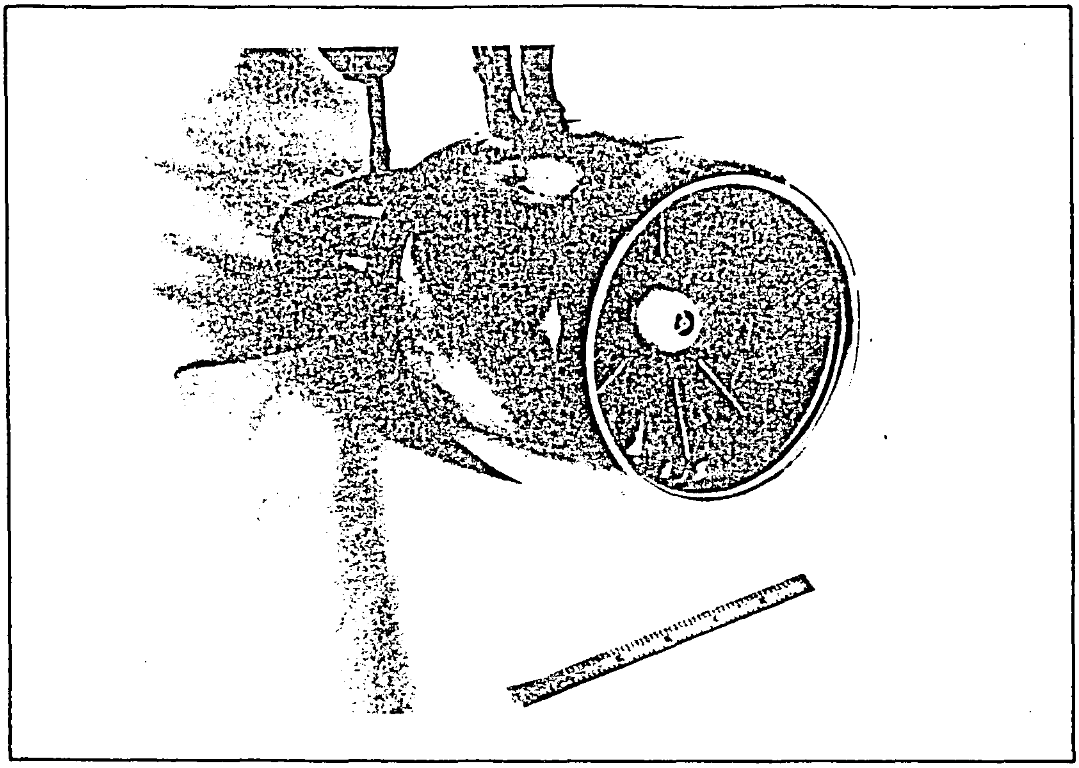

Figure 18: GE - CF 6 simulation with TPS

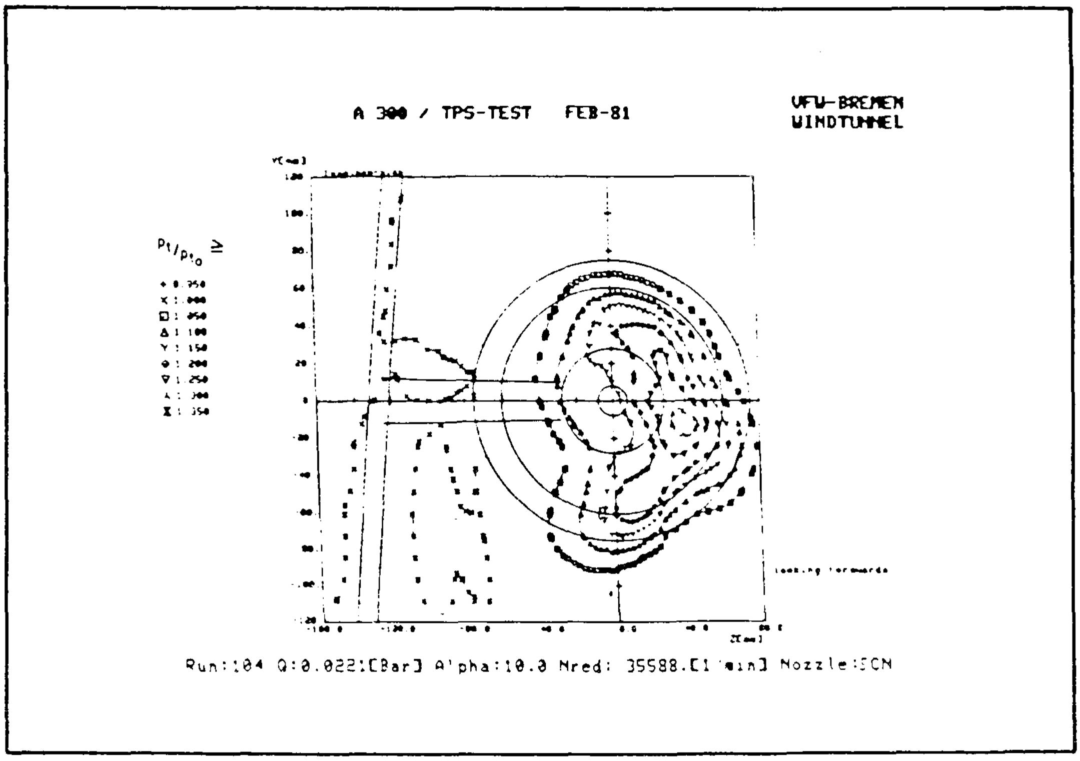

Figure 19: Typical wake isobars (start; $\alpha = 10^{\circ}$, short nozzle)

The operation of the TPS for rigid connection to the model /118-33
initially presents difficulties which must be removed by laborious detailed efforts:

- the reaction forces of the added compressed air must be determined exactly and compensated through calibration
- the primary air must be absolutely "dry". Already the least remaining moisture can lead to icings in the turbine and thus to fluctuations in rmp which make the measurements unusable
- the quantity of oil injected for lubricating the moving parts must correspond to the minimum of the required quantity because each drop of excess oil could lead to grease formations in the turbine and the exit nozzle because of the icing danger just mentioned which again would result in an erroneous measurement.

In the fall of 1980 VFW made an attempt to use the TPS technology within the framework of the Airbus family development. A power plant on loan from the NASA was useful during the waiting period for the power plant that was ordered to become familiar with starting control, control and operational behavior of the simulator.

Since the start of 1981 the TPS technology was used by VFW programmatically. Already the tryout measurements with the B10.3V-half model of the A 310 preliminary development phase produced the first important information concerning magnitude and trends of the interferences for geometrical changes of the external nacelle shape such as flap- and fore-wing deviations or those of the power plant such as length and shape of the fairings of the inner circle.

Three nozzles of different lengths were investigated on a half model of the Airbus A 300-B2/B4 also built to a scale of 1 : 16, as well as the influence of various smooth contours at the fairing of the outer circle. Here forces, pressure distribution on wings, Pylon, and power plant bearings, as well as tail measurements behind TPS provide information concerning the sensitive interference mechanism for power plant conditions ranging from "windmilling" to "maximum takeoff". Here the tail measurements were made with a moveable rake positioned closely behind the wing trailing edge. A randomly selected example in figure 19, with short nozzle for a starting power with $\alpha = 10^o$, shows the magnitude of the flow deformation produced by the nacelle through the mutual effect. /118-34

Similar measurements are planned for May 1981 with the half model of the actual project state. Model and power plant are being adapted at this time for this measurement.

3.4 - Planned future application

It has been shown that the combination of half model and TPS represent a valuable instrument for the development of a transport airplane. The most important low-speed flight characteristic: high-lift properties and power plant integration can be worked out with it decisively in the wind tunnel. In spite of this an additional improvement is already being planned with respect to the applicability of the results to the large-scale version: 2 large simulators for the A 300-Model fabricated to a scale of 1 : 9.5 for the DNW (German-Netherlands Wind Tunnel) have been ordered. These TPS's are a special production which can also be used in high pressure tunnels up to $p_t = 3$ bar. The TPS's operated till now were limited to a pressure level of about $p_t = 1.4$ bar for strength reasons. The newer larger TPS's are to be delivered in the fall of 1981 , the testing in DNW with the A 300 - full scale model could then begin in the middle of 1982 whereby the halved model could then be tested in the high pressure range of the ONERA F 1 (up to 3 bar) up to high Re numbers. In this way the chain of the high lift development would be closed: the "small" half model at a scale of 1 : 16 provides the optimum high-lift flap system in accordance with the difference method in the VFW tunnel and then a preoptimization of the power plant-nacelle-integration can take place cost effectively /118-35 with this model size in the high pressure tunnel (F1 or HST). The "large" half model at a scale of 1 : 9.5 provides results for flap effectivenesses and power plant interferences almost up to Re numbers of the large scale version for independently variable Mach numbers. Finally the DNW measurement with the 1 : 9.5 full scale model provide a reference value for the half-model measurements for some coupled Ma-Re- combinations. This then presents the possibility to convert the half model results to absolute values. The intention mentioned in section 2, to build up a tunnel wall suction still in 1981, serves the same purpose - first for the small half model in the VFW channel.

Naturally the described chain of procedures should find application for all the AIRBUS derivatives whose development is being decided upon. For this today's planning shows the following list of candidates:

- A 300 B2/B4 - continued development
- A 310
- A 320 - 100 (Single Aisle I)
- A 320 - 200 (Single Aisle II)
- TA 9 (2-engines)
- TA 11 (4-engines)

Beyond that the ZKP-large scale model with B10.3V wings, mentioned in section 3.1, will be utilized further within the framework of the Airbus family development in the ONERA-S1 MA. For the end of 1981, in cooperation with the ONERA, nonstationary pressure- and acceleration measurements are envisioned at the wing with hydraulically driven, harmonically excited flaperon, spoilers, and ailerons.

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