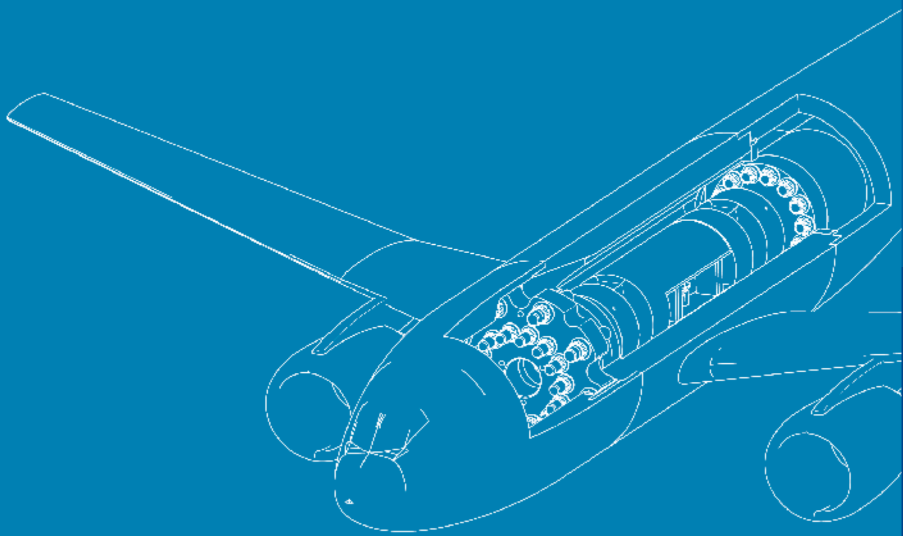
EUROPEAN TRANSONIC WINDTUNNEL



MODEL DESIGN HANDBOOK

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1 GENERAL

1.1 INTRODUCTION

This handbook specifies the criteria to be used for the design, construction, design analysis, quality assurance and documentation of Test Assemblies to be tested in the European Transonic Windtunnel.

The handbook shall be used as a basic guideline for all Test Assembly design aspects, including the models.

The handbook cannot cover all of the technologies that might be used and does not prevent the client from using alternative techniques. However, any deviations from the handbook shall be discussed and decided in consultation with ETW.

Upon request, ETW will advise clients on design and construction of Test Assemblies for a given type of test, to improve the quality and effectiveness of the test campaign.

1.2 RESPONSIBILITY

The guidelines contained in this document are intended to prevent any failure of Test Assemblies and their components in ETW. All clients are expected to provide, where appropriate, guarantees in the form of design and design analysis documents and construction and inspection reports, including material certificates. These are to be provided at least six weeks prior to the test.

The Test Assembly will only be tested in the requested operating envelope of the wind tunnel after approval and acceptance by ETW. The requested test envelope, incorporating an additional safety margin, has also to be approved and accepted by ETW.

The acceptance does not entail any obligatory verification on the part of ETW, for the purpose of preserving the model as such. Any partial or total destruction that may be caused to the model by its own specific properties in the envelope of the requested test programme falls under the client's responsibility.

ETW's acceptance of documentation provided by the client does not exempt the client from his contractual obligations.

1.3 APPLICABILITY

The requirements in this document are mandatory for the Test Assemblies:

a) during preparation in the Cart Rigging Bay and Quick Change Room in ambient and cryogenic conditions
b) during transport in the Transfer Hall in ambient and dry air conditions
c) during check-out in the Variable Temperature Check-out Rooms during ambient and cryogenic temperature conditions in dry air
d) during all requested wind tunnel testing conditions

The environmental conditions of the building rooms and the possible test conditions in the wind tunnel are given in Reference 1.

1.4 IMPLEMENTATION

For each test campaign ETW will nominate a Test Engineer. He has the delegated authority to manage day to day aspects of the test and acts as technical point of contact for the client.

Under the authority of the ETW Management, the responsible ETW Test Engineer has the delegated authority and duty to check the implementation of the criteria specified in this handbook in the documents provided by the client. This is to ensure that the Test Assembly design and construction meets the criteria of this handbook. Any deviations from these criteria are to be clearly identified in the documentation and to be addressed according to the deviation procedure given in chapter 6.

ETW may require that the client's design is checked by a third party (experts in the field) recognized by both ETW and the client.

Design Review Meetings will be held by ETW in coordination with the client during the design phase as required.

1.5 DEFINITIONS

Most of the definitions used in this document are explained in further detail in Reference 1. Additionally, the following definitions are given:

Test Assembly: Model, internal strain gauge balance and sting, all attached components, all specific equipment, e.g. sensors, external optical devices, specific data acquisition/processing equipment, etc.

Test Engineer: Responsible ETW engineer for the test campaign.

1.6 STANDARDS

Unless otherwise specified, design standards shall be in accordance with the applicable provisions of the following recognized standards, codes, or handbooks from International and National Authorities

a) EN, ISO
b) DIN, AD-Merkblätter, VDI
c) BS
d) NF
e) ASME, NBS, ASTM

Unless identified by date, the edition (including addenda and code cases) in effect at the start of design, shall apply.

The client shall submit to ETW the following general information on the Test Assembly, the envisaged test envelope and a first indication of the planned test programme prior to the start of detail design of the Test Assembly. This will allow ETW to initiate a planning programme for test entry and to coordinate availability of ETW equipment, stings, balances, etc.

2 MODEL AND TEST EQUIPMENT DATA

2.1 TEST ASSEMBLY CONFIGURATION

The dimensions of the Test Assembly shall be defined according to the recommendations for model sizing given in chapter 7.

The type of model and the purpose of the test shall be described.

All major components of the complete Test Assembly provided by the client have to be identified by the client and will be subject to individual checking.

2.2 PLANNING OF TEST ACHIEVEMENTS

The planned test envelope shall be provided to ETW in sufficient detail. The required wind tunnel performance envelopes are given in Reference 1.

A first draft of the expected test programme shall be submitted to ETW to allow basic and preliminary planning and optimization of the sequence of test runs and polars. The influence of thermal gradients in the Test Assembly and required time constants for Test Assembly conditioning might influence the design of the complete Test Assembly at an early stage of design.

The availability of ETW components (model cart) and equipment (balances, stings) has to be discussed and early occupation planning is required.

3 ENGINEERING DATA

At least six weeks prior to testing the client shall submit the following specified information, model data drawings, calculations, certificates, etc. to allow ETW personnel a complete check of the overall Test Assembly and its components.

Any deviations or requests for waivers to any part of this section must be submitted in writing to ETW for approval (chapter 6) via the Test Engineer at least six weeks prior to model delivery to ETW.

3.1 Drawings

A general layout drawing including complete top, front and side views, containing all outer dimensions, reference points and key dimensions such as the Moment Reference Point, 25% Aerodynamic Mean Chord, Balance Centre..., shall be delivered.

Assembly and sub-assembly drawings, relevant for stress analysis, for critical components of the model system shall be submitted to ETW for review.

If the model assembly and/or rigging is to be performed by ETW personnel the assembly and sub-assembly drawings shall present all functional dimensions and shall include instructions for assembly (type of filler, torques, joint components, etc.).

The detail drawings for critical components shall include, as far as practical, all pertinent indications concerning the material, manufacturing instructions, functional dimensions, shapes and surface conditions which are related to the stress analysis of the Test Assembly.

3.2 Test Programme

The Test Programme shall be provided including the following parameters:

a) model size and configuration
b) Mach number
c) total pressure
d) temperature
e) attitude

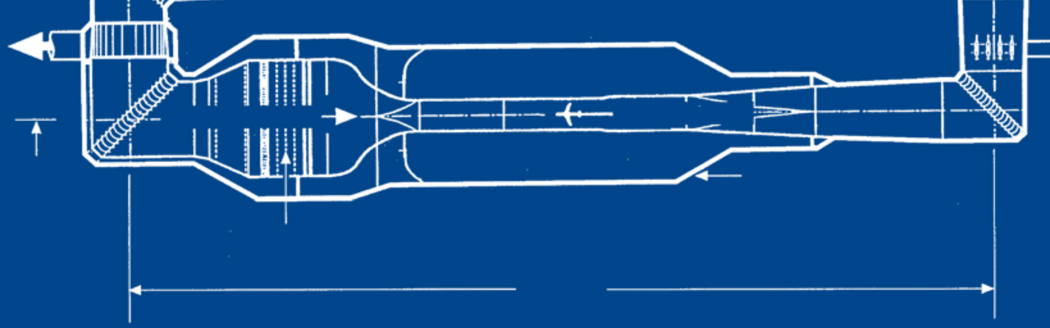
The selected test point used for the specification of the design loads shall be clearly identified and a reasonable estimate of the corresponding aerodynamic model coefficients for lift, drag, side force, pitching moment, yawing moment and rolling moment shall be presented with indicated accuracy limits and best estimate of unsteady aerodynamic forces.

3.3 Test Assembly Loads

To allow ETW personnel to undertake a complete check of the Test Assembly all required internal and external design loads induced from:

- gravity
- aerodynamic forces and moments
- thermal expansion/contraction forces
- dynamic load
- unbalance loads and gyroscopic effects for rotating parts

which are exerted on the Test Assembly as a whole and on its subassemblies and individual parts shall be determined for all critical parts of the model. This shall be for the worst cases for each highly stressed area of a component.



Partial configurations that may induce higher loading than complete configurations must also be considered.

For the critical components the various forces and moments should be listed explicitly. If necessary, the basis of the load estimates shall be given and it should be clearly identified if these are the maximum possible loads or those at the boundaries of a limited test envelope. The worst extremes of bands of uncertainty from stressing considerations should be used.

The maximum load estimate shall include all foreseeable dynamic load levels for the test campaign. If the dynamic loads are not known, a typical level corresponding to 25% of the maximum steady load shall be taken into account. This value may be increased if higher dynamic levels are expected during the test or reduced on the basis of proven test configuration data (to be discussed with the ETW Test Engineer). In any case, the dynamic level, used to demonstrate the structural integrity of the model, shall be clearly identified in the relevant stress analysis documentation.

For remotely operated aerodynamic controls, e.g. elevators, ailerons, rudders etc., runaway conditions must be considered.

It will be subject to agreement, where and how loads are to be monitored during the test, and the client shall be prepared to accept a possible limitation to the planned test envelope.

3.4 Stress Assessment

3.4.1 Analysis

The client shall provide for critical areas and conditions a complete and sufficiently comprehensive stress analysis for all mechanical and thermal loads for the Test Assembly during the wind tunnel test and conditioning activities.

a) The stress analysis is required to show that allowable stresses specified in chapters 3.6 and 3.7 are not exceeded for the worst load cases defined in chapter 3.3. If the required safety factors cannot be met, reduced values may be submitted to ETW for approval. This applies also for cases where Finite Element Analysis is not expected to give higher confidence than a standard handbook analysis.
   Such cases shall be identified as soon as possible and discussed in detail with the ETW Test Engineer.
b) Detailed analysis of critical components shall contain the following information for each component:

- a sketch showing forces and moments acting on the part
- any statements of assumptions and approximations
- sectional drawings of the part and inertia values used in the calculations
- physical properties, details of the heat treatment condition of the material
- corresponding drawing numbers.

For models having removable components (canards, winglets, stores, etc.) the client shall clearly specify the attachment method, calculate the maximum stress under the worst aerodynamic conditions and compare results to allowable.

c) The general equations along with their sources shall be given before substitution of numerical values.

d) The choice of the critical section chosen for the calculation, the point where the stresses are at their maximum shall be indicated clearly for each type of stress (tensile, compressive, bending, torsional, shear, etc.). These stresses shall be considered separately and then combined.
For complex structures, the coefficients used to define the resulting stress of the various combinations of forces and moments shall be indicated.
At rapid changes of sections, holes, corners, etc. the stress concentration factors should be applied.

e) The client shall analyse the secondary stresses (thermally induced stress) and effects of thermally induced distortions. He shall also analyse the combination of primary and secondary stresses which shall be lower then the yield stress.

f) For any finite element computer codes used, the code and the modelling names shall be indicated.
To give confidence in the result at areas where stress concentrations are identified a sufficiently fine resolution grid shall be applied. The effect of grid refinement shall also be shown.
Accurate colour print-outs showing the mesh and the von Mises stresses shall be included in the documentation.

3.4.2 Fatigue and Fracture Analysis

A stress assessment, performed according to the guide lines indicated in chapter 3.6.1 (Standard Handbook Analysis) and based on expected dynamic levels not exceeding ±25% of the maximum static load will not require a detailed fatigue investigation.

A fatigue and fracture analysis shall be carried out for all cases where:

- Reduced safety factors with Finite Element Analysis, as defined in chapter 3.6.2, are applied, and the wind tunnel test planning is such that the highly stressed components will be subject to more than 1000 load cycles exceeding 80% of the maximum load, and/or intensive testing at buffeting conditions are planned.

- Standard safety factors are applied (chapter 3.6.1) and dynamic levels are expected to exceed +/- 25%.

The stress ratio ($R\sigma = \sigma$ min/ σ max) used for these investigations shall be in line with expected dynamic load assumptions (see chapter 3.3). The client shall also indicate the method used to calculate the peak stresses which are likely to initiate a failure from fatigue and the life expectancy. Fatigue reduction factors such as stress concentration, fillet welds, threads, size effects, and surface finish are to be applied.

Further information regarding fatigue and fracture analysis is given in Reference 2.

3.4.3 Rotating Components

All test assemblies with fast moving components, e.g. TPS, propellers, etc., must be discussed and approved by ETW. Special precautions in design and experimental testing before tunnel entry are essential. Instrumentation must be provided to indicate vibration modes, etc.. Local high stress areas subject to fatigue must be identified and monitored.
Dangerous operating conditions are to be highlighted and analyzed during model design and information supplied to enable critical failure modes to be identified. Design methods must give modal characteristics including frequency for all significant modes, mater-

ial specifications, fatigue life limits, out-of balance limits and any condition of dynamic instability such as divergence speeds, whirl and flutter.

3.5 Material Selection

Materials shall be selected for ambient and cryogenic operation, using mechanical, thermal and physical properties from the latest issue of recognized standards or from test results. For critical components ETW may request tests to be conducted to confirm the mechanical properties on samples taken from the actual material from which the component is made. Particular attention shall be paid to the determination of the Charpy impact energy at the lowest test temperature.

All relevant properties of the selected materials shall be given and adjusted for all environmental effects including dynamic loads, e.g. test temperatures present during the period the material is under stress.

At ETW's request material certificates shall be provided for critical components as specified in chapter 4.2. A suggested source of information on materials is presented in Reference 2.

Critical components fabricated of non-metallic materials (e.g. composites, filler materials) shall be approved by the ETW Test Engineer following a presentation of test results for these materials applied to test samples with a similar configuration, tested at cryogenic temperatures with oscillating forces.

ETW is prepared to assist clients in any questions concerning material selection, procurement, and evaluation.

3.6 Allowable Stress for Metallic Components

If any difficulties arise from the stress evaluation or fatigue analysis, ETW is prepared to advise and to give, if required, technical support to the client.

3.6.1 Standard Handbook Analysis

This method can be employed for model components, where structural design optimisation is not a factor and the components are not monitored during the test.

Material properties are to be taken at the test temperature that gives the most conservative design.

The maximum allowable combined stress (tension/compression, bending, torsion and shear) is to be smaller than one third (1/3) of the minimum yield strength ($\sigma_{0.2}$).

The combined stress when compared to the allowable shall be calculated for the worst load cases (mechanical including dynamic plus steady thermal effects if necessary) and shall include stress concentration effects. The thermal stresses are to be algebraically added to the mechanical stresses.

The stress components shall be combined by using the von Mises criterion.

Maximum allowable shear stress (only if shear is the dominating stress like in dowel pins):

- one third (1/3) of the minimum shear strength. If not defined in the material data 60% of the yield strength shall be used as the minimum shear strength.

Maximum allowable buckling stress:

- one third (1/3) of the critical buckling stress. If not defined in the material data 80% of the yield strength shall be used as the critical buckling stress.

Maximum allowable contact pressure:

- two thirds (2/3) of the maximum allowable contact pressure defined in the material properties. If not defined in the material data the yield strength shall be used as the allowable contact pressure.

3.6.2 Finite Element Computer Analysis

This method should be employed where possible for all model components, where structural design is an important factor. It is in the authority of the ETW Test Engineer to decide if monitoring devices of these model components are required during the test or not.

The client shall show evidence that he is familiar with the proposed FE methods and that the FE method is well proven in the specific application envisaged. The client shall demonstrate its validity and justify confidence in the use of reduced safety factors. The FE method shall be presented to the ETW Test Engineer for approval.

If it is demonstrated to the satisfaction of ETW that the analysis gives a realistic prediction, the allowable stress values might be increased up to the values listed below:

The allowable combined stress (tension/compression and bending) is to be the smaller of the two following values:

- half (1/2) of the minimum ultimate strength
- three quarters (3/4) of the minimum yield strength.

In this method, the combined primary stress to be compared to the maximum allowable shall be calculated for the worst load cases (mechanical including dynamic plus steady thermal effects if necessary). The thermal stresses are to be algebraically added to the mechanical stresses. Material properties are to be taken at the test temperature that gives the most conservative design. The stress components shall be combined by using the von Mises criterion.

Maximum allowable shear stress for all combined loads:

- one third (1/3) of the minimum yield strength.

Maximum allowable buckling stress:

- half (1/2) of the critical buckling stress.

Maximum allowable contact pressure:

- two thirds (2/3) of the maximum allowable contact pressure defined in the material properties.

Every FEM analysis shall be proven by at least one standard handbook calculation applied on a section which can be easily analysed by this method and is suitable to compare with FEM results.

3.6.3 Fatigue and Fracture Analysis

If fatigue and fracture analysis are required (see chapter 3.4.2), the documentation shall include a detailed analysis (material fatigue/fracture data, life duration analysis on the basis of expected load cycles) including a short description of the method selected (HAIGH diagram, S/N curves, PARIS/FORMAN eqn., ...).

Further information regarding fatigue and fracture analysis is given in Reference 2.

3.7 Allowable Stress for Non-Metallic Components (Composites)

The main frame of the Test Assembly shall only be constructed of composite materials with prior written agreement from ETW. The design guidelines, if accepted, will be defined at that time. For the other elements of a non-critical nature made of composite materials the allowable stress is defined as follows:

The allowable combined stress (tension/compression, bending and thermal) is to be the smaller of the two following values:

- one third (1/3) of the minimum ultimate strength
- fatigue endurance limit stress.

Maximum allowable shear stress:

- one half (1/2) of the ultimate shear strength, both inter-laminar and transverse.

The values of the ultimate strength, fatigue endurance limit and the shear stress shall be determined experimentally on samples or on real parts.

Where appropriate, the combined stress to be compared to the allowable shall be calculated for the worst load cases (mechanical plus thermal) of any critical components and shall include stress concentration effects. The thermal stresses are to be algebraically added to the mechanical stresses. Material properties are to be taken at the test temperature that gives the most conservative design. Following agreement with ETW the ultimate stress, fatigue endurance limit and ultimate shear strength shall be determined experimentally on samples or on a real part at test temperature.

3.8 Stability and Dynamic Properties

3.8.1 Static Divergence

The safety factor against divergency shall be 2.0 (SF = 2.0) when the calculation is based on unproven aerodynamic coefficients and sting balance stiffness. The safety factor may be reduced to 1.5 (SF = 1.5) if the sting/balance stiffness is experimentally determined before the test, and the lift and moment curve slopes measured during the test at ETW are used for the calculation.

3.8.2 Dynamic Divergence and Flutter (if applicable)

A safety factor of two (2) on the dynamic pressure shall be used.

3.8.3 Oscillating Loads

For tests involving oscillating loads, a modified Goodman Diagram should be used. The gross allowable stress shall be that appropriate to 1.5 times the estimated mean stress and the maximum allowable stress, including a stress concentration factor, must be limited to two thirds of this gross value.

3.8.4 Mechanical Coupling

Any subassembly where a critical eigenfrequency could lead to destruction shall be subject to thorough examination.

The risks of mode coupling for all rotating elements shall be examined.

3.9 Loading Simulation

3.9.1 Metallic Materials

Where appropriate, static tests may be requested from the ETW Test Engineer and shall be conducted in lieu of the stress analysis. These static tests shall be based on the worst load case and shall be performed with the following loads:

a) 110% of the predicted operating load, where the loads can be directly and continuously monitored during wind tunnel testing
b) 130% the predicted operating load, where the loads cannot be directly monitored during wind tunnel testing.

The plots of the loads versus deflection for a complete loading cycle shall be included in the report and must not show any permanent deformation.

3.9.2 Non-Metallic Materials

Where appropriate, static tests may be requested as specified for metallic components (chapter 3.9.1).

3.10 Structural Joints

3.10.1 Bolted Joints

All transverse stresses like shear stress, must be transmitted by keys, pins, dowels, shoulders, etc, to avoid transmission of forces by friction alone. The assembly shall withstand the fracture of the most heavily loaded bolt as defined by the calculation. The allowable stresses are defined as follows:

The maximum stress in any bolt, due to model induced loads combined with torque applied during assembly, shall not exceed 80% of the maximum yield strength. A detailed analysis of the bolt stresses shall be performed, including an evaluation of the stresses induced during pre-loading, created by the external loads.

When using fasteners with a higher thermal expansion coefficient than the material of the joint, forces generated by thermal contraction shall be added to the preload. In the opposite case the thermal expansion has to be subtracted from the preload and compensated by increasing the preload.

The bolt engagement shall be sufficient to limit the shear stresses in the threads to the maximum values specified in chapter 3.6.1.

A torque list shall be supplied as part of the documentation.

Bolted assemblies must be pre-stressed to avoid separation under maximum force. The analysis shall show a sufficient remaining clamping force under the worst load case.

The bolt distribution, definition, tightness torque of threaded parts, stiffness ratios of the assembly and the torsional stress upon tightening are defined using the appropriate national standards listed in chapter 1.6.

Calculations shall be included for compressive and shear stresses in materials under screw heads.
Particular care is to be applied to the shapes of the threaded parts, to limit the stress concentration and crack initiation. For highly loaded and primary screws, rolled threads are recommended.

If necessary the threaded parts must be positively mechanically locked. Qualified locking systems such as Spiralock threads or All-tight screws, are also accepted.

Inserts shall be used for threading in light alloys and composites.

Use of adhesives, Loctite, etc., must be cryogenically qualified.

If bolts are fastened during a preassembly at the model manufacturer's workshop, the applied torque and the thread locking method should be documented in written form together with the date and signature of the responsible rigger. This document has to be submitted to the ETW Test Engineer.

3.10.2 Welded Joints

All welded joints not associated with pressurized systems are to be designed and fabricated in compliance with the standards listed in chapter 1.6.

For the choice of the appropriate welding technique, welding filler, weld design, analysis, manufacture and certification contact the responsible ETW Test-Engineer.
Some information about welding of typical model materials can be found in Reference 2.

3.10.3 Brazed and Soldered Joints

All brazed or soldered joints not associated with pressurized systems are to be designed and fabricated in compliance with the standards listed in chapter 1.6.
For the choice of the appropriate brazing or soldering technique, filler materials, design, analysis, manufacture and certification contact the responsible ETW Test-Engineer.

Some information about brazing and soldering of typical model materials can be found in Reference 2.

3.10.4 Bonded Joints

Bonded joints shall only be chosen when other fastening techniques cannot be used.

Only adhesive bonds shall be used which are qualified by the manufacturer and ETW for the intended loads, materials and environmental conditions.

Contact the ETW Test Engineer prior to any choice.
Bonding surface preparation and processing shall be performed according to the manufacturer's or ETW's instructions.

For bonded joints subject to aerodynamic or structural loads an analysis according to standards mentioned in chapter 1.6 or instructions of the bond manufacturer or ETW has to be performed. A safety factor of SF=5 has to be respected.

Thermal contraction is an important factor and should be considered while choosing the material for bonded joints.

3.11 Pressurized Systems

All pressurized components, vessels, and systems of the Test Assembly which have a product of the operating pressure (in bar) times the operating volume (in liters) of less than 200 are to be designed, fabricated, inspected, tested, and installed in compliance with one of the applicable codes and standards listed in chapter 1.6.

Pressurized components above this value are requested to be approved by TÜV Germany (German pressure vessel approval authority).

3.12 Electrical Equipment and Components

All electrical devices, insulation, and wiring shall be capable of operating within the test environment and shall be consistent with good design practice and safe operating procedures.

3.13 Seals and Gaskets

All closed cavities of the model body shall be sealed from the outer wind tunnel atmosphere. Flat contact faces of body parts are to be sealed with material qualified by ETW. Openings shall be sealed with ETW qualified filler materials.

When using wings made of several components, it is required to seal the contact faces with ETW qualified material in order to avoid aerodynamic disturbance due to leakage between the lower and upper wing.
Parts which move or deform relatively to each other under test loads shall be sealed using labyrinth techniques.

All contact faces to be sealed, shall be cleaned to be absolutely free from contaminants such as cooling liquid, oil, glue, fat, corrosion protectors etc..

For gaskets cryogenic qualified materials such as PTFE, Graphite or composites of both can be used. Other materials can be used after proven by a leakage test under cryogenic conditions.

Define gasket dimensions and preload according to standards mentioned in 1.6.

For more information on the seal and filler materials contact the ETW Test Engineer.

3.14 Filling holes

It should always be the objective of a model design to keep the number of holes cutting through the aerodynamic surface as low as possible. However these cannot be avoided.

For filling those holes ETW provide a selection of suitable filler materials and ETW's rigging personnel is well skilled in filling holes. Those holes shall be designed in a way that the filler can lock itself under an undercut or groove etc. Holes that will be partly filled by a screw head shall be deep enough as the filler needs to have a sufficient thickness.

From the upper face of the screw head to the surface should remain a distance of 1mm for small holes less than 5mm and at least 2mm for bigger holes.

3.15 Special Measurement Equipment

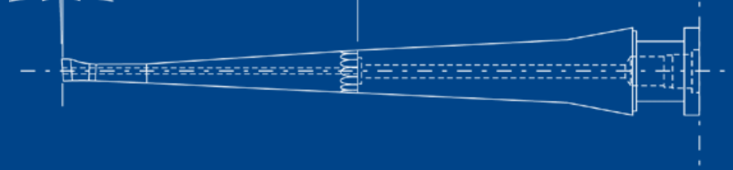
Foils used as a carrier for e.g. PSC Piezo Arrays or Hot Film Arrays shall be bonded to the surface with extreme care. Refer to chapter 3.10.4 Bonded Joints and contact the ETW Test Engineer for the choice of suitable foil material and bonds.

Such foils shall be bonded into a pocket with the same thickness as the foil itself to avoid aerodynamic disturbances. Take care that no air is enclosed underneath the foils and that it is sealed from other cavities as this can cause tearing off the foil.

No small components like Integrated Circuits, Microchips or other electrical elements made from hard materials like ceramics shall be directly attached to the foils. If those components have to be placed close to the foil, they shall be mounted in a separate cavity in a way that they can't be pulled off in case the foil tears off.

Paints like Temperature- and Pressure Sensitive Paint (TSP/PSP) shall be sprayed by ETW's subcontractors only. All surfaces to be painted shall be cleaned to be absolutely free from contaminants such as cooling liquid, oil, glue, fat, corrosion protectors etc.

Take care that no cooling liquid, oil, glue etc. can remain in gaps or pockets and can be pushed out when deformed under loading or thermo cycling, as this causes peeling off the paint.



4 QUALITY ASSURANCE

4.1 General

The design, manufacture, assembly, acceptance and testing of Test Assemblies must be achieved under controlled conditions. The ETW Test Engineer must, where possible, be kept informed at all stages through this process.

4.2 Pre-Checking Documents

For all critical components pre-checking documents must be prepared by the client and submitted to the ETW Test Engineer as soon as possible but at the latest six weeks in advance of testing. These documents should contain as a minimum:

- Written evidence, to control processes, for which uniform quality of the articles or materials cannot be assured by final inspection
- Design and Construction Report, containing:
- as-built drawings of the configuration to be tested, including electrical schematics and wiring diagrams, and the connection to the ETW equipment
- design loads
- stress analysis
- stability analysis (if applicable)
- inspection reports.

4.3 Material

The material of all critical parts must be checked and certified. The following acceptance tests have to be performed on each batch and heat treatment as applicable:

- Melt analysis
- Tensile test
- Notched bar impact test at -196 C, or lowest test temperature, for ISO-V-specimen
- Ultra sonic test, or similar NDT test, (homogeneity test of the structure)
- Heat treatment conditions.

4.4 Delivery Conditions of Semi-Finished Products

The delivery conditions must be in accordance with the material specification and the national or the international standards.

4.5 Identification of Semi-Finished Products

Each semi-finished product, forging, strips, plates, etc., shall be marked with:

- material code
- heat number, melt number
- manufacturers trade mark
- inspectors mark or stamp.

The markings shall have no deleterious effect on the product or its performance and shall be sufficiently stable to withstand normal handling.

4.6 Material Certificates

The results of material tests are to be included in a material certificate. For all critical parts of the Test Assembly a material certificate 3.1B according to EN10204 (Euro Norm) is necessary. For material tests performed outside the EU the certificates should be according to national standards with comparable specifications. The use of semi-finished material from non qualified manufacturers is not permitted.

4.7 Inspection and Testing During Manufacture

All components of a Test Assembly shall be subject to inspection and testing at the manufacturer's works in accordance with the designer's documents and the inspection plan.

4.8 Acceptance Tests

After the successful completion of all specified inspections and compiling all documents together the workshop acceptance test is fulfilled and should be recorded and signed.

An authorized representative of the client must sign an assurance that the model conforms to the requirements of this document.

4.9 Final Documentation

The final documentation must contain:

- as-built drawings
- checked and released stress calculations
- material certificates
- fulfilled and signed inspection plan with records from the tests
- torque values.

4.10 Packing and Transportation

The application of suitable packing material should ensure that the impact of acceleration and deceleration forces and any occurring vibrations on the component are sufficiently small to avoid any damage. The client is responsible for the packing and the selection of the most suitable preserving materials.

All transportation of Test Assemblies and components are to be insured by the Client. Very fragile equipment shall be packed with acceleration controls to detect any accident during the transportation.

4.11 Assembly, Installation, and Configuration Change Procedures

The procedure on installation and configuration changes shall be confirmed at a test planning meeting after receipt of the Design and Construction Report. Any areas impacting the test sequence shall be indicated to the client.

The procedures shall contain sequential steps for assembly including torque values, alignment criteria, etc., necessary to assemble, install and check-out all hardware. The configuration change requirements and the environmental conditions envisaged during the test campaign shall be defined taking account of the ETW model handling equipment.

5 DOCUMENTATION

4.12 Deviations

If a deviation from the requirements of this handbook is considered necessary, a written request for approval shall be submitted to the ETW Test Engineer. Approval or denial of the request shall be recorded by the ETW Test Engineer and retained in the files. The deviation request shall contain, as a minimum, the following information:

- identification of the component or system under consideration
- a description of the proposed deviation
- the requirement for which the deviation is being processed
- the reason for which the requirement cannot be fulfilled
- the technical assessment that the deviation from a requirement is acceptable due to:
- consistent limits for the test envelope
- on-line monitoring equipment
- others.

4.13 Approval Authority

If the integrity of a Test Assembly, or component, cannot be guaranteed, ETW will discuss the situation case by case with the client taking into account the risk and severity of a potential failure and any consequential downtime of the facility.

5.1 General

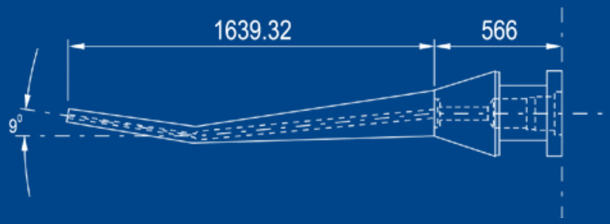
All documentation must be in English (except drawings, detailed calculations with self explanatory formulae and material certificates may be in the client´s own language if accompanied by sufficient explanations in English) and in the metric system of SI units (ISO 1000).

The Design and Construction Report (chapter 5.2) must be provided to ETW normally 6 weeks in advance of testing and latest 2 weeks prior to assembly on the model cart. However, every effort shall be made to prepare these documents in close cooperation with ETW and to allow ETW personnel to have access to the design preparation as early as possible.

5.2 Design and Construction Report

The report shall contain, as a minimum, the following:

a) As-built drawings of the configuration to be tested (only data relevant for assembly and stress analysis), including electrical schematics and wiring diagrams
b) Design loads
c) Stress analysis
d) Stability analysis (if applicable)
e) Required inspection reports.



6 DEVIATIONS

5.3 Assembly, Installation and Configuration Change Procedures

The detailed procedures on Test Assembly installation and configuration changes shall be confirmed at a planning meeting immediately after delivery of the Design and Construction Report as it may impact considerably the overall test sequence.

Typical procedures will contain sequential assembly steps, torque values, alignment criteria, etc., necessary to assemble, install and check-out all hardware. Where appropriate, the configuration changes and the envisaged environmental conditions for the Test Assembly during the test campaign shall also be defined. The design and procedures shall take account of the model handling equipment employed at ETW.
When a deviation from the requirements of this handbook is considered necessary, a written request for approval is to be submitted to the Test Engineer. Approval or denial of the request will be documented by the ETW Test Engineer and retained in the files.

6.1 Deviation Request

The deviation request shall contain, as a minimum, the following information:

a) a description of the proposed deviation
b) identification of the article or system under consideration
c) the requirement for which the deviation is being processed
d) the reason for which the requirement cannot be fulfilled
e) the technical assessment that the deviation is acceptable due to:
  • consistent limits for the test envelope
  • on-line monitoring equipment
  • others.

6.2 Approval Authority

Whenever the integrity of a Test Assembly cannot be fully guaranteed, ETW will discuss case by case with the client on how to handle the situation depending on the severity of a potential failure, risk and downtime for the facility.

7 MODEL SIZING CRITERIA

7.1 TRANSPORT AIRCRAFT MODEL

		ETW SUGGESTED	
Wing Span / Tunnel Width		b / w	≤ 65 %
Wing Area / Test Section Area		A_S / A_{TS}	≤ 5 %
Body Length / Test Section Height		L / H	≤ 1
Wing Chord / (Test Section Area)1/2		c / $A_{TS}^{1/2}$	≤ 10 %
Blockage	at M ≤ 0.85	A_{CS} / A_{TS}	≤ 0.5 (A / A* - 1)
	at M > 0.85	A_{CS} / A_{TS}	≤ 1 %

Where A_{CS} = Area, Model Cross Section

A_{TS} = Area, Test Section

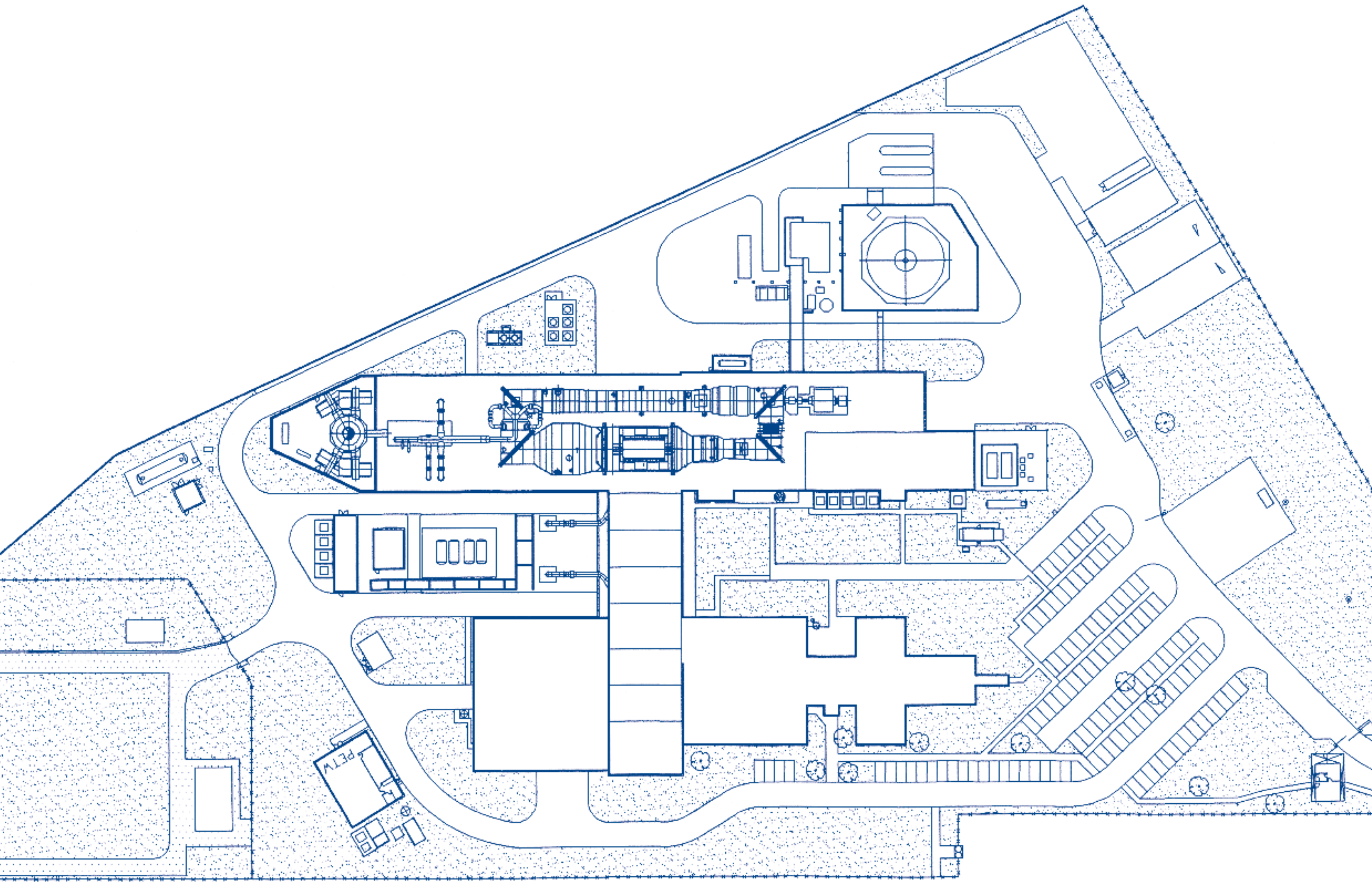
A/A* =Stream tube area relative to critical area = fn(Mach)

7.2 COMBAT AIRCRAFT MODEL

		ETW SUGGESTED	
Wing Span / Tunnel Width		b / w	≤ 35 %
Wing Area / Test Section Area		AS / A_{TS}	≤ 5 %
Body Length / Test Section Height		L / H	≤ 0.7
Wing Chord / (Test Section Area)$^{1/2}$		c / $A_{TS}^{1/2}$	≤ 12.5 %
Blockage	at M ≤ 0.85	A_{CS} / A_{TS}	≤ 0.5 (A / A* - 1)
	at M > 0.85	A_{CS} / A_{TS}	≤ 0.5 %

7.3 HALF MODEL

	ETW SUGGESTED
Span, Half Wing	≤ 1.4 m
Reference Area, Half Wing	≤ 0.4 m^2
Body Length	≤ 2.5 m
Mean Aerodynamic Chord	≤ 0.35 m
Half Model Cross Section Area	
(Including Peniche)	≤ 0.096 m^2



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