T-117 TsAGI HYPERSONIC WIND TUNNEL

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T-117 TsAGI is a large hypersonic blowdown arc heater wind tunnel. A schematic diagram of the tunnel is shown in Fig. 1.

The facility is provided with two interchangeable electrical arc heaters with a maximum power of 25 and 2,5 megawatts. The first heater is a two arcs heater and the second one is a one arc heater. The supply air is heated between coaxial electrodes by an electric arc rotated in a magnetic field.

There are available a set of axisymmetric contoured nozzles with anexit diameter of 1 m. A twenty one-finger Pitot rake is used to investigate test section flow fields.

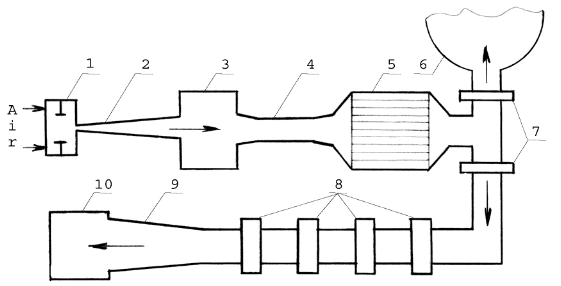

Fig. 1. Sketch of T-117 TsAGI wind tunnel. 1 – arc heater; 2 – nozzle; 3 – test section; 4 – diffuser; 5 – heat exchanger; 6 – vacuum tank; 7 – vacuum isolation valves; 8 – ejectors; 9 – subsonic diffuser; 10 – exhaust stack.

The test section is designed as an Eiffel chamber and equipped with two model support systems. The first system permits model injection to the flow and either pitch or yaw model motions. The pitch mechanism allows a motion either from –5° to 50° or from –30° to 25° and yaw mechanism – from –30° to 30°. It is possible to change model angular position either by steps of 1°, 2°, 3° and 5° or by continuous motion with the rate of 0.9 or 1.7 degrees per second. The second model support system is used for heat transfer investigations and provides fast model injection without any changes of model angular position during run.

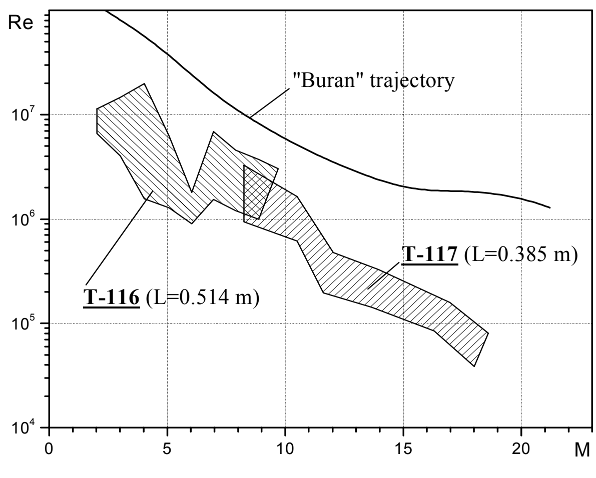

Fig. 2. The operating envelope for T-117 TsAGI

The maximum model size, which can be tested, is largely depended on the model geometry and the test conditions such as Mach number and angle of attack. The maximum model length and wings span are restricted to 1 m and 0,4 m correspondingly.

The test section has optical quality windows and ports to allow flow-field visualization or direct photography. Standard IT-228 interferometer is provided as a part of the facility instrumentation.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
23 Aug 2002	N/A	-

Title and Subtitle T-117 TsAGI Hypersonic Wind Tunnel	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Institute of Theoretical and Applied Mechanics Institutskaya 4/1 Novosibirsk 530090 Russia	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) EOARD PSC 802 Box 14 FPO 09499-0014	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
See also ADM001433, Conference held International Conference on Methods of Aerophysical Research (11th) Held in Novosibirsk, Russia on 1-7 Jul 2002

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
5

The operating time is restricted to approximately one or three minutes depending on an exhaust system in use (vacuum tank or four-stage ejector).

Currently available aerodynamic capabilities of T-117 TsAGI for aerodynamic testing are summarized in table below.

Capabilities of T-117 TsAGI for aerodynamic testing. $(\Delta M/M)_R$ – core flow radial variation, $(\Delta M/M)_{L=1m}$ – variation of Mach number along the centerline of the flow at the distance of 1 m.

	Nozzle						
	1	2	3	4	5	6	7
M	8.3	10.5	11.6-12.0	13.7-14.0	15.4-15.5	15.6-17.0	17.6-18.6
$Re_{1\,m}\cdot10^6$	2.4-8.5	1.6-4.3	0.51-1.24	0.37-0.85	0.4-0.5	0.11-0.41	0.1-0.21
$P_0\cdot10^{-5}$, Pa	13-45	38-100	46-103	45-100	100-106	57-200	72-154
T_0, K	770-900	1100-1800	1700-2000	1740-1950	2290-2920	2180-2900	2290-3430
Core, m	0.68-0.7	0.6-0.66	0.38-0.42	0.5-0.55	0.5	0.45-0.5	0.4-0.45
$(\Delta M/M)_R$	±1%	±1%	±1%	±1.5%	±1.2%	±1.1%	±1.5%
$(\Delta M/M)_{L=1m}$	–1%	–1%	+1%	+1%	–	–1%	–1.9%

The operating envelope of the T-116 and T-117 TsAGI with respect to "Buran" reentry trajectory is shown in Fig. 2.

Test section flow field investigation and validation tests on the model with well-known aerodynamic characteristics must be done before any tests on the models at any new operating regime. To estimate quality of the flow axial and radial Pitot pressure distributions are measured with Pitot pressure rake during calibration runs. The vertical Mach number distribution at 380 mm downstream of the nozzle exit for all available test regimes (see Table) is shown in Fig. 3.

T-117 facility became operational at 1979. A considerable amount of testing was performed up to date on models of different configurations. There were investigations of:

- total aerodynamic characteristics and loads on the model elements
- surface pressure distribution
- surface heat transfer rate distribution with phase change paints and transducers
- schlieren and interferometry flow field visualization
- surface streamline visualization

Examples of some experimental results will be done below.

The facility is provided with a set of six-component strain-gage balances for wide range of loads. They was used for total aerodyna mic characteristic measurements of "Buran" models in series of investigation programs. Figure 4 shows lift to drag ratio for "Buran" reentry trajectory. Comparison of ground test facility data and flight data shows a good agreement.

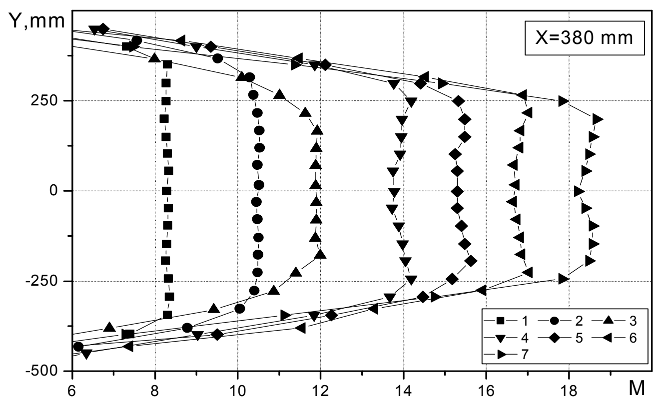

Fig. 3. Test section flow fields.

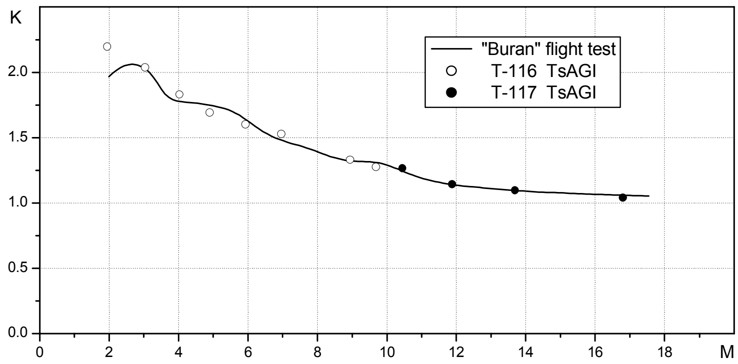

Fig. 4. Lift to drag ratio for “Buran” reentry trajectory.

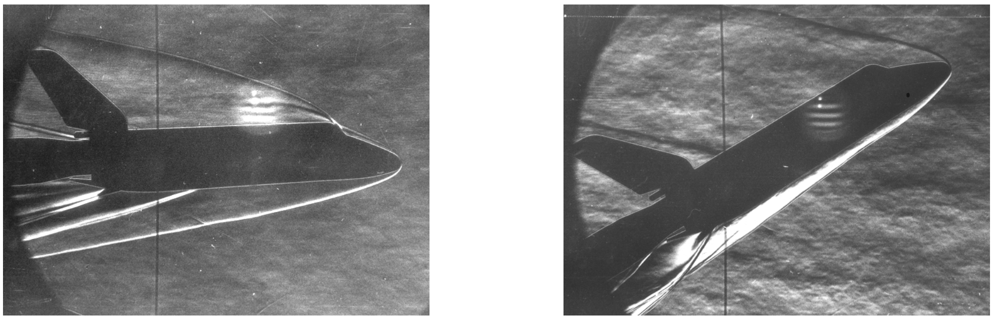

Fig. 5. Schlieren patterns of “Buran” model at angle of attack α=3˚ and α=42˚.

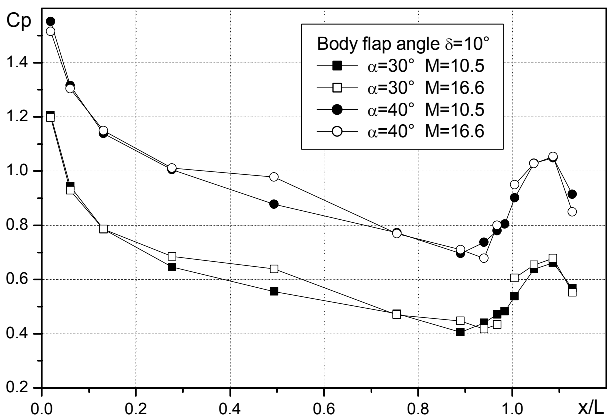

Fig. 6. Pressure coefficient distributions on the windward symmetry plane of the reentry vehicle.

Traditionally, flow field visualization supports balance testing. Figure 5 shows an example of schlieren patterns obtained during balance test of “Buran” at M=10.5. You can see bow shock impinging on the cabin at angle of attack α=3˚ and the shocks interaction near the body flap at α = 42˚.

Steel models with pressure transducers inside are used for pressure distribution measurements. Test duration is about 2 seconds to avoid transducer heating. Pressure tube from the surface orifice to the transducer must be as short as possible due to low pressure levels on the body. Pressure coefficient dis-tributions on the windward symmetry plane of the reentry vehicle with body flap angle of 10˚ are shown in Fig. 6.

Phase change paints [1], surface thermocouples and calorimeters are used for heat transfer investigations on the model surface. A heat transfer rate distribution obtained by phase change paints technique on the windward symmetry plane of the blunted cone at the angle of attack of 30° is show in Fig. 7. The same model was tested without and with turbulator. Figure 7 illustrates that transition occurred immediately after turbulator.

When the phase change paints technique is used simultaneously with surface streamline visualization it becomes possible to understand the peculiarities of heat transfer on the model surface more completely [1]. To obtain the surface streamline pattern, a large number of discrete drops of visualizing composition are applied to the metal model. They left tracks under the flow on the model surface. Regions of boundary layer separation and reattachment, lines of divergence and convergence can be found from analysis of surface streamline pattern. Fig. 8 shows such pattern obtained at the nose of reentry vehicle.

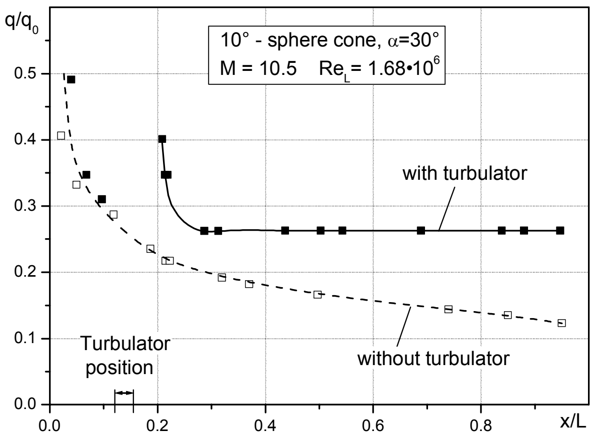

Fig. 7. Heat transfer rate distribution.

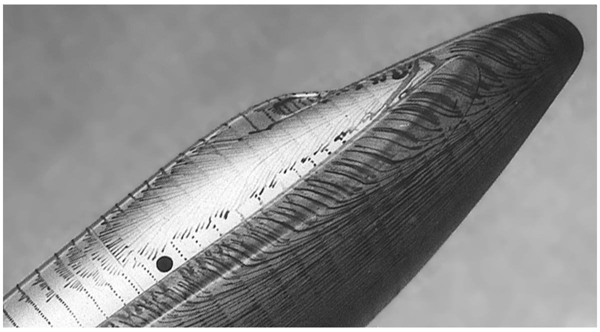

Fig. 8. Surface streamline pattern.

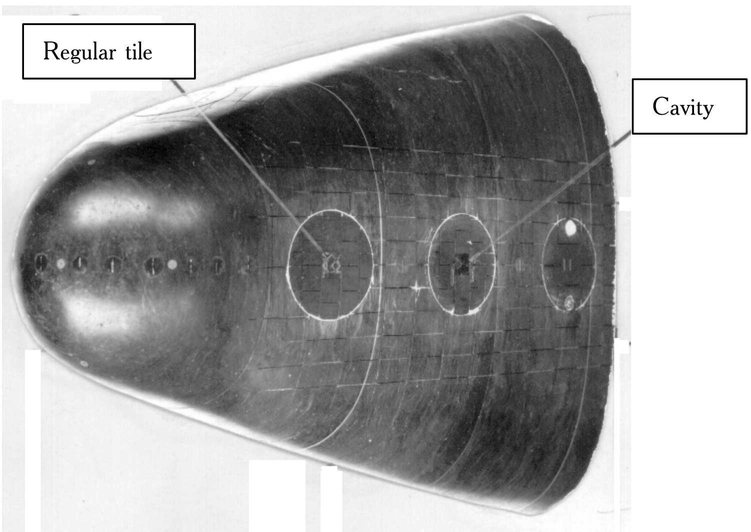

Fig. 9. Model for local heat transfer investigation.

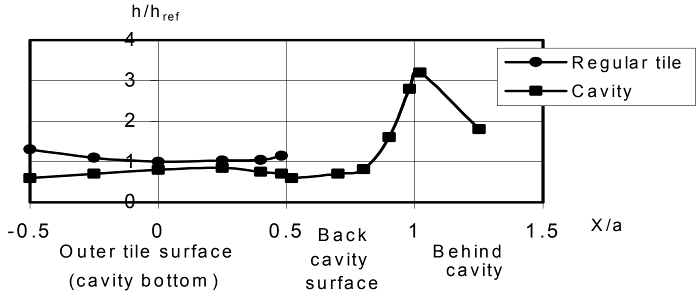

Fig. 10. Heat transfer coefficient distributions.

For local heat transfer investigation on the tile structure of "Buran" [1], the model of nose part (scale 1:15) has been used, Fig. 9. One of the regular tiles on the windward surface was equipped with the surface thermocouples. For investigation of effect of a tile falling out, one of the tiles was removed and cavity was equipped with thermocouples, too.

Tests were performed at Mach number $M_\infty = 13.7$, Reynolds number $Re_{\infty,L} = 1.2\times10^6$ and model angle of attack α=34°. Relative heat transfer coefficient distributions on the outer surface of regular tile and cavity are presented in Fig. 10. Relative heat transfer coefficient h/h_{ref} (h_{ref} – on the middle of regular tile surface, a =10 mm is the tile length) on the regular tile is monotonous enough, but some heat transfer rise takes place on the leading and rear tile edges. On the cavity surface, heat transfer distribution is non-monotonous. On the cavity back wall and directly behind rear edge, value of h/h_{ref} exceeds 1 essentially. This is due to a free shear layer incidence to these regions.

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