PRESENTATION
FOR THE INTERNATIONAL AIRCRAFT FIRE & CABIN SAFETY RESEARCH CONFERENCE

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DEVELOPMENT AND MAKING OF AN ACCELERATION SLED FACILITY FOR AIRCRAFT SEAT DYNAMIC TESTS

The provision of safe occupant restraint systems in an aircraft crash is one of the paramount aspects in the field of crashworthiness. That's why it is very important to accurately evaluate the structural strength and the injury criteria of a seat in the tests, in which aircraft emergency landing conditions are simulated. The aircraft accident investigations showed that the separation of seats from their attachments, the break-down of safety belts attachments and of some seat hard points, as well as severe injuries of people under emergency landing conditions occur very often. These facts showed both essential shortcomings of seats and restraint systems used and inadequate efficiency of the methods used for their testing.

Taking this into consideration, the Gromov Flight Research Institute (LII) began in 1980 to carry out research on the development of new methods for seat/ restraint systems tests, which would most fully simulate aircraft real emergency landing conditions and would make an addition to the traditional static tests.

The first aircraft seat dynamic tests in Russia were conducted at the LII dynamic test facility. It was an acceleration sled facility and was positioned outdoors. The impact action on a "seat-dummy" system was done by means of a firing gear. The dynamic action level at the test facility was such as to meet the Airworthiness Standards in force at that time in Russia (NLGS-3, item 4.3.1.1 and item 5. 11.2.2) and it didn't exceed 9 g in the center of gravity of the “seat-dummy” system (See Figure 1).

A simplified anthropometric dummy or an anthropomorphic dummy like "Hybrid II" was used for tests. The essential shortcoming of the LII test facility was the impact pulse instability. Besides, the test procedures didn't provide angle of yaw seat turn and the seat attachments deformation. Several types of seats for airplanes like IL-96-300, IL-114, Yak-42 and others were tested at this facility

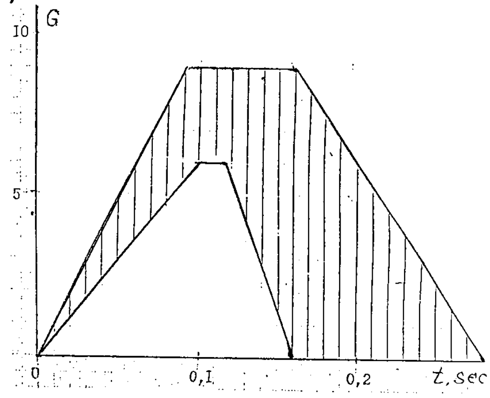
In 1992—1993 the Aviation Rules AP-25 and AP-23 were put in force in Russia. They were fully brought to conformity with the Federal Aviation Regulations, Part 25 and Part 23 in the field of survival. The new requirements defined the necessity of conducting seat/restraint systems dynamic tests in accordance with the Regulations and strictly keeping to the procedures imposed by Advisory Circulars (AC 25.562-1 and AC23.562).

At this time there was no specialized test facility for aircraft seat dynamic testing in Russia to fully meet the requirements of AP and FAR.

Seat system dynamic test procedures as a means of compliance with NLGS-3 5.11.2.2.

Test main conditions (1987):

- **Structural test, horizontal impact.**
- **$Gp_{cg} \leq 9.0$ in c.g. of seat-dummy system (acc. to 4.3.1.1).**
- **$Gp_S \approx 6.0 - 9.0$ on the sled (based on $Gp_{cg} = f\ (Gp_S)$).**
- **ATD – simplified anthropometric dummy/Hybrid II.**
- **$W_{ATD} = 80$ kg for pas. and fl/att. seats, and**
- **$W_{ATD} = 90$ kg for crew seats (acc. to 5.11.2.2).**



Required pulse shape (Gp_{cg})

Figure 1

In 1995 the State Governmental Scientific-Testing Area of Aircraft Systems undertook to make a test base for aircraft seat dynamic testing. Great experience gained by the test range in conducting different kinds of aeronautical engineering tests and in making test stand equipment considerably facilitated this work. Track tests, vibration tests, ballistic tests, environmental tests, thermal and some other tests are conducted at the test range in particular. The making of the test facility was carried out with the methodical support of the Aviation Register of the Interstate Aviation Committee and in the compliance with the requirements of the current standards

(AP-23, AP-25, AP-27, AP-29, FAR-23, FAR-25, FAR-27, FAR-29).

In the initial stage of work the specialists of the test range carried out a large volume of research to choose a test facility look, a test scheme, as well as research on the development of the impact pulse creation device design. Some designs of a pyrotechnic pusher and a pneumatic pusher were tried as means for impact pulse creation, as well as schemes of impact pulse creation by means of deceleration were considered. While developing the pyrotechnic pusher, positive results were obtained, but the pulse quality and its stability didn't satisfy us. A special hydraulic cylinder was developed and made for the realization of the testing scheme by means of deceleration. The principle of impact realization consisted in the preliminary sled acceleration and its collision with the rod of the rigidly secured hydraulic cylinder. The fluid resistance in the hydraulic cylinder was to provide the required deceleration law. The complexity of this design didn't allow the specialists to bring it to full-scale tests.

In the end, after the analysis of the obtained results, one of the tried designs of the pneumatic pusher was chosen. The choice criteria were test repeatability, easy and reliable adjustment of pulse parameters, as well as the required shape of the obtained impact pulse. In addition, the scheme of the impact pulse creation at the acceleration phase provided a number of advantages from methodical point of view. While developing the pneumatic pusher, our specialists developed adjustment techniques and design versions to test different masses of the test sled, as well as all the impact pulse shapes in accordance with AP and FAR. In 1997 our enterprise started to make a facility for aircraft seat dynamic testing based on the developed pneumatic pusher design and the experience of using the test range rocket sled tracks.

In parallel with the making of the test facility hardware, the development of measurement systems, automatic control systems and photographic instrumentation systems was carried out. The development of these systems was accomplished in accordance with the Society of Automotive Engineers Recommended Practice SAE J 211, Instrumentation for Impact Tests. As a result, the test facility "Kreslo" for aircraft seat dynamic testing was made at the FKP "GkNIPAS" enterprise. This is an acceleration sled facility with the sled running along the rail guides.

The test facility comprises the following equipment:

- accelerator
- sled park
- test dummies
- test track
- decelerator
- emergency braking device
- data measurement system
- automatic and control devices
- photographic instrumentation systems
- handling equipment (a winch, a hoisting device, trucks for transportation, etc.).

The schematic dynamic test facility is provided in Figure 2.

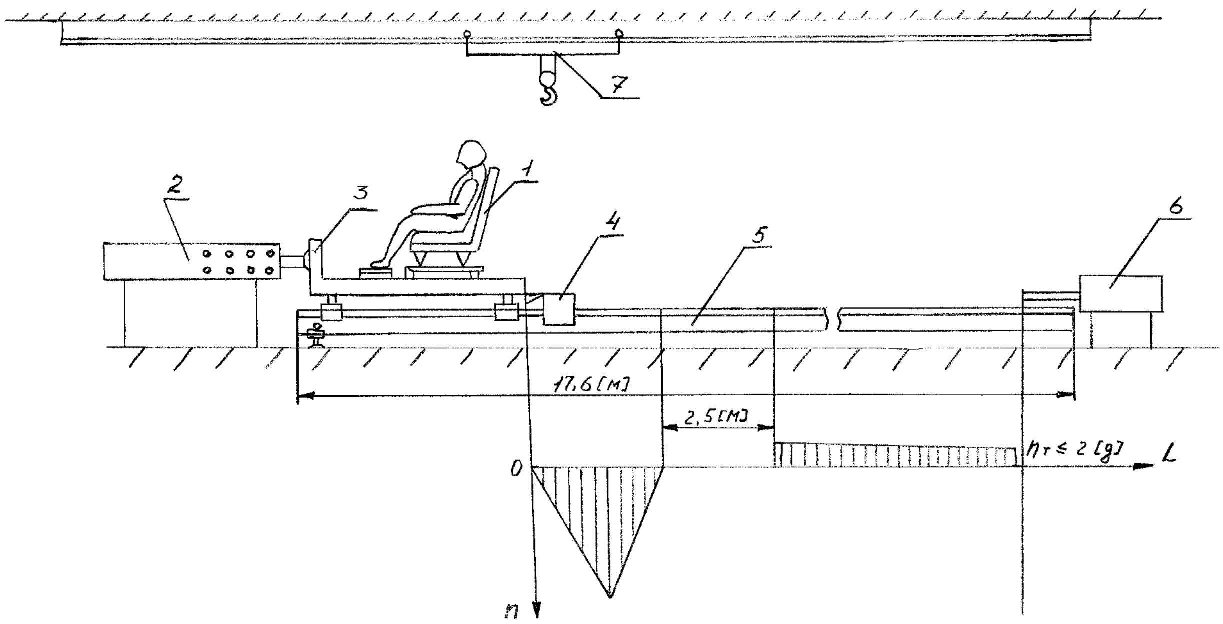


Figure 2. Schematic Test Facility and G's Diagram.

1 – Seat with test fixtures; 2 – Accelerator; 3 – Sled; 4 – Decelerator; 5 – Rail Guides; 6 – Emergency Braking Device; 7 – Hoisting Device.

The accelerator is designed to create a variable impact providing the movement of the sled with the test article along the test track according to the modes in compliance with the requirements of AP and FAR. The accelerator is based on the principle of a pneumatic actuating cylinder with an adjustable high-pressure air supply from a high -pressure vessel (a pneumatic accumulator). The schematic accelerator is provided in Figure 3.

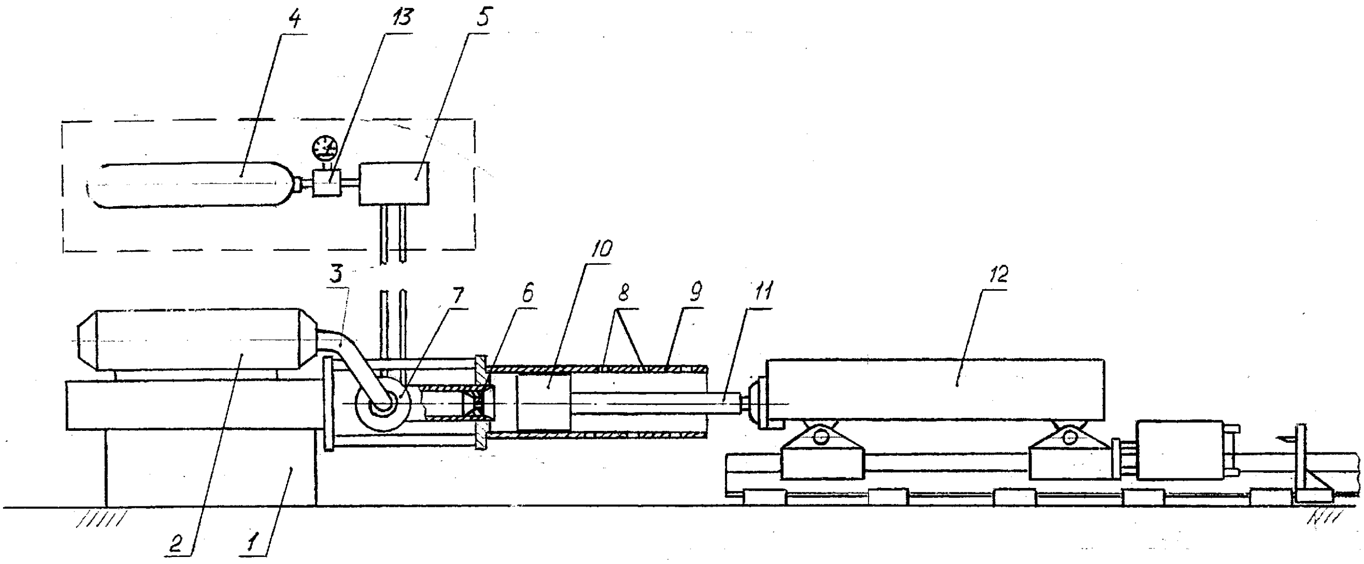


Figure 3. Schematic Accelerator

1 – Base, 2 – Receiver, 3 – Pipe Line, 4- Control Pneumatic System Air Vessel,
5 – Electro-Pneumatic Valve (EPV), 6 – Throttling Device, 7 – Cut-of f Valve,
8 – Air Release Hole, 9 – Pneumatic Cylinder, 10 – Piston, 11 – Rod,
12 – Test Sled, 13 – Pressure Regulator

The peculiarity of the pneumatic cylinder consists in the fact that the piston is secured on the test sled and doesn't have rigid connection with the cylinder. Besides a throttling device element is secured on the piston that controls the high-pressure air supply to the cylinder. The downward curve of the impact pulse is realized in the device by means of the air release from the cylinder through the pneumatic cylinder wall perforated in the given zone. The advantage of such a design is an easy device readjustment to different impact pulses by the working pressure choice in the receiver and by means of the part change (the cylinder body, the throttling device).

The accelerator provides obtaining impact pulses with the following deviations from the ideal (triangular) impact pulse:

- amplitude deviation, not more than plus 10 %
- time of obtaining maximum amplitude deviation, not more than minus 15 %
- movement velocity change deviation, not more than plus 15 %.

The sled is intended for installing a test article on it and transmitting the impact pulse to the test article. The measurement system transducers and the test fixtures are placed on the test sled .The mass of the test sled with a test article may be from 1,000 kg to 2,000 kg.

In accordance with the requirements of the standards the dynamic test facility is fitted with anthropomorphic test dummies like "Hybrid II" Fiftieth Percentile Male Test Dummy. The test dummies meet the requirements of 49 CFR, Part 572, Subpart B and have got the certificate of the manufacturer (Applied Safety Technologies Corporation, U.S.A.). For the test dummies preparation and calibration the enterprise made a special bay fitted with the standard calibration fixtures.

The test facility track of 17 m length is designed to provide rectilinear movement of the sled. After the impact pulse realization the test sled is running inertially for a distance of 2 - 4 meters. Deceleration G at this portion of the track is ~ 0.1 g - 0.2 g. As soon as the test sled reaches the deceleration portion, the friction decelerators are engaged and they bring the sled with the test article to a stop. The decelerators are made in the form of friction slippers with pneumatic control. G at the stop of the sled at deceleration does not exceed from 1.5 g to 2 g. The total time from the beginning of the impact pulse action until the sled deceleration moment is not less than 0.35 s.

The automatic devices are designed for the remote control of the accelerator, data measurement system, photographic instrumentation systems, for the monitoring of the control commands execution, as well as for giving official signals and common time signals to all the recorders.

The data measurement system is designed to measure Gs, velocities and loads necessary for the test conditions monitoring and determination of injury criteria. Taking into consideration the rigorous requirements of the Society of Automotive Engineers Recommended Practice SAE J211, it was decided to purchase test equipment from the most famous companies. The instrumentation was ordered in complete sets including gauges, cables and amplifiers from Endevco and Denton companies. The instrumentation has been certified by Gosstandart bodies of Russia and has been recognized as meeting the requirements of the Society of Automotive Engineers Recommended Practice SAE J211.

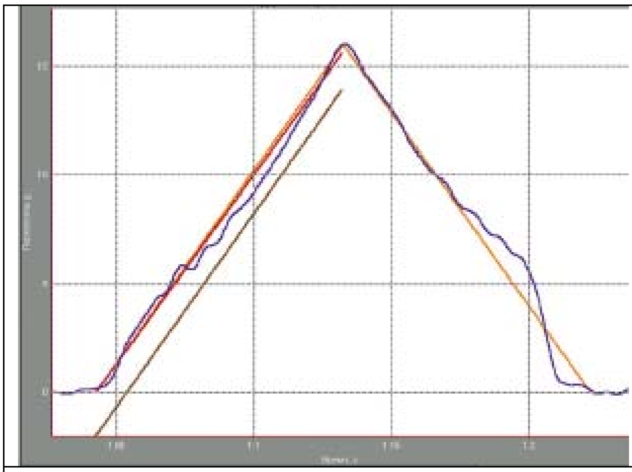
The photographic instrumentation system is designed for documenting the total test results, as well as for the determination of the dummy's movement parameters during a test. The photographic instrumentation system is equipped with four general-purpose high-accuracy cameras "Pusk -16" (film width 16 mm, speed rate up to 5,000 frames per second), three high speed motion-picture cameras "SKS-1M" (film width 16 mm, speed rate up to 4,000 frames per second) and the motion-picture camera "Gladiolus-1" (film width 35 mm, speed rate up to 240 frames per second). The motion-picture cameras are located in such a way that the adjacent cameras overlap the field of view that makes the photographic materials analysis easier.

The test facility "Kreslo" is positioned in a closed box with the environmental and lighting conditions to meet the requirements of the equipment used.

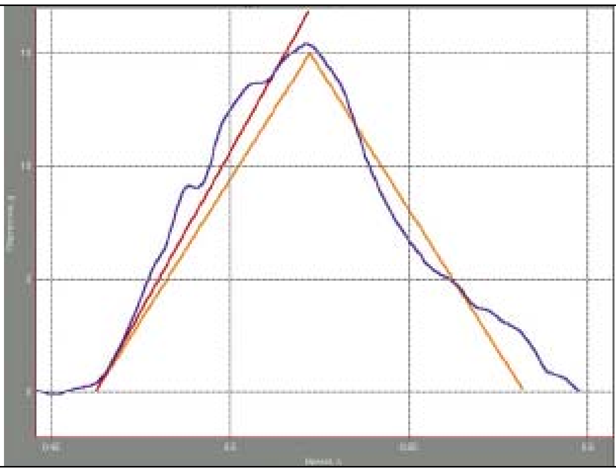
Based on the test facility "Kreslo" a test laboratory was established at the enterprise. In the first half of 1999 the test facility and the test laboratory were presented to the joint commission of the Aviation Register of the Interstate Aviation Committee and Gosstandart of Russia and certified by these bodies for the right to conduct certification testing (certificate ¹ IL -0008).

Testing at the facility is conducted in accordance with the test procedures of AP, FAR, AC 25.562-1A, AC 23.562-1, AC 20.562-1 and MOS-23. Impact pulse examples realized at the test facility are provided in Figure 4.

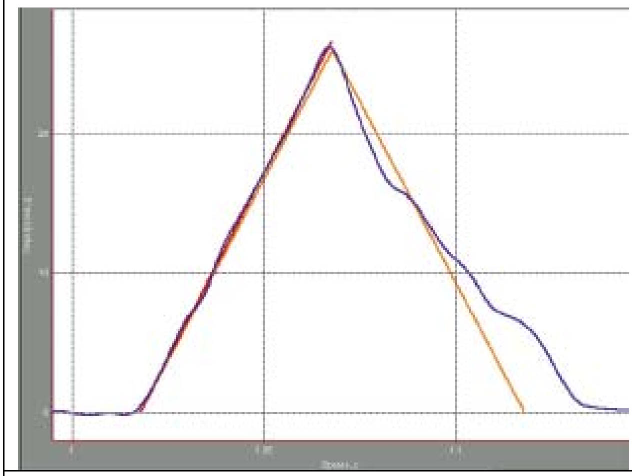
Certification tests of IL-96 T aircraft seats have been successfully tested at the test facility. The in-process tests videogram is provided in Figure 5. Currently, tests of aircraft seats for BE-103, S-80, TU-204 and some other airplanes are being conducted. At present our enterprise is involved in broadening the electronic and optical instrumentation potentialities, fitting the laboratory with anthropomorphic test dummies like "Hybrid II" including the dummies of our own manufacture. By now additional instrumentation has been purchased from Endevco and Denton companies that will allow to create additional measurement channels, a high speed video camera Phantom V 4.0 with the speed rate of up to 1,000 frames per second has been purchased from Photo-Sonics and a scanner for film processing has been purchased from Agfa.



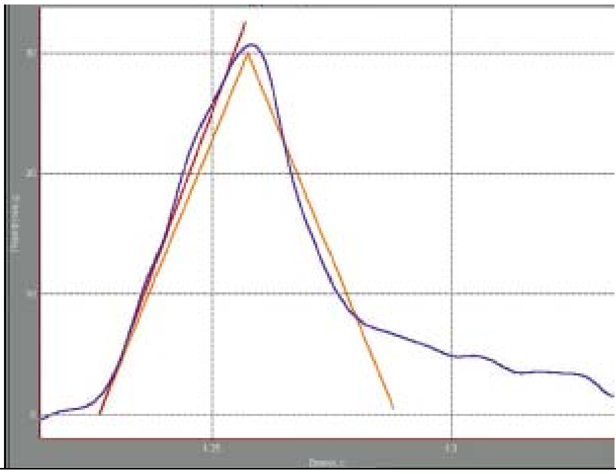
Parameter	Required value FAR 23.562	Computed value	Allowable
Peak load, Gp	not less than 15.000	15.397	Yes
Time of G increase, tr	not more than 0.060 sec.	0.054	Yes
Change in velocity per period, tr	not less than 4.725 m/sec.	5.393	Yes
Change in forward longitudinal velocity	not less than 9.450 m/sec	9.993	Yes
Criterion 2G			Yes



Parameter	Required value FAR 25.562	Computed value	Allowable
Peak load, Gp	not less than 16.000	16.018	Yes
Time of G increase, tr	not more than 0.090 sec.	0.090	Yes
Change in velocity per period, trr	not less than 6.700 m/sec.	6.701	Yes
Change in forward longitudinal velocity	not less than 13.400 m/sec	14.016	Yes
Criterion 2G			Yes



Parameter	Required value FAR 23.562	Computed value	Allowable
Peak load, Gp	not less than 26.000	26.194	Yes
Time of G increase, tr	not more than 0.050 sec.	0.048	Yes
Change in velocity per period, tr	not less than 6.400m/sec.	6.592	Yes
Change in forward longitudinal velocity	not less than 12.800 m/sec	13.955	Yes
Criterion 2G			Yes



Parameter	Required value FAR 29.562	Computed value	Allowable
Peak load, Gp	not less than 30.000	30.672	Yes
Time of G increase of overload, tr	not more than 0.031 sec.	0.029	Yes
Change in velocity per period, trr	not less than 4.550 m/sec.	5.071	Yes
Change in forward longitudinal velocity	not less than 9.100 m/sec	10.406	Yes
Criterion 2G			Yes

Figure 4 Examples of the Impact Pulses Obtained

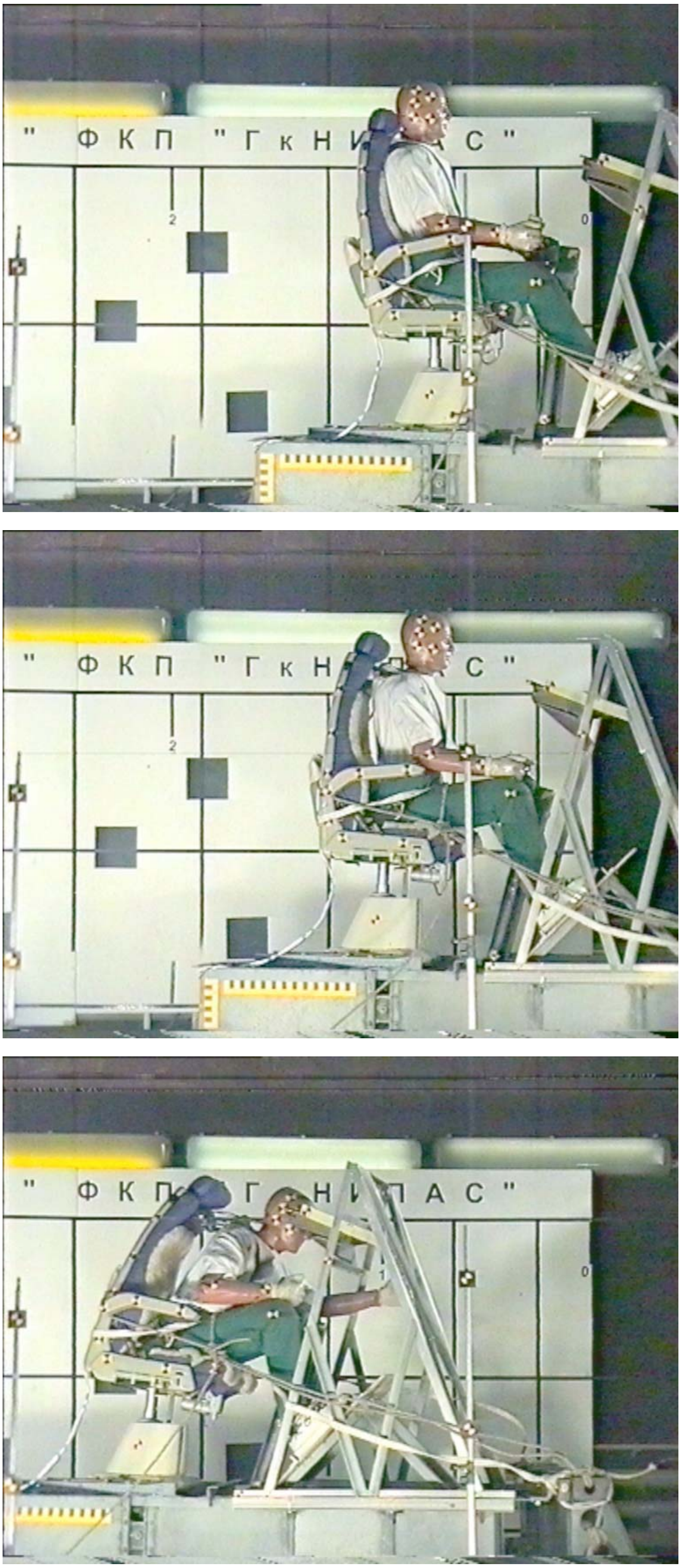


Figure 5 In-process Test Videogram

Much effort is made to the increase of the accelerator energy characteristics in order to increase test article mass. The work is being carried on at fitting the laboratory with software for mathematical simulation and prediction of test results, as well as at test procedure improvement, increase of the kinds of tests including automotive materiel. Besides, the laboratory together with the Aviation Register of the Interstate Aviation Committee and the TSAGI-TEST Certification Centre consult aviation companies in Russia and CIS on mastering this kind of testing that undoubtedly will increase flight safety level.

In August 2000 FAA specialists Mr. Van Gowdy and Mr. Stephen Soltis visited our laboratory for aircraft seat dynamic testing. The specialists of our enterprise are very much obliged to the FAA representatives for the provision of informative consultations on the questions connected with aircraft seat dynamic testing.