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Powerplant Cooling Flight Tests

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Flight testing is necessary in the process of showing compliance of the airplane with specific design requirements. Utva Aviation Industry performed numerous flight tests of Sova airplane in order to prove its safety. Along with airplane design, structure, performance and equipment, it was necessary to show compliance of the powerplant.
In this paper there is the analysis of the flight tests of the powerplant cooling in the most critical climbing case with maximum ambient atmospheric temperature for which approval is requested. Flight test report results are presented with defined minimum speed for these conditions proving our four-seater meets all requirements in its category

Key words: **Flight testing, powerplant cooling, critical conditions, minimum speed, test analysis.**

Introduction

CERTIFYING an aircraft is a long and demanding process. It was a challenge for Utva engineers and flying test team to define the means of compliance with CS 23 paragraphs [1, 2], write flight test plans and perform flight testing [3, 4] in order to comply with the requirements.

In this paper, compliance for several paragraphs of CS 23 E (Powerplant) will be demonstrated.

Certification

Requirements:

The CS 23.1041 "Colling-General" prescribes that the powerplant and auxiliary power unit cooling provisions must maintain the temperatures of powerplant components and engine fluids and auxiliary power unit components and fluids within the limits established for those components and fluids under the most adverse ground and flight operations to the maximum altitude and maximum ambient atmospheric temperature conditions for which approval is requested, and after normal engine and auxiliary power unit shutdown.

The CS 23.1043 "Cooling-Test" prescribes that if the tests of compliance with paragraph CS 23.1041 are conducted under ambient atmospheric temperature conditions, deviating from the maximum for which approval is requested, (minimal temperature for the certification is 38°C/100°F), the following correction must be applied to the recorded powerplant temperatures:

$$Corrected\ temperature = true\ temperature + \\ + 1.0\ [100 - 0,0036\ (Hp) - true\ OAT] \quad (1)$$

where:
- Pressure height - Hp [ft]
- Outside air temperature – OAT [°F]

Temperatures of engine fluids and powerplant components for which temperature limits are established, must be corrected by adding to them the difference between the maximum ambient atmospheric temperature for the relevant altitude for which approval has been requested (38°C/100°F) and the temperature of the ambient air at the time of the first occurrence of the maximum fluid or component temperature recorded during the cooling test.

The CS 23.1047 "Cooling test procedure for reciprocating engine-powered aeroplane" prescribes that the compliance with CS 23.1041 must be shown for the climb stage of flight. The aircraft must be flown in the configurations, at the speeds and following the procedures recommended in the aircraft flight manual, corresponding to the applicable performance requirements, which are critical relative to cooling.

Tests:

Aircraft Sova has Lycoming engine IO-390-A3A6 installed. In order to have specific CS paragraphs fully satisfied, the temperatures of all powerplant components and fluids that are recorded/measured during tests must be within the permitted limits.

Table 1. Temperature limits requirements

Component temp. [°F]	Max allowed
Oil temperature [°F]	235
CHT [°F]	475
EGT [°F]	1700
Battery temperature [°F]	110

In order to show compliance of the aircraft with the requirements of the mentioned paragraphs of the CS 23 regulation, the aircraft was tested in the following way: Data recording in flight was done using MVP-50P device, APIBOX, GT-50. Observed and processed data after this test were:
- Pressure height - Hp [ft]
- Indicated airspeed - IAS [kts]
- Outside air temperature – OAT [°C]
- Oil temperature [°F]
- Cylinder head temperature – CHT [°F]
- Exhaust gas temperature – EGT[°F]
- Propeller speed [RPM]
- Testing time - t [s]

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- Engine vacuum pressure – [inHg]
- Battery temperature [°F] (using GT-50 device)

Procedures for showing compliance with paragraphs CS 23.1041, CS 23.1043, CS 23.1047 were made on the basis of recommendations from the Flight Test Guide (FTG) for the certification of CS-23, section 5 Cooling, paragraphs 246 and 248.

- Perform the flight in an atmosphere without visible moisture during the flight.
- The configuration of the aircraft is with front centering (22%) and a maximum mass of 1200 kg.
- Pour fuel into both tanks up to the filler cap, i.e. total of 150 liters.
- The amount of oil must be critical, i.e. minimum for flight (4 Qts).
- Establish level flight at 1500 feet and maintain altitude at 75% maximum engine power (2450 RPM) until temperatures of all power unit components and fluids stabilize. (The temperature is stabilized when the change is less than 2°F per minute).
- After temperatures have stabilized, increase power to maximum and perform a climb maneuver corresponding to airspeed of 70 kts.
- Continue climbing to a maximum altitude of 10.500 ft.
- Monitor the parameters on the MVP-50P and the GT-50 device which is set to measure the temperature in the battery area.
- Record the temperature from the GT-50 device in intervals of one minute, due to impossibility of automatic recording.
- If at a speed of 70 kts, all parameters of the power unit are within the permitted limits, repeat the test with a speed of 65 kts on the route.
- If, at a speed of 65 kts, all powerplant parameters are within the permitted limits, repeat the test at speed of 60 kts on the route.

Analysis:

Record data from APIBOX and MVP-50P devices. If temperature is lower (minimum 38°C), the obtained values should be corrected using Eq. (1).

Make diagrams from the flight, as well as temperature diagrams of powerplant components. Analyze the temperatures and notice if the temperatures of the powerplant components are exceeded.

For the purpose of testing the powerplant cooling, the following devices were used: MVP-50P (for reading the temperature of the cylinder head, exhaust gases, engine RPM and oil temperature in the engine); APIBOX (for reading the external air temperature, pressure altitude and aircraft speed), while the temperature in the battery compartment was read from the GT-50 device.

The testing was performed in 2 (two) flights, flight No. 62 and flight No. 205.

Flight No. 62 was conducted on October 2, 2020 in weather conditions where the ambient temperature at sea level was less than 38°C, so the obtained values were corrected using the Eq. (1) There was no presence of moisture during the flight. The flight took place in the Pančevo airport area, under the ambient conditions given in the Table 2.

Table 2. Ambient conditions during flight No. 62

Time	Wind speed [kts]	Wind direction	Temperature [^{0}C]	Pressure [mbar]
13:50	5.6	140	28.5	994.5
13:57 Take off	1.7	130	30.8	
14:00	2.1	270	30.8	
14:05	6.0	200	30.3	
14:10	2.7	265	30.2	
14:15	2.7	260	30.1	
14:20	4.0	220	30.1	
14:25	2.6	220	29.5	
14:30	2.0	158	30.9	
14:35	2.2	130	31.1	
14:39 Landing	4.2	192	31.2	994.3

After the engine was started and warmed up to operating temperatures, takeoff and climb were conducted at maximum engine power and speed of 70 kts. The climb was performed at least 6 minutes after fluid and component temperature peaks were obtained or up to a maximum altitude of 10.500 ft with RICH configuration and max RPM.

Data collection was done with APIBOX device, MVP-50P, and reading from the GT-50 device. The pilot used radio communication to inform about the battery temperature by reading the GT-50 device, and based on that data, the diagram in Figure 4 was created.

Table 3. Cooling results with 70 [kts] on path

	MVP t. [°F]	Max corrected t. [°F]	Max allowed t. [°F]
Oil temperature [°F] 4940 ft Hp / 68°F OAT	206	220	235
CHT [°F] 1693 ft Hp / 86°F OAT	425	433	475
EGT [°F] 252 ft Hp / 91°F OAT	1354	1362	1700
Battery temperature [°F] 1718 ft Hp / 83°F OAT	93	104	110

Since the air temperature on the day of the test was lower than required 38°C, then the Eq. (1) was used for the MAXIMUM ACHIEVED CORRECTED temperature values.

The flight parameters during this flight are given in diagrams on the Fig.1.

The diagrams on Fig.2 to 4 show the graphical values of temperatures of fluids and components at a speed of 70 kts on path for which the temperature limits are given in Table 3.

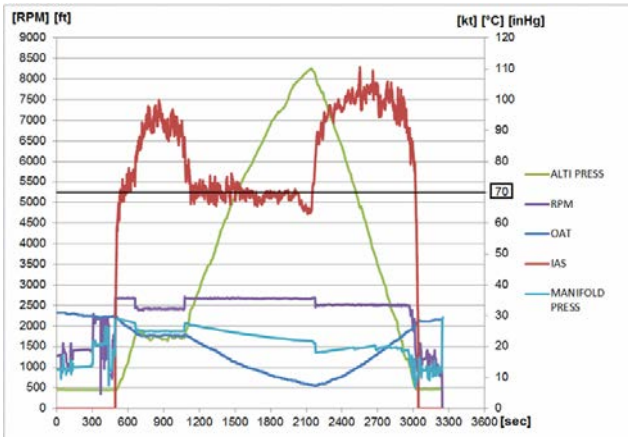

Figure 1. Flight parameters at 70 [kts]

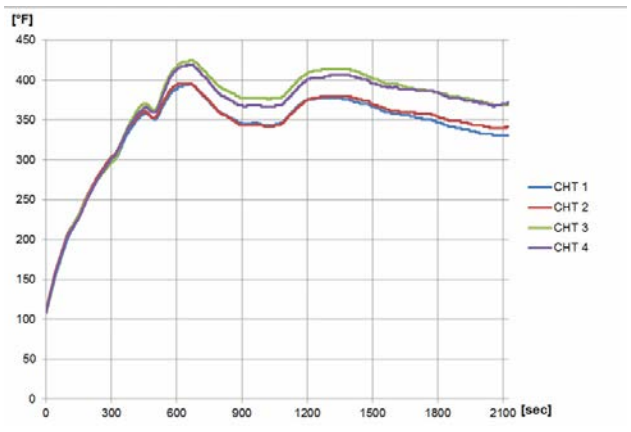

Figure 2. CHT at 70 [kts]

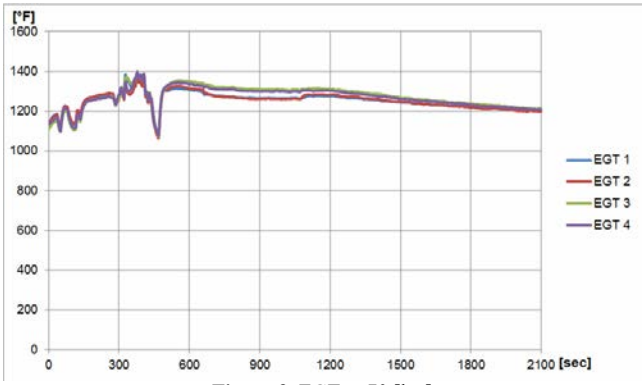

Figure 3. EGT at 70 [kts]

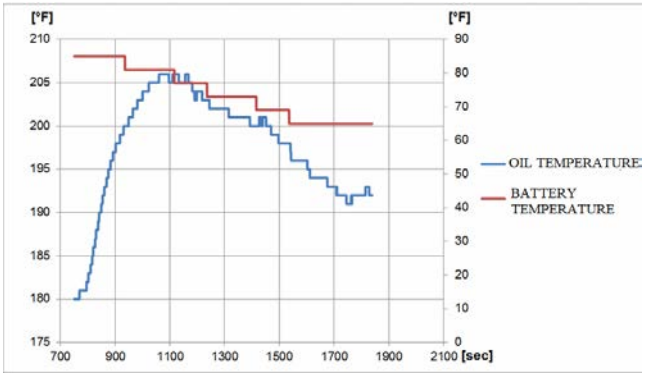

Figure 4. Oil and battery temperature at 70 [kts]

Figures 1-4 show that during the flight No. 62 at 70 kts, all requested parameters were within the limitations.

Considering that during the cooling test of the power unit, the maximum permissible temperature values were not reached at a speed of 70 kts on the path, the test was performed at a speed of 65 kts on the path in flight No. 205.

Flight 205 was performed on August 23, 2021 in weather conditions where the ambient temperature at sea level was 38°C, so there was no need to make a temperature correction. There was no presence of moisture during the flight.

The flight took place in the Pančevo airport area, under the ambient conditions given in the Table 4.

Table 4. Ambient conditions during flight No. 205

Time	Wind speed (kts)	Wind direction	Temperature (^{0}C)	Pressure (mbar)
14:50	4.0	110	39.0	1001.2
14:57 Take off	2.2	120	38.4	
15:00	3.1	120	38.1	
15:05	3.9	100	38.8	
15:10	4.1	110	39.0	
15:15	4.0	120	39.1	
15:20	3.7	140	39.5	
15:25	5.1	130	39.9	
15:30	3.8	120	40.8	
15:35	4.6	130	41.0	
15:39 Landing	5.2	140	41.4	1001.1

After the engine was started and warmed up to operating temperatures, takeoff and climb were conducted at maximum engine power and speed on the path of 65 and 60 kts. The climb was made at least 6 minutes after fluid and component temperature peaks were obtained or up to a maximum altitude of 10.500 ft.

Table 5. Cooling results with 65 [kts] on path

	MVP t. [°F]	Max allowed t. [°F]
Oil temperature [°F] 3900 ft Hp / 74°F OAT	230	235
CHT [°F] 3000 ft Hp / 68°F OAT	435	475
EGT [°F] 637 ft Hp / 94°F OAT	1341	1700
Battery temperature [°F] 3300 ft Hp / 81°F OAT	99	110

Since the air temperature on the day of the test was 38°C at sea level, then the Eq. (1) was not used.

The flight parameters during this flight are given in diagrams on the Fig.5.

The diagrams on Figures 6 to 8 show the graphical values of temperatures of fluids and components at a speed of 65 kts on the path for which the temperature limits are given in Table 5.

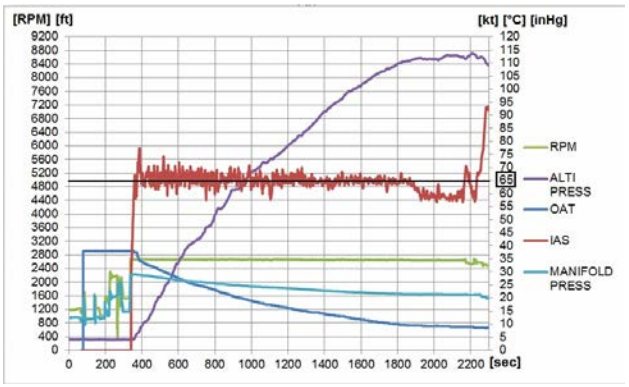

Figure 5. Flight parameters at 65 [kts]

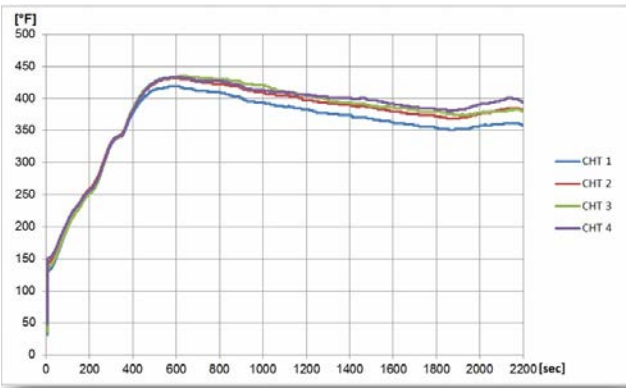

Figure 6. CHT at 65 [kts]

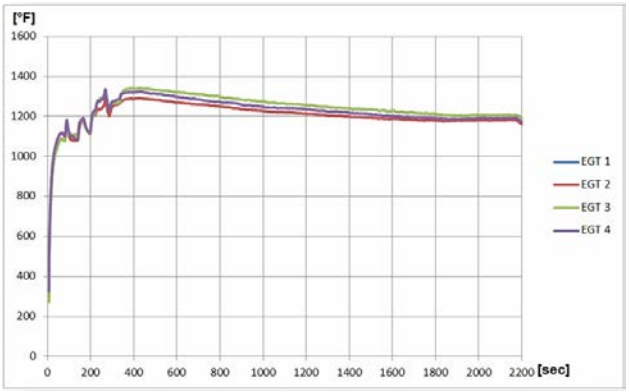

Figure 7. EGT at 65 [kts]

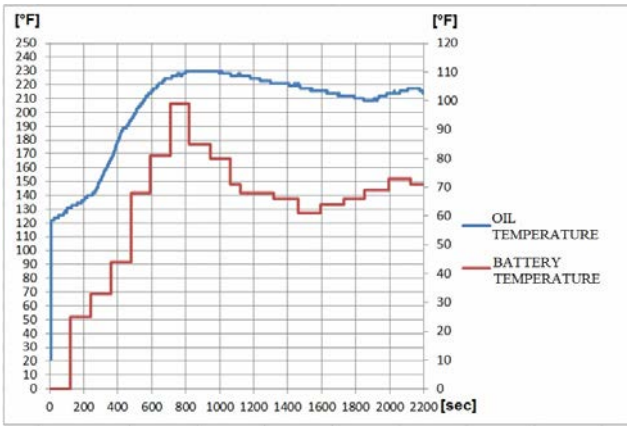

Figure 8. Oil and battery temperature at 65 [kts]

Figures 5-8 show that during the flight No. 205 at 65 kts, all requested parameters were within the limitations.

Considering that during the cooling test of the power unit, the maximum permissible temperature values were not reached at a speed of 65 kts on the path, the test was started at a speed of 60 kts on the path in the same flight.

Table 6. Cooling results with 60 [kts] on path

	MVP t. [°F]	Max allowed t. [°F]
Oil temperature [°F] 3600 ft Hp / 75°F OAT	230	235
CHT [°F] 3250 ft Hp / 78°F OAT	445	475
EGT [°F] 3450 ft Hp / 79°F OAT	1364	1700
Battery temperature [°F] 3528 ft Hp / 79°F OAT	105	110

Since the air temperature on the day of the test was 38°C at sea level, then the Eq. (1) was not used.

The flight parameters during this flight are given in diagrams on the Fig.9.

The diagrams on Figures 10 to 12 show graphical values of temperatures of fluids and components at a speed of 60 kts on a path for which temperature limits are given in Table 6.

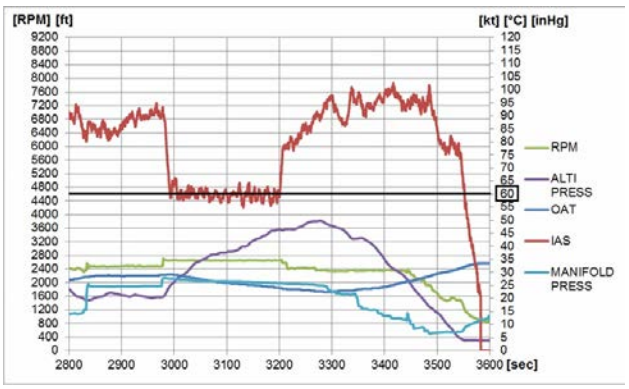

Figure 9. Flight parameters resulst at 60 [kts]

Figures 9-12 show that during the flight No. 205 at 60 kts, all requested parameters were within the limitations.

The "Lycoming Operational & Installation Manual" states that during takeoff, climb and maximum cruise speed the mixture control should be "RICH", so we did not "lean" the mixture as required in AMC 23.1047 (a)(8) (iii).

Since the engine manufacturer stated that the maximum power is the same as the maximum continuous power, then the climb was made at maximum power continuously for more than 6 minutes, not as specified in AMC 23.1047 (a)(8)(ii) & (iii).

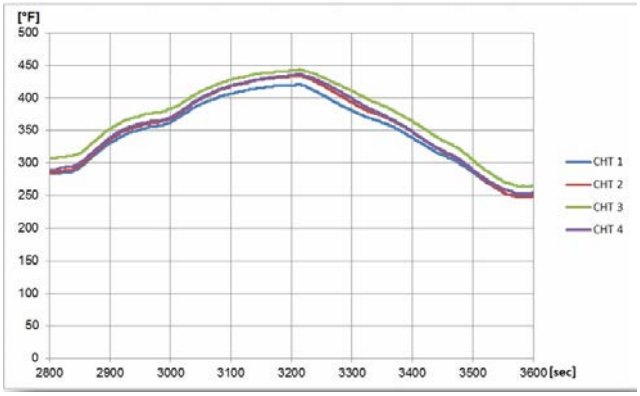

Figure 10. CHT at 60 [kts]

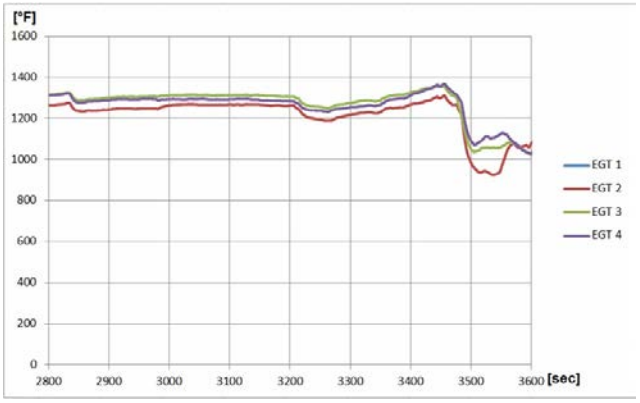

Figure 11. CHT at 60 [kts]

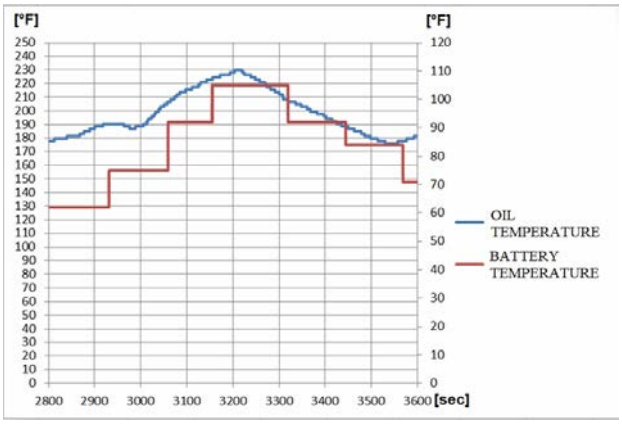

Figure 12. Oil and battery temperature at 60 [kts]

The power unit cooling test was performed with a critical amount of oil of 4 Qts, at maximum power and with a speed on the path of 70, 65 and 60 kts.

Testing of power unit cooling with a speed of 70 and 65 kts on path met the certification requirements because the maximum values of the component and fluid temperatures were not exceeded.

Power unit cooling test at 60 kts on path was aborted at 3250 ft because No. 3 cylinder head temperature reached the maximum recommended temperature of 435°F prescribed by Lycoming for extended engine life and tended to further growth.

The recommended minimum speed on the path in the climbing phase with a minimum amount of oil in the engine and an ambient temperature of 38°C is 65 kts.

Conclusion

Utva Aviation Industry is approved by Civil Aviation Directorate as a Design and Production organization.

Designing, producing and testing the aircraft at one place made the certification process of Sova easier.

R&D team considered this certification process as a chance to prove that Serbian industry is still competing in civil aviation with the world-known companies.

During these flight tests, compliance with paragraphs CS 23.1041, CS 23.1043 and CS 23.1047 was shown. Speed of 65 kts was defined as recommended minimum climbing speed with specified CS 23 requirements.

References

[1] Certification Specifications for Normal, Utility, Aerobatic and Commuter Category Aeroplanes CS 23, Amendment 3 Book 1

[2] Certification Specifications for Normal, Utility, Aerobatic and Commuter Category Aeroplanes CS 23, Amendment 3 Book 2

[3] RENDULIĆ,Z.: Mehanika leta

[4] MILOŠEVIĆ,V.: Ispitivanje aviona u letu

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Letna ispitivanja hlađenja pogonske grupe

Letna ispitivanja su neophdna u procesu pokazivanja usaglašenosti aviona sa specifičnim projektnim zahtevima. Utva Avio industrija je izvela brojna letna ispitivanja aviona Sova da bi dokazala njegovu bezbednost. Pored projektovanja, strukture, performansi i opreme aviona, bilo je neophodno pokazati i usaglašenost pogonske grupe.
U ovom radu, prikazana je analiza letnih ispitivanja hlađenja pogonske grupe u najkritičnijim slučajevima penjanja pri maksi Letna ispitivanja, hlađenje pogonske grupe, kritični uslovi, minimalna brzina, analiza rezultata ispitivanjamalnoj spoljnoj temepraturi za koju je trebalo pokazati usaglašenost. Prezentovani su rezultati letnih ispitivanja sa definisanom minimalnom brzinom za zadate uslove, čime je dokazano da naš četvorosed ispunjava sve zahteve u svojoj kategoriji.

Ključne reči: **Letna ispitivanja, hlađenje pogonske grupe, kritični uslovi, minimalna brzina, analiza rezultata ispitivanja**