Ignition systems for small engines

Ignition systems

- Purpose - igniting the fuel-air mixture in the combustion chamber by creating high temperature spots.

Ignition system	example	principle
Pyrotechnic igniter (PY)		Release of chemical energy stored in solid propellants
Electrical igniter (HE)		Electric beam

Electric igniter

- Multiple use
- Ignition protection – relight
  - Over-rich fuel-air ratio
  - A change in airflow at the compressor inlet
  - Ingestion of a bird
  - Ingestion of ice broken loose at the engine inlet
- Unsteady flame
- Redundancy

Pyrotechnic igniter

- Single use
- Electrically initiated burning pyrotechnic torches
- Burn duration: 2-10 sec
- Typically an end-burning charge produces a flow of hot gas and incandescent particles
- High energy density

Demands of ignition systems

- Selection of an ignition system depends on the requirements of the engine's operation profile:
  - Altitude start
  - Restart
  - Weight
  - Size
  - Reliability
  - .....

Design Trade-offs

- safety – reliability
- Weight/size – redundancy
- Reliability - redundancy

Case study

- Our ignition system consist of 2 pyrotechnic igniters to increase the ignition process reliability.
- Safety scenario – one of the pyro igniters wasn't initiated during the ignition process.
  - At the beginning this scenario was considered a success, but after additional consideration it was assumed that it will cause a failure and damage the engine.
  - This scenario was unaccepted by the user, so a test was needed to conform the potential damage.

Case study – Cont.

- A test was conducted which confirmed this failure mode – one igniter was electrically connected and the other one wasn't.
- The igniter burst and caused damage to the turbine's nozzle.
- The cause of the failure is an uncontrolled detonation.

Probability to failure

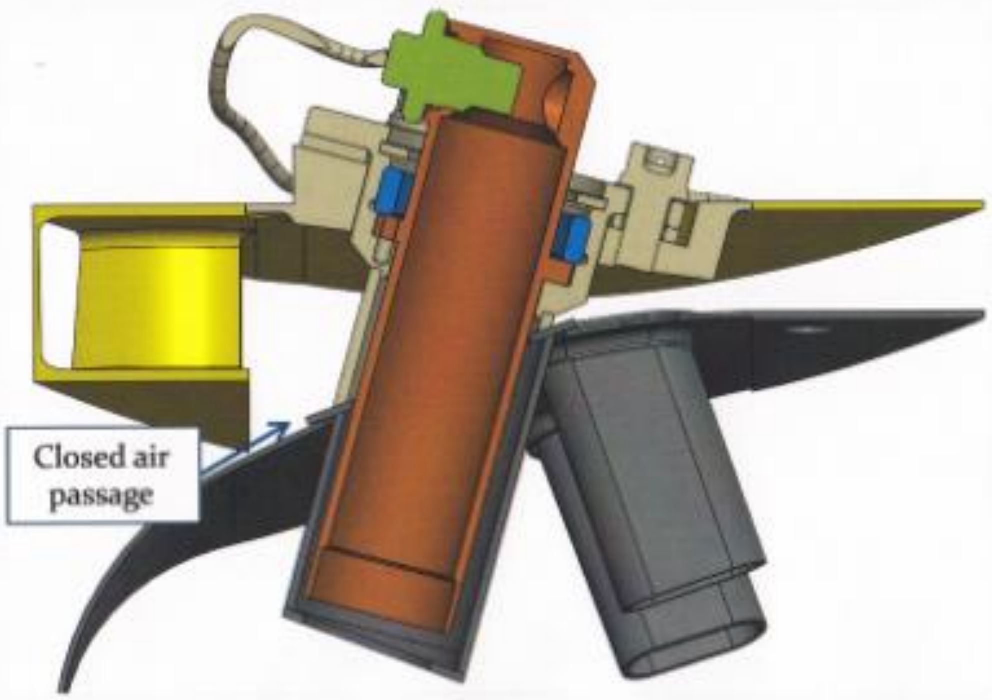
Configuration	Scenario	Probability
2 igniters	success	0.998
	1 success , 1 failure**	0.001999
	*failure	0.000001
1 igniter	Success	0.999
	* failure	0.001

- * The two were considered success, the probability of success in 2 igniters was higher then in 1 igniter, and the probability to failure in 2 igniters was 10^{-3} rather then 10^{-6} in 1 igniter.
- **When "1 success , 1 failure" was declared as a failure the result was exactly opposite.
- Today only one igniter is used instead of two –therefore paying in redundancy for reliability

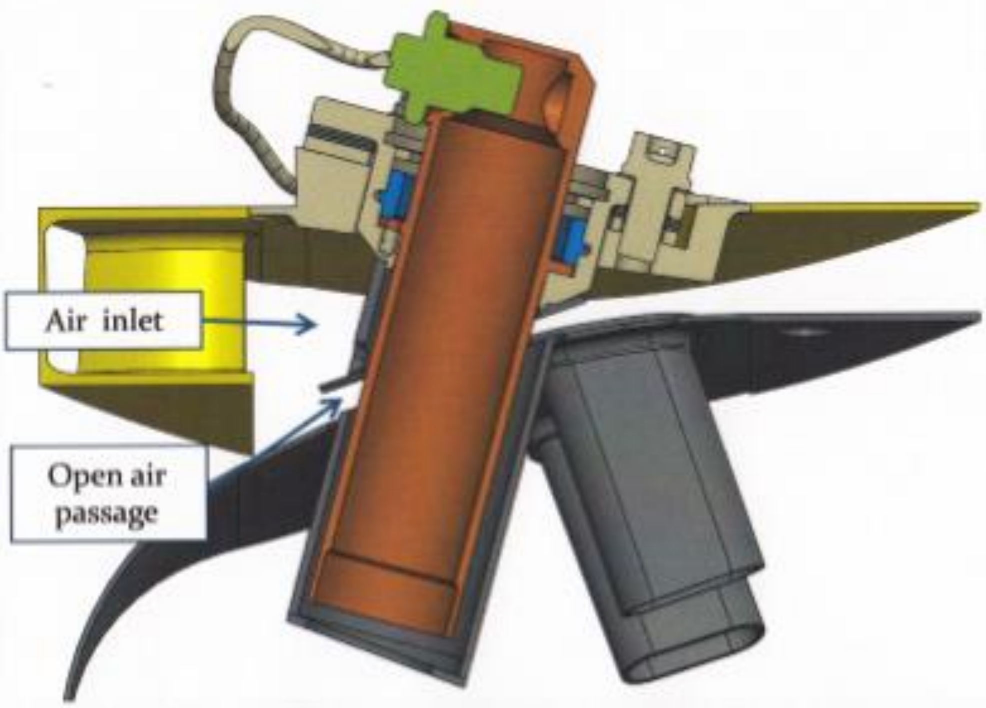
Possible solutions

- Two different types of solutions were suggested:
  - Outer solution – to lower the air flow temperature surrounding the igniter.
  - Internal solution – minimum change in the igniter, so it won't physically damage the engine if it will initiated by external heat and have the minimal performance parameters.

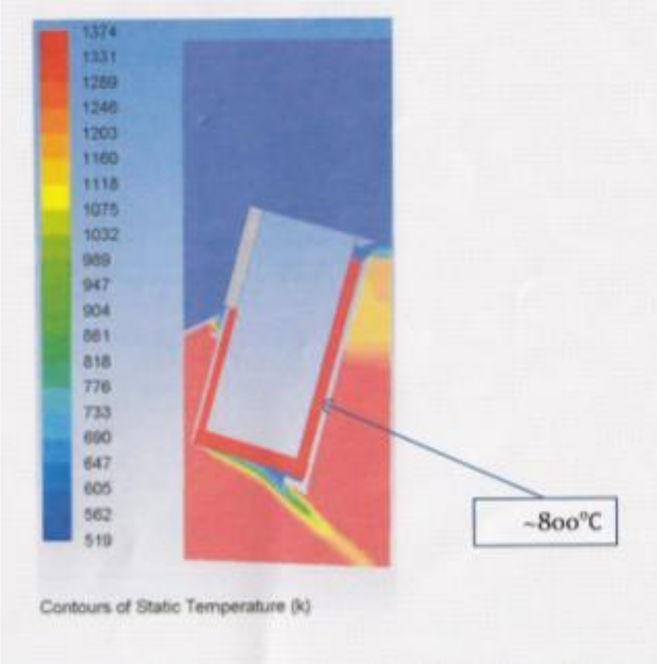
The "cup" original design

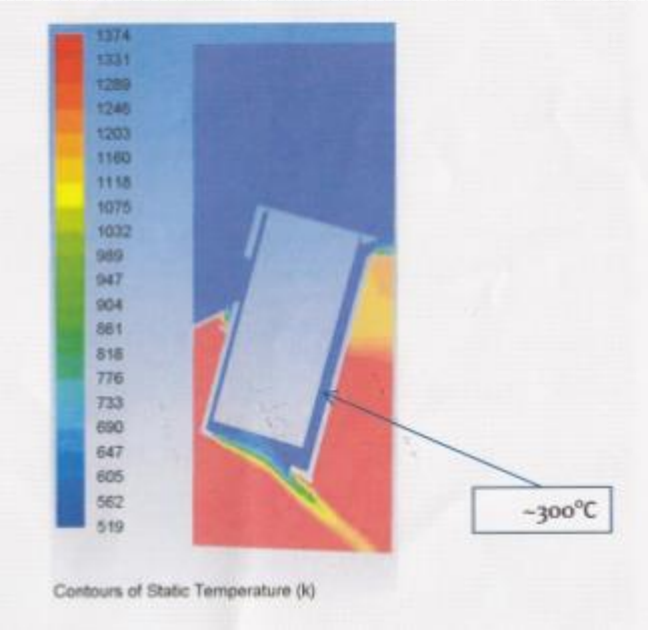


The "cup" new design

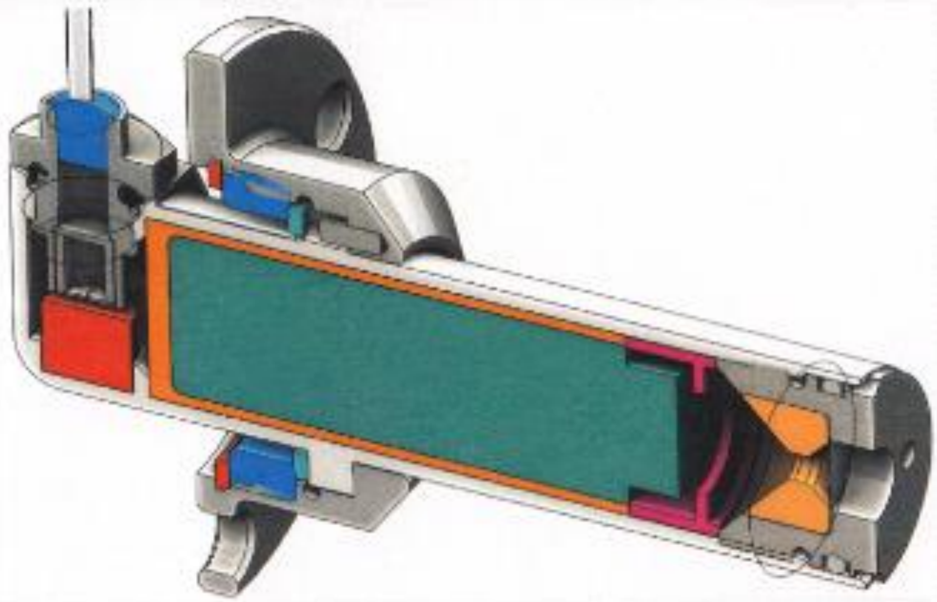


Temperature distribution





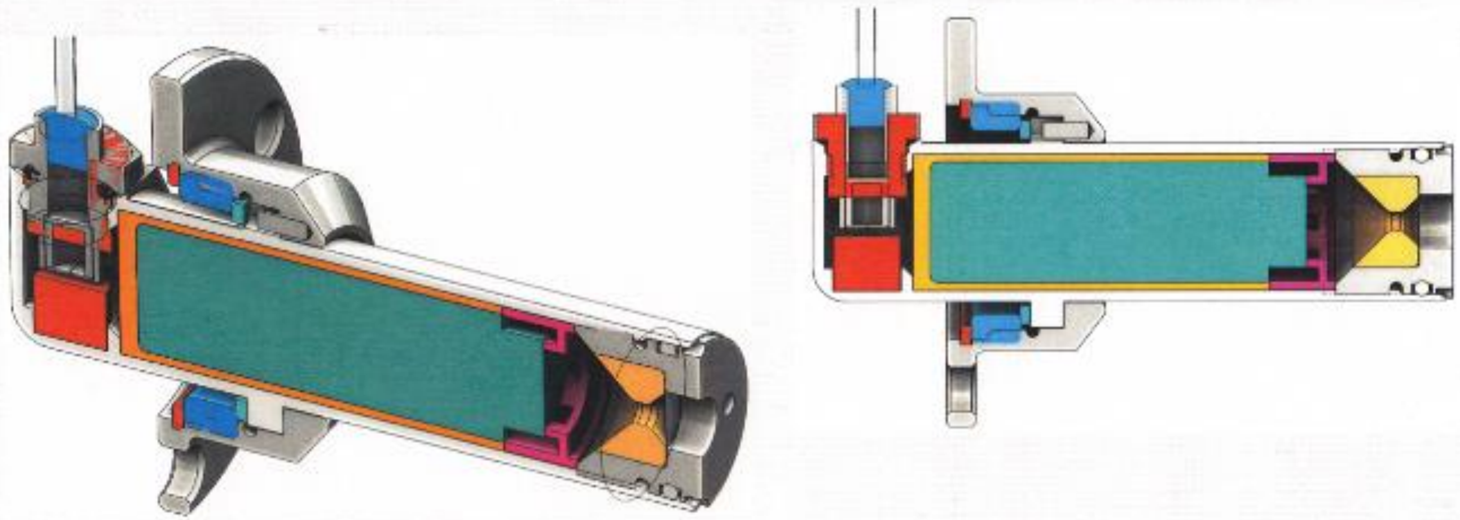
The igniter original design



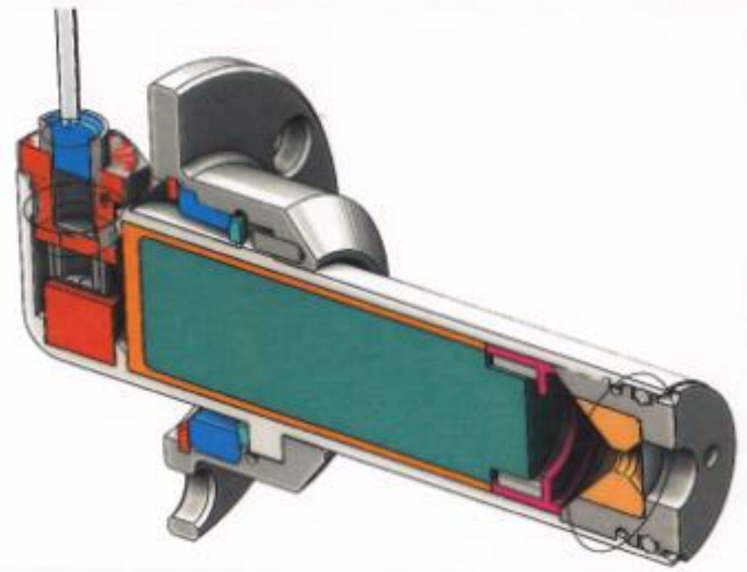
The internal solution

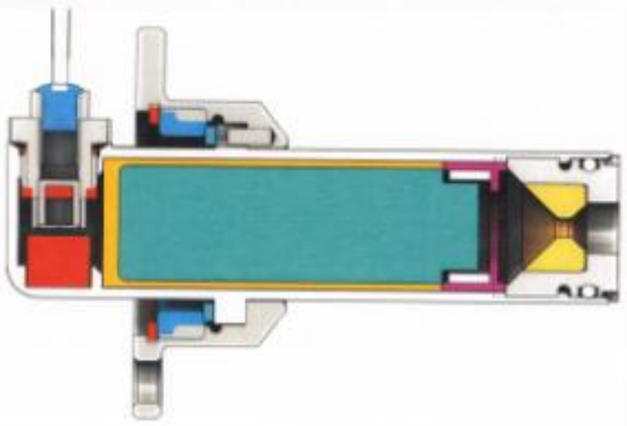
- The mechanism behind the ignition of the pyro igniter is by heat transfer convection.
- The demand from the new igniter design - at any heat profile, the burning of the solid propellant will begin from the front of the propellant.

Configuration 1 – “Flame holder”

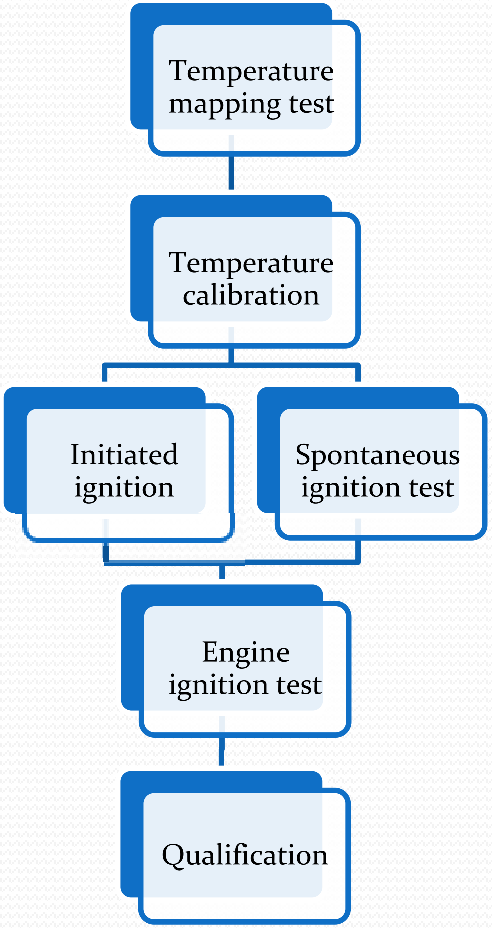


Configuration 2 – "Fuse"



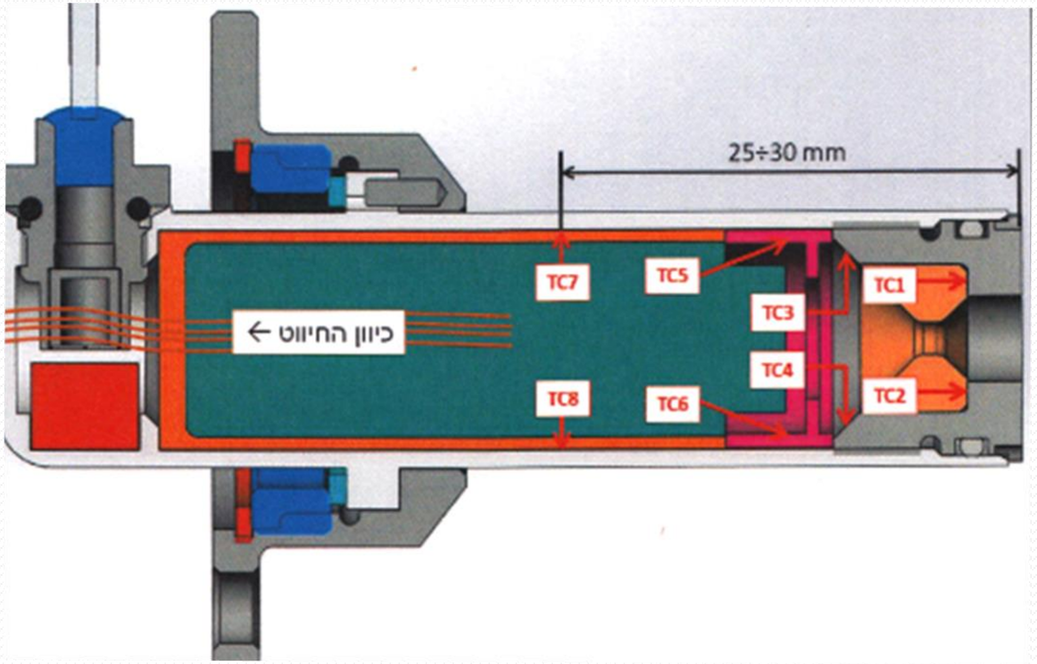


Test plan

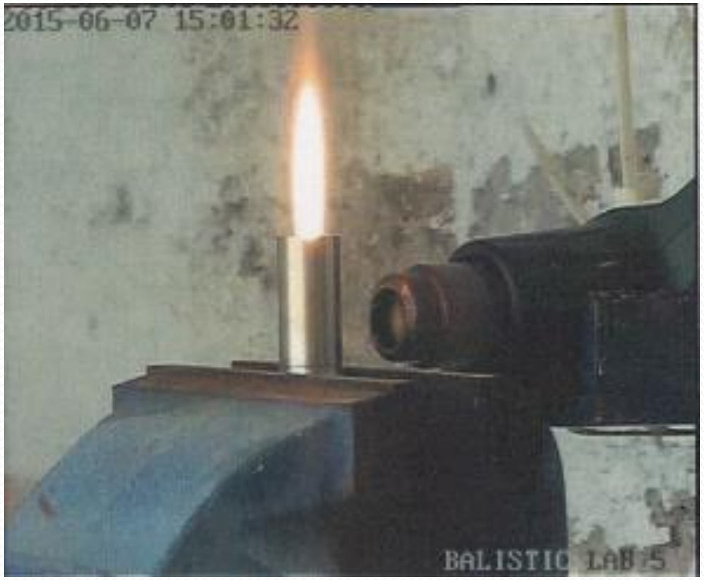


Temperature mapping test
Temperature calibration
Initiated ignition
Spontaneous ignition test
Engine ignition test
Qualification

Temperature mapping test



Spontaneous ignition test



Summary

- There are 2 types of igniters which are used in small jet engines – electric and pyrotechnic.
- The use of multiple components could come on the expense of the reliability.
- Two solutions were presented:
  - The outer solution – was successfully implemented in the engine.
  - The internal solution - a test was conducted on the “flame holder” configuration and it bursted. The next test will be conducted on the “fuse” configuration or a combination of them both.