Thermografieforum Eugendorf
7.-8. September 2012

THEORETICAL, EXPERIMENTAL AND NUMERICAL ANALYSIS OF THE NON ISOTHERMAL TURBULENT AIR FLOW

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THEORETICAL, EXPERIMENTAL AND NUMERICAL ANALYSIS OF THE NON ISOTHERMAL TURBULENT AIR FLOW

- **The goal and hypothesis of the research**

- As known from previous presentation on Thermografieforum our group is working on developing the thermographic method for determination the air flow pattern from different types of outlets.
- The goal of this work was to obtain the correlation between theory and practice as well as to prove it by means of numerical method. In this work the non isothermal air flow from two types of rectangle outlets has been examined.

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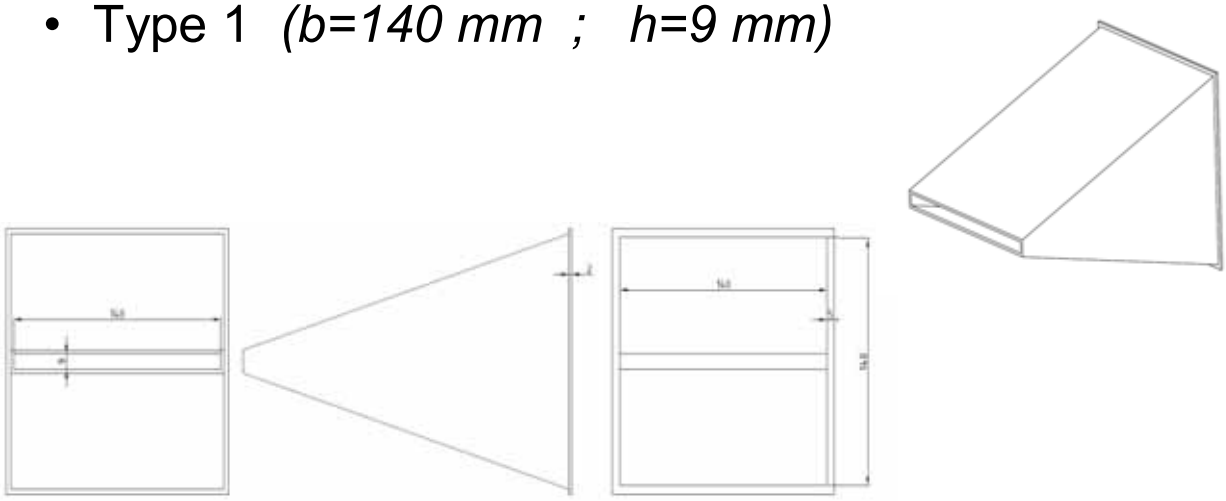
- The hypothesis was that by means of thermography it is possible to obtain data about; temperatures, but not about velocities.
- The idea was to find correlation between measured temperatures and belonging velocities and to confirm the results obtained by empirical relations from relevant literature.
- The research performed is a contribution for better understanding the flow patterns of non isothermal air jets living the outlets which are placed horizontal.

THEORETICAL, EXPERIMENTAL AND NUMERICAL ANALYSIS OF THE NON ISOTHERMAL TURBULENT AIR FLOW

- Dimensions of rectangular outlets:
- Type 1 *(b=140 mm ; h=9 mm)*



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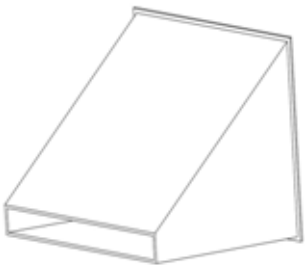
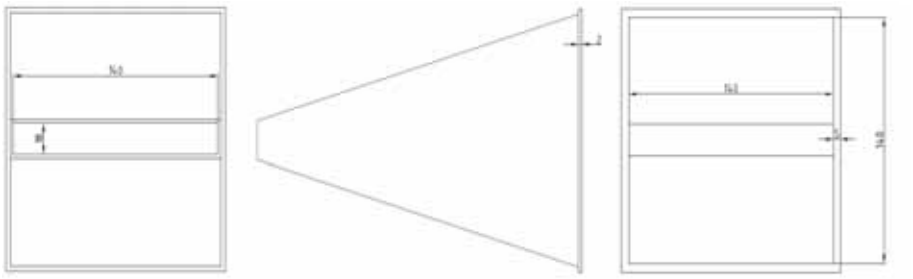
- Type 2 *(b=140 mm ; h=18 mm)*





THEORETICAL, EXPERIMENTAL AND NUMERICAL ANALYSIS OF THE NON ISOTHERMAL TURBULENT AIR FLOW

- **Methods used for analysis of the non isothermal air flow**
- Given problem of turbulent flow can be described by partial differential equations which do not have common solution. Because the flow is stochastic it could not be described analytical.
- In theoretical approach the quasi empirical equations given by German researcher B. Regenscheid has been used.
- The experiments and analysis was done in the range of outlet velocities from w_0= *3 to 10 m/s* .

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Equations for non isothermal air flow

- Central velocity:

$$\frac{w_m}{w_0} = K\sqrt{\frac{Ar}{m}(2{,}83\sqrt{\frac{x}{x_0}})}$$

- where

$$K = \sqrt{\frac{1}{m}} \qquad \text{constant}$$

$$Ar = \frac{g * \Delta T_0 * h}{T_0 * w_0^{\,2}} \qquad \text{Archimedes number}$$

m – mixing factor

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- Induction:

$$\frac{V_x}{V_0} = 2\frac{x}{x_0}\sqrt{\frac{b}{h}}$$

$$\frac{V_x}{V_0} = \frac{t_0 - t_{ok}}{t_{m,x} - t_{ok}}$$

- Average temperature in central line:

$$\frac{t_{m,x} - t_{ok}}{t_0 - t_{ok}} = \frac{3}{4} * \frac{T_u}{T_0}\sqrt{\frac{x}{x_0}} * \sqrt{\frac{1}{3} * \frac{(4 - \frac{1}{\lambda_0})}{1 + (\frac{x}{x_0} - 1)\frac{1}{\lambda_0}}}$$

$$\lambda_0 = \frac{b}{h} \qquad \text{side ratio}$$

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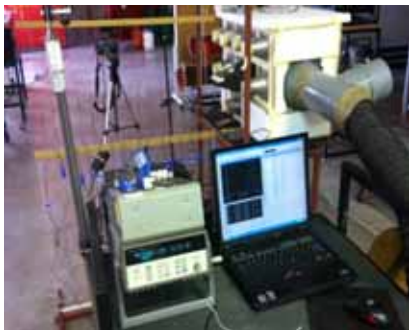
- Experimental rig



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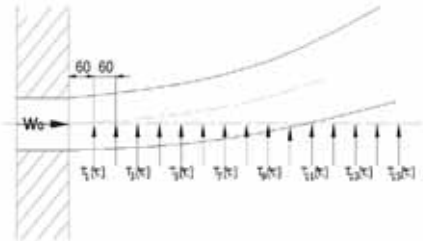
- **Temperature and velocity measurement:**
- Thermocouples and anemometer (Thermal probe)

Thermocouples net and position



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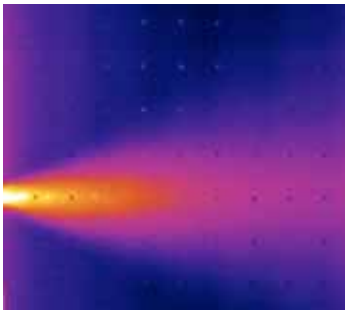
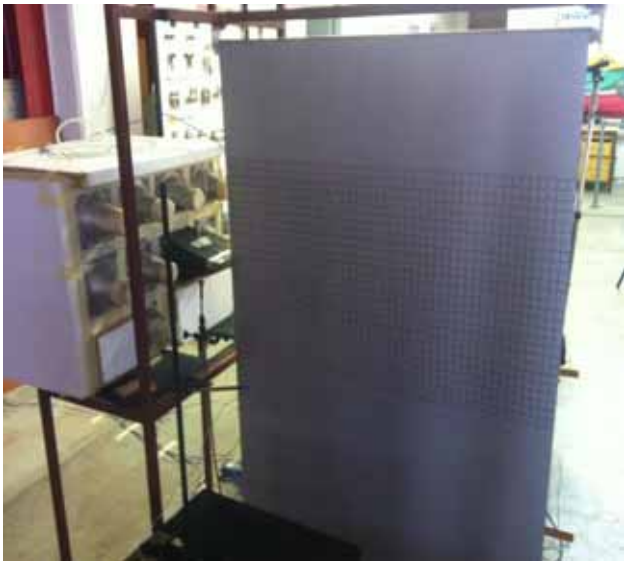
- Thermographic measurement (IR camera Flir 2000 SC)

Curtain *(ε=0,97)* with net and pointers for recording thermograms. Camera distance *L=1,5 m*





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- **Numerical simulation:**
- By discretization of partial differential equations using finite volume method the certain number of linear algebraic equations can be obtained. For solving this equations the iterative method should be apply.
- The problem was solved as two dimensional using FLUENT 12.0.6.
- First step was generation of control volume net in GAMBIT.

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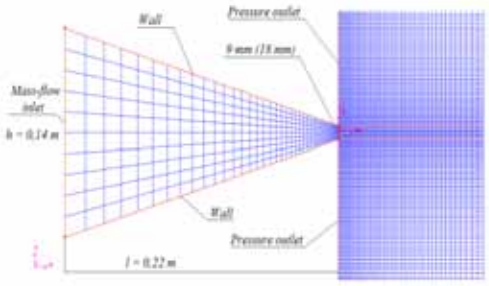
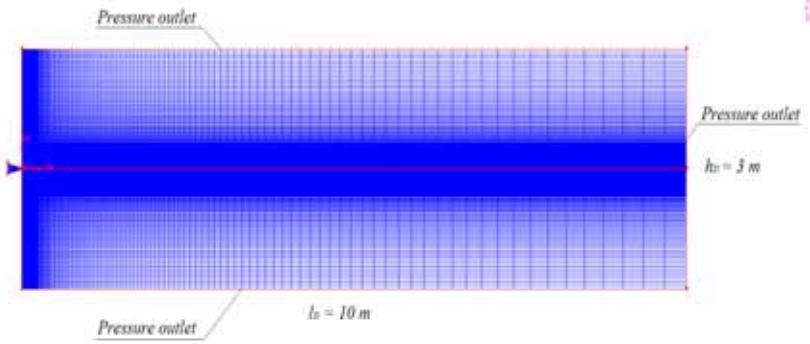
- The domain is 10 m long and 3 m high. For the outlet type 1 the net has 54650 elements and for type 2 it has 55940 elements.

Discretization at outlet





Discretization of domain

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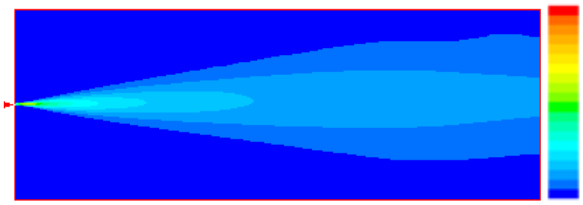
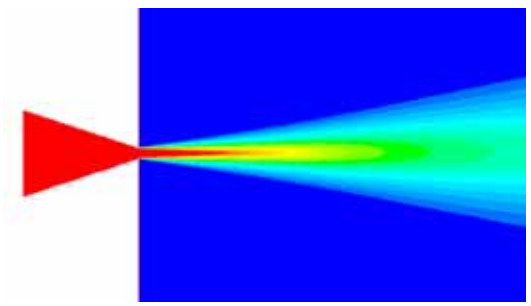


Temperature profile in domain

W_0 =10 m/s, ϑp=25,8°C, $\vartheta 0$=33,9°C



Profile in the region near outlet obtained with the same parameters

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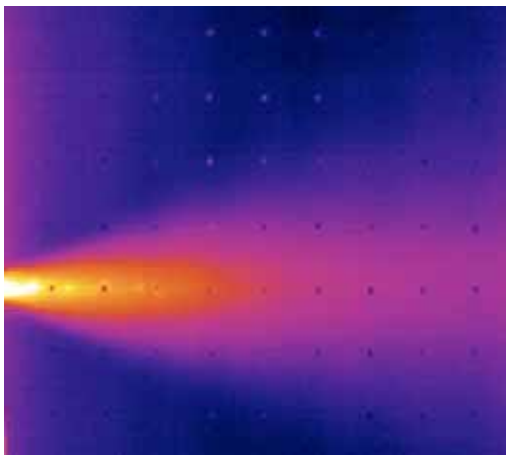

Fig.1 Thermogram of the air flow

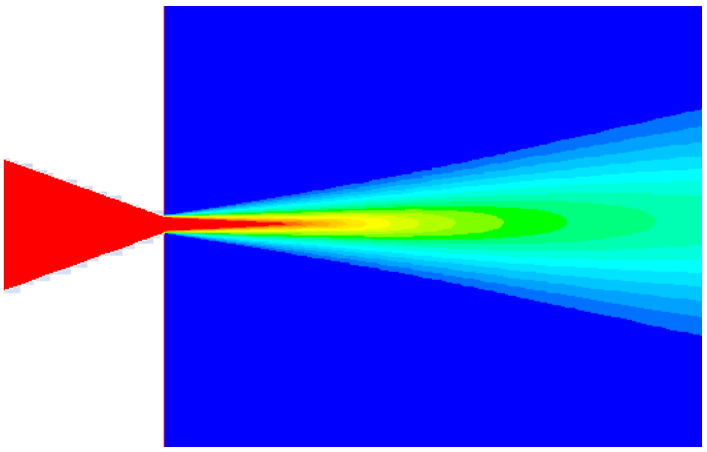

Fig 2. Numerically obtained flow

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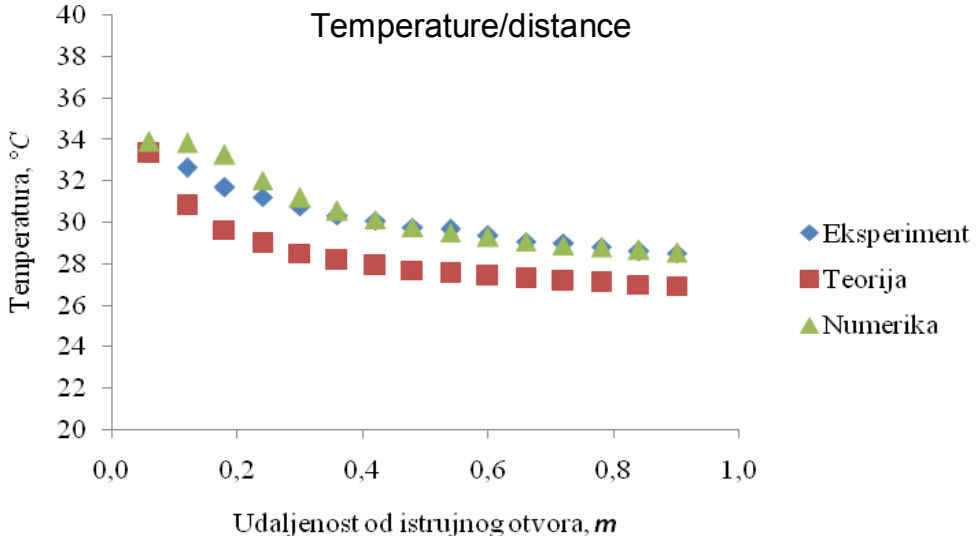
- Results:



W_0 =10 m/s, t_0= 33,92 °C tp=25,82 °C, dt=8,1 °C temperatures

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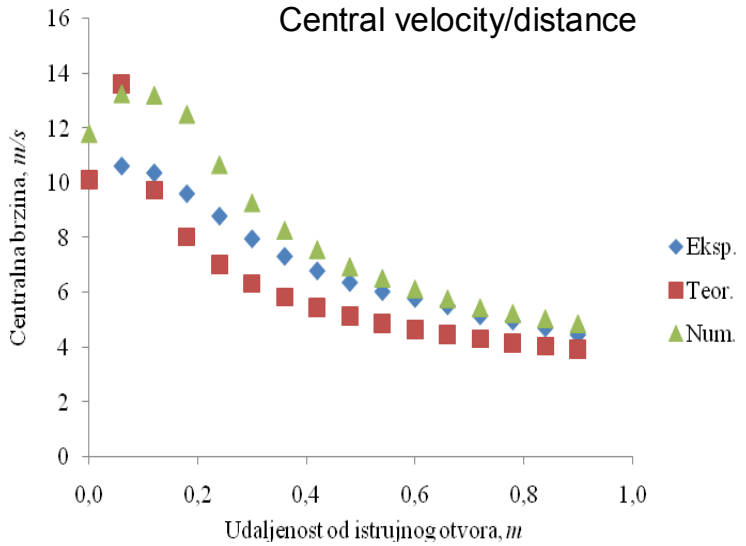

W_0 =10 m/s, t_0= 33,92 °C tp=25,82 °C, dt=8,1 °C
velocities

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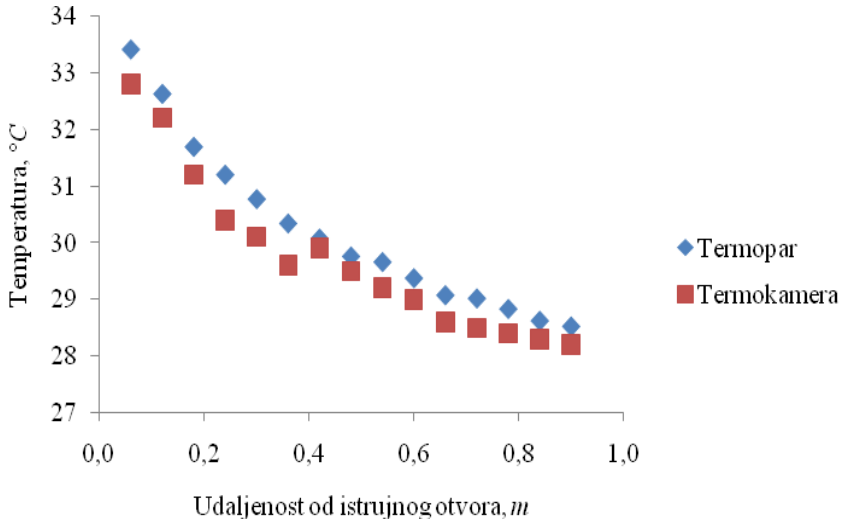

Comparison of temperatures obtained by IR camera and by thermocouples
W_0 =10 m/s, t_0= 33,92 °C tp=25,82 °C, dt=8,1 °C
temperatures

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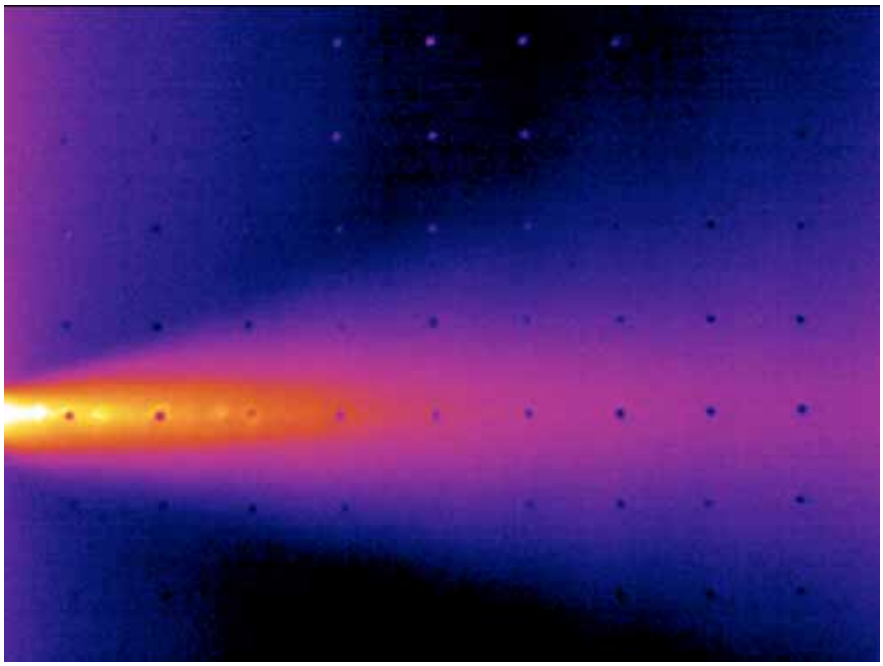

Thermogram obtained with velocity w_0=10 m/s

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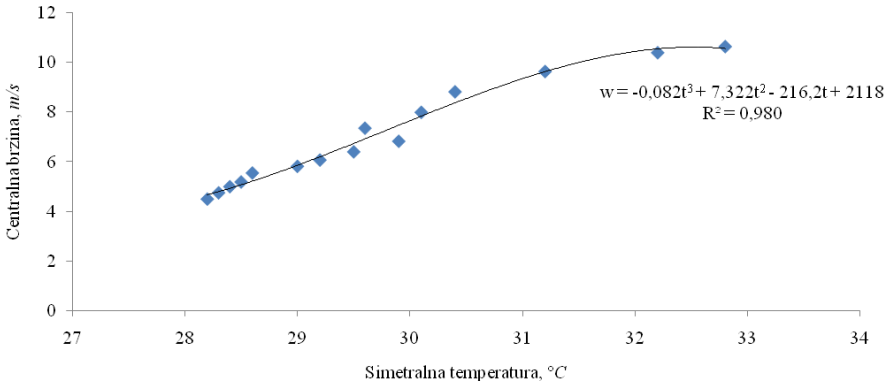

Velocities versus temperature. Polinom in the range of 0 to 0,9 m

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- **Conclusion**
- From the obtained results it can be concluded:

For higher velocities the calculation should be performed with longer core length (lower mixing factor).

The smaller high of the outlet and constant length results with smaller velocities on the equivalent distances.

Vena contracta is much more evident for outlets with greater high.

Analysis by IR thermography gives the satisfied results.

THEORETICAL, EXPERIMENTAL AND NUMERICAL ANALYSIS OF THE NON ISOTHERMAL TURBULENT AIR FLOW

- *The method is useful in development of different types of air outlets.*
- *The method is cheap, simple and quick.*
- *The procedure for numerical approach to obtain the air flow parameters is presented.*
- *Applied Realizable k-ε model of turbulence agree very good for distances greater of 0,3 m.*

- *The results obtained in this work gives a good base for development of new types of outlets for HVAC systems and also can be used in examination of existing systems.*

THEORETICAL, EXPERIMENTAL AND NUMERICAL ANALYSIS OF THE NON ISOTHERMAL TURBULENT AIR FLOW

- *This project was done by the group of students from the Faculty of mechanical engineering and naval architecture Zagreb.*
- Students: Alen Cukrov, Tomislav Horvat, Tin Vrandečić
- Mentor: prof.dr.sc. Srećko Švaić dipl.ing.

- *The students got the Rector award for this work.*

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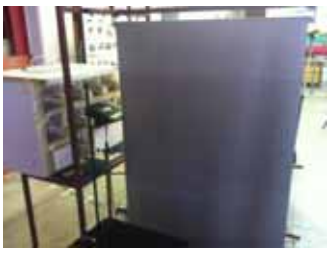
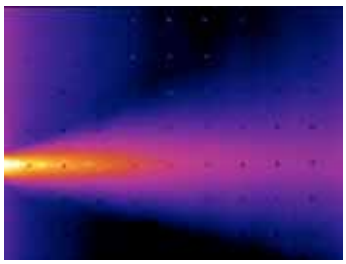

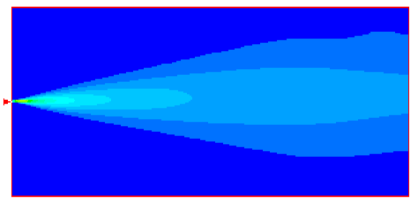

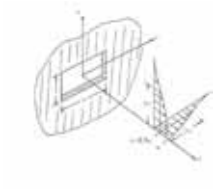

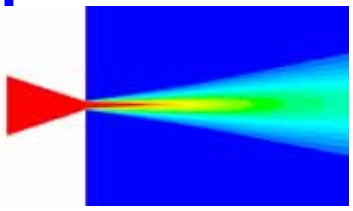

Thank you