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EXPERIMENTAL INVESTIGATION OF HEATED NONBUOYANT TURBULENT JET IN CROSS-STREAM: TEMPERATURE FIELD

M. Bojić & Z. Zarić

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1. Introduction

The deflected jet is often observed in a nature. Smoke issuing chimney into the atmosphere — the ordinary physical situation that motivated this study — is an example. Also the flow field beneath a V/STOL aircraft greatly resembles a jet in a cross-stream. Further example of deflected jet is film cooling by the normal injection of coolant through discrete holes in a wall.

Turbulent round jet in cross-stream is shown in Fig. 1. The cross-stream feeling the jet as an obstacle deflects it. As result of such of an interaction one senses the free jet structure (jet part of deflected jet), two bound vortices and the wake. The

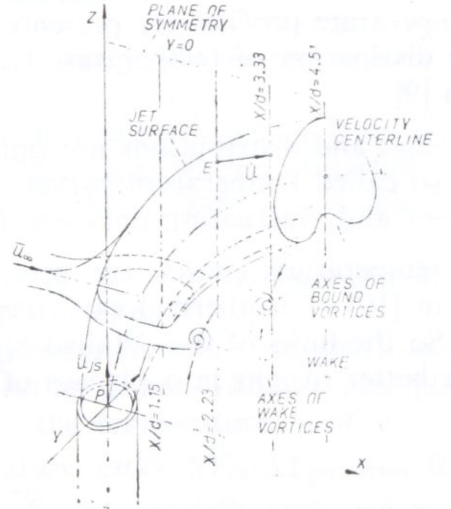

Fig. 1 Flow description and coordinates

cross-section of jet part is deformed by the cross-stream into kidney shape. The entrainment of the cross-stream into the jet makes the jet expanding and lossing its momentum. The vortices are formed on the lee side of the jet and the wake downstream of the jet with characteristic wake vortices structure.

There are a lot of experimental data on heated nonbuoyant jet in cross-flow [1, 2, 3, 4, 5, 6, 7]. For the jet to free-stream momentum ratio $J_s = \bar{\rho}_{js}\bar{u}_{js}^2/(\bar{\rho}_\infty \bar{u}_\infty^2)$ greater than 5 of this flow the temperature fluctuations were not measured but only mean velocities and mean temperatures and flow visuelisation performed. Without temperature fluctuation data available, so far, the investigations of the mutual interaction of the mean and fluctuating temperatures in the flow field could not be done. Furthermore as the detailed temperature field was not accessible the influences of the momentum field to temperature field were revealed comparing the temperature centerline evolvement to the velocity centerline development [3,4]. But these two centerline research gave the poor insight of this complex flows physics contrary to the case when the development curves of the temperature turbulence data are included in such a comparison as this is done in the present study. Here, $\bar{\rho}_{js}$ is the mean density of the jet at its exit, $\bar{u}_{js}$ the mean velocity of the jet at its exit, $\bar{\rho}_\infty$ the mean density of the cross-stream and $\bar{u}_\infty$ the mean velocity of the cross--stream.

The study presented here does not focus on the influences of changes of density, viscosity and temperature differences of the jet and cross-stream on the flow development as it was done before [1, 4, 5, 8]. Instead, this study is performed for only one set of similarity parameters: J_s and density ratio $\rho_{js}^* = \bar{\rho}_{js}/\bar{\rho}_\infty$ in order the concentrated research to be conducted of a physical picture of temperature field via different kinds of temperature data.

The characteristics of the flow confinement, and the exit velocity and temperature profiles of the jet make the present study to be unique. The flow confinement is characterized by the protrusion of the jet exit element into the cross-stream. The jet is issuing in the cross-flow from the pipe i. e. the jet exit velocity profile is not uniform. As this pipe is not thermally insulated, the jet temperature profile is also not uniform.

To obtain the data base for such study, here, not only mean temperature profiles, but fluctuating temperature profiles are presented: the intensity of temperature fluctuations and the dissipation of temperature fluctuations. Some of these results can be found also in [9].

On the basis of these data and distributions not only the temperature centerline is obtained but rather so called temperature curves. Via these curves the mutual interactions of the mean and fluctuating data are investigated.

The evolvements of temperature curves are compared to evolvements of momentum curves defined in [10] of isothermal experiment in [11] with the same J_s as J_s in this experiment. So the links of the detailed temperature and mometum fields are disclosed and the better insight into physics of such complex flow field is obtained.

2. Experimental technique

2.1. Experimental apparatus. The free (cross) stream was provided by the open circuit subsonic wind tunnel located at "Boris Kidrič" Institute at Belgrade, Yugoslavia. This tunnel is fully described in [10]. The test section was $b = 0.5$ m square, and 1.5 m long and placed at the suction side of the tunnel.

The mean velocity of the free-stream in the test section was maintained at $\bar{u}_\infty = 2.96$m/s for all measurements. The Reynolds number of free-stream was $Re = u_\infty b/\nu_\infty = 97700$ so the cross-stream was surely turbulent. The flow had the low turbulence intensity of 0.5%. Here ν_∞ is the kinematic viscosity of the cross-stream.

The jet flow was supplied by the centrifugal fan through the plenum chamber, nozzles, honey comb and screens to the exit steel pipe (Fig. 2). This pipe had its outer diameter of 25 mm, its inner diameter of d=23 mm and its

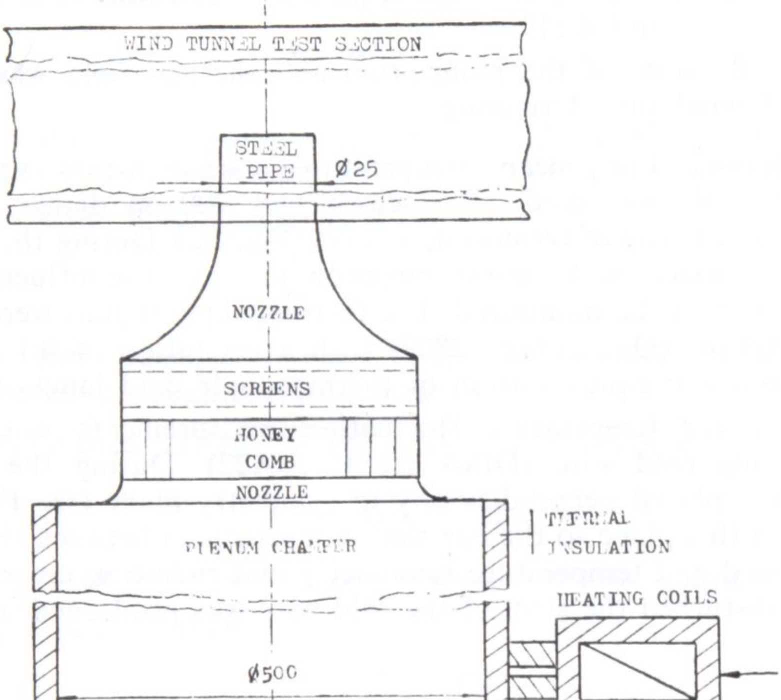

Fig. 2 Jet flow apparatus

lenght of 7.83 d. The pipe protruded by 5.65 d from the floor of the test section into the cross-wind. From this pipe, whose centerline was halfway between the side walls of the test section, the round jet was injected perpendicularly to the cross-stream (see Fig. 1).

The velocity profile of the jet at its exit cross-section was turbulent (not fully developed) with its shape factor of β=1.052.

Before entering the plenum chamber, the jet flow was heated by the heating coils of 2 kW mahimum heating power. The exit pipe placed at the test section was not thermally insulated so the temperature profile at jet exit cross-section was not uniform. The temperature ratio $\overline{\Delta T_{js}}/\overline{\Delta T_{jm}}$ was 0.834. Here $\overline{\Delta T_{js}} = \overline{T_{js}} - \overline{T_\infty}$ and $\overline{T_{jm}} = \overline{T_{jm}} - \overline{T_\infty}$ where $\overline{T_{js}}$ the spatially averaged mean temperature at the jet exit cross-section, $\overline{T_\infty}$ the mean temperature of the cross-stream and $\overline{T_{jm}}$ maximum mean temperature of the jet.

The jet exit Reynolds number was $Re_j = \bar{u}_{js}\, d/\nu_j = 15541$ where ν_j is the kinematic viscosity of the jet at its exit cross-section. Pratte and Baines [12] found that nonboyant deflected jet is undoubtely turbulent for Re_j of the order of 1000 and higher.

The jet to free-stream momentum ratio was $J_s=15$ and their temperature difference was $\Delta T_{js}=28.2K$.

The Froude number of this flow, defined as

$$F_d=\bar{u}_{js}\sqrt{\bar{\rho}_{js}}/(gd\mid\bar{\rho}-\bar{\rho}_{js}\mid)^{0.5},$$

was 85.5. Here, g is the gravitational acceleration. The analyses of the order of Fd — number term of Z-axis Navier Stokes equation showed (11) that this bouyancy term is 0.25% of all other terms of this equation.

The measurements were performed in the plane of symmetry $Y=0$ in directions $X/d=1.15$; 2.23; 3.33 and 4.51.

Neraly steady state of the momentum and thermal field was reached after several hours of wind tunnel running.

2.2. Instrumentation. For mean temperature measurements the copper-constantan thermocouple was used. The sensor was 200 μm diameter bare sphere junction placed on the top of termocouple stem (Fig. 3.a). During the measurements this stem was pasitioned in X=const. direction in order the influence of the stem to flow development to be minimized. The thermocouple signals were read through termocouple amplifier (Omega type 2809) with a resolution of 0.1 K. This amplifier had the electronic compensation of thermocouple cold junction.

The sensor for temperature fluctuation measurements was 5 μm — diam 1.25 — mm — long cold wire (DISA model 55A22). During the measurements the cold wire was placed perpendicularly to symmetry plane (see Fig. 3.b) i. e. to velocity vector in this plane so the convection mechanizm between the wire and the flow was enhanced and temperature asymmetry and radiation errors reduced. The flow not to be disturbed the stem of the cold wire was positioned in X=const. direction.

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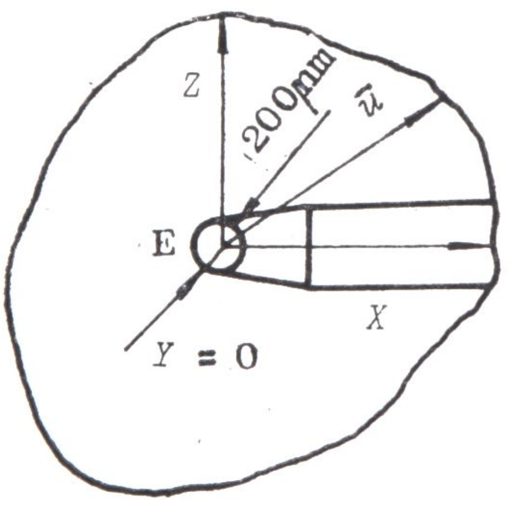

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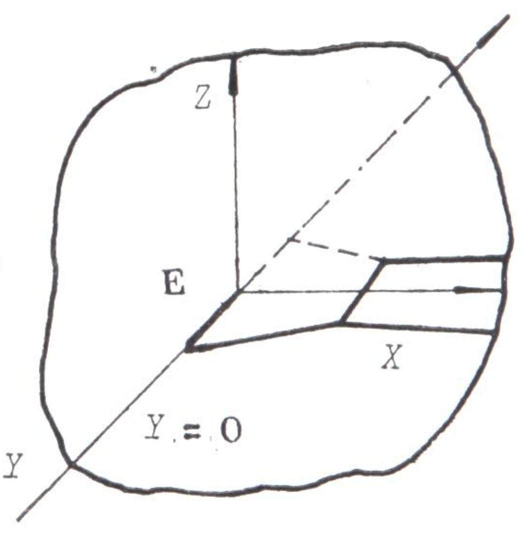

Fig. 3 Placements of sensors: a) for mean temperature and b) fluctuation temperature measurements

The cold wire was operated by a homemade resistance thermometer (10). The heating current of the resistance thermometer was adjusted to be 3.5 mA, so the resoltuion of 0.1 K, can be obtained with a negligible velocity contamination of the cold wire signal. The velocities of the flow (the wire was held perpendicularly to the velocity vector during its current adjustment and measurements were in the range of velocities encountered in the test section.

The time constant of this thermometer was found by the internal heating technique to be 2500 Hz. During this test the cold wire was placed in the air calibration flow of 3 m/s.

Becouse the maximum temperature difference in the studied flow is less than 100 K, than the linear relationship between the instantanous electrical resistance R of cold wire and its instantanous temperature T was used [13]:

$$R = R_0 (1 + \alpha T). \tag{1}$$

Here, α is the temperature coefficient of electrical resistance and R_0 the electrical resistance of the cold wire for $T=0°C$.

Ohms law gives $R = E_{cw}/I$ so it is:

$$E_{cw} = I R_0 (1 + \alpha T) \tag{2}$$

where E_{cw} is the instantaneous voltage diference at the ends of the cold wire and I the constant current through the cold wire.

The instantaneous voltage at the resistance thermometer exit is given as:

$$E_c = k_c (E_{cw} - E_{cwo}) \tag{3}$$

Here, k_c is the amplification constant and E_{cw0} reference voltage.

If (2) is put into (3) then

$$E_c = C_1 T + C_0 \tag{4}$$

where $C_1 = k_c I R_0$, $C_0 = (I R_0 - E_{cw0}) k_c$.

There are:

$$E_c = \overline{E}_c + E_{c'}, \quad T = \overline{T} + T', \tag{5}$$

where $\overline{E}_c$ and $\overline{T}$ are mean and E_c' and T' fluctuating quantities.

When equations (5) are substituted in (4) and the obtained equation averaged then

$$\overline{E}_c = C_1 \overline{T} + C_0, \quad E_c' = C_1 T'. \tag{6}$$

Moreover, there are:

$$\sqrt{\overline{T'^2}} = \frac{1}{C_1} \sqrt{\overline{(E_c')^2}} \tag{7}$$

and

$$\sqrt{\overline{\left(\frac{\partial T'}{\partial \tau}\right)^2}} = \frac{1}{C_1} \sqrt{\overline{\left(\frac{\partial E_c'}{\partial \tau}\right)^2}} \tag{8}$$

Quantities $\sqrt{\overline{(E_c')^2}}$ and $\sqrt{\overline{(\partial E_c'/\partial \tau)^2}}$ were read through the signal correlator and indicator (DISA model 55A06).

2.3. Discussion of experimental conditions. 2.3.1. *Confinement of the flow.* In the present study the jet exit pipe protrudes into the cross-stream. The dynamics of the flow and the dimensions of the jet, test section and pipe are such that during the measurements the jet does not touch the tunnel walls. In its measu. rement region such a flow can be designated as unconfined.

This is the first experimental study of nonbuoyant heated jet in cross-stream to be done for this kind of flow confinement. Namely, the exits of the jet of Kamotani and Greber [4], Antani and McMachon [5] and Andreopoulos [6] were placed, flush with flat plates situated in their wind tunnels. Challaghan and Ruggeri [1] Ramsey and Goldstein [3] did not use plates, but they injected their jets from the exits placed flush with the floors of their wind tunnels. All of these flows were the floor-bounded but the flow of Challaghan and Ruggeri was bounded not only by the floor but sides of the test section. The kind of flow volume used in experiments of Shandorov [2] is not known. As an example of totally confined flow is the round jet of Rathgeber and Becker [14] injected to the trasverse pipe flow.

Unfortunately, no study was, so far, devoted solely to the influence of the confinement of the heated jet in the cross-stream to the heat transfer in its flow-field.

2.3.2. *Jet exit profiles.* Only the jets of Ramsey and Goldstein [3] and Andreopoulous [6] were issuing in cross-streams from the pipes as it was in the present study but the momentum ratios of their experiments were different compared to J_s of this study. The jet in experments of Challaghan and Ruggeri [1] was injected to the cross-stream directly from the plenum. Jets of Kamotani and Greber [4] and Antani and McMahon [5] were injected from the nozzles. Bojic [10] did his similarity analyses for the heated and nonbuoyant jet in the cross-stream. He found that there is the influence of initial velocity profile on momentum field development. Unfortunately, nothing is, so far, published how the initial velocity profile shape influences the heat transfer in the flow field of heated jet in cross-stream.

In every experiment on heated nonbuoyant jet issuing in cross-stream published so far the jet exit temperature profile was uniform contrary to the present study where the jet exit pipe protruding into the cross-flow was not thermally insulated. In literature, so far, nothing is published related to the influence of shapes of temperature profiles to heat transfer dynamics.

2.3.3. *Viscosity effect.* Using Vaschy-Backingham theorem, Pratte and Baines [12] showed that the similarity parameter of the momentum field of their deflected jet is not Re_j, so Reynolds similarity holds and viscosity effects in such flow on its momentum field are negleable. In [10] similarity analises via Navier-Stokes equations reveled that Reynolds similarity can be applied to the momentum field of the heated nonbuoyant jet in the cross-flow. Also, the similarity analyses of energy equation indicated that Reynolds similarity holds for the temperature field of the same flow.

There are few experimental studies devoted to the influence of Re_j to the spread of visuelisation trajectoris of different deflected flows. Prate and Baines [12] and Margason [15] did such a kind of studies for air flows and Hoult and Weil [16] and Gordier [17] for water. They found out that there is no any influence of Re_j to such spread. There is no single experimental study devoted to the influence of Re_j to other flow features as well as heat transfer characteristics of deflected jet.

2.3.4. *Temperature difference effect.* So far, for the heated nonbuoyant jet in the cross-stream, only, Kamotani and Greber [4] studied the influence of temperature difference $\overline{\Delta T_{js}}$ on temperature field. They were interested in the evolvements of the temperature centerlines. They found that for $J_s=59.6$, the flow with $\overline{\Delta T_{js}}=177\,K$ and the flow with $\overline{\Delta T_{js}}=41.7\,K$ have different temperature centerlines. They also noticed that for $J_s=15.3$ these two flows have the same temperature centerline. In the present study there are $J_s=15$ and $\overline{\Delta T_{js}}=28.2\,K$.

The theoretical similarity studies in [10] confirmed previously discussed experimental results of [4] and showed undoubtely that the main similarity parameter of heat transfer in their heated deflected jet as a matter of fact is not only J_s but $\overline{\Delta T_{js}}$.

3. Experimental results

3.1. Dimensionless mean temperature. The distribution of dimensionless mean temperature

$$\theta_m=\frac{\overline{T}-\overline{T}_\infty}{\overline{T}_m-\overline{T}_\infty} \tag{9}$$

is shown in Fig. 4. for $X/d=1.15$. The distributions of θ_m for other values of X/d measured in the present experiments were presented in [9]. Here $\overline{T}$ is mean temperature, $\overline{T}_m$ maximum mean temperature for $Y/d=0$ and $X/d=$const. the measurement were performed.

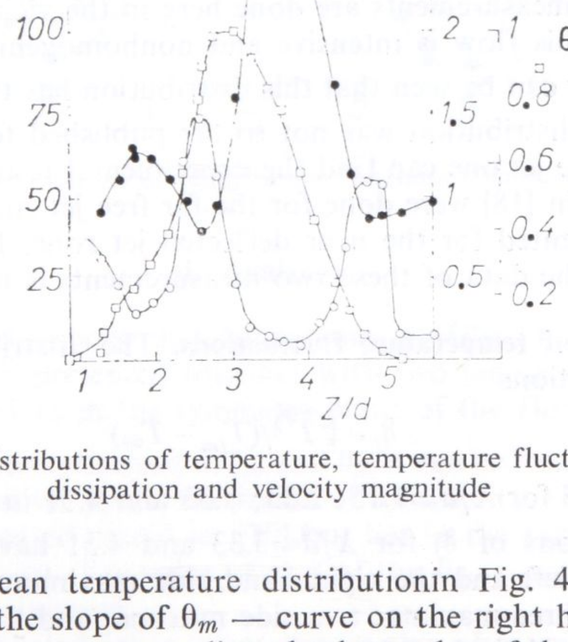

Fig. 4 Distributions of temperature, temperature fluctucation dissipation and velocity magnitude

Dimensionless mean temperature distributionin Fig. 4 has one maximum. The apsolute value of the slope of θ_m — curve on the right hand side of its maximum is nearly the same as corresponding absolute value of the slope of θ_m — curve on the left hand side of its maximum. Since, this is not the case with θ_m distributions in [9] for X/d greater than $X/d=1.15$, this may suggest that for $X/d=1.15$ two bound vortices do not have the crutial influence on the heat transport and the left hand side region of the temperature profile of the jet.

For $J\approx15$ as here, the mean temperature was, so far, measured only by Kamotani and Greber [4]. They presented their data in the planes perpendicular to the symmetry plane of their flow. But in their paper [4] there are not enough data, temperature profiles for $Y=0$ and $C/d=$const. to be reconstructed and compared to the θ_m — profiles obtained here.

On the other hand, the confinement of their heated nonbuoyant jet in cross-stream as well as the jet exit mean velocity and temperature profiles and temperature difference are distinct to these of the present jet.

Anyway, it was found that the temperature profile shape shown in Fig. 4 is similar to these that can be reconstructed from [5] and [8]. Antani and McMachon [5] did their experiments with nonbuoyant jet in cross-stream but for $J_s=64$ and $\Delta T_{js}=70\,K$. The jet of Bryant and Cowdrey in [8] is in the class of buoyant flows.

3.2. Dissipation of temperature fluctuation. The distribution of dissipation of temperature fluctuations

$$\Psi = 6\,a\,\overline{(\partial T'/\partial \tau)^2}\,d/[\bar{u}_\infty(\overline{T}_{jm}-\overline{T}_\infty)^2\,\bar{u}^2] \qquad (10)$$

is shown in Fig. 4 for $X/d=1.15$. Here, a is thermal diffusivity, T' fluctuating temperature, τ time and $\bar{u}$ mean velocity.

Quantity $\bar{u}$ used in this paper is measured by cilindrical pressure probe in the symmetry plane of isothermal nonbuoyant jet in cross-stream [10] for the same $J_s=15$ as here. It was estimated that the pressure probe in velocity field of turbulence intensity of 35% gives the order of the velocity 10% higher than the real velocity.

It should be noted that equation (10) used for the calculation of Ψ is valid [18] for locally isotropic, low turbulence and homogenious flow. Firstly, the assumption of localy isotropic flow is here justified only for fine structure of this flow. Secondly, the flow measurements are done here in the vicinity of the jet exit where the turbulence of this flow is intensive and nonhomogenious.

From Fig. 4 it can be seen that this distribution has two maxima and minima.

This kind of distribution was not so far published for jet in cross flow, but for plane heated free jet one can find the experimental results of Antonia et al [18]. The measurements in [18] were done for the far free jet zone but here in this paper the results are presented for the near deflected jet zone. It can be found that the order of values of the data of these two measurements is the same.

3.3. Intensity of temperature fluctuations. The distributions of intensity of temperature fluctuations

$$\delta_j = \sqrt{\overline{T'^2}}/(\overline{T}_{jm}-\overline{T}_\infty) \qquad (11)$$

are shown in Fig. 5 for $X/d=1.15$; 2.33; 3.33 and 4.51 in plane $Y=0$.

The distributions of δ_j for $X/d=3.33$ and 4.51 have two maxima on their opposite sides: the left and the right hand side maximum. The distribution of δ_j for $X/d=2.23$ has three maxima: two side maxima, and the central maximum, but the distribution for $X/d=1.15$ has two maxima: the central and the right hand side. The left hand side maximum is only initiated in this $X/d=1.15$ curve. Probably, if the measurements in the vicinity of the initiated maximum were more detailed, this maximum value would be properly recognized.

Side maxima are in the regions of the intermittent jet boundary. During the measurements of δ_j, in the vicinity of these regions, the cold wire senses either heated turbulent jet or unheated cross-stream and the large values of δ_j were obtained. In the begining of the jet development the sudden intensification of the entrainment of the cold fluid can be explanation for the existance of the central maximum in this area.

So far, for $J_s=15$ the intensity of temperature fluctuations was not measured.

For heated nonbuoyant jet in cross-stream only Andreopoulos [6] measured δ_j but his jet was floor-confined ($J_s \approx 0.25$) so his results can not be properly compared to the results published here. Corssin and Uberoi [19] measured δ_j in the free heated round jet ($\Delta T_{jm}=17\ K$). At the distance of 19.32 d downstream of their jet mouth the values of δ_j of the side maxima of their jet were 0.037. From Fig. 5 it can be seen that for $X/d=4.51$ this Corrsin and Uberoi value is approached by the values of side maxima of δ_j.

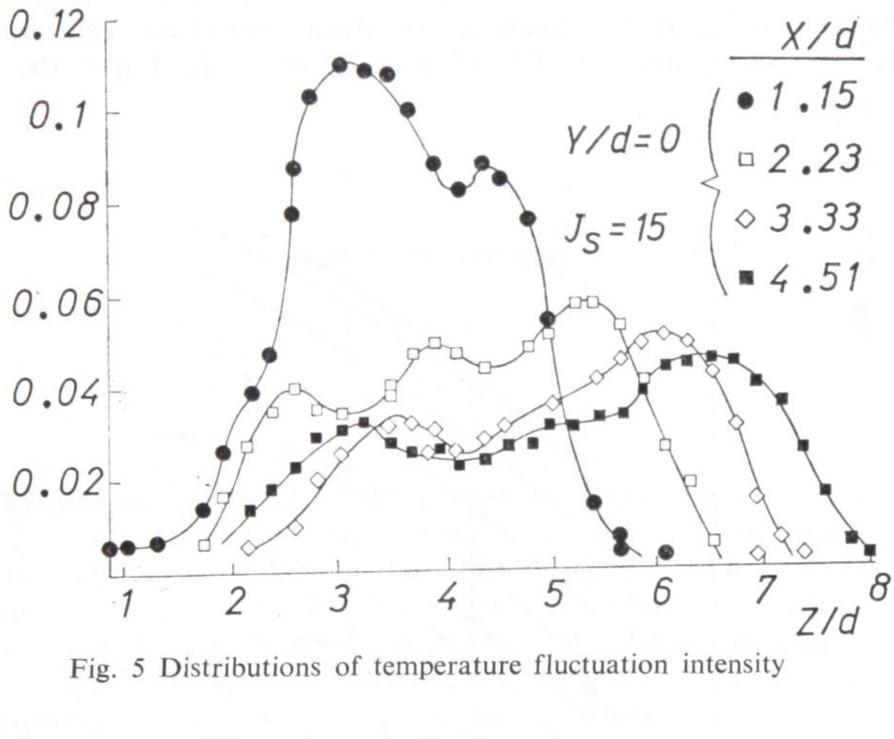

Fig. 5 Distributions of temperature fluctuation intensity

4. Analyses

4.1. Comparison of velocity and temperature profiles. In Fig. 4 the velocity profile $\bar{u}/\bar{u}_\infty$ from [11] is presented togather with two temperature profiles θ_m and ψ versus Z/d for $X/d=1.15$ in the symmetry plane of the flow $Y=0$.

Comparing the distributions of $\bar{u}/\bar{u}_\infty$ and θ_m it can be found that the maximum value of θ_m does not coincide to the maximum of $\bar{u}/\bar{u}_\infty$ as it is the case for the mixing of, for instance, free heated round jet [19] but lies in the region of the maximum velocity gradients of the jet. The value of Z/d of the θ_m — maximum is lower than Z/d value of $\bar{u}/\bar{u}_\infty$ — maximum.

For nonbouyant heated jet in cross-stream this phenomen was also reported by Kamotani and Greber [4] ($J_s=15.3$ and $\overline{\Delta T_{js}}=41.7\ K$, $J_s=15.3$ and $\overline{\Delta T_{js}}=177\ K$)

as well as by Ramsey and Goldstein [3] ($J_s=2.25$ and $\overline{\Delta T_{js}}=50\,K$; $J_s=4$ and $\overline{\Delta T_{js}}=$ $=50\,K$). The phenomen can be attributed to the mixing of hot inside fluid and entrained cold outside fluid by two bound vortices.

If it is clear that the dissipation distribution and the velocity profile are closely correlated so the left minimum of ψ coinsides to the left maximum of $\bar{u}$, the left maximum of ψ to the left minimum of $\bar{u}$, the right minimum of ψ to the right maximum of $\bar{u}$ and the right maximum of ψ to left minimum of $\bar{u}$. Because ψ is the molecular dissipation of temperature fluctuations it is natural to expect that the maximum of ψ is in the part of flow where processes are at the molecular level. These parts of the flow here are these with the lowest values of $\bar{u}$.

4.2. Temperature curves. The maxima and minima of the temperature distributions presented in this paper are chosen to be their characteristic values. The points in the plane $Y=0$ where these values occur are called the temperature points. The temperature curves are defined as loci of the temperature points. For the particular temperature curve in Table 1 one can find the corresponding temperature distribution and its characteristic value. Temperature curve $T4$ represents locus of maxima of θ_m or the mean temperature centerline. Temperature curves $T2$, $T6$ are loci of δ_j and $T1$, $T3$, $T5$ and T7 of ψ. In Fig. 6 the temperature

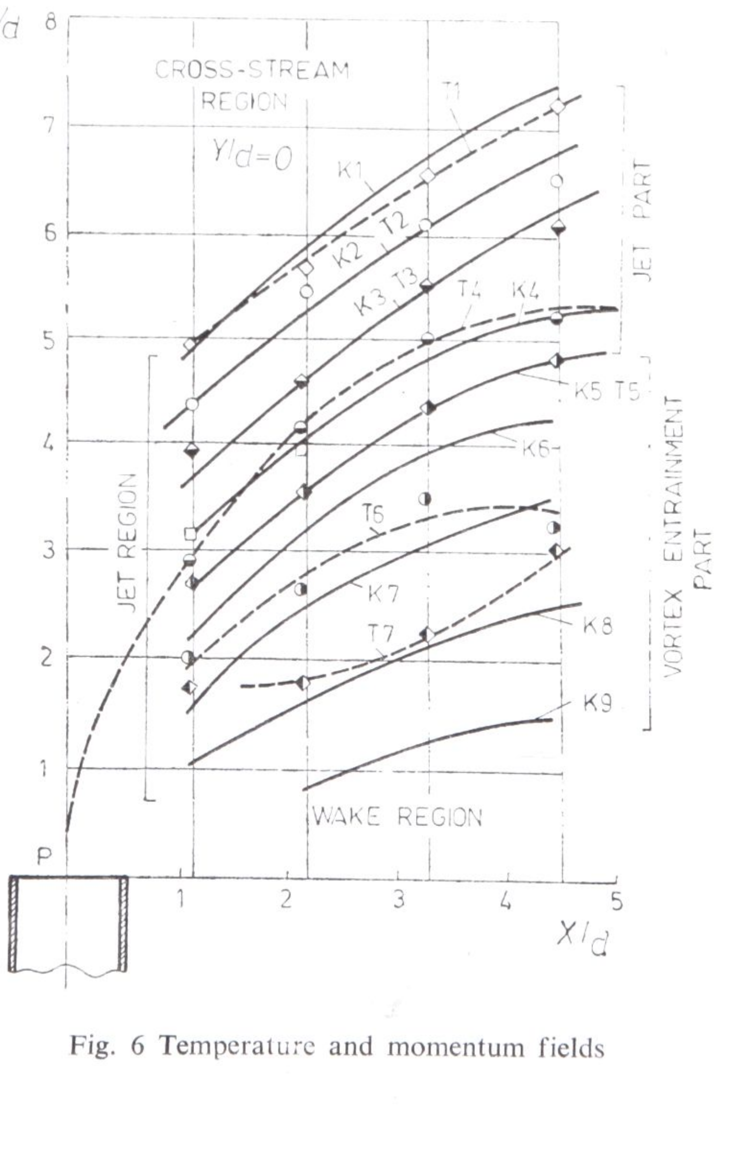

Fig. 6 Temperature and momentum fields

field is characterized by plotting the temperature points (their symbols are also given in Table 1 and temperature curves in the plane of symmetry of this flow.

In the literature for heated jet in cross-stream one can not find temperature curves other than the temperature centerline [3, 4, 8]. So this is the first time that temperature fluctuation distributions were used temperature curves to be obtained.

Table 1: Temperature curves

Temp. curve	Distribution	Characteristic value	Symbol of temperature point
T 1	ψ	Right hand maximum	◇
T 2	δ_j	Right hand maximum	○
T 3	ψ	Right hand minimum	⬙
T 4	θ_m	Maximum	◒
T 5	ψ	Left hand maximum	⬗
T 6	δ_j	Left hand maximum	◑
T 7	ψ	Left hand minimum	⬖

4.3. Momentum curves. In [10] momentum curves are similarly defined as temperature curves defined previously. They are loci of the points of particular characteristic momentum values (maxima, minima and inflections of momentum distributions) in plane $Y=0$. The momentum distributions used in [10] the momentum curves to be characterized were these of velocity, pressure and Reynolds stress. In [10] the total of the nine momentum curves $K1$ to $K9$ were delineated. Their descriptive names from [10] are given in Table 2. These curves are plotted together with temperature curves in Fig. 4.

On the basis of these momentum curves in [10] the flow field in the plane of symmetry is devided into three regions: cross-stream, jet and wake. The boundary of regions of cross-stream and jet is momentum curve $K1$. The curve $K9$ is the boundary curve of regions of jet and wake.

The jet region in [10] is devided into jet part ($K1$—$K5$) and vortex entrainment part ($K5$—$K9$).

4.4. Comparison of evolvements of temperature and momentum curves. From Fig. 6 one can see that in the area between $K1$ and $K5$ curve $T1$ follows closely curve $K1$ and $T4$ curve $K4$, but curve pairs $K2$, $T2$, $K3$, $T3$ and $K5$, $T5$ coincide. This is the jet part of jet region.

Table 2. Momentum curves and their descriptive names [10]

Curve	Descriptive name
K1	Stagnation curve of the cross-stream;
K2	Maximum shear stress curve of the jet and the cross-stream;
K3	Jet velocity centerline;
K4	Maximum shear stress curve of the jet and two boundary vortices
K5	Stagnation curve of the the two boundary vortices induced flow;
K6	Maximum tangential shear stress of two boundary vortices induced flow during its decceleration;
K7	Two boundary vortices induced velocity mfximum curve
K8	Maximum velocity direction change of two boundary vortices induced flow during its acceleration
K9	Maximum shear of two boundary vortices induced flow and woke.

The situation is different in the area surrounded by curves *K*5 and *K*9 (see pairs *T*6, *K*7 and *T*7, *K*8). The first pair *T*6, *K*7 has a similar behaviour as the pair *T*4, *K*4. Curve *T*6 lies more or less on the curve *K*7-maximum velocity curve of vortex entrainment part of the jet region, but not so closely as *T*4 lies on *K*4. However, it seems that further downstream curve *T*6 will coincide to curve *K*7. Curve *T*7 firstly approachs to curve *K*8 but further downstream of the jet exit this curve gets away from *K*8 and closer to the core of vortex entrainment part of jet flow.

There are no temperature curves nearby curve *K*9. As the curve *K*9 is the boundary of the jet and the wake, it is clear that temperature distributions do not delineate this flow clearly out of the wake.

Earlier, evolvements of temperature and velocity certerlines are mutually compared [3, 4] but here such a comparison of the development of seven temperature curves and nine momentum curves is for the first time published and disscused.

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ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ НАГРЕТОЙ НЕВЫТЕСНЯЕМОЙ ТУРБУЛЕНТНОЙ СТРУИ В ПОПЕРЕЧНОМ ПОТОКЕ: ТЕМПЕРАТУРНОЕ ПОЛЕ

Результаты экспериментальных исследований нагретой воздушной струии, которая подаётся через трубку, в поперечном вaздушном потоке, показанны при неизменяемыех отношений количества движения 15 и отновшению плотностей 0,927. Полученные распределения температуры водзуха и сответствующей интенсивности температурной флуктуации и дисипации температурной флуктуации, использованы для определения температурного поля так получаемой струии. Полученные резулятатые обеспечивают новые знания в этой области с точки зрения физикальности рассматриваемого явления.

EKSPERIMENTALNA ISTRAŽIVANJA ZAGREJANOG NEPOTISKIVANOG TURBULENTNOG MLAZA U POPREČNOJ STRUJI: TEMPERATURSKO POLJE

Rezultati eksperimentalnih istraživanja zagrejanog vazdušnog mlaza koji se izduvava kroz cev u poprečnu vazdušnu struju dati su za konstantni odnos količina kretanja od 15 i odnos gustina od 0,927. Rezultujuće raspodele temperatura vazduha kao i odgovarajućih intenziteta temperaturskih fluktuacija i disipacije temperaturskih fluktuacija upotrebljene su za određivanje temperaturskog polja tako dobijenog strujanja. Na bazi ovih rezultata dolazi se do novih saznanja o fizici ove pojave.

Dr Milorad Bojić,
Mašinski fakultet, Sestre Janjić 6
34000 Kragujevac, Yugoslavia

Dr Zoran Zarić,
Srpska akademija nauka i umetnosti
Knez Mihajlova 35
11000 Beograd, Yugoslavia