Puff Characteristics

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Abstract. The aim of this paper is to give an overview of characteristics of puffs that can be found in the literature engaged in sudden releases of gases. Moreover, experiments examining these processes will be described that have been recently carried out in the laboratory of Environmental Aerodynamics of the Institute of Thermomechanics AS CR in Novy Knin. It can be seen puff variation from replica to replica under the same release conditions from results.

Introduction

Air pollution is a problem that has annoyed people for numberless years. Therefore, many studies have been carried out to explore this problem. Nevertheless, only minimum studies are engaged in accidental or intentional escapes of gases although these crises are more frequent with the growth of inhabitants and thus the enlargement of conurbation. For all, we should at least mention the worst industrial environmental disaster in Bhopal. On December the third 1984 shortly after midnight a poisonous gas cloud escaped from the pesticide factory called Union Carbide. After the explosion, more than 20 000 people died. However, the research conducted by the BBC in 2004 pointed out that this disaster still causes people to fall ill and about 10 more people die every year. But you can be affected by an escaped dangerous gas cloud also in areas with no factory in the surroundings — near technological objects — winter stadiums, swimming pools or cooling chambers, for instance. This is the reason why these crisis situations have recently been studied in COST projects in Europe.

Puff dispersion

When gas (of a similar density like air) is suddenly released to the atmosphere, it is being dispersed by an ambient turbulent wind, by diffusion. Eddies that are much bigger than the puff size may transport puffs without any influence on their inner structure. Nevertheless, eddies of similar scales to that of the puffs distort the shape and distribution of material in the puffs.

The concentration evolution in time measured at a fixed place changes from replica to replica independently of the same release conditions — the ambient turbulent wind, the boundary conditions, duration of gas leakage and the gas source intensity (Figure 1). It’s because the time of the release is shorter in comparison with averaging time for turbulent flow. Therefore different releases pass over during different instantaneous velocity fields. Therefore the puff is transported by wind along different path. And this is the reason why many repetitions of puffs under the same release conditions have to be made.

Puff characteristics

To describe instantaneous gas releases some puff characteristics have to be defined. There can be
found more approaches to this problematic (e.g. Fischer et al. (2007), Bezpalcová (2006)). The following overview involves the most common puff characteristics examining each replica separately. All puff characteristics are graphically depicted on a mean puff (of 100 replicas) in Figure 2.

1. **Arrival time (travelling time, delay time)**
   Arrival time is the time when a puff cloud arrives to the detector position. It is usually defined as the time when concentration has exceeded a given threshold for the first time since the gas release and has remained above this threshold for a specified period of time.

2. **Peak time**
   Peak time is the time after gas release when maximum concentrations are detected.

3. **Ascent time period**
   Ascent time period is the time period between arrival time and peak time.

4. **Leaving time**
   Leaving time is the time when concentration decreases under a given threshold and remains below this value till the next gas release.

5. **Transport speed of a puff**
   Transport speed of a puff can be obtained by division of the distance between the place of gas release and sampler by arrival time, then this speed is called arrival or by peak time, then so-called peak speed is obtained.

6. **Descent time period**
   Descent time is the time period between peak time and leaving time.

**Experimental set up**

The experiments examining the processes of sudden releases of gas were carried out at the Environmental Aerodynamics laboratory of the Institute of Thermomechanics AS CR in Nový Knín. The scheme of the low speed wind tunnel that is in the laboratory can be seen in Figure 3.

**Figure 1.** Huge variation of puffs replicas under the same release conditions. Quantities represented on axis: vertical — dimensionless concentration $C^* = \frac{CU_{\text{ref}}L_0^2}{Q}$. Horizontal — dimensionless time $t^* = tU_{\text{ref}}L_0$. (U_{\text{ref}}$ reference speed, $L_0$ characteristic length, $Q$ source intensity).
Figure 2. Puff characteristics.

Figure 3. Scheme of wind tunnel.

Figure 4. Developing of the boundary layer.

<table>
<thead>
<tr>
<th>$z_0$</th>
<th>$d_0$</th>
<th>Power law exponent [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8</td>
<td>3.0</td>
<td>0.27</td>
</tr>
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Figure 5. Boundary layer parameters (in full scale).

The boundary layer in the tunnel was developed by spires and roughness elements (Figure 4). Its characteristics (see Figure 5) were measured and wind measurements were performed by Laser Doppler Anemometry. Concentrations were measured with the HFR400 Atmospheric Fast-Response-Flame-Ionization-Detector (FFID) of Cambustion.
The model placed into the tunnel can be seen in Figure 6. Its scale is 1:400. The zoomed scheme of the meted section with dimensions is depicted in Figure 7. The placement of the point ground level source is highlighted by a red point, FFID probe marked as a blue cross in Figure 7. Its scale is 1:400.

**Puff simulations**

The sudden releases of gas were simulated by the Programmable Logic Controller (PLC) Siemens LOGO! 12/24RCE 0BA7 and electromagnetic 3/2 valve ND5 (Figure 8).

Puffs were created by the following procedure:

The gas is transported in a hose to one valve orifice. It goes continually through the second orifice unless the voltage is set to the valve with help of PLC (Figure 9a). During the interval the valve is under voltage, it goes continually through the third orifice (Figure 9b), thereby the gas release is created.

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**Figure 6.** Model.

**Figure 7.** Scheme of meted section.

**Figure 8.** Equipment for puff conceiving — PLC Siemens LOGO! and electromagnetic valve.
Results

The frequency distributions of puff characteristics for 100 repetitions under the same release conditions (duration of gas release 1s) will enable us to see how they vary from replica to replica.

Figure 10 shows diagram of dimensionless arrival time. The variance of the cloud arrival from replica to replica is mostly caused by the large eddies motions that cause meander of the cloud. The material of the cloud is mostly due to the eddies of a similar scale like the puffs and the smaller redistributed, the shape is distort and so the maximum concentration varies from replica to replica (Figure 11). Moreover, puff can be split even in more or less split parts. The peak concentration may appear at whatever place of the gas cloud (Figure 12).

This is also one of the reasons why there is a really huge range of values on the horizontal axis in diagram of dimensionless leaving time frequency distribution (Figure 13). Another reason is the definition of the leaving time itself. It is based on the threshold, value chosen by experimenter. If it is too high, the edges of the cloud are cut away. If it is too small, the background concentration that jumps a lot after the puff leaves the detector position may be misinterpreted as the cloud.

Figure 10. Arrival time.

Figure 11. Peak concentration.
The period from the peak time till leaving time — called descent (Figure 15) — is longer in comparison with the time interval when the concentration rises — ascent time period (Figure 14). The case of this is the reservoir effect of the city. After the gas leakage, the whole surrounding area is fulfilled by this gas. When the source is closed the whole tracer caught by the up-lying canopy must pass through the detector position. Furthermore, the gas is flushed away only little by little from poorly ventilated areas — wake regions.
Conclusion

The two following replicas of sudden releases of gas will never be the same independently of the same release conditions. Therefore it is necessary to carry out many repetitions. Only this will enable us to predict the threat in case of accidental or intentional gas discharge.

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References