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INVESTIGATIONS OF BIOMETEOROLOGICAL STRESS IN THE SUBWAY SYSTEM OF NEW YORK CITY

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1. INTRODUCTION

Biometeorological stress arising from heat or coldness and sultriness is an important subject concerning thermal conditions of working and living environments. Interactions and influences on human beings have often been studied in urban climatology and are largely known.
A wide variety of different indoor and outdoor settings have been investigated, but very little has been heard about biometeorological investigations in underground public transportation systems.
Due to the fact that millions of people all around the world spend time in subway systems (e.g. stations, tunnels, trains) every day, it is of a particular importance to study and analyze respective impacts in these widespread underground environments that are only punctually linked to the outside atmosphere.

2. INVESTIGATIONS IN THE SUBWAY SYSTEM OF NEW YORK CITY

The subway system of New York City is one of the largest and most complex underground public transportation systems in the world, frequented by 1.3 trillion people per year. Due to its primary passive ventilation system, mainly forced by incoming and departing trains, the subway system is characterized by a very distinct atmosphere concerning thermal conditions and air pollution.
Striving to study thermal conditions in subway stations, a measurement program was developed for selected stations of the New York City subway system. The program aimed to determine and quantify the spatial distribution of thermal load inside a complex subway station with different levels and a widespread system of connections, exits and entrances. Interactions between inside and outside temperatures were also to be monitored. Furthermore, diurnal and annual variations of thermal conditions were of special interest.
For this purpose, measurements of air temperature, relative humidity, air velocity and infrared radiation temperature of walls, ceilings and ground surfaces were carried out, mainly in "Lexington Ave/59th Street" subway station. Data was collected 4 times a day within two 14-day periods in February/March 2000 and August/September 2000.
With the knowledge of the gathered meteorological data, evaluations of thermal conditions in the subway station can be made.
To make a distinct statement of thermal perception by human beings, the PMV-index (pedicted mean vote) was calculated, taking into consideration non-meteorological parameters like clothing and activity level as well.

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3. RESULTS

Results of measurements and calculations clearly show that passengers are exposed to high thermal stress inside the selected subway station.

3.1 Air temperature

Although it is not possible to obtain a comprehensive picture of thermal load by taking into account only air temperature, it is nevertheless useful to get a general idea of the thermal conditions in the evaluated subway station. As there is no direct radiation experienced underground, air temperature was found to be the most important parameter considering thermal conditions.
Figures 1 and 2 on the following page show mean air temperatures for the three different levels inside the subway station in comparison to the outside air temperature.
For the winter period, outside air temperature varied between 2.9°C (37.2F) and 19.7°C (67,5F), whereas inside air temperatures varied between 6.7°C (44.1F) and 24°C (75.2F).
For the observed summer period, outside air temperatures between 13.4°C (56.1F) and 28.7°C (83.7F) and indoor air temperatures between 19.1°C (66.4F) and 35.4°C (95.7F) were recorded.
Air temperatures inside the station show the typical diurnal variation, but a higher level and a lower amplitude. These high air temperatures inside the subway stations are mainly caused by the trains' air-conditioning and from acceleration and breaking in combination with the insufficient ventilation.

3.2 PMV-values

To make more precise statements about thermal load within the station, the calculated PMV-values comprise air temperature, vapour pressure and air velocity as well as non-meteorological parameters like activity and clothing.

The lowest level inside the station, with no direct connection to the outside, showed the highest thermal load with PMV-values between 0.5 and 1.5 in winter and 1.4 and 2.9 in summer (clothing fitting to outside conditions, standing).
For the other two levels that are directly connected to the outside by exits and gratings, PMV-values between -0.3 and 1.4 in winter and 0.1 and 3 in summer were calculated.
These PMV-values indicate that passengers waiting for the subway are experiencing thermal stress almost throughout the whole year.
Focussing on diurnal variations, highest thermal load was observed in the early evening, lowest values were recorded in the early morning.
Furthermore, one has to consider the impact of different activities and clothing that modify the perception of thermal load. Especially people working in the stations experience much higher thermal stress, PMV values up to 5 were calculated.

4. CONCLUSION

Investigations showed that passengers are exposed to high thermal stress inside the selected subway station. Reasons are the heat release from trains and other electrical equipment inside the stations. Especially in summer, when outside air temperatures are high, the passive ventilation system is working not very effective.

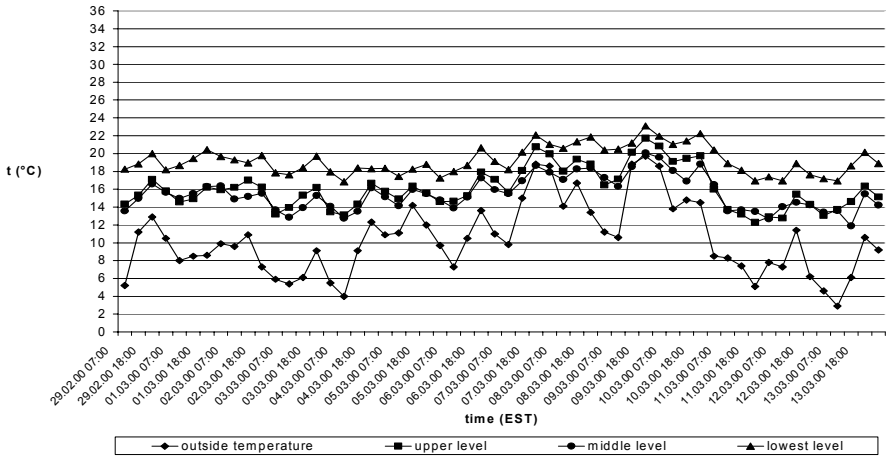

Fig.1: Air temperatures inside "Lexington Ave" subway station and outside air temperature (winter period)

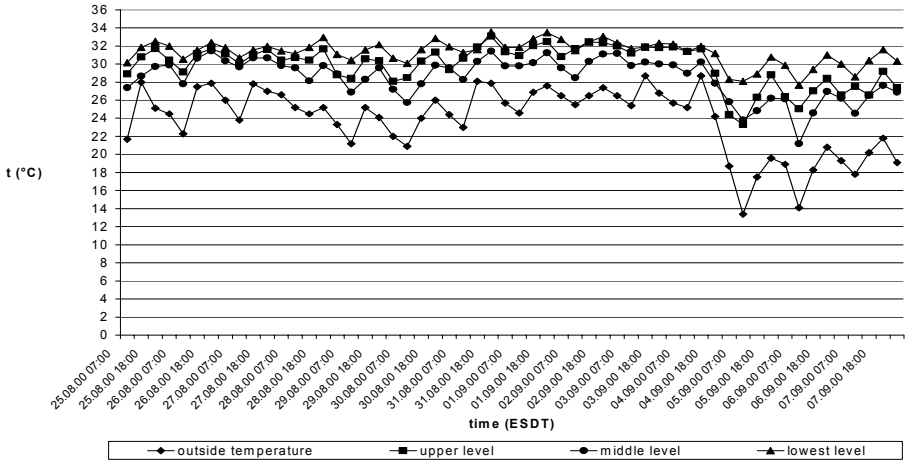

Fig.2: Air temperatures inside "Lexington Ave" subway station and outside air temperature (summer period)