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# Studying of the Thermal Obscuring Potentials of Some Mineral Dusts

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**Abstract:** Area-extensive infrared countermeasures will be necessary to defeat these new seekers. One effective component of these countermeasures will be infrared airborne obscurants, particles, essentially removing the original target from the imager's field.

The experimental studies concern with investigating the thermal screening potentials of some mineral dusts, which are commercially available and unhazardous.

The smoke was generated pneumatically within a designed smoke tunnel equipped with means for measuring the surrounding meteorological parameters such as the ambient temperature, and relative humidity. The thermal obscuring potential of the smoke cloud was thermally tested by using a thermal camera attached to a video recorder and a data processing system. The effect of the smoke cloud on the attenuation of the infrared radiation emitted from a selected target was recorded, analyzed and explained.

The experimental results indicate the capability of experimentally studying the potential of various mineral dusts as infrared obscurants

**Keywords:** Infrared countermeasures, powder, screening, smoke, obscurants

## 1. Introduction

Obscurants are man-made or naturally occurring particles suspended in the air that block or weaken the transmission of a particular part or parts of the electromagnetic spectrum, such as visible light, or infrared (IR) [1].

Sensory equipments (include the human eye, viewers, vision enhancement devices, trackers, and seekers) require a certain amount of energy (a minimum threshold) before they can perform their functions. A sensor will also fail to function if the level of energy, in the wavelength range that sensor is designed to work within, is too great (a maximum threshold) [2].

Bodies with a temperature greater than absolute zero emit electromagnetic radiation. Infrared radiation arises from the viberational and rotational motions of atoms and molecules in the emitting substance [3]. The character of radiation depends on the physical state of the source. Emission spectra of liquids and gases are characteristically lines or bands of discrete wavelength while solids, in most instances, radiate in a broad continuous spectrum [4]. If the material allows all possible transitions (thermal excitation of molecules), each atom provides

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a certain amount of radiation energy which statistically can take all possible values; the wavelength distribution will therefore be uniform and the radiation is then said to have a continuous spectrum [5]. The absorption of radiation by matter results in the apposite process, the absorption being more or less selective, depending on the wavelength and material. All bodies radiate copiously at these so-called normal temperature [6].

Tactical military electro-optics (EO) wavelength range encompasses the portion of the electromagnetic spectrum from approximately 0.4-micrometer wavelength to 15 micrometers. There are two atmospheric windows in the range 3-5 um and 8-12 um and extensively used by electro-optics systems. The EO sensing and guidance system technology can be divided into three broad classes of devices non-imaging IR systems, Imaging IR systems, and Laser guidance system [7]. Whatever the advent of military electro-optic systems and their guidance systems, The working key of all the advent systems in the present and future; depend totally on the sensing of the received infrared photons which emitted from the target. If these photons are prevented to reach, the detection systems of the most advent electro-optic system will not sense the target.

One effective component of these area- extensive IR countermeasures could be obscurants. In studying the thermal attenuation of infrared radiation, which emitted from an object received by sensor through obscurant cloud, there are two primary processes that affect the thermal transmission of infrared radiation: absorption, and scattering. The effect of these two factors is both a reduction in the thermal (infrared) photons that reaches the sensor from the target [8].
Airborne obscurants could be considered as common name for most mechanical smoke systems. Obscurant particles are, by necessity, high-aspect ratio, electrically conductive fibers or flakes with small minor dimensions (nanoparticles are interesting candidates) [9]. Metal flakes of copper or aluminum composition of submicron thickness and multimicron lateral face dimensions are recognized to be a potential source for an infrared screening cloud for military purposes. The metal powder is packed in a camouflage system such as a canister, missile, rocket or a gas generator and dispersed in the atmosphere [12].

## 2. Experimental work

### 2.1 Chemicals

All the chemicals used in this experimental work were of the commercial grade. They were used directly without any purification or treatment. These chemicals and their toxicity limits are shown in the following table (2.1). The choice of the investigated powders was based on recent study of obscurant materials, the toxic hazards, explosion hazards, availability, and economic aspects. These chemicals are available and with acceptable toxicological properties.

### 2.2 Instruments

The used instruments during different steps of the experimental work are illustrated in table (2.2). Complete specification, effective working ranges, and available diagrams of the used instruments are illustrated during the description of each step of the experimental work. The thermal characteristics of the produced cloud of smoke were measured by thermal imager model 760 LW Inframetrics of spectral range from 8-12µm. It was equipped with computer to record the thermal image of the infrared black body radiator model Graseby201/546 , which was taken to be an ideal target of absolute calibration accuracy and temperature stability ±2$^{o}$C. Thermal characteristics and data were processed and analyzed with a computer model

300PL PIV series, high performance 2.8 GH processor. The relative humidity values were measured by digital thermo-hygrometer model TFA 4001. Air velocity within the tunnel was measured by wind velocity meter model Waren H128. Weighing was performed using digital analytical balance type Stanton digital balance model 351BR. Drying was carried out by drying oven of type Veb-mlw model WS3.

## 2.3 Experimental Setup

Experimental setup consists mainly of specially designed smoke tunnel, thermal imager, data acquisition system, and infrared black body. The smoke tunnel used for testing the smoke powders was specially designed and constructed for the purpose of smoke testing. The smoke was generated pneumatically in the tunnel by dispersion of the powder sample within sample holder which made of PVC. Figure (2.1) shows dimensional disassembly and assembly drawing of the sample holder. The maximum mass could be loaded in this holder was about 100g. The infrared black body radiator was used to represent a field target. The thermal imager and the accompanied devices for recording and processing were placed at the other end. An air curtain is applied in front of them to prevent the smoke from diffusion outside. The effect of smoke in reducing temperature and radiation level of the infrared black body radiator with time was recorded, graphed and analyzed for each smoke sample. The setup used for measurements is illustrated in figure. (2.2).

## 2.3 Experimental Evaluation of Obscuring Efficiency of Smoke Powders.

### 2.3.1 Preparation of Smoke Powder Samples

(1) The smoke samples before testing were dried in drying oven at 110$^o$C for 5hrs and then cooled till reaching constant weight.
(2) The particle size was analyzed with 90μm, 54μm and 20 μm sieves by Dental vibrator model DV34
(3) The smoke samples of Cement-dust, ash and silica foam were weighed with the following masses 5g, 10g, 15g, and 20g. Five samples were prepared, since each experiment was repeated five times.

### 2.3.2 Testing of Smoke Powder Samples

(1) The sample under testing was placed in the sample holder
(2) The smoke tunnel circulation system and the computer are turned on at the same time. The outlet air from the tunnel blower disperses the smoke powder sample in the sample holder pushing it into the smoke tunnel in the front of the infrared black body radiator and so the smoke cloud propagated in the tunnel.
(3) The change in the observed temperature of the infrared black body radiator during the propagation of the smoke cloud in the tunnel and the disappearance of target thermal image is recorded on the recorded video.
(4) The setup is turned off when the observed temperature of the infrared camera reaches its initial value before testing.
(5) Every sample is tested five times to insure consistency and to minimize the experimental error.

### 2.3.3 Data Analysis

(1) The data was gathered by playing the recorded video in a slow motion. The variation in the temperature of infrared radiator caused by the smoke sample was tabulated with time.
(2) The transmittance of infrared radiation in the range of 8-14 micrometer through the smoke cloud is calculated.

## 3 Results and Discussion

Five different weights of smoke powder were chosen to produce different intensity of smoke when dispersed in the tunnel. Namely, 5, 10, 15, and 20g of the powders were loaded in the sample holders which correspond to maximum smoke concentrations of 0.56, 1.13, 1.7 and 2.26 $g/m^3$ respectively. The experiments were carried out in the smoke tunnel of total volume 8.85$m^3$, at 18$^o$C ambient temperature and relative humidity 35%. The black body radiator was set at 100$^0$C.

These proposed smoke concentrations were estimated by dividing the mass loaded in the smoke tunnel by its total volume, assuming that the maximum thermal attenuation occurs when the mass loaded is dispersed homogeneously in the tunnel neglecting any losses. The tested amounts of cement-dust were 5, 10, 15 and 20g, which correspond to maximum proposed smoke concentrations 0.56, 1.13, 1.7 and 2.26 $g/m^3$ respectively. Three datum were selected at 80%, 90% and 95%. thermal attenuation to compare between the tested samples.

It was found that thermal transmittance decreases during the propagation of the smoke cloud in the smoke tunnel due to the increase in concentration of the smoke materials. The minimum thermal transmittance occurs during experiment when the mass loaded in the tunnel achieves its maximum concentration, assuming homogenous distribution of the smoke cloud in the tunnel. After achieving maximum concentration of the smoke material, the concentration decreases due to gravitational sedimentation and so the thermal transmittance increases again. The obtained results are summarized in table (3.1). The obtained trends are shown in figures (3.1) to (3.3).

Figure (3.1) shows the effect of silica foam smoke clouds produced by different masses dispersed in the smoke tunnel on the thermal transmittance of infrared radiation. The particles' size of the tested powder was <20 um. By increasing the amount of silica foam powder loaded in the sample holder from 5 to 20g, the maximum attenuation of thermal radiation of the black body augments from 59% to 92%.

The same procedures are repeated with fly ash and cement-dust the results are shown in figure (3.2), (3.3). Figure (3.2) shows the effect of fly ash smoke clouds produced by different masses dispersed in the smoke tunnel on the thermal transmittance of infrared radiation. By increasing the amount of fly ash powder loaded in the sample holder from 5 to 20g, the maximum attenuation of thermal radiation of the black body augments from 66.7% to 96.9%.
Figure (3.3) shows the effect of cement-dust T smoke clouds produced by different masses dispersed in the smoke tunnel on the thermal transmittance of infrared radiation. By increasing the amount of cement-dust powder loaded in the sample holder from 5g to 20g, the maximum attenuation of thermal radiation of the black body augments from 78.7% to 98.9%.
Table (3.1) represents a review of the obtained results after testing of silica foam, fly ash, and cement-dust. It shows the variation of the maximums thermal attenuation with the masses loaded. It was found that, the maximum attenuation achieved by silica foam, fly ash, and cement-dust were 92.2%, 96.9%, and 98.9% respectively.

Figure (3.4) shows the effect of different smoke concentrations of silica foam, fly ash, and cement-dust on the transmittance of the infrared radiation of a black body radiator at 100 $^o$C, the relative humidity was 35% and the ambient temperature was 18$^o$C. It was found that silica foam achieving minimum thermal transmittance. The minimum thermal transmittance achieved by silica foam, fly ash, and cement-dust were 0.07, 0.03, and 0.01 respectively.

## 4 Conclusions

The experimental results indicate the capability of experimentally studying the potential of various powders as infrared obscurants.

The main conclusions of the present work are:

(1) Commercially available mineral dusts such as silica foam, fly ash, and cement-dust can be used in generation of aerosols, capable of thermal radiation attenuation.
(2) cement-dust exhibits the highest thermal attenuation, the next is fly ash and then silica foam
(3) The increase in smoke concentration leads to decrease in thermal transmittance

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**Table (2.1) Chemicals used in the present work and toxicity limits**

| No | Smoke producing powder | Particle size Range(μm) | Density (g/m$^3$) | TLV (mg/m$^3$) | Supplier |
|---|---|---|---|---|---|
| 1 | Cement-dust | 10-40 | 1.16 | 3.5 | Mena company, (EGYPT) |
| 2 | Fly ash | 5-25 | 0.98 | 2 | Ejicm company, (EGYPT) |
| 3 | Silica-foam | 0.2-20 | 0.31 | 1.5 | Mena company, (EGYPT) |

**Table (2.2) Instruments used in the present experimental work.**

| No | Instruments | Model | Using |
|---|---|---|---|
| 1 | Thermal imager | Inframetrics 760 LW | Experimental setup |
| 2 | Infrared black body radiator | Graseby201/546 | Experimental setup |
| 3 | Sample holder | Local fabrication | Experimental setup |
| 4 | Smoke tunnel | Local fabrication | Experimental setup |
| 5 | Digital thermo-hygrometer | TFA 4001 | Experimental setup |
| 6 | Wind velocity meter | Waren H128 | Experimental setup |
| 7 | PC computer | Pintum III 300PL | Data Analysis |
| 8 | Digital balance | Stanton 351BR | Sample preparation |
| 9 | Drying oven | VEB-MLW WS3 | Sample preparation |
| 10 | Dental vibrator( Sieving) | DV34 | Sample preparation |

**Table (2.3) Basic specifications of the used smoke tunnel [11].**

| Item | Specification |
|---|---|
| Material | iron sheets |
| Cross-section | 0.8 X 0.8 m |
| Length | 6 m |
| Average air velocity | 0.4m/s |
| Total volume | 8.85m$^3$ |
| Blower power | 2hp |

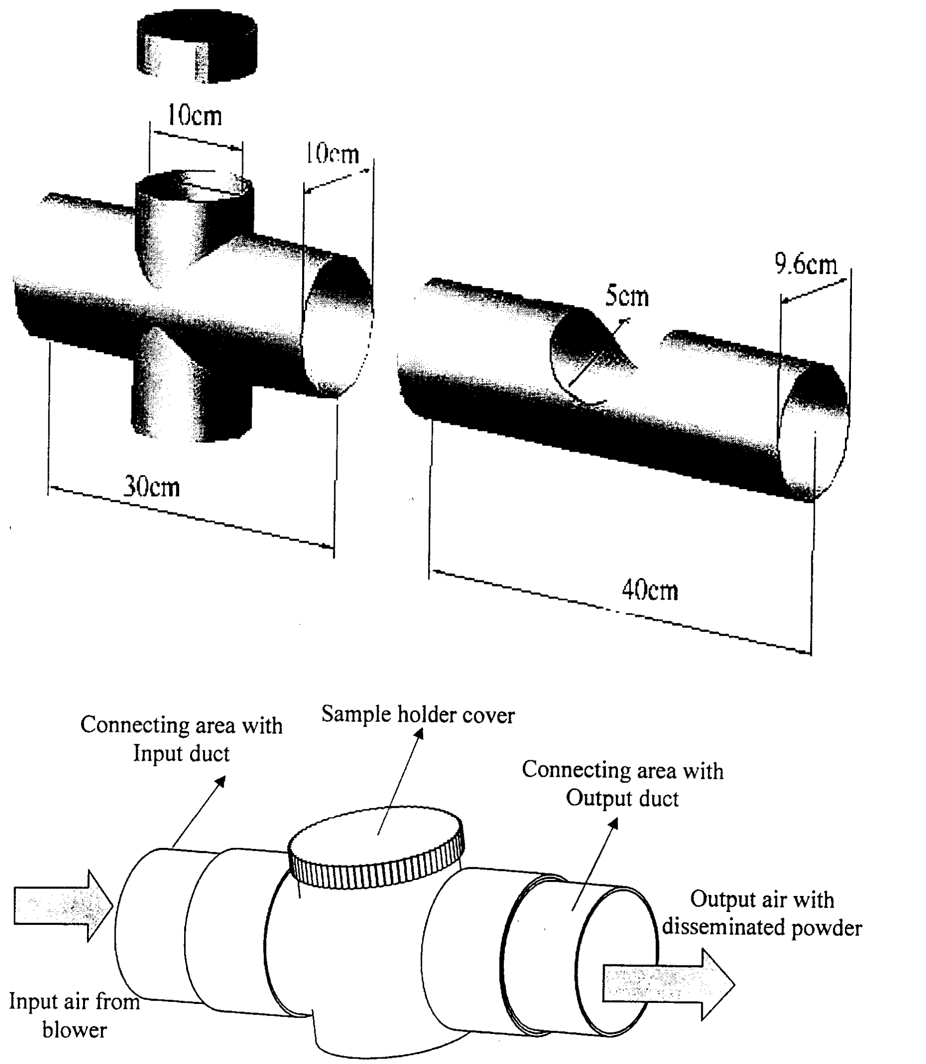


Figure (2.1) Disassembly and assembly drawing of the sample holder

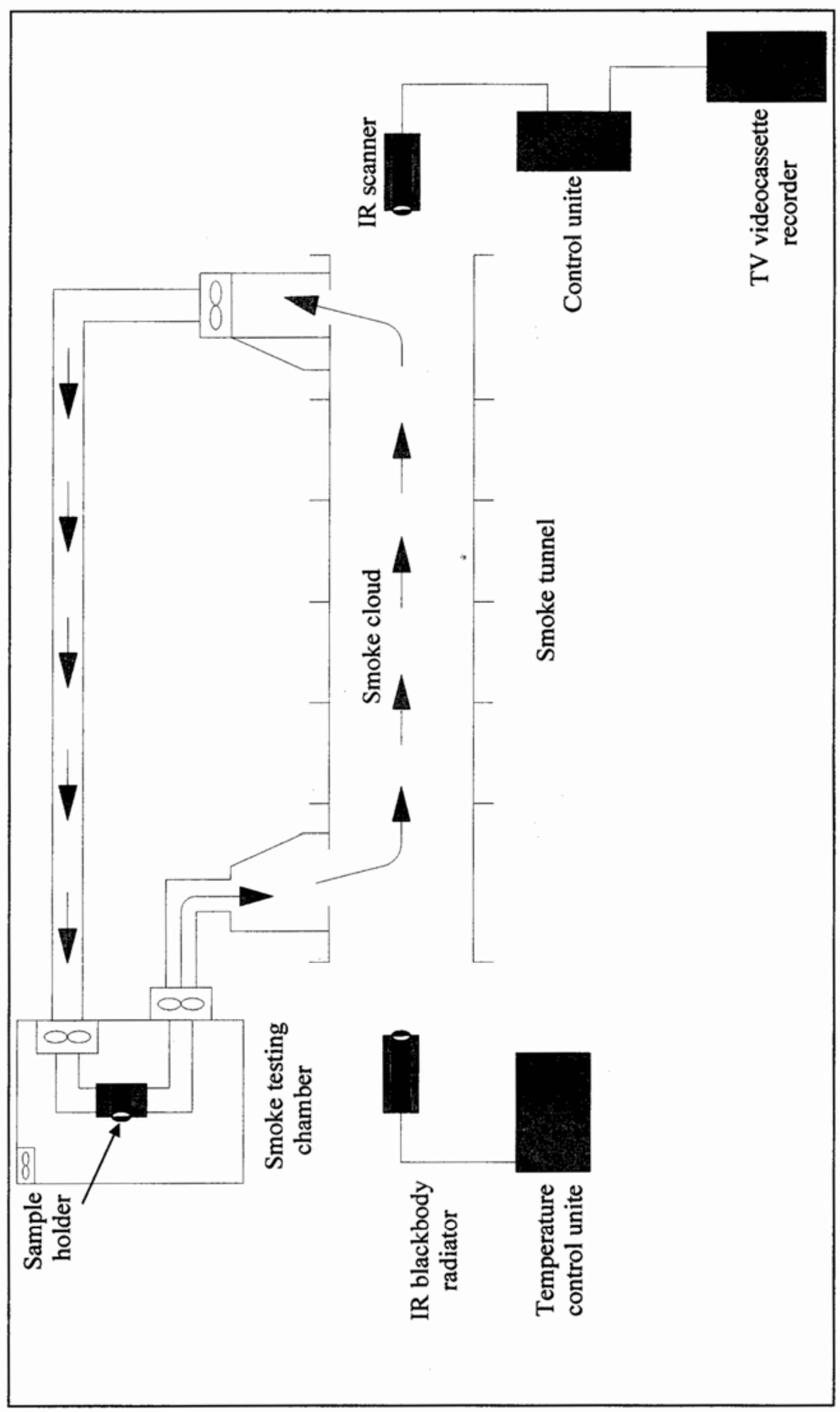


Figure (2.2) Schematic diagram of the laboratory setup used for generation and evaluation of the investigated powders


**(a)** **(b)**

**Figure (2.3) Inframetrics Infrared Radiometer model 760 IR Imaging Radiometer. (a) Inframetrics 760 thermal scanner. (b) Inframetrics thermal image-processing systems**

**Figure (2.4) Graseby infrared black body IR radiator with temperature controlling.**

**Table (3.1) Attenuation of infrared radiation of a black body radiator at 100°C by smoke producing powders at relative humidity 35% and ambient temperature 18°C.**

| Smoke powder | Cement-dust | Fly ash | Silica. foam |
|---|---|---|---|
| Smoke concentration sufficient for 90% attenuation. ($g/m^3$) | 1.6 | 1.6 | 2.26 |
| Smoke concentration sufficient for 95% attenuation. ($g/m^3$) | 2.26 | 2.26 | --- |
| Minimum thermal transmittance | 0.01 | 0.03 | 0.07 |

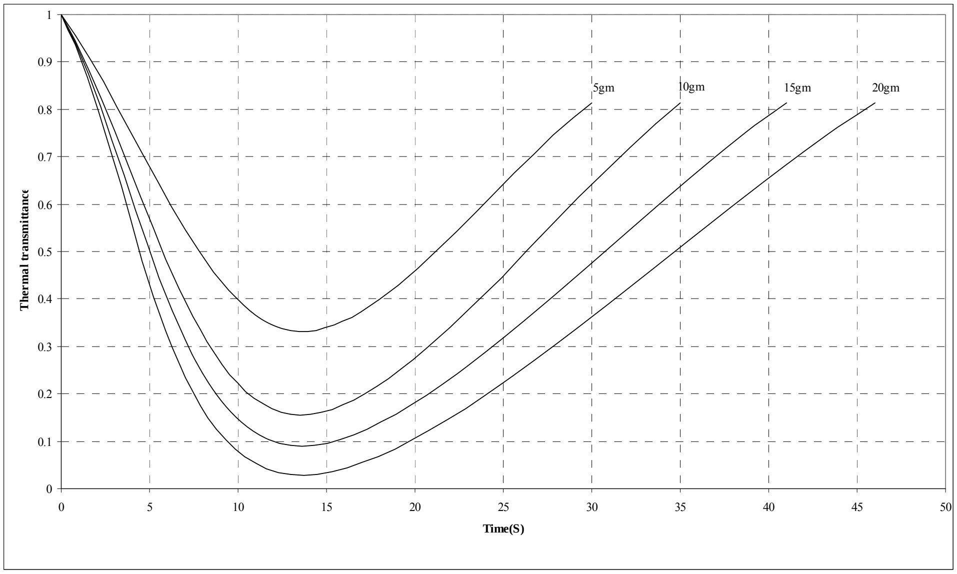


**Figure (3.1) Attenuation of infrared radiation emitted from black body radiator at 100$^o$C by fly ash at relative humidity 35% and ambient temperature 18$^o$C**

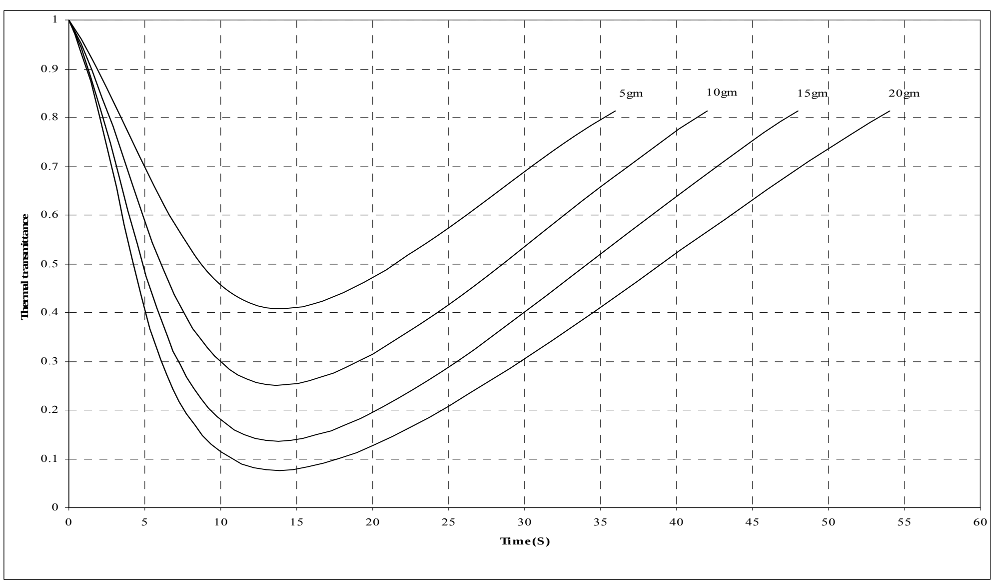


**Figure (3.2) Attenuation of infrared radiation emitted from black body radiator at 100$^o$C by silica foam at relative humidity 35% and ambient temperature 18$^o$C.**

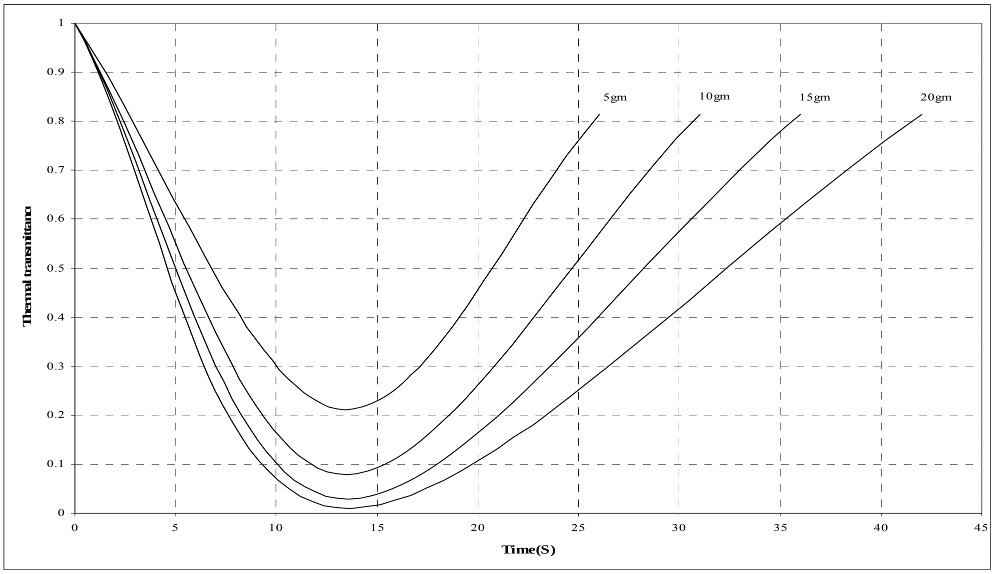


**Figure (3.3) Attenuation of infrared radiation emitted from infrared black body radiator at 100$^{o}$C by cement-dust at relative humidity 35% and ambient temperature 18$^{o}$C.**

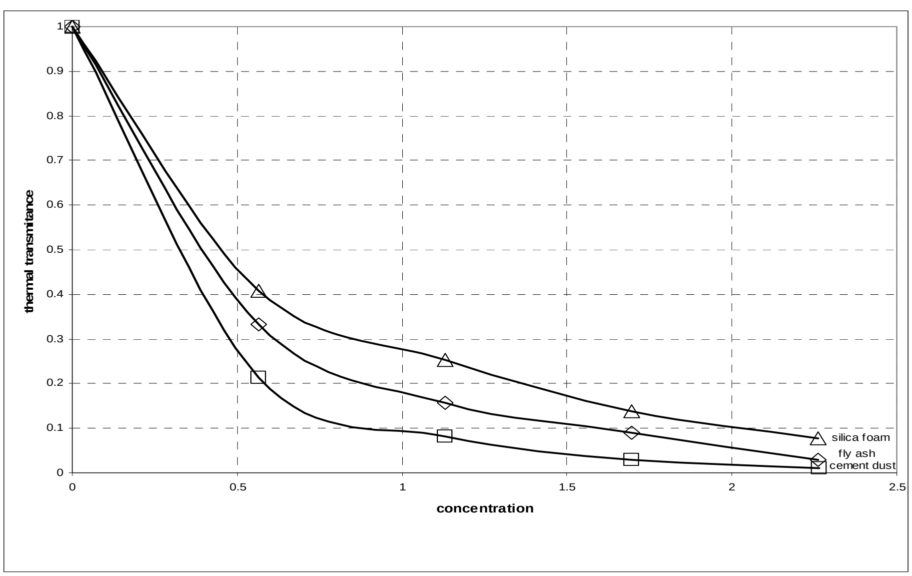


**Figure (3.4) The effect of calcium carbonate, talc powder, and carbon black smoke concentrations on the transmittance of infrared radiation of black body at temperature 100oC, relative humidity 35% and ambient temperature 18$^{o}$C.**