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REDUCTION OF THERMAL IMAGE OF A HOT PLATE BY STEALTH TECHNOLOGY

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ABSTRACT

Stealth is the art of concealing targets from detectors. The stealth technology aims to the design and proposal of materials and techniques that can lead to the reduction of the target signature in the infrared, visible, acoustic and radar domains.

In this papers, a textile barrier (cover) treated with different chemicals is used to reduce the thermal signature of a hot plate. The reduction of the infrared radiation emitted from the hot plate was measured and recorded by an infrared camera.

Different types of textile have been examined and it was found that, white duck textile is the best. This textile reduces the difference between the temperature of the hot plate (100 ^{0}C) after the textile barrier and the back ground temperature (25 ^{0}C) to (15 ^{0}C) at a distance of 1 cm without any treatment.

The distance between the hot plate and the textile barrier was studied in the range from 1 cm to 5 cm and it was found that, as the distance increased the temperature of the hot plate after the barrier decreased. The results show that, white duck textile without any chemical treatment reduces the thermal image of a hot plate at 100 ^{o}C by almost 83%. while its treatment by white emulsion paint reduces the thermal image of the same hot plate by 90%.The addition of titanium dixide to the paint increases the percent reduction to 91%. The other chemical additives such as talc powder,calsium carbonate, calsium sulfate, and carbon black gives lower results since these additives affect the brightness of the treated surface. However, as the areal density of these additives increases from 5.5 mg/cm^2 to 11.1 mg/cm^2, the results become almost the same like the treatment with paint only due to the increase in absorption.

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1. INTRODUCTION

Stealth means to deceive and conceal the target and to minimize the possibility of its detection. The detections of the object, whether it is by eye or through any sophisticated detection device can be avoided by making the target match's the surrounding medium. All sensory equipment (human eye, viewers, tracker, seeker,…) require a certain amount of energy before they can perform their function. Sensor will also fail to function if the level of the energy in the wavelength range that sensor is designed to work within is too great [1].

Generally this may be done by using some paints or textiles and other coverings, which have adequate properties to match with the surroundings so as to conceal the target.

Coating requirements to control radiation emissions from an object can act by absorbing or reflecting the incident solar radiation or thermal self emitted radiation. These coating materials operate in the visible and IR regions.

Light in visible and IR regions falling upon a coated surface either enters the paint film or reflected by the surface. The light entering the film is either diffusely reflected or absorbed by the pigments, particles or transmitted through the film to reach the substrate under the paint coating and either absorbed or reflected back through the film. Radiation, which are neither reflected nor diffused, are absorbed by the material and converted into heat or chemical energy [2].

2. EXPERIMENTAL PROCEDURE AND RESULTS

2.1 paint and Chemicals.

All paint and chemicals used in this work were of commercial grade. They are used directly without any purifications or treatment. They are shown in Table 1. and Table 2. respectivily.

2.2 Textile samples

Texitle samples are local made and their characteristics are listed in Table 3. These types have many different chemical compositions and in its number of strings in warp and weft also in its areal density (weight per cm2).

The set up used in this work consists of controled temperature hot plate, textile sample holder and a thermal imager model 760 LW. inframtrics of spectral range from (8-12μm) [3].

Treated samples are weighed by a digital analytical balance type stanton with accuracy 0.01 g.

The setup is used to measure and record the thermal image of the hot plate with or without textile barrier as a function of time.

The distance between the hot plate and the thermal imager was fixed to be 150 cm while the distance between the hot plate and the sample holder varied from one to five cm.

Different types of texitle (camouflage textile, white textile, proplene textile, green duck, and white duck) have been examined.

3- RESULTS AND DISCUSSION

3.1 Effect of the type of textile

The different textile samples were placed at 1cm from the hot plate which has a temperature of 100 oC; the results are shown in Fig.1. From the figure it is shown that, white duck has the minimum temperature difference between the hot plate and its background. Consequently, it has the maximum camouflaging ability between the tested textile samples. This behavior can be attributed to its high reflectance to the incident IR radiation. This temperature difference increases by approximately 8 ^{0}C in time interval of 30 minutes. More over this textile is used in the manufacturing of tents so it is suitable for its application in comouflaging tents. This textile has good mechanical properties so it can be used for long time without damage

3.2 Effect of the distance between the hot plate and samlpe holder

The figures shown in Fig.2 describes the distance between the sample holder and the hot plate as a function of the temperature difference. It is shown from the figure that, as this distance increase the temperature difference between the background and temperature of the outer surface of the textlie sample decrease. This temperature difference increases by approximately 5 degrees in time interval of 30 min. The choice of 5cm distance to be the datum of these measurment is due to its suitability as a reasonable air gab between the camouflage tent and the hot target in the field.

3.3 Effect of chemicals added

These chemical additives were added with a suitable concentrations in an emulsion paint mostly based on acrylic resins. The mixture is then used for the treatment of the textile samples. The treated samples are dried to a constant weight and its areal density is calculated before any thermal measurement.

3.3.1 Effect of titanium oxide

TiO_2 is added to the paint by two concentration the first gives areal density of 5.5mg/cm^2 and the second gives 11.1mg/cm^2. The increase in concentration of TiO_2 makes the paint more thick and heavy in use also it makes cracks on the paint surface when it is applied to textile. The sample was placed at 5cm distance from the hot plate (100 ^{o}C) and the treated textile surface facing hot plate. The data are represented in Fig.3 . It is shown from the figure that, temperature difference change from 5.5degree to 8 degree at low areal density and from 4 degree to 6.8 degree at high areal desity in time interval of 20 min.

3.2.2 Effect of talc powder

The talc powder is added to the paint to study its thermal camouflaging properties since it is used as an obsecuring material in mechanical smoke in the infrared region [6]. Talc powder was added with concentrations similar to that of titanium oxide and gives the same areal densties. Higher concentrations of talc powder produce a mixture of paints which is more viscus and difficult in the treatment of the surface of textile. The sample was placed at 5cm distance from the hot plate and the treated face at the front of hot plate. The results are shown in Fig.4 it is clear from the figure that, the temperature difference comes from 5 degree to 7 degree at high concentration and comes from 6.5 degree to 10.9 degree at low concentration in time interval 20 min. This result indicate that, as the concentration of talc powder increase in the paint the thermal camouflage properties increase However this increase in concentration is limited by the thickness and mechanical properties of the paint layer on the textile.

3.2.3 Effect of adding $CaCO_3$

Calcium Carbonate was added with two concentrations the first is 5.5mg/cm^2 and second is 11.1 mg/cm^2.

The increase in concentration of calcium carbonate affects the homogenity of the paint mixture and it becomes more difficult in treatment of the textile surface. From Fig.5 it is shown that, the temperature difference changes from 4.9 degree to 7.8 degree in time interval of 20 minutes for higher concentration and for lower concentration it changes from 7.5 degree to 11 degree at the same time interval

3.2.4 Effect of adding $CaSO_4$

Calcium sulfate was added in two concentrations the first is 5.5mg/cm^2 and the second is 11.1mg/cm^2. As the previous chemicals the increases in concentration of calcium sulfate make coagulation in the mixture of paint and difficulty in spreading it on the surface of textile. From Fig.6 it is shown that the temperature difference changes from 4.9 degree to 7.5 degree for high concentration and from 6.8 degree to 11 degree for low concentration at time interval 20 min.
All the previous chemicals additives didn't change the color of the paint. The color of the paint stills white.

3.2.5 Effect of adding Carbon Black

Carbon black gives textile gray color. The same amount of all additives of chemicals were added to be tested at same conditions and amount but the density of carbon black was small to the other chemicals so the same amount of it give large volume so the amount of carbon black becomes less than other chemicals. Also carbon black was tested in two concentrations the first is 3.7mg/cm^2 and the second is 7.4mg/cm^2. It is clear from Fig.7 the temperature difference changes from 5 degree to 7.9 degree for high concentration and from 6.4 degree to 8.9 degree for low concentration in time interval 20min.

The summary of these results were collected in Table 4. where the values of thermal obscuring efficiency are presented and calculated on the bases of 25 ^oC as a background temperature. It is clear that, white duck textile treated with white emulsion paint only (22.5mg/cm^2) is similar in its efficiency to that of titanium dioxide treatment. However, the other chemical additives talc powder, calsium carbonate, calsium sulphate, and carbon black give results almost the same which is less than that of the previous two samples by (1-2)%. This behaviour may be attributed to the dependance of the efficiency of thermal obsecuring on the reflectance of treated surface since titanium oxide gives the more bright mixture. The reason for the similarity of results of textile treated with white paint only and that of titanium dioxide is due to the composition of white paint emulsion which contains 20% titanium oxide as shown in table 1.

4- CONCLUSION

1- White duck textile without any chemical treatment reduces the thermal image of a hot plate at 100 ^{o}C by almost 83%.
2- Treatment of white duck textile by white emulsion paint reduces the thermal image of the same hot plate by 90%.The addition of titanium dixide to the paint increases the percent reduction to 91%.
3- The other chemical additives such as talc powder,calsium carbonate, calsium sulfate, and carbon black gives lower results since these additives affect the brightness of the treated surface. However, as the areal density of these additives increases from 5.5 mg/cm^2 to 11.1 mg/cm^2, the results become almost the same like the treatment with paint only due to the increase in absorption.

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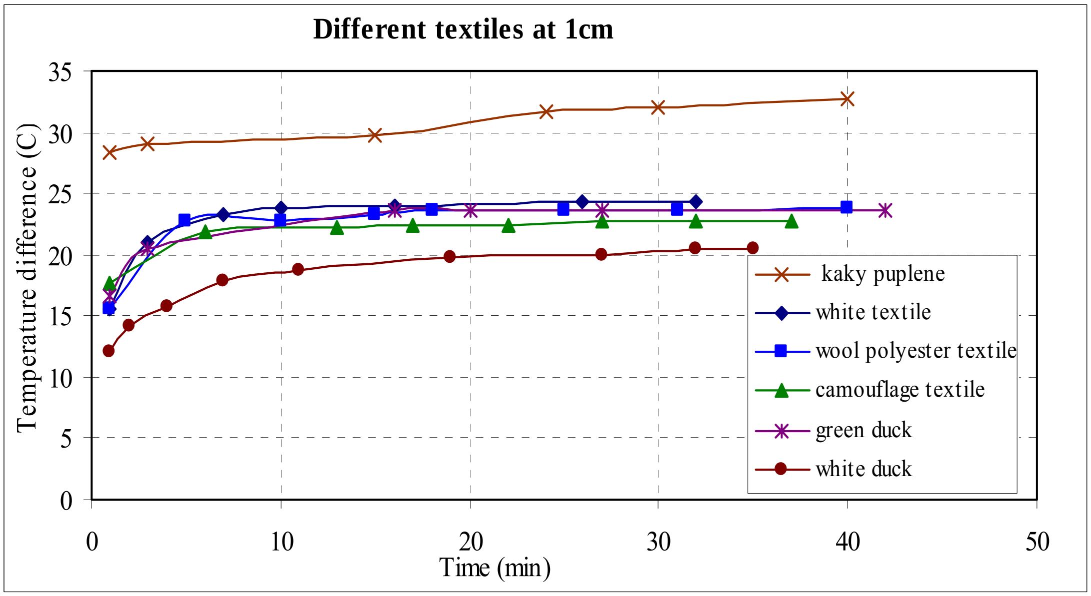

Fig.1. Effect of different types of textiles on temperature difference between the hot plate and background with time.

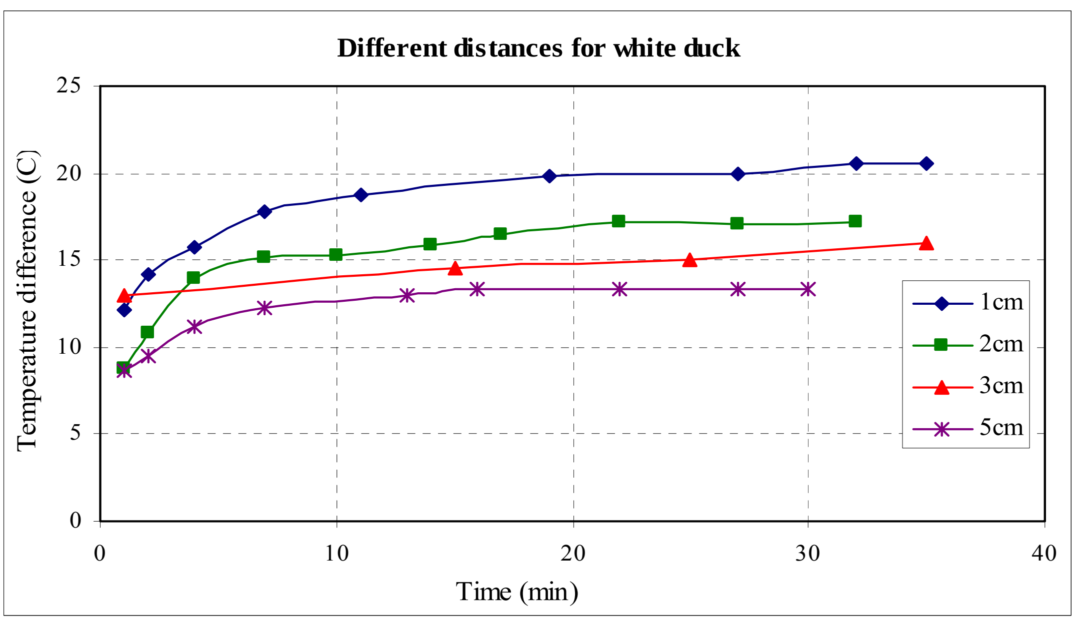

Fig.2. Effect of different distances of white duck textile without treatment on temperature difference with time.

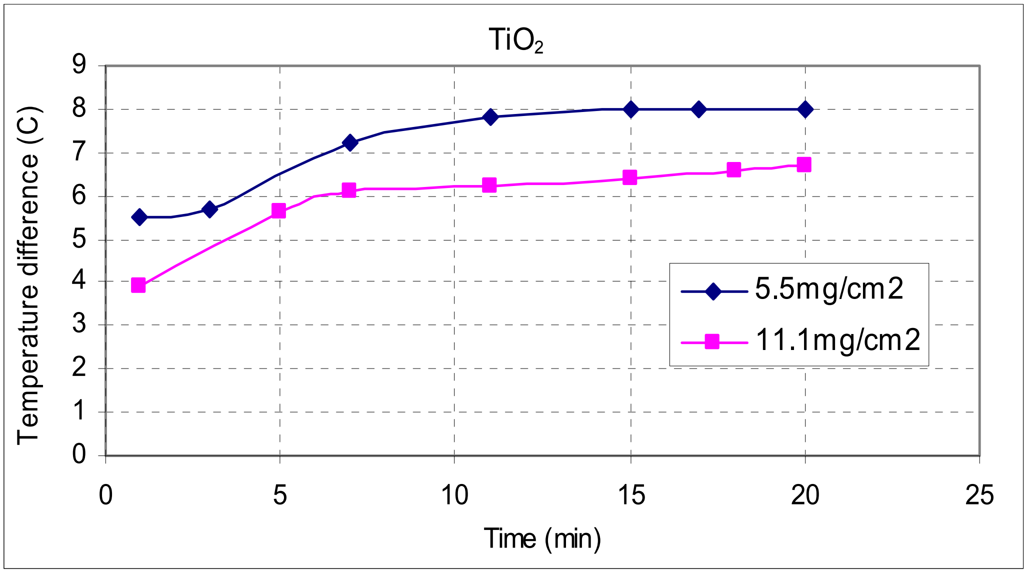

Fig.3. Effect of adding different concentrations of TiO_2 to emulsion paint on temperature difference with time.

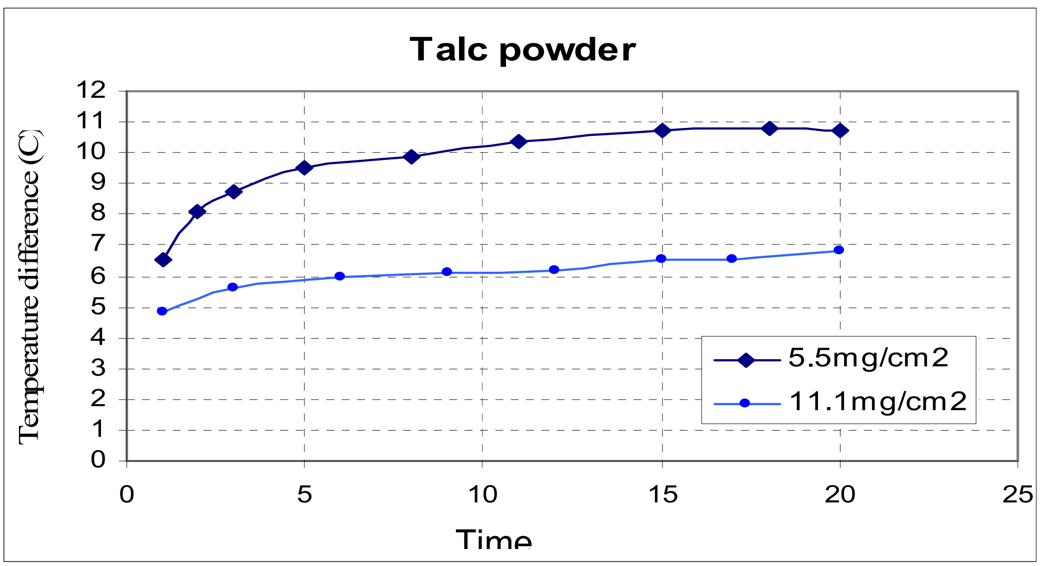

Fig.4. Effect of adding different concentrations of talc powder to emulsion paint on temperature difference with time.

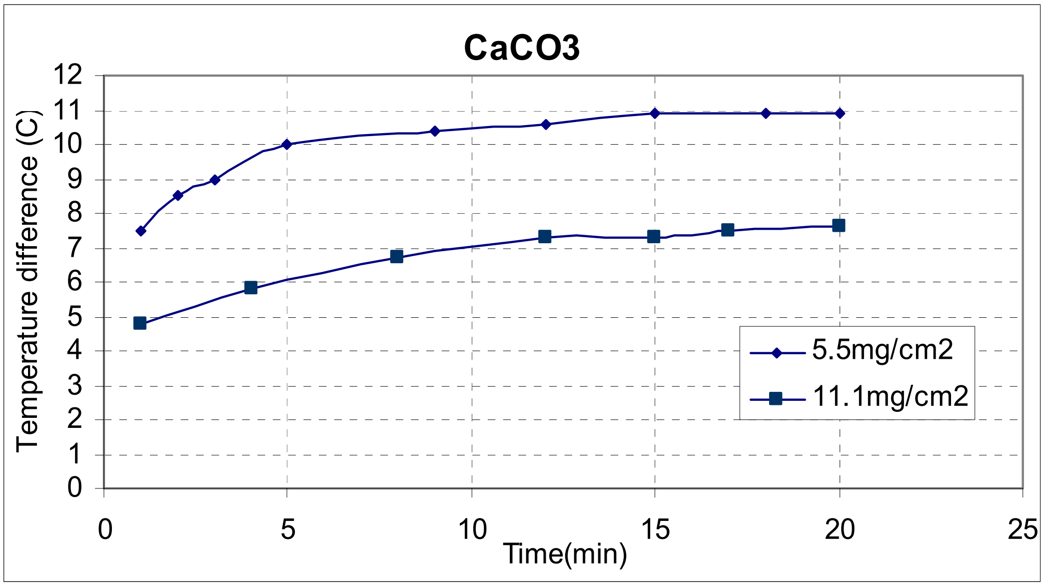

Fig.5. Effect of adding different concentrations of Calcium Carbonate to emulsion paint on temperature difference with time.

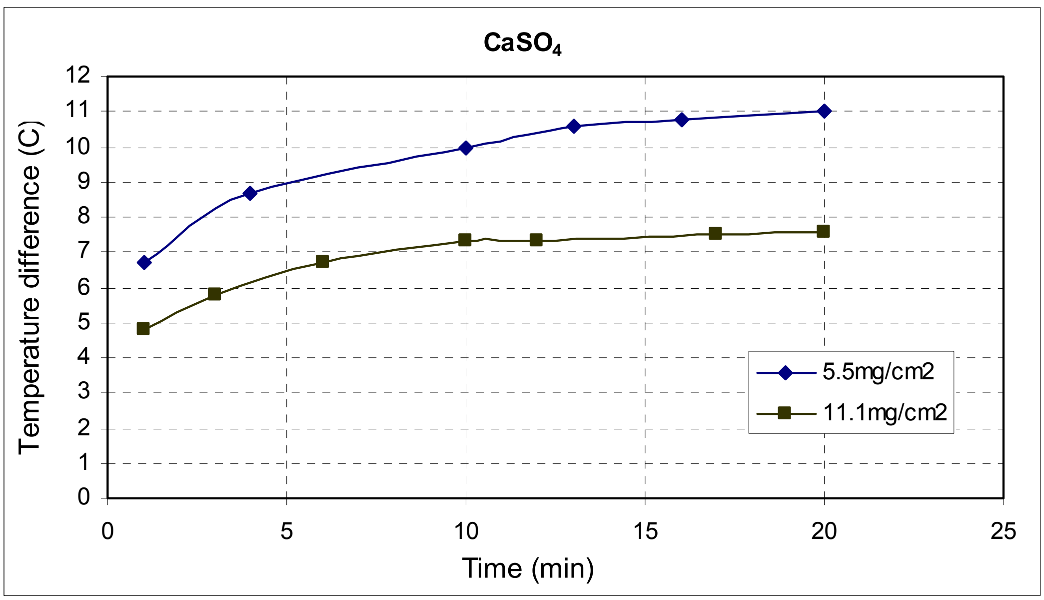

Fig.6. Effect of adding different concentrations of Calcium sulfate to emulsion paint on temperature difference with time.

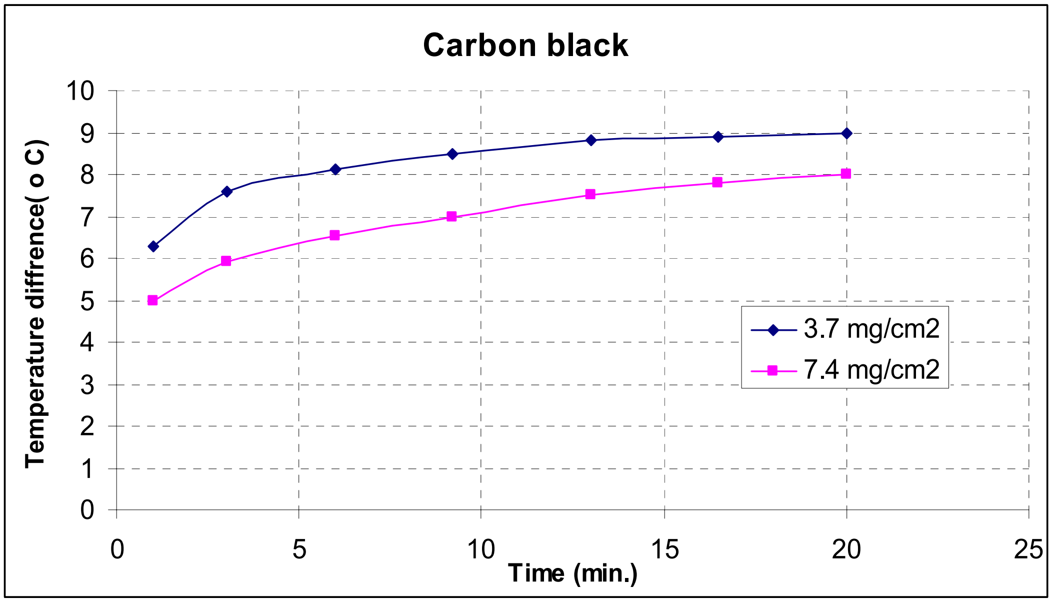

Fig.7 Effect of adding different concentrations of carbon black to emulsion paint on temperature difference with time.

Table (1) Composition of emulsion paint used..

Type of paints	Components	Color	Company
Emulsion paint	latex TiO2 fillers H2O additives	White	ISLAMIC INTERNATIONAL PAINTS &CHEMICAL INDUSTRIES (ISIPAC)

Table (2) Chemicals used in this work

No	Proprieties / Name	Chemical formula	M_{wt} (g/mol)	Supplier
1	Calcium carbonate	$CaCO_3$	100.09	MENA company (Egypt)
2	Talc powder (Magnesium silicates)	$Mg_3Si_4O_{10}(OH)_2$	379.29	EJICM company (Egypt)
3	Carbon black	C	12.011	Columbian chemical company (USA)
4	Calcium sulphate	$CaSO_4$	136	Morga company (Egypt)
5	Titanium Dioxide	TiO_2	80	Morga company (Egypt)

Table (3) Types of textile and its properties.

Properties	Samples name					
	Camouflage textile	White textile	Wool mixed with polyester	Poplene	Green duck	White duck
Weight/ m^2	215 g	215 g	300g	110 g	425 g	450 g
No. of yarn in 1 cm 1. warp 2. weft	43 23	38 19	40 22	54 26	19 10	18 14
Tensile strength in kg 1. warp 2. weft	85 35	80 35	90 45	40 20	140 90	156 140
Composition	65 % cotton 35% polyester	50% cotton 50% polyester	45% wool 55% polyester	50% cotton 50% polyester	50% cotton 50%fiber	50% cotton 50%fiber

Table(4) Effect of different additives on the efficiency of themal obsecuring

Operating time(min.)	Areal density (mg/cm^2)	pure White duck	White duck and Paint	White duck and TiO_2	White duck and Talc powder	White duck and $CaCO_3$	White duck and $CaSO_4$	White duck and Carbon Black
0	zero	89						
	5.5		94	94	91	90	91	92
	11.1			95	93	93.6	93.6	94.9*
20	zero	82.6						
	5.5		90	89	85.6	86.6	85	88.8
	11.1			91	92	89.7	89.8	90

* This values are estimated for the specified areal density**.**