CENTRAL WEAPONS LABORATORY

May, 1970

REPORT

Dealing with Green Camouflage Color for Vehicles

PLAN

Presented by working group[1] organized in London in 1969 for B.M.S. Camouflage

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[1] Italy and Belgium have not participated appreciably in this work.

TABLE OF CONTENTS

CHAPTER 1

History of STANAG Plan 2323 on "Standardization of Camouflage Paints"

1.1. Origin of Plan:

In 1954 (MAS Army (54)66), SHAPE supported a British proposal for standardization of camouflage equipment and techniques and suggested a high priority study for standardizing paint for military vehicles.

The "ground" office of the BMS organized (MAS Army (55)41) a team of camouflage experts who "standardized a basic color or range of colors to be used on military vehicles."

1.2. History and Positions Taken by the Various Countries:

1.2.1. Meeting of January 1956

France has a report of the January 1956 meeting, which only dealt with an exchange of information on national policies with respect to the color of camouflage paint used in the European theatre. At that time, these paints were the following:

France:	a matte army green; a "2 tone" paint being considered.
United Kingdom:	a matte olive drab for combat vehicles. a bright "deep bronze green" for wheeled vehicles.
Denmark:	a single paint called "defense standard color FN/
Canada:	a single color identical to that of the United Kingdom.
Netherlands:	a single matte paint with brightness equal to or less than 15%.
Belgium:	a bright or matte "Belgian khaki". a "2 tone" paint was being considered.

The colors employed were often very similar to each other. Therefore, the infrared reflectance considered was of the order of 20% to 30% for all of the countries, except for France and Belgium, which recommended a "2 tone" paint with reflectances of 60% for photographic detection and 25 to 35% for detection by sight.

Only the United Kingdom considered using a bright paint in time of war. This was the only country which believed that a "bright" paint would be more deceptive than a "matte" paint.

It was decided that experiments would be conducted jointly by the United Kingdom and the Netherlands in order to compare bright and matte paints. It was requested that the various countries specify the colors that they considered using in the future and that they exchange samples of these.

1.2.2. Meeting of December 1956

The experiments conducted by the United Kingdom and the Netherlands reached the following conclusions: the Netherlands decided that a "matte" color produced a better deception effect. However, the United Kingdom decided that the "matte" and "bright" colors were equally effective for camouflage purposes. Nevertheless, the United Kingdom discovered other advantages for bright paint in other areas (protection of vehicles against rust, stimulation of the combatant, etc.).

The various nations defined their position with respect to the selection of colors. Except for three countries, the colors selected were very close to the US olive drab. France used a matte army green but also thought of employing the US olive drab. The other two exceptions were the Netherlands with its "matte gray" and the United Kingdom with its two colors of "bronze green" and olive drab, the latter being very different from that of the US.

At the end of the meeting, the following were proposed:

1. Selection of a tolerance ellipse whose center would be one of the US olive drab shades (to be selected from among the three) with a tolerance for the reflectance. This ellipse was to be defined in such a manner that all of the colors in the zone were to be very close to each other as far as the naked eye was concerned.

2. A solid color for transport vehicles, variegation being permitted for the armored vehicles.

3. With respect to the US tests, the following IR references should be accepted:

   20% ± 5% from 0.9 to 1.2 microns
   25 to 40% from 0.7 to 0.9 microns.

1.2.3. 1958 Meeting

The experts limited themselves to presenting the methods for measuring specular brightness used by their respective nations. Incidently, these methods were all different.

France proposed that the basic color be camouflage paint of shade 34087 described in NF 595 (USA), which it considered using while continuing to call it "matte army green".

1.2.4. March 1959 meeting

The objective of this meeting was to draw up a preliminary STANAG plan to be submitted to the various general staffs.

The discussion dealt essentially with specular brightness. Denmark and Holland favored matte paints (brightness from 10 to 15%) while the United Kingdom recommended a brightness value of 80%. France then proposed a semi-bright paint (brightness between 15% and 35%). The representative of Great Britain was the only one who did not agree with this proposal, just as he had objected to the infrared reflectances proposed during the December 1956 meeting. It seemed to everybody that he even opposed the principal of standardization itself.

In spite of this, a preliminary STANAG plan was drawn up and included the following points:

1. Definition of a color parallelogram only for the European theater.

2. Use of a single color paint for all vehicles except tanks.

3. A brightness value between 10 and 35% (method of measurement not standardized).

4. Values of IR reflectance as follows:

   20% ± 5% from 0.9 to 1.2 microns
   25 to 40% from 0.7 to 0.9 microns.

1.2.5. November 1959 Meeting

The representatives of the Netherlands and the United States pointed out that, because of the appearance of new detection methods, the important thing with respect to IR reflectance was the average chlorophyl curve for the various countries.

The IR reflectance clause of the preliminary plan was eliminated.

1.2.6. October 1960 Meeting

SHAPE and AFNOR TH did not approve the STANAG plan, considering it to be too restrictive, since its limited vehicle paint to a single color. They believed that standardization of camouflage at the BMS level was not necessary.

Denmark and Norway accepted the plan as did the RFA.

Canada rejected the plan. Its matte enamel green paints are not in accordance with the STANAG. Furthermore, it believes that the clause dealing with brightness is not valid.

The USA rejected the plan since it did not want to limit use of camouflage patterns and considered that the polygon did not permit a sufficient choice of varied colors to obtain an effective pattern.

At the end of these exchanges, the question was asked whether it was advisable to retain the team of camouflage experts in view of the sparseness of the results obtained.

1.2.7. January 1961 Meeting

In spite of the opinions of the USA and the Belgian delegations, it was decided to retain the equipment in order to "exchange information".

A proposal by Denmark and France was then accepted. This proposal considered the definition of one or several polygons in order to include a larger number of colors in the STANAG. Furthermore, it was judged necessary to standardize the method for evaluating specular brightness.

1.2.8. March 1961 Meeting

Actually, the positions taken by the various countries had not changed by this date.

1. The United Kingdom believes that the STANAG is useless.

2. The Netherlands and West Germany believe that different colors and therefore several polygons are needed for camouflage.

3. France, Belgium and Canada recommend a basic color for the Central European theatre in addition to a range of colors for variegation.

4. Norway requests authorization of the use of white for camouflage in snow covered areas.

Following this meeting, it was decided to draw up a questionnaire to be presented to the various general staffs. In particular, this questionnaire would ask whether standardization was useful or not and what would be the advantages and disadvantages of standardizing.

1.2.9. 1962 Meeting

This meeting discussed the analysis of answers to the questionnaire.

The positions taken by the various countries did not change and it was decided to abandon STANAG plan 2323.

CHAPTER 2

General Bases for a STANAG Defining a Common Camouflage Green

2.1. Background: The Milan-Hot Case

The Milan and Hot devices consists principally of a launcher tube and a missile.

The development of the specifications dealing with these devices, which will be manufactured partly in Germany and partly in France, has required creation of a standardization committee which has worked for several years.

A subcommittee has been charged with the problems of painting and therefore of colors.

All of the problems dealing with marking colors for the ammunition were solved quickly by referring to the STANAG No. 2321 which deals with colors for marking ammunition.

Because of a lack of an adequate STANAG, the problem of the background color, i.e., the camouflage green with IR reflectance, required a special study which lasted two years and which ended in the selection of a well-defined camouflage green.

2.2. Interest in a Common Green Paint

2.2.1. France and Germany agree on the use of this green in all of the purchases made jointly by these two countries.

2.2.2. There is a chance of this problem of green arising everytime a military purchase is made internationally where close examination of the definition of the paints used may be desired.

It seems that if two countries have different colors, use in one country of the paint employed by the other country poses problems if the customer is difficult to satisfy with respect to reproducibility of his color. Furthermore, if each country paints with its own color, there will be difficulty in assembling parts manufactured in the two countries.

It will be necessary to apply an additional layer, masking the inscriptions, which will involve a great deal of labor.

2.2.3. All of these difficulties would be avoided if there were available a common camouflage green suited to the European theatre and defined in a STANAG.

2.3. Timeliness for Working Out A Stanag on a Common Camouflage Green.

The time is ripe for taking care of this problem since:

1. We have had experience with the difficulties involved with drawing up such a document.

2. We are now aware of the differences in the equipment.

3. Several countries are considering changing their camouflage green.

In view of these various circumstances, the B.M.S., in June 1969 at London, tried to assign the study of this question to France, Germany and Denmark.

2.4. General Provisions for Establishment of a STANAG Defining a Common Camouflage Green and Conditions for Its Use

2.4.1. Definition of "NATO Army Green"

This green is defined using a maximum number of guarantees with respect to the requirements imposed (specifications) and to the methods of checking them (inspection methods).

2.4.2. Use of this "NATO Army Green"

For domestic military equipment, each country will employ NATO green if this seems to be opportune.

For military equipment which is purchased in the international market, the member nations of the B.M.S. are obliged to employ NATO green.

3. Definition of a Common Army Green and Justification for the Selection.

3.1. General Remarks

3.1.1. Each country has a variety of types of landscape. Each type occurs more or less frequently. Furthermore, each category of foliage occurs more or less frequently, but to an extent which is not generally known.

Under these conditions, each nation's army green presently employed has been defined in accordance with criteria which are not perfectly scientific, but which are partly subjective. Advantage may be taken of this uncertainty to define a common NATO Green.

3.1.2. A medium green has been selected from among the various national greens. This color used in the finish painting of military equipment gives it a basic camouflage which can rather easily be adapted to specific terrains by additional means, either equipments or artificial methods.

3.2. Technical Bases

3.2.1. Color references.

Standards for green used until then by the various nations was used as a starting point.

Taking into account the differences in apparatus, measurement had to be made of all of these standards with the same apparatus in order to arrive at a valid comparison.

France was assigned the task of making the measurements. The following equipment was used:

3.2.1.1. For measurements of x, y and Y: the Leres spectrophotometer, with integrated power supply and circuit, model Trilac, using magnesium oxide as the white standard.

3.2.1.2. For measurement of specular brightness: the photo volt brightness meter, with probe 660 A, using black Carrare glass as a standard.

3.2.1.3. For measurement of reflectance in the infrared area: The Beckman spectrophotometer model DK 2 AR, using magnesium oxide as the standard for white.

3.2.2. Results of Measurements

The results obtained for the various greens are listed in a Table and a graph that appear in Appendix 1. The proposed NATO standard appears among the greens considered.

3.3. Justification for the Specifications imposed on NATO Green

3.3.1. Reflectance Curve

3.3.1.1. General Form

The curve arrived at has the essential characteristics of the chlorophyl curve. Various experiments have shown that a green paint which is acceptable to the eye, but whose curve is not of the chlorophyl type, is easily detected by employing combinations of filters and films whose band pass is situated at the point where the curve for this paint deviates markedly from the chlorophyl form.

3.3.1.2. Special conditions.

In order to obtain a curve that resembles the chlorophyl curve as much as possible, it is necessary that:

1. The maximum at 550 nanometers must be greater in magnitude than the minimum at 670 nanometers.

2. The rise after this minimum at 670 nanometers must be as sharp as possible.

3. The maximum must be located below or at 800 nanometers.

In order to obtain good results in ordinary infrared photography or with false-color film as well as with night vision equipment, it is necessary that the reflectance in the infrared region be between 35 and 40% from 750 to 800 nanometers and between 25 and 40% from 800 to 1,200 nanometers, and that the reflectance does not increase beginning with 800 nanometers.

3.3.2. Color

According to the trichromatic coordinates, it can be observed that the color is very close to the greens employed by various countries as is confirmed by a rapid visual examination.

The color proposed is an acceptable compromise. Changing it slightly in order to satisfy the requests of any country would require work and time without any hope of improving it appreciably.

3.3.3. Specular Brightness

Three categories for brightness have been proposed:

3.3.3.1. It is certain that the bright paints have the best mechanical and chemical resistance since they contain more binder which confirms these properties.

3.3.3.2. It is generally admitted that the matte paints are best for camouflaging.

3.3.3.3. The semi-bright paint is a compromise, both technically because of the arguments presented above and practically, since, depending on the country, the green used on the vehicles is matte, semi-bright or bright. It is to be recommended for an international purchase where the two contracting countries employ paints of different values of brightness.

REPORT DEALING WITH GREEN COLOR FOR VEHICLES

APPENDIX 1

RESULTS OF MEASUREMENTS OF GREEN STANDARDS FOR VARIOUS COUNTRIES

1. General Remarks

1.1. Measurement Conditions:

1.1.1. For x, y, Y:

Apparatus employed: Leres spectrophotometer, model Trilac with integrated circuits. Standard: Magnesium Oxide.

1.1.2. For Reflectance Curve

Apparatus employed: Beckman spectrophotometer, model DK 2 AR with integrated circuit. Standard: Magnesium Oxide.

1.1.3. For Specular Brightness:

Apparatus employed: photovolt brightness meter, probe 660 A. Standard: Black Carrare glass.

Each result represents the average of several measurements taken.

1.2. References

The results mentioned below have appeared in reports issued by the Central Weapons Laboratory:

Report No. 1394/CE, dated July 22, 1969: American Colors.
Report No. 1395/CE, dated July 22, 1969: French, Danish and Canadian Standards (matte shades)
Report No. 2207/CE, dated October 31, 1969: German, Dutch, English and Canadian Standards (bright shade).
Report No. 2596/CE, dated Dec. 15, 1969: Franco-German Green 1022.

2. Results Obtained.

2.1. The results obtained appear in a green plate. They are summarized in a table with several comments.

2.2. They should be taken into consideration particularly in regard to x, y, and Y, since France has measured standards taken from the National Standards of the USA, the United Kingdom, Canada, and Germany whose color (x, y and Y) are prescribed, but which do not always have the value of infrared reflectance required by the military specifications of these countries.

Country	Color Reference	x	y	Y	B_s %	Class of Specular	Type of Sample Measured
Franco-German (1022)	Army green	0.321	0.338	0.102	10	Semi-bright	Official cardboard standard
Germany	RAL 6014	0.330	0.340	0.090	1.1	Semi-bright	Official cardboard standard
England	Green deep bronze Ref.: 224 1964	0.318	0.363	0.044	7.4	Bright	--
Canada	Green 503.101/1965	0.328	0.340	0.059	32	Semi-bright	--
	Green 503.301	0.324	0.335	0.074	0.5	Matte	--
Denmark	Matgrunmaling SM 67	0.342	0.363	0.110	0.7	Matte	Painted metallic plate
USA	Olive drab 34 087	0.330	0.345	0.104	0.3	Matte	Official cardboard standard
France	Army green 2420 IR	0.326	0.337	0.100	2.35	Semi-bright	--
Holland	Light green, Ref.508	0.324	0.332	0.098	11	Semi-bright	Painted metallic plate
Denmark France Germany	"Army green I.R. NATO"	0.330	0.351	0.092	20	Brilliant semi-brilliant Matte	Painted metallic Plate

3. Conclusion

In view of the numerical results obtained the proposed Franco-Germany Green for NATO is a medium green.

If this is compared visually with the various standards submitted, it can be seen that it is not very different from each one of them.

standard

REPORT CONCERNING GREEN COLOR FOR VEHICLE CAMOUFLAGE

APPENDIX 2

Results of measurements taken in the spectral region of false-color film.

APPENDIX 2

Importance of False-color film for experimenting with camouflage paints.

1. Pictures Taken in narrow spectral zones

Experiments with camouflage colors dealing with their re-emission with respect to that found in nature, are conducted essentially by taking pictures in narrow spectral zones. The purpose is to take pictures in spectral regions which are as narrow as possible and to make comparisons of the agreement existing between the camouflage colors and those of nature in each of these spectral regions.

Because the troops in the European sector will nearly always seek to camouflage themselves in green vegetation, a green camouflage color which is well suited to overall re-emission of green vegetation is particularly important.

Ordinary black and white reconnaissance film, which covers all of the spectral region from 400 to 700 nanometers, largely eliminates the deviations in re-emission which occur between camouflage color and natural color. Neither is man, using the naked eye, capable of perceiving deviations in the blue, red and infrared spectral regions, since the greatest sensitivity of the eye in the green region is located at 550 nanometers.

On the contrary, the picture taken in narrow spectral regions supply information on the agreement of re-emission of camouflage colors with those in natural colors within a given spectral region. Nevertheless, they do not indicate what the agreement is among the various spectral regions considered separately.

2. The Detecting Effect of False-color Film

False-color film permits simultaneous covering of several spectral regions and interpreting them by comparison with a given reproduced color.

"Ektachrome-Infrared-Aero-Film", whose three layers are sensitive to color are sensitive in the following regions (when a dark yellow filter, Kodak-Wratten 12 or OG 515, Jenaer Glas is used) (see Figure 1):

from 510 to 580 nanometers (green)
from 580 to 675 nanometers (red)
from 675 to 890 nanometers (infrared)

We observe that the camouflage paints, in contrast to those present in nature, which show us most often in red, have shades ranging from blue to pink and including violet.

3. The Ratio Between the Red and the Infrared Spectral Regions is Decisive

Analyses and evaluations of reflectance curves made up to the present time for pictures taken on false-color film, have revealed that the ratio of surfaces below the reflectance curve, i.e., the ratio between the region from 580 to 675 nanometers and the region from 675 to 890 nanometers, is decisive for the red or blue tones. With respect to the film, this means the ratio of exposure time between the layer sensitive to red and the layer sensitive to infrared. The region from 510 to 580 nanometers (layer sensitive to red) is of little importance here and only changes the colors very slightly (Figure 2).

Figure 3: Graphic representation of the displacement of colors, the ratio of the surfaces below the reflectance curve being from 580 to 675 nanometers and from 675 to 890 nanometers:

4. Difference between appearance of Colors Re-emitted by Green Camouflage Compared to those of Vegetation

The reflectance curve for green vegetation indicates a ratio of red to infrared surfaces (below the reflectance curve) for false-color film of about 1:11 and 1:14, whereas re-emission of green camouflage paints gives smaller ratios.

Ratio of surfaces below the reflectance curve between the region from 580 to 675 and the region from 675 to 890 nanometers.

While the green vegetation always exhibits a minimum of re-emission in the region between 650 and 680 nanometers (red) and a minimum of re-emission in the region from 750 to 1,200 nanometers (infrared), the camouflage colors in question have neither an absolute minimum in the red nor high proportional re-emission in the infrared.

5. Limits for Color Inversion

While looking for the limits of color inversion of "Ektachrome-Infrared-Aero-Film", it was established that, for a ratio of red to infrared up to 1:5.5, the color is reproduced as blue and that, in the region between 1:6 and 1:8.5, the tone reproduced is displaced from violet to carmine. For a surface ratio of 1:9 or higher, the color appears to be red (Figure 3).

Picture taken in false-color film
"army green"

Figure 5

6. The Value of Information Given by False-Color Film

This is where the importance of false-color film as an aide in experimentation shows up.

Since, on the one hand, the requirement for rigorously adapting the appearance of re-emission of the surrounding vegetation and on the other hand, the absence of respresentative measurements of green vegetation (edge of forest of deciduous trees, for example), it is possible to observe in the study of camouflage paints, with the aid of false-color film, to what extent these paints correspond to the overall re-emission of vegetation (re-emission of the leaf by itself, reduced by the shadows between the various leaves).

The objective sought is to obtain as small a value as possible of re-emission in the infrared of the camouflage paint whose ratio of re-emission relative to the two other spectral regions (green and red) nevertheless produces a reproduction in red. If this is confirmed

by the false-color film, the appearance of the re-emission in the green, red and infrared also produces a camouflaging effect in these regions, as far as other reconnaissance methods are concerned.

This is why the information obtained by use of false-color film is interesting not only from the viewpoint of its possible use as a means of reconnaissance to which we could object because of technical, logistic and financial difficulties. The fact is that the quantitative exploitation of the colors produced by the pictures makes it possible to use the film to compare the ratio between the spectral response of the vegetation and the camouflage paint in three spectral regions (green, red and infrared).

The comparison may be considered to be representative to a great extent, since these three regions are recorded simultaneously in one photograph and since the difference in re-emission between the camouflage paint and natural vegetation (provided, of course, that the treatment is homogeneous) shows up immediately as a displacement of colors.

7. Conclusion

The photograph in Figure 6 (as well as the slides shown to the B.M.S. by West Germany) proves that the "I.R. Army Green" proposed to the B.M.S. by the Working Group is, from the point of view of terrain camouflage, technically better than the other greens available to West Germany for taking the pictures.