A STOP SIGN FOR USE IN THE DARK

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STICHTING WETENSCHAPPELIJK ONDERZOEK VERKEERSVEILIGHEID

INSTITUTE FOR ROAD SAFETY RESEARCH (SWOV)

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Foreword

The investigation into the suitability for use in the dark of the stop sign as defined in Article 106 (b) of the Netherlands Traffic Rules and Signs Regulations was carried out by SWOV at the request of the Royal Netherlands Touring Club ANWB and on the instructions of the Ministry of Finance.
To enhance the value of the study SWOV contacted all the users of the official stop sign in the Netherlands, viz. the Ministries of Finance, Justice, Agriculture & Fisheries and Transport & Public Works.
An ad hoc committee was formed by the representatives of these ministries. This made it possible for any other particular requirements of the users to be taken into account as the work proceeded, although the investigation was based in the first instance on optimum visibility of the sign in darkness. After a listing of the circumstances under which the sign was used had been drawn up, SWOV's Human Factors division (D. J. Griep) formulated a number of requirements which the sign had to satisfy. It was found that the stop sign in use at present did not meet these requirements in full and under all circumstances.
As a result of these findings SWOV entrusted the Institute for Perception RVO-TNO, Soesterberg, with a development programme. This programme was carried out by the Visuology Branch (J. J. Vos, assisted by J. Boogaard and H. J. Leebeek), and the results in the form of some prototypes were shown to representatives of the groups of users. One of these prototypes was then developed and tested further, after which KEMA (N.V. tot Keuring van Electrotechnische Materialen, Arnhem) and appropriate manufacturers were consulted to learn whether the new sign as developed could be manufactured at acceptable cost. The reply was in the affirmative.
KEMA will be able to test the sign at Arnhem. The provisional specifications drawn up in conjunction with KEMA are included in this report.
The new sign does not differ by daylight from the one used up to the present. In darkness, however, it flashes alternately a red light and a central blue 'point light. Confusion can be prevented if the sign is used by all persons authorized to stop road users.
Introduction of the new sign will entail amending the definition of stop signs as given in the Netherlands Traffic Rules and Signs Regulations.

January 1969

E. Asmussen

Director, Institute for Road Safety Research (SWOV)

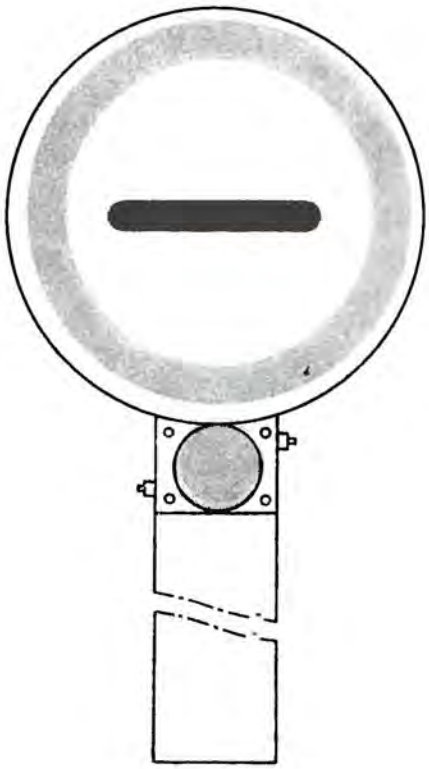


Figure 1
Stop sign as referred to in Article 106 of the Netherlands Traffic Rules and Signs Regulations

1 Present statutory regulations

The directions to road-users of interest for the present study are laid down in Articles 103, 105 and 106 of the Netherlands Traffic Rules and Signs Regulations, which read as follows:

Article 103: Directions to road-users to be given by officials and other persons responsible for controlling traffic and recognizable as such shall be given verbally or by means of hand signals, either to individual road-users or to the traffic as a whole.

Article 105: The hand signals may be clarified by means of a white or black and white stick.

Article 106: In order to convey to a road-user that he is required to stop, use may be made, without prejudice to that laid down in the preceding Articles, of:

a. by day, a stop sign consisting of:

a round white disc with a red edge inside which the name of the service concerned can be stated in black letters, all in accordance with model n of Appendix I (see Fig. 1), or a red flag at level crossings or tram-line crossings;

b. by night, a stop sign consisting of:

a red light moved rapidly up and down, or a round white disc with red edge, both of transparent material, with a red light underneath by means of which a rapid up-and-down red light signal is first given which, as the road-users to be stopped draw nearer, is switched off and replaced by the transparent sign: the service concerned can be stated in black letters in the white part, all in accordance with model n of Appendix I (see Fig. 1);

c. a stop sign consisting of:

a transparent sign mounted on a police-car and including the words 'Stop' or 'Stop Police' in red letters illuminated against a dark background.

Stop signs as referred to in this Article may also be used by officials authorized to stop road-users for purposes other than the directing of traffic.

2 Circumstances under which the signs are used

For use at night one has a choice between a red light and a stop sign as described under Article 106 (b) in the form of a tabletennis bat with a red light in the handle (further referred to as 'bat-type signs'). The latter are in fact still used only by Ministry of Agriculture & Fisheries inspectors and by State Traffic Inspectorate staff. Customs officers use red lamps, as do the police officers. Motorized police officers normally use an illuminated transparent sign on their cars or a loudspeaker. The use of a red lamp, with or without bat-type signs, is usually limited to secondary roads, users generally considering such signs too dangerous for use on busy roads.

The stop sign proves to be inadequately recognizable in practice. Ministry of Agriculture & Fisheries and State Traffic Inspectorate staff who use the signs are not as a rule in uniform and are not therefore recognizable by their dress. Officers in uniform are not, or insufficiently, recognizable when controlling or halting traffic in the dark on unlit roads.

It has to be accepted that there is a definite element of risk to both the road-user and the official in stopping traffic during darkness; it is frequently impossible to make even a rough estimate of distances and speeds under such conditions.

3 Requirements for an effective stop sign

3.1 Visibility

If it is assumed that the sign should be visible to oncoming traffic at sufficient distance for an approaching driver to stop before he reaches it, the minimum visibility distance needed can be calculated according to the formula for the braking distance S:

$$S = RT.v + \tfrac{1}{2}\frac{v^2}{a}$$

where: RT = reaction time of driver + vehicle
a = braking deceleration of vehicle
v = speed of vehicle

For a = 4 m/sec/sec
RT = 3 sec
v = 31 m/sec
a braking distance of approx. 200 m is obtained.

A reaction time of 3 seconds for driver + vehicle may be considered as not impossible when faced with unexpected events.

The minimum braking deceleration - on a dry and clean road surface - as laid down by law for passenger cars is 5.2 m/sec/sec.
In most cars, however, the maximum braking deceleration is not only determined by the brakes themselves but also by the coefficient of friction between tyres and road surface.
The braking decelerations achievable in practice are accordingly of the order of 7-10 m/sec/sec.

The surface roughness of wet roads, however, is often considerably less than that of dry roads, making the friction coefficient less too.
The State Roadbuilding Laboratory considers a (State) highway with a roughness of 0.51 when wet still adequately rough.
Braking decelerations of approx. 4 m/sec/sec will be attainable by passenger cars on such a surface.
Although buses and trucks as a rule can only manage lower braking decelerations

on a dry road surface - the law requires 4.5 m/sec/sec and 4.0 m/sec/sec respectively for them - the braking deceleration on a wet surface (with properly adjusted brakes) will not be very much lower than for cars. Since buses and trucks are normally driven less fast than cars, the situation is less critical here. It may therefore not be unrealistic - taking the most critical situation as starting point - to base one's calculations on an attainable braking deceleration of 4 m/sec/sec. [1])

A speed of 110 km/h is not as a rule exceeded by most (85-90 %) drivers on roads without separate carriageways; this has been demonstrated by speed measurements carried out for SWOV's study 'Speed limits outside built-up areas.'

A braking distance of about 200 m could be taken as the minimum distance from which the stop sign should be visible for oncoming drivers. When considering that the sign has to be spotted in darkness on unlit roads, the visibility distance could be expressed in terms of the minimum intensity required for the light incorporated in the sign.

The present signs, i.e. the red light either combined or not with an illuminated bat-type sign, can satisfy these requirements. This does not, however, mean that a stop sign that can be seen from 200 metres off is also distinguished as an official stop sign. And it is this recognizability which has to be taken as a primary requirement when assessing the effectiveness of a stop sign.

3.2 Recognizability

A yardstick for the recognizability of the stop sign is the extent to which it is specific for the situation in which it is used. A red light is not always distinguishable as an official stop sign, partly because similar lights are also used by persons who are not authorized to halt traffic. Little improvement is obtained with the use of an illuminated bat-type sign, since the present versions are only perceived as blurred spots at the distance in question (200 m). It will be evident that a 'smudge' of light of this type provides little useful information about the person seeking to stop the traffic.

[1]) Data on the braking deceleration of cars were provided by H. G. Paar, research engineer Institute for Road Safety Research (SWOV).

4 Possible improvements

4.1 The increasing of the distance at which the sign is recognizable to 200 m appears at first sight to be possible by selecting a stronger power source and combining the stronger light thus obtained with a larger sign. However, if the sign is to be used with ease it cannot be made too large. To make the present bat-type sign visible at the required distance by means of a stronger light, something like for instance a car battery would have to be used.

4.2 An alternative could be not so much to make the sign itself but the officer holding it clearly distinguishable by having the light shine on him. This solution could only work for uniformed officials, while in this case too the present power source - single batteries in the handle of the sign - are not strong enough to make the official clearly recognizable at the required distance.

4.3 Improvement of the recognizability of the present sign would still be possible by better arrangement of the elements making up the disc and applying special lenses, hence in principle without deviating from the present dimensions and design (model n, Appendix I to the Netherlands Traffic Rules & Signs Regs.). This would not, however, be sufficient to make the sign distinguishable at the required 200 m distance. Moreover, if lenses were applied the beam would have to be accurately directed.

4.4 For a solution which will guarantee that the sign will be properly distinguishable at a greater distance, it will accordingly be necessary to depart from the present design.
A contract with the Institute for Perception RVO-TNO, Soesterberg, was drawn up for a research programme to be carried out on the basis of 4.3 and 4.4 with a view to the development of an improved stop sign.

5 The research programme

5.1 At the initiative of the State Traffic Inspectorate a prototype improved stop sign in accordance with the definition given in the Traffic Rules and Signs Regulations was produced by industry.
This prototype differed from the current model by having a better light distribution and a flashing instead of a non-flashing red light in the handle of the illuminated sign. This first prototype was designed chiefly to improve the visibility of the sign. The result of the changes introduced was that the visibility distance was in fact clearly improved but that the distance at which the sign was distinguishable remained very much the same, staying around 50 metres and even tending to decrease, since the red light and the black 'bar' in the sign failed to show up against the bright white light. Different materials or beam patterns of the light did not yield any better results.

5.2 A real improvement of the present stop sign in such a way as to make its - statutorily defined - shape distinguishable at a greater distance proved to be impossible. It was found to be essential to depart from the present model if any such improvement were to be obtained. The research carried out by the Institute for Perception RVO-TNO took as its starting point that it had to be possible to develop a specific sign based on the variation in the sign's light pattern. To this end a red light was fitted behind the white transparent area of the 'bat'. This improved night-time recognizability in the sense that red is known to mean danger. However, this in itself is not specific enough for the sign to be recognized as meaning stop. To accentuate the specific nature of the sign the red light was accordingly combined with a small blue 'point light' in the centre, so that the sign shines alternately red and blue. When this combination was tested it was found that oncoming drivers spotted an alternately red and blue light over 200 m away. From about 150 m distance the red light was distinguished as a round sign, and the sign was distinguishable as such at about 50 m. The distance was, however, greater when the sign was caught in the headlights of an approaching vehicle, because the edge around the 'bat' was in retro-reflecting material.
When the lights incorporated in it are not switched on the new sign is outwardly the same as the bat-type stop sign used up to now, viz. a round white disc with a red edge, as in model n of Appendix I to the Netherlands Traffic Rules and Signs Regulations.

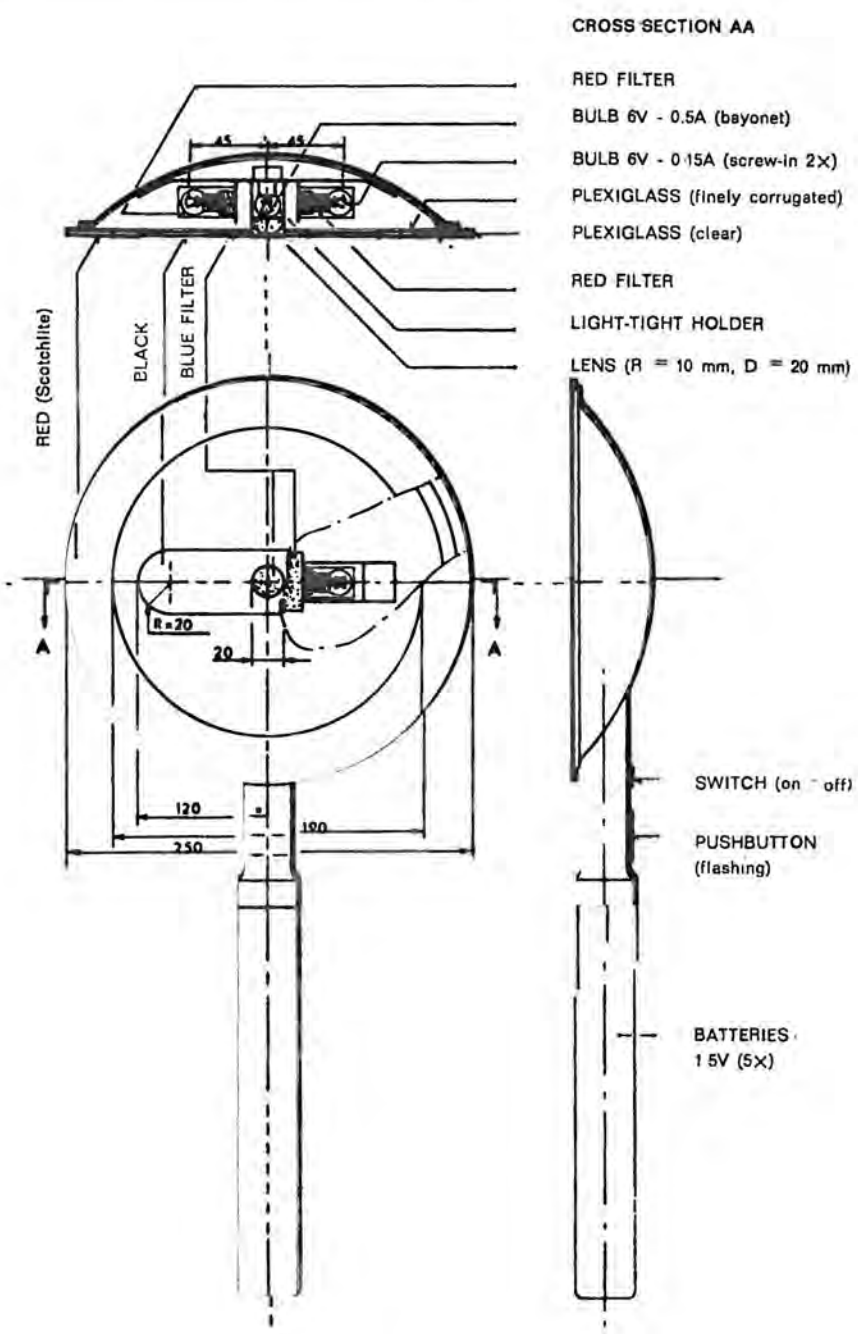
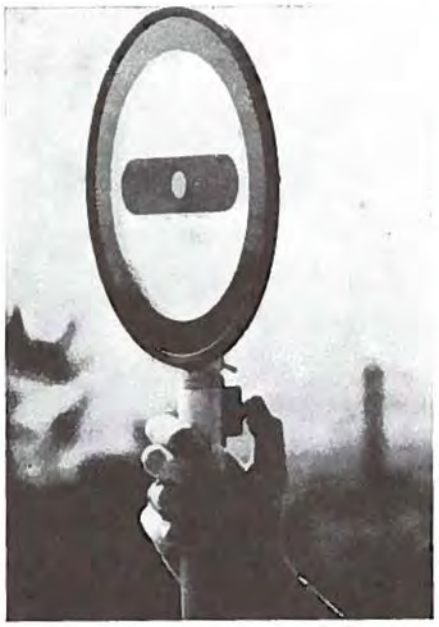


Figure 2
Design of the laboratory model



Front/side view

Appearance close up, when the sign is illuminated in headlights and with the blue light on (the central blue light also irradiates very strongly in photographs)

Opened up

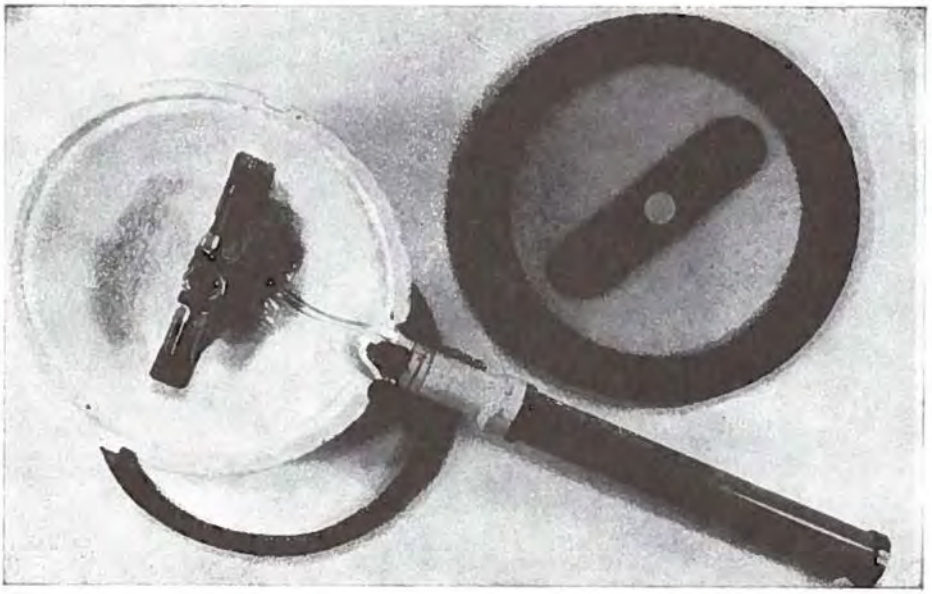


Figure 3
Some photographs of the laboratory model stop sign.

The result of the development work in the form of a laboratory model was shown to representatives of the bodies using the stop sign. This model was unanimously considered suitable as basis for a prototype, the sign being deemed sufficiently specific for application as an official stop sign during the hours of darkness (see Fig. 2,3).

Section 7 gives the specifications as prepared in consultation with KEMA N.V. (N.V. tot Keuring van Electrotechnische Materialen) on the basis of the model developed by the Institute for Perception RVO-TNO. Further details on the development work may be found in that Institute's report IZF 1967-C 3 (in Dutch).

6 Summary

The present official stop signs for use at night — a red light or a red light in combination with an illuminated white bat-type sign — are not sufficiently for road-users. For the present type of sign to meet the requirements in this respect it would have to be made far too large and heavy for a man to handle.
A new stop sign has accordingly been developed, which in daylight looks the same as the existing one — a white disc with red edge — but differs from it when used at night in that it incorporates a red light and a small blue 'point light' which flash alternately. This light pattern can be considered sufficiently specific for confusion with unofficial stop signals to be out of the question. Road-users who have come to within 150 m of the sign can recognize it as a round signal, while at 50 m the details of the sign can be made out independently of the alternately red and blue flashing lights.
When the sign is lit up by the dipped lights of an oncomming vehicle, the distance at which it is recognizable is greater. This effect is obtained by having the red edging of the sign in retro-reflecting material. Recognizability could be further increased by the new sign being utilized as uniformly as possible by the groups of users for whom it has been developed.
When the red and blue lights are switched off the sign looks like the present stop sign, viz. a round white disc with a red edge, with inside the disc a black bar in which the name of the service can be stated if required.
Those who operate by daylight, however, would find a simple, e.g. wooden, bat-type sign sufficient. In this case it would be advisable to increase the sign's daytime and dusk visibility by having the red edging in fluorescent material.
In view of the different appearance of the new sign when used in the dark, an appropriate amendment will have to be made to the present Traffic Rules and Signs Regulations.

7 Specifications for stop signs

7.1 Dimensions

The dimensions in mm are given on Fig. 4.

7.2 Weight

The total weight, including batteries, may not exceed 1000 grammes. The equilibrium point should not be above the line A-A.

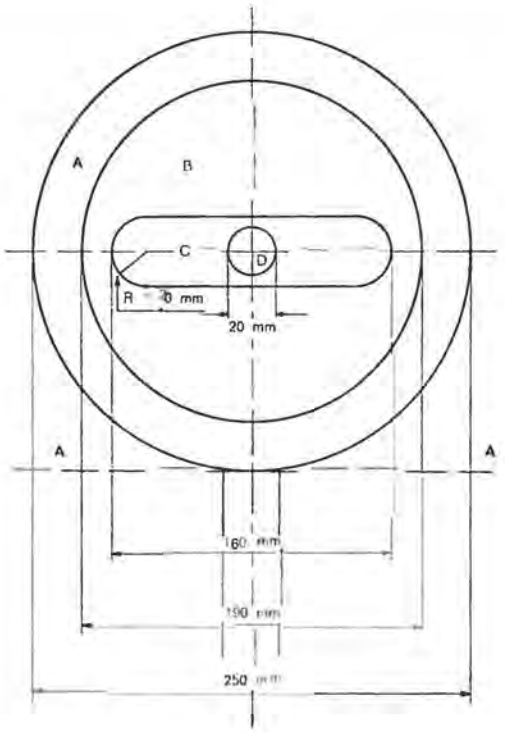


Figure 4

7.3 Photometric requirements (1)

Edge A (Fig. 4): Red retro-reflecting material, which meets the following colorometric requirements:

$$y < 0.290 + 0.080\,x$$
$$y > 0.313$$
$$y > 0.881 - 0.933\,x \text{ (2)}$$

The retro-reflection factor of the material must satisfy:

$$1500 < \beta_r < 4500 \text{ (2)}$$

The diffuse reflection factor of the material must satisfy:

$$\beta_d > 4.5 \text{ (2)}$$

Field B: Finely corrugated colourless material. The red light should have a forward intensity of at least 0.3 cd at a horizontal angle of $\pm 8°$ and a vertical angle of $\pm 6°$ with respect to normal for the face. An adequately even quality is in any case ensured if the proportion between the brightness values of any two 7-sq.cm parts (approx. 3 cm diameter) is never greater than two.

The colour of the red light must satisfy:

$$x > 0.980 - y$$
$$y > 0.305$$
$$y < 0.320 \text{ (3)}$$

The inside of the bowl-shaped back of the sign, by which the colour impression of the field B is determined, must be white.

This white must satisfy the following requirements:

$$y > 0.604 - 0.970\,x$$
$$y > x$$
$$y < 0.695 - x$$
$$y < 0.020 + x \text{ (2)}$$

Bar C: Black material.

(1) The colours have been fixed by the colour specification system as accepted by the Commission Internationale de l'Eclairage (CIE, Cambridge 1931).
(2) These specifications are taken from the Norm Verkeerstekens ('Traffic Signs Standard'), NEN 3381. For the circumstances under which these specifications apply reference should be made to that Standard.
(3) These specifications have been taken from the Norm Verkeerslichteninstallaties ('Traffic Signals Standard'), NEN 3322. For the circumstances under which these specifications apply reference should made to that Standard.
(4) These specifications have been taken from DIN 6163 (German Standard). For the circumstances under which they are applicable reference should be made to that Standard.

Field D: This field must have a forward intensity of at least 2 cd at the angles as referred to under field B.

The colour of the blue light must satisfy:

$y < 0.065 + 0.805\,x$
$x < 0.400 - y$
$x < 0.133 + 0.600\,y$ (4)

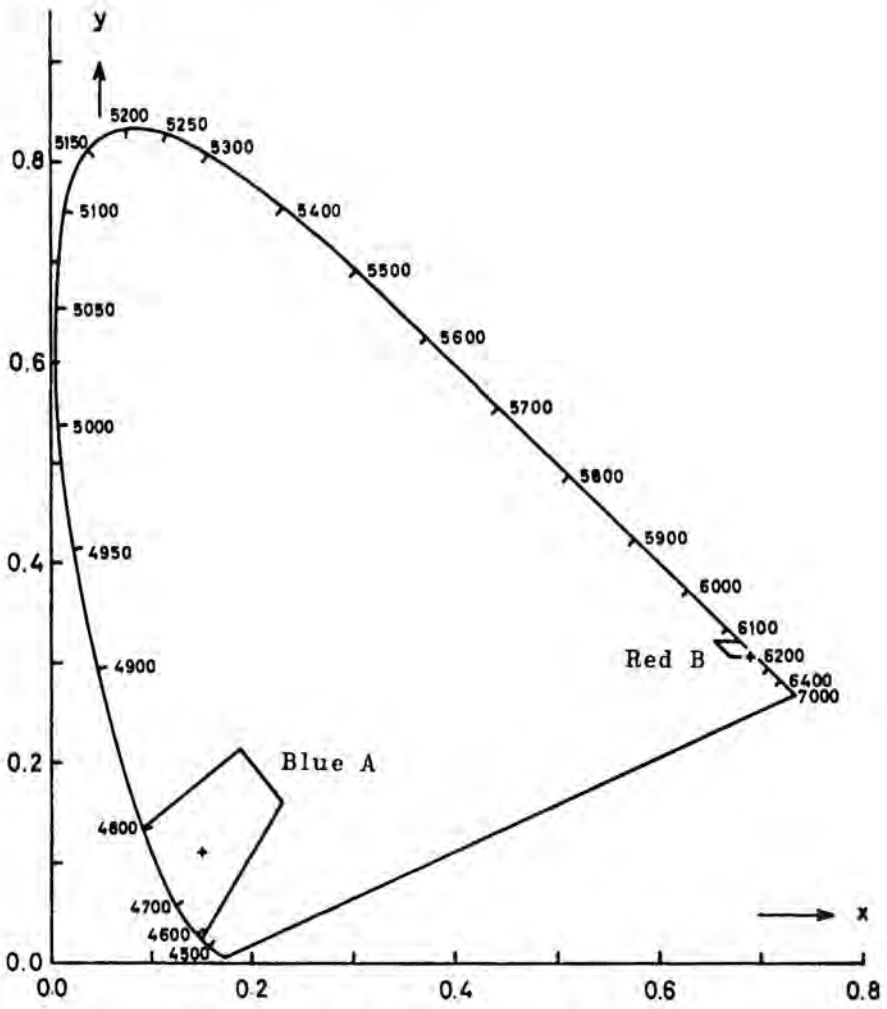


Figure 5
Colorimetric requirements. The red and blue colours used in the laboratory model are indicated by +

7.4 Electric switching

The switching mechanism must be such that the red and the blue lights can flash on and off alternately. An intermediate position must be impossible.

7.5 General

The entire sign should be in unbreakable material and of a design such as to guarantee good functioning and efficient use over a protracted period, as assessed by the testing authority.