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THE SIGHT AND HEARING OF RAILWAY
EMPLOYÉS.*

By WILLIAM THOMSON, M. D.,
PROFESSOR OF OPHTHALMOLOGY, JEFFERSON MEDICAL COLLEGE.

SHORTLY after the demonstrations of Professor Holmgren, in Sweden, of the dangers in transportation to persons and property on land and sea from color-blindness, the writer called the attention of the officers of the Pennsylvania Railroad to the subject; and, at the request of the president, Mr. Thomas A. Scott, and the vice-president, Mr. Frank Thomson, he undertook to solve the problem of eliminating these dangerous men from their service. To his first statement that there were probably four per cent of men incapable of distinguishing unerringly between red and green flags by day, or lights by night, it was responded that their signals alone would detect such men, and force them from their places, since, as we all know, the most imperative orders in railway administration are transmitted through the visual organs, in the white of "Safety," the green of "Caution," and the red of "Danger"; and it was considered by the officers of the road impossible for men color-blind to pass the thousands of signals in daily use on their thousands of miles of road without detection. A very slight search dispelled this idea, and a demonstration of the defect before the Society of Transportation Officers of the Pennsylvania Railway aroused the members of it to the dangers to be feared, and led to the appointment of a special committee to aid the writer in completing a system which would have practical value, with the Gen-

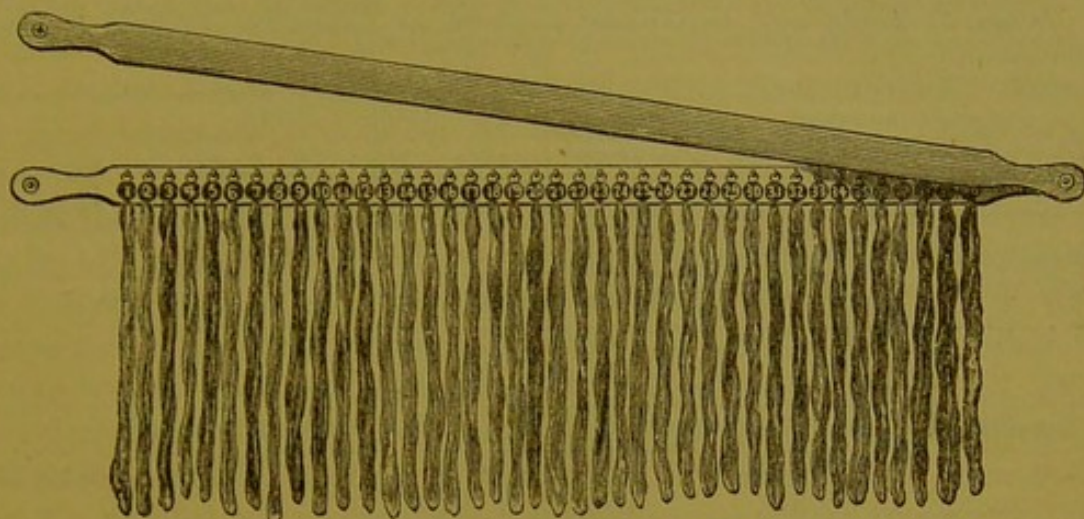
* Read before Section B of the American Association for the Advancement of Science, at Philadelphia, September 8, 1884.

eral Manager, Mr. Pugh, as its chairman, to whose keen interest much of its success is now due.

The magnitude of the task then began to appear, when the forty or fifty thousand employés of five thousand miles of track, with their ten or twelve thousand men actually dependent upon signals of color for their guidance, of whom four per cent might be color-blind, and ten per cent so defective in visual power, for form and hearing, as to render them dangerous, arose before the imagination. To have adopted the method of Holmgren for the color-sense, by which an accomplished ophthalmic surgeon would conduct the examination of each man, would have demanded years of his entire time, would have been so tardy as to allow large additions to the force before it could be accomplished, and was soon rejected as impracticable; neither was it thought possible to train a sufficient number of the company's surgeons to perform this special task with fairness to the men and safety to the company. To secure the co-operation of the employés the officers needed a system that could be applied locally on each division, quietly and confidentially, and at the convenience of the men, without compelling them to lose much time. Any undue publicity, or inexorable law that would compel the summary discharge of from ten to fifteen per cent of their trained operatives, would have disorganized the service, and destroyed the discipline of the company; and for their own protection, and as a duty to the public, the officers were willing to put on trial any practicable scheme, without the pressure of any over-anxious public opinion or hostile legislation.

These, and other considerations of weight, led the writer to the invention of an instrument for the examination of the color-sense, which could be efficiently used by any intelligent, instructed official, and a record of it permanently kept for the information of the officers, and as a guide for the action of any surgical expert whom the road might appoint to superintend the entire system. This consists of forty skeins of wool, each one attached to a movable button, having figures from 1 to 40 inscribed on them, suspended from two flat sticks, so arranged that the numbers are concealed. Holmgren's method of matching colors is adhered to, and the test-colors to be matched are green, rose, and red: the skeins from 1 to 20 being used for green, those from 21 to 30 for rose, and from 31 to 40 for red; upon the *odd* numbers are suspended green, rose, and red skeins; upon the *even* ones those "confusion colors" which the experience of the writer had taught him would be the most likely to be selected by the color-blind. In its use a green skein is placed before the person at a few feet distant, and he is directed to select those of that color from the stick, and to turn them away or throw them over; then the rose, then the red; and as this is done for each test-skein, the numbers upon the buttons are inspected and recorded upon a blank. So simple is this system that the division superintendent, who is responsible for the examination, may forget

all its details if he but remember that upon the blanks submitted to him for his action must appear only *odd* numbers, and that if the *even* ones are mingled the case is one of color-blindness.



DR. THOMSON'S COLOR-TEST.

For the acuteness of vision the best and most simple method is to employ letters of known size at given distances ; and, as we might meet with men who could avail themselves of opportunities to learn by heart those of "Snellen," ordinarily used, the writer had a rotary disk constructed on the same principle, whereby but a few letters were exposed to view, but many more could at will be brought into sight when desired. For the hearing, a watch and the voice in conversation were used.

These instruments, together with the Rules and Regulations now submitted to you, won the approval of the committee of railroad-officers, were put into practical use in two thousand preliminary examinations, were adopted by the highest officers, accepted by the Board of Directors, and ordered to be put in force upon the entire road, under the supervision of the writer as their surgical expert. His duties were to assure himself of the accuracy of all instruments, to give instructions to the examiners of the different divisions in their use, to give his opinion upon any doubtful cases, their blanks being placed before him, and to examine personally any men sent for the purpose, and to render fit for service, by medical or surgical treatment, or by proper correcting glasses, any capable of such relief.

From an inspection of the blanks, and a knowledge of the men, the Division Superintendent could deal with most of the cases by suspending or transferring them to other duties. The blanks of the color-blind, and those much below the standard of vision, were transmitted to the surgical expert, and, upon his advice, the men could be sent to his office, where the color-blind were re-examined by the "stick" by Holmgren's method, by that of Stilling, advised by the last International Congress, and by Donders's instrument, by which the lights of the lamps and signals at night are so perfectly imitated in color, size,

WEST JERSEY RAILROAD COMPANY.

CAMDEN, January 19, 1883.

EXAMINATION OF SIGHT AND HEARING OF

James A. Morris, aged twenty-two, employed as Locomotive Fireman, Applicant for ———.

ACUTENESS OF VISION.		RANGE OF VISION.	
The number of the series seen at twenty feet distant.		Least number of inches at which type D—0.5, in test-type pamphlet can be read.	Right eye, 4½ inches. Left eye, 4½ inches.
Right eye	20-30	FIELD OF VISION.	
Left eye	20-30	Good or defective	Good.

Color-Sense.

Test-skein submitted	Name given.	NUMBERS SELECTED TO MATCH.
A—Green	Green.	3, 26, 24, 7, 11, 22, 15, 5, 1, 17, 28, 9, 19, 30, 13.
B—Rose	Red.	37, 33, 29, 12, 39, 31, 21, 35, 25, 27, 23.
C—Red	Red.	37, 33, 31, 35, 23.

SECOND COLOR-TEST.			THIRD COLOR-TEST.		
Number shown.	Name given.	Numbers selected.	Flag shown.	Name and use given.	Numbers selected.
24	Green.	26, 22.	Soiled White.	Safety, White.	2, 4, 6.
39	Yellow red.	Could find no match.	Soiled Green.	Caution, Green.	36, 38.
30	Blue.	26.	Soiled Red.	Danger, Red.	37, 33, 31.

Selection prompt or hesitating:

Prompt.

Hearing.

RIGHT EAR.		LEFT EAR.	
WATCH.	CONVERSATION.	WATCH.	CONVERSATION.
8 feet.	20 feet.	8 feet.	20 feet.

Remarks:

Escaping steam prevented watch-test.

J. J. BURLEIGH, Examiner.

Acuteness, right eye defective. Range, good. Field, good. Color-sense, defective. Hearing, see Remarks.

JOS. CRAWFORD, Superintendent.

NOTE.—Those approved marked "Appd."
Those not approved marked "Not appd."

Fac-simile of one of the blanks.

and intensity, and the degree of color-defect measured by means of the ratios that exist between the sizes of the openings transmitting the colored light and the distances at which the man may be placed; the small opening which should be seen by the normal eye at five metres distant, is in diameter one millimetre, while the largest, twenty millimetres, when used at five metres, if not recognized, shows $\frac{1}{20}$ of color-

sense, or at one metre shows $\frac{1}{100}$, or at one third of a metre or one foot shows but $\frac{1}{300}$ of color-sense, where many fail to distinguish the color even at this short distance: finally, by coarse tests of colored glasses placed in front of large gas-lights, and by flags shown near at hand. No color-blind man has lost his place without the satisfaction of a professional examination, and a full demonstration of his defects in most instances even to his own satisfaction. Should he fail to see the red, for example, at five metres, of the large opening in Donders's instrument, or of a gas-light with a red glass before it, calling it green, he would be directed to obey the green signal and approach it slowly, walking up to it until when within one metre or less he might perhaps recognize it as the danger-signal, when too near to prevent an accident. Color-blindness, it must be remembered, is in some respects like deafness, and with its various degrees there are different possibilities of disaster.

No excitement has arisen, no interference with the business of the road, no color-blind man has escaped detection, very few mistakes have been made by the examiners, not a single word has been changed in the instructions, and there is nothing now to amend, except perhaps to make the color-stick into a smaller, more elegant, and self-registering instrument.

One simple test not hitherto mentioned has been used in the first moment of the writer's examinations, by placing a piece of cobalt-blue glass in front of the man's eye, and directing him to look at a gas-light of moderate size like a candle, at twenty feet distance; this glass transmits both blue and crimson light, and the normal eye sees a rose-colored flame surrounded by a blue halo, while the color-blind sees no red, but describes it as composed of two shades of blue only.

That the color-blind depend upon the relative intensity of the lights to distinguish them is shown by the fact that, if over a white light we place a medium shade of London-smoke glass, it will probably be called "green," while a deeper one will be called "red." In like manner, if a red glass, then a green one, are placed before the light alternately, and then tints of red and green of other depths, the man will often call one red, red, and the other red, green, or *vice versa*. In the display of flags that have been in use, a very bright or clean red one having been correctly called, if it be thrown carelessly near by so that it can be compared by the man, and another somewhat soiled be shown, he may pronounce the latter green, and adhere to the opinion even when he takes it in his hand, being misled by the brightness of the cleaner one, and the relative dullness of the other.

This photograph-picture of the color-stick gives in its tints only various ones of gray, since, as we know, colors are incapable of being rendered by this color-blind process, whereas color-blind men have lost but the reds and greens, preserving perfectly the power to see yellows and blues. If, therefore, we were to paint blue that part of the print

between 21 and 30, we who are not color-blind could form a clear conception of its appearance to color-blind persons, and appreciate how impossible it must be for them to conceal their defects under the investigation of the color-stick. Rose, being composed of red and blue in equal quantities, appears as a tint of blue to the red-blind, and green must look to them gray.

It has not been the duty of the writer to investigate cases of accident which might have been caused by defects of sight, but he has been assured by officials that a solution will hereafter be found in them for those hitherto insoluble mysteries where men, otherwise credible, have so flatly contradicted themselves and the circumstances of the case. By one prominent officer he was told that, being upon a train at night, delayed by some slight accident, he himself took a red lantern, and, going a proper distance back, placed himself on the track in the way of an on-coming train, but, finding his light not observed he was compelled to dash it into the cab to attract the engineer's attention, and arrest him in his progress to a collision. Upon the examination of another engineer, his superior officer being present and convinced of his marked color-blindness remarked that, but a short time before, the man had run into the rear of a train properly protected by a red light in the hands of a brakeman some distance in the rear, that the most careful investigation had resulted only in the suspension of the brakeman for not having gone far enough back, but that he was now satisfied that the color-blindness of the engineer had been the real cause of the accident. Some slight or minor accidents recently led to the discovery that another engineer had by some oversight not been tested in his division, and this led to his examination and detection there, and to his conviction by the writer as a color-blind. Still another case now presents itself. An engineer some time ago ran over and killed a brakeman, holding a danger-signal on the track in front of his engine, and no satisfactory explanation could then be given; but the division examiner predicted that he would probably be found color-blind, and on his examination this proved to be the case.

As a fact it may be safely assumed, in the various emergencies of a railway service, by day and by night, the year round, that, if an accident could occur from such and such contingencies, it will be but a matter of time when it will become a verity.

In a recent popular article on "Control of Vision," Dr. Jeffries, who has done more than any one in this country to call attention to its necessity, laments the entire failure in Connecticut, and the partial failure in Massachusetts, to obtain efficient legislation to compel railroads to expel their deficient men. He tells us of the like condition of things in England; and finally adds that the Pennsylvania Railway alone has availed itself of scientific advice. Perhaps if the system adopted by it had then been described and urged as most in keeping with our institutions, we might hope to see all the roads in

the country following its example ; but the advice which might be accepted, if proffered in a practicable manner, has been hitherto urged upon the officials by means of hostile newspaper articles, and agitation for legislation to place their entire extra force at the mercy of State-appointed examiners who might disorganize it and bring it into great confusion. There seems to be a natural hesitation on the part of medical men to place the examinations for color-blindness in the hands of laymen, and an equal unwillingness on the part of railroad officials to submit their force to the inspection of a numerous corps of medical examiners, but the solution is found in the use of the instrument described, which merely enables non-professional persons to make a record of certain selections and place them on paper, where they can then be submitted to a surgical expert, who can as well decide upon that evidence as though he were present at the examination, with the understanding that all doubtful cases are to be examined by him in person.

What is gained by this? The expense under the law passed in Massachusetts and Connecticut was estimated to be from two to three dollars per man, to be paid by the roads, and with a penalty of two hundred dollars for the employment of any man not provided with the certificate of an expert appointed by the Governor of the State. For this sum, say three hundred dollars per one hundred men, the road could be informed that from ten to fifteen employés were unfit for its service ; no provision was made for the correction by glasses, or other treatment of the trained men, otherwise so valuable, and no time was allowed to replace men especially fitted for certain duties ; the roads were to be thus taxed for the more than decimation of their entire force, while the employés were subjected to a pitiless scrutiny that would end in the summary dismissal of about fifteen per cent from the discharge of duties for which they had spent, perhaps, years of training. It can easily be understood why such a law would be resisted by all the political or other influences of the entire railway force in a State, from the directors and presidents to the lowest employés, and should awaken also the opposition of the holders of its securities.

By the system adopted on the Pennsylvania Railway, the men below their standard are detected unerringly by their own officials ; those color-blind are sent to the surgical expert, and after his decision are yet retained in the service where possible, being placed where their defects can work no harm. Any valuable men below the standard of visual power can be sent for treatment to their surgical expert, if the officers so decide, or the men can elect to have their defects treated elsewhere, upon the condition that they can pass the proper examination afterward. The one plan, it is evident, is expensive, irritating to the whole *personnel*, and disorganizing, while the other is economical, confidential, and orderly. By a wise liberality in aiding men to have their defects removed by proper glasses, etc., the officers of the road

have been able to carry out their wishes without any noticeable opposition from the employés, and have thus effected for hundreds what would otherwise have cost them thousands of dollars if any plan hitherto proposed had been adopted.

Since only the color-blind and those needing surgical skill have been sent to the expert, he has not been in a position to give statistical tables of the examinations, and he therefore submits the following letter from Mr. Charles E. Pugh, the General Manager, to substantiate his statements, and bear witness to the success of the entire system :

Dr. William Thomson, Surgical Expert, Pennsylvania Railway Company, 1426 Walnut Street, Philadelphia.

PENNSYLVANIA RAILWAY COMPANY, OFFICE OF THE GENERAL MANAGER, }
233 SOUTH FOURTH STREET, PHILADELPHIA, PENNSYLVANIA, April 26, 1884. }

DEAR SIR : The practical examination of our employés as to their acuteness of vision, color-sense, and hearing, in accordance with the system proposed to us by you and carried out under your supervision, has been extended to all the various divisions of the Pennsylvania Railway ; has embraced nearly all of the men engaged in duties requiring the use of signals now in the service, and will be used hereafter in the selection of men placed on such duty, or in the employment of new men entering our service.

In approaching the completion of the task of examining those now in our service (more than twelve thousand employés having been submitted to your system), I desire to express to you our entire satisfaction with the rules and regulations, tests and instructions prepared by you, as well as with the personal supervision and instruction of examiners, and examinations and decisions upon doubtful cases and persons referred to you for final action.

Our division superintendents and their staff-officers have been able to deal promptly with the great majority of defective men, and thus avoid the necessity of availing themselves of that clause in the instructions which provides for an expert examination in each suspected case, and have in this way carried out your purpose without undue excitement among the men, in a speedy and confidential way, and with economy to the company.

The proportion of those defective in color-sense, vision, and hearing, was found, by the examination of two thousand men before the adoption of this plan, to be four per cent of the first and about ten per cent of the latter ; and I am satisfied from my reports that all those thus deficient are being relieved of duties which they can not perform, and that the great dangers to the public, and to the other employés, of loss of life, and to the company of possible destruction of property, have been averted, so far as their defects are concerned.

I am frequently asked by prominent officers of other railways and Government officials to give an opinion as to the practical usefulness

of our system of examination, and it affords me much pleasure to emphatically commend it in all its details ; and I feel that we have good reason to be satisfied with this, the first successful attempt to bring the entire body of men engaged in signaling upon a railway in our country under control by the practical application of scientific facts. Having eliminated these dangerous persons from our present force, we propose to keep it free from them in the future by a steady application of our present system. Yours truly,

CHARLES E. PUGH, *General Manager.*

To this great corporation, extending through six States, operating five thousand miles of track, with nearly if not quite fifty thousand employés, and responsible for the lives of millions of people each year, must be accorded the honor of having been the first to obtain the desired control of the visual defects of their men by a wise and intelligent application of scientific laws. Their example has been extensively followed elsewhere, and their instrument has been obtained by more than thirty other roads from the manufacturers. It has also been ordered by "The Board of Trade of England," by many distinguished medical men abroad, and has recently been, with the entire system, adopted, and will no doubt be put into operation by a director of the Southwestern Railway in England. There is no longer any reason why losses of life and property should occur in railway service from visual defects ; and an enlightened public opinion should now insist upon the adoption of some similar plan upon the hundred thousand other miles of railway now being operated in our country.

Having been placed as the American representative on the Committee on Control of Vision at the International Medical Congress in London three years ago, I have urged upon the Naval Committee of our Congress the value of this large experiment, with a view to have a law passed to form an International Commission to establish a uniform system of signals, examinations, etc., both on the land and on the water. There is no doubt that accidents must occur on the sea ; and the recent loss of the Tallapoosa has not only been ascribed to a wrong interpretation of the colored signals, but the commission appointed to investigate the accident has been especially directed to examine for color-blindness the lookouts on the two ships.

