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DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
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THE SAFETY OF PORTABLE MOTION PICTURE PROJECTORS

1. Purpose

This Bureau has been requested from time to time to examine motion picture projectors with reference to safety of operation on board steamers under the jurisdiction of the Steamboat Inspection Service, and in connection therewith most of the makes of machines in use have come before us for test. A summary of the results is herewith made at the request of government units concerned with the public showing of film.

2. Characteristics of Motion Picture Film

As it developed from these examinations that the principal hazard is inherent in the film itself, a brief statement of the characteristics of motion picture film will be given.

In the manufacture of motion picture films, it is customary to distinguish between the raw film, and the same film after it has been coated with a photographic emulsion. For present purposes we shall consider briefly the preparation of the raw film. It is a flexible, water-resistant, transparent material prepared from cellulose nitrate, commonly called nitrocellulose, or from cellulose acetate. Films are prepared by pouring a solution of the film material upon a moving belt or revolving drum, and allowing the solvents to evaporate. It is customary to recover the solvents used. The steps involved consist of the preparation of a suitable solution, filtering and removing air bubbles from the solution, formation of the film, removal from the belt, and the drying of the film.

The common type of motion picture film is made from cellulose nitrate, an inflammable material prepared by treating cotton or cellulose with a mixture of concentrated nitric and sulphuric acids. The product must be thoroughly washed and stabilized, and is subsequently dissolved with the addition of camphor in suitable solvents and diluents. The solvents commonly used are amyl acetate or "banana oil", ethyl acetate, and acetone; the diluents are generally benzene (benzol), and denatured alcohol. The film obtained consists of an intimate mixture of cellulose nitrate and camphor, and is essentially celluloid. Substitutes for camphor have been

proposed from time to time, and a few of these are occasionally used. Camphor however, appears to produce maximum strength, transparency, and elasticity. The prepared film must be carefully dried and seasoned, before it is ready to be coated with a photographic emulsion.

The second type of motion picture film is the so-called non-inflammable film. It is prepared by treating cotton with acetic anhydride in the presence of a catalyst such as sulphuric acid, zinc chloride, or sulphuryl chloride, and the product is known as cellulose acetate. The temperature must be carefully controlled, as slight variations in temperature during acetylation give rise to brittle films and products of low viscosity, particularly when sulphuric acid is used to catalyze the reaction. The product of acetylation is soluble in chloroform and as a rule insoluble in acetone. It must be carefully hydrolyzed to a hydroacetate which is insoluble in chloroform, but soluble in acetone. Other esters of cellulose such as cellulose formate and cellulose butyrate have been proposed for the manufacture of non-inflammable films, but for various reasons have not been used.

Cellulose acetate is inherently more brittle than cellulose nitrate, and the brittleness is overcome by incorporating in the film so-called plastics. These have a function analogous to that of camphor in the films of cellulose nitrate. Cellulose acetate may be combined with a great number of plastics, with the production of varying degrees of hardness and elasticity. Camphor is not suitable for the purpose. Triphenyl phosphate is commonly used. It possesses the advantage of reducing the combustibility of the acetate film. Other useful plastics are calol, benzyl benzoate, benzyl acetate, diethyl phthalate, and triacetin. These are but a few among many which have been proposed. The most important solvents of cellulose acetate consist of tetrachlorethane, generally used in combination with alcohol, ethyl lactate, di-acetone alcohol, methyl ethyl ketone, acetone, methyl acetate and ethyl acetate. Mixtures of alcohol and benzene are used as diluents, but these in combination with a solvent of cellulose acetate also have a solvent action on the ester.

The ordinary type of film is that prepared from cellulose nitrate. It contains oxygen, the element of its potential destruction, in a highly available form. The readiness with which it burns is too well known to require comment. The gases resulting from combustion of celluloid consist chiefly of oxides of carbon and nitrogen, methane, hydrogen and nitrogen, together with volatilized camphor, which under certain conditions may form an explosive mixture with air.

Films prepared from cellulose acetate do not contain available oxygen. They are combustible but not inflammable. When

subjected to temperatures higher than 150° C., cellulose acetate melts and is decomposed. The gelatin emulsion used on all films has some fire-proofing action. However, the amount of this used is insufficient to produce any marked effect. For all practical purposes, films of cellulose acetate containing triphenyl phosphate may be considered safe as used in motion picture projectors. A film of such material, if ignited while being used, will cease to burn as soon as the source of heat is removed.

It is claimed that such films become brittle more readily and have proven less durable than films of cellulose nitrate. Acetate films are said to possess or develop a "grained" surface. These defects may have been caused by faulty methods of manufacture.

The manufacture of cellulose acetate plastics is a more recent development than the manufacture of cellulose nitrate or pyroxylin plastics. Cellulose acetate admits of a variety of combinations with other compounds. As new combinations become known, it may be expected that films will be developed which present none of the disadvantages of present day acetate films, assuming that such disadvantages exist. Future developments should make possible a non-inflammable film with qualities equal to those of the nitrate film, and the product should practically compete with the nitrate film in price. At the present time, there is less difference in the price of the two types of film than has existed in the past.

3. Essential Details of Projector and Attendant Hazards

The projector consists essentially of an aperture frame or plate in which the film is exposed, mechanism for moving the film at intermittent speed through the aperture, safeguards for the film in the plate, on the sprockets and reels, a lamp and container, a reflector and a condensing lens for focusing the light from the lamp on the film in the aperture, and a dispersing lens for projecting the image on the screen.

(a) Electric Appliances. The fire hazards involved in the electric circuit, as such, are small provided equipment and connections conform with the ordinary requirements applicable to such installations. The lamp and rheostat present some hazard, depending on the design and location. If contained within the same case as the mechanism and not properly separated or insulated therefrom ignition of film might occur by contact with them. In our experiments with the projectors the types examined seemed fairly safe from this standpoint. The top of the lamphouse and rheostat whether contained in the case with the mechanism or separate, may however be hot enough to ignite

inflammable film, depending on size and ventilation, ignition with some machines occurring in a few seconds and not at all with others. It is therefore a necessary precaution to avoid placing film, even for brief intervals, on top of lamp or rheostat.

(b) Projecting Light. This is generally in the form of a Mazda lamp ranging from the 60 watt size for the small machines to 1000 watt or more for the semi-portable models. The carbon arc is not much used at present for portable projectors. Besides generally giving a more intense and hot light than the filament lamps, fires have frequantly been caused by contact of hot discarded carbons with film outside of the machine.

The projecting light between the condenser and aperture is often hot enough to ignite film placed in its path, ignition occurring in one second with a large semi-portable model using a carbon arc lamp. As enclosed in the case with the operating mechanism, or attached to the same, the path is usually well guarded. Where the lamphouse is separate from the housing for the mechanism, ignition of inflammable film might occur from careless handling outside of the machine.

Between the aperture and projecting lens the light should be guarded against contact with film on the sprockets, which is usually accomplished with a continuous sheet metal shield. In one model the light after passing through the aperture is reflected at 90° and outside of the path of the film by means of a triangular prism. If this prism is removed for any reason such as cleaning, and the light turned on before replacing, it will fall directly on the film on the sprockets and cause ignition. Beyond the projecting lens the light is sufficiently cool to obviate danger of ignition, particularly if guarded within the case.

(c) The Aperture and Film Guards. The aperture provides an opening of size sufficient for the projection of one picture or frame. It is guarded by sliding contacts or shoes at the sides and the clearances above and below are made as small as consistent with easy passage of the film. The film passes through the aperture at an intermittent speed of about one foot per second. If stationary and unprotected, light from the lamp would ignite it inside of a few seconds. The film is therefore generally guarded when not in motion by an automatic shutter that falls and shields the film when stationary or when its speed falls below a certain rate, this shutter being generally operated by a governor connected with the

main sprocket shaft. Some machines have in addition a hand operated shutter. In some the motor and light are on the same circuit so the film cannot normally be exposed when not in motion. However it is generally possible to stop the film with the speed regulator, hence this arrangement should not be depended upon for guarding inflammable film without an automatic shutter, or without reliable means for cooling the light before it reaches the aperture. In some recent models, using 300 watt lamps, the latter is claimed to be accomplished by the use of special lenses or liquid cells. We have as yet made no investigation of these improvements. Under ordinary conditions of operation, film may stop in the aperture while the mechanism is operating due to breaking of the film, or tearing of the perforations that engage the sprockets, or it may be exposed by failure of the safety shutter to operate.

Tests were made with all the machines examined to determine the time required for ignition of exposed stationary film in the aperture. It was found to vary considerably with the intensity of the light, the color of the film, and the amount of the silver deposit on it, the more transparent film requiring a longer time for ignition. With carbon arc, ignition of nitro-cellulose film took place in from one half to one second, the time with 300 to 1000 watt Mazda lamps ranged from 3 to 6 seconds, and in the case of a miniature model designed for use with slow-burning film, ignition of colored inflammable film took place in 10 to 25 seconds with a 70 watt light, which was the highest brilliancy obtainable. A puff of smoke and flame issues from the aperture. Holes equal to the width of the frame and from one to two frames wide were generally burnt in the film, the fire being confined by the shoes and gates around the aperture. In only one case, with a machine designed for use with slow-burning film, did a fire spread beyond the plate. The number of tests made with each machine was not sufficient to determine definitely whether fire in the aperture under some conditions might spread to film outside, as all operating conditions could not be duplicated. All the machines examined were new, the mechanisms were in perfect condition and allowance must be made for conditions that arise with longer use. It is known that at least with some types of machines fire has been thus communicated to the film on the sprockets and reels.

The automatic shutter should close in ample time to prevent ignition of film when the machine slows down or stops. The tests indicate that this condition is fulfilled, the shutters generally closing in less than one half the time required for ignition of the film. The automatic shutter, when closed affords protection to the film for at least a few minutes. We obtained ignition with one machine after exposure behind the shutter for 4 minutes. The experiment indicates desirability of shutting off the light soon after the machine is stopped.

(d) Protection for the Reels In some machines the reels are open and housed in the case with the mechanism, in others, while housed within the case, the reels are enclosed within sheet metal partitions with film openings guarded by fire rollers or brushes, and again the reels are contained in separate magazines above and below the mechanism.

Tests with the fire rollers guarding the magazines showed that they will stop a fire in film on the sprockets from being communicated to film on reels when the film is stationary, but when moving fire is likely to pass through them into the magazine on which the film is being wound. Passing burning film through a narrow slot of some length appears to have as much extinguishing effect as the rollers. Since film fire is ex-extinguished with difficulty and the burning of one reel takes less than 2 minutes, the operator should leave the booth immediately on ignition of film on the reels, and if not in a booth the machine should immediately be taken out of the assembly room. The wiring connections should be made so they can be easily disconnected. A push button or similar switch should be inserted in the main current lead and kept in hand during operation so the light and motor can be quickly shut off in case of minor trouble.

4. Provisions for Exit

The operator should be familar with the requirements for exit and where the responsibility devolves upon him should have the necessary conditions of safety complied with. General regulations applicable to assembly rooms will be supplied on request.

5. Motion Picture Booths

For a proper degree of safety in using nitro-cellulose film the operation should be conducted within a properly constructed booth vented to the outside of the building. Specifications for such booths will be furnished upon request.

The unvented portable booths are almost without value as far as preventing danger and panic from fire, smoke, and fumes.

6. Storage of Film

Film in the amounts needed for one or two exhibitions should be stored in lined metal containers, preferably single or with separate compartments for each film. In greater quantity storage should be in insulated cabinets, and permanent storage is best made in suitably constructed and vented vaults, with temperature control.