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The Use of Polyethylene Film as a Scenic Medium

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THE USE OF POLYETHYLENE FILM
AS A SCENIC MEDIUM

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This thesis submitted by Paul K. McCullough in partial fulfillment of the requirements for the Degree of Master of Arts from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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ABSTRACT

This paper deals with the use of fan-inflated polyethylene film as a scenic medium. Undertaken as part of the design of The Little Prince, produced as the University Theatre children's theatre production in April 1973, it is devoted to the techniques involved in constructing scenery from polyethylene film. The chemical and physical properties of polyethylene film are described. Construction techniques begin with the floor plan and model. Upon completion of the model, a light weight polyethylene film is fitted to the set model, cut and marked in the same manner as a costume is fitted to an actor. The completed pattern is then transferred to an enlargement grid and the film for the set is marked and cut. The film is temporarily pinned together and inflated and the final fitting is made. The seams are then heat-sealed, using either a commercial heat-sealing iron or a salvaged clothing iron. The set is inflated and positioned.

Inflating techniques are discussed, as are the propellor-type and squirrel-cage fans used for the inflation. Diagrams are included illustrating the fans and their soundproof housings. Special problems such as rate-of-inflation, low-pressure flapping, and venting for both practical and decorative units, are brought up and solutions based upon experience with The Little Prince are presented. Anchoring the set is discussed at length and various techniques for anchoring are presented, along with proposals for preparing the inflated polyethylene set for touring.

The conclusion based upon production experience is that the inflatable polyethylene scenic unit presents an interesting alternative to standard construction techniques, although its use is limited to stylized productions in proscenium theatres, due to the inherent limitations in the medium. Restrictions include surface texture and gloss, limited acceptance of paint, and lack of structural rigidity, as well as sightline, masking, and noise suppression problems.

INTRODUCTION

In the spring of 1973 I was selected to be the designer of the University Theatre's children's theatre production of Antoine de Saint Exupery's The Little Prince. The play was an adaptation by the director, Ms. Sandra Norton, and her cast, of the book of the same title. The director expressed a strong preference for a set constructed of inflated plastic film. Polyethylene film, formed into various shapes and inflated by small fans, has been an artistic medium. Unfortunately, the use of plastic film as a scenic medium is a comparatively new development. The University of Iowa had used it during their 1971-72 production season in Ionesco's Exit the King, designed by Tom Bliese, but the published material concerning their construction techniques discussed only the basics of forming and sealing the unit. Chemical and engineering manuals contained a wealth of information concerning chemical and physical properties of polyethylene film, including several techniques for sealing the edges of the unit together. Given the paucity of material on our specific problem, we were forced to progress slowly and with considerable experimentation. This work is the end result of that experimentation, combined with as much of the technical data as seems appropriate to the needs of the scene designer/technical director who might wish to further explore the possibilities of the particular medium.

CHAPTER I

POLYETHYLENE FILM

Design Considerations

The prime function of stage scenery is to provide an environment within which the actor can perform. It defines and delimits the acting area and, along with lighting, helps to establish the mood or tone of the production. In one way or another, the set also assists the audience by giving an idea of locale and time. The designer's final consideration is decoration; the set should be visually interesting in itself, as long as it doesn't detract from the actor or the play.

In his search for means of discharging his duty to actor and audience, the designer continually explores the possibilities of new materials and techniques. Although the theatre industry lacks the means and technology necessary for research in and development of totally new scenic materials, it is the recipient of an abundance of technological "fallout" from other industries. The plastics industry has been a frequent, if unwitting, benefactor of the stage. Styrofoam, Celastic, plexiglass, and Lucite, although not developed with theatre in mind, have been eagerly adopted by the set designer and incorporated into scenic units to supplement and often replace the traditional muslin and wood.

Polyethylene was developed in the United States during World War II, and has since found its way into common usage in a myriad of forms. Polyethylene film has been employed in the scene shop for years, primarily as a drop cloth to prevent damage to both plant and scenery from spilled paint. Its almost complete chemical neutrality has made it an excellent mold release when working with fiberglass and associated materials. Several years had passed after sculptors became aware of its potential before the dramatic community began to experiment with the possibilities of using polyethylene film as a scenic medium.

Plasticity is a term which is frequently encountered in works on theatrical design, referring to almost any tool in the repertory of the designer from lumber to lighting, yet the idea of taking the shop drop cloth, melting the edges together, filling it up with air, and using it on the stage as scenery seems to have been overlooked for longer than perhaps it should have been.

Using the techniques for shaping explored later in this work, polyethylene film is a plastic medium, both in the strict chemical sense and the somewhat freer artistic use. An inflated polyethylene film scenic unit can be constructed in almost any form, as long as its limitations are not overlooked.

The inflated set's greatest limitation, a shiny, definitely modern look, is also one of its greatest attributes. Although inappropriate for a realistic or naturalistic period piece, inflatable scenery comes into its own for fantasy, surrealism, or children's theatre, to mention just a few. Depending on its use, the inflated set can be hard or soft, heavy or light, dynamic or static, transparent or virtually opaque. If the unit is fully inflated, it appears hard, yet if an actor pushes against it, it yields readily, springing back into shape as soon as the pressure is released. When partially inflated, the unit has a soft mushy appearance, but at the same time, it has a hard appearance because of its gloss. When translucent film is used in the construction, it has many of the qualities of theatrical scrim, taking on the color of whatever light hits it. When the film is front-lit, it becomes opaque. Backlighting makes the film virtually vanish, and any action either behind or inside it becomes clearly visible. Smooth to the touch, polyethylene film appears shiny and featureless; however, imperfections in manufacture and construction, combined with the stress from internal air pressure, textures the surface. The illusion of tremendous depth can be achieved by using translucent plastic; audience members can easily see a person or an object through the walls of the construction, yet the slight cloudiness of the film gives a feeling of distance which increases with each additional thickness.

The Little Prince provides an excellent example of many of these qualities. As produced by the University Theatre, The Little Prince was interpreted as a series of flash-back, dream-sequence episodes, tied together by the character of the Little Prince. The short episodes take place on individual planets, each inhabited by a different symbolic character.

The design concept called for an ephemeral, non-specific, unit set, for reasons financial as well as aesthetic. The number of individual scenes, each calling for a different locale, combined with a reluctance to break the flow of action, precluded any sort of realistic treatment. The dream/memory format demanded an insubstantial, transitory quality about the sundry environments. Finally, it is difficult in working with children's theatre to ignore the visual impact of sheer spectacle, a temptation to which director and designer both succumbed.

The resulting design called for two massive units, amorphous in outline, but bearing a resemblance of sorts to sand dunes due to the fact that the story begins and ends in a desert. These units were constructed of translucent polyethylene film. Both units were collapsed on stage when the audience entered the theatre; the act curtain was open, showing a "bare" stage. At the appropriate time after the show began the stage was covered with dry ice fog. Once the stage was covered, the fans were started and the set rose up out of the fog, which was lit with several different colors (see Appendix).

The set was practical, with openings in the front of each unit, through which the actors made their entrances and exits. The entrance of the Little Prince was particularly effective, since his costume had bands of wheat grain lamps, powered by a battery pack under the costume, sewn into the arms and legs. The Prince crept into the tunnel while the plastic was front-lit, making the downstage surface opaque. As the stage lights dimmed, the Prince switched on the lights in the costume. The audience became suddenly aware of his presence, although due to the milky quality of the plastic all that was visible was a figure outlined in light, and the other-world quality of the character was established.

Differences in locale were established with lighting, each different color and lighting angle changing the set. Due to the properties inherent in the plastic, including the fact that the cyclorama was visible through the scenery, the solidity and mass of muslin or styrofoam was avoided; the action had a background, yet at the same time, the set seemed always ready to vanish at a moment's notice, an effect reinforced by its disappearance amidst more clouds of dry ice fog near the end of the production. The effects described above would be difficult, if not impossible, to achieve without the use of some form of translucent plastic film.

Chemical Properties of Polyethylene

Since its introduction in the U.S. in the years immediately following World War II, and particularly since the development of the linear high density type in the early 1950's, polyethylene in one form or another has become familiar to almost everyone. Due to its unusual chemical resistance, combined with a physical strength, and non-toxic properties, it has been manufactured into food and laboratory chemical storage containers, corrosion-resistant tank liners, bottles, tubing, dishpans, garbage cans, laundry baskets, electrical insulation, and countless numbers of other products. It is the largest volume plastic in the U.S., having first passed the billion pounds per year mark in 1961.[1]

Polyethylene $(--H_2C--CH_2--)_n$ is manufactured by polymerizing ethylene (CH_2=CH_2), an unsaturated gas which is present in natural gas and which is also a large-volume by-product of petroleum cracking. Polyethylene is compatible with a number of additives, resins, waxes, fillers and plasticizers. It mixes readily with polyisobutylene, guttapercha, natural rubber, and Butyl rubber. Polymerization is a reaction process in which molecules of a specific substance combine with each other, producing a macromolecule of the same substance.

There are three different forms of polyethylene, formed by two separate manufacturing processes. All three forms are chemically the same. What differentiates them is a difference in physical properties and density. Low density (branched) polyethelene has the lowest melting point and lowest tensile strength. It is termed "branched" because the linear chain which is its basic structure is connected to other chains at random intervals. Because the molecules are interconnected at random intervals, they lie at odd angles to each other, making the whole unit less dense than the other forms of polyethylene.[2]

Low density polyethylene is formed in high pressure polymerization

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[1] Herbert R. Simonds and James M. Church, A Concise Guide to Plastics (New York: Reinhold Book Corporation, 1963), p. 219.

[2] S. J. Kaminsky and J. A. Williams, Handbook for Welding and Fabricating Thermoplastic Materials (Norwood, Mass.: Kamweld Products Co., 1964), p. 131.

requiring temperatures ranging from 175^{0}F to 570^{0}F and pressures between 15,000 psi and 45,000 psi, using an oxidizing catalyst such as benzoyl peroxide.[3] The Low density polyethylene is readily shaped by vacuum or press forming operations. It is generally used making film, sheets, tubing, rod, and block stock, all of which are adaptable to stage use. It is sold either in black or its normal milky-white color.[4]

High density (linear) polyethylene has a high working temperature as long as the stresses placed on it are low. It is frequently used for medical purposes because it can be autoclaved. Under normal temperatures, linear polyethylene has the highest working stress and corrosion resistance in the family. The molecular chains of high density polyethylene have fewer branches than those of low density polyethylene. They consequently lie closer together, increasing both density and potential strength. This form is sold in black, natural, or natural with an ultraviolet stabilizer.[5] Linear polyethylene is manufactured by a low pressure process. The process involves temperatures ranging from 120^{0}F to 520^{0}F. Pressure ranges between 45 psi and 1175 psi.[6]

Medium density polyethylene, the third form, is also manufactured by the low pressure process. Tensile strength for the medium density falls between those of branched and linear, as does its maximum working temperature.[7]

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[3] Lionel K. Arnold, Introduction to Plastics (Ames: Iowa State University Press, 1968), pp. 87-88.

[4] Kaminsky, p. 132.

[5] Ibid., p. 133.

[6] Arnold, p. 88.

[7] Kaminsky, pp. 132-133.

Physical Properties of Polyethylene

Polyethylene falls between rigid and nonrigid plastics. In a very thin film, it may be transparent; as the thickness of the plastic increases, so does its opacity.[8] Because of its good melt flow properties, polyethylene makes a good material for mass production using almost all plastics molding techniques. It accepts color additives well and the finished products have a wide variety of colors.[9]

In film form, its shelf life is virtually unlimited over a wide temperature range (see table). Mechanical actions such as crumpling, creasing, or sealing have a negligible effect on its strength. Its wide use in the building trade is due, among other things, to polyethylene's extremely high electrical resistance and negligible water absorption.[10]

Polyethylene has an excellent chemical resistance. It is insoluble below 60°C and at room temperatures is resistant to inorganic acids, alcohols, and fatty oils. When exposed to ultraviolet light, including that in sunlight, surface crazing appears, but stabilizers may be added to prevent crazing. Carbon black may be added to prevent oxidation at higher temperatures.[11] Stabilized film should be used for outdoor productions or those making extensive use of black light.

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[8] William Schack, ed., A Manual of Plastics and Resins in Encyclopedia Form (Brooklyn: Chemical Publishing Co., Inc., 1950) p. 356.

[9] Simonds, pp. 54-55.

[10] Schack, p. 357.

[11] Thelma R. Newman, Plastics as an Art Form (New York: Chilton Book Company, 1964), p. 293.

TABLE 1

PHYSICAL PROPERTIES OF POLYETHYLENE FILM

Specific gravity	
Low density polyethylene	0.910-0.925
Med. density polyethylene	0.926-0.940
High density polyethylene	0.941-0.965
Tensile strength	2,000-3,000 psi
Elongation	200-800%
Burst strength	50 psi
Tear strength	100-300 g/mil
Refractive index	1.52
Minimum operating temp.	-70°F
Maximum safe operating temp.	225°F
Heat seal temp.	250-400°F
Flash ignition temp.	645°F
Self-ignition temp.	660°F
Chemical resistance	
Strong acids	Excellent
Strong alkalis	Excellent
Oils, greases	Fair
Ketones, esters	Good
Hydrocarbons	Fair

Availability of Polyethylene Film

Several companies manufacture polethylene film under various trade names. Major manufacturers are E. I. DuPont de Nemours & Company, Inc., the Dow Chemical Company, Firestone Tire and Rubber Company, and Celanese Corporation of America. Because it is a standard material in the construction trade, film is kept in stock at most lumber yards and hardware stores. The standard roll of polyethylene film is 100 ft. long and is available in thickness of 1, 2, 4, and 6 mil and widths of 4, 8, 10, 12, 16, 20, 24, 26, and 32 feet. Most retailers stock both black and translucent.

TABLE 2

POLYETHYLENE FILM
AVERAGE COST/100 SQ. FT. (SEPTEMBER 1973)

Thickness in mils	Cost/100 sq. ft.
1	$ 0.30
2	$ 1.14
4	$ 1.08
6	$ 1.65

CHAPTER II

FROM SKETCHES TO FINISHED SET

The Scale Model

After the designer's sketches and floor plans are approved, construction begins with a scale model of the structure as it will appear on stage. One of the major problems faced by Tom Bliese, the designer of the University of Iowa's production of Exit the King, was developing a pattern for the inflated polyethylene hand which overhung King Berenger's throne. When mathematical calculations failed to provide a viable pattern, Bliese turned instead to a model, around which a pattern was fitted.[12]

After having worked with a scale model, I would suggest that the larger the scale model, the better the finished product will be. For The Little Prince, we constructed a 1-inch to 1-foot model, twice the standard scale for renderings and floor plans, but even this large scale proved unsatisfactory for two reasons. First, it is difficult, even with a 1-inch to 1-foot model, to fit even a simple model such as ours because of lack of space. If there is intricate detail or even a corner with limited clearance, fitting the plastic pattern material, holding it in place, making the cuts necessary to fold the pattern around a curve, and marking it with an indelible marker becomes an exercise in frustration. The second consideration is margin of error. If the pattern from a 1":1' model is 1/8 inch off, enlarging

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[12] Laurilyn Rockey, "Problem: Exit the Castle," Theatre Crafts, November/December 1972, pp. 13-14.

the pattern will magnify the error up to $1\frac{1}{2}$ inches; the smaller the model is, the greater the error will be when the pattern is enlarged. Add to this an inch or two draftsman error during the enlarging and even a slight error in the model and the designer finds that there is a 4-12 inch discrepancy in the finished product. If a set piece is made up of several individual sections of plastic, it becomes difficult to compensate for that much error, even with such a forgiving medium.

Patterns

After the model has been constructed, the pattern material is fitted to it in much the same way that a costumer fits a costume to an individual actor. After experimenting with several different substances, it was found that the most obvious material, polyethylene film, was also the most suitable, though it is preferable to use a thinner gauge than that used for the set. Plastic film works best because of its transparency: the designer can see both model and pattern, making fitting less difficult; and, when the pattern is enlarged, the pattern can simply be taped to a grid, leaving all the grid lines visible. (Having the grid visible makes an enormous difference when the draftsman is working six or eight feet inside the large grid.)

Indelible felt-tip marking pens were used at first, but soon abandoned when it was discovered that the supposedly indelible ink wipes right off with virtually no effort. A wax china pencil makes easily visible lines which take considerable effort to remove.

Fitting

Once the pattern is completed, it is enlarged using a standard enlargement grid. The pattern piece is placed on a one-inch grid and then the lines are transferred to the set plastic, which has been spread out over the one-foot squares of the enlargement grid. A wax china pencil is best for drawing the lines on the set plastic. Once the seam lines are drawn in, the plastic is easily cut with a knife or scissors, leaving six to twelve inches outside the lines for seam allowance.

It is now time to fit the set pieces together. Bliese sealed the seams immediately.[13] I would recommend that sealing be postponed until the unit has been fitted to the designer's satisfaction. Once sealed, the seam can only be taken in, because it is impossible to open a properly heat-sealed seam. If the seam has to be let out and it has already been sealed, the entire unit must be discarded and new pieces cut.

This situation can be avoided if the scenic unit is completely assembled using wig pins and inflated. After the unit has been inflated, it is a simple exercise to take in and let out seams where necessary, until the optimum result has been obtained. Seam plastic can be slashed to round corners, just as fabric is slashed when sleeves are fitted to a bodice. When satisfied with the unit, seam sealing may commence.

Wig pins are the strongest method we discovered for holding the various sections of set together for fitting. There is no solvent or cement which will hold on polyethylene; the same holds true for assorted brands and types of adhesive, electrical, or office tape. The wig pins, because of their relative thickness and large heads, puncture the heavy plastic without bending or puncturing the fingers of the fitter.

One final comment should be made concerning fitting. While any number of different seams can be made during the heat-sealing process, the simple lap joint works best for the fitting operation. The lap should be made with the plastic closest to the fan lapped <u>under</u> the next pattern piece, which should be lapped under the next farther out and so on. This prevents

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[13] <u>Ibid.</u>, p. 14

the air stream from the inflation fan from working under the plastic and pulling out the wig pins.

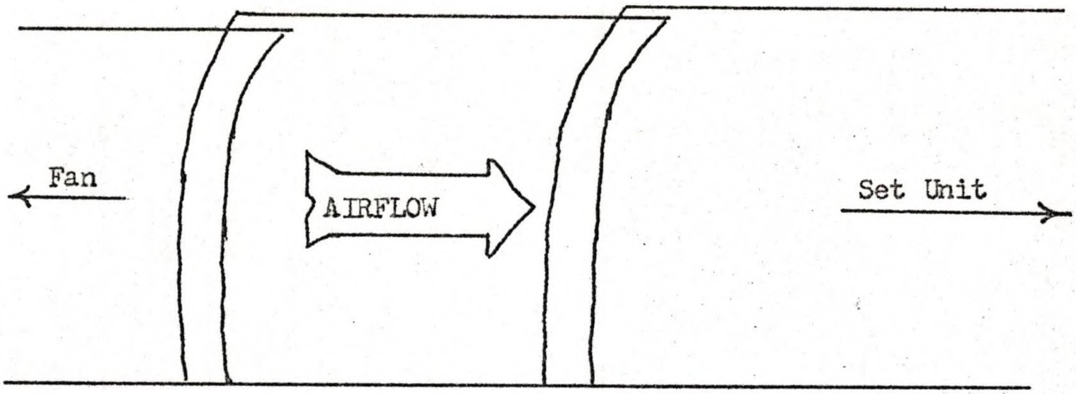

Fig. 1. -- Lapping each piece under the one next farther out prevents airstream from catching a trailing edge.

Sealing the Seams

Due to the chemical inertness, polyethylene film cannot be joined with a solvent-type cement without curing the seams under heat and pressure. A "cementable" surface can be obtained using oxidizing dip or flame treatments,[14] but the expense of the equipment necessary is difficult to justify for theatrical usage. A weak bond may be made with some pressure-sensitive adhesives for special applications.[15]

Some progress has been made on the development of an ultrasonic welder which uses mechanical vibrations to bring the molecules together permanently between two sheets of polyethylene film, but the expenditure of power is too great to make practical the sealing of more than points or short bars.[16]

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[14]The Society of the Plastics Industry, Inc., Plastics Engineering Handbook, 3d ed. (New York: Van Nostrand Reinhold Company, 1960), pp. 487-488.

[15]Schack, p. 358.

[16]Robert D. Farkas, Heat Sealing (New York: Reinhold Publishing Corporation, 1964), pp. 14-15.

For those who are interested only in straight line or open moderate curve seams, a thermal impulse sealer might be acceptable. It uses a low inertia thermal element, operating under pressure, to bring the plastic up to seal-temperature. It maintains the pressure until the seal has cooled.[17] Limited application and tooling costs make this technique impractical for all but the wealthiest theatres.

The simplest and most popular form of heat-sealing thermoplastics is that of thermal heat-sealing. This involves the use of a heat source with continuous and essentially constant temperature. Several commercial thermal heat-sealing devices are available, ranging from a jaw-type to hand held models similar to small electric clothes irons. For theatrical purposes, the hand held models are sufficient. An electric clothes iron will serve with honor if the temperature control is set in the middle range and adjusted as circumstances dictate. The most inexpensive, and hence, least sophisticated commercial sealer is a nickel-plated copper shoe, which slips over the tip of an electric soldering iron (Fig. 2). Temperature control, if any, is minimal. The seam will be the same width as the shoe.[18]

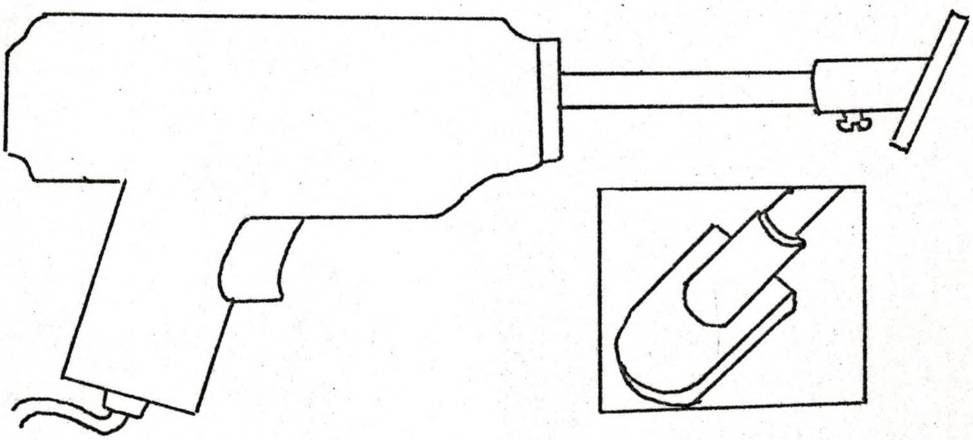

Fig. 2.--Soldering iron with shoe.

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[17]*Ibid.*, p. 14.

[18]Society of the Plastics Industry, p. 506.

A wide seam is also characteristic of an only slightly more sophisticated commerical hand held sealing iron. The shoe is larger and the unit it thermostatically controlled.[19]

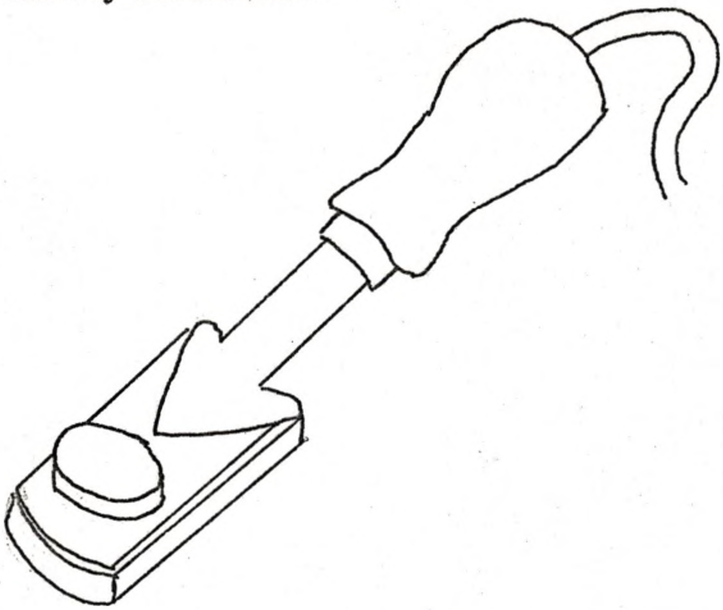

Fig. 3.--Commercial thermostatically controlled sealing iron.

A certain skill is required to operate the third type of hand sealing iron. This consists of a rotating wheel on the end of a heated shaft. Seams made with this particular tool are narrow because it is essentially a spot iron; that is, only one point of the wheel is in contact with the surface at one time. Operator skill is required to maintain optimum speed and pressure. The seal will be incomplete if the iron is moved too quickly or without enough pressure. Conversely, too much pressure or too slow a speed will tend to extrude the melted plastic, leaving the weld thin and weak.[20]

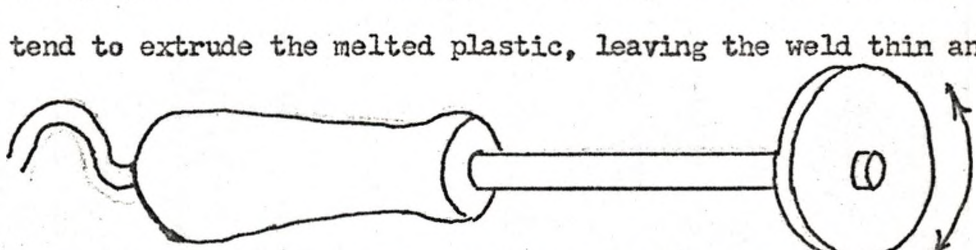

Fig. 4.--Commercial wheel-type sealing iron.

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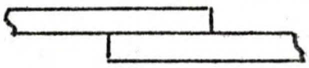
[19] Farkas, p. 26.

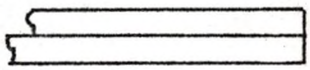
[20] *Ibid.*, pp. 26-27.

One of the first problems encountered in heat sealing polyethylene film is the tendency for the molten plastic to stick to the heating source, causing pulls and tears and puckers in the seam. This is caused by the sharp melting point of the resins involved.[21] Beginning the weld with a starting temperature of 250°F and gradually increasing temperature while experimenting with pressure will do much to alleviate this situation.[22] A Teflon-coated sealing iron will ease sticking, as will a slip sheet of some material with a higher operating temperature, frequently paper, cellophane, glassine, or acetate.[23] The construction crew of The Little Prince found that an electric clothes iron with an aluminum foil slip sheet produced acceptable results, although the seam varied in width from one to five inches. Three-quarter inch plywood was used to back the seam while sealing was in progress. After the weld had cooled, the slip sheet was simply peeled off and re-used, often five or more times.

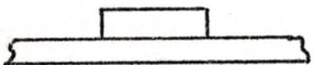
Commercial welding machines produce a number of different seals, only a few of which are of interest to the theatrical technician. Only welds which can be obtained without special sealing equipment are discussed below. The four seals illustrated in Figure 5 can be executed with the rudest equipment, yet they will maintain their integrity almost as well as commercial seals if care is exercised in their fabrication.



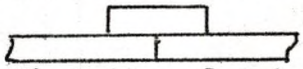
5a. Overlap seal.



5b. Layup lap seal.



5c. Applique seal.



5d. Butt seal and applique.

Fig. 5.--Seals for theatrical heat-sealing.

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[21] Schack, p. 358.

[22] J. Alex Neumann and Frank J. Bockhoff, Welding of Plastics (New York: Reinhold Publishing Corporation, 1959), p. 114.

[23] Schack, p. 358.

The overlap seal requires the least expenditure of effort and time. Requiring little time to align, the overlap has the greatest strength, due to the fact that all pressure against it is in shear. In inflated scenery, the pressure tends to be uniform against the entire inner surface of the unit, pulling on the seal both in a plane parallel to the surface and in a plane perpendicular to it. This is the seal used for The Little Prince set. The applique seal shares this strength, by itself and in conjunction with the butt seal.

While weaker than the applique and overlap, the layup lap seal is stronger than the butt seal. This particular weld should be useful in a situation where it is desirable to have a lip or skirt for external firring, (see Chap. IV, "Anchoring and Shifting"). The seam may be oriented either into or out of the unit, depending on the particular application, (see Fig. 6).

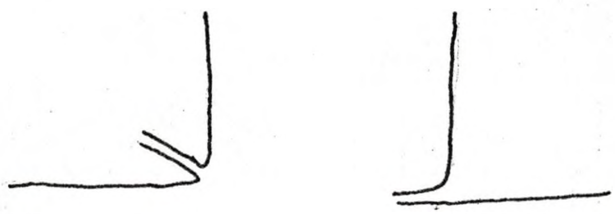

Fig. 6.--The layup seal may be oriented either into or out of the unit.

Applique seals can be utilized in any situation where additional strength is required. It is particularly useful in reinforcing the corners of practical openings in scenic units which might take a beating due to heavy traffic..

The butt seal, while an intrinsically weak bond due to the thinness of the film and the impracticability of satisfactory edge-to-edge contact, when combined with the applique becomes an acceptable joint when time does not permit a damaged section to be excised and replaced.

CHAPTER III

INFLATION

Fans

In discussing the fans necessary to inflate polyethylene film scenic units, it must be remembered that the fan for each particular set must be chosen with regard to its specific application. Variations in set size, set usage, required speed of inflation, and wing space make hard and fast rules difficult to establish. Some general considerations are worthy of mention however.

Fans are capacity rated in terms of cubic feet per minute (cfm). This must be the prime consideration in the purchase or rental of fans. A large set which must be quickly inflated in view of the audience, requires a greater volume of air in a shorter time than a small decorative unit. Practical units (that is, units through which actors make entrances and exits) require larger fans than decorative or background units because there is a greater air spill loss through the exit and entry portals. Once inflated, practical units require more maintenance volume than decorative units which often have only a few small vent openings.

A set which must go up in view of the audience requires a higher volume fan than a unit which can be inflated at leisure during a ten-minute act break. In order to inflate a set piece in under one minute demands a fan with a rated capacity of <u>at least</u> as many cfm as the calculated capacity in cubic feet of the scenic unit. One hundred fifty per cent capacity allows a margin of safety; in other words, a decorative set piece with a calculated capacity of 1,000 cubic feet would need a fan with a rated output of approximately 1,500 cfm to insure inflation within a one minute period. A practical unit should have a fan with a two to one output to calculated unit volume ratio, owing to the greater air loss through exit portals. If the fans are equipped with a universal motor, the fan can be run through a dimmer board and motor speed (and consequently fan air output) can be controlled with some accuracy, allowing a much wider range of inflation time.

Squirrel-cage fans (Fig. 7) are more efficient than the older propellor-type. They turn out a greater volume of air in terms of power requirements. They are, however, noisier because the flow of air is channeled

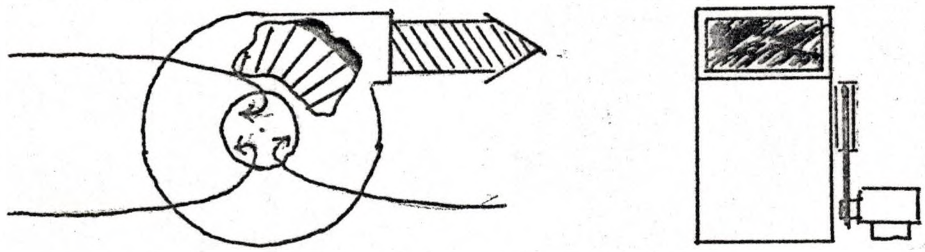

Fig. 7.--Squirrel-cage fan.

through a smaller opening than in an equivalent capacity propellor fan. Care must be exercised as well, to prevent cavitation and subsequent loss of volume due to operation at speeds higher than manufacturer's specifications.

The propellor fan (blade type) illustrated in Fig. 8 is less efficient than the squirrel cage fan, but tends to run quieter because the air flow is less concentrated with consequently less wind noise. A fan with a solid shielding, as shown in the illustration on the following page, is recommended to prevent air loss to the sides and to simplify attachment of the air transmission tunnel.

During the early fitting inflation periods, the technician will discover quickly that there is a noise and movement problem inherent in the

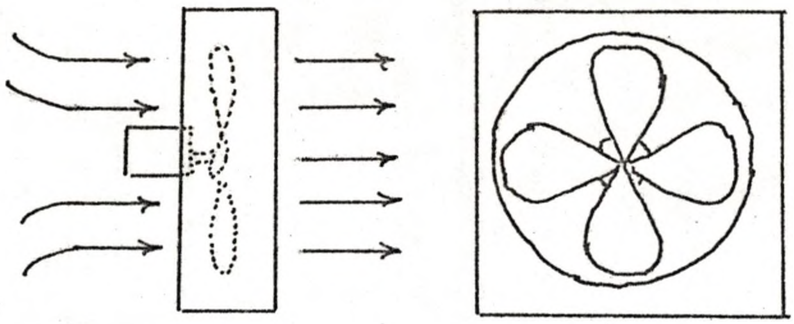

Fig. 8.--Propellor (blade-type) fan.

use of fans and flexible plastic scenery. Due to venturi effect, a low pressure zone exists for a short distance immediately adjacent to the fan or the entry of the air transmission tunnel, causing the plastic film to partially collapse for a short distance and, in the case of a practical unit, to flap to a greater or lesser degree, with subsequent movement of the entire unit. This is more a problem of the squirrel-cage fan than the propellor type. Decorative units can maintain higher pressure, ameliorating the flapping to a large degree once the unit has been fully inflated, although the partial collapse will remain.

The flapping problem was solved in The Little Prince by framing out the first few feet of the tunnel, allowing the speed of the air flow to decrease to a reasonable level and minimizing the venturi effect before it arrived onstage, (Fig. 9). This appears, however, to be a problem which must be solved specifically for each unit on an individual basis. The Little Prince had enough wing space to allow a rather bulky framing arrangement to be used; happily our tunnel was large enough, because of the necessary off-stage exits to permit the framing.

Although a squirrel cage fan must, of necessity, be mounted outside the tunnel, a propellor fan may be mounted inside the end of a large exit tunnel if space requirements so dictate. The end of the tunnel must be framed out and offstage portals placed in the side wall. Fig. 10 shows an inside mounted fan which proved successful in The Little Prince when a shallow wing area demanded conservation of space to allow anti-flap framing to be installed.

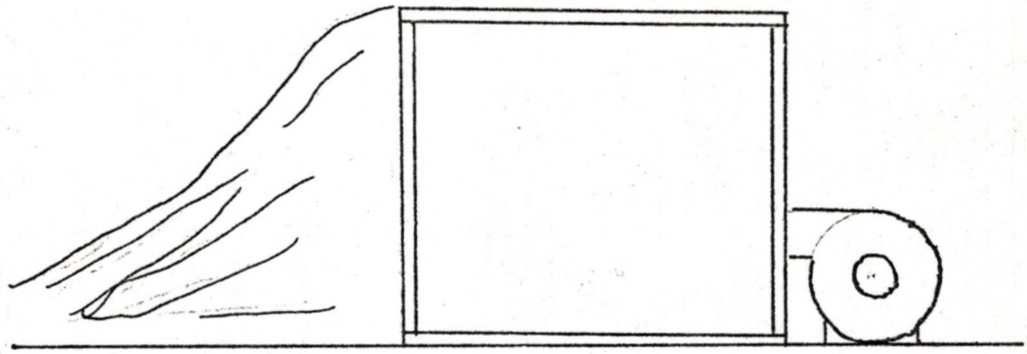

Fig. 9.--Framing arrangement for The Little Prince.

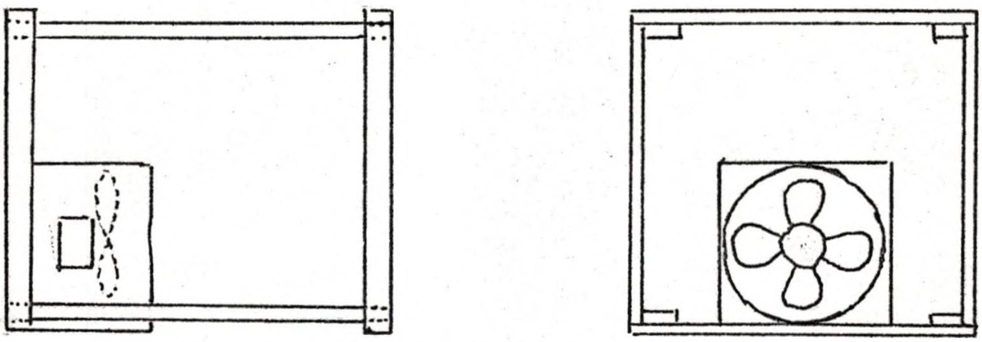

Fig. 10--Inside mount fan for The Little Prince.

Soundproofing the Fan

The first comment offered by the director of a production involving inflated scenery after the first inflation will pertain to the noise levels of the fans and escaping air. While a whisper of air escaping through vents and portals is unavoidable, the sound levels may be significantly lowered by sound-insulating the fans or isolating them from the stage. Isolation is the best solution if space requirements allow a long relatively straight run for the air transmission tunnel. Bliese placed his fan under the stage and ran the tunnel through a trap in the stage.[24] This solution is limited to trapped stages, unless the technical director will permit his stage floor to be cut through. Alternative positions are in the scene shop or a far corner of a deep wing.

If space limitations dictate fan placement near the stage, some form of sound-insulation must be provided to reduce motor and fan noise to minimum. The first step is to insulate the fan unit from the floor to prevent vibration from being transmitted and amplified by direct contact conduction. This step alone will significantly lower noise levels, but there will still be air-borne transmission of the inherent air, motor, and vibration noise. The problem is further complicated by the necessity for free air movement, both for greatest efficiency of inflation and for cooling the fan motor. An insulated box with sound baffles in front of the air intake (on the sides for squirrel-cage; the end for propellor) is the best solution. Care must be taken to restrict airflow as little as possible. Fiberglass insulation or flexible foam are both excellent sound absorbing materials with which to line the box, (Fig. 11). The entire inner surface

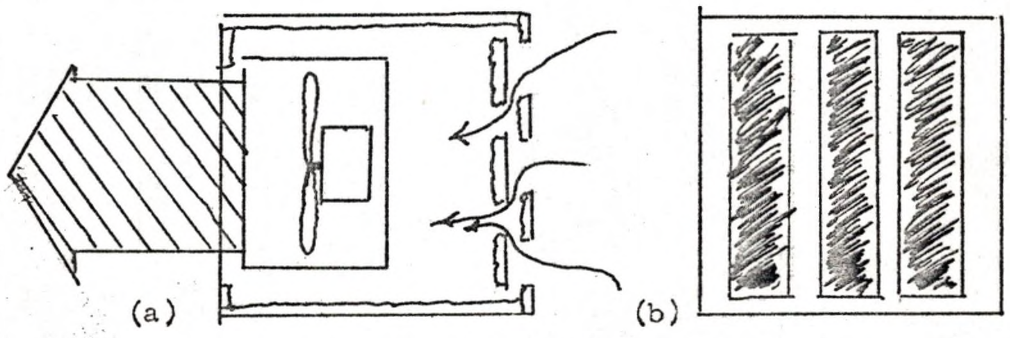

Fig. 11.--Top (a) and end (b) views of sound-insulation box for a propellor fan.

of the box should be faced with sound insulation and the fan should be shock-mounted to prevent transmission of fan vibration by conduction

[24] Rockey, p. 14.

through mounting hardware. A thick rubber mat placed under the box will further silence the fan unit. Spray foam-in-place styrofoam might work as a sound insulator, either to line the box or sprayed directly on the fan housing, although the writer has no experience with it in this capacity.

Compressed Air

Although not used in The Little Prince, in special circumstances compressed air might be used to inflate small, well-sealed polyethylene film decorative units. Deflation could be accomplished by means of a release valve built into the unit and tied off while the unit is inflated (Fig. 12). This method would serve best for small special effects property pieces, but requires masking for the air tank or high pressure hose. The primary advantage for compressed air inflation is freedom from external connections, providing a completely self-contained unit. Aside from the obvious dangers of working with high pressure air, access to the tank valve and the risk of possible over-inflation and subsequent rupture render this technique impractical for most application.

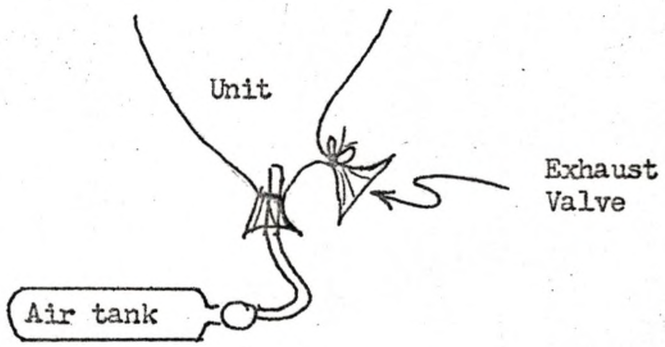

Fig. 12.--A system for compressed air inflation of special-use scenic units or properties.

Venting

To prevent rupture of scenery or overloading of fans working under overload conditions, provisions must be made in the inflated unit for escape of surplus air pressure. In a practical unit, with portals for passage of actors, the portals themselves serve as vents. Decorative units must, however, have openings made in them for releasing excess pressure. It is wise to applique reinforcing pieces of plastic over the ends of air vents to prevent them from being enlarged for any reason.

Practical units, especially those which must inflate in view of the audience, present a special problem. While slit vents in decorative units do not open sufficiently to cause appreciable problems in inflation, portals on the other hand must be secured or large volume air spill will prevent the unit from fully inflating. Partial inflation will hold the portal open, aggravating the situation. Even when fully inflated, portals must have a flap of some sort to guard against unwanted air loss. Actors must be instructed to make sure that the flap closes properly, where it will be held closed by air pressure. Failure to close the flap results in partial collapse of the unit (Fig. 13). The top and bottom edge of the

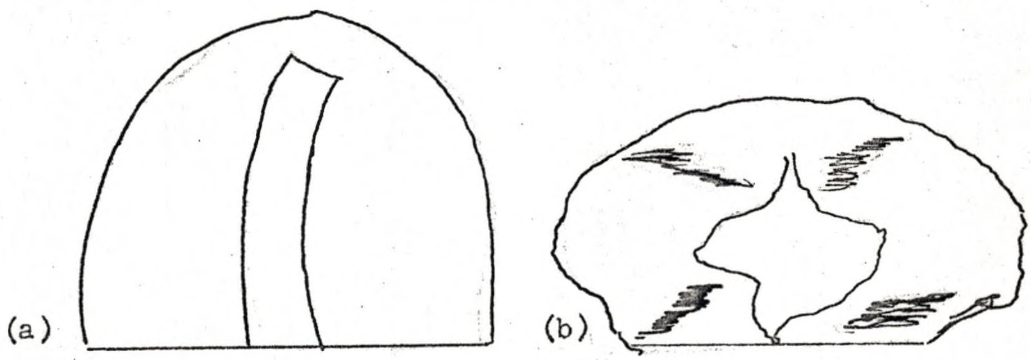

Fig. 13.--Portal with flap (a) and portal without flap (b), causing partial deflation.

flap should be sealed against the other side of the opening and portals should be as high as practical to prevent flaps from tearing lose, allowing air pressure to blow the flap through the opening and deflating the unit (Fig. 14). While the unit is inflating, the portal opening must be held closed. This may be accomplished by sewing small pieces of Velcro to both edges of the opening, using appliques to reinforce the sewn areas.

For small portals, simply overlapping the edges as much as possible prior to inflation often proves effective.

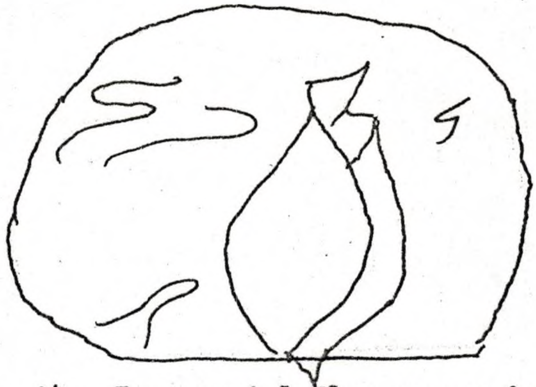

Fig. 14.--Torn portal flap causes deflation.

Decorative scenic units require venting to prevent rupture of seams. In some cases, once the set has reached full inflation, fan speed can be decreased until maintenance pressure is reached. If a variable speed fan is unavailable, slits should be cut in the upstage side of the unit where they are less unsightly and the whisper of escaping air is muted by curtains or legs. The positioning of the vent holes should be chosen so as not to cause movement of the cyclorama or other draperies.

Deflation

The technique for deflating a scenic unit depends primarily on the length of time necessary to achieve the desired result. If slow deflation for mood purposes is necessary, fan speed may be slowed until the appropriate pressure loss is obtained by balancing input volume against air loss through vents and portals. Simply turning off the fan speeds the process, although control is lost over the speed of deflation. Stagehands during an act break may manually collapse the set, as may actors if the action calls for it. Finally, an exhaust fan installed backstage can be used to pull the air from the unit if an extremely rapid collapse is desired. This last method however, is complicated by the necessity of covering the exhaust fan while the set is up and removing the cover prior to deflation.

CHAPTER IV

SPECIAL CONSIDERATIONS

External Support of Inflated Scenery

After having gone through the process of construction and inflation, the designer should prepare himself to find that the finished product bears only a limited resemblance to what he envisioned. This generally stems from the sometimes overlooked concept that air confined under pressure tends to equalize that pressure over the entire surface area inside the container. Stated another way, air pressure in an inflated plastic set will attempt to form the unit into a sphere and, failing that, it will try to assume a cylindrical form. Attempts on the part of the designer and technicians to form a flat-sided or rectilinear shape will meet with failure if some form of external support is not employed.

The University of Iowa set crew discovered this when attempts were made to keep the set from ballooning out, and it was unsuccessful. An effort was made to pull the offending wall in by cross-connecting it with the upstage side, but the polyethylene strips they welded between the two walls snapped due to the air pressure. Finally, the problem was solved by holding the wall in with sections of concrete-reinforcing wire mesh.[25] Solutions to this problem are as myriad as the problems themselves, but will undoubtedly have to be resolved as they appear. Solutions will vary depending upon artistic, technical, and equipment limitations.

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[25] *Ibid.*, p. 14.

Anchoring and Shifting Inflated Scenery

The method of anchoring any inflated unit depends upon whether or not the unit will be shifted during the course of the production. A permanent set is easily anchored by firring strips nailed to the floor. The firring need not be carefully contoured and may be installed inside the unit. Construction cost and time may be saved by omitting a plastic floor, since leaks will be sealed during initial installation, just as any tucks or binds in the plastic caused by inaccurate firring can be removed.

Floor segments should be sealed into a set designed to be shifted in order to maintain the integrity of the unit if for any reason the firring should be improperly installed when the unit is spiked. A layup lap joint (Fig. 6b) oriented outward, provides a convenient skirt for the firring strips. This permits all anchoring to be done from the outside, obviating the necessity of sending grips into the collapsed bag or inflating the bag in order to install the firring, then recollapsing it if it has to go up in front of the audience. The firring should be contoured to fit the outside skirt, preventing the set from binding and puckering when it is inflated, and provided with some form of quick release such as modified improved stage pegs.

If there is sufficient wing space, the unit can simply be rolled up against the fan when not in use and unrolled into position when needed. Curtailed wing space means that the unit or air transmission tube should be rigged with a quick-connect to the fan to prevent having to move both bag and fan as a single unit. Although a collapsed set unit is lightweight, it is extremely bulky and hard to handle. The fan and accompanying soundproofing, on the other hand, is not only bulky, but extremely heavy.

Touring an inflatable set requires a slightly different anchoring technique. The technician must be prepared for virtually any form of stage floor, from the standard softwood stage floor to the varnished hardwood or even concrete and tile of gymnasium flooring. Because flooring can vary so much, particularly when touring schools, the technicians must be prepared for the possibility that he will be unable to screw or nail the firring strips to the floor.

Two solutions become apparent, both involving the use of contoured and weighted firring strips. If the stripping is made up in short lengths, it should be easily handled by the small touring crew. The firring strips need not be heavily weighted; during the initial set-up of The Little Prince it was discovered that 2x4 in four to six foot lengths easily held down the bottom edges against the internal air pressure, although additional lengths were necessary near the fan. It should be noted that the Prince set had no floor and that there was some leakage of air under the 2x4. A floored unit would probably build up greater pressure, and there would be a tendency for the area where floor meets walls to balloon because of pressure equalization. However, a variable speed fan would help to alleviate the situation, for it could be slowed after the set reached full inflation and only maintenance pressure continued.

The anchoring strips must be in some way affixed to the skirt or the set's tendency to balloon could pull the skirt from under the firring. If time permits, pockets could be formed from polyethylene film and welded to the skirt, or fabric pockets could be sewn to a reinforced skirt. The firring strips would simply be inserted into the pockets and the set spiked. A simpler technique might involve setting grommets into a reinforced skirt, with corresponding hand-bag-type fasteners installed on the firring. Large snap fasteners might also work. Large snap fasteners or grommets should be used in order to spread the load over a larger area.

CHAPTER V

CONCLUSIONS

In order to evaluate the potential of inflatable polyethylene scenery, as used in The Little Prince, it is necessary to review some of the characteristics of polyethylene film. It is a chemically inert, physically strong, gloss surface thermoplastic, capable of being joined to itself only by the application of heat. Effective sealing of seams can be accomplished with minimal equipment and effort. It is available in two colors, black, and a translucent milky-white, from a wide variety of local dealers at very low prices.

Easy workability and low unit cost make polyethylene film attractive to the technician. A small crew with a salvaged clothing iron can build a set such as the one for The Little Prince in only a few days with a total cost of approximately fifty dollars. Fans may be purchased, borrowed, or rented. The Little Prince fans, one borrowed, one purchased, cost the production approximately seventy-five dollars, bringing the total set budget to less than one hundred fifty dollars.

The great tensile strength of polyethylene film makes it difficult to tear or puncture, but should some accident befall the unit, it may be repaired with an applique patch and a hot iron in only a few minutes. Its light weight and small size when deflated make pleasant the thought of inflatable polyethylene scenery for touring groups; even a large set with two or more fans should fit easily into a station wagon or small van.

The tendency for internal pressure to equalize in the freestanding inflated set unit leads to a roughly circular cross-section. Any rectilinear form requires external support. The venturi effect and subsequent flapping of the unit must also be taken into account in preparing the final designs. These air pressure effects vary from set to set, making each unit a case to be dealt with individually.

Complex forms or intricate detail are difficult to render in polyethylene film, due to the difficulties encountered with air pressure. The tendency for all forms to round out when inflated makes it difficult to predict exactly what form the finished product will take; creases flatten out and "flat" walls bulge outward at the center. The simpler and less specific the form, the fewer the problems encountered in achieving the design objective.

Although the illusion of rigidity can be achieved, true rigidity is an impossibility. Any time the unit is touched, it moves. The air turbulence engendered by a passing actor causes the unit to quiver. This movement is magnified by the shifting highlights on the shiny surface. Since the surface of the individual unit is effectively a single plane with equal air pressure at all points, external pressure against any point is transmitted throughout the whole unit, the effects decreasing with the distance from the point of application. Because greater air pressure increases the surface tension, the higher the internal pressure, the more rigid the unit will tend to be. The relationship between fan capacity and unit volume is discussed in detail in Chapter IV.

The waxy surface coat renders standard painting and texturing techniques useless. Some paints, notably acrylics and spray-on auto paints, may be used, but with limited success, since the flexing of the film when the unit is inflated and deflated tends to make the paint peel off. However, the translucent white film may be effectively colored with stage lights, although the surface remains uniformly smooth and shiny. The uniform texture makes small units impractical for large theatre situations unless the scenery is non-specific in form. A small specific shape does not read well from any distance; translucency and lack of texture allow light to pass through the surface, lighting all surfaces of the unit equally. In the translucent film, light tends to be trapped in the surface of the plastic, resulting in a uniform glow throughout the whole unit, with a consequent loss of definition. Black film units also present a problem in definition due to the uniformity of color and reflection. Depth and definition is lost in black units because of the difficulty in distinguishing one black form from another at a distance, although black film tends to have more definite highlights than the translucent.

These factors severely limit the use of inflatable polyethylene scenery. It is best utilized in stylized productions where verisimilitude is not a design factor. Due to its inertness, polyethylene film is difficult to disguise. Even should paint be used to color and texture the plastic, the physical characteristics engendered by air pressure against flexible film remain. There is no way to separate one property from the others. Although the shape may vary from one set to another, each inflated polyethylene scenic unit must of necessity possess characteristics virtually identical to those of every other inflated polyethylene scenic unit: if the designer is not willing to accept any one of those limitations, he must hunt for a different medium.

If these limitations are acceptable, the designer must determine whether or not inflatable scenery is suitable to the stage upon which he must work. Although small units might be used on a trapped arena stage, sightlines, masking, and noise factors tend to preclude the use of all but the proscenium stage. In order to justify its usage, the polyethylene set demands a certain magnitude. Although true that its virtual transparency allows an audience to see action through the set, this effect is limited in its usage because of the distortion which occurs due to manufacturing flaws in the plastic. Blocking action behind an inflated set, like blocking behind scrim, loses impact and effectiveness in direct proportion to the length of time involved. An audience which must strain to see loses interest rapidly.

The fans must be masked. Their on-stage use is limited by noise caused by the rush of intake air, even if the fan unit has been soundproofed. Finally, the writer was told by the cast of The Little Prince that the noise of vented air made it difficult for the actors to hear each other. There were no problems hearing in the audience because the air noise was absorbed by the hanging masking before it left the stage house.

It appears then that the inflated unit is best used as background scenery and with that most of the action taking place downstage of it. Noise factors at this time dictate that the audience be isolated from the set to the greatest degree possible, commensurable with visuability and audibility. These factors suggest that the proscenium stage, with its sound absorbing masking and wings, is the most practical production area, with thrust staging second, and arena staging third.

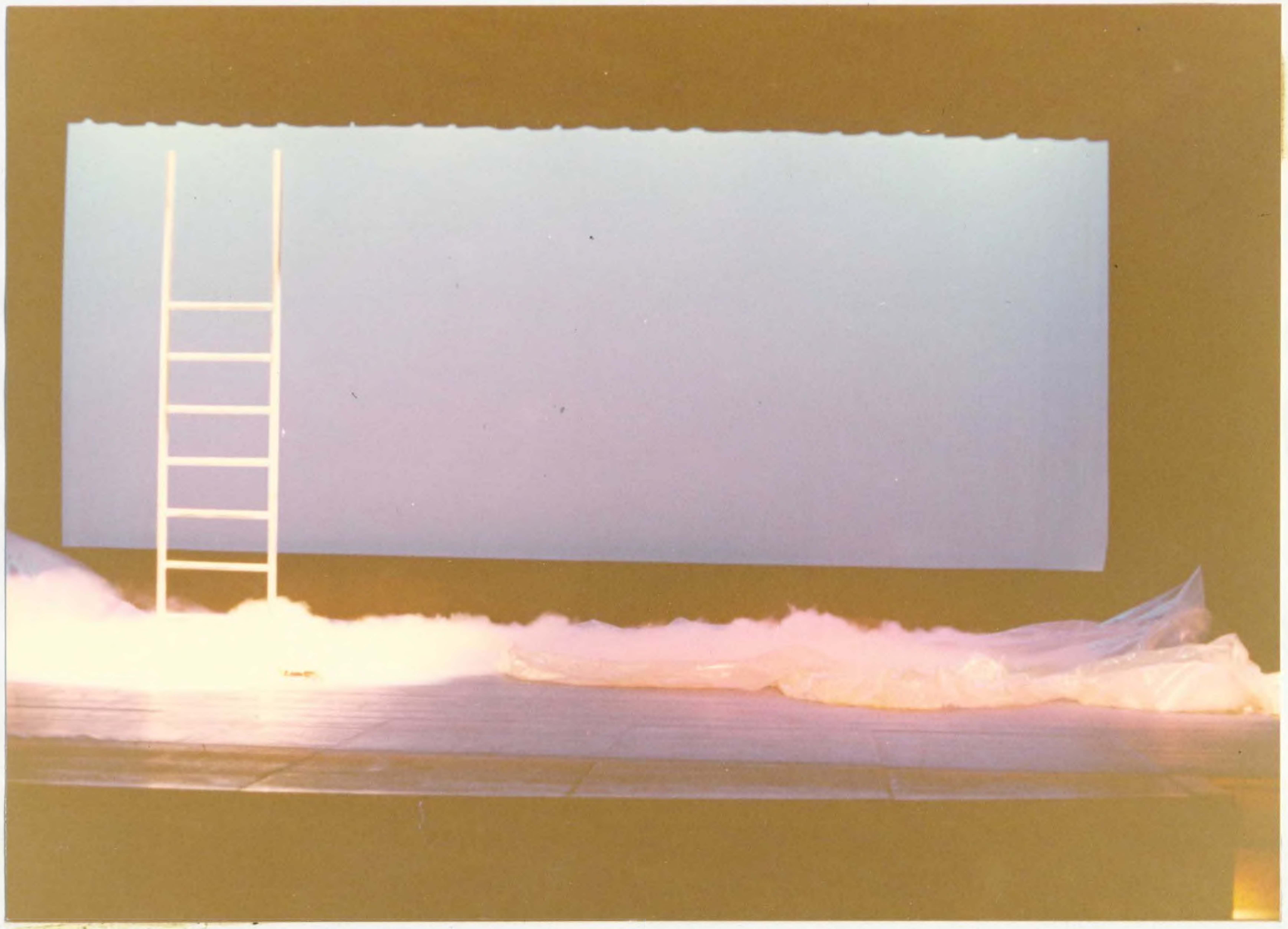
The inflated polyethylene set has a dynamic quality unmatched by any other construction technique. One is always aware on an almost subliminal level of the opposing forces which shape the unit; there is an ever-present feeling of contained power. Yet despite this feeling of potential force, there is an inherent softness about this type of scenic unit. The slightest pressure anywhere on its surface will cause the entire set to move perceptibly. The set is strong yet vulnerable.

The less tangible molding force of stage lighting can produce an intricate and subtle change of character and mood without corresponding physical movement. Inflated scenery takes to stage lighting as if polyethylene was developed for illumination, passing from virtually opaque to effectively transparent with almost infinite gradations in between. A thing as subtle as a slight shift in lighting angle can transform a solid sand dune into a cloud. These factors were all used to good advantage in The Little Prince. Combined with the "magic" appearance and disappearance of the set out of the mist, the inflated unit formed an appropriate environment for this children's fantasy. If the designer is willing to accept the challenges offered by inflatable polyethylene scenery, its advantages as well as its inherent drawbacks, he will find that the results can indeed be satisfying.

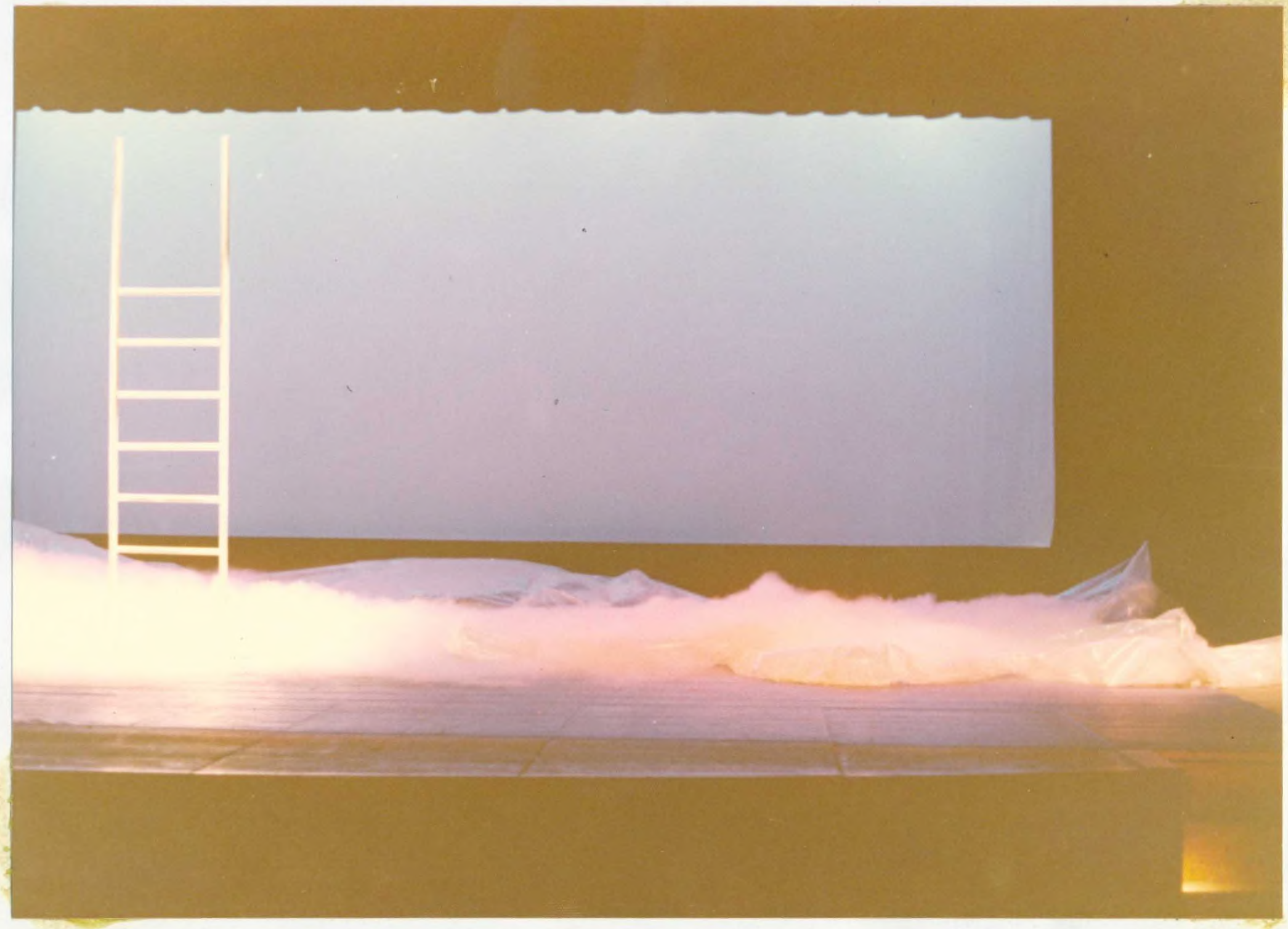
APPENDIX

INFLATION OF THE LITTLE PRINCE SET,
FROM START OF FANS TO FULL INFLATION

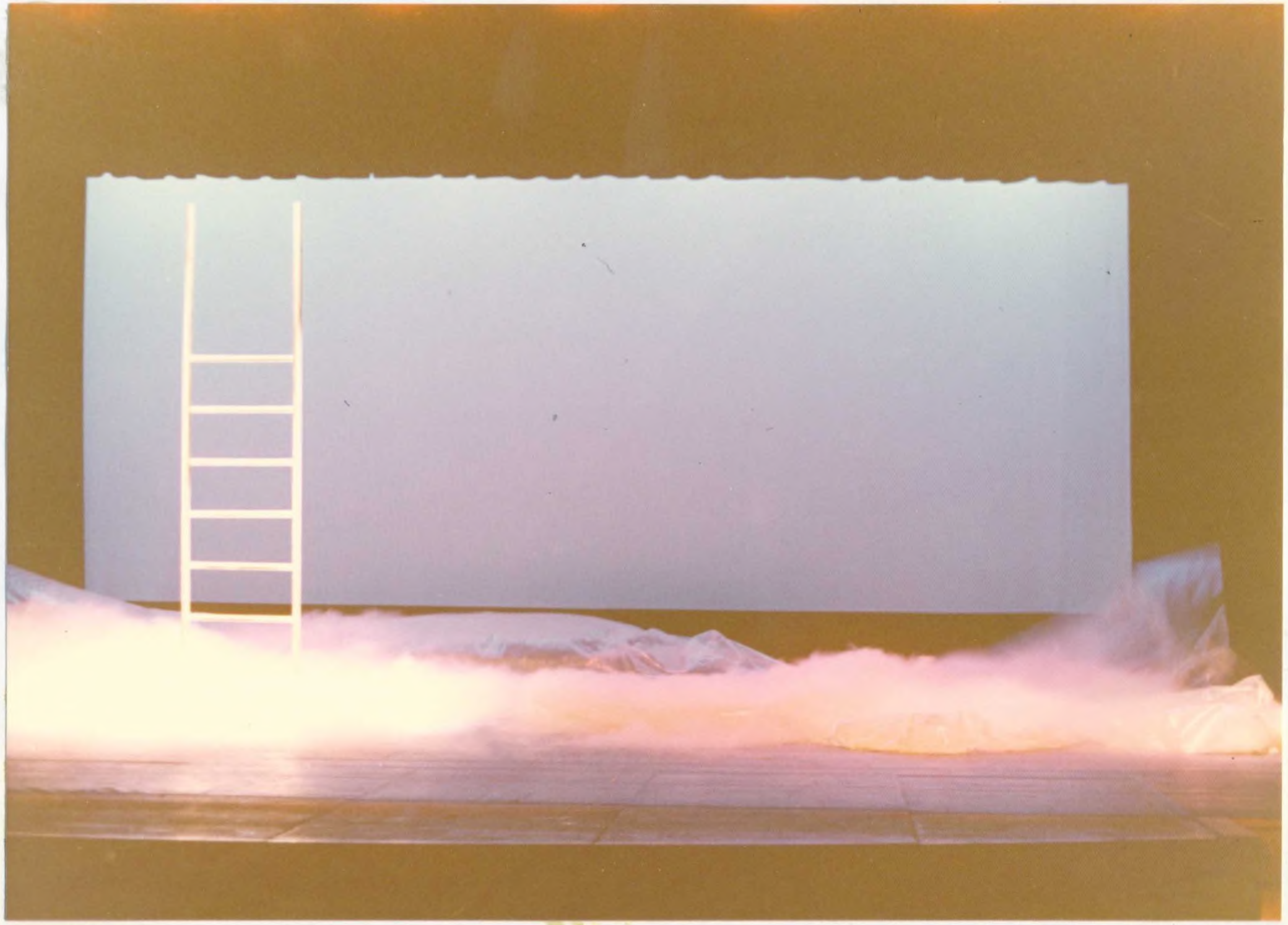
(Elapsed time between photographs: Five seconds)



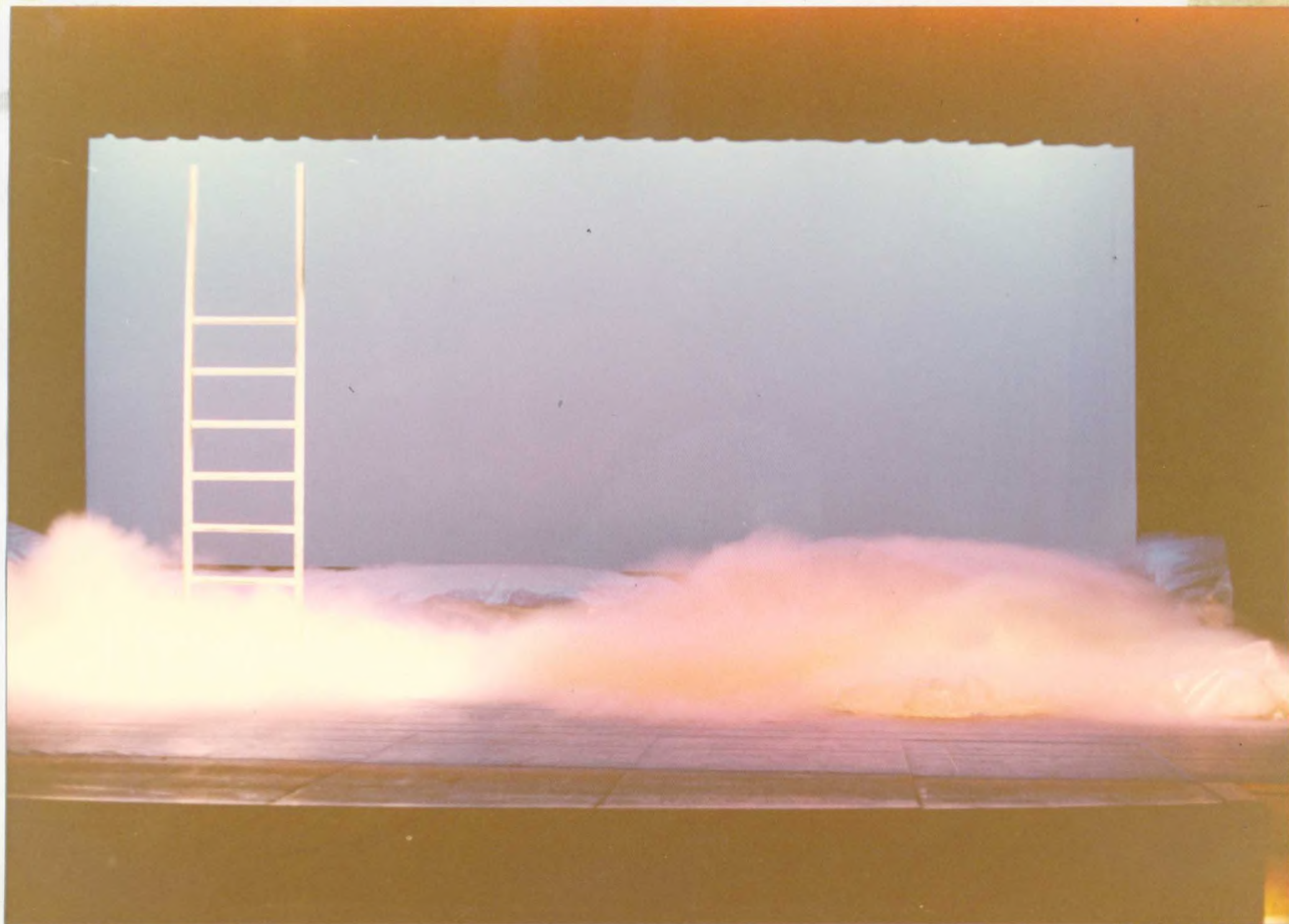
START OF INFLATION



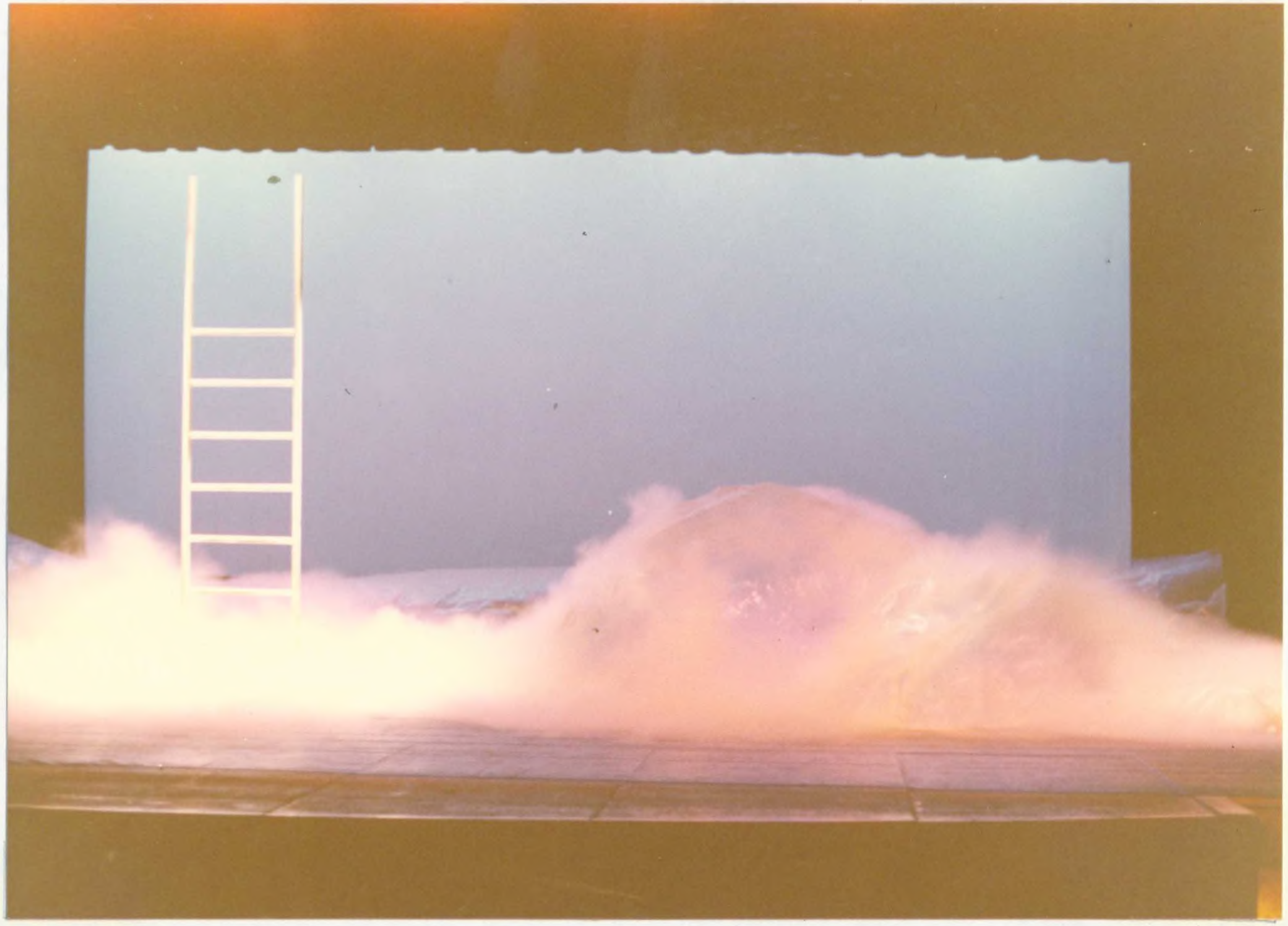
ELAPSED TIME: 5 SECONDS



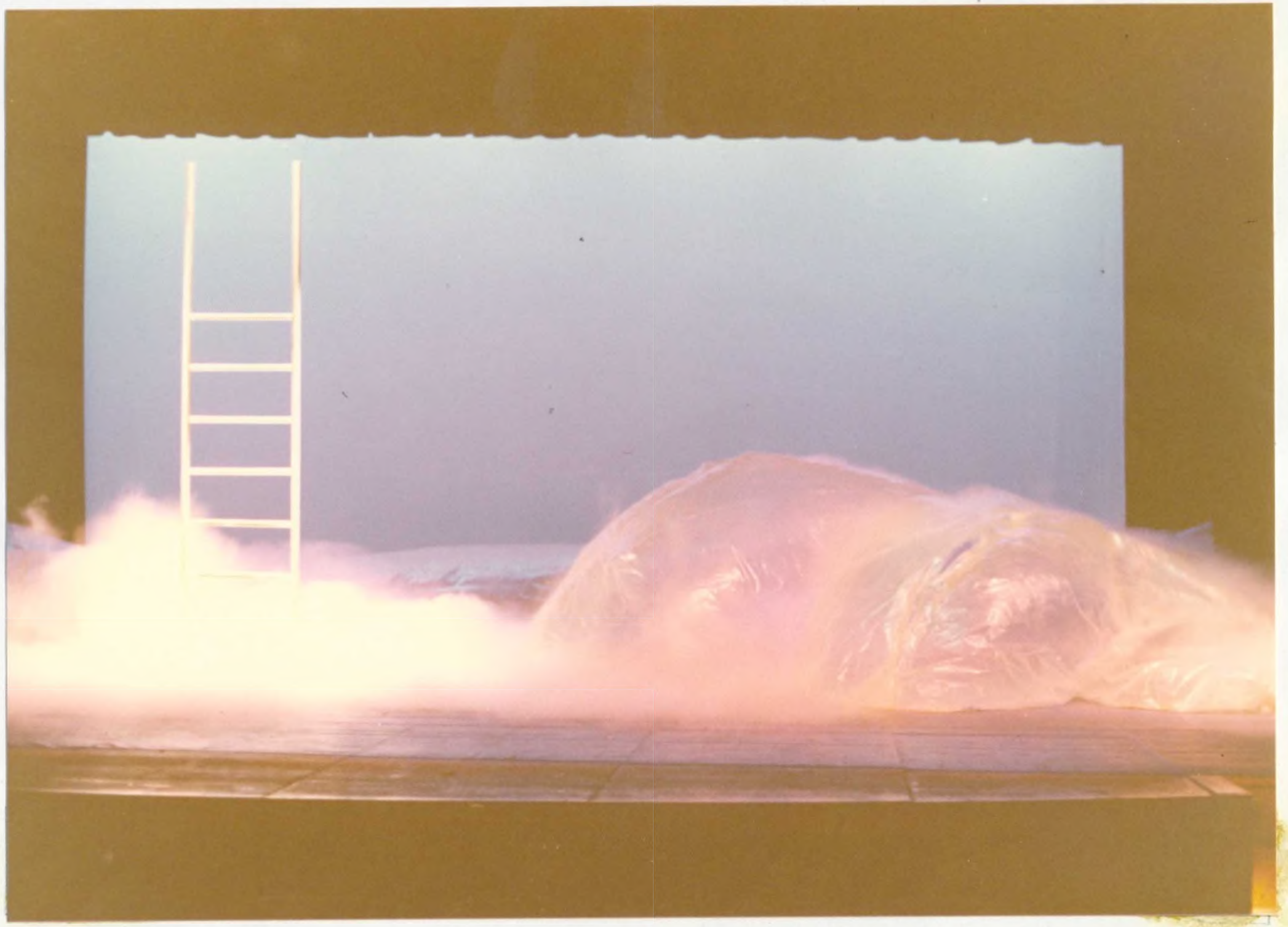
ELAPSED TIME: 10 SECONDS



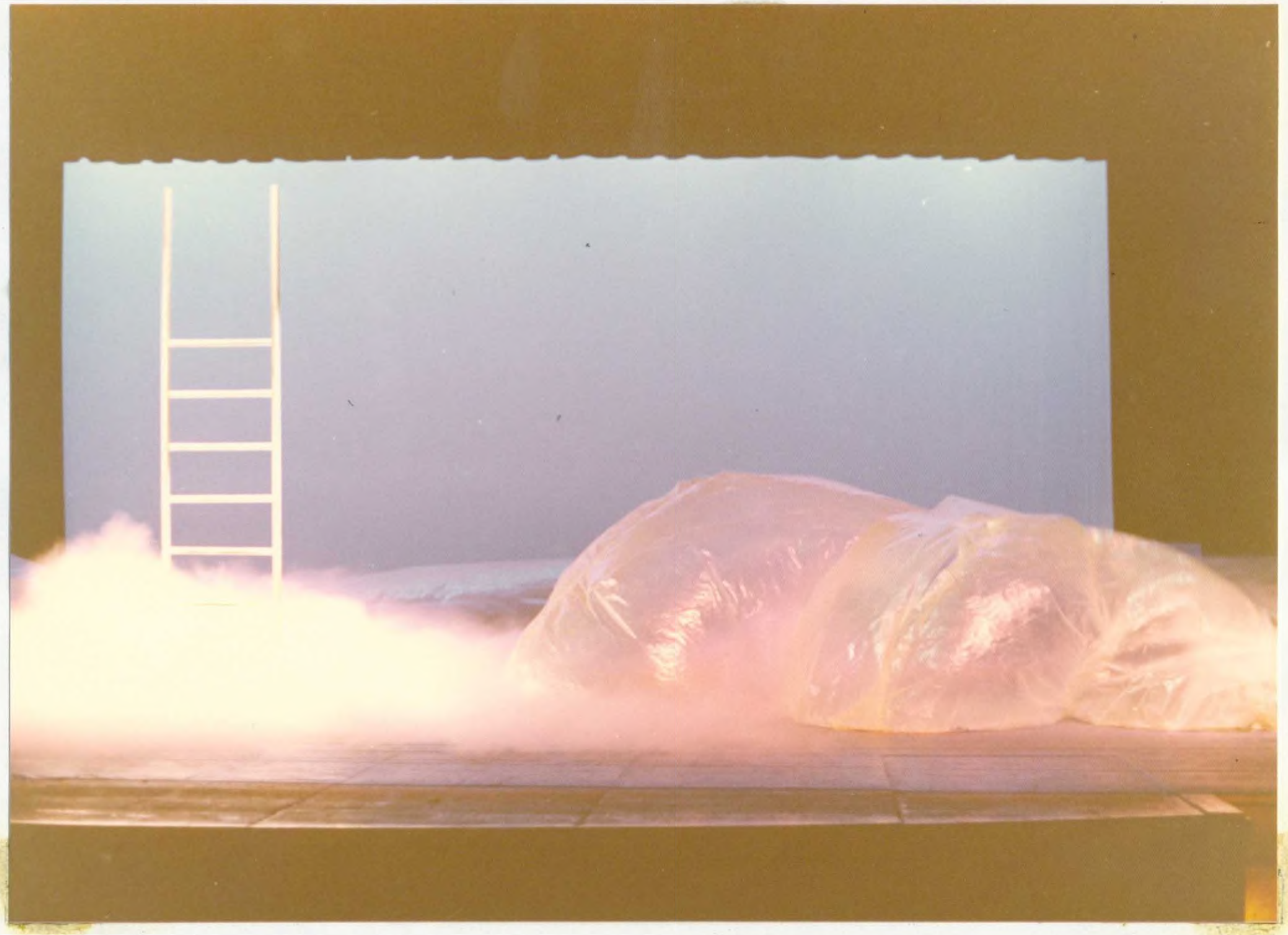
ELAPSED TIME: 15 SECONDS



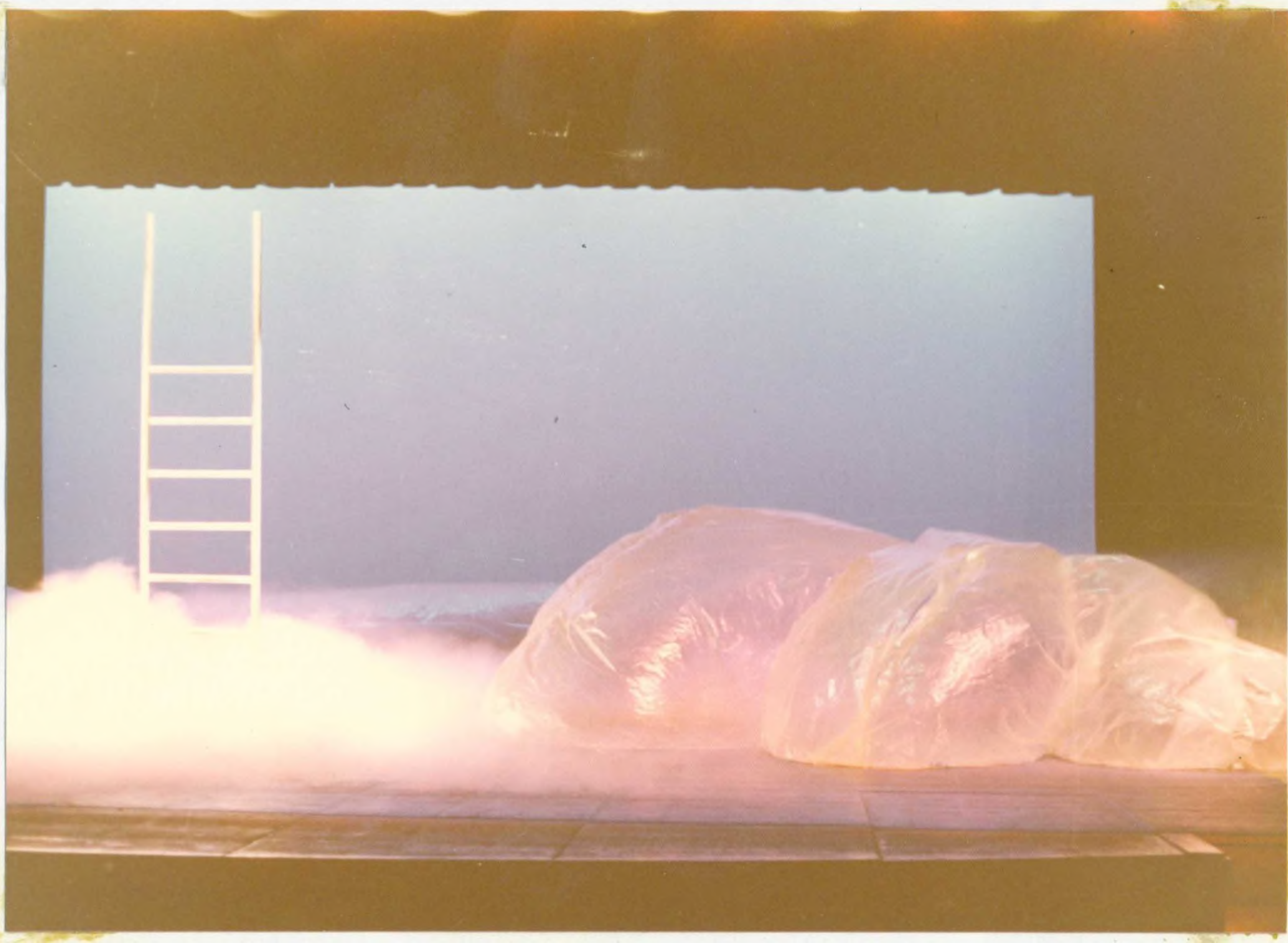
ELAPSED TIME: 20 SECONDS



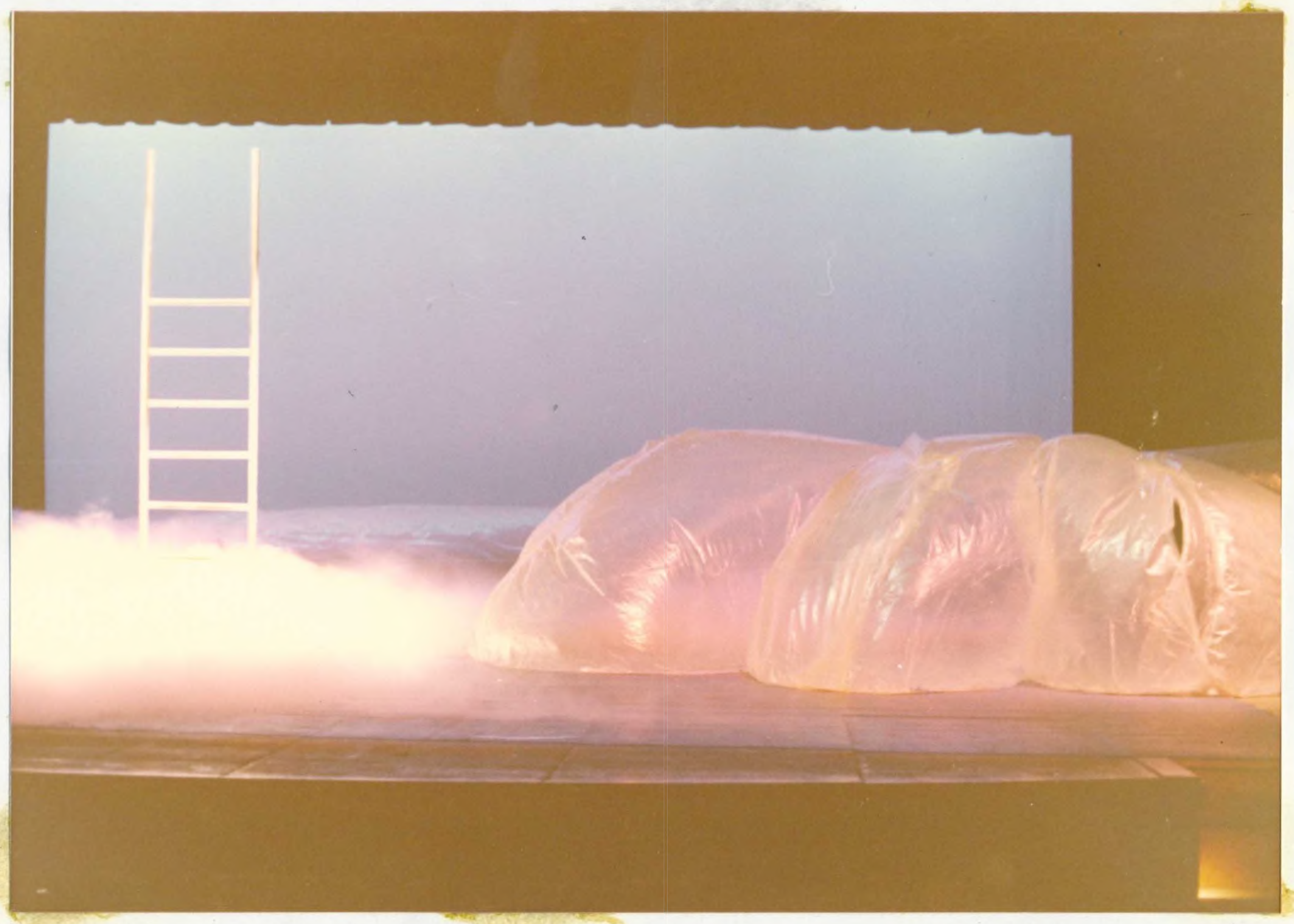
ELAPSED TIME: 25 SECONDS



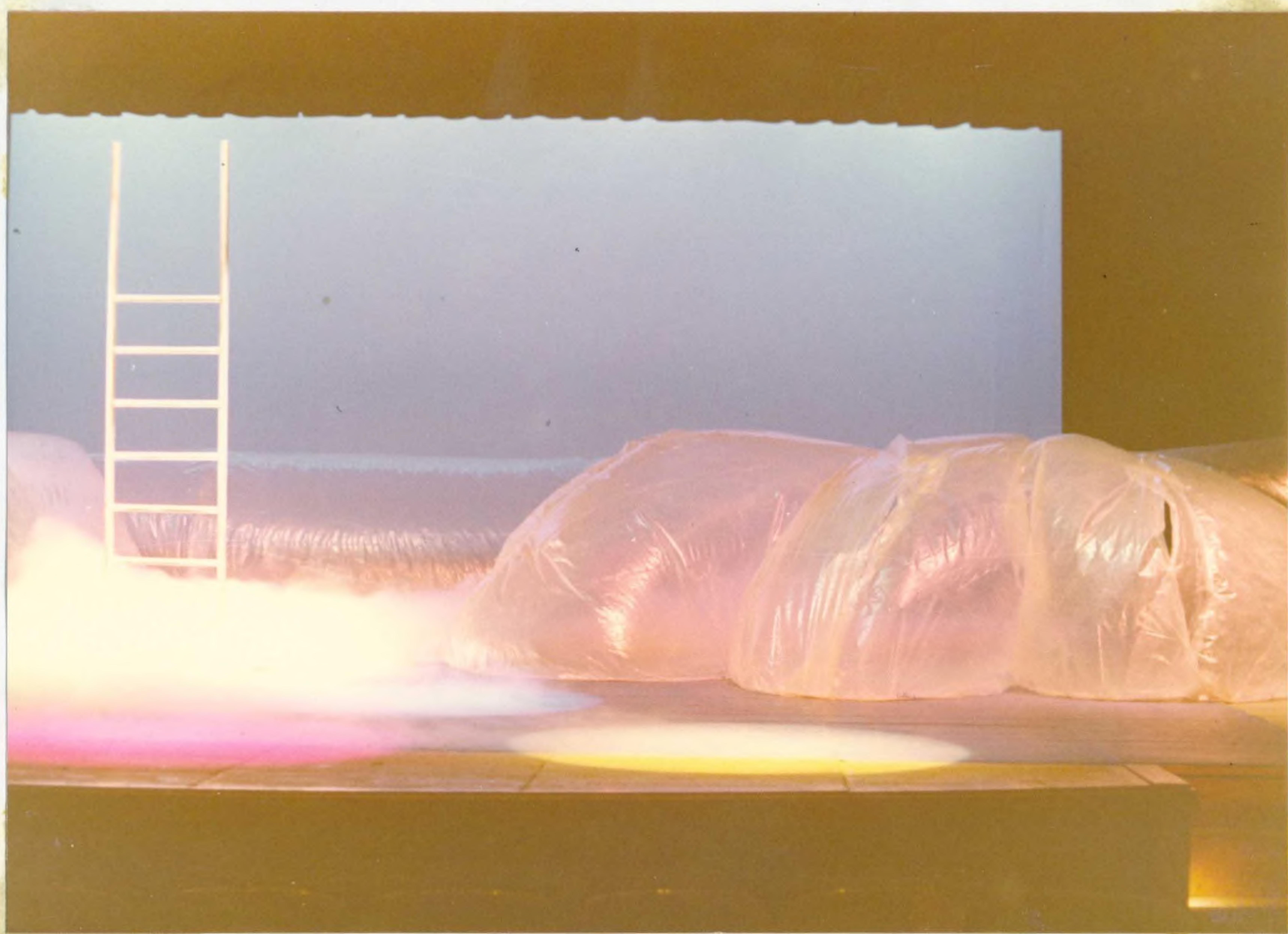
ELAPSED TIME: 30 SECONDS



ELAPSED TIME: 35 SECONDS

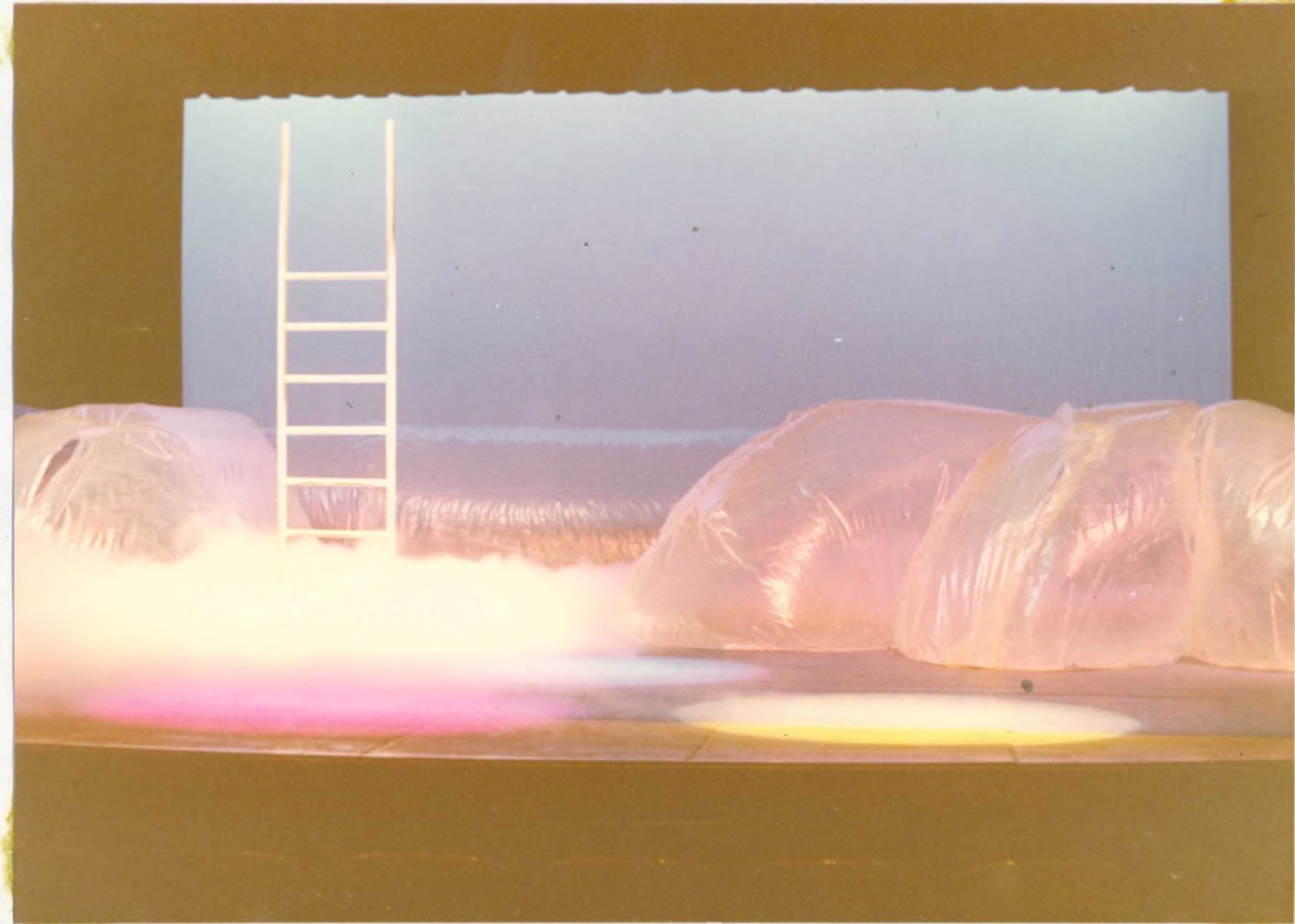


ELAPSED TIME: 40 SECONDS



ELAPSED TIME: 45 SECONDS

47



FULL INFLATION: 50 SECONDS

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