Aug. 21, 1934. W. J. ELSER 1,970,956

METHOD OF DESICCATING LIQUIDS AND SEMISOLIDS

Filed May 16, 1931 3 Sheets-Sheet 1

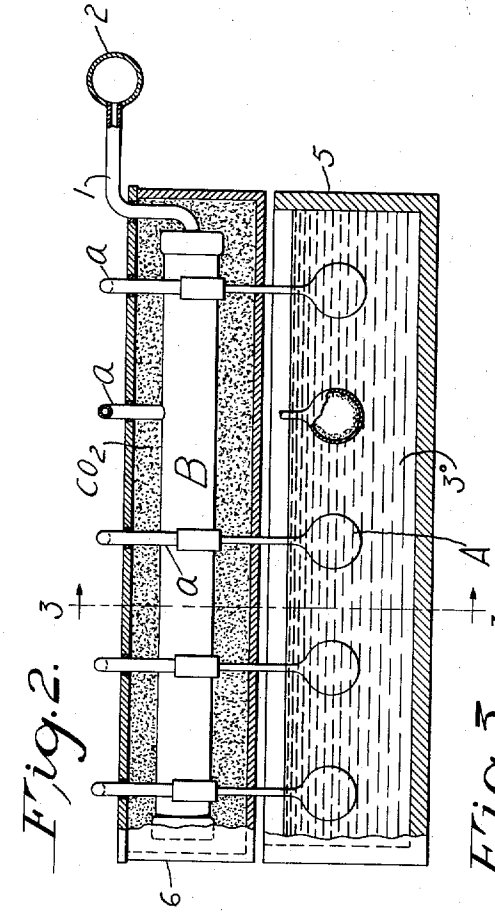


Fig. 2.

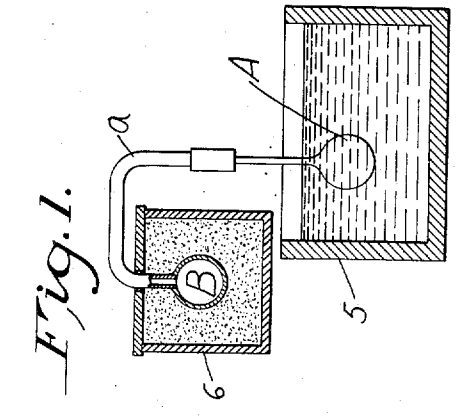


Fig. 1.

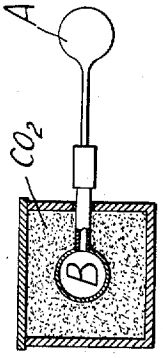


Fig. 6.

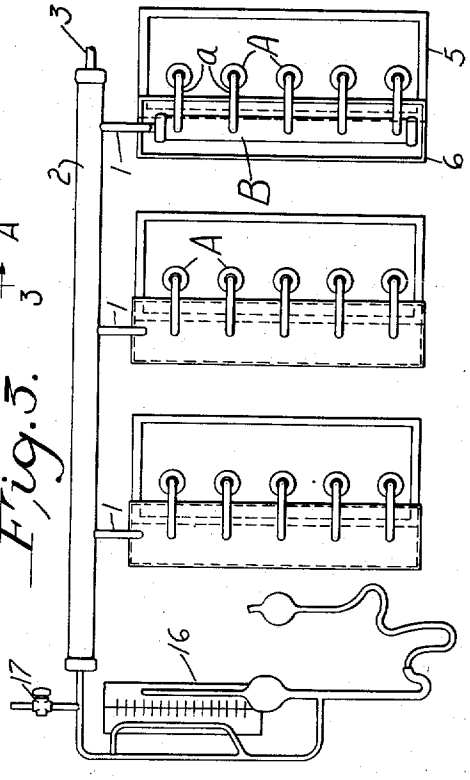


Fig. 3.

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METHOD OF DESICCATING LIQUIDS AND SEMISOLIDS

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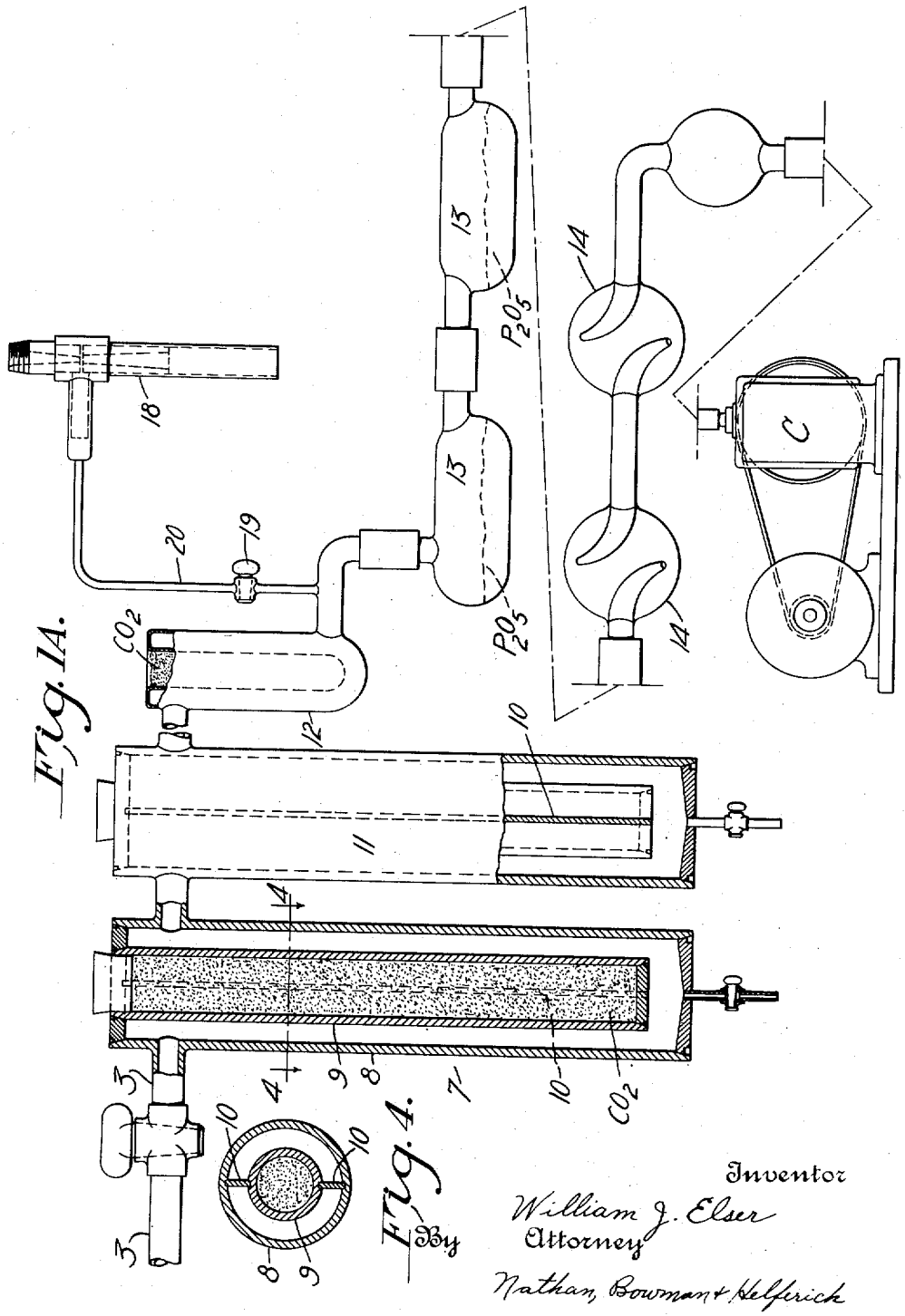


Fig. 1A.

Fig. 4.

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Fig. 8.

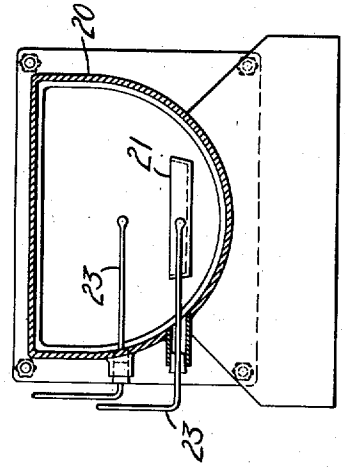


Fig. 9.

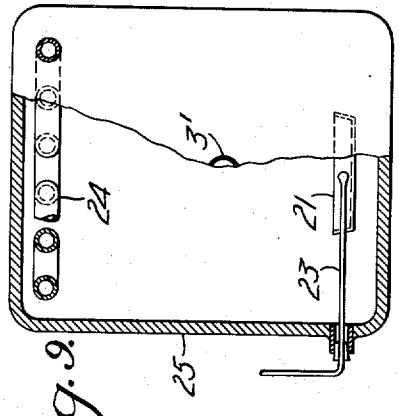


Fig. 7.

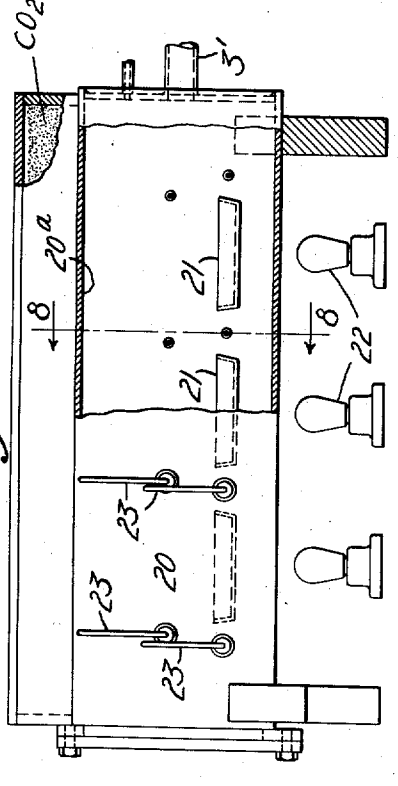
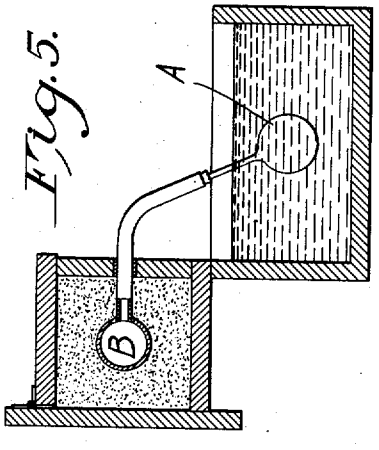


Fig. 5.



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UNITED STATES PATENT OFFICE

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METHOD OF DESICCATING LIQUIDS AND SEMISOLIDS

William J. Elser, Old Greenwich, Conn.

Application May 16, 1931, Serial No. 537,898

8 Claims. (Cl. 99—5)

This invention is concerned with the proposition of so-conditioning liquids and semi-solid materials containing proteins or other biological derivatives that, without alteration in their essential properties, they may be preserved for future use in unaltered form. To carry out this conception, this invention, through the agency of suitable apparatus, subjects the material to a method of treatment which converts it into a permanent product capable of being, at any subsequent time, restored to its original form and equally available for immediate usage.

If the water constituent and gases of blood-sera and semi-solid materials could be eliminated without altering their other characteristics, or introducing any foreign substance, it was apprehended that the thus-desiccated product would not be subject to deterioration, and by the mere addition of pure water, could be used in lieu of the original fresh material for all purposes. This expectation has been realized as herein explained.

It has likewise been established that if, prior to and during the operation of withdrawing the water from the material, such water be segregated from the tissues and cells so far as possible, then can its evaporation occur without deterioration. To this end, the material is, as a preliminary step, chilled below the freezing point of water; the chilling being performed expeditiously with the object of segregating the water in the form of crystals as minute as possible. If this condition be maintained until the water has completely been removed by evaporation of these ice crystals, and if the evaporation be caused to take place expeditiously, it is certain that no deterioration will result.

Inasmuch as the vapor pressure of water below its freezing point is exceedingly low (4.58 m.m. Hg. at 0° C.; 4.22 at −1° C.; 3.88 at −2° C.; 3.57 at −3° C. and 3.28 at −4° C.) evaporation requires to be carried out through specially contrived means and under particular conditions.

This admits of being set forth to better advantage through reference to the annexed drawings in which:—

Figures 1 and 1A combined represent one form of apparatus well adapted to carry out the desiccation of quantities of sera in accordance with this invention. Fig. 2 is a longitudinal sectional view through one of the desiccating units illustrated in Fig. 1. Fig. 3 is a sectional view taken along line 3—3 of Fig. 2. Fig. 4 represents a sectional view through line 4—4 of one of the vapor traps illustrated in Fig. 1A. Fig. 5 is a modified form of the connections between the sera containers and the condensing chambers. Fig. 6 is a similar connection adaptable however for cold storage room purposes. Fig. 7 represents an improved form condensing chamber within which are placed trays of the material to be desiccated. Fig. 8 is a sectional view through line 8—8 of Fig. 7. Fig. 9 is a further form of condensing chamber and which is cooled by means of a refrigerating coil instead of CO_2 snow or other refrigerant as in Figs. 2 or 7.

The primary elements of the apparatus comprise a container A for the serum, a condensing chamber B for the collection of the water withdrawn from the serum, and a pump C for withdrawing all initial air or other gases from the system and for maintaining it under a high vacuum.

It may here be noted that this system neither depends upon nor contemplates chemical absorbents for performing the desiccation. Although such agents, as for example, phosphorus pentoxide have a powerful affinity for water, and a very low vapor pressure, nevertheless they (or perhaps, certain impurities thereof) are volatile to the extent of their vapor pressures, and may bring about changes in the serum such as to defeat the purpose of the invention. This has been demonstrated to be a fact.

It is, therefore, proposed to avoid such absorbents and to accomplish the desiccation by employing a condensing chamber, the inner surfaces of which are maintained at a temperature so low that the vapor pressure of water (ice) in contact therewith will be materially lower than ice at 0° C. or a few degrees lower. To illustrate, (assuming the pump is capable of producing a complete vacuum) if the condenser be surrounded by CO_2 snow its wall will be cooled to a temperature of about −70° C. At this temperature, ice has a vapor pressure of only about .0025 and hence the water vapor evolved by the frozen serum (under a vapor pressure of about 3.0 m. m. Hg.) will be caused to condense to the extent of maintaining in the space a vapor saturation of a very low order; to wit, only such as corresponds to a pressure of .0025 m. m. Hg. If instead of solid CO_2, there be used liquid air to cool the condenser, the differential in vapor pressure will be even greater; to wit less than 6.6×10^{-16} m. m. Hg.

In the interest of rapidity of evaporation of the water from the serum and of its speedy accumulation as ice in the condenser, it is desirable to approach the foregoing ideal condition as nearly as possible. This pre-supposes a pump capable of

removing all of the initial air and gases from the system. While no pump can create a perfect vacuum, pumps are available which will exhaust the system to as low a pressure as 0.007 m. m. Hg. (or lower). By resorting to such a pump, in combination with the system as described, it has been found to be possible to dehydrate sera effectively.

Considering the case from the standpoint of the minimum pressure creatable by the pump (say 0.007 m. m. Hg.) the condenser should be maintained at a temperature at which the vapor pressure of water (ice) is less than 0.007. At a temperature of minus 61 degrees C., the vapor pressure of water is 0.007; and the condenser should be kept below this point under these conditions. So long as the pressure in the system is lower than about 3.0 m. m. Hg., the frozen water in the serum will be above what may be said to be its boiling point and hence will evaporate speedily.

Certain practical considerations are likewise noteworthy. The material should be arranged to present a relatively large surface, and the condensing area should be no more remote than need be from the material; for water-vapor extends but slowly in a vacuum. The first condition may be attained easily, as a preparatory step, by rapidly revolving the bulb containing it, while held in a slanting position, in a freezing bath such as an ice-salt mixture at between −12° and −20° C. This will interiorly coat the bulb with a film of the frozen material. The second condition relates to the arrangement of the apparatus. This may now be described through detailed reference to the annexed drawings.

Referring more particularly to Figs. 1 and 2, it will be observed that a series of bulbs or containers A are illustrated as connected by short tubes *a* to a common condensing chamber B which is connected by means of tubes 1, 2 and 3 to the remainder of the drying apparatus illustrated in Fig. 1A. The bulbs containing the frozen mixture to be desiccated are maintained at a temperature slightly below zero by being submerged in a suitable coolant contained in a tank or vessel 5, or if desired and if local conditions permit the bulbs may be arranged to extend laterally from the condensing chamber B as in Fig. 6. This last mentioned arrangement is particularly adaptable for cold storage room purposes, that is, in such cases wherein the apparatus is set up in a room or chamber in which the temperature is maintained constant and at approximately −3°, thereby dispensing with the baths 5.

The condensing chamber B is, in this figure, enclosed in a box 6, filled with CO_2 snow which cools the walls of the chamber B to a temperature approximately −70° C. whereby the vapors rising from the bulbs A will immediately condense and solidify on the interior thereof. It may be here stated that the interior surface area of the condensing chamber is so proportioned with respect to the volume of sera to be dried that the accumulation of ice rapidly formed therein is deposited in a thin layer more or less evenly over the entire inner surface.

The air is then withdrawn from the condensing chamber and evaporation of the sera takes place. One end of the chamber B is connected to a high vacuum pump C and in order that no moisture is carried to the pump, the air is first passed through a series of traps and dryers now to be explained. Referring to Fig. 1A, it will be seen that the exhaust line 3 connects with a vapor trap 7 which comprises two tubes 8 and 9, one within the other, which are separated longitudinally by two baffle plates 10 arranged diametrically opposite each other, as shown in Fig. 4. The inner tube 9 and baffle plates 10 are placed a short distance from the bottom of the outer tube 8, thereby forming a U shaped chamber, as shown in Fig. 1A, for the passage of the exhaust air. The inner tube 9 is cooled by filling same with CO_2 snow and as the exhaust air comes into contact therewith a rapid chilling takes place which removes moisture that has passed the main condensing chamber B. This operation is again repeated by passing the air through a second vapor trap 11, constructed in all respects identical with the trap 7.

The pump is still further safe guarded against sucking moisture laden air by the insertion of a third vapor trap 12, which in principle operates as the traps 7 and 11, but is made of transparent glass so that whatever moisture is condensed therein is apparent to the observer as a frosty ice deposit. The inner tube of the indicator trap is painted black so as to increase the visibility of the minute particles of ice that may form therein.

Before the withdrawn air reaches the pump it passes through one or more drying tubes or chambers 13 which are partly filled with a water vapor absorbing powder such as phosphorous pentoxide (P_2O_5) which takes up the last vestige of moisture that may still be carried by the air as it is withdrawn by the pump. Dust traps 14 collect and retain the particles of P_2O_5 powder that may be picked up and carried to the pump when the powder is perfectly dry and when the volume of air and the rate of flow is great as is the case during the early periods of evacuation. This may be more clearly understood if it will be remembered that when the apparatus is first set up and ready for operation, the pump, in withdrawing the air, gases, etc., in large quantities.

The pumping operation is continued until the desired degree of vacuum (say .007 m. m. Hg.) is reached, and then shut off.

If there is no leakage of air into the system after the vacuum is attained the drying process continues rapidly and uninterruptedly until the product is thoroughly dried. However, as a practicable problem, a high vacuum is difficult to maintain and, therefore, it is preferable that the pump be left connected with the system and operated intermittently or continuously to maintain the vacuum so that the drying process will not be retarded.

For the purpose of keeping a record of the degree of vacuum maintained when drying a given mixture an indicator or gauge such as the conventional MacLeod gauge 16 is attached to the system preferably at a point remote from the pump. Accurate readings may then be taken and comparative records made of various mixtures undergoing desiccation.

Upon completion of a drying operation bulbs are removed and corked. The apparatus is then quickly and easily "defrosted" by opening the cock 17 which connects the tube 1 with a source of dry air that is drawn through the condensing chamber and vapor traps by suitable means, such as, for example, a water pump 18. A stop cock 19 placed in the conduit 20 leading to the pump effectively closes this line when the pump C is operating to evacuate the system.

It is obvious that various other forms and arrangements of condensing chambers may be re-

sorted to without departing from the principle of operation underlying this invention. Fig. 5 illustrates a modified form of the connection between the bulbs A and cooling chamber B in order to reduce the distance that vapor must travel before being condensed. It may be here stated that the chamber B may be connected directly to the traps and pump previously explained and that any number of the containers A may be connected therewith according to the amount or quantity of mixture that is desired to be dried.

Larger quantities of the mixture may effectively be dried by placing it in pans or trays inserted within a vacuum tank or chamber in which the differential in temperatures are maintained. Such an apparatus is depicted by Figs. 7 and 8 in which 20 indicates an air tight chamber in which the trays 21 are placed and supported a short distance from the bottom thereof.

The top of the drying chamber is covered with CO_2 snow, held in place by a wood frame, which chills the under surface 20^a thereof to approximately $-70°$.

The product to be dried is placed in the pans 21 within the drying chamber and the latter connected to the pumping apparatus by means of the conduit 3' and the entire system evacuated. As evacuation proceeds the gases contained in the product are liberated and escape with the air and when the vacuum therein reaches a certain value, boiling of the liquid occurs which is followed by freezing brought about as the result of rapid evaporation.

The liberated vapors when coming into contact with the chilled surface of the drying chamber immediately condense and freeze thereon, practically none of the vapor passing to the CO_2 traps 7, 11 and 12 and in this manner the material whether in liquid form or in solid form or whether it be serum or any other semi-solid containing protein that is placed in the pans 21 is quickly and easily desiccated.

So that the temperature of the product does not reach a value so low as to impede vaporization of the liquid heating means may be provided, such as the lamps 22, for maintaining a given temperature in the lower areas of the drying chamber 20 to counteract the cold transmitted to the product by the chilled top surface of the tank, and the cold caused by the evaporation of the liquids. A series of thermometers 23 placed in the chamber indicate the temperature existing in the immediate vicinity of the product to be dried and at other sections of the chamber so that the heating elements 22 may be regulated accordingly.

Similarly, the degree of chill given to the top surface may be regulated by the use of a refrigerating coil 24 placed near the surface thereof and which may be controlled in the conventional manner. Fig. 9 illustrates a drying chamber 25 in which the refrigerating coils have been placed and which in other respects is similar in operation to the apparatus illustrated in Figs. 7 and 8.

Rapid evaporation of the liquids and the speedy accumulation of ice is still further accelerated if the product to be dried is first charged with a gas, such as CO_2 gas (because of the relatively large quantity thereof that can be absorbed in water) and the aerated product placed in the bulbs or trays and dried in the manner previously explained.

Presenting the material in a frothy state hastens the drying process because of the greater number of areas that are exposed or subjected to the differential temperatures in the vacuum and, as a consequence, vaporization of the liquid takes place more quickly. Care should be taken, however, in the pre-charging of the product so that only enough gas will be injected to give the material the desired degree of porosity when frozen. If the material is too highly charged with a gas, excessive frothing occurs, when a vacuum is created, to such an extent that the material escapes from the open trays. It is desirable to cause frothing, but it should not be excessive and I have found that somewhat less than 25% by volume of CO_2 gas for a quantity of serum 7 m. m. deep in a tray measuring 1½'' x 6'' x 7'' will be sufficient to cause frothing of the liquid. There are certain factors, however, which must be taken into consideration when determining the amount of charge, chief among those being the efficiency of the particular apparatus employed and the rapidity of evacuation, other variables such as local temperatures, the peculiarities of a given specimen to be dried, the charging gas used, etc., must also be considered and inasmuch as local conditions govern each particular case the amount of pre-charging is usually determined by test. Suffice it to say, however, the greater the charge, the shorter will be the interval of time required in transforming semi-solids to a dry state.

The product prepared by the foregoing method, and through the agency of apparatus such as described, is in the nature of a dry powder readily soluble in water or capable of absorbing water to revert to its original condition. It is quite sterile and remains so for a long period of time, if not indefinitely, if not exposed to unfiltered air. So far as I have been able to determine, through many delicate tests applied to a great variety of different immune and normal sera as well as by the use of different sensitive indicators, the product is not altered in its initial properties and it will remain unalterable in this state; certainly if kept in a vacuum in an ordinary refrigerator.

In view of the importance of producing sera unaltered and unalterable with absolute certainty, I have, in disclosing my discoveries, set forth all such conditions and steps as have definitely resulted in success. Some of these, admit of modification or omission in going from the general case to certain specific instances.

Where, for example, an absolute sterility is not essential in the product, the procedure and apparatus is capable of simplification and the quantities that can be handled may be increased by 100 or even 1000 fold, and even such large quantities can be produced sterile by adapting sterile precautions. Thus, chilling by conventional refrigerating means may be resorted to; in other specific instances, the preliminary step of conditioning the material by quickly freezing it, ab initio, need not be imperative; in still other specific instances, the period of desiccation of the chilled material may be materially extended and a smaller differential in vapor pressure employed without causing deterioration of the product. Whether such variations may safely be resorted to must needs be contingent upon the material undergoing desiccation and the use for which it is destined.

It is a fact, for illustration, that very gradual freezing, as it takes place in nature, results in deterioration of certain immune sera, and for that reason rapid freezing was tried, found to be

successful, and accordingly prescribed as the best mode now known to me for putting my invention into effect.

Believing that the discoveries and invention herein disclosed may open a field of useful research, I hereby disclaim any intention to restrict any original and experimental work of any kind, and hereby dedicate to the public the use of the same for all such purposes; all, however, with the express reservation and understanding that their usage for all commercial purposes shall remain entirely under my control and direction.

I, therefore, claim:

1. The method of rendering sera immune to deterioration and effectively available for future use which consists in exposing to a temperature approximately zero degrees centigrade the serum and in vacuo subjecting the water vapor emitted thereby and at a space therefrom to a temperature much lower than 0° C. whereby the serum will be desiccated to a dry powder capable of being restored to its original condition upon the addition of water.

2. The art of desiccating a serum into a stable product which consists in exposing it in film-like form and while maintained at a temperature approximately one or two degrees below zero to a vapor-space under a reduced pressure, and simultaneously maintaining a portion of said vapor-space at a temperature lower than zero degrees centigrade to condense, in the form of ice, all water-vapor given off by the serum.

3. A process of desiccating a serum without biological alteration into a stable form which consists in maintaining it in a closed chamber at a temperature relatively less than 0° C. and simultaneously maintaining a communicating receptacle at a temperature of about —70° C. or lower for a sufficient period of time to enable all of the water content of the serum to be transported to and retained in frozen form by the said remote wall of said chamber, said closed chamber and receptacle being maintained at a lower pressure than that of the vapor pressure of water.

4. The method of transforming without deterioration semi-solids containing protein to a dry state available for future use which consists in exposing to a temperature approximately zero degrees centigrade the water content of a given semi-solid and in a vacuum and subjecting the water vapor emitted thereby and at a space therefrom to a temperature lower than said first mentioned temperature.

5. The method of desiccating semi-solids containing protein without deterioration which consists in vaporizing the water content of a given semi-solid at a temperature approximately zero degrees centigrade and subjecting the water vapor emitted to a temperature lower than said approximate zero degree centigrade and at a point removed from the material undergoing desiccation.

6. The method of transforming without deterioration semi-solids containing protein to a dry state which consists in charging the semi-solid with a gas, to a temperature approximately zero degrees centigrade the water content of the charged semi-solid in a vacuum, and subjecting the water vapor emitted thereby, and at a space therefrom, to a temperature lower than said first mentioned temperature.

7. The method of desiccating semi-solids containing protein without deterioration which consists in charging the semi-solid with a vaporizing accelerator, vaporizing the water content of the charged semi-solid at a temperature approximately zero degrees centigrade and subjecting the water vapor emitted to a temperature lower than said first mentioned temperature and at a point removed from the material undergoing desiccation.

8. The method of converting semi-solids containing protein to a dry state without deterioration which consists in aerating the semi-solid material by charging the said material with a gas, under a given pressure, subjecting it to a lower pressure whereupon the semi-solid charged material is caused to expand in aerated form; exposing the said material while in that form to a temperature approximating two degrees below zero centigrade, and then vaporizing the water content thereof and collecting same at a place removed from the material undergoing dessication.

WILLIAM J. ELSER.

CERTIFICATE OF CORRECTION.

Patent No. 1,970,956. **August 21, 1934.**

WILLIAM J. ELSER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, line 94, claim 6, after "gas," insert the word exposing; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 30th day of October, A. D. 1934.

Leslie Frazer

Acting Commissioner of Patents.

(Seal)

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Believing that the discoveries and invention herein disclosed may open a field of useful research, I hereby disclaim any intention to restrict any original and experimental work of any kind, and hereby dedicate to the public the use of the same for all such purposes; all, however, with the express reservation and understanding that their usage for all commercial purposes shall remain entirely under my control and direction.

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2. The art of desiccating a serum into a stable product which consists in exposing it in film-like form and while maintained at a temperature approximately one or two degrees below zero to a vapor-space under a reduced pressure, and simultaneously maintaining a portion of said vapor-space at a temperature lower than zero degrees centigrade to condense, in the form of ice, all water-vapor given off by the serum.

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