1948

Economic problems involved in the operation of the solutions department of hospital X

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http://hdl.handle.net/2144/15804
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THESIS

Economic Problems Involved in the Operation of the Solutions Department of Hospital X

by

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(A.B. Brown University 1940)

presented in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION
TABLE OF CONTENTS

Introduction.................................................................page i

SECTION I

Chapter I, The History of Parenteral Medications........page 1

Derivation of word; first allusions to intravenous therapy in early Egyptian history; transfusion of Pope Innocent VIII; discovery of circulation of blood by William Harvey, 1613; transfusion of sheep's blood by Jean Denys of France, 1667; re-animation of exsanguinated dogs, 1783; experiments with transfusion in England, France, and Germany in 1600's; use of citrate to prevent the clotting of blood; use of pooled plasma and serum; discovery of the Rh factor; first experimentation with saline; invention and perfection of continuous drip method of administration; parenteral fluids in use today.

Chapter II, The Blood Bank.............................................page 16

Advantages of a blood bank; personnel; the blood donor; processing of plasma; results of using pooled plasma; "banking principles; precautions to be observed in transfusing blood; directions for cleaning and sterilizing donor sets.

Chapter III, Commercially Prepared Solutions..............page 24

Guide for purchasing commercial fluids; commercial companies began manufacture of fluids in 1920's; physical facilities of commercial laboratories; technics and purity checks; legal responsibility of manufacturer; advantages of commercially prepared parenteral solutions.

SECTION II

Chapter I, Hospital Prepared Solutions..................page 30

Location and necessary space; personnel; selection of method--absorptive filtration method, semi-closed, semi-automatic system; water stills, distilled water checker; filters; flasks; Fenwal sealing unit; care of
rubber tubing; care of needles; assembling of infusion sets; sterilizers; the sterilization of solutions; care of Fenwal apparatus.

SECTION II

Chapter II, Cost Analysis..............................................page 69

Volume of parenteral solutions prepared; volume of infusion sets; cost of material and supplies; wages; direct and indirect costs; overhead; imputed costs; percentage of general hospital expense; expenses of solutions department broken down into unit costs; comparison of hospital unit costs to commercial unit costs.

Conclusion...............................................................page 106

Bibliography............................................................page 111
TABLE OF ILLUSTRATIONS

Figures, Exhibits, and Graphs

Figure 1....Plan of the solutions room at Hospital...page 32

Figure 2....Penwal Preparation Unit................. page 41

Figure 3....Directions for preparing the concen-...page 42
trate solutions

Figure 4....Portable vacuum and pressure pump.......page 44

Figure 5....Diagram of still used above sink to......page 46
produce distillate for rinsing equipment

Figure 6....Diagram of still used in Penwal Prepa-...page 47
ration Unit for producing distillate
for the manufacture of parenteral sol-
lutions

Figure 7....Penwal Distilled Water Checker..........page 50

Figure 8....Improperly cleaned flasks.................page 52

Figure 9....Penwal system for administration of.....page 60
intravenous fluids

Exhibit 1...Operating Report--Hospital X Quarters...page 75

Exhibit 2...Operating Report--Hospital X Common.....page 77
Expense

Exhibit 3...Operating Report--General Administra-...page 79
tion

Exhibit 4...Operating Report--Distribution of.......page 81
Certain Hospital X Expense Balances
to Operating Departments

Exhibit 5...Equipment, Repairs, Supplies for Year...page 83
1947

Exhibit 6...Equipment--Capital Items...............page 83

Exhibit A...Operating Report--Solutions Department..page 85

Exhibit C...Expense Incurred by the Solutions De-...page 87
partment for the Year Ending Dec. 31,
1947
TABLE OF ILLUSTRATIONS

Figures, Exhibits, and Graphs

Exhibit 7....Volume output of 2000 cc. flasks of fusion fluids on a monthly basis

Graph 1.....Volume output of 2000 cc. flasks on a monthly basis

Exhibit 8....Monthly volume of 1000 cc. flasks of solutions prepared by solutions department

Graph 2.....Monthly volume of flasks and reactions to parenteral solutions

Exhibit 9....Infusion sets autoclaved during 1947

Graph 4.....Weekly and monthly composite volume of sets autoclaved for the year 1947

Exhibit 10...Cost of infusion sets

Exhibit 11...Production and chemical costs

Exhibit 12...Labor cost of solutions manufactured

Exhibit 13...Overhead cost of solutions manufactured

Exhibit 14...Comparative costs--cost of hospital solutions

Exhibit 15...Commercial versus hospital manufactured solutions

Exhibit 16....Actual savings to hospital by manufacturing its own parenteral solutions
INTRODUCTION

The subject of a cost analysis of the parenteral fluids department of Hospital X was suggested to me by its chief of the laboratory staff. This doctor felt that many recent enthusiastic articles in favor of hospital-prepared solutions did not present the entire picture; nor have both sides of the question of hospital-prepared solutions versus commercially purchased fluids been presented in one study to the best of our knowledge.

It is with the express thought in mind that a study may be of value to those hospitals who are contemplating setting up a parenteral fluids department, or to those who are re-evaluating their present department, that this thesis was written.

In order to give recognition to those men who through many centuries have experimented with parenteral fluids, often alone and against grim opposition, a brief history has been written.

Because so often a short cut would result in economy of time, it has been necessary to emphasize the medical aspects of parenteral medications. There can be no short cuts in preparing fluids meant for intravenous infusion.

The identity of the hospital studied has been kept anonymous to give one freedom to offer constructive criticisms. The discussion is also intended to point out that adequate expenditures on the part of the hospital are absolutely necessary in order to insure proper facilities for the production of
safe parenteral fluids.

The chapter on costs is patterned after theoretical cost analysis procedure—taking into consideration overhead costs of the institution, direct and indirect, administrative costs, imputed cost of supervision, rent, money invested, plus the actual cost of supplies and chemicals used, as well as wages of personnel. In order to get a comparable cost, it has been deemed necessary to follow this procedure.

I am grateful to the Director of Laboratories of Hospital X for making available to me the records of the department since its inauguration. I also wish to acknowledge the assistance given me by the technician in charge of the parenteral fluids department. I wish to thank Mr. Justus J. Schifferes, managing editor of The Journal of Parenteral Therapy, for sending me all the issues of that Journal which have been published since its inauguration in 1944.

Representatives of Macalaster-Bicknell Company, manufacturers of Fenwal equipment, have been most helpful in supplying me with information about the Fenwal system. Abbott, Baxter, and Cutter Laboratories have graciously given me the information I requested in regard to commercially prepared solutions.

I am grateful to several prominent middle-western hospital administrators who have given me the benefit of their experience both with hospital-prepared solutions and with commercially purchased fluids.
I wish to thank Dean William G. Sutcliffe of the College of Business Administration for reading this thesis and for the valuable suggestions he offered. Acknowledgment is also made to Professor William L. Lomax and Professor Raymond L. Mannix for their assistance in the assembling of material for the thesis.
SECTION I
Chapter I
The History of Parenteral Medications

In the past, the term "parenteral medications" has been applied to all drugs and fluids which were administered to the patient by channels other than the alimentary tract. The derivation of the word parenteral can be traced to two Greek words: "para" meaning beside, and "enteron" denoting intestine. In the modern hospital, however, because of extensive research, careful study, and controlled experiment, the term "parenteral medications" has been narrowed down to include only those exactly compounded fluids which are administered by intravenous injection or by hypodermaclysis. Because whole blood is the most important parenteral fluid, it would be difficult to discuss parenteral fluids without giving due consideration to the blood transfusion service which is an integral part of the parenteral fluids department.

Our modern parenteral fluids department and transfusion service is the result of much trial and many errors. The first fragmentary allusions to intravenous therapy come to us from early Egyptian history (1). It appears that these people had some knowledge of transfusing blood from one human to another. An ancient Hebrew manuscript is supposed to contain these words: "Naam, leader of the armies of Ben-Adad, King of Syria, afflicted with leprosy, consulted physi-

cians, who in order to cure him, drew out blood from his veins and put in that of another."  

Eubages makes reference to blood transfusion. Pliny and Celsus mention it, but only to condemn the practice. In the eighth book of the *Metamorphoses*, Ovid represents Pelias pleading with Medea, the sorceress, to renew his youth. Medea was supposed to have severed a vein in the throat of Pelias, and withdrawing the blood of old age, poured in a life-giving fluid. This particular parenteral medication which the sorceress concocted was supposed to have contained, among other things, the blood of a black ewe, fresh semen, and fluid from the entrails of a wolf. Full vigor allegedly returned to the ancient Pelias. According to Ovid, blood transfusion was a sorcerer's art.

The unsuccessful attempt to prolong the life of Pope Innocent VIII is an oft-cited case of an early blood transfusion, and an oft-disputed one. In his *Life of Savonarola*, Villari mentions that the blood of the aged Pope was passed into the veins of a young man, whose blood in turn was transfused into the vessels of the aged one. A Jewish doctor made three unsuccessful attempts at blood transfusion using each time a vigorous young man. The three youths died, possibly of air embolism, and Pope Innocent VIII also promptly expired on April 25, 1492. A. H. Matthews in his *Life and Times of Rodrigo Borgia* does not agree with this version.

because he maintains that the circulation of blood was not discovered until the early sixteen hundreds, and that the idea of blood transfusion could not occur to one not familiar with the circulation of blood. Raynaldus and Infessura state that the three youths died because all their blood was withdrawn, and that the Jewish physician prepared a draught from the blood which failed to save the sick pontiff's life.

Drinking blood was not a new idea. Ore, however, accepts this story and believes that it is the first demonstrable instance in history where the entrance of air into the veins was the cause of death (1).

Horace Manchester Brown translated a passage from the works of Andreas Libavius which were published in 1615. The translation follows:

"Let there be a young man, robust, full of spirituous blood, and also an old man, thin, emaciated, his strength exhausted, hardly able to retain his own soul. Let the performer of the operation have two silver tubes fitting into each other. Let him open the artery of the young man, and put into it one of the tubes, fastening it in. Let him immediately after open the artery of the old man, and put the female tube into it, and then the two tubes being joined together, the hot and spiritous blood of the young man will pour into the old one as if it were from a fountain of life, and all of his weakness will be dispelled. Now in order that the young man may not suffer from weakness, to him are given good care and food." (2)

Some authorities who have studied the history of intravenous therapy regard the preceding passage seriously, while others regard it as satire.

For the first time, William Harvey described the circulation of blood to his London classes in 1613; however, he did not publish his findings until 1628. (1) This ushered in the scientific era in the study of the blood. The first suggestion of intravenous medication came from Giovanni Colle, of Padua, in 1628. (2) He proposed the mingling of medicaments with transfused blood. Francesco Folli, a Florentine physician published a book in 1652 entitled: A Pair of Medical Scales in which are weighed Not Only The Infusion of Medicines and other Novelties, but Also the Favorable and Unfavorable Opinions as to the Transfusion of Blood. He was apparently familiar with the theory and had devised a technique for it. He suggested the use of a silver tube to be put into the artery of the donor, and a bone cannula to be inserted into the vein of the recipient with a hollow tube from the blood vessel of some animal to be used to join the two. He added a lateral branch to allow for the escape of air as the blood pulsed through the tube from artery to vein.

Johannes Sigmund Elsholz, of Brandenburg, advocated intravenous medication in a book published in 1667. He presented the cases of three soldiers whom he had treated by the intravenous injection of a small amount of aqua planataginiis by means of a syphon. (3) During this same period,

(1) Harvey, William, De Motu Cordis, Frankfort, 1628
(3) Hagensen, C. D., and Lloyd, E. B., One Hundred Years of Medicine, Sheridan House, New York, 1943, p 279.
Mauritz Hoffman, a physician, in his lectures at Altdorf, advocated transfusing the blood of youth to cure melancholia, epilepsy, and hypochondriacal diseases. Fracassatus, Malpighi, and von Helmont did much experimentation with animal blood in the late 1660's.

In 1667, Jean Denys, of Montpellier, Louis Fourteenth's personal physician, treated a young man suffering with fever by preparing the carotid artery of a sheep and inserting it into one of the patient's veins. The young man recovered; however, subsequent transfusions of animal blood made by Denys resulted in the death of the patient.

An eminent surgeon, named Laury, believed that certain particles in the blood were destined to nourish particular parts of the body. He believed that animal stupidity and instincts would be transmitted to man, and that the particles which nature intended to produce horns on a bull might also produce horns on a man.

The very conservative, non-progressive Faculte de Medicin, in Paris, attacked all experimenters with blood at that time, and caused an ordinance to be passed which forbade transfusion without the express permission of the Faculte de Medicin.

At Oxford, England, in 1665, Richard Lower and Christopher Wren, experimenting on animals, caused the blood

(1) Hagensen, C. D., and Lloyd, E. B., One Hundred Years of Medicine, Sheridan House, New York, 1943, p 279.
to pass from the vertebral artery of one of these animals into the jugular vein of another by using hollow quills united with the blood vessel of a horse. It was inevitable that the idea of using animal blood dominated the times.

The *Journal des Savants* of January 23, 1668, contains the following paragraph:

"A soldier was affected with verole ancienne, with numerous exostoses. Into a vein of his arm was injected three drams of the purgative liquor. Great pain in the elbow, swelling of the arm; at the end of four hours the medicament began to react; after five hours, bowel evacuation; the same in the days following. The exostoses diminished, and soon there remained no trace of Lues venera."

In 1682, a physician of Leipsic, named Ettenmul-ler, advocated the injection of intervals of small amounts of blood in treatment of fevers, scurvy, and hypochondrias. In 1683, Kaufmann and Purmann, two surgeons of Fronfort-on-the-Odor, gave a transfusion of lamb's blood to a man afflicted with leprosy, and thereby cured him. During this period, England, France, and Germany vied with each other as to whom should be given the credit for inventing intravenous therapy as it is known today. The question was never officially settled; because, perhaps, the credit rightfully belongs to all.

The *Philosophical Transactions* for the year 1700 (1) cites a few instances where intravenous medication was tried in Germany:

"We have injected by a Syphon, about 2 Dr. of a laxative Medicine into the Median Vein of the right

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Arm of 3 patients in the Hospital at Dantzick. One of the Patients was a lusty robust Soldier dangerously infected with the Venereal Disease, and suffering grievous Protuberations of the Bones in his Arms. He, when the purgative Liquor was infused into him, complained of great Pains in his Elbows, and the little Valves in his Arms did swell so visibly that it was necessary, by a gentle Compression of one's Finger, to stroke up that Swelling toward the Patient's Shoulders. Some 4 Hours after it began to work, not very troublesome, and so it did the next Day, insomuch that the Man had 5 good stools after it. Without any other Remedies those Protuberances were gone, nor are there any Footsteps left of the above-mentioned Disease.

"The other two Trials were made upon the other Sex. A married Woman of 35, and a Sewing-maid of 20 Years of Age, had been both of them from their Birth very grievously afflicted with Epileptik Fits, so that there was little Hopes left to cure them. They both underwent the Operation, and there was injected into their Veins a laxative Rosin, dissolved in an Anti-epileptical Spirit. The first of these had gentle Stools for some hours after the Injection and the next Day; the Fits recurring now and then, but much milder, and are since altogether vanished. As for the other, viz., the Maid, she went the same Day to Stool 4 times, and several times the next; but by going into the Air, and taking Cold, and not observing any Diet, cast herself away. It is remarkable, that it was common to all to vomit soon after the Injection, and that extremely and frequently."

In 1714 Nuck wrote in his Operationes et Experimenta Chirurgicia a history of blood transfusions (1). He considered the transfusion of human blood valuable in the case of severe hemorrhage; however, he objected to using animal blood for humans. In 1749, more than three-quarters of a century after the Faculte de Medicin had imposed its interdict on transfusions, Cantwell, one of its members, conservatively advocated the use of transfused blood in extreme emergencies. In 1783, Michel Rosa, a professor at Modena,

published the results of his experiments in transfusing ani-
mals in *The Lettere Fisiologiche* (Napoli, 1783). Through ex-
perimentation he proved that a greater than normal quantity
of blood could be injected into the vessels of a normal
healthy animal without filling them. He also reanimated ex-
sanguinat ed dogs by transfusing into their veins, the blood
from the arteries of another animal.

At Cambridge, England, in 1792, a physician named
Harwood, dramatically reanimated an exsanguinated dog by
means of blood transfusion before an audience of physicians
and students (1). During the same year another English phy-
sician, Russell, of Suffolk, effected a cure in a boy suffer-
ing from rabies by substituting the blood of two lambs in his
circulation. Except for these few specific instances, inter-
est in transfusion lagged until 1818, when James Blundell, an
English obstetrician, devised a funnel-shaped apparatus into
which he built a syringe that forces the blood through a
tube into the patient's veins. It was a forerunner of our
modern syringe. He used this procedure to treat severe hem-
orrhage of childbirth with some success. Stimulated by
Blundell's work, French and German physicians experimented
with transfusions. In a communication published in the
*Transactions of the Medico-Chirurgical Society* in London,
Blundell indicated the advantages to be gained by the use of
a syringe in blood transfusions: "promptitude, for human
blood is always at hand, the abundance in which the blood

may be transfused, and most important, the opportunity it offers of throwing human blood in human veins." (1)

In 1828, Usher Person, of Providence, wrote On The Administration of Medicines by The Veins (2). He reported how a certain Dr. Hall experimented with self-administration of castor oil intravenously. His report of the results of this experiment discouraged others from attempting it. Four years later, J. Mauran, of Providence, described an instrument he had invented which would eliminate the introduction of air into the veins during intravenous medication.

In England, in 1838, James Blake described to the British Association for the Advancement of Science the first of his extensive researches concerning intravenous medication (3). Blake eventually emigrated to San Francisco and continued his researches there.

In 1873, Franz Gessellius, of Germany, published a full list of all those who had worked on the various aspects of intravenous therapy in European countries (4). Another report in 1876 cited 381 human blood transfusions and 154 animal blood transfusions. However, the large proportion of fatal reactions made transfusions unpopular.

In 1853, Alexander Wood, an Edinburgh physician, invented the hollow steel needle which when attached to a

(3) Ibid, p 15.
(4) Ibid, p 17.
syringe, made subcutaneous injection of fluids possible.

The phenomena of blood transfusions continued to fascinate physicians. A glimmer of understanding of the complexity of blood was demonstrated in 1869 when Criete showed that human red blood cells would clump together when placed in animal blood serum. Leonard Landois, professor of physiology at Greifswald, after a series of experiments proved that the blood serum of one species would dissolve the red blood cells of another species. The publication of this work in 1875 marked the termination of the use of animal blood for human transfusions. Nevertheless, the fact remained that even when human blood was used for transfusion it sometimes produced fatal results. Subsequent discoveries made by Maraglino (1892), Landsteiner (1901), and Eisenberg (1901) accounted for the cause of the fatal reactions. It was demonstrated that it was possible for the blood serum of one individual to cause the red blood corpuscles of another to clump or agglutinate. The agglutinated corpuscles then might undergo hemolysis, that is, break up and disappear. Landsteiner described three groups. In 1902, De castello and Sturli described a fourth group. Jan Jansky of Prague (1907) and Moss (1910) made four classifications with the exception that Moss reversed the Jansky (1) groups I and IV. To avoid confusion and the possibility of fatal accidents, human blood is designated as belonging to

four main groups according to the International Nomenclature. To avoid reaction, a transfusion is made from the compatible blood group.

After the blood grouping was successfully carried out, there remained the problem of blood clotting. Grile worked out a difficult procedure of connecting the donor's artery and the recipient's vein with a cannula. However, this did not come into popular use. In 1913, in Boston, Kimpton and Brown made a successful attempt to overcome clotting by using a common large tube, coated on the inside with paraffin, both for collecting the blood and for injecting it into the patient's veins. In New York in the same year, Edward Lindeman, a young pediatrician, worked out a method of using a series of a dozen twenty cubic centimeter syringes. This method of preventing clotting depended upon the speed and cooperation of the operators. It was the method of choice and received wide popularity in the United States.

In 1914 a new and more practical method of preventing clotting was announced by four different men working independently. They were Richard Weil and Richard Lewisohn of New York, Albert Hustin of Brussels, and Luis Agote of Buenos Aires. The method consisted of adding sodium citrate to freshly drawn blood. In 1916 Rous and Turner added dextrose to the citrate solution. This method is in use today.

With the British Army in World War I, Sir John Makins explained that at that time military conditions did
not allow opportunity for hemolytic tests. When it was possible to delay transfusions a day, ten cubic centimeters of the donor's blood was injected into the recipient as a test for compatibility. However, blood transfusions were given without hemolytic tests in desperate cases. Canadian doctors, working in casualty clearing stations in France, popularized the use of whole blood preserved in a dextrose-citrate mixture for transfusion (1).

Defibrinated placental blood was first used in 1914 at the Maimonides Hospital in Chicago by George Rubin for transfusion (2).

In more recent times, blood plasma and blood serum have been used in place of whole blood. Blood plasma is the fluid portion of the blood which has been prevented from clotting by the addition of sodium citrate. Blood serum is the fluid which remains after blood clots. Plasma or serum can be stored over long periods of time in a dried or frozen state. During World War II our armed forces were supplied with dried blood plasma processed from whole blood, collected from civilian donors by the American Red Cross.

In spite of compatible blood grouping, there seemed to be yet another factor which caused hemolytic reaction after blood was transfused. Landsteiner and Weiner, after experiments with the blood of rhesus monkeys, identi-

fied it as the Rh factor (1). The scope of this paper is not great enough to involve a lengthy discussion of the Rh factor; however, a brief explanation is in order. 85 per cent of all persons, irrespective of their blood groups, have red blood cells which contain an agglutinogen term Rh positive. The remaining 15 per cent of the population have Rh negative blood, and their blood cells are capable of forming anti-Rh agglutinins. They are capable of iso-immunization under the following conditions: 1. When more than one transfusion of Rh positive blood is given to an Rh negative individual, or, 2. When a mother with Rh negative blood bears a child whose blood is Rh positive (the father's blood being Rh positive.) After such iso-immunization, the Rh negative person may suffer severe hemolytic reaction if transfused with Rh positive blood. These hemolytic reactions usually do not occur until after a variable number of transfusions (more than one) of Rh positive blood. The reactions are mild to severe depending upon the individual and the number of transfusions. Manifestations of iso-immunization also do not usually occur in the first pregnancy of a woman with Rh negative blood. In later pregnancies, the mother forms an increasing number of anti-Rh agglutinins which cause a hemolytic anemia in her Rh positive infants known as erythroblastosis fetalis. Lately, dramatic work has been done in slowly replacing the entire blood supply of an infant affected with erythroblastosis fetalis.

While blood is usually the circulatory restorative of choice, other parenteral fluids are used. In Leith, Scotland, in the early eighteen hundreds, Thomas Latta did the first known experimenting with saline. During the great cholera epidemic in Britain in 1832, saline was used by Latta and his colleagues with some success. During the remainder of the century, it was used for cholera, both in England and India (1).

It was in Naples in 1865 that Arnaldo Cantani originated the process of injecting saline into the subcutaneous tissues where it was promptly taken up by the blood stream. He called this process hypodermaclysis, and it is still widely in use today. The process by which saline was given slowly by intravenous method was perfected by Rudolf Matas at the Charity Hospital in New Orleans in 1888. However, it wasn't until 1910 that he devised the continuous drip method whereby saline could be given at a certain number of drops per minute over a considerable period of time. (2)

The past decade has seen other additions to the parenteral fluid family. Five per cent dextrose in water can be used successfully to restore the volume of circulation. Ten and twenty per cent dextrose has also been used successfully in certain instances. As in the case with saline, dextrose can also cause water-logging of the tissues when used to excess. Gum acacia, a complex carbohydrate,

(2) Hoogensen, C.D., and Lloyd, E. B., One Hundred Years of Medicine, Sheridan House, New York, 1943, p 284.
was used for a short period after World War I, but undesirable characteristics prompted the discontinuance of its use. Gelatin solution and pectin were also used with a measure of success. There have been many refinements in the formulae for parenteral fluids in recent years, and research continues both in the commercial laboratory and in the hospital research department.
Chapter II
The Blood Bank

Hospital X established its blood bank in the late 1930's. Its continued growth and development have been based upon its merits. The value of a blood bank can be demonstrated by a consideration of the following facts:

1. Blood of all types is immediately available for routine or emergency use.
2. Uncommon types of blood are available at all times.
3. The blood is safe from the standpoint of the transmission of syphilis.
4. The cost to the patient of a blood transfusion is reduced.
5. The blood serves as a ready source of plasma (all blood over 21 days old is converted into plasma by the department.)
6. Responsibility for all transfusions is centered in the director of the service and his immediate associates.

In contrast to these important advantages, there are no important disadvantages. Disposable tubings and modern preservative solutions which are available commercially make it possible and practical for even the small hospital to operate a blood bank. Theoretically, erythrocytes age and deteriorate with storage, but the use of modern preservative solutions minimizes this. Hemolysis is minimal or nil if the technic of withdrawing, preserving,
and storing of blood is rigidly controlled.

The blood bank is under the direct supervision of a member of the medical staff who is interested in the subject of transfusions. It is his duty to select and supervise the other members of the transfusion service, and to stimulate research and progress in regard to banked blood.

Competent, reliable nurses and technicians are essential to a properly functioning bank. At Hospital X, the personnel of the blood bank consists of the following people: 1. The blood bank technician, who performs all venipunctures; 2. graduate and/or student nurses who take blood pressures and prepare the patient for venipuncture; 3. a technician, a member of the regular laboratory staff, who makes hemoglobin determinations on all donors, and obtains samples for Wasserman tests, for typing, and for Rh determinations; 4. a volunteer worker, who is assigned to the two examining rooms where the blood is collected. This volunteer worker is responsible for taking the donor's history. She also contacts visitors of those patients who are indebted to the bank for blood to make appointments for friends and relatives to donate blood. She is responsible for securing written permission from the donor for the blood to be withdrawn.

The blood donor should be between the ages of twenty-one and fifty-five, and in good physical condition.
A blood donor should be rejected for any one of the following reasons:

1. Fever.
2. Recent respiratory infection or other acute illness.
3. Serious chronic or transmissible illness.
4. History of syphilis or positive Wasserman.
5. History of jaundice during the past 6 months.
6. History of malaria.
7. History of use of atabrine during past 2 years.
8. Poor physical status.
9. Hemoglobin below 12.5 Grams in women.

After the blood has been collected in a bottle containing A.C.D. solution (sodium citrate, citric acid, and anhydrous dextrose), it is stored in a specially designed cylindrical refrigerator (1). Hospital X uses the refrigerator made by the General Electric Company. It has revolving shelves, thus allowing access to any flask without unduly agitating the other flasks on the shelves. Flasks are grouped on the shelves according to blood types. Flasks of freshly drawn blood are placed on the lower shelves. After they have been released by laboratory tests, they are placed on the shelf with their particular blood group. The temperature of the refrigerator in which the blood is stored is kept between 3 and 5 degrees Centigrade. This temperature control is checked daily. It is of interest to note that as an additional check, a red light glows on the central telephone switchboard if the temperature varies above or below the prescribed level. Blood should not be allowed to freeze,

nor should it be heated before administration.

Blood is routinely processed into plasma at the end of twenty-one days. This is done by simply taking blood of the same major group and siphoning the plasma into a 500-cc. Fenwal bottle.

At Hospital X, a very compact and economical cabinet was constructed to be used while the plasma was being processed. The cabinet consisted of a workbench with an attached hood. A hinged glass window in front of the technician prevented breath and dust contamination. A 20-cm. opening is located beneath the window to admit sterile gloved hands. A sterile gown is worn. In order to eliminate active currents of air, the top of the hood is closed. A Westinghouse Sterilamp is attached to the upper part of the hood. The cabinet is portable, and when in use is placed in a clean room away from traffic.

A 5-cc. sample of the plasma is added to a culture media and allowed to incubate for two weeks. The plasma is placed immediately into a deep freeze cabinet, and it is ready for use when released by laboratory tests. Just before being used, the flask of plasma is thawed by immersion in a 100 degree water bath.

Hospital X discontinued the pooling of plasma in keeping with more recent scientific findings. Recently, some research has been done on the use of pooled plasma and group-0 blood. A detailed account of this work is beyond the scope of this paper; however, the summary of these
findings reads as follows:

1. A study has been made of certain complications attending the transfusion of group-0 blood and pooled plasma containing incompatible isoagglutinins. The investigation was conducted in a U. S. Army General Hospital and Evacuation Hospital, during the course of the European campaign.

2. Febrile hemolytic reactions, accompanied by chills, were rarely observed following either single or multiple transfusions of group-0 blood into recipients whose blood groups were A, B, or AB. Three reactions, accompanied by hemoglobinemia and hyperbilirubinemia, were observed in the course of 265 consecutive transfusions of this type, and incidence of 1.1 per cent. The isoagglutinin titer of the blood implicated in these reactions in each case exceeded 1:500.

3. Studies, which included serial Ashby counts and, in some instances, blood volume measurements, indicated that asymptomatic blood destruction involving the recipient cells was occasionally produced by single, and almost invariably by multiple, transfusions of pooled plasma or group-0 blood, when administered to patients of other blood groups.

4. In contrast to the findings after the injection of cell-free hemoglobin solution, a disparity was noted between the degree of hyperbilirubinemia and hemoglobinemia produced by these transfusions. This suggested that most of the hemolysis produced by incompatible plasma does not occur in the free circulation.

5. An increase in the osmotic fragility of the recipient erythrocytes was frequently observed following transfusions of group-0 blood and pooled plasma in patients of blood groups other than group-0, the occurrence of this phenomenon being related to the concentration of incompatible isoagglutinins and frequency of their administration. (1)

In considering the incidence of transfusion, experience has shown that approximately 70% of the patients needing transfusions can be predicted several days in advance. These patients are requested to build up a credit in the blood bank.

by furnishing one or more donors. The blood is collected regardless of type. If the full amount of blood credited to the patient is not used, it becomes the property of the hospital. If a patient requires a transfusion in an emergency, he becomes indebted to the bank for the amount furnished and must secure donors to replace the blood on the next banking day. At Hospital X, banking days are held four days weekly with both afternoon and evening hours being offered to accommodate those who work during the day.

There is a small incidence of reactions (1 to 3%) to blood transfusion. If a greater incidence of reaction occurs, one should suspect faulty technic or faulty supervision of the various banking procedures; because, in the majority of cases, the reactions are pyrogenic in nature and are therefore preventable. The other causes of reactions which occur but infrequently may be classified as follows: hemolytic, embolic, allergic, and reactions due to circulatory overload.

There are certain precautions to be observed in transfusing blood in order to guard against reactions. They are as follows:

1. Use pyrogen free solutions.
2. Always filter blood.
3. Rinse equipment immediately after use.
4. Clean equipment thoroughly and promptly.
5. Use pyrogen free distilled water for rinsing equipment during cleaning.
6. Laboratory controls must be rigid, and records must be accurate.
7. Do not give hemolyzed or over-age blood.
8. Do not give blood which has been frozen.
9. Do not heat blood before administering
10. Give blood to allergic and cardiac cases cautiously. (1)

Carefulness in cleaning donor and recipient sets cannot be over-emphasized. Various hospitals have devised their own procedures for the care of the sets. They vary a little; however, the importance lies in following carefully a definite, thorough routine. There can be no short cuts!

The routine which follows is a good one:

Directions for cleaning and sterilizing donor and recipient sets:

1. Immediately after use, completely disassemble all parts, and rinse thoroughly with cold water.
2. Check tubing for holes and stickiness. If of inferior quality, discard and replace. Discard inferior washers and other parts.
3. Remove adhesive with ether.
4. With an asepto syringe wash all materials with hydrogen peroxide.
5. Stretch tubing to loosen any blood left in it. Repeat step 4 if necessary.
6. With an asepto syringe and green soap, wash tubing and other parts thoroughly. Use a pipe stem cleaner in the drip cap adapters. If glass adapters do not come clean, place in nitric acid over night. Check adapters for any chips at ends. A very small chip causes leakage of blood during transfusion.
7. Rinse very thoroughly with hot running water. Use plenty of water.
8. Rinse very thoroughly with distilled water (pyrogen free).
9. Allow to drain dry. Do not wipe dry.
10. Assemble parts into the correct sets.
11. Check assembled sets under a bright light.
12. Have a supervisor or responsible graduate nurse check all sets before wrapping.
13. Wrap. Autoclave for 15 minutes at 15 pounds pressure within four hours after cleaning.
14. All sets are to be labeled, dated, and initialed by the person who cleaned them.
15. New tubing is boiled for 15 minutes in 5% sodium carbonate and cleaned as above before using (2).

(2) Ibid, p 12.
At Hospital X, the sets are cleaned and sterilized in the solutions room. They are the responsibility of a technician.

Insofar as the cost of a blood transfusion is concerned, the patient is charged a flat rate for a transfusion according to his financial circumstances. Since the blood bank has been in operation, indigent patients have been transfused without cost to the hospital.

Although blood donors are a self-selected group, about five per cent have shown positive Wasserman tests. The social service department sends these people a tactfully worded letter requesting them to return to the hospital for an interview. During the interview, the donor is told verbally about his misfortune in order to prevent family complications. Arrangements are then made for his treatment.
Chapter III
Commercially Prepared Solutions

In order to give due recognizance to parenteral solutions manufactured by commercial laboratories, letters were sent to the more prominent laboratories and to prominent physicians and hospital administrators who have had experience both in manufacturing their own solutions and in using those prepared by commercial laboratories.

This chapter is intended as a presentation of the arguments in favor of commercially prepared solutions.

There are many fine commercial laboratories which are engaged in the manufacture of solutions at present. If one elects to purchase solutions instead of preparing them in the hospital, the reputation of the manufacturer rather than the persuasiveness of the salesman can be used as a guide in selecting the laboratory from whom to purchase the fluids. Since it is a highly competitive field, the cost of solutions varies but little with the different companies. Each manufacturer has his own distinct bottle for dispensing fluids, and the one selected should offer a technic which can be mastered readily by any member of the medical or nursing staff. Some laboratories offer the solutions in a vacuum sealed bottle as a means of controlling pyrogens. Another manufacturer advertises a no-vacuum bottle, maintaining that this is desirable because there is no inrush of unfiltered air to contaminate the solution. Pyrogens in this case have been controlled by some method of ultra-filtration,
and the bacteria have been controlled by sterilization.

In the 1920's, commercial companies made their debut as manufacturers of parenteral solutions by preparing the fluids in 100-cc. size ampules. In the 1930's, they entered the preparation of large volume infusion solutions. One producer was marketing these solutions in a very expensive 500-cc. and 1000-cc. Pyrex ampoule with double points. These ampoules were so very expensive that it was impractical to use them as single administration containers, and it was also impractical to ship them back to the manufacturer because of the danger of breakage. Another solution on the market during this period was offered in a special flint glass bottle, the inner surface of which had been treated to make it resistant to solubility. The container was satisfactory, but the solutions were sealed with a large rubber stopper which imparted to the solutions a strong odor and taste of rubber. Research brought forth many refinements in containers and solutions.

Commercial companies engaged in the preparation of parenteral fluids are seemingly in a better position to more nearly approach the ideal in the manufacture of solutions than are the majority of hospitals. The commercial company is able to devote its entire time and energies to the various aspects of the manufacturing process, and it has a staff of scientists to call upon in dealing with problems of research. To the hospital, whose primary
function is the care of the sick, the preparation of parenteral fluids can be but one of its many additional undertakings. The small hospital would find difficulty in subsidizing research. A highly trained worker is necessary in order to manufacture some of the valuable, more complex solutions which the commercial companies are offering today.

As a matter of good business, most reputable companies employ ultra-scientific methods. The solutions are prepared in air-filtered, air-washed rooms. (Not many hospitals are able to offer such ideal conditions.) The technicians engaged in the actual preparation of fluids wear sterile gowns, face masks, and caps. Commercial companies routinely make bacterial counts on the raw chemicals—such as dextrose—which are used, and the chemicals they use meet U.S.P. standards or have even greater purity. Some companies advertise "fractionated distilled water." This term is used to designate water which has been distilled from ordinary distilled water which had been previously treated with an alkali and permanganate. The first part of the distillate which contained all of the ammoniacal contaminants is discarded—only the middle "fraction" is used.

Each manufacturer has his own system of technics which he uses as purity checks. One manufacturer uses the following system: each batch of solutions is kept in
quarantine for several days until released by bacteriological tests. The samples taken for sterility tests are from different levels and different positions in the autoclave to assure that there are no "air pockets" which have insulated some of the bottles from the high temperatures necessary for sterilization. The chemical tests for the identity of the ingredients and the quantitative determination of the active ingredients assures the fact that no mistake has been made. Pyrogen tests are made routinely on samples from each autoclave load of fluids. These are some of the factors which make for greater safety in the use of solutions prepared by a reliable company.

All these precautions to produce a pure, pyrogen-free solution are in vain if, in the hospital, care is not taken to provide pyrogen-free tubing, needles, and adapters.

The manufacturers of solutions have to comply with the Federal Food, Drug, and Cosmetic Law, and with the various state laws which stipulate that the solutions comply with standards set up by the United States Pharmacopeia for injections.

The manufacturer is under legal obligation to see that his solutions are entirely free from any substance or substances which might produce reactions or undesirable effects on patients. The legal responsibility of the commercial laboratory extends to the point where the solutions are turned
over to a common carrier. However, it does not extend to the administration of infusion fluids, because rubber tubing, needles, and glass adapters are often a source of pyrogens when they are improperly cleaned. If reactions occur during the use of commercial solutions, one should first eliminate the tubing etc. which are used in administration, before one condemns the product.

One hospital administrator (1) in a large middle-western hospital, after experience with hospital-prepared solutions, changed to those which were commercially prepared; not because he wanted to accomplish a saving, but because he felt that it was difficult to prepare solutions of equal purity to compare with those offered by a reputable commercial laboratory.

In discussing his experience with hospital-prepared fluids, a prominent middle-western hospital consultant (2) found that since each flurry of reactions meant a break in technic, the break had to be traced to its source each time. After working for three to four years with the program this large hospital decided to purchase its infusion fluids. A cost study made by the hospital during this period (1938) indicated that the cost of purchased fluids was 10-15% higher than those the hospital manufactured. The hospital made the selling price to patients just high enough to pay for those given to the free patients.

(1) Confidential communication, Chicago, Ill., Nov. 29, 1947.
(2) Ibid, Nov. 25, 1947.
Another prominent administrator (1) maintained that there were other factors to consider which were more important than costs. He enumerated them as follows:

1. Moral responsibility of the hospital to the patient to provide safe, pure, therapeutic agents.

2. Freedom from worry over reactions due to impurities.

3. In the event of serious reaction, the legal position of the hospital is more solid when using commercial solutions than when using hospital prepared ones.

4. The wide variety of solutions offered by commercial companies.

5. The research work carried on by commercial companies should in part by supported by the hospitals in order for the hospital to be in position to benefit from the results of this research.

SECTION II
Chapter I
Hospital Prepared Solutions

The hospital which undertakes the manufacture of parenteral solutions has many problems to solve. These problems are not insurmountable, but they require careful thought and planning, and willingness on the part of the hospital to make the necessary expenditures to insure a properly equipped department which will produce parenteral solutions which are pyrogen-free.

Location and Necessary Space

The first of these problems deals with the location of the parenteral fluids department and the amount of space to be allocated to the department in order for it to function efficiently. The solutions department should be centrally located, and should be situated in a "clean" portion of the hospital away from the paths of traffic. Central location facilitates the receiving of supplies and the distribution of fluids. In the older type hospital, the ideal location may be hard to find; however, this should in no way adversely influence the preparation of solutions providing adequate space and physical facilities are available. The suggested area is four to five square feet per hospital bed. One authority (1) maintains that the criterion of space needed should be based on volume of work done, and al-

allows .24 square feet per flask manufactured on a basis of monthly output.

At Hospital X, the solutions room is located in the basement of the hospital adjacent to a centrally located elevator; however, it has the disadvantage of being located next to the receiving entrance where various hospital supplies are received and dispensed. The solutions room is too small for the present production of solutions. The monthly volume of solutions averages 3750 flasks. Allowing .24 square feet per bottle, the room should contain 900 square feet. If one were to consider the more generous allotment of space, based on bed capacity, the room should contain 1200-1500 square feet, because there are approximately 300 beds in the main hospital of Hospital X. Actually, the dimensions of the solutions room are 24 feet by 25 feet, or 600 square feet. This allows but .16 square feet per bottle and only 2 square feet per bed. Careful planning and forethought as to the placement of equipment is necessary for the best possible utilization of space. At Hospital X the Fenwal preparation unit is located in the center of the room, crowding the workers, and with the space immediately in back of it poorly utilized.

The materials which comprise the walls and the floors of the room should be restful to the eyes, and most important, easy to keep clean! At Hospital X the walls are of brick painted yellow, and the floors are of cement, painted dark grey.
Plan of
Solution Room
Hospital X
Boston, Mass.
Scale--1/4" = 1'0"

Figure 1
The sterilizers and stills which generate heat should be in a separate room, if possible, or they should be recessed outside the solutions unit. There are some water stills which operate by remote control. At Hospital X the two stills are located in the same room where the solutions are prepared. The sterilizer is recessed in a wall, but the wall is not a solid one, for there is a wide aperture above the autoclave which allows dust to blow freely into the room. A filtered air system which removes the overheated air, and introduces fresh air through filters by means of a suction fan is highly desirable to prevent bacteria-laden dust from entering the room, and to make the room more comfortable for the workers preparing the fluids. Hospital X has no such filtered air system.

Personnel

Another very important factor to take into consideration in the manufacture of parenteral fluids is the selection of personnel. Let us consider the pharmacist. The exact compounding of medicines is a part of his training and belongs to his profession. The trained pharmacist supervises the preparation of parenteral solutions in many commercial laboratories. Sterile medications comprise a large percentage of the total drugs administered to patients. The pharmacist has an exact technical knowledge of the properties of different chemicals under varying conditions. For example, heat affects solutions of chemicals in various ways; the pharmacist is in position to draw upon his techni-
cal knowledge. If one is to concede that the pharmacist is the person of choice, then the solutions room should be part of the pharmacy.

The nurse supervisor is another person who is frequently in charge of the solutions room. Her training has given her a good understanding of the need for sterile, pyrogen-free solutions. She has probably witnessed febrile reactions in patients receiving intravenous fluids. She is schooled to a rigid observance of sterile technic, and her nurse's training has given her therapeutic knowledge in regard to the administration of parenteral fluids.

Many hospitals employ technicians to supervise their parenteral fluids department. The technician has knowledge of sterile procedures, volumetric measurements, and laboratory tests. However, unless her work is of unusually high calibre, the technician is not the person of choice to have charge of a solutions department. Technicians, in certain instances, may work under conditions a pharmacist or a nurse would not tolerate. This will be illustrated as the chapter proceeds using Hospital X as an example.

In 1932, when Hospital X began the manufacture of parenteral fluids, a student nurse was assigned by the Nursing School Office to be responsible for their preparation. Later, graduate nurses took over the department.
From 1939 to 1941, a pharmacist was employed, but toward the end of his period of service he became careless and developed many short cuts in technic with resulting reactions. Graduate nurses were again employed and the number of reactions decreased. With the onset of the war, and the disappearance of graduate nurses into the armed services, technicians were employed to take charge of the department. At present, a graduate unregistered technician supervises the preparation of parenteral fluids. She is an intelligent, conscientious worker who fully realizes the seriousness of her work. She is well-versed in the technique; however, she works under several distinct handicaps. Her criticisms, which I believe to be well-founded, will be discussed later in this chapter.

The department is adequately staffed insofar as the number of workers is concerned. The technician in charge has general supervision of the department. She orders supplies, keeps the records, checks up on the flasks of solutions needed by the different floors of the hospital, sharpens needles, and keeps the equipment used in the preparation of fluids in good working order. Two other technicians are responsible for the actual preparation of solutions, and their duties of preparing the equipment and making the solutions are interchangeable. A fourth worker is employed to wash bottles and prepare the various sets used in the administration of parenteral fluids and the collection of blood.

In considering the various people to take charge of a solutions room, one must take into consideration the
personal equation: the conscientiousness of the individual which will utilize to the fullest his technical skill or therapeutic knowledge.

Selection of Method

After the location and the personnel have been selected, the next step is the selection of the method to be used. Modern scientific methods have ruled out the technic of preparing fluids which consisted of collecting distilled water into a large container from a still located somewhere in the hospital. This container of distilled water was taken to the room where the solutions were to be prepared. The chemicals were weighed and added to the distilled water, and the resulting solution was filtered through ordinary filter paper into Erlenmyer flasks; these were capped with paper or gauze and autoclaved. It was a chance method at best, but the manufacture and knowledge of parenteral fluids was in its infancy.

At Hospital X this practice was in general use at the time. The apparatus used in the administration of the fluids was makeshift. It consisted of an open neck graduated bottle, any type rubber tubing, an expensive Kaufman syringe, improperly gauged needles. When the intravenous infusion was to be given, the flasks of distilled water, ampoule of glucose, and the apparatus were collected and carried to the floor. The ampoule of glucose was opened and the necessary amount poured into an open bottle. The flask of distilled water was heated, and the contents added to the bottle.
All parts of the apparatus were boiled in pyrogen filled tap water. The percentage of reactions was variable. These reactions following the injection of sterile distilled water were suggestive of protein shock. Mild reactions were accompanied by a moderate elevation of temperature. In the more severe reactions, the elevated temperature followed chills, and pain in the back and legs accompanied by occasional nausea, vomiting, and diarrhea. The severe reaction was characterized by a marked fall in blood pressure, cyanosis, circulatory collapse, and even death.

In 1911, Wechselman (1) reported that upon standing, distilled water acquired the property of producing febrile reactions which he believed due to bacterial contamination. Müller (2), Holt, and Penfold (3) confirmed Wechselman's findings, and described thirteen types of bacteria capable of producing febrile reactions. However, the removal of these bacteria by Birkefeld filtration did not eliminate febrile reactions. Various investigators at this time were considering as the cause of such reactions: individual susceptibility; impurities from chemicals, glassware, and rubber; the rate of injections, and the amount injected; the temperature of the solution; and the hydrogen

(1) Wechselman, Neuere Erfahrungen über Intravenose Salvarsan injektionen ohne Reaktionserscheinungen, München, Med. Wehnschr, 1911, p 1510.
ion concentration of the solution—a concentration higher or lower than that of the blood. The above conjectures were tested both experimentally and clinically without producing the expected results. There remained only the interpretation of the reactions given by Florence Seibert (1) of New Haven (1923-27), namely, that reactions were caused by impure water—water containing pyrogens. Pyrogens are soluble, ultra-filtrable substances produced by certain water-borne bacteria which are not inactivated by temperatures usually used in sterilization. Therefore, it was established that contamination of distilled water was due to air-borne bacteria or pyrogenic exotoxins. Several recommendations were made in order to secure a pure distilled product which was safe for intravenous injection: 1. Distillation in a still designed to prevent entrainment; 2. sterilization within one to three hours after distillation; 3. prompt sealing to protect sterility; 4. the rinsing of tubing and glassware with freshly distilled water to remove any pyrogenic exotoxins which may have dried on their surfaces; and 5. a source of pure raw materials.

This brings us to a consideration of the technics in use today, technics based on scientific principles.

Absorptive Filtration Method

There are two main technics which, if followed carefully, will produce a solution that is safe for intravenous injection. The first of these is the absorptive filtration method. It was first described by Co Tui (1) and his associates in 1936, and was perfected at the Bellevue Hospital in New York. This method bases its technic on the assumption that although freshly distilled water may be free from pyrogens, the chemicals used may not be. The entire volume of distilled water and the desired chemicals is prepared. This solution is passed through special bacterial and pyrogen retentive filters which filter out bacteria and absorb pyrogens from whatever source they may originate. There are disadvantages to this method. The retentive filter is expensive; the cost being in the neighborhood of $1000. The filters have a saturation point for pyrogens after which their efficiency is diminished. In a hospital preparing a large volume of parenteral fluids daily, the total bulk is awkward to handle.

The Semi-Closed, Semi-Automatic System

The semi-closed, semi-automatic system of preparing parenteral fluids—widely known as the Fenwal System—

was perfected by Dr. Carl W. Walter (1) of the Peter Bent Brigham Hospital, in Boston, in 1935. It consists of the preparation of a concentrated stock solution of chemicals in freshly distilled water. This stock solution is drawn through a fritted glass filter by means of a Comco suction pump into a semi-closed system which consists of pairs of burettes. Into one pair, the concentrated stock solution is forced by pressure pump; into the second pair, distilled water runs by gravity. By adjustment of the size of the measuring burettes, the concentrate and sufficient distilled water is delivered volumetrically into the flask, one pair of burettes emptying while another pair is filling. Hospital X uses this semi-closed, semi-automatic system.

**Water Stills**

To save later headaches, careful consideration must be given to selection of other equipment. Of prime importance is a good still. Water stills range in size from 1 to 30 gallons per hour output, and in cost from approximately $97 to $604 delivered. Stills are designed to use steam, gas, electricity, gasoline, and kerosene; however, in most cases, the still should be the steam-operated type because steam is a readily available, economical source of power in a hospital. It is important to choose a still offered by a reputable manufacturer. There are single, double, or triple

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FENWAL PREPARATION UNITS

This unit complete with work bench as illustrated above, requires only water, steam and drainage connections.

To insure the constant accuracy in the manufacture of parenteral fluids, two different techniques have been developed to accommodate a volume capacity from 25 liters per week to 250 liters or more per day.

FENWAL Preparation Unit A is a semi-automatic volumetric technique while the Preparation Unit B is a gravity metric technique.

Figure 2 From the Fenwal Manual
FENWAL PREPARATION UNIT A
(Volumetric)

This unit operates with the aid of a dependable pressure-suction pump (page 18) and will accurately deliver the required amount of concentrate stock solution and distilled water, by a single attendant, at the rate of one liter every 30 seconds, by simply turning a valve.

**TECHNIQUE**

1. Have adequate quantity of freshly distilled water in carboy. (G)
2. Have freshly prepared Concentrate solution ready.
3. Position suitable burettes (Q) on the stationary panel (L). (See page 14 for sizes.)
4. Filter the freshly prepared Concentrate solution through filter (A) into the 9 liter Pyrex container (C) using suction from pump (J).
5. Shut off valve (B).
6. Change tubing on pump (J) from suction to pressure outlet (about 2 pounds).
7. Attach tubing from Concentrate solution bottle to forward outlet of valve (R) and the tubing from the distilled water carboy (G) to the rear outlet of valve (R) and open valve at (I).
8. Valve (R) is now opened and two left chambers (Q) of unit (L) automatically fill and accurately measure the correct amount of distilled water and Concentrate solution.
10. Valve (R) is turned 90 degrees and the two left hand chambers (Q) empty in container (K), while simultaneously the right hand chambers fill and shut off at the correct amount.

11. Another clean container (K) is brought under outlet at (R) and valve (R) is turned back to original position. This action causes the right hand chambers to empty while the left ones are filling.

Continue as described on page 24.

12. This procedure is continued until the required number of containers are filled.

**EXAMPLE**

"5% Dextrose in Distilled Water"

Concentrate solution used is 50% Dextrose. Chambers used are 100 ml. in forward position for Concentrate solution and the 950 ml. capacity for distilled water are placed behind the smaller chambers, so that on the left hand of valve (R) we have one 100 ml. and one 950 ml. chamber. The combining of these capacities will result in a 1000 ml. unit of 5% Dextrose in distilled water with a 5% loss figured for sterilization at 250°F. for 30 minutes.

**DIRECTIONS FOR PREPARING THE CONCENTRATE SOLUTIONS**

1. Heat distilled water almost to a boil.
2. Add required amount of sodium chloride and dissolve.
3. Gradually add required amount of dextrose and stir slowly.
4. Add balance of distilled water to correct weight.

(Always add dextrose to saline mixture, never saline to dextrose.)

<table>
<thead>
<tr>
<th>Solution Desired</th>
<th>Chemicals in Concentrate Solution</th>
<th>Net Weight of Concentrate Solution (Made up by Adding Distilled Water)</th>
<th>Barettes used in Automatic Mixing Chamber For Concentrate Solution</th>
<th>For Distilled Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% Dextrose in Distilled Water</td>
<td>1000 gm. Dextrose C.P. anhydrous</td>
<td>2355 gm.</td>
<td>100 ml.</td>
<td>950 ml.</td>
</tr>
<tr>
<td>10% Dextrose in Distilled Water</td>
<td>1000 gm. Dextrose C.P. anhydrous</td>
<td>2355 gm.</td>
<td>200 ml.</td>
<td>850 ml.</td>
</tr>
<tr>
<td>5% Dextrose in 0.85% Saline</td>
<td>1000 gm. Dextrose C.P. anhydrous 170 gm. Sodium Chloride C.P.</td>
<td>2405 gm.</td>
<td>100 ml.</td>
<td>950 ml.</td>
</tr>
<tr>
<td>10% Dextrose in 0.85% Saline</td>
<td>1000 gm. Dextrose C.P. anhydrous 85 gm. Sodium Chloride C.P.</td>
<td>2380 gm.</td>
<td>200 ml.</td>
<td>850 ml.</td>
</tr>
<tr>
<td>0.85% Saline Solution (Normal or Physiological Saline Solution)</td>
<td>85 gm. Sodium Chloride C.P.</td>
<td>1055 gm.</td>
<td>100 ml.</td>
<td>950 ml.</td>
</tr>
<tr>
<td>4% Sodium Citrate Solution</td>
<td>40 gm. Sodium Citrate C.P.</td>
<td>1049 gm.</td>
<td>50 ml.</td>
<td>None</td>
</tr>
</tbody>
</table>

Additional formulae available for your specific needs, Ringer's Solution, Sulfanilamide Procaine, etc.
**EXAMPLE**

"5% Dextrose in Distilled Water"

Concentrate solution used is 50% Dextrose. Burette 100 ml. of the stock solution into clean counter-balanced container and add distilled water to total weight of 1055 grams.

This total volume will give a 1000 ml. final solution of 5% Dextrose in distilled water, allowing a 5% loss in sterilization at 250°F. for 30 minutes.

**DIRECTIONS FOR PREPARING THE CONCENTRATE SOLUTIONS**

1. Heat distilled water almost to a boil.
2. Add required amount of sodium chloride and dissolve.
3. Gradually add required amount of dextrose and stir slowly.
4. Add balance of distilled water to correct weight.

(Always add dextrose to saline mixture, never saline to dextrose.)

### Solution Desired

<table>
<thead>
<tr>
<th>Chemicals in Concentrate Solution</th>
<th>Net Weight of Concentrate Solution (Made up by Adding Distilled Water)</th>
<th>Concentrate Added to Each Container</th>
<th>Net Weight of Solution (Made up by Adding Distilled Water)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% Dextrose in Distilled Water</td>
<td>1000 gm. Dextrose C.P. anhydrous</td>
<td>2355 gm.</td>
<td>100 ml. 1066 gm.</td>
</tr>
<tr>
<td>10% Dextrose in Distilled Water</td>
<td>1000 gm. Dextrose C.P. anhydrous</td>
<td>2355 gm.</td>
<td>200 ml. 1085 gm.</td>
</tr>
<tr>
<td>5% Dextrose in 0.85% Saline</td>
<td>1000 gm. Dextrose C.P. anhydrous 170 gm. Sodium Chloride C.P.</td>
<td>2405 gm.</td>
<td>100 ml. 1086 gm.</td>
</tr>
<tr>
<td>10% Dextrose in 0.85% Saline</td>
<td>1000 gm. Dextrose C.P. anhydrous 85 gm. Sodium Chloride</td>
<td>2380 gm.</td>
<td>200 ml. 1085 gm.</td>
</tr>
<tr>
<td>0.85 Saline Solution</td>
<td>170 gm. Sodium Chloride C.P.</td>
<td>1108 gm.</td>
<td>50 ml. 1049 gm.</td>
</tr>
<tr>
<td>4% Sodium Citrate Solution</td>
<td>40 gm. Sodium Citrate C.P.</td>
<td>10.49 gm.</td>
<td>50 ml. None</td>
</tr>
</tbody>
</table>

Additional formulae available for your specific needs, Ringer’s Solution, Sulfanilamide, Procaine, etc.

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**Figure 3 From the Fenwal Manual**
stills available on the market. There is a margin of safety in the use of double or triple stills where several persons of varying experience may have to operate the still, and where the still is not carefully used and maintained. However, double and triple stills require more space than do single stills. They are slow in operation and they are difficult to clean.

"Singly distilled water is sufficiently pure for intravenous use provided several precautions are taken to prevent pollution of the distillate. First, intelligent operation and maintenance of the still are essential. Second, chemically pure distilled water cannot be stored unless it is hermetically sealed in sterile containers; hence, distilled water must be collected in a storage tank just large enough to contain a working supply." (1)

The principle by which various stills operate is essentially the same. The steam coil at the bottom of the still serves as the source of heat used to evaporate the water. The vapor rises from the surface and passes through a large disengaging space where it meets with a series of baffles. The baffles are designed to trap any entrained particles or moisture droplets, thus allowing only pure, dry steam to enter the condenser. The condenser is usually lined with tin because of its resistancy to distilled water. It is desirable that the condenser be located at a short distance from the evaporating surface, thus permitting any droplets of moisture to fall back. When the water is heated too rapidly, the resulting explosive ebullition of

A valuable piece of apparatus used in the FENWAL Preparation Unit is the portable vacuum and pressure pump. The motor and compressor are built into a compact unit, encasing all moving parts to prevent accidents. The slides in the rotor of this pump are certain to operate satisfactorily at all times because of an ingenious air groove cut into the rotor. The pump is equipped with an oiling system, which assures proper lubrication. This pump also contains felt filters for both pressure and suction lines; the filters are easily replaced by removal of only three screws. The filters are extremely dense, and not only clean the air, but prevent foreign matter from entering the pump. A combination regulating and safety valve controls the vacuum or negative pressure up to 26" while another valve controls the positive pressure up to 30 pounds.

This unit is wired so that the pump may be operated by foot control if desired. To operate, simply plug into your electrical outlet and throw on switch.

Figure 4 From the Fenwal Manual
steam carries entrained particles past the series of baffles which are effective when the still is carefully operated. Automatic water and steam controls can best rectify carelessness or inexperience in operation of the still. An outlet to the still called the degasser allows gaseous impurities to escape.

Having decided upon the type of still, the hospital must next determine the size of still which will best meet its needs. If the still is to be used only in the parenteral therapy unit, one need but consider the total volume of solutions prepared daily plus the volume of distilled water required to rinse flasks, tubing, and other items of equipment. If the still must furnish distillate to be used in other parts of the hospital, a larger still is indicated. An overestimation of one's needs is to be preferred to an underestimation.

At Hospital X there are two ten gallon per hour stills. One still is located above the sink where the flasks and tubings are washed and the distillate is used for rinsing these and other items of equipment. The other still is part of the Fenwal Preparation Unit and the distillate is used for the preparation of solutions. These two stills are adequate for the preparation of approximately 3750 flasks per month. Having two stills enables the department to continue its operation when one still is relinquished for cleaning every six months. The cleaning schedule for a still is determined after an analysis of the tap water and a consultation with the hospital engineer.
Figure 19.—Diagrammatic elevation of a still illustrating baffles and condenser.

Figure 5  Diagram of still used above the sink at Hospital X. The distillate is used for rinsing equipment.

Figure 17.—Diagrammatic elevation of a still illustrating baffles and condenser.

Figure 6 Diagram of still used in Fenwal Preparation Unit for producing distillate for the manufacture of parenteral solutions.

**Distilled Water Checker**

In order to ascertain whether the distillate is of sufficient purity for parenteral use, a distilled water checker is another required piece of equipment. By U.S.P. standards, distilled water must contain less than ten parts of total dissolved solids per million parts of water. Some authorities recommend discarding the distillate which records more than two parts of dissolved solids per million parts of water. These same authorities recommend checking of the distillate before and after operation of the still. (At Hospital X, three parts of total dissolved solids per million parts of water is allowed, and the distillate is checked but once weekly.) When more than one still is used, it is of equal importance to check the distillate from the still used for rinsing equipment, as it is to check the distillate used in the actual preparation of parenteral fluids. Water checkers operate on the conductivity principle, and the purity of water is readily determined by measuring its conductivity. The conductivity of distilled water is increased about fifty per cent by one part per million of chloride ion. The presence of electrolytes in freshly distilled water is an indication of contamination. Those inorganic substances, such as pyrogens, which are not electrolytes usually occur in combination with electrolytes. If a high purity meter reading is obtained, biological tests must be made to determine whether the impurities are pyrogenic in nature. This test consists of injecting ten cubic centimeters of the solution
into the ear vein of a rabbit and recording its rectal temperature for four hours following the injection. The rabbit's normal temperature varies from 101 to 103 degrees Fahrenheit. If the solution contains pyrogens, the rabbit's temperature will rise to 105 or 107 degrees.

**Filters**

The Fenwal fritted glass filter has been specially designed to use with the semi-automatic, semi-closed system for vacuum filtration, being chemically, thermally, and mechanically resistant. It removes all foreign particles and produces a crystal clear solution. However, it does not remove pyrogens or bacteria as do the asbestos filters used in the absorptive filtration method. In the Fenwal system, a carefully produced distillate and a hermetic seal control the pyrogens, and sterilization takes care of possible bacterial contamination. For those chemicals which cannot be autoclaved, some method of ultra-filtration is indicated.

**Flasks**

The Fenwal flask is made of thick pyrex glassware. It is resistant to high heat and a high vacuum. In shape, it is designed to withstand the "water hammer" which results when fluids under a high vacuum are jarred. The stable surface of the Fenwal flask is resistant to hydrolysis by the solution it contains. The flask must be free of the initial soil as well as the insoluble deposits which form as a result of interaction between washing compounds and water.
FENWAL DISTILLED WATER CHECKER

The operation of the distilled water checker is extremely simple, and accurate results may be obtained by anyone, even though not technically trained. The checker operates on the electrical conductivity principle. It consists of a compact and accurate wheatstone bridge, and a conductivity cell. Water may be checked as easily as looking at a meter.

1. Connect cell to terminals on water checker.
2. Plug line cord into AC electrical outlet 110 volt.
3. Place cell into water to be tested. Move cell up and down, once or twice, under level of water to insure removal of any air inside cell casing.
4. Determine temperature of the solution.
5. Set lower dial to the proper temperature of the water.
6. Rotate upper “balancing” dial, meanwhile observing the action of the “indicating eye.” When the dark segment in the “eye” reaches its widest angle, the bridge is in balance. The dial at this point will then directly indicate the “parts per million” in terms of sodium chloride contained in the water. Water containing more than 2 parts per million should be rejected for use in preparing parenteral solutions.

Figure 7 From the Fenwal Technical Manual
When glassware has been used repeatedly without proper cleaning, a greasy film forms on the surface of the glass which is extremely difficult to remove. When distilled water is poured from a flask a film of water spreads over the inner surface, this film breaks up immediately, and droplets form wherever the greasy soil clings to the surface of the glass. Clean glass will show no "water breaks" after the final rinsing with distilled water and will be crystal clear on drying. The procedure recommended by the Fenwal manual is as follows:

1. Rinse with tap water to remove any solution left in the container.
2. Clean with hot Calgolac solution in Fenwal pressure cleaner for at least 30 seconds.
3. Rinse three times with freshly distilled water using the Fenwal Rinser.
4. Inspect for "water breaks."
5. Invert in rack and let drain.
6. Container is now ready for use.
7. If container is not used within six hours, the cleaning process should be repeated.

Fenwal Sealing Unit

Rubber bushing: When the Fenwal flask has been filled with fluid, a rubber bushing molded of non-toxic rubber is placed in the neck of the flask. It is designed to fit snugly in the neck of the flask in such a way that it will not be drawn inward during sealing or when the vacuum is formed; nor will it be drawn outward when the stopper is withdrawn. New rubber bushings require special care before being used for the first time. They are covered with a 0.5% sodium carbonate solution and autoclaved for thirty minutes at fifteen pounds pressure. This solution is discarded
Container A illustrates the numerous droplets formed by the "water break" which is caused by grease or other soil reducing the surface tension of the film of water so that it retracts to form droplets; clean containers must be free of the white, opalescent film of insoluble deposit of alkali earth soaps as shown in B; container C shows a possible source of bacterial growth in residual blood; this may be avoided by prompt washing of container after use.

Figure 8 Improperly cleaned flasks. From the Fenwal Technical Manual
and the bushings are next rinsed with a 1% solution of hydrochloric acid. Finally, they are rinsed with distilled water until neutral to litmus paper. Routine care of the bushings requires their being washed in hot soap and water or a hot dish-washing compound such as sodium metaphosphate. The bushings are then rinsed with distilled water until neutral to litmus paper. They are stored in a clean container until ready for use, and then rinsed once more in distilled water immediately prior to use. Occasionally bushings acquire a slick, slimy feel and require scrubbing with a stiff brush.

**Metal stoppers:** The metal stoppers which fit into the rubber bushings are designed of stainless steel to resist attack of saline solutions as well as being resistant to tarnish from air or steam. The stopper is shaped like a mushroom, covering and protecting the rubber bushing. There is a longitudinal channel cut in the lower half of the cap to allow air and steam to escape during sterilization—when the metal cap is inserted part way into the rubber bushing. On removing the flasks from the sterilizer at the completion of the sterilizing cycle, the stopper is pushed down completely so that the solid portion of the stem forms a hermetic seal with the bushing. Stainless steel stoppers are washed with hot soap and water or a dish-washing compound, using a pipe cleaner to clean the stem. Then they are rinsed with distilled water until neutral to litmus paper. They can be stored in a clean container and rinsed once again with distilled water before being used. At Hospital X, the extra
stoppers not used on one day are autoclaved for use on the following day.

**Rubber Tubing**

The rubber tubing used in parenteral therapy must be selected carefully. A non-toxic rubber tubing should be chosen with a small lumen about 1/8 inch in diameter. This has two advantages: the amount of the inner surface of the tubing exposed to the fluid is decreased; and secondly, the fluid will tend to run through the tubing in a solid column expelling all the air instead of running down one side, gutter fashion. The inner surface of the tubing must be smooth and free from pits and wrinkles which would serve as lodging places for blood clots or dried solution, a potential danger point for the growth of bacteria. It is more economical to select tubing of a type which will withstand a minimum of seventy-five sterilizations without losing its elasticity. The manufacturers of Fenwal equipment recommend the following preparation and care of rubber tubing:

**Preparation of Rubber Tubing**

All new rubber tubing should be processed to remove the "bloom" before being used. Tubing treated in the following manner will give satisfactory results:

1. Fill rubber tubing with 0.5% sodium carbonate solution.
2. Autoclave for thirty minutes at 250 deg. F. exhaust line temperature.
3. Rinse lumen with 1% solution of hydrochloric acid.
4. Run distilled water through tubing until neutral to litmus paper.
5. Tubing is now ready to be cut into desired lengths.
Care of Rubber Tubing

1. Disconnect tubing from glassware and run cold tap water through the tubing to remove any solution that may remain in the tubing. If the tubing is full of blood run 1 ½ hydrogen peroxide through it to leech out the blood.

2. Wash in Fenwal Pressure Cleaner with hot Calgo-lac solution for one minute.

3. Run freshly distilled water through the tubing until neutral to litmus paper.

4. Clip off ends of worn tubing.

5. Do not dry tubing but assemble the sets while tubing is still moist." (1)

The Fenwal system has an automatic washer which will cleanse both flasks and tubing. However, while convenient, the washer is not absolutely essential to the manufacture of safe parenteral solutions. The alternate technic recommended by the Fenwal system is outlined below:

"Alternate technic

1. (Same as in Care of Rubber Tubing)

2. Assemble tubing in lengths, using glass connectors which are inserted into the tubing for a shorter distance than the glassware.

3. Connect to a burette full of 0.5% sodium carbonate and trickle the cold alkali thru it, for 15 minutes.

4. Heat tubing to boiling over a hot plate, while the alkali trickles thru it, for 30 minutes.

5. Rinse as above with 1% solution of hydrochloric acid, then distilled water." (2)

Hospital X has a mechanical washer for automatic cleaning of tubing and glassware which the technicians who prepare the solutions consider too time-consuming for use. This is merely the personal opinion of the technicians and is not a reflection on the mechanical washer which other hospitals have found to work satisfactorily. The technicians have devised the following technic for cleaning flasks

(2) Ibid, p 15.
and rubber tubing: The bottles are filled half-full of soap solution and hot water, and scrubbed manually with a strong long-handled brush, they are rinsed in tap water and then distilled water, and stored upside down on a cart to allow the excess water to drain out. The rubber tubing is rinsed piece by piece with cold tap water under pressure to remove dried solution or old blood clots; it is then put to soak in soap solution for 24 hours, after which time it is rinsed again with cold tap water under pressure, and finally with distilled water. Any excess of tubing is autoclaved at the end of the day for use the following day.

The glass vent tubes and adaptors are rinsed with tap water, washed in hot soap and water or a dish-washing compound; this fluid is drawn through the inside of the vent tube or adaptor with the aid of suction. Distilled water is finally drawn through them in the same fashion as a final rinse. These pieces of glassware should be used almost immediately.

**Needles**

The size and type of needle selected for intravenous work will depend upon the preference of the physician and the use for which it is intended. There are various methods of cleaning soiled needles. The bore of the needle should be reamed with a snugly fitting stylet to forcibly remove any adherent particles. For the same reason, the hub of the needle should be cleansed manually with a wooden applicator wrapped with cotton. Hot soap solution should be
forced through the needle several times, then ether, and as a final rinse--distilled water. The needle is then inspected for cleanliness, sharpness, and weakness. "Needles should not be sterilized with stylets in place because the electrolytic action set up between the stylet and the needle causes early erosion and weakening." (1) At Hospital X needles are soaked in soap solution for an hour, cleansed with an applicator wrapped with cotton, rinsed with soap solution, tap water, and distilled water. They are sorted, inspected for burrs, and wrapped in clean gauze squares. They are autoclaved with the infusion sets. The Fenwal system offers individual glass needle holders into which a single needle is placed. The glass needle holder is covered with a compress cloth and then autoclaved.

Whether the hospital elects to purchase commercial solutions or to prepare its own, the care with which the intravenous sets are assembled is most important. The solution may be pyrogen-free yet the source of pyrogenic reactions may be found in the sets used for administration--in the tubing or the needles if they are carelessly assembled. The inner surface of the rubber tubing, needles, glass vent tubes, and glass observation tubes must be chemically clean in order to secure safe, reactionless infusions. With this in mind, some commercial companies are recommending the use of single administration plastic or cellophane tubing. This tubing is discarded after it has been used once. While it

has its advantages in lessening the possibility of pyrogenic reactions and as a time-saver, the hospital which has the equipment and the personnel for preparing its own solutions should not find the preparation of tubing unduly time-consuming.

At Hospital X the sets are assembled as follows:

A. Infusion set
   1. One vent tube
   2. One short length of rubber tubing (approximately ten inches)
   3. One Murphy drip bulb
   4. One long length of rubber tubing (approximately forty inches)
   5. One glass needle adapter

B. Clysis set
   1. One vent tube
   2. One short length of rubber tubing (approximately ten inches)
   3. One clysis drip bulb
   4. Two long lengths of rubber tubing (approximately forty inches each)
   5. Two glass needle adapters

C. Blood Donor set
   1. Two short lengths of rubber tubing
   2. One Murphy drip bulb
   3. One donor glass sleeve
   4. One rubber bushing
   5. One steel rod
6. One long length of rubber tubing
7. One glass needle adapter

D. Blood Administration (Recipient) set
1. One vent tube
2. One rubber bushing
3. One recipient glass window
4. One dispensable nylon filter
5. One long length of rubber tubing (approximately fifty to sixty inches)
6. One glass needle adapter

E. Kelly Transfusion set
1. One Kelly bottle
2. One short length of rubber tubing
3. One Murphy drip bulb
4. One long length of rubber tubing
5. One glass needle adapter

All the sets are placed in an aluminum pan with a clamp for the rubber tubing and a few small sponges. (Suitable needles may be autoclaved with the sets, or they may be autoclaved separately in Fenwal needle holders.) The pan is then placed in a sterilizing envelope and tied. The sets should be placed in the autoclave in such a fashion that the aluminum pans are vertical. This allows the steam to replace the air in the kits and sterilizing temperatures are rapidly developed. The kits should be sterilized for 30 minutes at 15 pounds pressure--250 degrees exhaust line
FENWAL SYSTEM FOR ADMINISTRATION OF INTRAVENOUS FLUIDS

1. Read identification tag.

2. Jar container to obtain water-hammer click. (Fig. E.) If click is not produced, request another container, since it must be assumed that this seal was broken.

3. Select suitable vein of patient and disinfect overlying skin.

4. Open sterile infusion set.

5. Invert FENWAL container once or twice to wet pin of the stainless steel stopper.

6. Remove stopper from bushing using a rocking, twisting motion. (Fig. F.)

7. Insert vent tube into orifice of rubber bushing to occlude the orifice, and momentarily tip the container to wet the hole in the bushing. Wiggle the vent tube into the bushing so that the two circumferential ribs or beads rest in the proper position within the bushing. (Fig. G.)

8. Check the identity of the solution.

9. Invert FENWAL container and hang in holder for same. (Fig. H.) When negative pressure has been created (shown by bubbles appearing in container) pinch tubing between fingers. Attach proper size needle to adapter from needle holder.

10. Apply tourniquet to patient's arm to occlude venous return.

11. Release tubing and drive the air from infusion set.

12. Hold needle at level of vein and adjust rate of flow by shifting height of container on infusion pole.

13. Make venipuncture, open tourniquet, and check the flow of fluid.

14. Clean equipment and containers with cold tap water as soon as possible after infusion and return completely to the supply room.

*Note—If negative pressure is not created, i.e. if container is inverted with clamp closed, FENWAL vent tube may leak solution through "Air Vent" until the positive pressure is relieved. FENWAL vent tube will not leak when used as suggested.

Figure 9 From the Fenwal Technical Manual
temperature. (At Hospital X, the kits are autoclaved for twenty minutes at 250 degrees exhaust line temperature.) When the sterilizing cycle is completed, the sets should remain in the autoclave with the door slightly ajar in order to dry.

**Sterilizer**

The sterilizer should be located within the parenteral therapy unit. Because it generates a great deal of heat, it should be recessed into a wall or, when feasible, be located in a room adjacent to the room where the actual preparation of parenteral fluids takes place. Since all steam sterilizers work under the same broad principles, any type of autoclave may be used for sterilizing solutions. If a new sterilizer is being contemplated, it would be preferable to purchase a serum sterilizer which is specially designed for sterilization of liquids. The serum sterilizer does not have the conventional outer steam jacket. This construction cuts down on the sterilization period, and therefore on the amount of time that sensitive solutions are exposed to heat. Square sterilizers will accommodate a greater load of bottles than will round ones. One authority states, "Unless the sterilizer is sufficiently large, much of the technician's time will be spent 'watching it'; therefore, we should bear in mind when selecting a new one that it is better to put a little more money into a piece of equipment which will remain in the hospital than into years of added salary which will go
out of the institution." (1)

The Sterilization of Solutions

Dr. Carl W. Walter has written an excellent pamphlet on sterilization, and the following is quoted from the section on the sterilization of solutions:

"The sterilization of solutions presents an apparent inconsistency in technic (of sterilization) because flasks are put in the sterilizer in an upright position, and no provision is made for a horizontal path for the escape of the air from partially filled flasks. The presence of water alters the problem, however. The temperature developed in a load of textiles depends upon the temperature, and hence the pressure, of the saturated steam, that condenses inside the bundle. The temperature of the water in a partially filled flask depends only upon the temperature of the walls of the flask. In saturated steam, therefore, the temperature of the liquid ultimately approaches that of the surrounding steam, and vaporization inside the flask becomes sufficiently rapid to fill the flask with saturated steam, driving off the air even though there is no horizontal path for its escape. The air is displaced so completely from unstoppered flasks that when the flask is stoppered and cooled, a 29-inch vacuum results.

"The sterilization of solutions presents a second problem not encountered in sterilizing dry goods. At the end of the sterilizing cycle, flasks of solution are as hot as the surrounding steam, and because the liquid is subjected to the vapor pressure of the steam, it is in a stable condition. However, if the steam pressure in the sterilizer is vented, this equilibrium is upset, the solution becomes too hot for the pressure exerted upon it, and excessive vaporization occurs. This may result in concentration of the solution, or, if the vaporization is explosive, much of the solution may be lost during the violent ebullition of steam which occurs when the pressure is relieved. To prevent this, the steam to the sterilizer jacket, as well as to the chamber, should be shut off and the whole sterilizer permitted to cool to 200 degrees before the sterilizer door is opened. Under these circumstances, the solutions lose heat to

the steam in the sterilizer, which in turn loses heat to the walls of the sterilizer. The pressure decreases as the temperature falls and equilibrium is maintained through the cooling cycle.

"Successful sterilization of solutions also demands a detailed knowledge of their characteristics. It is useless to attempt to sterilize a chemical that decomposes at a temperature lower than that used in the sterilizer. Hydrogen ion concentration is important since many chemicals are stable only under specific conditions. It is therefore important to use pure distilled water as the diluent. Improperly rinsed glassware may add residual alkali from detergents to the solution and cause decomposition. The use of soft glass may permit the development of an alkaline reaction at the liquid-glass interface.

"For example, dextrose solution can be sterilized without deterioration when the pH is acid and the containers are made of hard glass. If the pH is alkaline, caramelization occurs and the solution turns brown. Solutions of procaine hydrochloride can be sterilized in a steam sterilizer in hard glass containers if 0.001-normal hydrochloric acid is used as the diluent. On the other hand, solutions of sodium tetraiodoophenolphthalein must be kept alkaline or precipitation occurs. This drug must be dissolved, without shaking, in carbon dioxide free water, sterilized, and hermetically sealed so that carbon dioxide has no access to it. The three solutions mentioned can be sterilized at 250 degrees F. for 30 minutes, hermetically sealed, and stored indefinitely without appreciable deterioration." (1)

Care of Fenwal Apparatus

Since chemically pure distilled water cannot be stored unless it is hermetically sealed in a sterile container, it must be collected in a storage tank just large enough to contain a working supply. In the Fenwal system, an inverted pyrex carboy fitted with a stop cock is de-

signed to collect the distillate directly from the still. After the day's quota of fluids has been prepared, the carboy can be drained dry. At the end of each day, the unit used in preparing the solutions is dismantled, and each glass section is cleaned, rinsed in distilled water, covered with clean compresses, and stored thusly for the night. The rubber tubing used is rinsed and, when not in use, is kept in a solution of 70% alcohol. Each morning, the unit is reassembled, each section being first rinsed with distilled water. The same process takes place when the type of solution is changed. For example, having prepared saline solution, all the equipment must be cleaned again before glucose in water solution is prepared. The filter used in preparing the stock solution is cleaned in the same way, except at the end of the day, it is soaked in a potassium dichromate acid solution.

At Hospital X, a conventional autoclave is used for the sterilization of solutions. Its capacity is 88 flasks, and it is recessed into the wall of the solutions room.

The technician in charge offers the criticisms which appear in the following paragraphs, but she has been unable to correct them; therefore the work is carried out under many distinct handicaps. In the first place, the room is too small. There are three portable carts in the room; one of these is used to load flasks of fluids into the auto-
clave, another is used to hold the flasks after they have been washed and rinsed and put to drain, the third is used to distribute solutions to the floors. These carts are constantly in the way, and must be moved to make room for the technicians to work.

A large quantity of used bottles are returned daily, and the technicians are hard put to find a place to store them until they can be washed and put into use. Storage of the soiled blood bottles returned from the blood bank is another real problem. These bottles are filled with soap solution and soaked overnight in order to remove protein substances. Several months ago, a movable cart, designed to fit under the sink, was ordered to hold these bottles so that they need not rest on the floor under the sink while they were being soaked.

Another particularly annoying condition exists. As it was mentioned previously, the solutions room is situated in the basement of the hospital, and there are a number of overhead pipes in the room. Heat generated by the autoclave and the two stills keeps the room very warm and humid. The overhead pipes "sweat," and drip across the length of the room. Awareness of this factor makes the technicians very careful not to leave clean material in the line of the drip; however, it is an ever present source of potential contamination.

When the solutions come out of the autoclave, the
room becomes overheated and very humid. In order to make working conditions bearable, the door leading into the corridor is opened, or in the summer, the window is opened to clear the air. When the window is opened, dust blows into the room from the courtyard. There is no fan in the room to exhaust the humid air and bring in filtered fresh air.

The lighting is inadequate, but new lights have been ordered and they are hoped for in the near future. The technicians have no place to hang their coats, and they are hung in any convenient place in the room. This is not particularly desirable, and lockers have been ordered to fill this need.

One of the most trying annoyances is the lack of cooperation between the engineering department and the solutions department. In a hospital, the engineering department is one of the busiest; however, to the technicians who work in the solutions room, the policy of the engineering department seems to be one of repair instead of maintenance. The solutions department is most dependent on steam in order to function at all since both the autoclave and the stills are steam operated. At fairly frequent intervals, the steam is turned off for an hour or two without any advance warning. Recently, one of the stills began to give trouble, and the trickle of distilled water it produced finally stopped. It took two weeks for the engineering department to get at the root of the trouble, which involved installing a new trap and blowing air out of the steam line. During this period,
the production of fluids was decidedly cut down, and it was necessary to purchase a quantity of commercially prepared solutions. The sink frequently drains slowly. It is absolutely necessary that the sink be kept clean and freely draining in order to insure the cleanliness of the flasks rinsed in it. Prompt, efficient service in maintenance and repair would greatly alleviate one of the most trying problems facing the solutions department.

There is no drainboard to catch the drip from the burettes used in filling the flasks at the Fenwal preparation unit. A clean compress is placed under the flask being filled, but it must be changed frequently for it becomes soaked. The workbench becomes wet and must be mopped up frequently. A drain-board-sink arrangement would simplify matters greatly.

The technicians do not wear gowns or masks when preparing solutions, but dress in street clothes. Recently, however, they decided to keep their hair covered. This wearing of street clothes is undesirable because it brings another source of potential contamination into the room.

The technicians engaged in the manufacture of fluids at Hospital X have said that they would enjoy making solutions in an air-conditioned room of adequate size equipped with fluorescent lighting, and with sufficient storage space for sets used in the administration of fluids, flasks of solutions, and for the chemicals used. They are
chagrined when reactions occur, but they state that they honestly feel that they are doing the best they can considering the handicaps under which they work. In a hospital, it is difficult to make sweeping changes because of the lack of funds; however, the solutions department is one of the most important, and conditions here should very nearly approach the ideal.
Chapter II
Cost Analysis

Many hospitals, in seeking ways and means of reducing operating costs, have endeavored to manufacture their own parenteral solutions. Many have found the task too expensive, while others have found it to be economical and have continued to manufacture their own solutions.

Hospital X has been manufacturing its own parenteral fluids for more than fifteen years, but a thorough cost analysis has never been undertaken to ascertain the advisability of maintaining the department. Many untoward reactions have been experienced by the recipients of fluids during this time, and studies have been made to determine the causative agents.

Personnel changes have been recommended and instituted. New technics have been advised and instituted. Finally, a new system was installed in the early 1940's. The reactions persisted, and to this day, the problem still presents itself. This past year, the Director of Laboratories sought to explain and account for the incidence and severity of reactions experienced by recipients of parenteral fluids following their administration. The reactions have averaged fifteen per month for the past few years. To the best of my knowledge, a successful answer had not been attained, nor was a satisfactory solution to the problem arrived at.

In the light of these factors, it would be expedient to consider a strong recommendation for the reorganization
of the solutions department—including personnel and the physical set-up of the department. The final result of the cost analysis, whether in favor of maintaining the department or of discontinuing it, should be tempered by the fact that the safety of the patient is of paramount importance. With this thought in mind, the results of the cost analysis must remain secondary.

In developing the cost analysis for Hospital X, full weight was given to the department's full share of overhead cost, imputed cost of management, and the department's share of the running expense of the hospital.

It may be of interest to note some results of cost analysis studies which were done by other hospitals as a forerunner. Because Hospital X manufactures but a small variety of solutions, only those figures pertaining to the solutions manufactured will be quoted.

(See Cost Analysis Study on page 71)
<table>
<thead>
<tr>
<th>Solutions</th>
<th>Fenwal Total Unit Cost</th>
<th>Commer. Unit Cost</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hosp.#1</td>
<td>Hosp.#2</td>
<td>Hosp.#1</td>
</tr>
<tr>
<td>0.85% Saline (1000 cc.)</td>
<td>$.18</td>
<td>$.02</td>
<td>$.60</td>
</tr>
<tr>
<td>0.85% Saline (2000 cc.)</td>
<td>.36</td>
<td>.04</td>
<td>1.05</td>
</tr>
<tr>
<td>5% Dextrose in 0.85% Saline (1000 cc.)</td>
<td>.22</td>
<td>.44</td>
<td>.80</td>
</tr>
<tr>
<td>5% Dextrose in Water (1000 cc.)</td>
<td>.20</td>
<td>.13</td>
<td>.75</td>
</tr>
<tr>
<td>2.5% Dextrose in 0.42% Saline (500 cc.)</td>
<td>.13</td>
<td>---</td>
<td>.35</td>
</tr>
<tr>
<td>Distilled Water (2000 cc.)</td>
<td>.26</td>
<td>---</td>
<td>1.05</td>
</tr>
<tr>
<td>10% Dextrose in Water</td>
<td>.11</td>
<td>.30</td>
<td>.90</td>
</tr>
</tbody>
</table>

It is readily seen that Hospital #1 and Hospital #2 show variances in costs which strongly suggest inadequate and incomplete cost analyses. It appears that the savings in each case are more than 100%. The method used in obtaining these figures was as follows:

Hospital #1 included costs for:

1. Materials used in manufacture, sterilization, and cleaning glassware.
2. Labor.
3. Depreciation on fixed equipment.
4. Breakage and replacement, including all accessories, supplies, and containers.
5. Return on money invested at 5%.

6. One quarter of supervising cost.

Hospital #2 merely used the cost of materials plus labor.

At about the same time a similar study was conducted at Hospital X, which resulted in the following comparisons, based on the cost of materials plus labor:

<table>
<thead>
<tr>
<th></th>
<th>Hosp. Cost</th>
<th>Comm. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotonic Saline (1000 cc.)</td>
<td>$0.19</td>
<td>$0.49</td>
</tr>
<tr>
<td>10% Dextrose in Saline (1000 cc.)</td>
<td>$0.37</td>
<td>$1.21</td>
</tr>
</tbody>
</table>

The cost analysis as developed will determine the actual cost incurred by the solutions department in the manufacture of parenteral solutions, and in the preparation and autoclaving of the various infusion sets.

The revenue derived from the recipients of parenteral solutions will not be considered because it is not pertinent to the problem at hand. The same revenue would result if commercially prepared solutions were used in place of the manufactured product of the department.

The unit cost of each item of the various classifications will be obtained by breaking down the total of solution costs for the year.

"In general, to obtain manufacturing costs per unit of product, it is necessary to go through the following steps, in the order given:

1. Determine the costs incurred in each department of the business without regard to the function of the department.
2. For each service department, determine the costs which are applicable to manufacturing and allocate them to the manufacturing departments for which they were incurred.

3. After steps 1 and 2 have been completed, allocate the costs of each manufacturing department to the products manufactured in the department.

4. To obtain the total manufacturing costs of a particular product, add the costs for that product incurred in the several departments.

5. To obtain the unit cost, divide the total (step 4) by the number of units produced." (1)

Explanation to Exhibit 1

In obtaining the operating costs for the year for the solutions department, the following exhibits (1 to 5) have been prepared to illustrate the accounting method used to obtain various costs allocable to the solutions department.

Exhibit 1 shows the method used to arrive at the overhead cost that is to be charged to the solutions department. This charge represents that portion of the overhead incurred by the operating department of the hospital, such as: housekeeping, heat, light, power—as charged by the power plant, and maintenance. These charges are allocated to the various divisions of the hospital on the basis of the area they occupy in the hospital.

The amount of $1372.11 obtained as overhead cost is represented by Column 3 of Exhibit A—the Operating Report for the solutions department. This amount is also used in Exhibit C, line 3, in compiling the amount of expenses incurred by the solutions department.
Exhibit--1

Operating Report
Hospital X Quarters
For the Year Ending December 31, 1947

Overhead Costs
Housekeeping--Salaries & Wages
Linen & Blankets
Maintenance
Supplies & Expenses
Total Housekeeping

Heat, Light, Power--Chg. by Power Plant
Purchased Electricity
Purchased Gas
Totals

Maintenance--Salaries & Wages
Chg. by Power Plant
Supplies & Expenses
Totals

Combined Costs--------------------------

Distribution of Costs
(On % of Hospital X Area Occupied) % Month Year

<table>
<thead>
<tr>
<th>Medical &amp; Surgical Care</th>
<th>74.8</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Room</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>Delivery Room</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>X-Ray Department</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>Medical School</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>General Administration</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Dietary</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>Medical Records</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Solutions--(See Exhibit A, Column 3)</td>
<td>0.7</td>
<td>$1372.11</td>
</tr>
<tr>
<td>Nursery Care</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>School of Nursing</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Blood Bank</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Social Service</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Combined Distribution</td>
<td>100.0%</td>
<td></td>
</tr>
</tbody>
</table>

$
Explanation to Exhibit 2

To obtain the administrative costs chargeable to the solutions department, it was necessary to first obtain the common expense of the hospital. This over-all expense as obtained under heading #1 of Exhibit 2, is distributed to Hospital X and subdivision Hospital #1, on the basis of the percentage of payroll incurred by each hospital. Hospital X had a payroll representing 71.6% of the total payroll. This portion of the combined costs, as obtained under heading I-B, was charged to Hospital X.

This amount is carried forward to Exhibit #4, where it is combined with the administrative costs as obtained in Exhibit #3.

The 28.4% of combined costs allocable to subdivision Hospital #1 is disregarded as the solutions department is situated in Hospital X.
Exhibit---2

Operating Report
Hospital X Common Expense--Chargeable in Part
to Subdivision Hospital #1
For the Year Ending December 31, 1947

I--Costs

A. Routine Administration
Salaries & Wages
Quarters--Hospital X
Out-Patient Department
Subdivision Hospital #1
Telephone--Salaries & Wages
Supplies & Expense
Supplies--Direct & Rqstn.
Postage & Printing
General Expense

B. Other Quarters (Miscellaneous Personnel)
Salaries & Wages
Charged by Power Plant--Residences
Water
Supplies & Expense
Maintenance

Combined Costs--------

II--Basis for Division

<table>
<thead>
<tr>
<th>Hospital X</th>
<th>Payroll</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>71.6%</td>
</tr>
<tr>
<td>Subdivision Hosp.#1</td>
<td>28.4%</td>
</tr>
<tr>
<td>Totals------</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Distribution of Costs

<table>
<thead>
<tr>
<th>Subdivision Hosp.#1</th>
<th>28.4%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital X---(For Department Distribution)</td>
<td>71.6%</td>
</tr>
</tbody>
</table>

(See Exhibit--4)

Totals-------------
Explanation to Exhibit 3

The expenses of General Administration are compiled under heading #1 of Exhibit 3. Due to the fact that 20% of the salary of the Director of Laboratories is considered an "additional cost" in the operation of the solutions department (as shown under Exhibit C, item 9) his salary is not to be included in that of General Administration in Exhibit 3.

Again, as in Exhibit 2, these total costs as compiled in Exhibit 3, are divided between the hospital units on the basis of percentage of payroll.

The amount charged to Hospital X is forwarded to Exhibit 4.
Exhibit--3

Operating Report
General Administration
For the Year Ending December 31, 1947

I--Costs

Salaries & Wages
Quarters--Hospital X
Subdivision Hospital #1
Out-Patient-Department

<table>
<thead>
<tr>
<th>Division</th>
<th>Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital X</td>
<td></td>
</tr>
<tr>
<td>Sub. Hosp. #1</td>
<td></td>
</tr>
<tr>
<td>Out-Pt.-Dept.</td>
<td></td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td><strong>$</strong></td>
</tr>
</tbody>
</table>

II--Basis for Division

<table>
<thead>
<tr>
<th>Division</th>
<th>Payroll</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital X</td>
<td></td>
<td>73.3</td>
</tr>
<tr>
<td>Sub. Hosp. #1</td>
<td></td>
<td>21.1</td>
</tr>
<tr>
<td>Out-Pt.-Dept.</td>
<td></td>
<td>5.6</td>
</tr>
<tr>
<td><strong>Totals------</strong></td>
<td><strong>$</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

III--Distribution of Costs

<table>
<thead>
<tr>
<th>Division</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out-Patient-Department</td>
<td>5.6</td>
</tr>
<tr>
<td>Subdivision Hospital #1</td>
<td>21.1</td>
</tr>
<tr>
<td>Hospital X (For Department Distribution)</td>
<td><strong>73.3 $ XYZ</strong></td>
</tr>
<tr>
<td>(See Exhibit--4)</td>
<td></td>
</tr>
<tr>
<td><strong>Totals------</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>
(See other side)
Explanation to Exhibit 4

In Exhibit 4, the charges as obtained in Exhibits 2 and 3 are combined and the amount is distributed to the various operating departments. The distribution is based on the payroll for services for the current month.

Item II of Exhibit 4 lists the various departments with the percentage of the payroll incurred by each.

The $1962.65 charged to the solutions department is forwarded to Exhibit A which is the completed "Operating Report" for the solutions department.
Exhibit--4

Operating Report
Distribution of Certain Hospital X Expense Balances to Operating Departments
For the Year Ending December 31, 1947

I--Balances for Distribution

<table>
<thead>
<tr>
<th>General Administration (See Exhibit 3)</th>
<th>Current Month</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hosp. X Share of Common Expense (See Exhibit 2)</td>
<td>$__________</td>
<td>$ABC</td>
</tr>
<tr>
<td>Totals-------------------------------------</td>
<td>$__________</td>
<td></td>
</tr>
</tbody>
</table>

II--Distribution of Above to Hospital X Operating Departments Based on Hospital X Payroll (For Services) for the Current Month

<table>
<thead>
<tr>
<th>Service</th>
<th>Payroll</th>
<th>%</th>
<th>Resulting Charges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Med. &amp; Surgical Care</td>
<td>$2.9</td>
<td></td>
<td>$1962.65</td>
</tr>
<tr>
<td>Nursing Care</td>
<td>40.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School of Nursing</td>
<td>3.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Service</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical Records</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratories</td>
<td>14.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solutions (See Exhibit A)</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pharmacy</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Bank</td>
<td>1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Rooms</td>
<td>4.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delivery Rooms</td>
<td>1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-Ray Department</td>
<td>9.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anesthesia</td>
<td>7.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiotherapy</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special Services</td>
<td>1.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals------------------------</td>
<td>$100.0%</td>
<td></td>
<td>$__________</td>
</tr>
</tbody>
</table>
Explanation to Exhibits 5 and 6

Exhibit 5 summarizes the actual expenditures for equipment, repairs, and supplies, as obtained from the hospital purchase journal, and from requisitions. The total expenditures are forwarded to Exhibit A, Column 2, to become a part of the total expenditures by the solutions department.

Exhibit 6 lists all capital items purchased by the hospital to equip the solutions department. Yearly depreciation is based upon the life expectancy. The amount of yearly depreciation of $401.06 is forwarded to Exhibit C, Item 6, to be included in the total expenses, direct and indirect, incurred by the solutions department.
### Exhibit--5

Equipment-Repairs-Supplies for Year 1947

#### 1--Equipment:

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity/Size</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needles</td>
<td>218 doz. (16-20 g)</td>
<td>$395.50</td>
</tr>
<tr>
<td>Rubber tubing</td>
<td>(4100 ft.)</td>
<td>$456.00</td>
</tr>
<tr>
<td>Flasks</td>
<td>136 doz. (1-2000 cc)</td>
<td>$2791.17</td>
</tr>
<tr>
<td>Stainless steel stoppers</td>
<td>(1076)</td>
<td>$2133.95</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td>$2315.67</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$8087.29</strong></td>
</tr>
</tbody>
</table>

#### 2--Repairs:

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity/Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure cleaner</td>
<td>(twice)</td>
<td>$54.75</td>
</tr>
<tr>
<td>Fenwal pressure suction pump</td>
<td>(three times)</td>
<td>$27.30</td>
</tr>
<tr>
<td>Gomco pump</td>
<td>(twice)</td>
<td>$12.55</td>
</tr>
<tr>
<td>Stopcock to fit shut-off valve</td>
<td>(twice)</td>
<td>$6.00</td>
</tr>
<tr>
<td>Four-way valve</td>
<td></td>
<td>$2.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$103.10</strong></td>
</tr>
</tbody>
</table>

#### 3--Supplies, Chemicals, etc.:

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity/Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial solutions</td>
<td>(27 doz.)</td>
<td>$246.60</td>
</tr>
<tr>
<td>Soap</td>
<td>(2 1/2 drums)</td>
<td>$131.25</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Saline, glucose, dextrose</td>
<td>$864.00</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td>$483.17</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$1725.02</strong></td>
</tr>
</tbody>
</table>

**Totals** (See Exhibit A, Col. 2) **$9915.41**

### Exhibit--6

Equipment--Capital Items

Capital Purchases within Last 5 Years

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Life Expect'y</th>
<th>Yearly Depre.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autoclave</td>
<td>$3636.00</td>
<td>20 yrs.</td>
<td>$181.80</td>
</tr>
<tr>
<td>Still--Fenwal 9154 (10 gals.)</td>
<td>460.80</td>
<td>10 &quot;</td>
<td>46.08</td>
</tr>
<tr>
<td>Pressure pump 9713</td>
<td>131.40</td>
<td>10 &quot;</td>
<td>13.14</td>
</tr>
<tr>
<td>Storage tank--Fenwal 9060</td>
<td>45.00</td>
<td>10 &quot;</td>
<td>4.50</td>
</tr>
<tr>
<td>Rinser--Fenwal 9716</td>
<td>38.50</td>
<td>10 &quot;</td>
<td>3.85</td>
</tr>
<tr>
<td>Pressure cleaner</td>
<td>650.00</td>
<td>10 &quot;</td>
<td>65.00</td>
</tr>
<tr>
<td>Scales (weights)</td>
<td>175.00</td>
<td>10 &quot;</td>
<td>17.50</td>
</tr>
<tr>
<td>Consolidated still--(10 gal.)</td>
<td>315.00</td>
<td>10 &quot;</td>
<td>31.50</td>
</tr>
<tr>
<td>Gomco pressure pump</td>
<td>131.40</td>
<td>10 &quot;</td>
<td>13.14</td>
</tr>
<tr>
<td>Stainless steel sink</td>
<td>491.00</td>
<td>20 &quot;</td>
<td>24.55</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>$6074.10</strong></td>
<td></td>
<td><strong>$401.06</strong></td>
</tr>
</tbody>
</table>

(Exhibit C)
Explanation to Exhibit A

The completed "Operating Report" for the solutions department (Exhibit A) is a compilation of all expenses as obtained in Exhibits 1 to 5. All of these expenses, which represent salaries and wages, supplies and direct expenses, quarters of Hospital X, share of general expense for Hospital X, are summarized in Column 6—the year to date totals.

Column 6 totals $17623.61; this amount represents the actual expense incurred by the solutions department. This amount is forwarded to Exhibit C, to be added to the indirect or imputed costs chargeable to the department.
**Exhibit - A**

Operating Report - Solutions Department
For the Year 1947

<table>
<thead>
<tr>
<th>Month</th>
<th>1 Supplies &amp; Dir.</th>
<th>2 Salaries &amp; Wages</th>
<th>3 Quarters Exp. (see Ex. 5)</th>
<th>4 Hosp. X</th>
<th>5 Share of Gen. Exp.</th>
<th>6 Cost for Month</th>
<th>Tot. Sol. for Year to Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>$432.75</td>
<td>$1933.49</td>
<td>$114.32</td>
<td>$227.24</td>
<td>$2707.80</td>
<td>$2707.80</td>
<td>$2707.80</td>
</tr>
<tr>
<td>Feb.</td>
<td>359.35</td>
<td>2533.39</td>
<td>90.86</td>
<td>136.45</td>
<td>3120.05</td>
<td>5827.85</td>
<td>5827.85</td>
</tr>
<tr>
<td>Mar.</td>
<td>429.43</td>
<td>639.50</td>
<td>86.77</td>
<td>178.86</td>
<td>1334.56</td>
<td>7162.41</td>
<td>7162.41</td>
</tr>
<tr>
<td>Apr.</td>
<td>403.42</td>
<td>234.13</td>
<td>110.05</td>
<td>158.93</td>
<td>906.53</td>
<td>8068.94</td>
<td>8068.94</td>
</tr>
<tr>
<td>May</td>
<td>353.73</td>
<td>88.15</td>
<td>127.52</td>
<td>161.54</td>
<td>730.94</td>
<td>6799.88</td>
<td>6799.88</td>
</tr>
<tr>
<td>June</td>
<td>345.05</td>
<td>505.66</td>
<td>129.94</td>
<td>178.00</td>
<td>1158.65</td>
<td>9958.53</td>
<td>9958.53</td>
</tr>
<tr>
<td>July</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug.</td>
<td>1006.49</td>
<td>1526.01</td>
<td>305.64</td>
<td>431.24</td>
<td>3269.36</td>
<td>13227.91</td>
<td></td>
</tr>
<tr>
<td>Sept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct.</td>
<td>346.02</td>
<td>232.20</td>
<td>164.80</td>
<td>148.63</td>
<td>891.05</td>
<td>14118.96</td>
<td></td>
</tr>
<tr>
<td>Nov.</td>
<td>346.60</td>
<td>428.40</td>
<td>130.20</td>
<td>106.16</td>
<td>1067.36</td>
<td>15186.32</td>
<td></td>
</tr>
<tr>
<td>Dec.</td>
<td>346.60</td>
<td>1794.48</td>
<td>112.01</td>
<td>182.20</td>
<td>2437.29</td>
<td>17623.61</td>
<td></td>
</tr>
</tbody>
</table>

Total: $4373.44 (See Ex. C.)

$9915.41 (See Ex. C.)

$1372.11 (See Ex. C.)

$1962.65 (See Ex. C.)

$17623.61 (See Ex. C.)
Explanation to Exhibit C

It is the practice in hospital accounting to charge departments with actual expenses incurred in the operation of that department. However, in order to arrive at a true manufacturing cost, it is advisable to charge indirect and imputed economic costs to the solutions department.

Exhibit C does just that. Items 1 to 4 are actual costs charged to the department, and items 6 to 9 are additional costs not charged by the hospital accounting system.

The total economic cost thus derived is $23,324.67. This amount represents the total which should be charged to the solutions department. But, this amount represents the total expense for the department in the manufacture of parenteral solutions and the preparation of infusion sets. This dual purpose of the department requires further subdivision of the total cost of $23,324.67, which is accomplished on pages 96, 97.
Exhibit--C

Expenses Incurred by the Solutions Department
For the Year Ending December 31, 1947

Costs--Actually charged to the Solutions Department

1. Salaries and wages (See Exhibit A, Col. 1) $4373.44
2. Supplies and expenses--Direct (See Exhibit A, Col. 2) 9915.41
3. Quarters--Hospital X (See Exhibit A, Col. 3) 1372.11
4. Share of General Expense--Hosp.X (See Exhibit A, Col. 4) 1962.65
5. Total business cost (See Exhibit A, Col. 6) $17623.61

Additional Costs--not charged by hospital accounting system

6. Yearly depreciation of capital equipment in solutions room (See Exhibit 6) 401.06
7. Imputed interest on investment 6% on $15,000 (See Exhibits 5, 6) 900.00
8. Imputed rent--$200.00 per month 2400.00
9. Supervision--20% of Director of Laboratories' salary 2000.00 $5701.06

Total Economic Cost $23324.67
The remaining task of dividing the total cost chargeable to the solutions department was resolved in the following manner: It was necessary to obtain the total production of parenteral solutions plus the total number of infusion sets prepared for the year.

Exhibit 7 shows the volume of output of 2000 cc. flasks of parenteral solutions and Exhibit 6 that of 1000 cc. flasks.

Exhibit 9 shows the total of infusion sets prepared by the department.

These totals formed the basis for distributing the total cost on the basis of actual time spent in preparation and manufacture of each product.

This method is explained on pages 96, 97.
(See other side)
<table>
<thead>
<tr>
<th>Month</th>
<th>Distilled Water</th>
<th>Saline</th>
<th>5% Dextrose in Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>81</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>202</td>
<td>27</td>
<td>7</td>
</tr>
<tr>
<td>March</td>
<td>310</td>
<td>76</td>
<td>17</td>
</tr>
<tr>
<td>April</td>
<td>316</td>
<td>280</td>
<td>7</td>
</tr>
<tr>
<td>May</td>
<td>209</td>
<td>113</td>
<td>40</td>
</tr>
<tr>
<td>June</td>
<td>190</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>239</td>
<td>159</td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>225</td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>229</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>349</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>255</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>370</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>2975</td>
<td>1329</td>
<td>71</td>
</tr>
</tbody>
</table>
Graph #1

Volume Output of 2000 cc. Flasks on a Monthly Basis
(See other side)
Exhibit--8

Monthly Volume of 1000 cc. Flasks of Solutions
Prepared by Solutions Department

<table>
<thead>
<tr>
<th>Month</th>
<th>0.85% Saline</th>
<th>5% Saline</th>
<th>5% Dext. in 85% Saline</th>
<th>5% Dext. in Wat.</th>
<th>10% Gluc. in Wat.</th>
<th>2.5% Dext. in 4% Saline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>1024</td>
<td>90</td>
<td>163</td>
<td>550</td>
<td>71</td>
<td>25</td>
</tr>
<tr>
<td>Feb.</td>
<td>1344</td>
<td>30</td>
<td>287</td>
<td>772</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>Mar.</td>
<td>1180</td>
<td>146</td>
<td>233</td>
<td>1003</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>Apr.</td>
<td>1398</td>
<td>43</td>
<td>335</td>
<td>1007</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>May</td>
<td>1193</td>
<td>29</td>
<td>244</td>
<td>733</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>June</td>
<td>1022</td>
<td>71</td>
<td>429</td>
<td>899</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>July</td>
<td>1342</td>
<td>29</td>
<td>411</td>
<td>885</td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>Aug.</td>
<td>981</td>
<td>29</td>
<td>293</td>
<td>672</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Sept.</td>
<td>1331</td>
<td>69</td>
<td>360</td>
<td>921</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>Oct.</td>
<td>1437</td>
<td>29</td>
<td>190</td>
<td>880</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov.</td>
<td>1504</td>
<td>42</td>
<td>301</td>
<td>928</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec.</td>
<td>1502</td>
<td>38</td>
<td>299</td>
<td>1320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>15258</td>
<td>645</td>
<td>3555</td>
<td>10570</td>
<td>83</td>
<td>227</td>
</tr>
</tbody>
</table>
MONTHLY VOLUME OF FLASKS AND REACTIONS TO PARENTERAL SOLUTIONS FOR THE YEAR 1947

Graph #2

NUMBER OF MONTHLY REACTIONS TO ALL PARENTERAL SOLUTIONS ADMINISTERED

0.85% SALINE
1000 c.c.

5% DEXTROSE IN WATER- 1000 c.c.

5% DEXTROSE IN
0.85% SALINE
1000 c.c.

- 5% Saline (1000 c.c.)
- 2 1/2% Dextrose in 0.42% Saline (1000 c.c.)
- 10% Dextrose in Water (1000 c.c.)
- 5% Dextrose in Water (2000 c.c.)
(See other side)
Exhibit--9

Infusion Sets Autoclaved 1947
By the Solutions Department

<table>
<thead>
<tr>
<th>Month</th>
<th>I. V.</th>
<th>Kelly</th>
<th>Clysis</th>
<th>Blood Donor</th>
<th>Filter Set</th>
<th>Funnels</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>435</td>
<td>95</td>
<td>65</td>
<td>191</td>
<td>193</td>
<td>68</td>
<td>1047</td>
</tr>
<tr>
<td>Feb.</td>
<td>599</td>
<td>216</td>
<td>48</td>
<td>280</td>
<td>2</td>
<td>175</td>
<td>1320</td>
</tr>
<tr>
<td>Mar.</td>
<td>650</td>
<td>138</td>
<td>58</td>
<td>319</td>
<td>57</td>
<td>129</td>
<td>1360</td>
</tr>
<tr>
<td>Apr.</td>
<td>637</td>
<td>124</td>
<td>37</td>
<td>365</td>
<td>110</td>
<td>115</td>
<td>1397</td>
</tr>
<tr>
<td>May</td>
<td>746</td>
<td>186</td>
<td>46</td>
<td>330</td>
<td>139</td>
<td>161</td>
<td>1408</td>
</tr>
<tr>
<td>June</td>
<td>804</td>
<td>147</td>
<td>34</td>
<td>326</td>
<td>108</td>
<td>128</td>
<td>1547</td>
</tr>
<tr>
<td>July</td>
<td>723</td>
<td>169</td>
<td>41</td>
<td>298</td>
<td>90</td>
<td>167</td>
<td>1488</td>
</tr>
<tr>
<td>Aug.</td>
<td>587</td>
<td>116</td>
<td>43</td>
<td>276</td>
<td>64</td>
<td>104</td>
<td>1190</td>
</tr>
<tr>
<td>Sept.</td>
<td>622</td>
<td>130</td>
<td>62</td>
<td>255</td>
<td>83</td>
<td>118</td>
<td>1270</td>
</tr>
<tr>
<td>Oct.</td>
<td>850</td>
<td>219</td>
<td>63</td>
<td>427</td>
<td>115</td>
<td>245</td>
<td>1619</td>
</tr>
<tr>
<td>Nov.</td>
<td>933</td>
<td>173</td>
<td>49</td>
<td>318</td>
<td>141</td>
<td>143</td>
<td>1757</td>
</tr>
<tr>
<td>Dec.</td>
<td>933</td>
<td>193</td>
<td>90</td>
<td>401</td>
<td>175</td>
<td>187</td>
<td>1969</td>
</tr>
<tr>
<td>Totals</td>
<td>8519</td>
<td>1906</td>
<td>636</td>
<td>3786</td>
<td>1277</td>
<td>1740</td>
<td></td>
</tr>
</tbody>
</table>
Weekly and Monthly Composit Volume Of Sets Autoclaved
For the year 1947
(I.V., Kelly, Clysis, Blood Donor)
(Recipient Filter Sets, Funnels)
Graph #4
Now that the total manufacturing cost has been determined, it is necessary to determine the unit cost of each item manufactured and prepared in the solutions department.

By actual timing of the amount of time consumed in the preparation of infusion sets and the washing of flasks for the blood bank, it was possible to determine the time spent in the actual manufacture of parenteral solutions.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Hours per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time spent on infusion sets</td>
<td>40</td>
</tr>
<tr>
<td>Time spent washing flasks for blood bank</td>
<td>4</td>
</tr>
<tr>
<td>Total working time</td>
<td>44</td>
</tr>
</tbody>
</table>

The total working hours per week (4 girls) 176 hours per week

Hours spent on other than parenteral solutions 44 hours per week

Total hours for parenteral solutions 132 hours per week

Since one-quarter of the working time and one-quarter of the facilities of the department are used in the preparation of the infusion sets, one-quarter of the total solutions department expense for the year must be charged to infusion sets—minus the following:

(See next page)
### Depreciation costs
- Depreciation costs: 401.06
- Commercial solutions: 246.60
- Chemicals: 864.00
- Repairs on Fenwal equipment: 103.10
- Equipment--Fenwal: 7240.79
- New pump--l: 131.40
- Steel sink--$: 125.00
- Imputed rent: 1800.00
- Imputed interest: 675.00

Total: $11586.95

**These expenses do not apply to the preparation of infusion sets.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solutions department cost</td>
<td>$23324.67</td>
</tr>
<tr>
<td>Amount not applicable to infusion set</td>
<td>$11586.95</td>
</tr>
<tr>
<td>Allocable total</td>
<td>$11737.72</td>
</tr>
</tbody>
</table>

Of the total cost charged to the solutions department, only $11737.72 is subject to allocation for the preparation of infusion sets. Considering the hours worked on a weekly basis, one-quarter of the total time is spent on infusion sets; therefore, the amount charged to the preparation of infusion sets is:

$11732.72 times .25 or $2934.43

**Cost per unit of various sets:**

**Grand total of sets prepared:** 17864
### Exhibit--10

**Cost of Infusion Sets**

<table>
<thead>
<tr>
<th>Sets</th>
<th>Prep. Time</th>
<th>Number Prep.</th>
<th>Time Spent</th>
<th>Allclb Cost</th>
<th>Cost per Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intravenous</td>
<td>110&quot;</td>
<td>8519</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kelly</td>
<td>110&quot;</td>
<td>1906</td>
<td>95.74%</td>
<td>$2809.43</td>
<td>$0.174</td>
</tr>
<tr>
<td>Clysis</td>
<td>110&quot;</td>
<td>636</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood donor</td>
<td>110&quot;</td>
<td>3786</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recipient filter</td>
<td>110&quot;</td>
<td>1277</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Funnels</td>
<td>44&quot;</td>
<td>16124</td>
<td>4.26%</td>
<td>125.00</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17864</td>
<td>100.00%</td>
<td>$2934.43</td>
<td></td>
</tr>
</tbody>
</table>

Because the first five classifications of sets have the same working time, they were grouped together. The resulting cost is .174 cents per infusion set, and .08 cents per funnel set.
Parenteral Solutions Cost

As previously determined, of the total cost incurred by the solutions department, $11,737.72 was allocable to the preparation of infusion sets. From the total cost of $23,324.04, a net of $11,737.72 was found to apply to both products. Of this $11,737.72, only $2,934.43 was allocated to the preparation of infusion sets. This leaves a total of $20,390.24 as applicable to the manufacture of parenteral solutions.

Exhibit--11

Production and Chemical Costs

<table>
<thead>
<tr>
<th>Solution--</th>
<th>Production</th>
<th>Chemical</th>
<th>Total Chemical Cost</th>
<th>Cost per Flask</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 cc.</td>
<td># Flasks for Year</td>
<td>(grams)</td>
<td></td>
<td>(Chem.)</td>
</tr>
<tr>
<td>.85% Saline</td>
<td>15258</td>
<td>129693</td>
<td>$51.88</td>
<td>$.0034</td>
</tr>
<tr>
<td>5% Saline</td>
<td>645</td>
<td>32250</td>
<td>12.90</td>
<td>.02</td>
</tr>
<tr>
<td>5% Dext. in .85% Sal.</td>
<td>3555</td>
<td>479925</td>
<td>119.40</td>
<td>.0334</td>
</tr>
<tr>
<td>5% Dextrose in Water</td>
<td>10570</td>
<td>528500</td>
<td>315.10</td>
<td>.03</td>
</tr>
<tr>
<td>2.5% Dext. in .42% Sal.</td>
<td>227</td>
<td>6640</td>
<td>3.79</td>
<td>.016</td>
</tr>
<tr>
<td>10% Glucose</td>
<td>83</td>
<td>8300</td>
<td>4.98</td>
<td>.06</td>
</tr>
<tr>
<td>total</td>
<td>30338</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Solution--2000 cc.

<table>
<thead>
<tr>
<th></th>
<th># Flasks for Year</th>
<th>Chemical</th>
<th>Total Chemical Cost</th>
<th>Cost per Flask</th>
</tr>
</thead>
<tbody>
<tr>
<td>.85% Saline</td>
<td>1329</td>
<td>22593</td>
<td>9.13</td>
<td>.0068</td>
</tr>
<tr>
<td>5% Dextrose in Water</td>
<td>30</td>
<td>3000</td>
<td>1.80</td>
<td>.06</td>
</tr>
<tr>
<td>Distilled Water</td>
<td>2975</td>
<td>34672</td>
<td>$518.98</td>
<td></td>
</tr>
</tbody>
</table>

Cost of Dextrose and Glucose: $0.24 per pound or .0006 cents per gram
Cost of Saline (NaCl): $0.15 per pound or .0004 cents per gram
Analysis of Labor and Overhead Costs

The over-all time to prepare 1000 cc. flasks of salines (labor of preparing the stock solutions plus autoclaving) is 70 minutes per flask; and 75 minutes per 2000 cc. flask of saline.

The over-all time to prepare 1000 cc. flasks of dextrose solutions (labor of preparing the stock solutions plus autoclaving) is 90 minutes, and 95 minutes to prepare 2000 cc. flasks of dextrose.

In the preparation of infusion sets, the labor time consumed was computed to be one-quarter of the total. Therefore, three quarters of the yearly labor cost is then charged to the manufacture of solutions.

$4373.44 \times .75 = 3579.98$

To obtain a weighted cost according to the amount of time required in the preparation of the various solutions, the following method was used: the preparation time of 70 minutes for normal saline was used as the base or unit one (1). The increased preparation time for each successive solution increased the base unit by the appropriate fraction.

From Exhibits 7 and 8 the number of 1000 cc. and 2000 cc. flasks of saline and dextrose produced was obtained.
<table>
<thead>
<tr>
<th>Size of Flask</th>
<th>Number Produced</th>
<th>Unit Labor Cost</th>
<th>Unit Overhead Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 cc. Saline</td>
<td>15903</td>
<td>$.093</td>
<td>$4.16</td>
</tr>
<tr>
<td>2000 cc. Saline</td>
<td>1329</td>
<td>$.0996</td>
<td>$.458</td>
</tr>
<tr>
<td>1000 cc. Dextrose</td>
<td>14435</td>
<td>$.1196</td>
<td>$.525</td>
</tr>
<tr>
<td>2000 cc. Dextrose</td>
<td>30</td>
<td>$.1282</td>
<td>$.565</td>
</tr>
<tr>
<td>2000 cc. Distilled Water</td>
<td>2975</td>
<td>$.0826</td>
<td>$.359</td>
</tr>
</tbody>
</table>

Total: 34672 (See Ex.12) (See Ex.13)

<table>
<thead>
<tr>
<th>Working Time</th>
<th>Ratio</th>
<th>x Producing</th>
<th>Weighted Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- 70</td>
<td>1</td>
<td>15903</td>
<td>15903</td>
</tr>
<tr>
<td>2- 75</td>
<td>1 0.5</td>
<td>1329</td>
<td>1423.9</td>
</tr>
<tr>
<td>3- 90</td>
<td>1 2/7</td>
<td>14435</td>
<td>18559.3</td>
</tr>
<tr>
<td>4- 95</td>
<td>1 2.5</td>
<td>30</td>
<td>40.7</td>
</tr>
<tr>
<td>5- 60</td>
<td>6/7</td>
<td>2975</td>
<td>38477.8</td>
</tr>
</tbody>
</table>

Weighted Production

Each of the above categories were computed for labor cost.
Exhibit--12

Labor Cost of Solutions Manufactured

<table>
<thead>
<tr>
<th>Unit Labor Cost for:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>( \frac{$3579.98}{38477.8} ) = 0.093 1000 cc. of Saline</td>
</tr>
<tr>
<td>2.</td>
<td>( 1 \times \frac{0.5}{7} \times 0.093 ) = 0.0996 2000 cc. of Saline</td>
</tr>
<tr>
<td>3.</td>
<td>( 1 \times \frac{2}{7} \times 0.093 ) = 0.1196 1000 cc. of Dextrose</td>
</tr>
<tr>
<td>4.</td>
<td>( 1 \times \frac{2.5}{7} \times 0.093 ) = 0.1282 2000 cc. of Dextrose</td>
</tr>
<tr>
<td>5.</td>
<td>( \frac{6}{7} \times 0.093 ) = 0.0826 2000 cc. of Distilled Water</td>
</tr>
</tbody>
</table>

Overhead Costs

- Total allocated to solutions department: $20,390.24
- Minus labor cost: $4,373.44
- Total overhead allocable: $16,016.80

Since the preparation time for the various solutions is different, it is advisable to apportion the overhead costs in the same manner in which labor costs were apportioned. Again using the same listing as 1 to 5 as above:

Exhibit--13

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( \frac{$16,016.80}{38477.8} ) = .416 overhead cost per 1000 cc. of Saline</td>
<td></td>
</tr>
<tr>
<td>2. ( 1 \times \frac{0.5}{7} \times .416 ) = .456 Cost per 2000 cc. of Saline</td>
<td></td>
</tr>
<tr>
<td>3. ( 1 \times \frac{2}{7} \times .416 ) = .535 Cost per 1000 cc. of Dextrose</td>
<td></td>
</tr>
<tr>
<td>4. ( 1 \times \frac{2.5}{7} \times .416 ) = .585 Cost per 2000 cc. of Dextrose</td>
<td></td>
</tr>
<tr>
<td>5. ( \frac{6}{7} \times .416 ) = .359 Cost per 2000 of Distilled Water</td>
<td></td>
</tr>
</tbody>
</table>
### Exhibit --14

Comparative Costs
Cost of Hospital Solutions

<table>
<thead>
<tr>
<th>1000 cc. Flask</th>
<th>Chem. cost per flask</th>
<th>Labor Cost</th>
<th>Overhead</th>
<th>Cost per flask</th>
</tr>
</thead>
<tbody>
<tr>
<td>.85% Saline</td>
<td>$0.0034</td>
<td>$0.093</td>
<td>$0.416</td>
<td>$0.5124</td>
</tr>
<tr>
<td>5% Saline</td>
<td>$0.02</td>
<td>$0.093</td>
<td>$0.416</td>
<td>$0.529</td>
</tr>
<tr>
<td>5% Dextrose in .85% Saline</td>
<td>$0.0334</td>
<td>$0.119</td>
<td>$0.535</td>
<td>$0.6874</td>
</tr>
<tr>
<td>5% Dextrose in Water</td>
<td>$0.03</td>
<td>$0.119</td>
<td>$0.535</td>
<td>$0.684</td>
</tr>
<tr>
<td>2.5% Dext. in .42% Saline</td>
<td>$0.016</td>
<td>$0.119</td>
<td>$0.535</td>
<td>$0.67</td>
</tr>
<tr>
<td>10% Glucose</td>
<td>$0.06</td>
<td>$0.119</td>
<td>$0.535</td>
<td>$0.714</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2000 cc. Flask</th>
<th>Chem. cost per flask</th>
<th>Labor Cost</th>
<th>Overhead</th>
<th>Cost per flask</th>
</tr>
</thead>
<tbody>
<tr>
<td>.85% Saline</td>
<td>$0.0068</td>
<td>$0.099</td>
<td>$0.458</td>
<td>$0.5638</td>
</tr>
<tr>
<td>5% Dextrose in Water</td>
<td>$0.06</td>
<td>$0.128</td>
<td>$0.585</td>
<td>$0.757</td>
</tr>
<tr>
<td>Distilled Water</td>
<td>$0.083</td>
<td>$0.369</td>
<td>$0.442</td>
<td></td>
</tr>
</tbody>
</table>
Exhibit—15
Commercial versus Hospital Manufactured Solutions
(Commercial Bulk Purchases--same basis)

<table>
<thead>
<tr>
<th>Solution</th>
<th>Co. A</th>
<th>Co. B</th>
<th>Average</th>
<th>Hospital to Hosp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.85% Saline</td>
<td>$0.60</td>
<td>$0.60</td>
<td>$0.60</td>
<td>$0.51</td>
</tr>
<tr>
<td>5% Saline</td>
<td>$0.60</td>
<td>$0.60</td>
<td>$0.60</td>
<td>$0.53</td>
</tr>
<tr>
<td>5% Dext. in .85% Sal.</td>
<td>$0.60</td>
<td>$0.60</td>
<td>$0.60</td>
<td>$0.69</td>
</tr>
<tr>
<td>5% Dext. in Water</td>
<td>$0.75</td>
<td>$0.75</td>
<td>$0.75</td>
<td>$0.68</td>
</tr>
<tr>
<td>2.5% Dext. in .42% Sal.</td>
<td>$0.75</td>
<td>$0.75</td>
<td>$0.75</td>
<td>$0.67</td>
</tr>
<tr>
<td>10% Glucose in Water</td>
<td>$0.90</td>
<td>$0.90</td>
<td>$0.90</td>
<td>$0.71</td>
</tr>
<tr>
<td>.85% Saline--2000 cc.</td>
<td>$1.05</td>
<td>$1.05</td>
<td>$1.05</td>
<td>$0.56</td>
</tr>
<tr>
<td>5% Dext. in Water</td>
<td>$1.30</td>
<td>$1.30</td>
<td>$1.30</td>
<td>$0.76</td>
</tr>
<tr>
<td>2000 cc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distilled Water--</td>
<td>$1.05</td>
<td>$1.05</td>
<td>$1.05</td>
<td>$0.44</td>
</tr>
<tr>
<td>2000 cc.</td>
<td></td>
<td></td>
<td></td>
<td>$8.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Per cent of savings to hospital 30.5%
Exhibit--16

Actual Savings to Hospital by Manufacturing Its Own Parenteral Solutions

<table>
<thead>
<tr>
<th>Solution--1000 cc.</th>
<th># Units Produced</th>
<th>Savings per Unit</th>
<th>Total Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>.65% Saline</td>
<td>15258</td>
<td>$.09</td>
<td>$1373.22</td>
</tr>
<tr>
<td>5% Saline</td>
<td>645</td>
<td>$.27</td>
<td>174.15</td>
</tr>
<tr>
<td>5% Dext. in .65% Saline</td>
<td>3555</td>
<td>$.11</td>
<td>391.05</td>
</tr>
<tr>
<td>5% Dext. in Water</td>
<td>10570</td>
<td>$.07</td>
<td>739.90</td>
</tr>
<tr>
<td>2.5% Dext. in .42% Saline</td>
<td>227</td>
<td>$.08</td>
<td>16.16</td>
</tr>
<tr>
<td>10% Glucose</td>
<td>83</td>
<td>$.19</td>
<td>15.77</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solution--2000 cc.</th>
<th># Units</th>
<th>Savings per Unit</th>
<th>Total Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>.65% Saline</td>
<td>1329</td>
<td>$.49</td>
<td>651.21</td>
</tr>
<tr>
<td>5% Dextrose in Water</td>
<td>30</td>
<td>$.54</td>
<td>16.20</td>
</tr>
<tr>
<td>Distilled Water</td>
<td>2975</td>
<td>$.61</td>
<td>1614.75</td>
</tr>
<tr>
<td>Totals</td>
<td>34672</td>
<td>$.244</td>
<td>$5194.41</td>
</tr>
</tbody>
</table>

The analysis, as computed, shows a definite savings to the hospital in manufacturing its own solutions. The actual savings of $5194.41 is more significant in that this amount is the actual amount saved.

Exhibit C on page 87 shows the expenses incurred by the solutions department plus the imputed economic costs. It is evident that $7734.76 of overhead costs, direct and indirect, have been absorbed. Supplies and wages have been covered, and $401.06 has been set aside as depreciation on capital equipment. An additional $900 has been
realized as a return on capital investment.

It must be concluded that financially, it is more economical for Hospital X to manufacture parenteral solutions than it is to purchase them from commercial companies. In fact, the 30.5% savings to the hospital, as indicated by Exhibit 15, compares favorably with commercial manufacturing costs, as this is usually the representative mark-up sought by manufacturing companies.
Conclusion

The primary consideration on which the hospital should base its decision as to whether or not it elects to manufacture its own parenteral solutions is the safety of the patient. The hospital fails in the leading role it should play in the community if it neglects to provide the best available diagnostic and therapeutic agents for its patients. Hospital prepared parenteral fluids which produce only an occasional flurry of reactions are not good enough. Anyone well-versed in parenteral therapy knows that the faulty technic which produces fluids that cause mild reactions may at some time produce solutions which will result in a severe reaction.

After the hospital has satisfied itself that it will be able to produce safe, pure parenteral fluids, it must next decide whether it has sufficient space and physical facilities, and personnel to administer the department; and the hospital must be prepared to make the necessary expenditures to provide adequate equipment for the department.

A cost analysis of the solutions department of Hospital X shows that it is less expensive to manufacture its own solutions than it is to purchase them from commercial companies.

By preparing its own parenteral fluids, Hospital X contributes to its operating revenue (as shown in Exhibit 16.) The hospital actually saved $5194.41 in 1947 by manu-
facturing solutions. This amount looms large to the non-profit, charitable hospital which must depend upon moneys obtained from endowments, legacies, bequests, and annual gifts for its operation in addition to the revenue acquired from its patients. In pre-war time, 75% of the hospital's total revenue was obtained from patient income, while today these earnings approximate 70%. The remainder of the hospital's operating income must be derived from the means listed above.

Our present-day economic situation need not be enlarged upon. Inflationary prices and operating costs are at an all time high. Taxes are cutting deeply into surplus profits and into large incomes. Inheritance taxes are designed to prevent large accumulations of wealth. These facts make it difficult for charitably minded individuals to be as generous in their philanthropy as has been their wont in the happy past. Deprived of a large amount of income from this source, it has been necessary for hospitals to use their capital to offset the large yearly deficits. Therefore, endowments and reserve cash are being depleted.

In the light of these facts, we can understand that a savings of $5194.41 effected by a charitable hospital assumes a great importance. It represents a 3% return on an endowment of $175,000, an amount which any hospital would welcome to its shrinking endowment funds.

The fact that $7734.76 of overhead costs, direct
and indirect, have been absorbed should not be overlooked. Supplies and wages have been covered, and $401.06 has been set aside for depreciation on capital equipment. An additional $900 has been realized as a return on capital investment. This amount (of overhead costs) is comparable to a 3% return on approximately $280,000 of endowment.

Recent hospital assemblies and institutes have advocated more stringent controls and more modern accounting systems in order to more accurately determine where the hospital dollar is being spent. The adoption of this recommendation would be a step in the right direction. It is true that accounting alone will not solve the hospital's problems; however, by proper methods of accounting, profitable operations may be distinguished from unprofitable operations.

Now that the profitableness of manufacturing its own parenteral solutions has been established for Hospital X, the following recommendations may be advanced. These are evolved from personal observation and are intended as an effort to point out objectives to strive for and pitfalls to avoid. They are made in the interest of securing safe, pyrogen-free infusion fluids.

1. Daily checking of the distillate from both stills with the purity meter both before and after preparation of parenteral fluids instead of the present practice of checking the distillate but once each week.

2. Use of the automatic washer for cleaning glassware and
tubing instead of manual cleaning.

3. Use of the Penwal flasks within four hours after cleaning—or a repetition of the complete cleaning process—instead of the present method of cleaning the flasks and leaving them to stand overnight for use the following day without additional cleaning.

4. Careful review of the ideal technic for cleaning all the apparatus as recommended by the Penwal system.

5. A revision of the technic for cleaning blood bottles so they need not be left under the sink to soak.

6. Some type of exhaust fan to remove the overheated air from the room so that the windows and doors need not be opened. A filtered air system would be ideal.

7. The leaving off by the workers of their outer wraps in another room. When lockers are installed, they should be placed in the corridor, not in the solutions room.

8. The wearing of uniforms by the technicians.

9. The wearing of clean gowns, caps, and face masks when preparing solutions, glassware, or infusion sets.

10. Closer cooperation between the engineering department and the solutions department, so that the equipment can be maintained in a good state of repair.

11. Reorganization of the department under the pharmacy.

12. Enlargement of the facilities of the solutions room.
With the exception of providing enlarged facilities for the solutions room, adoption of these recommendations by Hospital X will not necessarily mean a large expenditure. Hospital X has provided excellent equipment for the manufacture of parenteral solutions, and the tightening up of technic will insure a safe, pure, pyrogen-free infusion fluid of which the hospital can be justly proud.
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