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Scope of Study: This report deals with the history and development of lacquer, its characteristics, application methods, and the equipment necessary for its proper use. Desirable characteristics of a lacquer finish, as well as some of the common faults, are discussed. General information, rather than technical data, concerning the modern finishing product known as "lacquer" is presented. The equipment described does not include all types that are available, but typical equipment used in industry that is suitable for use in the school shop is discussed. A complete glossary of common finishing terms is not included, but some of the terms used in the lacquer industry are defined. Common faults of lacquer finishes, such as blushing, orange peel, bridging, discoloration, sags and runs, and how to overcome them are discussed.

Findings and Conclusions: Lacquer is a very old finishing material, having been in use for more than 2,000 years. Present day lacquers are quite different, in composition and characteristics, from the early lacquers used by craftsmen in the Orient. Within the last thirty years vast improvements have been made in nitrocellulose lacquers, and they have largely replaced other finishes in industry. The automotive industry led the way in making lacquer popular, but in recent years the furniture industry has become a great consumer of the product. In order to maintain pace with the finishing industry, industrial arts departments need to install spray painting equipment in the school shops. Students should be instructed with the materials and equipment used in industry.

ADVISER'S APPROVAL: L. H. Bengtson

LACQUER AND LACQUERING

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A Report

by

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CHAPTER I

THE PROBLEM, ITS ORIGIN AND DESCRIPTION

Finishing of wood, metal, and other products has three primary purposes. These purposes are for preservation, beautification, and cleanliness. The use of protective coatings has been an art for many centuries and has undergone many changes. The materials in use today are superior to their forebearers in composition, as well as in methods of application.

Following World War I, industry began to seek better and faster means of finishing its products. Through chemical research the discovery of new solvents for nitrocellulose was made, and lacquer became an important product in industry. The automotive industry was primarily responsible for the rapid adoption of lacquer, but since 1922 it also has hargely replaced other finishes used in the furniture industry.

Origin of the Study. Constant striving for improved finishing materials and methods of applying them has led to the increased use of lacquers. Demands for a quick setting, quick drying, hard, durable, and flexible finishing material have largely been met by lacquer. Today, nitrocellulose lacquers have largely replaced the varnishes in industrial finishing plants.

Finishing of projects constructed in the industrial arts class is an important phase of instruction. The origin of this problem was due to the desire of the writer to increase his knowledge of lacquer and lacquering processes.

Need for the Study. In many industrial arts departments, finishing is merely incidental to the construction of a project. The student is not given an opportunity to learn the value of various finishes and the characteristics of the materials used. Instructors and students alike fail to realize that finishing is a highly specialized industry in itself, and that modern materials and methods should be introduced into the program of industrial arts. The writer feels that the collection of material on the subject of lacquer and lacquering will be of value to himself, and to other industrial arts instructors.

Objectives of the Study. The objectives of this study are (1) to present a brief history of lacquers and their development, (2) to present methods of application of lacquers, (3) to define some common faults of lacquer finishes and their remedies, and (4) to discuss equipment necessary for the proper application of lacquers by the spraying method.

Delimitations of the Study. It is not the purpose of this study to give technical information concerning the formulation of lacquers. General discussion of the various constituents is meant to show the characteristics of the lacquers before and after application. Little reference is made to pigmented lacquers in the study. Pigmented, or colored lacquers, are merely clear lacquers with colors added, and the methods of application are the same. The equipment described in the study does not include all types that are available, but typical equipment used in industry that is suitable for use in the average school is discussed.

Method of Research. The library method of research was used in the preparation of this study. Books, magazines, and pamphlets were obtained from the library of Oklahoma Agricultural and Mechanical College, Stillwater, and the personal library of Professor L. H. Bengtson, under whose guidance this study was made.

Similar Studies. Loyal G. Cherry in an unpublished report, prepared at Oklahoma Agricultural and Mechanical College and entitled *History and Development of Lacquers*, describes the early history of lacquer and its development into the product we know today. In this study several special types and uses of lacquer are described. The various constituents of lacquer and their purposes are discussed in clear, non-technical terms.

Wood Finishes and Finishing Materials Used in Oklahoma High Schools, an unpublished report prepared in 1951 by Robert L. Kingsley at Oklahoma Agricultural and Mechanical College, contains material on lacquers. In addition to a short history of lacquer, information concerning the number of schools in Oklahoma that are using lacquer for finishing their projects is included.

Definition of Terms. Following is a list of definitions for terms that are common to the lacquer industry. These definitions are quoted from a Glossary found in Martin's book, *Lacquer and Synthetic Enamel Finishes*. (A9, page 401)

1. *Amyl Acetate.* An ester by the esterification of acetic acid with amyl alcohol. Solvent for nitrocellulose and used quite extensively in lacquers. (page 404)

2. *Amyl Alcohol.* One of the higher alcohols which is present in fusel oil. (page 404)

3. *Benzene.* A very light gravity coal tar distillate which is more commonly called "Benzol." Do not confuse the spelling of benzene with that of benzine, which is an entirely different product, derived from the distillation of petroleum oils. It is better, to avoid confusion, to use the benzol to designate the light gravity coal tar product. (page 407)

4. *Binder.* The binder in a lacquer is that liquid portion which binds the pigment particles together after the material has become dried. Such products as plasticisers and nitrocellulose are usually referred to as binder. (page 408)

5. Butyl Acetate. A lacquer solvent produced from butyl alcohol by a reaction with acetic acid. It is water white in color and has a characteristic ethereal odor. Butyl acetate is a "middle" boiling solvent and used to a great extent in lacquer manufacture. (page 416)

6. Butyl Alcohol. An alcohol of a higher boiling range than grain alcohol or wood alcohol. It is obtained from corn by fermentation. It is valued for its blush retardent nature and is used extensively in lacquer manufacture. Butyl alcohol in the presence of a minimum amount of an ester excites solvation on nitrocellulose. (page 416)

7. Camphor. A white, translucent solid of a peculiar characteristic odor, which is derived from a species of laurel tree grown chiefly in Formosa. In the earlier days of lacquer it was used as softener or plasticiser to give a flexible film. It is seldom used in present day lacquer manufacture because of its high volatility. (page 418)

8. Cellulose. The principal constituent of raw cotton and many other fibres obtained from the vegetable kingdom. Of interest to the lacquer industry because of the fact that nitrocellulose, which is used so extensively in lacquer, is prepared from cellulose by treatment with chemicals. (page 419)

9. Cotton Linters. The short fibres of cotton which adhere to the cotton seed when cotton is ginned. These short fibres are cut from the seed with special machinery and are used for the manufacture of nitrocellulose, which is used so extensively in lacquers. (page 426)

10. Diluents. In the manufacture of nitrocellulose lacquers certain volatile liquids which are not solvents for nitrocellulose are used to lower the viscosity and give other desirable properties. These materials as a class are called diluents. Diluents may be solvents of gums at the same time they are non-solvents of nitrocellulose and

therefore often serve an excellent purpose in holding gum solutions in mixtures with nitrocellulose solutions. (page 432)

11. Lacquer. The term "lacquer" has been so abused that it is no longer possible to know exactly what type of material is being referred to without additional explanation at the time of using the term. Originally the term referred to quick drying thin bodied materials of all kinds, later it was applied to very thin oil varnishes, with or without color, which dried quickly; then to very quick drying spirit varnishes containing alcohol, benzol, acetone, amyl acetate and other quick evaporating solvents, with or without nitrocellulose, in combination with various gum resins. Later the term has been applied almost exclusively to spirit varnishes containing nitrocellulose, with or without gum resins in solution. It is best for clearness to refer to thin bodied varnish lacquers as "spirit varnishes" or "shellac substitutes" and to solutions containing appreciable amounts of nitrocellulose as "nitrocellulose lacquers." (page 454)

12. Nitrocellulose. The product obtained by subjecting cellulose to a treatment with a mixture of nitric acid and sulphuric acids, which nitrates the cotton linters. Ordinary raw cotton or the "linters" from around the seeds are most frequently used for making nitrocellulose. For different purposes the cotton is nitrated in different degrees but for use in lacquers, nitrocellulose of about 12 per cent nitrogen content has been found most adaptable. (page 462)

13. Plasticiser. Usually high boiling solvents added to lacquers to increase the elasticity and flexibility of the dried film. Also sometimes spoken of as softeners. (page 469)

14. Resin. A solid or semi-solid organic substance, chiefly vegetable, which is soluble in ether, alcohol or in similar solvents, but not in water. In our industry, the term "resin" is commonly used to designate the resinous materials or so-called gums used in the manufacture of finishing materials. (page 476)

15. Solvent. A liquid that is capable of dissolving any given material is referred to as a solvent for that material. (page 487)

16. Synthetic Resin. Resins prepared by artificial means. Some of the synthetic resins are ester gum, and others are of the phenol formaldehyde and phthalic anhydride types. (page 492)

CHAPTER II

HISTORY AND PHILOSOPHY OF INDUSTRIAL EDUCATION

Man has long recognized the need of possessing a trade requiring the skill of hand. Economic and social reasons forced man to use his hands, and to develop skill in the use of tools. Examples of industrial education are to be found in early history and the Middle Ages. No real impetus was given education until the Renaissance and the development of the printing process. The Monastic Schools of the fifteenth century aided in making education popular. From a very inauspicious beginning, industrial education, as we know it today, has grown and undergone many changes, both in theory and in practice. Industrial education in Europe was furthered by the Industrial Revolution, and had made much progress before the people in the United States recognized a need for industrial education. Early industrial systems in the United States were influenced by the systems used in Europe.

Part A. Early History

Industrial education had its beginning in the home. The father taught his son, or another man's son, whom he treated as his own. The apprenticeship system was continued until the Industrial Revolution created a greater need for a system of industrial education, and existing theories were put into practice. The two systems used in European countries that had the greatest influence on industrial education in the United States were the Russian system and the Sloyd system.

The Renaissance Period. The early days of the Renaissance produced a number of educational writers who presented theories for a form of industrial education. Prominent among these writers were Johann Amos Comenius, and Johann Heinerich Pestalozzi. Comenius believed that instruction in words and things should go together.

> Comenius has been called the "father of modern pedagogy." This is because of his early formulation of principles and methods which two centuries later, were in harmony with the main current of pedagocial development. (A3, page 39)

Johann H. Pestalozzi has been called the "father of manual training." He established an industrial school, Neuhof, in 1774. Pestalozzi firmly believed that the condition of the poor in Switzerland could be improved through education, and his school was founded to give training to the poor children of his district. He believed that education should prepare for life in the home. He used the object method of teaching the traditional school subjects.

The Russian System. The first industrial education system of scientific principles for analyzing workshop operations into their elementary processes, and to base the course of study on these analyses, was the Russian System. It was developed in 1830 in Moscow at the School of Trades and Industries, later called the Imperial Technical School. The elementary processes of shopwork were arranged in a graduated series of controlled manipulative exercises. The leaders felt that if the pupil learned the fundamental tool processes and manipulations, training in a specialized field was not necessary.

The Russian system was exhibited in the United States at the Centennial of 1876. John D. Runkle, president of the Massachusetts Institute of Technology, saw the exhibit, and was impressed with it as a method of teaching manipulative skills in connection with regular college work. He later founded the School of Mechanic Arts at the Massachusetts Institute of Technology. Instruction was based on the Russian system.

The Sloyd System. The first system for teaching the manual arts to gain world wide recognition was the sloyd system. The peasants of the Scandanavian countries had long practiced handicrafts in their homes, and this interest caused the early introduction of crafts into their schools.

In Finland, Uno Cygnaeus, a Lutheran preacher and teacher, was selected to work out a system of folk schools. He was well acquainted with the writings of Pestalozzi and Froebel, and patterned his school after their teachings.

The time of the student was divided among studies, domestic industries, and work in the fields.

In 1887, Otto Salomon, of Sweden, visited Cygnaeus, and from him received the idea that sloyd should be a part of the elementary school course of instruction. He learned that sloyd should be organized on a pedagogic basis, rather than on an economic basis. Salomon returned to Sweden and developed what he termed educational sloyd. He arranged short courses that were attended by the folk-school teachers of his district. These summer courses made Swedish sloyd famous, and were eventually attended by teachers of other countries. The school at Naas became a great center of sloyd influence. The general characteristics of Salomon's educational sloyd are (1) making useful objects; (2) analysis of processes, and (3) educational method. The influence of the school at Naas continued to broaden, and eventually affected the growth of industrial education in the United States and England.

Part B. Industrial Education in America

The Franciscan schools in New Mexico represent one of the earliest attempts at industrial education in America. These schools, established in 1630, were very similar to the Monastic Schools in Europe. The Franciscan missionaries were the teachers at first, but as the natives became skilled some of them were used as instructors. In addition to academic subjects the boys were taught tailoring, shoemaking, carpentry, black-smithing, bricklaying, carving, and stonecutting. The girls were taught sewing and spinning.

Apprenticeship in America. The American colonies retained many of the characteristics of the apprenticeship system as practiced in England. The apprenticeship system furnished the youth both a general education and a technical education. The master was bound by law to comply with the rule of a general education at the same time he taught the youth a trade.

Toward the last of the eighteenth century and the early part of the nineteenth century the apprenticeship system began to deteriorate. With the introduction of machines and labor saving devices, the apprenticeship system ceased to exist entirely. Industry left the homes, and small shops and factories employing large numbers of people were built. The decline of apprenticeship had begun prior to the Industrial Revolution, but its complete decline was hastened by that event.

Between the years from 1700 to 1775 little progress in industrial education was made in the United States. In 1779, the de la Howe State School in South Carolina was founded as an agricultural school. In 1814, the Farm and Trades School, established in Boston for the education of handicapped and underprivileged children, offered training in nearly a dozen vocations. This type school contributed much to the development of industrial education in the United States.

The Morrill Act. The people living in the frontier areas of the United States began to demand a practical education for the masses. The schools that had been established in the east were primarily for the professional classes, and did not benefit the people in the rural areas of the country. In 1859, Senator Morrill, of Vermont, introduced a bill in Congress requesting land endowments to support secondary schools. The bill was vetoed at this time, but was signed by President Lincoln in 1862. A state was allotted thirty thousand acres of land for each of its senators and representatives in Congress. The money realized from the sale of this land was to be used to endow, support, and maintain at least one college to teach agriculture and the mechanical arts. The establishment of these land grant colleges contributed greatly to the manual training movement in the United States.

The Manual Training School. St. Louis, Missouri, became the center of the manual training movement in the United States. In 1877, Calvin M. Woodward, Professor of Mathematics and Mechanics and Dean of the Polytechnic School of Washington University, founded the St. Louis Manual Training School. The movement gained recognition, and within a few years similar schools had been established in all the major cities of the United States. The Russian system of teaching handwork was adopted by these early manual training schools.

The Russian system was well received, and manual training made rapid gains for a few years. It was discovered, however, that the system lacked appeal to the children that were receiving the instruction. The work done by the pupils produced objects that possessed no utilitarian value and had no beauty. Realizing the inadequacy of the system, American educators began to look for other methods or systems. The Swedish sloyd system was introduced in America by Professor John M. Ordway. The sloyd system had its faults, but was recognized as superior to the Russian system, and was adopted for use in the United States.

During the development of the manual training schools, there was widespread disagreement as to whether the general education or vocational aspects of the program was most important. This controversy was due, in part, to a vocational educational movement that was gaining recognition throughout the country.

Industrial Arts. In 1906, the National Society for the Promotion of Industrial Education was organized, and attacks on the manual training program were made by its leaders. These repeated attacks prompted writings by men engaged in teaching manual training, and eventually brought about the changing of the name of the program. Most of the writings appeared in two periodicals that were founded during the height of the controversy. These were the Manual Training Magazine and the Industrial Arts Magazine.

The writings of Charles R. Richards, Dean James E. Russell, and Frederick G. Bonser were most influential during this period. It was Russell who suggested that the name of the program be changed from manual training to industrial arts.

The Manual Training Magazine, later called the Industrial Education Magazine, and the Industrial Arts Magazine, now called the Industrial Arts and Vocational Education Magazine, were important publications in the field of industrial education. In addition to these periodicals, many books were published during the early 1900's that did much to broaden and enrich manual training, or industrial arts, in the high school.

Industrial Arts Education and Vocational Education. In 1917, with the passage of the Smith-Hughes Act, the Federal government recognized the two separate areas of industrial education. Since that time, industrial education has been divided into industrial arts education and vocational industrial education. It became generally recognized that there was a need for, and a place for, both in the educational program.

Industrial arts is a part of general education for all boys and girls, while vocational industrial education is intended to train workers in the skilled and semi-skilled occupations that are a part of industry. Even though the branches of industrial education are separate, they should not be isolated. Each branch complements the other in a comprehensive plan of industrial education. (A6, page 52)

Recent Developments in Industrial Arts. Within the past thirty years, industrial arts as a school subject has developed greatly. Not only has the number of schools offering industrial arts increased, but also the subject matter, or fields of instruction, have been widened. New units or areas of instruction have been added to maintain pace with new equipment and raw materials used in industry. Woodworking and drawing were the primary areas of instruction in the manual training movement and in the early days of industrial arts. To these areas have been added machine shop, sheet metal, electricity, printing, textiles, plastics, leatherwork, ceramics, and others. These courses afford an opportunity for the student to explore his ability and interest with tools and materials typical of the industries.

Originally, industrial arts shops were equipped, organized, and administered as what is known as unit shops. These shops were equipped to teach one type of shopwork under one teacher. If more than one area was to be taught a separate shop was required. This system is still used in large schools, where the enrollment is sufficient to require more than one teacher.

More recently the general shop has gained in popularity throughout the country. The general shop is one that is equipped to teach two or more areas of shopwork at the same time under one teacher. The plan is well suited to fulfilling the objectives of industrial arts, especially at the Junior High School level. Small schools with limited enrollment and funds can offer the students several areas of instruction in one shop with one teacher. Such areas of instruction as woodworking, drafting, graphic arts, ceramics, electricity, transportation, and plastics are most commonly found in the general shops. Most general shops are equipped to teach four or more of these areas. Selection of areas for a particular program depends on the grade level, type of school, community, and the specific objectives of the shop course being offered.

Another significant development in recent years is the laboratory of arts and industries, as the program is called in many of the large city high schools. The laboratory of arts and industries has been developed to meet the needs of boys who desire to elect advanced shopwork as part of their education, but have no desire to take a straight vocational course. This program, which had its beginning in the late thirties, is very similar to the general shop. The laboratory gives the high school boy opportunity to explore and learn about a whole field of industry, as well as to learn the use of processes and materials on an advanced level.

Part C. Philosophy of Industrial Arts

The present day industrial arts program is an integral part of general education, and the objectives of both are essentially the same. However, the objectives of industrial arts may be extended beyond those of general education. Industrial arts is an important part of the education of both boys and girls. It provides them with an understanding of their modern industrial environment, and of the effect it has on their economic, social, and cultural life.

Definitions. Education has different meanings to different people. To aid in the understanding of present day conceptions of education, the following definitions are quoted:

1. Education is the result of experiences whereby we become more or less able to adjust ourselves to the demands of the particular forms of society in which we live and work. (A15, page 1)

2. General Education is a broad type of education aimed at developing attitudes, abilities, and behavior considered desirable by society but not necessarily preparing the learner for specific types of vocation or avocational pursuit. (A7, page 183)

3. Industrial Education. A generic term including all educational activities concerned with modern industry and crafts, their raw materials, products, machines, personnel, and problems. It therefore includes both industrial arts and vocational industrial education. (A6, page 7)

4. Vocational Education. That part of the total experience of the individual whereby he learns successfully to carry on a gainful occupation. (A15, page 2)

5. Vocational Industrial Education. Preparation for entrance upon and making progress in "trades" and industrial occupations of all kinds. (A15, page 7)

6. Industrial Arts. One division of the "practical arts" with character and purposes associated with general education. To the extent that the exploratory or occupation-finding aim is emphasized, it is a much-needed prerequisite of vocational-industrial education. Each must complement the other in the selection of and preparation for entrance upon wage-earning trade and industrial pursuits. It also has other important contributions to make toward the general education of all students irrespective of their future vocations. (A6, page 7)

7. Industrial Arts is the study of materials and of the desirable changes made by hand or by the several manufacturing processes from the raw state into products designed to meet the consumers needs and comforts for daily living. (A14, page 5)

Objectives of Industrial Arts. As has been stated, the objectives of industrial arts and those of general education are in close agreement. In our highly developed industrial society it is necessary that every boy and girl be given the opportunity to develop knowledge and appreciation of industrial life. Youth of today should understand his modern industrial environment, and the direct bearing it has on his economic, social, and cultural life. Some of the objectives of industrial arts education are the following:

1. To provide opportunities for the development of fundamental shop skills and appreciations which will serve as a basis for further vocational training and advancement.

2. To acquaint youth with conditions in industry both from the standpoint of the employer and the employee in order that they may appreciate and better understand their problems.

3. To familarize students with the products of industry in order that they may be more intelligent consumers.

4. To provide opportunity for purposeful exploration and experimentation especially on the junior high level in order that the boy may further discover his aptitudes and interests.

5. To develop intelligent followership as well as leadership through various shop activities including the shop personnel organization plan.

6. To promote proper habits of safety and health particularly as they relate to shop activities and conditions in industry.

7. To articulate industrial arts with mathematics, science, design, and other school subjects especially from the standpoint of application so that it may be a vital part of the student's general education.

8. To provide opportunities for growth where the learning and skills required are commensurate with the capacity of the student, and where he really experiences the satisfaction that comes from success and the completion of a worth-while task.

9. To provide opportunities for the development of desirable habits of thinking through learning, analysis, planning, application, and performance in the shop.

10. To help develop well-rounded out individuals capable of using their hands and their heads whether it be in pursuit of wholesome leisure-time activities or in the more serious business of earning a living. (B11, page 200)

Education develops concurrently with the economic development of the nation. During the past decade the economic life of the United States has been characterized by its complexity, and by sudden and rapid changes. Industrial arts is an important means of meeting these changes. The areas of instruction presented represent occupational life to the youth either for guidance, training, or interpretative purposes. The experiences and skills gained through industrial arts helps the young man or woman to meet the ever changing conditions of economic society more intelligently.

CHAPTER III

A BRIEF HISTORY OF LACQUER

The term "lacquer" is derived from the Hindu word "lakh" which means 100,000, in reference to the thousands of small insects which produce "lac," or shellac, on certain trees in India and Indo-China. Through the centuries the term "lacquer" has been applied to at least three finishing materials of quite different composition. The earliest of these finishes was used around 500 to 600 B. C. by the Japanese and Chinese to decorate their highly carved wood products. Just prior to World War I, a spirit-varnish used in Europe and the United States was called lacquer. Present day lacquer is a finishing product having a nitrocellulose base, and is in no way related to its forbears.

The first nitrocellulose was made in 1838. However, it was some time before the use of "gun cotton" as a lacquer medium was realized. Alexander Parkes obtained a patent for a liquid cellulose lacquer, and in 1855 exhibited samples at the London Exposition. His was the first patent granted for such a product, and wide publicity was given it as a result of the Exposition. At this time, however, lack of knowledge of solvents, and of nitrocellulose itself, caused lacquer to be of limited industrial value.

Part A. Early History of Lacquer

The earliest known forms of lacquers were in use in Japan and China more than 2,000 years ago. Workmen in these countries applied this protective coating to their highly carved boxes and screens, and it was said to be superior to anything else in the world. It had brilliant and permanent luster, which is unchangeable with weather conditions.

Oriental Lacquers. In China and Japan a ready made varnish is obtained by making incisions in the tree called Uneshi-Nu-Ki, and catching the sap which exudes. When the sappy exudation first comes from the tree it is gray brown in color, and is viscous and mucilaginious in consistency; but, after exposure to the air, it turns nearly black, and forms a tough, thick covering. This substance is peculiar in that it does not harden in a dry heat, but does harden if placed in a damp atmosphere for several hours.

Oriental lacquers are like oil-varnishes in that they dry by oxidation, as do the varnishes. This is entirely different from present day nitrocellulose lacquers, which dry by evaporation. Various substances are added to the natural lacquer that is taken from the trees, but mostly they are considered as adulterants. The Chinese sometimes add Tung-oil or perilla-oil, while the Japanese thin the same raw material with camphor.

Some authorities think that the Japanese lacquer films or coatings are more durable than finishes made from any of our best resins. (A12, page 286) Finishes made from them have a brilliant and permanent luster that is impervious to weather conditions as well as to varnish-removers and other solvents.

Burma Lacquers. The black lacquer, or "thitse" of Burma, is compounded in a manner somewhat similar to that used in making the famous Japanese lacquer, but the raw material is obtained from a different tree. The Burma lacquer is slower drying than the Japanese lacquer.

Part B. Lacquer in Europe and the United States

Prior to World War I the lacquer used in Europe and the United States was simply a spirit-varnish, which was largely shellac. It was made both in clear and colored solutions, and was used primarily on metals to prevent tarnishing and to give a soft pleasing luster.

England. It was not until 1855 that nitrocellulose, or "pyroxylin," came into commercial use as a finishing material. That year in England, Alexander Parkes was given a patent covering the use of a liquid nitrate composition as a protective coating. (A10, page 498) Characteristics of early solvent mixtures made the product unsuitable for general industrial use. Its most general application was as a covering for skin cuts and abrasions.

The United States. We owe the modern cellulose lacquer, however, to J. H. Stevens, who, for the Celluloid Company of New Jersey, United States of America, in 1882, was the original patenter of the use of amyl acetate, various oils and ethers, amyl formate, methyl salicylate, ethyl formate and ethyl alcohol, and benzol as solvents and plasticisers. He has every right to be called the father of the cellulose lacquer industry. (A8, page 4) However, World War I started lacquers on the upward path that has led to the product as we know it today. Need for dope for airplanes and solvents for processing nitrocellulose explosives stimulated research along these lines, and greatly increased knowledge in the field of nitrocellulose chemistry.

At the close of World War I manufacturers of explosives were faced with the problem of large quantities of cellulose nitrate and butyl alcohol, that had no apparent commercial value in time of peace. This fact, coupled with the dissatisfaction of automobile manufacturers with existing enamel finishes on their products, aided the rapid growth of the lacquer industry in the United States.

Chemists announced that cellulose nitrate and butyl alcohol could be used to manufacture lacquer, and lacquer was definitely established as an essential part of the paint industry. The discovery of low viscosity cotton and the ester type solvents, ethyl, butyl, and amyl acetates, caused a rapid growth in commercial and industrial use of lacquer.

In 1925, 12,205,206 gallons of lacquer were produced, and in 1942, 49,441,510 gallons were produced. (A10, page 499) Thus, in a period of only seventeen years the annual production of lacquer had increased more than four times.

The first important exhibit of furniture finished with nitrocellulose lacquer was at the Chicago World's Fair in 1893. It was not until 1922 that commercial production of nitrocellulose lacquer, of a type more like that of the present day, appeared in the United States. Since 1922 lacquer has largely replaced varnish in the furniture industry.

Using varnish finishes the furniture manufacturer required from several days to weeks to finish his product, but with the advent of the quick drying lacquer this time was materially reduced. An example of the procedure used in finishing furniture with lacquer is as follows:

1. Coat of lacquer sanding sealer, sanded within one hour with dry sandpaper. (6/0).
2. Two coats of lacquer, with one to two hours between coats.
3. Rubbed following day.

Thus, the time for finishing furniture is reduced from a period of days to a matter of a few hours. The resulting saving in time and labor is of benefit to the consumer, as well as to the manufacturer.

Recent Developments. Since 1922 many improvements have been made in lacquers. One of the most significant improvements has been the development and use of synthetic resins. (B4, page 20) Early lacquer, made in the old conventional method, produced finishes that lacked distinctiveness, and confronted manufacturers with many problems such as cracking, chipping, softness in the film, slow drying, brittleness, and unappealing appearance. These and other problems have been removed by the use of synthetic resins.

Considerable credit for the growth of the lacquer industry can be attributed to the introduction of cheap butyl acetate and butyl alcohol as solvents for nitrocellulose and resins, and the substitution of inexpensive hydrogenated napthas, such as solvess, for the more costly diluents, particularly toluol and xylol. (B18, page 423) The use of synthetic resins has added distinctly better qualities and more varied uses to lacquer. However, other changes have simply reduced the cost of production so that, at present, lacquer is available at prices that compare favorably with that of high grade varnishes.

Through experimentation, different combinations of synthetics can be made to produce the characteristics desired in a finish. Such specific requirements as sufficient build, desired lustre, thickness of the film, resistance to alcohol, and resistance to extreme temperature changes have been met.

It should be stated that there is no all-purpose lacquer, and that the composition of lacquer varies with its purpose. Also, no lacquer thinner is available that is suitable for thinning all lacquers. The user of lacquer should obtain the product having the characteristics desired, and then use the thinner recommended by the manufacturer.

Lacquers are now available for use with a brush, for spray gun application, for furniture, for exterior coatings, for undercoats, for roller spreading, for lacquer enamels in various colors, and for a host of other special uses. Any of these lacquers may be made from prepared stock solutions. The manufacturer, by using prepared stock solutions of nitrocellulose of different viscosities, various resin solutions, a few plasticizers, and diluents of several types, can make almost any kind of lacquer that is desired.

<u>Composition of lacquer</u>. In the <u>Monthly Labor Review</u> for July, 1932, the five basic parts of lacquer and their purposes are listed as follows:

1. Nitrocellulose, forming about ten percent of the lacquer, gives a water-proof quality, hardness, and durability.

2. Solvents and diluents, 77 per cent, dissolve the nitrocellulose and gums and give quick drying properties.

3. Gums or resins, 5 percent, thicken the lacquer and increase its adhesive qualities.

4. Softeners or "plasticisers," 5 percent, prevent brittleness.

5. Pigments or coloring materials, 3 percent, give color and add to the durability of the coating. (B18, page 57)

From the basic formula for lacquer can come endless variations that do not have any of the shortcomings that were found in the early lacquer finishes. Much of this is due to the increasing number of synthetics that are now being used.

CHAPTER IV

APPLICATION OF LACQUER

Two primary methods of applying lacquers to furniture are available to the worker. Special brushing lacquers may be obtained, but the most acceptable method is mechanical, by means of a spray gun. This second method of application has been largely responsible for the widespread use of lacquer in the furniture and automotive industries. In recent years many schools and colleges have installed spraying equipment for use in industrial arts programs, as well as vocational instruction.

Brushing Lacquers. Cellulose brushing lacquers have found a limited use for small articles, especially for the home worker. Lacquers are the most difficult of all wood finishes to apply with a brush. Brushing lacquers have characteristic hardness, gloss, and are quick drying. They do not brush easily, particularly on large surfaces.

Arthur Jones in his book, *Cellulose Lacquers, Finishes and Cements*, (A8, page 255) lists the following defects of the average cellulose brushing lacquer:

1. Bad odour.
2. Pigments liable to settle-out to a hard mass.

3. Obliterating capacity very low.

4. The paint dries too quickly and pulls on the brush.

5. Cuts into any previous coat.

Recently, spirit-gum lacquers, with synthetic resin-gum, have been produced as brushing lacquers. They can be brushed and applied very much like oil paints, they possess much greater film-forming properties, and they are more durable than the best oil paints. They give an exceedingly rich enamel gloss and can be heavily pigmented.

Applying Lacquer With a Brush. As has been stated, lacquer is the most difficult of all finishes to apply with a brush. Since this is true, the following suggestions, as listed by A. C. Newell in Coloring, Finishing and Painting Wood, (A12, page 327) will be helpful to the wood finisher:

1. Proper undercoats are absolutely necessary. Shellac or special lacquer undercoats should generally be used over other finishes before lacquer is applied. On new unfinished wood, shellac makes a good sizing which will seal up the pores of the wood and help give "body" to a lacquer finish.

2. Brushing-lacquer must be applied very rapidly and carefully, using a brush or brushes of the proper size. Each stroke of the brush should completely cover a certain area as the lacquer is flowed on the surface.

3. The brush must be kept wet or full of lacquer while in use, and should be wiped on the point only after refilling from the can or pail.

4. Open-grained or porous woods must be filled properly, and surfaced with shellac or specially-prepared lacquer undercoat, in order to make level surfaces, because lacquer does not flow into the cell-openings and fill them as other finishes do.

5. Brushing-lacquer must be flowed over a surface with a wet brush held at an oblique angle instead of perpendicular to the surface. Lacquer is always flowed over a surface and cannot be "brushed out."

6. The finisher must stand in a position that will enable him to see well, because the surfaces must be covered properly and completely at the first application. Retouching improperly covered spots after the lacquer has set even for a few seconds will produce a rough finish wherever the brush touches the edges of the partly dried films surrounding the unfinished area.

7. All removable doors and all pieces of furniture, whenever possible, should be placed in such a position that lacquer can be applied on horizontal rather than on vertical surfaces.

8. Whenever it becomes necessary to join a partly-set lacquer-film to a new wet coating, it is best to soften the edge that has begun to thicken by the use of another brush and lacquer reduced to one-half strength with thinner.

9. If lacquer does not spread freely under a brush, it is often advantageous to thin the mixture with a thinner, which can be secured from the lacquer manufacturer.

10. A small amount of thinner placed conveniently near is helpful when spots or drippings must be removed before covering a surface.

11. The brush should be cleaned with a properly prepared thinner as a solvent after a lacquering job has been completed. A cheaper brush-cleaning liquid than lacquer-thinner can be made from denatured alcohol and acetone mixed half and half.

12. No sandpapering between coats of lacquer is necessary unless the surface has become roughened and must be leveled or smoothed.

13. Only one coat of some brands of lacquer can be applied smoothly over a surface when a brush is used. The solvents in lacquer are so powerful that they are apt to soften an undercoat of lacquer, and the friction of the brush is often sufficient to cause roughness and undesirable brush-marks. If proper undercoats are used one coat of lacquer applied with a brush will usually make a good finish. Brushing lacquer generally has more "body" than spraying lacquer.

14. While lacquer sets very quickly, it should be given sufficient time for hardening between coats and before rubbing.

Lacquer coatings set very quickly, and can be handled in a few seconds. They dry very rapidly by evaporation, and not by oxidation. Even though this is true, it is best to allow about 24 hours between coats, especially with brushing-lacquers. Two to three days should be allowed for the drying of the last coat before the final rubbing and polishing.

It is important to remember that the final lacquer coat should be applied in a thin coat, just enough to cover and set quickly. A final coat that is too heavy remains wet long enough to allow the solvents to penetrate into the previous coats and cause bad orange peel.

Sanding, Rubbing, and Polishing Lacquer. It is sometimes necessary to sand between coats of lacquer. This is true if, for any reason, the surface is rough, or has other defects that will interfere with the final smooth finish. Sanding is usually done with wet sandpaper, preferably Grit No. 150. The sanding of lacquer is slow work due to the hardness of the material, but it has the same improving effects as rubbing and polishing do for varnish.

Very fine pumice stone should be used for the final rubbing. Either oil or water process may be used. When water is used for lubrication, the addition of a mild soap flake is recommended. Rubbing should be done lengthwise of the grain with a felt pad just as in rubbing a varnished article.

Other methods for rubbing lacquer feature the use of 3/0 steel wool dipped in water and working with a continuously wet surface without pumice. Lacquer naturally has a much lower sheen than varnish, and one or the other methods of rubbing should be employed so that its full body will show up. The final sheen or gloss is determined by the amount of cutting done during the rubbing operations, and by the amount of polishing with wax which the piece of furniture receives. If a dull finish is desired it may be accomplished by applying paste wax with 4/0 or 5/0 steel wool.

Spray Gun Application. Great speed is required in the application of lacquers, and can be obtained by the use of spray equipment, which spreads a film of lacquer evenly and smoothly on large surfaces. Equipment necessary for this type of application consists of an air compressor, spray gun, hose, and air transformer.

Using a spray gun requires a very definite technique. The worker who has had good experience with the paint brush usually develops this technique easier than if he had just started with the spray gun. His understanding of materials and the preparation of surfaces, upon which they are applied, give him an understanding of the work he is doing.

Spraying Technique. The first thing required in spray gun operation is always to spray at right angles to the surface and at the same distance from it. (A5,page 70) The distance that the gun is held from the work is variable with the material being sprayed. It may be 8 inches to 12 inches, but as soon as the correct distance is found it should be maintained throughout the finishing process.

The entire arm and body should always be moved with the gun to keep it at right angles to, and the same distance from, the work. Maintaining a steady sweep and keeping the gun always at the same distance will produce an even and smooth coating. The rule to remember then is to set a steady, even pace, or speed of movement, of the gun across the work and keep it.

To avoid the material piling up at the edges of the work, each stroke should pass all the way across the work and be carried beyond the edge, or the trigger released just a moment at the edge before beginning the next stroke. Each stroke should overlap the preceding one by about one third. The spray stream only gives a full coating for about three-fourths of its width, and an uneven coating will result if the strokes are not overlapped sufficiently.

To emphasize the rules for spray gun use, Crewdson, in his book, Spray Painting, Industrial and Commercial, (A5, page 161) gives the "Sprayer's Ten Commandments" as follows:

1. Be sure that the surface to be sprayed is perfectly clean and in proper condition for coating, otherwise wet spots, crawling and poor adhesion will result.

2. If possible, all materials for application should be at room temperature before using. When brought in from the cool store room they should not be used until their temperature has been gradually raised to that of the warm room in which it is to be applied.

3. Maintain correct room temperature and normal humidity. The temperature of the finishing room should be around 70 degrees F. and the humidity about 50 per cent. A working balance between materials, temperature, surface temperature, room temperature and humidity must be maintained at all times if satisfactory results are to be expected.

4. Always spray at right angles to the surface. Failure to do this will cause uneven spraying, ripples and runs.

5. Maintain an even movement, or rate of speed across the work, carrying each stroke all the way across, and for a short distance beyond the edge, before returning on the next stroke.

6. Keep the movement of the gun parallel to the surface.

7. Use only enough air pressure to properly atomize the material being sprayed. Too little air pressure, as well as too much, will cause such defects as orange peel and roughness.

8. Overlap all strokes, by at least one third to form an evenly coated surface.

9. Open the drain cock on the air transformer at frequent intervals so as to allow trapped oil and water to escape.

10. Last but not least, use only the best materials and equipment.

The beginner with the spray gun usually has a tendency to use a pivoting or circular motion of the wrist or forearm. This brings the gun near the surface when directly in front of the body and pulls it away from the work when swung to the right or left extremes. This will cause part of the surface to be too dry, and part of it will be too wet, and an unsightly finish results. By adherring to the "Sprayer's Ten Commandments," (A5, page 161) as listed above, and diligent practice, guesswork can be eliminated and superior finishes can be had.

Adjusting the Spray Gun. Before starting a finish job with the spray gun, the operator should give careful consideration to a study of the proper nozzle adjustment for the particular work to be done. Modern spray guns are capable of adjustments from a round cone spray, suitable for small articles, to a wide fan spray, for covering large areas. The spray best suited to the job at hand should be selected. Before starting on the project to be finished, a good practice is to use card board panels to test the quality of the spray work, air pressure, and fluid volumes to suit the work to be done.

Cleaning the Spray Gun. Finishing materials or solvents should not be left in a spray gun or container overnight. The gun should be cleaned thoroughly each time it is used. It should not be placed in lacquer thinner and left. The nozzle should be removed and cleaned, even if it is to be used again in an hour or two.

To clean the gun:

1. Remove the cup and pour out the contents.

2. Wash out the cup with thinner, then partly refill it again with thinner and replace it on the gun.

3. Open the gun and spray the thinner for a short time.

4. Alternately open and close the fluid tip and one air port while pressing the trigger.

5. Remove the cup and pull the trigger to blow out excess thinner remaining in the gun.

Care should also be given to pressure containers, fluid hoses, and any other equipment used. Dirty equipment means poor quality work, and clean equipment means good quality work.

Hot-Spray Lacquers. New hot spraying techniques for the application of nitrocellulose lacquers are being used in the automobile and furniture industries. Heating the lacquer before spraying performs the same function as the addition of thinners to spray it in the conventional way. Heating reduces the viscosity without reducing the solids content, as do the thinners. The resultant heavier solids content permits fewer coats, thus saving time and labor costs.

> If lacquer is heated, its viscosity is reduced and a solution with up to 40% solids can be sprayed giving a thicker coat. While this principal appears elementary, only recently has safe, practical heating equipment been developed and made available for general use.
>
> Hot-spray lacquers now account for about 5% of the total volume of lacquers used, but growing interest and new installations of heaters point to an increase in this proportion. (B14, page 56)

Such lacquers require changes in the solids content and in the type of solvents. This makes the hot-spray lacquers somewhat more expensive than cold-spray lacquers, but the resultant savings in coatings required offsets this extra cost. The thickness of the coatings is 40 percent to 55 percent thicker when the hot-spray process is used.

Automatic Spraying. During World War II, automatic spraying machines were developed for painting many items of military equipment. Since that time many automatic spray painting machines have been installed for painting varied kinds of peace-time products.

> Automatic spray painting has many advantages. During periods when there is a scarcity of labor, it conserves skilled workers. Properly adjusted and maintained it produces a consistently uniform finish. Once established the distance between the spray guns and the surface to be coated remains constant. The spray pattern, atomizing, and fluid pressures, as well as the position of the spray guns, are under the control of one man rather than a number of individual spray operators who often have widely different ideas on any one or all of these important phases of spray painting.
>
> Mechanical controls that regulate air and fluid pressure, the length of time the spray guns are open, plus the skip-spray device with which automatic spray machines are equipped--these features provide a saving in material that is usually impossible in hand spraying. Last but by no means least is the production possibilities of these machines. It is possible to predetermine the volume of production per hour. With adequate supervision, cleanliness and maintenance, this rate of production will go on indefinitely. (B1, page 36)

It is not conceivable at this time that high schools or colleges will install either the hot-spray system or the automatic system of spraying. Both methods of lacquer application are, however, definitely established in industrial finishing plants. Almost any item that can be sprayed by hand can be sprayed automatically.

CHAPTER V

SOME COMMON TROUBLES IN SPRAYING LACQUER AND HOW TO OVERCOME THEM

Lacquers, as a furniture finish, have many advantages over varnishes and varnish-enamels. Conspicious among these advantages is that they set quickly and dry hard sooner than varnishes. On the other hand, this fact makes it practically mandatory that lacquer be applied by the spraying method. In spite of the skill of the operator and the high quality of materials and spraying equipment used, certain failures of finish appear. The ability to recognize these failures, and correct them, is essential to the furniture finisher.

Spray Gun Troubles. All finish failures are not due to the lacquer itself. Experienced spray painters are able to diagnose the trouble, and act accordingly. Some of the common spray gun troubles, and their causes, are as follows:

1. Jerky or fluttery spray: Caused by air leak. Look for loose air cap, loose fluid tip, clogged vent in cup lid; or broken edge of glass cup or defective gasket on a suction type spray gun.

2. Excessive spray fog: Due to too much pressure for the amount and kind of fluid being sprayed.

3. Spatter: Too much material for capacity of tip, or dirty air cap.

4. Unbalanced spray: Dirty center orifice, or clogged air vent in cap.

5. Split spray: Too much air pressure and too wide a spray.

6. Oil or water spots: Transformer needs cleaning. It is not stripping properly. (A18, page 137)

Some of the above failures can be avoided by proper maintenance of equipment. Careful mixing of lacquer and adjustment of the spray gun will eliminate others.

The chemical composition of lacquers prevents their use under certain conditions. The user of lacquer should become acquainted with the difficulties in its application, and the characteristics of its failures.

Blushing. Blushing is an effect that is peculiar to lacquer, and is manifested as a white cloudy effect on the coated surface. It is caused by moisture. Maintaining a normal humidity of around fifty percent in the finishing room will correct most of the causes of blushing.

Improper functioning of the air transformer may be the cause of blushing, by allowing moisture to come through the compressed air line. It should be checked for cleanliness and distance from the compressor. The transformer should be at least twenty five feet from the compressor.

Bridging. Lacquer does not penetrate poorly fitting joints, but forms a film across them. Strain on these parts causes the lacquer to break along the opening. The sprayer should make certain all open joints, or other defects, are repaired before spraying is begun.

Discoloration. Spots of grease, oil in the line, and dirty fingerprints, from careless handling of the work, will appear as discolorations after the lacquer has been applied. The only way to get rid of such spots is to remove the finish, clean the surface, and refinish. Careful handling of new work prior to finishing is a desirable habit to be developed by all furniture finishers.

Orange Peel. Orange peel is a common lacquer fault. It is so called because it resembles the texture of the outside surface of an orange. Several possible causes and suggested remedies for this defect are presented in a pamphlet published by the Binks Manufacturing Company. (Cl, page 2) They are as follows:

Possible Causes	Suggested Remedies
1. Lacquer not thinned out sufficiently.	1. Add the correct amount of solvent by measure.
2. Not depositing a wet coat.	2. Check solvent. Use correct speed and overlap of stroke.
3. Gun stroked too rapidly.	3. Avoid "whipping." Take slow deliberate strokes.

Possible Causes	Suggested Remedies
4. Insufficient air pressure.	4. Increase air pressure or reduce fluid pressure.
5. Using wrong air nozzle.	5. Select correct air nozzle for the material and feed.
6. Gun stroked too far from surface.	6. Stroke the gun 6 to 10 inches from surface.
7. Overspray striking a previously sprayed surface.	7. Spray detail parts first. End with a wet coat.

Sags and Runs. When uneven coats are applied to a surface the excess material sags and forms runs. Oftentimes this is caused by stroking the gun too close to the surface or at the wrong angle to the surface. The operator should stroke the gun 6 to 10 inches from the surface and at right angles to it.

Roughness. Too much air pressure for the material being sprayed or holding the spray gun too far from the surface gives a rough, pebbly surface. The solvents in the lacquer evaporate so quickly that the solid particles of spray dust strike the surface, leaving a "sand-paper" like effect.

Dust, Dirt, and Lint. Conditions within the finish room and handling of the unfinished work will either cause or control dust and dirt in the finish. The finish room should be as clean and dust free as possible at all times. Articles to be sprayed should be perfectly clean before taking them to the spray room.

Cleaning of the piece to be finished should be done outside the finish room. The operator should dust the piece thoroughly with a clean, lint free rag, and then blow off the surface with compressed air.

The lacquer should be strained before using. This will free it of any foreign matter that would be blown onto the surface during the spraying operation. Disposable strainers may be obtained for this purpose. A clean cheese cloth can be used as well.

CHAPTER VI

SPRAY PAINTING EQUIPMENT

Every industrial arts shop should have an area designated for finishing. This area should be free of dust, well lighted, and have adequate ventilation. It should be so located that it can be constantly supervised. The finishing area should be well equipped for the proper storage, handling, and application of finishing materials. If spray painting is to be done some type of booth should be provided. Also, an exhaust system is necessary where spray painting is done.

When purchasing spraying equipment, good quality merchandise should be purchased from a reputable manufacturer. Much of the success of spraying lacquer is dependent on the quality of the equipment used. The equipment should include a spray gun, an air compressor, hose, air transformer, and a pressure regulator.

<u>Part A. Spray Guns</u>

The spray gun could well be considered the most important piece of spraying equipment. There are several types and makes of spray guns available that are of satisfactory quality.

> One should be selected that gives (a) thoroughness of atomization; (b) control of spray of a uniform size and shape; (c) ease of operation, adjustment, and ability to clean; (d) fluid control and fluid cut off. (A9, page 31)

Several different types and sizes of nozzles are supplied for spray guns which make possible the handling of many different kinds of materials. No one fluid tip or air cap is satisfactory for all types of materials or surfaces.

Types of Spray Guns. Spray guns are of attached container or separate container type. These two types are further divided into Bleeder and Non-Bleeder, External and Internal Mix, and Pressure, Gravity, or Suction Feed Guns. The pamphlet "A B C of Spray Painting Equipment," (C2, page 3) published by the DeVilbiss Company, describes the types of guns as follows:

1. Bleeder Type Gun. A gun that bleeds air continually. By "bleeds" is meant an intentional leakage from some part of the gun. This prevents air pressure building up with small air compressing outfits having no pressure controlling device such as Unloader or Pressure switch. In this type of gun, trigger controls flow of fluid only.

2. Non-Bleeder Type Gun. A gun equipped with an air valve which shuts off the air when the trigger is released. In this type of gun, trigger controls both air and fluid. It is used with compressing outfits having a pressure controlling device.

3. External Mix Type Gun. A Gun which mixes air and material outside the Air Cap.

4. Internal Mix Type Gun. A gun which mixes air and material inside the Air Cap.

5. Suction Feed Type Gun. A gun whose Air Cap is designed to create a vacumn (Fluid Tip protrudes above Air Cap) and thus draw material from the container. This type gun is usually limited to quart size containers or smaller.

6. Pressure Feed Type Spray Gun. A gun whose Air Cap is not necessarily designed to create a vaccumn (Fluid Tip is flush with Air Cap). On this type air pressure is required to force material from container to gun.

7. Gravity Feed Type Spray Gun. A gun that can be fed from an overhead container by force of gravity. The Air Cap for this should be of the Suction Feed Type.

For spraying lacquer, any of the above types of guns can be used. However, the gravity feed type is not recommended for use in the school finishing room. The position of the container, on the top or side of the gun, limits not only its capacity, but also the handling of the gun during spraying operations.

The size, material, type, and area of the surface, and the production rate all must be considered in selecting spray equipment. A small gun, with suction feed cup attachment, can be used when it is not practical to use a large separate container with its quantity of one type or color of material. Suction feed is more convenient where spraying is limited to small quantities and different colors. There is no fluid hose or tank to clean.

The pressure-feed tank, or separate container, is used in fast, continuous production. It is also possible to use a pressure-feed cup attachment to obtain the same result as that obtained from the use of the tank. Generally, it is most practical to use a production type spray gun with a variety of air caps and fluid tips.

Parts of the Spray Gun. The spray painter must have a knowledge of his spray gun and the functions of its component parts. This is necessary for the proper adjustment and maintenance of the gun. The modern spray gun consists of two principal parts. They are (1) the gun body assembly, and (2) removable spray head assembly.

The gun body assembly consists of five main parts. These parts are (1) the spreader adjustment valve, (2) air valve, (3) fluid needle adjustment, (4) sprayhead locking bolt, and (5) the gun body. The function of each of these parts is as follows:

1. The Spreader Adjustment Valve. This valve controls the air to the spreader horn holes of the air cap. By means of a graduated dial various spray patterns may be obtained.

2. Air Valve. The air valve is in the gun body and controls the air. It is opened and closed by the pull and release of the trigger.

3. Fluid Needle Adjustment. This valve controls the movement of the fluid needle. This permits more or less material through the nozzle.

4. Sprayhead Locking Bolt. The sprayhead locking bolt locks the removable spray head to the gun body.

5. Gun Body. The gun body has a pistol grip and serves as a housing for the above mentioned parts.

The sprayhead is an assembly consisting of the air cap, fluid tip, fluid needle, and spray head barrel. These parts are removable as a unit from the gun body assembly. The advantages of this feature are as follows:

1. Quick change from one material or color to another. One Spray Gun Body with several heads will answer purpose of what otherwise may require several guns.

2. Ease of cleaning.

3. In case of damage to front of gun, new gun body is not required.

4. An extra Spray Head can be substituted for one being repaired or cleaned. (C2, page 4)

A wide variety of spray heads are available. They incorporate many air cap and nozzle combinations for use with many types of materials. The function of the component parts of the spray head are as follows:

1. Air Cap. The air cap is that part of the front of the gun which directs the air into the material stream and atomizes the material into a suitable spray pattern.

2. Fluid Tip. The fluid tip is that part of the spray head which meters and directs the fluid into the air stream. It provides a seat for the air cap.

3. Fluid Needle. The fluid needle attaches to the fluid needle attachment valve and projects through the fluid tip. It controls the material flow through the nozzle.

4. Spray Head Barrel. That part of the spray head to which the air cap is attached.

The proper combination of air cap and fluid tip must be used to get the most satisfactory performance. The combination for a particular material can be obtained from spray gun manufacturers. Most air caps work best with certain nozzle (opening in fluid tips) sizes.

Standard Nozzle Sizes. The size of a nozzle is indicated by a letter stamped on the collar of the needle and on the outer edge of the fluid tip. Standard sizes are as follows: A - C - D - E - FF - FX - F - G. Size "A" is the largest, and the smallest is size "G". Sizes E - FF - FX - F are most commonly used.

Fluid Containers. There are three types of material containers used with a spray gun. These are cup, tank, and bucket types. They may be made of metal, glass, or paper, and are attached directly to the gun itself, or by means of a fluid hose.

Cup containers are available for suction, gravity, and pressure feed guns. The quart size suction feed type containers are recommended for light and medium weight materials, such as lacquer, that are used in small quantities. These cups have either a screw top or clamp top for fitting to the gun.

For large scale production pressure type material tanks are almost essential. Capacity of pressure tanks vary from one gallon to ten gallons, or more. A good quality tank will be plated on the inside to resist rust and corrosion.

The cover of a pressure type tank contains an air regulating valve, a pressure gauge, air and material outlet tubes, and cut-off valves. The principal of operation is described by Crewdson in his book, Spray Painting, Industrial and Commercial, (A5, page 55) as follows:

> Air pressure is forced on the surface of the material in the tank and causes the material to rise up the material tube and through the hose to the gun. When it reaches the gun head, it contacts the regulated air being forced through the ports and is broken up, or atomized.

The pressure type cup containers operate on the same principal. In this case, however, no fluid hose between the container and gun is used. The cup is attached to the underneath side of the gun, and the fluid is carried to the gun tip by a tube that projects nearly to the bottom of the cup.

Part B. Air Compressors and Accessories

The air compressor selected should produce more air than is actually required to perform the work to be done. The compressor may be either a single stage or two stage type. A single stage type compressor is used where the maximum pressure does not exceed 100 pounds. The two stage type is usually used where maximum pressures exceed 100 pounds. A two stage unit is more economical than a single unit if pressures in excess of 100 pounds are used.

Single Cylinder Compressors. Small, single cylinder, portable air compressors for small jobs will be satisfactory in many shops. Crewdson, in Spray Painting, Industrial and Commercial, (A5, page 56b) describes such a unit as follows:

> The air compressor is piston type, single cylinder and has a 2 inch bore by 1 3/4 inch stroke. Its displacement is 2.2 c.f.m., and the maximum working pressure is 40 pounds. The unit has a small air chamber which removes pulsation, thereby insuring an even flow of air. The air chamber also serves as an oil and water extractor, and is equipped with a safety valve, drain cock and ¼ inch connection for air hose. The ¼ H P electric motor has a long cord and plug so that the unit can be quickly connected to a light socket for instant use. The spray gun is pressure feed type, internal atomizing, and has a one quart metal cup.

A unit such as the one described above is well suited for light maintenance work, small repaint jobs, and finishing of furniture. However, larger capacity piston type compressors with a storage tank are recommended for general use.

Combination Units. Compressor units having an air storage tank may be either stationary or portable. Usually, the portable unit has a smaller air receiver and is equipped with a handle and wheels. When an air receiver is used the compressor should be fitted with an automatic electric cut-out or an unloader. Either the cut-out or unloader causes the intake valve of the compressor to be held open when the pressure in the tank reaches a predetermined amount, thereby preventing the compressor from pumping air. When the pressure within the tank falls below a certain point the unloader, or cut-out, functions to admit air into the compressor.

Air is heated when it is compressed. As the air cools, the moisture, which has been drawn in, condenses and settles in the tank in the form of water. This makes it necessary to drain the tank daily. If this is not done the water will eventually find its way into the hose and onto the surface being sprayed. The use of an air transformer between the tank and the gun will help to relieve this situation, but does not eliminate the necessity of draining the air container daily.

Air Transformers. The purpose of the air transformer is to provide a means for indicating and regulating the air that is delivered to the spray gun. It also serves to collect oil, water, and dirt that may get into the main line. A suitable air transformer consists of the following:

1. Air pressure regulator.
2. Regulated pressure outlets, for spray guns.
3. Regulated pressure gauge.
4. Main line pressure gauge.
5. Main line pressure outlets, for dusting gun, pressure feed tank, or high pressure pneumatic tools.
6. Baffles which trap most condensation in air.
7. Easily replaceable cotton waste filter which removes final traces of moisture from air. It also traps oil and dirt.
8. Conveniently located valve for draining water and oil that has been removed from air. (A5, page 60)

It is advisable to locate the air transformer as far from the air compressor and as near the spray gun as possible. Air is heated as it is compressed, and should be cooled before going through the transformer; otherwise the full benefit of condensation will not be realized.

Hose. The length of the air hose, as well as the inside diameter, is to be considered in selecting and installing spray painting equipment. Both factors present resistance to the passage of air, and if the hose is too long, or the inside diameter too small, the air pressure at the gun will be reduced. For best results the pressure at the gun should be the same pressure as registered at the compressor, or at the transformer, if it is not near the spray gun.

> Fluid hoses also need consideration. The sizes generally used are the 3/8 inch and ½ inch. With small guns and light bodied materials a 5/16 hose may be satisfactory. For heavy bodied materials, a 5/8 inch or a 3/4 inch inside diameter might be required. Fluid hose is of special construction made to resist the action of the solvents in the material passing through. (A5, page 56)

In most school shops the fluid container will be a cup attached to the gun itself, and no fluid hose will be necessary. However, for production jobs where a pressure container of large capacity is used the fluid hose is necessary, and consideration must be given to the selection of the proper size.

Air hose and fluid hose are distinguished by their color. Air hose has red rubber, or orange braid cover. Fluid hose is black. Inside diameter of air hose may be ¼ inch, 5/16 inch, or 7/16 inch. From compressor or air transformer to gun 5/16 inch I. D. (inside diameter) hose is recommended, however, ¼ inch I. D. may be used with small units, provided the length does not exceed 12 feet. If a pressure feed material tank is used, 7/16 inch I. D. is recommended from compressor to pressure tank.

Part C. Spray Booths

The spray booth may be of the dry or water wash type. Selection of the type of booth depends upon the size and shape of the objects to be finished. For the school shop an upright, dry booth is recommended. Relatively small objects requiring a small quantity of lacquer per item can be adequately and safely finished in a dry booth.

Water wash booths are more practical for high speed finishing of large objects. This is true especially in production work where automatic spraying is done. The increased amount of atomized material and over-spray make the water wash booth almost essential in many industrial plants.

Dry Booths. The best way to remove spray vapors is by means of a spray booth with ample exhaust capacity. The vapors from lacquer are toxic and highly inflammable, and it is necessary to remove them from the finishing room. The exhaust fan should have a vapor proof motor and the propeller blades should be of non-sparking metal.

The booth should be equipped with distributing plates between the work and the exhaust fan. These baffle plates cause an even flow of air current toward the exhaust fan, and collect much of the waste material. This aids in cleaning the booth.

Vapor proof and explosion proof lights are necessary. Water or foam type fire extinguishers should be provided. The booth should be cleaned frequently to reduce the fire hazards. Special preparations are available that can be sprayed onto the walls and floor of the booth to form a removable inner lining. When the material becomes laden with lacquer residue it is merely stripped from the walls and destroyed. If such aids are not used it is necessary to scrape the booth at intervals. A special brass, or other non-sparking metal, scraper should be used to scrape the metal sides and floor of the booth.

Turntable. A turntable in the booth is a practical necessity for spraying chairs, tables, and other pieces of furniture. These may be purchased, or made from materials available in the average shop. The use of a turntable makes it unnecessary for the operator to walk around the piece, thus getting between it and the exhaust. Neither will handling the piece be necessary during the spraying operation.

Water Wash Spray Booth. Water wash spray booths cleanse the lacquer laden air by the air wash method. This type booth is recommended in locations where standard exhaust fans would be objectionable, or where a suitable stack can not be provided outside the building. The water wash booth prevents the discharge of heavy solid lacquer residue outside of the building.

CHAPTER VII

SUMMARY AND RECOMMENDATIONS

In the past thirty years the finishing industry has developed to the extent of being one of the world's major industries. The growth and development of the industry is due largely to the development of lacquers and the spraying method of application. The characteristics of nitrocellulose lacquers make it desirable for industrial finishing even at higher original cost than other available materials. Savings in time, labor costs, and storage facilities more than make up for the difference in cost, and many manufacturers use lacquers exclusively.

The most desirable characteristics of a finishing material for furniture are to be found in one or the other of the lacquers available today. Quick drying, hardness of film, resistance to water and alcohol, elasticity, and transparent beauty are some of the desirable characteristics to be had in a lacquer finish. It should be remembered, however, that there is no one "all purpose" lacquer.

In order to obtain the best results in a finish, high grade materials and equipment should be used. Materials should be applied according to the manufacturers specifications. This is especially true with respect to the use of thinners in the lacquer. Using improper thinners can cause disastrous results when the finish is applied.

Recommendations. The finishing department is an important part of an industrial plant, and improvements are constantly sought. The finishing room of the industrial arts shop should occupy a comparable position for student instruction. Where possible, facilities should be provided for finishing student projects by the methods used in industry.

When purchasing equipment for spray paint, reliable manufacturers should be consulted. Generally speaking, production type spray guns with interchangeable spray heads, and compressor with a greater output capacity than needed should be purchased. Maintenance and replacement requirements will be less if this is done.

More emphasis should be placed on the finishing phase of woodworking. Wood finishing can well be made a separate course of study in the school shop at the high school level. Shop instructors can increase their professional knowledge by attending schools conducted by various manufacturers of finishing products.

Problems For Future Studies. There are unlimited possibilities for future studies involving the use of lacquer in school shops. The writer feels that the following studies would be of interest and value to the field of industrial arts.

1. A study of comparative cost of finish coats of lacquer and varnish.

2. A study of special purpose lacquers.

3. A study of the cost of installing spray painting equipment in the school shop.

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