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Title of Study: WATER-RESISTANT GLUES SUITABLE FOR INDUSTRIAL ARTS SHOPS

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Major Field: Industrial Arts Education

Scope of Study: An attempt has been made in this report to compile information about water-resistant glues that may be of benefit to teachers in the selection of the proper glues for industrial arts shops along with general information on gluing. This research study includes a brief history of glue, general information and properties of water-resistant glues, and other information such as safety precautions, and mixing procedure. The technical information was omitted as much as possible in order to make this a report of general nature. Information such as prices may be secured from glue manufacturers and dealers.

The material in this report was secured from periodicals, pamphlets, books, and information sheets furnished by manufacturers of water-resistant glues. The Forest Products Laboratory of the United States Department of Agriculture furnished much material.

Findings and Conclusions: Only a small amount of the material in this report comes from textbooks on industrial arts. In many cases this form of assembly material is neglected in class discussions and study, therefore, many undesirable experiences may result.

Recommendations are made in the last chapter of this report in relation to the proper selection of a water-resistant glue. The types and quantity of material to be glued deserve much consideration in the selection of the proper glue.

ADVISER'S APPROVAL L. H. Bengtson

WATER-RESISTANT GLUES SUITABLE FOR

INDUSTRIAL ARTS SHOPS

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By

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CHAPTER I

INTRODUCTORY STATEMENT

The proper use of materials is a vital function of the industrial arts teacher. It is therefore necessary for the teacher to have a general knowledge of all the materials used as to the history of development, how they are manufactured and distributed, their costs, and most important, the correct usage for best results. The selection of the proper material requires the teacher to possess much information in order that adequate materials are supplied.

The proper instruction on the use of all industrial arts supplies should be a part of the course of study for each field in all industrial arts shops. New uses for old products are continually being discovered as well as new materials with a variety of uses.

Purpose of the Study. The purpose of this study is to familiarize teachers with the types of water-resistant or waterproof glues that are available and suitable for use in industrial arts shops. This study does not contain technical information other than general physical properties such as storage, pot life, and temperature control of glues. Some of the advantages and disadvantages of the glues now available are mentioned.

Statement of Problem. Water-Resistant Glues Suitable for Industrial Arts Shops is the title given this report, as it explains the nature of the study in a short simplified phrase. The selection of the proper glues may be made simpler if the types of suitable water-resistant glues for industrial arts shops are available.

Need for the Study. There are few products that are more important to industrial arts teachers than water-resistant and waterproof glues as methods of joining materials for long endurances under extreme conditions of exposure. This information could be most helpful to industrial arts teachers as it may be collected and filed for ready use when needed. With much consideration of the different developments of this problem, the results indicate a reasonable justification of this study.

Available Literature. The majority of the available literature on this subject comes from the companies that manufacture these products, as not many books have been published on this subject that would be of actual value to the industrial arts teacher. For the most part books that are available are highly technical and designed for the chemist or engineer in the phases of research and production.

There are a few books that are published by associations of glue manufacturers and research institutions that are not of a technical nature and may be understood easily. The information sheets and brochures used by the manufacturers to advertise and describe their products to the public can be secured upon request to the manufacturers and distributors. Publications of this nature supplied much of the material for this report with specification sheets assisting.

Letters Requesting Publications. Letters requesting any information that is published on the types or kinds of water-resistant or waterproof adhesives suitable for use in industrial arts shops, were mailed to manufacturers of water-resistant glues. Replies were received from almost all of the manufacturers still in business with either publications, addresses of authorities, or bibliographies of published material. A number of publications were received from the United States Department of Agriculture, Forest Products Laboratory, Madison, Wisconsin. Samples of glue were received from three manufacturers.

Definitions of Terms. The following definitions are of terms used in this report and are taken from books and periodicals listed in the bibliography.

Adhesive: a product with sticking or adhering qualities that is often referred to as glue, paste, and cement. (12, page 1)

Assembly Period: the time elapsing between the spreading of glue on the surfaces and the application of full pressure to the glue-coated surfaces. (46, page 1)

Catalyst or Hardeners: a hardening agent for synthetic resin adhesives. A substance which influences the speed of the reactions of other substances. (27, page 4)

Cement: a term sometimes used for liquid glue, especially fast-drying tube types of glue. (5, page 489)

Cold Setting: glues that will set at normal room temperature without the aid of heat. (57, page 3)

Filler: walnut shell and grain flours added to the glue to reduce cost or provide body. The adding of fillers lowers the water-resistant qualities of the glue proportionately. (33, page 1)

Working Life: the length of time during which the glue retains fluid enough to be worked. (35, page 7)

Moisture Content: the amount of water contained by the wood. (27, page 7)

Storage Life: the period during which the glue may be safely stored before use. (27, page 6)

Liquid Glue: generally limited to certain glues of animal and sometimes plant origin that are supplied in liquid form ready to use. (41, page 1)

Glue Joint: the parts of the material that the glue is applied to that are to be in contact. (39, page 1)

Synthetic Resins: products of chemistry that originate from raw materials derived from coal, air, petroleum, and water. (42, page 1)

Industrial Arts: the part of general education that deals with experiences in occupations, use of tools and materials, and processes in some form related to industry. (9, page 32)

Manual Arts: an early means of identifying shop instruction, usually of hand projects to develop hand skills. (It was later changed to Industrial Arts.) (9, page 32)

Manual Training: the early type of instruction on shop activity in which manual skill was necessary. (Later replaced by manual arts.) (9, page 32)

Working Drawing: a drawing showing enough information that will enable the item to be made without the need for other information. (7, page 84)

The General Shop: a shop where two or more separate types of activities are taught at the same time by the same teacher. (12, page 25)

The Unit Shop: a shop where only one activity is taught at a time by one teacher. (12, page 98)

This report includes a brief history of industrial arts, a history of glue, and a brief appraisal of gluing. Chapter VI reviews the findings of the report and makes some recommendations. The general nature of this report is to compile useable information on the types of water-resistant glue. Some information on mixing procedures and safety precautions are included.

CHAPTER II

HISTORY OF INDUSTRIAL ARTS

The history of industrial arts had its beginning when human life appeared on the earth and has steadily advanced from that time until the present. The content of this chapter is broken down into the important periods of education that have a direct bearing on industrial arts, the important leaders, their views, results of experiments, and other events that influenced the program.

Early History. Manual skills were developed in the period of savagery to help the prehistoric creature secure food, provide shelter, and devise better weapons for the protection of himself and family. These skills were passed on to the next generation by imitation. Also new skills and procedures were developed by each descendant.

The ancient Jews believed that a boy should be taught a trade, as well as religion. The Jewish law placed the responsibility of teaching the trade on the father. As a result of this thinking, each boy was sent to school for the Rabbi's instruction each morning and the afternoons were spent with the father, learning the father's trade.

Many a famous Rabbi was noted, in addition to his religious duties, for his skills or trades. "The Rabbi who gave one-third of the day to study, one-third to prayer, and one-third to labor was mentioned for special honor." (3, page 14) It was the national belief of the Jews that a manual occupation was one important step in producing useful citizens of society.

The Greeks, during the Homeric age, respected their handicraftsmen, but in later years they took a negative viewpoint of the manual or mechanical arts craftsman. They used slaves and hired persons for these tasks as they believed it would ruin the bodies of the upper classes by depriving them of the time and energy for defense of the nation, social life, and government. Yet these ill-fated craftsmen were the foundation upon which the Greek and Roman civilization grew, by continually improving and passing these skills on to the next generation.

The Dark Ages. The monasteries were the institutions which kept manual arts at their highest during the dark ages of Europe. The monastery was a part of the church the monks used for serious study of religious writings. It was isolated from all outside contacts, yet within their walls they used a method of manual labor that is considered a form of education. The ninth century brought much new construction and rebuilding of these monasteries and the oldest working drawing on record was dated 820 A.D. This drawing was made as a suggestion for rebuilding a monastery.

The Benedictine monasteries developed a high degree of skill in bookmaking as early as 529 A.D. through learning-by-doing. The manuscripts had to be written in longhand, and many hours of labor were required to copy one book. Copy work produced highly skilled scribes. The great demand for books prompted the instruction of scribes.

Printing Press. The invention of the printing press in 1450 enabled the world to put into books more easily the things that had been recorded up to this time in writing by hand. Also, it made these manuscripts available in larger numbers for more people. This revolutionized the teaching methods in use up to the time of the printing press invention.

Apprenticeship. The apprenticeship system came into existence as the craftsmen progressed in knowledge and new skills were developed. It was in use even before any type of formal education was available to the middle and lower classes of population. Apprenticeship, at one time, was used as a final supplement to the formal education in about all types of industrial trades. Education was made available to the paupers and lower classes of the population in this way, since the apprentice was given benefit of all the master's knowledge. The industrial revolution created a need for skilled workmen faster than this process could prepare them; therefore, it became necessary to devise another method which was a vital factor in industrial arts education.

Sixteenth Century. Two fundamental ideas in the modern method of teaching industrial arts developed from the sixteenth century. The first is that impressions are the basis of thought, and consequently of knowledge, the origin of the laboratory method. The second idea, learning by doing, is a process of working with hands and tools to develop a skill. Early thinking led to the adoption of these industrial arts principles. (3, page 30)

During the two centuries after the invention of the printing press, many ideas from leading European educators and philosophers were developed. Martin Luther of Germany (1483-1546) protested against the tyranny and harsh treatment of the boys in the monastery schools. Rabelais (1483-1553), in France, approached knowledge through the use of objects and the observation of processes as he attacked the formalism, insincerity, and shallowness of the Church, the School, and the State. Richard Mulcaster (1531-1611), an English schoolmaster and head of the Merchant Taylor's School from 1561 to 1586, was given credit for establishing drawing, an early form of modern science in education as one of the fundamental studies at that school. Comenius advocated teaching according to the order of nature and the arts, and like Rabelais, he believed that instruction in words and things should go together. Children should learn as much as possible from the Great Book of Nature, and like Luther, he believed there should be schools for both sexes. John Dury, John Milton, Franke, and Rousseau contributed to the advancement in education through their schools and writings. Samuel Hartlib, a civic-minded English merchant, proposed a college of agriculture during this period.

Middle Ages. John Heinrich Pestalozzi (1746-1827), known as the father of industrial arts, was the first man to organize hand work as a regular part of a school program in his many schools and repeated the successful use of manual labor both skilled and unskilled. He also used the later of these two methods in instruction. "Either we go from words to things or from things to words." (3, page 119) The process of teaching from the real objects took the pupils into the fields and shops demonstrating the understanding of the skills desired. Although Pestalozzi never used actual tool instruction, his drawing and form study was definitely in the industrial arts field. As a direct result of his Industrial School established in 1774, many such schools were established in all parts of Europe immediately thereafter.

Philip Emanuel Von Fellenberg (1771-1844) established the Hofwyl School in 1799 using many of Pestalozzi's principles and attracted much attention in Europe and America. Fellenberg believed education must be reformed and extended, but that each class of people should be taught separately. Manual labor was used at Hofwyl for physical training as well as for practical experience. Agricultural, manual labor, and industrial reform schools in large numbers were established as a result of the developments at Hofwyl.

Other educational leaders who used the Pestalozzi ideas and theory were John Fredrick Overlin (1740-1826), of France, who is believed to have established the first infant school, and Robert Owen (1771-1858) who started a school for children, teaching them the weaving trade at Lanark, England. Joliann Fredrick Herbart (1776-1841) and Friederick Wilhelm Froebel (1783-1852) of Germany were influenced by Pestalozzi. Herbart felt that every man should learn to use his hands. The handwork was a method of teaching the subjects of the period, as mechanical dexterity was more important than gymnastics. (3, page 161) Froebel established the first kindergarten school in 1837, built around handwork as the center because education should begin with manual activities.

<u>More Recent Foreign Developments.</u> The School of Trades and Industries of Moscow was reorganized in 1868 and became known as the Imperial Technical School. It was soon recognized as one of the leading schools of that time in Europe. The principle purpose of the school was to develop an educational program for civil and mechanical engineers, draftsmen, foremen, and chemists. The length of the course was six years and the method of instruction resembled that given at the "Ecole

Centrale des Arts et Manufactures in Paris where the course instruction was supplemented through practical experience in the workshop". (3, page 15)

The shops were manned by both hired workers and students; as a result, more attention was given to work experience and less to teaching. Consequently, this phase of learning soon was proved unsatisfactory because of the imitative procedure. This led Victor Della Vos, director of the school, to establish the instruction shops or unit shops separate from the production shops that were building industrial machinery. This educational achievement by Della Vos was the first attempt at organized vocational education for groups in the unit shop with each student having a work bench and a set of tools. This instruction was formal and consisted of making a series of exercise models, each exercise a little more difficult than the preceding model. This course of study was developed through occupational analysis.

The Slovd Movement. During the period of reorganization of the Imperial Technical School in Moscow, the other northern countries of Europe (Finland, Denmark, Norway, and Sweden) were developing the teaching ideas known as sloyd, expressed by many of the German educators in the Scandinavian countries. The movement for this type of instruction in manual arts originated in Germany. Cygnaeus (1810-1888), a Lutheran preacher and teacher, was given the task of working out a system of schools in Finland. Into these schools went a regular course of handwork, with the teacher of these arts being a regular professional teacher and not just a craftsman. The purpose of these crafts was to produce useful objects in the homes, both for home use and for sale.

Also, it provided something to do during the long winter evenings when outside employment was impossible. The tools used were simple and the articles produced were useful. The sloyd movement, which once flourished with vigor, started to decline when the invention of the steam engine provided power for mass production of these articles formerly made by hand in the homes. This left the men and boys with nothing to do in the long evenings but visit the taverns in this period of the nineteenth century. Therefore, by 1846, this situation forced the people to organize associations to combat these evils of leisure. These associations convinced the leaders in national policy of the importance of sloyd.

The Swedish Government took action in 1872 to try to help the advancement of sloyd by granting an annual appropriation of 2,500 crowns, and later increased the amount to 27,000 crowns, to stimulate interest and instruction in sloyd, enabling Otto Salomon to establish a sloyd school in Nass in 1872. The school had a curriculum of carpentry, carving, turning, blacksmithing, basketmaking, saddlery, stone cutting, fretwork, painting, drawing, mechanics, mathematics, and physics. The school used seven hours each day for sloyd and three hours for the rest of the instruction. Also, the school became an important influence in the sloyd movement in later years. (4, page 62) (15, pages 12-80)

The industrial arts movement in Germany received much inspiration from these new sloyd developments in Denmark and Sweden. In 1879-1880 the Leipsiz Society for Public Welfare began a workshop for boys under the leadership of Waldemar Goetze (1843-1898) who was a very progressive leader in the manual training movement in Germany until his death. This industrial arts movement developed by Goetze in Leipzig soon spread over southern and central Germany. The developments were so rapid that by

1909 about forty per cent of all eligible students took part in some form of manual training instruction.

French Influence. Manual training in France was being developed from an earlier type of shopwork instruction which was chiefly economic or industrial in its purpose. Trade and technical schools for boys and girls of twelve years and older were being organized over the nation, and in 1827 the School of Christian Brothers of Saint Nicholas was established in Paris, followed by La Mertiniere School at Lyons in 1831. All of these European ideas in industrial arts had some influence on early American experiments in this field.

Early American Industrial Arts. The industrial arts program was adopted in many European countries and well advanced before its importance was recognized in the United States by many prominent American educational leaders. Much study of the European developments was made and absorbed quickly, as well as ideas coming from the new factory system.

The earliest industrial arts training in the United States took place in the Franciscan mission schools in New Mexico. They taught carving, carpentry, brickmaking, and related skills that would be of benefit to the Indians who inhabited the area. Similar programs were conducted by other missions in California and Florida.

The early English colonists brought some of the industrial arts ideas and methods with them to the new land. One was the apprenticeship method. The colony of New Plymouth in 1641 adopted the English Poor Law of 1601. This law gave the colony the power to apprentice the poor children to provide them with some education. This means of education was particularly successful. Its effectiveness was increased as the town representatives were the authorities.

The First American Public School. The 1647 decision of the General Court of Massachusetts provided the means of public support, creating the first public or free school in America. A school teacher was hired and the teacher's salary was paid by the town citizens. Massachusetts is noted for its early leadership in free education for all classes of the population. The law of 1647 states: "Every township of fifty or more householders must appoint and pay the salary of a school teacher." (3, page 269) After the Revolutionary War, the thirteen colonies began to expand the educational establishments and facilities.

Post Revolutionary Period. In 1787 Cokesbury College in Maryland began to educate students in gardening and carpentry, as an example of early American industrial arts education. The American manual labor movement from 1825 to 1834 brought in many principles of the Fellenberg Academy for the lower classes in America. The difference was that in Europe only the upper class with money for the tuition was admitted and manual labor was used for physical development. The labor was used as a means of payment of tuition and living expenses in the American method. Reverend Elias Cornelius (1794-1832) combined the two aims of Fellenberg and established the Andover Theological Seminary at Andover, Massachusetts. The purpose of this school was to save the souls of the boys and girls by teaching them to read the Bible, and to enable them to earn an honest living. Other schools were the Oneida Institute of Science and Industry at Whitesborough, New York, and the Manual Labor Academy at Germantown, Pennsylvania. The use of manual labor for the purpose of earning board and education, as well as providing physical development as Fellenberg stressed, was the practice of these schools.

The manual labor movement reached its highest point about 1834 and was succeeded in America by the mechanics institute movement which was similar to the movement in Great Britain during the earlier part of the nineteenth century. The first school of this type was established in 1820 by the General Society of Mechanics and Tradesmen of New York City. Another was the Franklin Institute of Philadelphia in 1824. The lyceum movement which had many statesmen as supporters, strived to educate those who could not be educated at the mechanic institute schools and is often referred to as a step in building the American ideal of popular education in applied science and engineering. American higher education was beginning to progress at a more rapid pace.

In 1862 the Land Grant Act sponsored by Representative Justin S. Morrill (1810-1878) of Vermont was passed, creating the state agricultural and mechanical colleges. These colleges brought about rapid growth in shopwork. Instruction in engineering shopwork was needed more after it was realized that graduate engineers with shopwork experience were hired in preference to engineers without this experience. When this was discovered, the new method of Russian shopwork instruction was brought in for experimentation.

Russian Influence in America. Della Vos, in 1876, exhibited at Philadelphia a method of instruction from the Moscow Imperial Technical School that created much interest among American educators. It led to adopting the principle of a separate shop for each unit of instruction with each student having individual work spaces and tools. The student learned the purpose, care, and use of tools by making projects direct from a working drawing. A project had to be completed before a new one could be started. Class instruction of this nature requires more than just enough knowledge to construct the project.

Calvin M. Woodward (1837-1914) of Washington University at St. Louis established the St. Louis Manual Training School in 1880. It was the beginning of manual training secondary schools in the United States with few exceptions. The course of study was primarily manual training and the schools, supported at public expense, were apart from regular high schools. A major factor in getting manual training established in the regular high schools was that leading engineering schools would accept graduates from manual training high schools without an examination. The school administrators began to realize the advantages of manual arts in the high school programs and by 1900 there were approximately one hundred cities that had added manual arts to the general course of education. Industrial arts soon spread throughout the entire educational program, and the training of teachers was begun in universities as well as land grant colleges and normal schools to supply the demand. The next important development in the field of industrial arts education was the Smith-Hughes Act of 1917.

Industrial Arts Since 1917. The Smith-Hughes Act of 1917 started the vocational programs in the United States by federal subsidizing of the fields of agriculture, home economics, and industrial education. There was some clashing of ideas and opinions between industrial arts and vocational industrial education, as there is a close relationship and overlapping of teaching. It was thought that the predominant would absorb the weaker, but these difficulties were soon worked out and each program worked independently of the other. Industrial arts is a part of general education, whereas vocational education trains students for a definite job or for a specific occupation. They are similar as some of the same equipment, teaching methods, and materials are used. The industrial arts has branched into a general shop in addition to the still used unit shop.

The General Shop. The general shop is the teaching of several shop activities at the same time in the same shop by one teacher, as opposed to the unit shop where only one activity is taught at a time. The general shop fits the needs of the 6-3-3 plan of education that was being started by being able to satisfy the requirements of the junior high school that needed a shop program for getting students acquainted and finding interest in the industrial arts program. Also it began to be accepted by a majority of the school administrators in the early 1930's.

During World War II, the industrial arts program was changed to some extent to meet the needs of war production. Since that time, it has been expanding and progressing into the changing peacetime needs of general education.

Modern Philosophy. Basically the philosophy of industrial arts has not changed to the extent of a complete reorganization. The addition of new philosophies in recent years has been necessary to keep the student prepared for new trends as they develop. Modern philosophies are flexible enough to allow for adjustment that results from changing conditions in industry. Many such changes have direct or indirect effect on the economic and social life of the nation.

An exploratory method is used with reasonable success among groups in the elementary grades. The purpose of this is manifold; in addition to satisfying curiosities, developing appreciation, and social adjustments, other worthwhile benefits are achieved. The productive use of leisure time, such as do-it-yourself projects, are encouraged.

The development of a degree of skill in as many fundamental industrial processes as is practical is one of the main objectives of the present-day program. Appreciation of skills and crafts will help increase consumer knowledge of many products. Industrial arts programs are being improved to keep abreast with modern living. The broadening of these programs will be noticed in the future solution of many of the complex problems facing American society.

CHAPTER III

HISTORY AND USES OF GLUE

The story of the origin of the use of glue by mankind remains unknown as far as the actual time it came into use; however, there is evidence of glue being used approximately 4,000 years ago by skilled artisans during the reigns of the Pharaohs of Egypt. It is believed by many that the first glue was of animal origin due to early man being in close contact with animals for the purpose of securing food, clothing, and shelter.

Origin of Glue. Whether the use of glue for holding wood parts together came before metallic fasteners, such as nails, may never be known. It is certain, however, that hand tools with cutting edges of hardened or otherwise processed metals were in use as far back as any records of the use of glue can be established. The ancient Egyptian artisans used a form of glue flakes broken up and heated over a fire. This was probably an animal glue made from cooking hides.

King Tutankh-Amen's (1365 B.C.) tomb was opened by Lord Carnavan and Howard Carter in 1922. The cedar casket which was made by skilled craftsmen had joints fastened with glue, and these glue bonds were still strong.

Some recorded knowledge of glue began to appear about 200 B.C., and claims are made that glue was used in the manufacture of furniture in China prior to the ninth century. The Greeks had early knowledge of glue as stated by the handbook:

> The Ancient Greeks were well acquainted with glue and called it Kolla. This old Greek word is interesting because from it two words have been derived which are important in any account of glue. One of these words is colloid (glue-like) and is the name given to the chemical family of which glue is a typical member. The other word is collagen (glue-producing). It is this name that has been given to the protein which produces glue. (61, page 4)

Recent History of Glue. The first factory for the commercial production of glue was established in Holland about 1690. The first American glue factory was established at Boston in 1808 by Elijah Upton, and in 1814 a patented process for producing glue from animal bones was introduced. Most of this product, like the earlier glues, went into the manufacture of furniture.

The furniture industry was the primary user of glues at this time because it had been found very successful for holding the parts of furniture together without the visibility or bulkiness of other types of fasteners. This knowledge had been passed on to each generation along with new discoveries that improved the quality of glue as well as methods of production. Most of the glue used in the early furniture industry was animal glue; however, the English had knowledge of fish glue. The English had established a glue industry about the turn of the eighteenth century.

The glue industry showed rapid increase during the nineteenth century in the United States in both the number of glue manufacturers and amount of glue used. The twentieth century, however, has recorded so many new developments in glue making and consumption that the glue industry has been expanding rapidly to meet these demands.

History of Water-Resistant Glue. Prior to World War I, glue of animal nature was the only major adhesive that was available in large quantities, and its uses, other than for furniture making, were by the rapidly increasing textile, paper, and book-binding industries. The demands for new types of glues with water resistant properties presented the glue industry with much need for research into the synthetic field.

Waterproof qualities of glue were developed by adding a small quantity (about one per cent) of ammonium or potassium bichromate to glue liquid. This method was followed by adding a small amount of formaldehyde to glue liquid and letting this dry for some time. Another early method of producing water-resistant glues was by the dissolving of glue in equal quantities of water and linseed oil with the aid of heat. Claims were made that each of these methods produced water-resistant or waterproof glue bonds. In 1913, J. A. Taggart states:

> A patented process has recently been put out for which the claim is made that it can be applied to any glue irrespective of grade or make, rendering it absolutely waterproof. The result is attained by mixing the glue with certain chemicals in specified proportions and then adding a certain amount of formaldehyde. Any amount of glue can be treated and the process is said to be most effective. (18, page 84)

World War II brought about large scale uses of glue of synthetic origin in the aircraft and boat-building industries. The glue industry has been able to meet all demands as well as improve the modern adhesive that has been essential in helping to develop and extend the field of plastics. These improvements have increased the strength and added to the life of glue bonds under the most difficult conditions. A large number of other products has been greatly advanced by forms of modern synthetic adhesives that are water-resistant, transparent, heat resistant, and fungi resistant. The animal adhesives did not possess enough of these properties to contribute to this success.

The casein glue is possibly the oldest water-resistant glue known. It will weaken under continuous immersion in water or exposure to extreme dampness, but it possesses water-resistant properties. Casein glue is made from milk and milk products. Casein has been known as food from the earliest times. Egyptian, Greek, and Roman history reveal that the knowledge of cheese made from the milk of domestic animals is very ancient. It is used as an adhesive in the gluing of wood and is believed to be an ancient art. Chinese craftsmen, craftsmen of the ancient Mediterranean countries and European artisans of the middle ages have all left some evidences of the use of a crude casin in wood gluing. It is possible that it was made from the curd of soured milk mixed with quick lime. The elementary use of albumin glues, or dried blood glues, as a wood adhesive, is believed to date back many centuries. The particular characteristic that will rate them as a glue is the ability to convert from an uncoagulated to a coagulated condition. This creates water resistance when used as a wood glue since the coagulated condition cannot be reversed by heat or chemical means without injuring the wood structure first. However, it will lose strength upon aging and is subject to mold and fungi growths.

Some vegetable glues such as soybean glue are water-resistant and resemble casein glue due to the protein content. Fish glues possess some water-resistant properties that are not present in animal glues. This is partially due to the slow drying process which enables the glue to penetrate deeper into the wood.

The synthetic resin glues were used in somewhat limited scale prior to 1935, at which time they were introduced as woodworking glues. The major development on a large scale began during World War II and is still increasing. These resin glues are products of the vast chemical industry that was advanced by World War II and originate from raw materials derived from coal, air, petroleum or natural gas and water. Although the raw materials are readily available, the complex production methods required for resins makes production difficult.

Most types of resin glues, except the polyvinyl-resin emulsion of glues, are thermosetting types, which undergo an irreversible chemical curing reaction that produces insoluble, infusible, glue films in the joint. The polyvinyl-resins emulsions glues are thermo-plastic resins, that is, remain in a reversible state and soften on subsequent heating. All thermosetting resins contain formaldehyde, but the term formaldehyde is usually omitted from the name for simplification reasons. It is during the chemical hardening reactions of the thermosetting resin glues that the joint strength is developed. These reactions may be speeded up by use of a catalyst added to certain resin glues or by increasing the glue-line temperature by different methods. In addition to catalysts, fillers and other substances may be added to resin glues to improve the spreading and penetration properties.

CHAPTER IV

WATER-RESISTANT GLUES SUITABLE FOR INDUSTRIAL ARTS SHOPS

Water-resistant glue has many uses and purposes in the industrial arts shops. Each area has its own need for this type of glue and the correct choice for the specific operation is essential. The preparation and application of each glue should be done according to the manufacturer's directions for best results. The use of water-resistant glues has increased as more information about the benefits from this type of gluing has been released. Many of the difficulties that were encountered in the past have been eliminated by chemical experiment and research. Water-resistant glues are generally thought of as mineral or synthetic glues; however, certain forms of the vegetable and animal glues have been rendered water-resistant by chemical additives or combining with other adhesive resin.

Part A

Mineral and Synthetic Resin Glues

The first major use of resinous glues was in the manufacture of plywood where extremely strong glue bonds are a necessity. World War II created a great need for marine type glue bonds that would resist salt water for long periods. Much chemical research went into the development of the synthetic resins, most of which exist in the mineral elements of nature.

<u>Resorcinol Resins.</u> This form of glue must be used with a catalyst and is now available as a cold setting glue. It is considered waterproof and has been used in marine construction as well as other outdoor items such as army skis and exposed furniture. It is now available in small packages for household and small shop use. Most resorcinol resin that is packaged in small quantities consists of two parts; liquid resins and powder catalyst which may be kept indefinitely in a tightly closed container. The required proportions of each may be measured or weighed according to the specifications for the operation.

The temperature of the storage place for resin or liquid parts has not been determined for periods over one year, but there is evidence that it may be kept indefinitely. Freezing does not have any effect on it as long as it is thawed at room temperatures. The catalyst powder has an indefinite storage life at normal room temperature and is not injured by freezing. This glue has a pot life of about four and one-half hours at seventy degrees Fahrenheit and gradually decreases as temperature rises. It may be spread with a brush, a gun, or regular roller spreading machine. If a roller spreading machine is used, corrugated rollers are recommended.

The assembly time of this glue is sufficient for most industrial arts shops where the closed assembly is used. The closed assembly requires the pieces to be laid together soon after spreading, where all clamps and equipment are handy. There is plenty of time at ordinary room temperature for open assembly in which the glue joint or glue spread is exposed freely to air while other stock is being spread. The thickness of the glue mixture depends upon the moisture content of the wood to be glued, humidity, and room temperature. Work should be laid out so glue spread parts are put under pressure as quickly as possible.

The pressures for resorcinol resin glue bonds range very low with successful results, but best results in the use of any glue are obtained where the glued surfaces are brought into uniform contact. A pressure of seventy to one hundred and fifty pounds per square inch is recommended; however, well fitting joints may require less pressure than a joint that does not make good contact. The length of time pressure is required depends on how the material is handled.

The glue joint will not be damaged by handling and machining if this general rule is applied. When the squeezed out glue from the joint has become sufficiently hard that it cannot be dented with a fingernail or a sharp instrument, the pressure may be removed. A period of from two to five days is required after the removal of the pressure before the joints reach the full capacity of strength and water resistance. The complete curing period may be shortened considerably by heating. For example, hardwood that should stay in the clamps for ten hours at seventy degrees Fahrenheit could be taken out of the clamps at three and one-half hours if the temperature is raised to ninety degrees Fahrenheit. Therefore, temperature is an important factor.

The moisture content of the wood should never be more than fifteen per cent at the time of the spreading operation. Once resorcinol resin type glue has set, it cannot be softened or dissolved as it possesses properties that are irreversible. Other precautions should be taken to prevent physical injury.

Safety Precautions. The hands of the user should be washed frequently in cool or cold water with a mild soap before the glue dries.

Rubber gloves should be worn and non-greasy protective hand creams applied whenever possible. The use of warm or hot water or alkaline cleaners only make the glue dry faster. The catalyst powders give off harmful vapors that cause irritation of the nostrils, watering of the eyes, and severe headaches. Caution should be taken to avoid inhaling the vapor or powder of the catalyst, especially in places lacking ventilation. Allergic individuals or persons with skin eruptions should avoid exposure to resorcinol resin glues and eliminate skin contact as much as possible. Resorcinol resins are destructive to clothing because once set it cannot be removed without destroying the fabric. The brushes may be cleaned in cold water before the glue has dried, and should be stored in cold water.

Phenol-Resin Glue. Phenol-resin glue is available in both hot and cold press types, but the most widely used is the cold press with special acid catalyst that will cure at room temperature. The phenol-resin glues are available in both liquid and powdered form but the short storage life of the liquid makes the powdered form more practical. The assembly time after spreading is about ten minutes at seventy to eighty degrees Fahrenheit, and it is best suited for wood containing about six to twelve per cent moisture. Phenol-resin glued joints, when completely cured, are highly resistant to water, the action of solvents, oils, acids, alkalies, wood preservative, and fire retardant chemicals.

The chemical properties of phenol-resin glues are similar to those of resorcinol-resin glue. However, it gives a dark reddish glue line and is soluble in water or alcohol solution. The commercial mixtures are usually combined with walnut shell flour or other fillers, but the smaller the amount of filler the more durable are the glue bonds.

The use of phenol-resin glues has declined since the mixture of phenol-resin and resorcinol-resin glues has been prepared and marketed. The phenol-resorcinol glues produce a lighter glue line and are cheaper.

Phenol-Resorcinol Resin Glue. The combined preparation of phenol and resorcinol resin glue became available and proven about 1944 for use mainly in wood aircraft construction. Its cold setting, ease of workability, and extreme strength under the most difficult conditions were known before this time, however, it was not available in large quantities due to production difficulties. After much research it is now available in small packages of liquid resin and powder catalyst for home and small shop use. The phenol-resorcinol resins contain a lower resorcinal content, therefore they cure more slowly and are lower in price.

All resorcinol type resins may be used for bonding wood to wood, wood to metal, metal to metal, vulcanized fiber, hard rubber, masonite, glass-fibers, celotex, asbestos, natural and synthetic rubber, acrylic and nylon plastics, plexiglass, lucite, and other materials. The catalyst will differ if both surfaces are absorbent and all surfaces should be free from grease and wax before application. Some surfaces such as plastics, wood, and metals should be prepared by sanding, planing, or similar roughening operations, and rubber should be treated with sulphuric acid. Absorbent surfaces require slight pressures of fifty to one hundred and fifty pounds per square inch while contact pressure is sufficient for non-absorbent surfaces. The assembly time for materials other than wood should be longer. Open assembly time of approximately thirty minutes to allow the solvent an opportunity to escape is recommended by most manufacturers.

Mixing Procedure. Resorcinol resins that are thickened by loss of solvent may be thinned with denatured ethyl alcohol or water, or both; however, the thinner should not exceed fifteen per cent of the resin weight. The catalyst should be slowly added to the resin while stirring. It will dissolve readily, but stirring should continue until the mixture is lump free.

The mixed preparation should stand for approximately ten to fifteen minutes before application to be sure that the catalyst is completely absorbed by the resin; however, the mixing procedure itself usually will not take over ten minutes. If exceptionally large quantities are mixed at one time, the chemical reaction that takes place during the mixing gives off heat, and it may become necessary for the mixture to be cooled somewhat to prevent the pot life from being shortened too much.

Urea-Formaldehyde Glue. This is an easily prepared water-resistant glue that is permanent and has great strength, especially between bonds of wood. Urea-resin glues are available in powder and liquid forms to be used with or without added catalysts, fillers, and extenders; also, urea-resin glues are formulated for use from room temperature settings to hot press settings as required by the operation. The glue lines range from colorless to light tan and have only a moderate dulling effect on tools. The high water and moisture resistance combined with great strength makes it satisfactory for many types of joint-gluing and veneer work; however, it is sensitive to high temperatures and not recommended for much exterior use. Several room temperature-setting urea-resin glues are available in small retail packages for small scale shopwork, and require only the addition of water with the proper agitation to prepare for use. Special modifiers may raise the resistance to elevated temperatures and water-resistant properties for a desired operation; also, the addition of cereal flours reduces the water resistance of the glue in proportion.

The liquid urea-resin glue is a free-flowing, milky white liquid of light viscosity, which may be diluted with water. It has a storage life at seventy degrees Fahrenheit of about ninety days with lower temperatures decreasing the storage life as the viscosity increases with age. The urea-formaldehyde resin adhesives mix easily with the catalyst that is selected for the operation and will yield a practically waterproof bond that is stronger than the wood itself. These bonds will withstand weathering and immersion in water, resist molds and bacteria, are non-staining, and the mixture spreads easily.

The moisture content of the wood should be from six to ten per cent when the cold press method is used. If the materials are too dry they tend to absorb too much moisture from the glue line before it sets. This will result in weak glue joints. Relative humidity of from forty to sixty per cent gives best results. The glue spread should be wet and tacky when pressure of approximately one hundred pounds per square inch is applied, and the thickness of the spread will depend upon the types of wood to be glued. The time between the spreading and applying of pressure will depend upon temperature, humidity, catalyst, etc., but pressure should be applied within twenty minutes for all liquid urea-resin adhesives. The minimum drying temperature should be about seventy degrees Fahrenheit. The pressure time may range from eight to twenty-four hours and after that length of time stock can be worked, but the maximum water resistance and strength will not be reached before about five to seven days.

The powder form of the urea-formaldehyde resins adhesives has most of the properties of the liquid type, and is mixed with water at about five parts resin to three parts water. It may be mixed in any type container except copper. Care should be taken not to allow any alkaline content material to be in contact with urea resins as it will retard the setting. The powder dissolves readily by stirring. The mixture may be thickened by adding more powdered urea-resin or thinned by adding more water. The powdered urea-resin adhesives may be stored two years or longer in a dry place without any damage provided the temperature is approximately seventy degrees. It may be stored for shorter periods at hotter temperatures, but long periods of extreme heat will damage the adhering characteristics.

The time between spreading and the application of pressure is shorter than for the liquid urea-resin. The pressure should be applied within ten to fifteen minutes. Wood with a moisture content up to fifteen per cent may be successfully bonded. The thickness of the spread depends upon the density of the material, and the amount of pressure depends upon type and condition of material. Tight fitting joints require less glue and pressure than a rough fitting joint. Care should be taken to avoid breaking down the fibres of the wood with too much pressure, whereas a rough hardwood joint may require up to three hundred pounds of pressure per square inch. The pressure time will vary from two to twelve hours depending upon atmospheric conditions.

Polyvinyl-Resin Glues. Polyvinyl-resin glue is the newest type of wood glue and is now available in ready-to-use liquid form. This glue sets by losing water to the wood and not by a chemical reaction. It sets at room temperature and leaves a colorless glue joint that does not dull tools. The water-resistant properties have been improved, but the joint will not stand as much stress as other synthetic resins, because they are somewhat elastic. An all purpose glue for both hard and soft wood or combinations of either makes it suitable for home and small shop uses as it possesses these general characteristics: ready to apply, fast setting, odorless, water resistant and unchanged by freezing.

It may be stored in its original container, however, after being stored for some time it may be necessary to discard the film that covers the surface before stirring thoroughly. A small amount of water may be added to improve spreading or to replace the moisture that is lost during the storage period, but normally it requires no dilution or heating. The glue may be transferred to a glue pot providing the pot is not constructed of copper or iron, as they tend to discolor the adhesive and result in a dark glue line. A clean brush is satisfactory for spreading, but the brush should be kept immersed in the adhesive to prevent a film from forming. A spreading temperature of from seventy to eighty degrees Fahrenheit is recommended, but the temperature at spreading should not be lower than fifty degrees Fahrenheit.

The joint should be put under pressure of twenty-five to fifty pounds per square inch within five minutes after spreading. The pressure time may be as short as thirty minutes but the material should not be machined or worked that soon. The curing time before machining should be long enough to prevent sunken joints, and the squeeze-out should be dry enough to have lost its gumminess. This will depend upon weather conditions. Accordingly, the time between removing an assembly from pressure may vary from one hour to several hours due to the amount and type of handling or machining to be done. The maximum strength is attained after five to seven days.

There is no particular advantage in the application of heat in setting as no chemical reaction takes place. Inasmuch as the resins are thermoplastic, the use of heat in setting may be actually undesirable. The rate of setting of glue joints at normal room temperature is comparable to that of hot animal glue.

> Recent studies have indicated that some polyvinyl-resin emulsion glues are promising as replacements for animal glue in assembly joints such as dowel, mortise-and-tenon, and lock corner joints. Their fast setting is an advantage, and the elasticity or cold flow in a nonexposed joint under dimensional changes in the wood may actually be an advantage. (62, page 5)

Melamine-Formaldehyde Resin Glues. Melamine-formaldehyde resin glues are mainly hot press colorless adhesives and are available in both liquid and powder forms, however, the powder form is more widely used as it is water and alcohol soluble. The cured bonds are very water resistant or waterproof and melamine resin glues possess about the same characteristics as phenol-resorcinol resin glues, but they are higher in price. The high curing temperature requirement limits the use of the straight melamine resin glues to a few special applications. These resins, however, are mixed with urea-resins glues to improve the durability and strength of that glue and yet are available at an acceptable price. This combination produces a colorless glue suitable for hardwood as well as softwood and is capable of curing at lower temperatures.

Silicate of Soda Glues. This glue, when combined with casein glues, produces strong glue bonds that are water resistant, strongly resistant to molds and fungii, and relatively low in price. The straight silicate of soda glue is not very successful when exposed to extreme moist conditions. It is soluble in water which made it an early known wood adhesive.

Other Water-Resistant Synthetic Resin Glues. The use of plastics in the industrial arts shops necessitate the bonding of many types of plastic joints. There are many preparations on the market and they are classified as to the type of material used. The most important safety feature required for acetate base cement is proper ventilation, as no acids are involved. The general appearance will be a water white solvent that has low flammability. It may be stored in bottles or non-treated tin containers with no thickening or deterioration from prolonged storage.

Plastic projects cemented with this type of glue will set almost instantly due to the rapid penetration of the solvent. Jigs are necessary only in clamping poorly fitting joints or seams. Handling, buffing, and other finishing operations may be done within an hour after application. Small plastic projects are best cemented by brushing the liquid on one surface and then pressing this surface into position. The surface becomes softened and when pressed into position will adhere to the other surface, leaving a clear, bubble-free seam that is as strong as the plastic itself.

The vinyl plastic base cements are versatile, transparent adhesives that will cement dissimilar plastic and plastics to non-plastics, such as plastics to glass, metal, wood, leather, and fabric; mend crockery, wood furniture, and other general household items. It is not necessary to apply heat or pressure nor to prepare the surfaces to be cemented; however, the type of operation will determine the preparation of the surfaces. These cements are available in two forms, a free-flowing, water-white liquid applied by brush for best results, and a thicker grade which is prepared by dissolving vinyl-plastic powder or vinyl scraps in the thin vinyl liquid. A filler for uneven surfaces may be made by this method. The method for using vinyl-plastic cement is to apply a generous layer to one surface and assemble immediately. Adhesion will result in a few seconds with the full strength of the bond developing in about thirty minutes.

Durability of Mineral and Synthetic Resin Glues. The principal differences between glues of this origin is the durability, or resistance to joint deterioration under normal conditions. Generally the glues of the same type made by different manufacturers are similar in durability but they may have different additives to produce specific results.

The similar glues in durability are the moderately alkaline phenol-resin, resorcinol-resin, and straight melamine-resin glues. When used properly, they will produce joints that are as durable as the wood itself, under all severe conditions. Heat will not destroy the glue bonds before the wood itself is damaged, nor are the bonds weakened by fungi or bacteria, and termites avoid the glue bonds.

The water resistance of the glue joints is high when the joint is properly fitted. High humidity, exposure, and continuous immersion in water will not destroy the joint. Thus, in general it is hard to destroy the joint without first destroying the wood itself. (27, page 21)

Part B

Animal Glue

Animal glue is the oldest type of glue known to man. It is an organic colloid of protein derivative which has adhesive producing characteristics. The maximum potentialities of this adhesive were not developed until the last quarter century when extensive research was begun to meet the demand for large amounts of glue required in American manufacturing.

Animal glues, being a protein derivative, are easily made water resistant by treatment with agents that are insoluble in water. Formalin and formaldehyde-yielding chemicals with sodium acetate are used extensively in rendering animal glue water resistant, as their reactions are easily controlled. The water resistant animal glue of this nature possesses a high melting point, is stable against changing atmospheric conditions, and will hold up after limited water exposures. Glue bonds of this type are not exceptionally hard but rather flexible to allow for the swell that develops in the wood as it absorbs moisture and contracts as the wood dried out, without danger of cracking or breaking apart at the joints. Thus, it provides a live type glue bond.

Casein Glues. Records show that casein glue was used by the Egyptians five thousand years ago for gluing woods and papyrus. It was probably made by ancient wood craftsmen by mixing curds of sour milk with some form of quick lime.

The use of casein glues did not become very important until World War I when a satisfactory water resistant glue was needed for airplane construction. Much research went into the development of casein glue during that period and after World War I to satisfy the need of the fast growing aircraft industry.

The principal ingredient of casein glue is skimmed milk treated with weak acids to separate the curd from the whey. The whey is removed and the curd is dried and ground into powder to become raw casein. The raw casein is screened and classified according to types of glue desired by the manufacturer, then mixed with lime and other alkaline solvents, depending upon the specifications. Large consumers may purchase the raw products and blend them according to their requirements, but for small shop use it may be purchased in small prepared quantities as needed.

Casein glue has extensive use where water resistance is required. It is satisfactory for assembly gluing. The sensitiveness to workroom temperatures as low as fifty degrees for many glues does not affect casein glue which will set successfully at low temperatures. The bonds between rough and poor fitting joints are held securely by casein glues.

The water resistance will depend upon the mixture used. Many recently released preparations are claimed to hold successfully material that has absorbed up to twenty per cent moisture, and the growth of molds and fungi have been held to the minimum.

The stains that result from the reactions of the alkali in the casein glue and the acid in the wood may be reduced by lowering the alkaline content of the glue, thus reducing the water resistance.

The mixing procedure is simple with proportions of about one part casein mixture to two parts water by weight. Small prepared packages on the market may vary slightly as to mixing instructions but the powder mixture is added slowly to the water while stirring slowly. Lumps will appear at first, but after standing about fifteen minutes they will break up and a smooth spreading glue is obtained.

The assembly period of casein glues is about fifteen minutes under normal conditions, and pressure should not be less than one hundred pounds per square inch for soft woods and two hundred pounds per square inch for hard woods. The pressure time is approximately twenty-four hours for most assembly operations with full water resistance reached after five to seven days.

Casein glues that have been treated by adding copper salts have increased the water resistance in addition to producing more durable bonds when exposed to mold and fungi. Copper chloride or copper sulphates are dissolved in water and added to the mixed casein glue. The adding of copper salts to the casein powder glue before soaking may cause corrosive action to metal containers when the glue is soaked and mixed. A smooth violet-colored glue will result.

Casein glues containing a little lime are improved greatly by the addition of copper salts. A low lime content casein glue will be more resistant to moisture than a glue with more lime in it, and copper salt does not shorten the life or period of workability of the glue as much as more lime would.

Part C

Vegetable Glues

Vegetable glues are principally made of starch type glues that contain little if any water-resistant properties. However, vegetable glues with high protein content, such as soybeen base glues, have a water resistance similar to casein glues.

Soybean Glues. These are glues made from soybean protein and were introduced about 1925 for the manufacture of plywood. Soybeans are not a native product of the United States but are an imported crop that has been adapted to the agriculture in this country in recent years. This large scale production of soybeans has made soybean protein-base adhesives the most economical water-resistant glue on the American market. The properties of soybean glues, like many new glues, have brought about many changes and adjustments in the glue industry, and they have taken a prominent place in the American glue industry.

The properties of soybean glues are similar to all protein base glues but do not have much tackiness and their flowing characteristics resemble cements. The assembly period is twenty to twenty-five minutes between spreading and applying pressure. The high alkali content of soybean glues has about the same staining effect as casein glue on light woods.

CHAPTER V

A BRIEF APPRAISAL OF GLUING

New and interesting wood products are being released to the public every day. These include all kinds of do-it-yourself items the handyman can easily make of wood and other materials. These items generally require simple and complex gluing operations, yet seldom is any mention made as to the type of glue best suited or the best gluing procedure. Information on gluing is necessary because it is as much a part of the entire operation as cutting, machining, assembling, and finishing.

The glue industry has kept pace with home craftsmen by making literature available that will assist in the selection of the proper glue for the best results on each requirement. In many events, however, a popular glue will be misused and the project will give unsatisfactory service. This will often discourage the use of a satisfactory glue for many other purposes for which it has been proved to be ideal.

New glues should be evaluated for operations, durability, and water-resistance before being introduced to the general public. The proper procedure for the best results for the joints of different construction and performance will prolong actual life of the project. Joint qualities will depend upon both the glue and the method in which the glue is used in the gluing operation. Therefore, both the user and manufacturer have the responsibility for the proper results. The problem of estimating the probable performance of glues of different materials, under different conditions, for different types of service, is highly technical and may be treated as such, but the consideration of a few factors may result in more satisfactory experiences. To assure good glue bonds, the United States Plywood Corporation lists the following seven steps in correct gluing techniques.

1. Good quality glue.

2. Mix carefully in proportions as directed by the manufacturer. Be sure mixing equipment is clean.

3. Surfaces to be joined must be well fitting -- (any part of the joint which is concave or convex gives that much less gluing contact and weakens the joint). The surfaces must be clean and free of dust, oils, resin, gum, sealers, finish, and oxidation, which are incompatible with the absorption of glue into the pores of the wood.

4. The mixed glue, the wood, and the workroom temperature should not be lower than seventy degrees Fahrenheit.

5. Spread the glue over one hundred per cent of the surface. No bare spots. Excess glue in one spot may or may not spread over bare spots. The quantity spread should be sufficient to cover both sides after they have been brought together.

6. Assembly time: that period in which pressure must be completed before any part of the glued surface loses its tack.
   a. Open Assembly -- where surfaces to be joined are kept separate and apart freely exposing the spread glue to the air.
   b. Closed Assembly -- where pieces are laid together as soon as the spreading has been done.

   The assembly time is that period from the commencement of the spreading operation until pressure has been completed. Temperature and humidity prevailing at the time of gluing influence the assembly time.

   The assembly time for open assemblies is somewhat shorter than for closed assemblies.

7. Pressure -- must be adequate and uniform. The old woodworkers had an axiom -- "Wood must come to wood".

> In all cases pressure should be such that the surfaces are brought together over one hundred per cent of their surfaces and all excess glue squeezed out. It is impossible to accurately recommend the pressure in pounds per square inch since this is influenced by the type of work being glued. Generally, seventy pounds per square inch on joining work and one hundred fifty pounds to two hundred fifty pounds per square inch on flat work is correct.
>
> Duration of pressure should be for such time as will set the glue to withstand any weakening from pulling-away-action of the wood -- usually 2 to 7 hours. Where the assembly is subjected to further woodworking operations at great vibration, additional time under pressure is advisable. (63, page 1)

Possible Causes for Defective Joints. A glued joint of wood may give excellent service if properly fitted, made of suitable material that is properly seasoned, and the correct glue is chosen. The factors are necessary but the exposure of the joint under each condition may vary. External and internal pressures on a joint may appear to exceed requirements by being capable of supporting greater stress and strains yet break down under lesser strains. Moisture from the air entering the wood pores may cause the fibres to expand, or fast drying may cause fibre contraction. These are internal pressures that cause breaking down of the glue joints. Unforeseen failures may be avoided by a little knowledge in the form of instructions as to the general purposes of the glue and conditions upon which best results may be expected.

Water or moisture may have effect directly upon the glue itself by softening it. This may be exceptionally true of the older types of non-resin glues. Also, moisture may start chemical reactions with protein base glues. Few glues on the market are actually soluble in water after being properly cured but some will absorb water in the same manner as the wood to cause a softening effect that results in a weakened joint, which may give way at a later time to either external or internal pressures.

Heat and cold may effect some plastic-type glues. A softening effect may result from only mild continuous heat, or a crumbling and cracking from excessive cold temperatures. Heat will tend to speed up a chemical reaction, and is probably an important factor in the short durability of some glue joints where chemical change takes place. A chemical reaction may result from treated wood which contains substances that react with a chemical in the glue. Chemicals in the glue may destroy the wood around the joint, and it is possible that some acids in untreated wood may react unfavorably with some glue used, but this has not been established with much validity. The durability of a glue joint is dependent upon many factors, Mr. R. F. Blomquist states:

> Both the initial quality of a glue joint and its durability under expected service conditions must be considered in selecting a woodworking glue. Factors that cause glued joints in wood to deteriorate include moisture, heat, microorganisms, and mechanical stresses that develop as a result of dimensional changes in the wood. Methods now available for evaluating the durability of glued joints include long-term exposures of controlled conditions and weathering, actual service tests, and accelerated durability tests. The advantages and limitations of each of these methods is reviewed with typical examples. There is a great need for further coordinated service testing and the development of more reliable accelerated durability test methods for glues and glued products. (43, page 1)

<u>The Selection of a Satisfactory Glue.</u> The number and types of trade name brands of glues available to the industrial arts teacher often make the selection of proper glue difficult; however, this choice may be simplified by keeping in mind the type of gluing jobs that is

most likely to be presented. A reference may be kept from past experiences, manufacturers literature, and independent or government research reports.

Kind of Glue Joint Involved. The design, size, and type of materials used require consideration as well as the type of joints. Some joints such as a butt joint of two end grain surfaces may be very difficult to glue satisfactorily with any glue, whereas other joints may be glued successfully with almost any type of glue. Glues are classified generally for the job they are best suited, some for light assembly work with the aid of dowels or dovetail joints, and others for the heavier types of assemblies. The ability of some glues to serve successfully for a variety of purposes must not be overlooked.

Consideration of Available Facilities. The requirements of some glue for special facilities to produce satisfactory results must be considered. Equipment will vary for different types of glues. However, many glues are suitable for some phases of industrial arts shop use with general equipment available. The selection of glues for small projects is likely to be more difficult than for larger operations due to special equipment needed. The temperature requirements for the shop, the material used, the length of time needed for pressure, are important in selecting a glue. Glue must have a reasonable pot life before spoiling as well as a fair storage life before preparation for use, as many supplies are purchased in advance for industrial arts shops.

The Length and Type of Service Expected. The type of service expected from a glue joint requires some care in selection of the glue.

All glues, when properly used, will in most cases give high original dry-joint strength, if that dryness is retained; however, the resistance of the glue joints to deterioration in undetermined service has influenced the wider use of improved resistance types of the newer resin glues such as phenol-resorcinol and melamine-resin glues which will withstand severe conditions.

The Cost of the Glue. Since prices of material are important in industrial arts shops, the wise purchase of glues is necessary. The cost must be considered as to waste due to short pot life, mixing, and types of spread required. There will be no price list included in this report because prices and conditions are constantly changing, however it is recommended that prices be investigated at the same time the proper glue is selected.

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

The industrial arts program is an important section of general education. Its position is continually expanding to keep abreast with constant advancements and changes in this highly industrial and technical society. This situation is forcing the schools to give the younger generation more understanding of this new era of automation that the world is now entering. This is being done to the extent of teaching the basic information and practical skills in many fields of the most rapid advancing industries that have practical teaching materials available.

The purpose of developing recreational and vocational ideas is to put to beneficial use the more leisure time that is becoming available to each new generation, to maintain the appreciation for good workmanship and design of the past and present, and to increase the consumer knowledge on the purchase, use, and maintenance of the modern products of everyday living. Vocational ideas may be developed by exploring different fields offered in industrial arts which may lead to the discovery of an interest that will encourage further exploration and possibly lead to the selection of a life profession.

Responsibilities received in industrial arts courses will develop the characteristics of good leadership, social relationships, cooperation, and general understanding that are necessary in developing youth for good citizens.

<u>Summarized Findings.</u> The importance of the information available on the use of water-resistant and waterproof glue is impressive. Much material is available describing the chemical and physical properties, recommended application procedure, and precautions, of water-resistant glue. It is rapidly becoming one of the leaders in the field of fasteners by the wide acceptance received by the American industrial and technical society. This subject requires far more study than what is covered in this report.

An attempt is made in Chapter IV to list the water-resistant glues in three groups; synthetic resins, animal, and vegetable glues. The synthetic resin glues are perhaps the most water-resistant and have been given much research in their development of new uses and strength. The popularity of these glues is increasing rapidly since they are now available in small packages at reasonable prices, and the strength and durability under the most severe conditions are astounding. The others mentioned have their place as water-resistant glues, many for special situations or base mixtures for other preparations.

The industrial arts teacher may improve the quality and durability of many projects made under his supervision by some general knowledge of these new preparations. A file of information sheets and brochures may be obtained from manufacturers of glue and research foundations to provide up-to-date information on these products and the requirements they will meet satisfactorily.

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47. Resorcinol Resin Adhesives and Catalyst, Monsanto Chemical Co., Seattle, Washington, October 1953, No. W D 4, 6 pages.

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59. Vinyl-Plastic Base Cement, Schwartz Chemical Co., New York, Data Sheets, R-51, V-5, n.d., 2 pages.

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APPENDIX A

MANUFACTURERS OF WATER-RESISTANT GLUES WHO REPLIED TO REQUEST FOR INFORMATION

1. Armour and Company, 1355 West 31st Street, Chicago 9, Illinois.
2. The Arabol Manufacturing Co., 110 E. 42nd Street, New York 17, New York.
3. Armstrong Cork Co., Lancaster, Pennsylvania.
4. Armstrong Products Co., Argonne Road, Warsaw, Indiana.
5. American Cyanamid Co., 30 Rockefeller Plaza, New York 20, New York.
6. American Polymer Co., Peabody, Massachusetts.
7. The Borden Co., 350 Madison Avenue, New York 17, New York.
8. B. B. Chemical Co., 784 Memorial Drive, Cambridge 39, Massachusetts.
9. Bond Adhesives Co., 537 Johnson Avenue, Brooklyn 37, New York.
10. Bakelite Corporation, 30 East 43rd Street, New York 17, New York.
11. Catalin Corporation of America, 1 Park Avenue, New York 16, New York.
12. E. I. DuPont de Nemours and Co., 2607 Live Oak Street, Dallas, Texas.
13. Forest Products Laboratory, Madison 5, Wisconsin.
14. H. B. Fuller Co., 181 West Kellogg Blvd., St. Paul 2, Minnesota.
15. Koppers Co., Inc., 4101 San Jacinto, Houston 14, Texas.
16. Monsanto Chemical Co., 911 Western Avenue, Seattle 4, Washington.
17. Minnesota Mining and Manufacturing Co., Detroit 2, Michigan.
18. National Casein Co., 601 West 80th Street, Chicago 20, Illinois.
19. National Adhesives, 3641 S. Washtenaw Avenue, Chicago 32, Illinois.
20. Nickey Brothers, Inc., 2700 Summer Avenue, Memphis 12, Tennessee.

21. Praisley Division of Morningstar, Nicol, Inc., 1770 Canalport Avenue, Chicago 16, Illinois.

22. Rohm and Haas Co., Washington Square, Philadelphia 5, Pennsylvania.

23. Barrett Division, Allied Chemical and Dye Corporation, 40 Rector Street, New York 6, New York.

24. Synvar Corporation, Wilmington, Delaware.

25. United States Plywood Corporation, 55 West 44th Street, New York 36, New York.

26. Schwartz Chemical Co., Inc., 326 West 70th Street, New York 23, New York.

27. Timber Engineering Co., 1319 Eighteenth Street, N. W., Washington 6, C.

28. Nickolson and Company, 161 First Street, Cambridge 42, Massachusetts.

29. Philadelphia Quartz Co., Philadelphia 6, Pennsylvania.

30. Forest Products Research Society, Box 2010, University Station, Madison, Wisconsin.

31. National Association of Glue Manufacturers, Inc., 55 West 42nd Street, New York 36, New York.

APPENDIX B

LETTER MAILED TO MANUFACTURERS

A copy of the form letter which was sent to the manufacturers of water-resistant and waterproof glue is on the following page.

OKLAHOMA INSTITUTE OF TECHNOLOGY
OF THE
Oklahoma Agricultural and Mechanical College
SCHOOL OF INDUSTRIAL ARTS EDUCATION
AND ENGINEERING SHOPWORK
Stillwater, Oklahoma

Gentlemen:

I am starting a research project as a partial fulfillment of the requirements for a Master of Science degree at the Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma. This report will be confined to the types or kinds of water-proof or water-resistant adhesives suitable for use in industrial arts shops. Mr. L. H. Bengtson, Associate Professor, School of Industrial Arts Education and Engineering Shopwork, is my major advisor.

I would appreciate any information that is published by your company about this subject. Please send duplicate copies of this material to my advisor, Mr. Bengtson, for his files.

Sincerely yours,

Bobby W. Long
145 North Academy Street
New Braunfels, Texas

Approved by:

L. H. Bengtson

L. H. Bengtson, Associate Professor
School of Industrial Arts Education
and Engineering Shopwork

VITA

Bobby Wayne Long

Candidate for the Degree of

Master of Science

Report: Water-Resistant Glues Suitable for Industrial Arts Shops

Major Field: Industrial Arts Education

Biographical:

Personal Data: Born at Wister, Oklahoma, June 20, 1926, the son of Samuel Jesse and Ida Long.

Education: Attended elementary, junior high and high school at Wister, Oklahoma. Graduated from Tulsa Central High School, Tulsa, Oklahoma, in 1944. Received Bachelor of Science degree from Southeastern State College, Durant, Oklahoma, in 1949. Began graduate study at Oklahoma Agricultural and Mechanical College in the summer session, 1950.

Professional Experience: Taught junior and senior high school industrial arts, mathematics, and social studies at New Braunfels and Chillicothe, Texas, and Whitesboro, Oklahoma. Served in the United States Navy during World War II. Business experience consists of employment by automobile dealership and one year as machine operator in a machine shop at Tulsa, Oklahoma.

Member of Iota Lambda Sigma.

Title: WATER-RESISTANT GLUES SUITABLE FOR INDUSTRIAL ARTS SHOPS

Author: Bobby Wayne Long

Report Adviser: L. H. Bengtson

Typist: Dorothy Watkins