

Preparation of Corrugating Adhesives

*A Project of the Process and Quality Control Committee,
Corrugated Containers Division*

W. O. Kroeschell, Editor

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Preface

This monograph is really a revision of Special Technical Association Publication (STAP) No. 3 which was so popular that it has been unavailable, except on microfilm, for several years. The present monograph is constructed on the base of that STAP published in 1965. Since much of that work is still valid, it forms a considerable part of this monograph. For that we acknowledge with highest praise the contributors to STAP No. 3: F. G. Ewing, Clinton Corn Processing Co.; M. L. Hamilton, Container Corp. of America; D. E. Lucas, Corn Products Sales Co.; A. L. Magnuson, Potlatch Forests, Inc.; and C. B. Myers, Diamond Shamrock Corp.

The purpose of this monograph is no different from STAP No. 3. It summarizes available information on adhesives used in the corrugating operation in manufacturing corrugated board. Now as then, the most widely used materials are based upon starch, sodium silicate, and synthetic resins, but considerable modifications and improvements have been made since 1965. Automatic and semi-automatic equipment has been developed for adhesive preparation. The authors of the monograph have tried to include all those innovations which have been commercially proven.

The sponsoring Process and Quality Control Committee and its division, the Corrugated Containers Division, authorized the preparation of the monograph because increasing demand for a reprint of STAP No. 3 indicated a real need for the information within the industry. The changes made dictated a revision rather than a reprint. The Task Group also decided to present the data in the metric system as well as British units to give the monograph wider applicability throughout the world.

Proper adhesive preparation is an essential element to the manufacture of good board off the corrugator. The monograph not only tells how to prepare the adhesive but describes proven quality control methods to evaluate the preparation. Special adhesives have been a key to the broader use of corrugated board in new applications.

The monograph was prepared by the Task Group listed on the Contributors Page. In general, a chapter was prepared by one of the authors and edited for clarity and accuracy by one of the reviewers.

PREFACE

Upon combining, however, it was frequently felt desirable to locate certain sections in other chapters; therefore, no single chapter is really the work of a single author. We acknowledge with thanks the work of each in completing this volume.

In addition to the authors, credit should be given to the reviewers: W. T. Gooding, Diamond Shamrock Corp.; S. Lagergren, Container Corp. of America; W. MacDonald, International Paper Co.; R. K. Miller, Union Camp Corp.; and M. Wolf, Tri-Wall Containers, Inc. Also, we acknowledge with thanks the contribution of the following persons who commented and edited parts of the manuscript: Harry J. Bettendorf, Walter Halpert, J. B. Abston, F. E. Paluch, R. J. Croker, and P. R. Warren.

We are indebted to the Corrugated Industry Development Corp. tion, J. F. Stevenson, Managing Director, for permission to include the description of the adhesive consumption system developed by them. The description was written by E. A. Biorseth of the Mead Corp. and W. A. Nikkel of the Westvaco Corp.

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Contents

Preface.....	v
Contributors	x
CHAPTER	1
1. Introduction.....	1
History.....	1
Starch Manufacture	2
2. Preparation of Starch Adhesives.....	5
Introduction.....	5
Equipment for Starch Adhesive Preparation, Circulation and Storage	5
Typical Preparation Equipment Capacities	5
Various Systems Available	8
Two-Phase System	8
Ringwood Automatic Adhesive Preparation System.....	8
Adhesive Mixing Equipment Automatic Starch Preparation System	10
Viscomatic Process	11
Circulation	14
Circulation Equipment.....	14
Additional Equipment and Care	17
3. Starch Formula Variables	18
Introduction.....	18
Importance of Correct Formulation.....	18
Two-Tank Mixing System.....	19
Single-Tank Mixing.....	22
Two-Viscosity Starch Adhesive Systems.....	23
Special Adhesive Formulae.....	25
Materials Available	26
Modified Corn Starches.....	26
Chemically Modified High Amylose Starch.....	26
Chemically Modified Waxy Maize Starch	27
Chemically Modified (Ethylated) Corn Starch	27
Wheat Starch Adhesive.....	28
Special Formulas for Heavy Domestic Board.....	28
Viscosity	29
Adhesive Solids	30
Gelatinization Temperature	31
Borax, Its Functions and Use	31
4. The No Carrier System	34
Introduction.....	34
Typical Formula.....	34
Equipment	35
Flexibility of the Adhesive Formula and Process.....	36

CONTENTS

Viscosity and Water Binding Characteristics	37
The Board Produced	37
5. Special Starch Adhesive Formulations	38
Introduction.....	38
Water Resistant Adhesives	38
Resin Additives.....	39
Urea Formaldehyde Resins	39
Ketone Formaldehyde Resins	40
Special Proprietary Adhesives	41
Calcium Cyanamide/Formaldehyde	41
Resorcinol Formaldehyde.....	42
High Amylose Adhesives.....	43
How to Run Water Resistant Adhesives	44
Other Starch Adhesives for Specialty Uses	44
Low pH Adhesive	44
Mold Resistant Adhesive	45
Resin Emulsion Adhesives.....	46
6. Quality Control of Starch Adhesives.....	47
Introduction.....	47
Viscosity Test	47
Procedure.....	49
Gelatinization Temperature.....	50
Procedure.....	51
Equipment and Procedure for Determining Gel Point.....	53
Solids Content	54
Equipment and Procedure.....	56
Iodine Staining of Glue Lines.....	56
Procedure.....	56
Adhesive Consumption.....	57
7. Analysis of the Glue Lines in Corrugated Board	60
Introduction.....	60
Experimental Approach	62
Single Face Glue Line.....	63
Double Face Glue Line.....	69
Quality Comparison of Glue Lines	71
Summary.....	73
8. Silicate of Soda	74
Introduction.....	74
Pumps and Piping.....	74
Quality Control.....	75
Specialty Silicate of Soda Formulations	75
Self-Cleaning Clay-Silicate Process	76
Clay-Starch-Silicate.....	79
Hot Clay-Silicate	81

CONTENTS

9. Protein/Silicate Corrugating Adhesives	83
Introduction.....	83
General Properties, Reaction of Soy Proteins	84
Protein/Silicate Waterproof Adhesives	85
Basic Heat-Set Waterproof Formula.....	86
Modified, Lower Cost, Protein/Silicate Heat-Set Water-Resistant Adhesive	87
Basic Cold-Set Waterproof Protein/Silicate Adhesive.....	88
Plant Scale Formulas and Mixing Instructions	89
Protein/Silicate, Heat-Set Waterproof.....	89
Protein/Silicate, Flour Extended.....	90
Protein/Silicate, Cold-Set Waterproof.....	91
 References.....	 93
 Index	 94

Introduction

HISTORY

The first adhesives used in the corrugating industry were cooked starches and flours that were prepared by heating these starches with 12-15 parts of water. The warm starch adhesive was applied in much the same manner as is done today. While these mixtures produced very satisfactory adhesive bonds, operating speeds were very low because of the necessity of removing the relatively large amount of water from the adhesive line. Commonly, the single face operation had to be performed separately from the double backer operation in order to allow time for the adhesive to set.

By World War I, silicate of soda had been introduced and rapidly became the industry standard. Since the combining formulation contained very little water, it was well suited to a corrugating operation with limited heat facilities. Silicate bonds by the loss of water, by evaporation and penetration into the liner and medium. This can be accomplished at ambient conditions but, of course, is accelerated by elevated temperature; the faster the need for adhesion, the more heat is required. Silicate added substantial weight to the finished board, was brittle and stiff, and made a firm, hard board with a good printing surface. Silicate of soda, a general term applied to a group of commercial materials composed of different proportions of sodium oxide (Na_2O) and silica (SiO_2), is manufactured by fusing a mixture of sodium carbonate and sand in open hearth type furnaces at 2400-2700°F. The resulting fusion product, upon dissolving in water, gives a practically clear, viscous solution at high concentration. The adhesive is generally sold as a water solution, with concentrations closely controlled to give viscosities suitable for the intended applications. Delivered in this liquid form, it is ready to use without further processing unless special properties are desired. Sodium silicate may also be obtained in solid glass form (briquette or crushed). In this case, the glass is dissolved in water under heat and pressure to produce the adhesive of desired characteristics.

The economics and operating characteristics of silicate of soda had to be equaled by starch before it could compete in the field of corrugating adhesive. The concept of cooking starch *in situ* was first mentioned by Lawrence L. Duerden who developed a double facer corrugator section for Robert Gair Co., date of patent, March 7, 1899. However, the concept was not pursued and commercially developed. In 1934, Jordan V. Bauer of Stein Hall Co. conceived the process which was patented in 1936 and has led to the broad acceptance of starch as a corrugating adhesive. The process consisted of a novel manner of using a starch adhesive where high temperatures are available after the adhesive line has been formed. The starch adhesive principle is based on the suspension of raw, or uncooked, starch by a cooked starch carrier or viscosity stabilizer. The carrier provides sufficient viscosity or body to allow deposition of the adhesive film on the corrugated flutes. As the combined board is subjected to the heat of the corrugating operation, the uncooked starch on the adhesive line gelatinizes or thickens to form the adhesive bond.

While the principle of the starch adhesive is not complex, many formulation variables and mixing techniques are involved in obtaining the best operation.

The preparation of the carrier or suspending starch is improved by the presence of caustic soda during the cooking process. The alkali serves to lower the temperature at which the starch will gelatinize. It improves the cohesiveness of the finished formula and provides the means of controlling the gel point of the mix.

The uncooked starch portion of the adhesive is simply suspended in water to which borax has been added. When the cooked carrier is combined with the raw starch and applied to the paper, the borax improves the starch adhesive by increasing the tackiness.

Other additives are included in this basic formula. These will be described in detail in the following pages.

The basic concepts of the starch adhesive are applicable to starch products from all the usual sources. Corn starch is most widely used, but tapioca, wheat, and potato starches also provide satisfactory adhesives in this basic preparation technique.

STARCH MANUFACTURE

The term starch covers a number of related substances. In nature, the starch is found as microscopic granules. In the plant, the starch will be

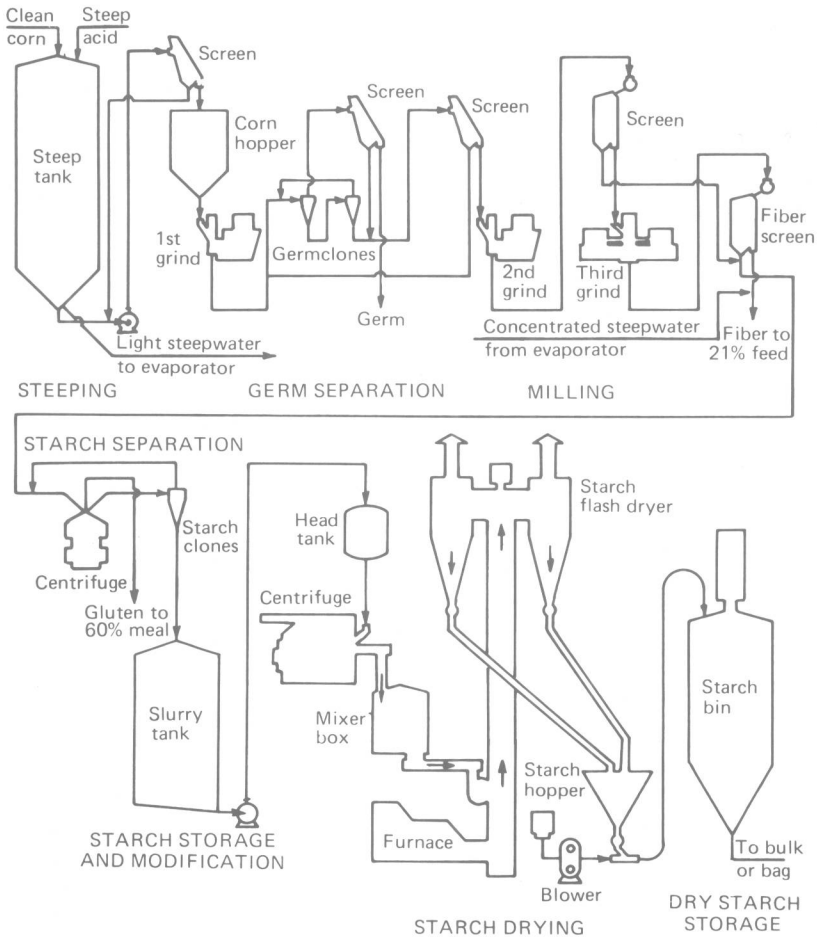


Fig. 1.1. Manufacture of starch schematic flow diagram.

found with proteins, other carbohydrates, oil, fibrous and inorganic materials. Corn kernels contain about 60–65% starch. After separation of the other materials, the starch is obtained as a granule. The shape of the starch granule may be oval, spherical or irregular, and the size is usually in the range of 2 to 150 microns (0.1 to 6 thousands of an inch) in diameter.

Basically starch is a carbohydrate, a polymer of glucose. When completely broken down by acid hydrolysis, starch yields D-glucose. Indeed this process is used to produce this sugar. Two principal kinds of carbohydrate or polymerized glucose are found in starch. These are the straight chain polymers called amylose and the branched chain, amylopectin. The proportions of the two materials will vary considerably depending upon the source of the starch. Ordinary corn and potato starches contain about 20% amylose.

In addition to carbohydrates, the starch granules contain a number of minor constituents, fatty acids, phosphorous, silica acid, and nitrogenous substances.

Starch grains are insoluble in cold water even after prolonged soaking, but after the outer membranes are broken by crushing or grinding, the granule swells in water. Hot water will swell the starch granule. At a specific temperature, the granules burst in the phenomenon called gelling.

In the manufacture of starch from corn, the shelled corn is first cleaned by screening and air separation (Fig. 1.1). The cleaned corn is then steeped in warm water containing sulfurous acid. This softens the gluten and loosens the hull. The steeping also dissolves some of the inorganic salts, carbohydrates, and protein. The softened kernels are ground in special mills which crack the kernels but do not injure the germ which contains the oil. This is separated by floating or in centrifugal separators.

The settled fraction is further ground as finely as possible and screened to remove the fibrous material. The gluten which contains the protein is removed from the heavier starch granules by floatation (called tabling) or by centrifuging. The starch slurry is then dewatered and finally the starch is dried. Commercial corn starch has a moisture content of 12–13%.

Preparation of Starch Adhesives

INTRODUCTION

Until recent years, there have been few deviations from the standard two-phase system for preparing corrugating adhesives (Fig. 2.1). This chapter will attempt to touch briefly on the "old" standard systems and also make the reader aware of the many variations in methods and systems that are available today.

EQUIPMENT FOR STARCH ADHESIVE PREPARATION, CIRCULATION, AND STORAGE

As the technology of corrugating adhesives, their formulation and application, has advanced dramatically in the past decade, the equipment necessary for proper preparation, distribution, and storage of these adhesives has also improved.

Equipment manufacturers provide components and complete systems for quick, efficient, and economical processing of the adhesives now in general use. They make available cooking and blending mixers, pumps and piping for circulation systems, storage tanks, metering equipment, temperature controls and gauges, and accurate recording equipment. All are scientifically designed to perform their individual functions when properly erected and maintained. Details leading to the development of the equipment have derived from research and in-plant use over many years.

TYPICAL PREPARATION EQUIPMENT CAPACITIES

Two of the more common systems in use today are the nominal 333 and 666 U. S. gallon (1260 and 2520 liter) mixers. They are dissimilar only in the volume of adhesive produced. As can be seen in the

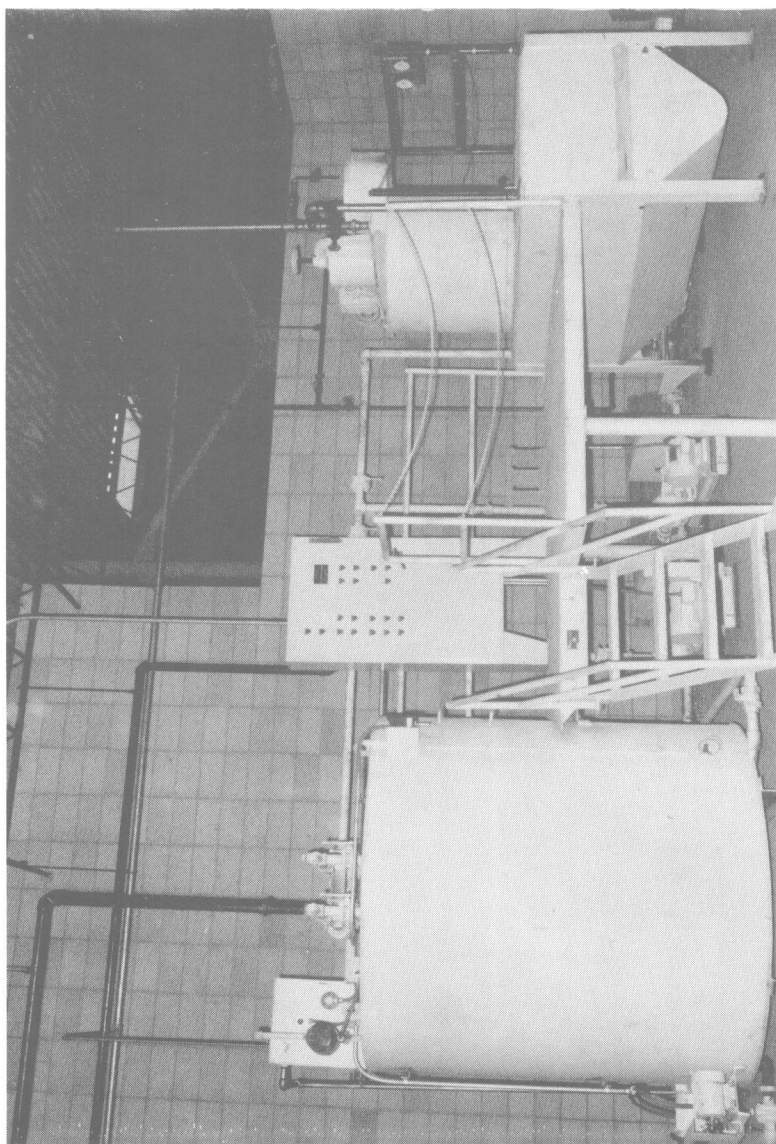


Fig. 2.1. Equipment for a two-phase mixing system.

following table, that volume is greater than the nominal value. Frequently, formulae will yield a batch size larger than the nominal size. This will be true in this pressbook. The nominal size will be retained, however, to designate the equipment which can be used.

The systems using this mixing equipment basically use the two-phase process, with a primary, or cooking phase, and a secondary, or blending phase. Some installations utilize only a blending phase and mix the entire adhesive in the secondary mixer. The following table lists the capacities of different sections of these typical mixers.

Standard 333 gal (1260 liter) batch:

	Gallons	Liters
Primary Mixer		
Cone section capacity	9.3	35.2
Straight section capacity	4.12 gal/in.	0.62 liter/mm
Total capacity (4 in. from top or 10.2 mm from top)	129.9	491.7

Bottom or secondary mixer where cooked and blended raw starch are combined:

V-Bottom Type

Trough section capacity	136.8	517.9
Straight section capacity	14.5 gal/in.	2.16 liter/mm
Total capacity (7 in. from top or 17.8 mm from top)	336.0	1271.8

Round-Bottom Type

Trough section capacity	18.31	693.0
Straight section capacity	13.2 gal/in.	1.96 liter/mm
Capacity of straight section	250.5	948.1
Capacity of mixer (9 in. from top or 22.9 mm from top)	314.9	1192.0

Standard 666 gal (2520 liter) batch:

Primary Mixer

Cone section capacity	12.8	48.4
Straight section capacity	5.93 gal/in.	0.8 liter/mm
Total capacity (4 in. from top or 10.2 mm from top)	202.6	766.6

	Gallons	Liters
Bottom or secondary mixer:		
V-Bottom Type		
Trough section capacity	241.3	913.2
Straight section capacity	19.43 gal/in.	2.90 liter/mm
Total capacity (9 in. from top or 22.9 mm from top)	639.6	2420.8
Round-Bottom Type		
Trough section capacity	398.1	1507.0
Straight section capacity	19.6 gal/in.	2.92 liter/mm
Capacity of straight section	294.168	1113.4
Capacity of mixer (9 in. from top or 22.9 mm from top)	620.9	2350.2

VARIOUS SYSTEMS AVAILABLE

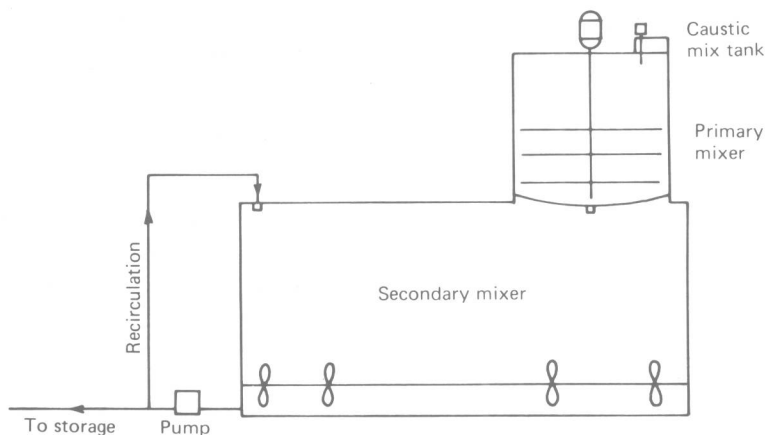
Today there is a wide variety of starch preparation systems available to the industry. Each system has its own advantages, and the needs of any one particular plant should be carefully analyzed before selecting a system. The following descriptions are general, and it must be noted that these are not necessarily standard systems. Many variations of these systems are available, and they can be designed around a particular plant's needs and capacities.

Typical Two-Phase System

The typical two-phase system (Fig. 2.2) is the most commonly used system in the industry because of its many advantages. It can be automated with a jet cooker and bulk starch system.

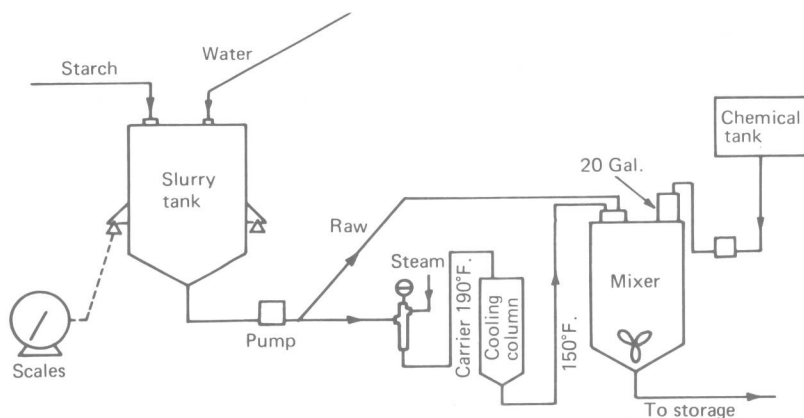
Ringwood Automatic Adhesive Preparation System

The Ringwood system (Fig. 2.3) is a fully automatic jet cooking system that prepares a batch slurry by weight of components added. The raw starch (secondary) is prepared in the slurry tank and pumped to the mixer. The cooking chemicals (pre-mixed caustic and liquid borax) are added to the mixer, and the slurry is kept under agitation. The carrier water is added to the slurry tank along with the carrier starch.



STEPS: (1) Water primary & secondary; (2) Starch primary; (3) Add caustic to primary; (4) Cook primary; (5) Add borax to secondary; (6) Add starch to secondary; (7) Add cooling water to primary; (8) Drop primary into secondary; (9) Final mix; (10) Pump to storage.

Fig. 2.2. Typical two-phase system. It can be automated with jet cooker and bulk starch system.



STEPS: (1) Raw starch water; (2) Raw starch; (3) Transfer to mixer; (4) Add chemicals; (5) Add carrier water; (6) Add carrier starch; (7) Jet cook carrier; (8) Final mix; (9) Pump to storage.

Fig. 2.3. Ringwood Automated Jet Cook System. Utilizes a slurry tank where both the water and starch are weighed. The raw portion is pumped to the blend tank; the "carrier" portion is then weighed in the slurry tank and cooked through a jet.