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TECHNICAL REPORT
68-37-CM

TAN-O-QUIL-QM TREATMENT FOR FEATHERS AND DOWN

by
George Cohen

August 1968

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Clothing & Organic Materials Laboratory
TS-159

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by

GEORGE COHEN
Textile Engineering Section
Textile Research and Engineering Division

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FOREWORD

This report describes the development and application of the Tan-O-Quil-QM process for the treatment of feathers and down which was developed by the U. S. Army Natick Laboratories. The process represents a major improvement in the quality of these materials and has been described as "the most outstanding development in the last hundred years in the field of down and feathers." It has been adopted widely commercially both in the United States and abroad, and is required for these materials when used in pillows to be sold by most leading retail, chain stores and mail order houses in this country.

The development of the Tan-O-Quil-QM process represents the culmination of a program carried on by the U. S. Army since World War II to procure a better and less expensive filling material for the sleeping bags supplied to the Armed Forces. During World War II, adoption of a sleeping bag filled with waterfowl feathers and down by the Army, increased the demand for these materials beyond the supply normally available in the U.S. To augment the supply, the development of a process to upgrade chicken feathers, which are available in unlimited supply, was undertaken. The Tan-O-Quil-QM process did permit the upgrading of chicken feathers substantially. However, the degradation of their quality due to commercial methods of production and marketing of chickens, often after a short growth period, eliminated such feathers as potential material for sleeping bags.

In contrast, the substantial improvement in the quality of waterfowl feathers by the Tan-O-Quil-QM process has permitted a reduction in the amount of waterfowl down required for a suitable mix with desired filling properties. Accordingly, this process is used today by the Army in reducing both cost of sleeping bags and the necessary amount of down, while at the same time making wider use of waterfowl feathers.

As a result, the substantial improvement in the quality of waterfowl feathers by the Tan-O-Quil-QM process has permitted a reduction in the amount of waterfowl down required for a blend with desired filling properties. Accordingly, this process used today by the Army has reduced both the cost of sleeping bags and the necessary amount of down, while making a wider use of waterfowl feathers which are more available. All sleeping bags now procured by the Military Services are filled with Tan-O-Quil-QM-treated waterfowl feathers and down.

The credit for this development goes to Mr. George Cohen of the U. S. Army Natick Laboratories and Dr. Adolf Schubert, chairman, National Research Council Advisory Board on Quartermaster Research and Development, Committee on the Development of Substitutes for Waterfowl Feathers and Down, under whose guidance as a consultant, this process was conceived. In addition appreciation is expressed to the firms in the American feather and down industry who cooperated most generously in providing the use of their facilities for full-scale trials, thus helping to make this improvement in military equipment a reality.

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ABSTRACT

The Tan-Q-Quil-QM treatment for feathers and down involving the use of a chrome tanning agent to improve the filling power and a hydrophobic chrome complex to increase the water repellency, can be carried out in acid resistant equipment of the type now used by Industry to process feather filling materials.

The treated feathers and down are free from dust, exceptionally clean, and will not develop an odor when wet. Treated feathers have increased filling power even after laundering and drycleaning. They also have a higher degree of water repellency. The increased filling power of treated waterfowl feathers has made is possible to reduce the requirement for down in military sleeping bags.

Pillows filled with crushed, treated chicken feathers have retained their added bulk after two years of continuous use.

While no formal tests have been carried out, subjects who are allergic to feathers reported an absence of symptoms when sleeping on pillows filled with treated feathers.

User tests in 1958 and 1959 indicated that treated whole chicken feathers could be used as a diluent for waterfowl feather and down blends in sleeping bags. However, more recent work has shown that the level of filling power obtained in this earlier work cannot be currently realized. This is attributed to the fact that feathers from chickens which are now sent to market at 6 to 8 weeks of age, as against 12 to 16 weeks previously, have large quantities of immature feathers which are not amendable to treatment. Consequently, the use of treated chicken feathers is not recommended for this purpose. Furthermore, the great improvement in filling power of treated waterfowl feathers has made it more desirable to reduce the overall requirement for down in sleeping bags.

TAN-O-QUIL-QM TREATMENT FOR FEATHERS AND DOWN

I. Introduction and Objectives

Waterfowl* feathers and down have been used for generations in bedding items and, from the standpoint of warmth and comfort, are excellent filling materials. For use in military sleeping bags, there are other criteria which also must be considered. Weiner[1] lists these as follows:

Filling Power	- Ability to maintain a large volume under low pressure
Compressibility	- Ability to be compressed to a small volume under high pressure
Resilience	- Ability to return to original volume when compressive forces are released
Fluffability	- Ability to redistribute filler to maximum volume in bag by mechanical agitation such as shaking
Low Absorption	- Ability to repel water
Softness	- Free of irritating elements such as stiff quills
Drapeability	- Ability to conform easily to the contours of the body
Warmth	- This factor is related to many listed above
Cleanliness	- Including freedom from odor, mildew, and moth infestation
Fire Resistance	- Highly desirable
Launderability	- Capable of being easily laundered without losing any of the above properties
Durability	- Ability to maintain optimum physical and mechanical properties after continued use

*The term waterfowl refers to domesticated duck or geese.

The following could also be added to the above list:

Non-allergenic	- Free from any tendency to cause allergies commonly caused by the dust in filling materials
Stability	- Resistant to deterioration or rot, particularly in use or when wet
Light in weight	- Of minimum bulk density, which is usually expressed as pounds per cubic foot at a given pressure
Availability	- Available in large quantities at reasonable prices

Weight and bulk are particularly important for portability and maneuverability in the field. As pointed out by Rene and Vanderbie(2), "Sleeping gear can only be considered functional if the soldier is willing to carry the complete assembly with him. In many instances, soldiers have gone on bivouac without the complete gear because of their individual attempts to reduce their total load".

Waterfowl down meets many of the above criteria. This material, which is found as an undercoat next to the skin of the waterfowl, comprises about 18 percent of its total feather and down coating. An extremely lightweight, resilient material that can be compressed to a fraction of its original volume, it is made up of down clusters, each of which consists of light, fluffy filaments extending out in all directions from a quill point. Loconti(3) attributes the excellent filling power of down to its large number of long filaments and its three-dimensional configuration.

At one time, the use of an all-down filler for military sleeping bags was seriously considered but, because of its shortage, a mixture of down and waterfowl feathers was used instead. It was then found(4) that the feathers actually improved the functional efficiency of the down by retarding its tendency to mat. The most practical blend from the standpoint of availability, cost and performance was a mixture containing 40 percent down and 60 percent feathers. This mixture will be referred to as the "40/60 mixture." An all-down filler may still be used, however, when weight and compressibility are of paramount importance.

The total yearly consumption of waterfowl feathers and down in the United States normally is about 15 million pounds, most of which is imported since domestic production is only about two million pounds(5). Most of this foreign production is in Eastern Europe, Russia, and the Far East, primarily. Obviously, the availability of this material would be greatly reduced in a time of emergency. During World War II, the availability of waterfowl feathers and down became so limited that the U.S. Government froze all available supplies so that they could be held for use in military sleeping bags(6). During the Korean War, when for the first time sleeping bags were issued to all troops, action was taken to stockpile waterfowl down and feathers for military sleeping bags. This product was placed on the Department of Defense List of Critical Materials, and several million pounds purchased for the stockpile.

U.S. Army research on filling materials since the end of World War II has, therefore, been concentrated on the development of a potential substitute to replace or extend the down and feather mixture used in Army sleeping bags. At the start of this program, chicken feathers appeared to be the most promising substitute because of their availability and their physical chemical similarity to waterfowl feathers. It has been estimated that as much as 120 million pounds of chicken feathers are produced annually in this country alone(7).

Table I gives, in centimeters, the range of filling powers* of chicken and waterfowl feathers, down, and the 40/60 mixture. These differences are illustrated in Figure 1. It is evident that chicken feathers lack the filling power of down or waterfowl feathers.

TABLE I

FILLING POWER OF UNTREATED FEATHERS AND DOWN

	Filling Power (cm)
Chicken feathers	1.5 to 2.8
Waterfowl feathers**	3.5 to 7.0
Mixture of 40% waterfowl down and 60% waterfowl feathers	5.5 to 7.0
Waterfowl down	6.0 to 12.0

* See Page 15 for the method used to measure filling power.

** Waterfowl feathers, as the term is used in this report, when used by themselves contain 10 percent down as required in current Federal Specifications. Chicken feathers do not contain down.

While waterfowl and chicken feathers resemble each other in many respects, they differ in that the quill or shaft of the former is curved. This curvature of waterfowl feathers, which is retained even after laundering in a confined area such as a pillow or sleeping bag, accounts for their superior filling power as compared with chicken feathers. However, while chicken feathers are rarely curved in their natural state, they can be curved by a number of relatively simple processes, such as treatment with a mild alkali or acid, or wetting in water and drying in a relaxed state in a current of hot air. The curvature thus obtained is not permanent, as it is lost if the feathers are re-wet and dried in a confined space, such as in a pillow or sleeping bag.

Feathers are proteinaceous materials made up of keratin, which contains fibrous proteins of the general formula $NH_2 CH (R) COOH$, where R represents a number of different possible side-chain groups, among which are cystine groups containing sulfur[8, 9, 10]. Feathers are, therefore, susceptible to degradation in the presence of excess moisture, with the resulting development of unpleasant odors, a decrease in filling power, and a subsequent loss of insulating value. A great advantage would be realized from a treatment that, in addition to improving the filling power of feathers, would at the same time prevent their decomposition in the presence of moisture.

A program was, therefore, initiated by the U.S. Army Quartermaster Corps to develop methods of modifying chicken feathers so that they could be used as a substitute for waterfowl feathers and down. The work was carried out by the Army Quartermaster Research and Engineering Command* at Natick, Mass. and its predecessor organization at the Philadelphia Quartermaster Depot, the Mellon Institute for Industrial Research, the Alexander Smith Company, and the Tanner's Council Research Laboratory at the University of Cincinnati. Some of the research was summarized in a series of papers presented at a symposium held at the Army Quartermaster Research and Engineering Command in April 1955[11][12]. Later work by the Tanner's Council Research Laboratory and the Army Quartermaster Research and Engineering Command resulted in the development of the Tan-O-Quil-QM treatment. The entire program was carried out with the assistance and guidance of members of the National Research Council (NRC) Advisory Board on Quartermaster Research and Development, Committee on the Development of Substitutes for Waterfowl Feathers and Down, under the chairmanship of Dr. Adolf Schubert.

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* Now the U.S. Army Natick Laboratories

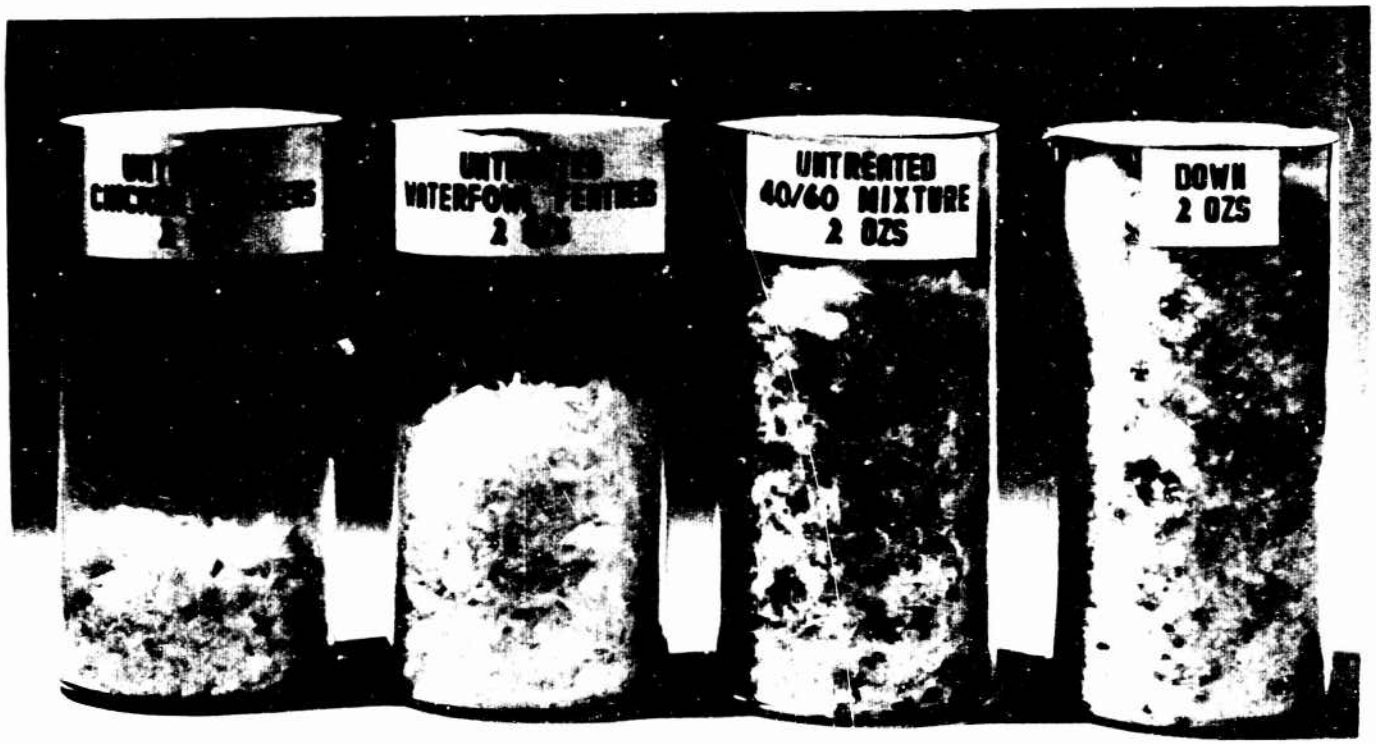


Figure 1. Filling Power of Untreated Feathers and Down

II. The Development of the Tan-O-Quil-QM Treatment

A. Chemical Composition

The name "Tan-O-Quil-QM" was selected to designate the process[13] developed for treating feathers and down to improve their use as a filling material for sleeping gear. The process consists of a method of treatment with a tanning agent to improve the filling power, and with a water repellent to impart water repellency.

1. Basic Chromic Sulfate Tanning Agent

Previous work[14] had shown that the filling power of chicken feathers is greatly improved by treating them with basic chromic sulfate, a commercial material[15] widely used as a tanning agent for leather. In this report, unless otherwise stated, the term "basic chrome sulfate" refers to this commercial material. The improved filling power obtained by treating feathers with this tanning agent, however, was not retained if the feathers were laundered in a confined space, such as in the channels of a sleeping bag. This is shown in Table II.

TABLE II

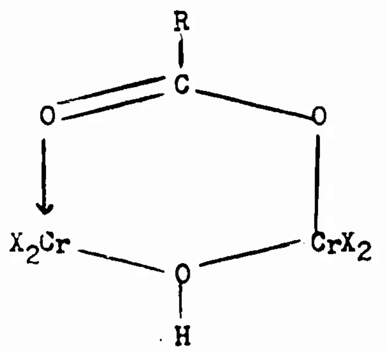
EFFECT OF BASIC CHROME SULFATE ON FILLING POWER OF WATERFOWL FEATHERS

	Filling Power (cm)	
	Initial	After Laundering
Untreated	5.4	4.5
10% Basic chrome sulfate	7.3	4.5

2. Chrome Complex Water Repellent

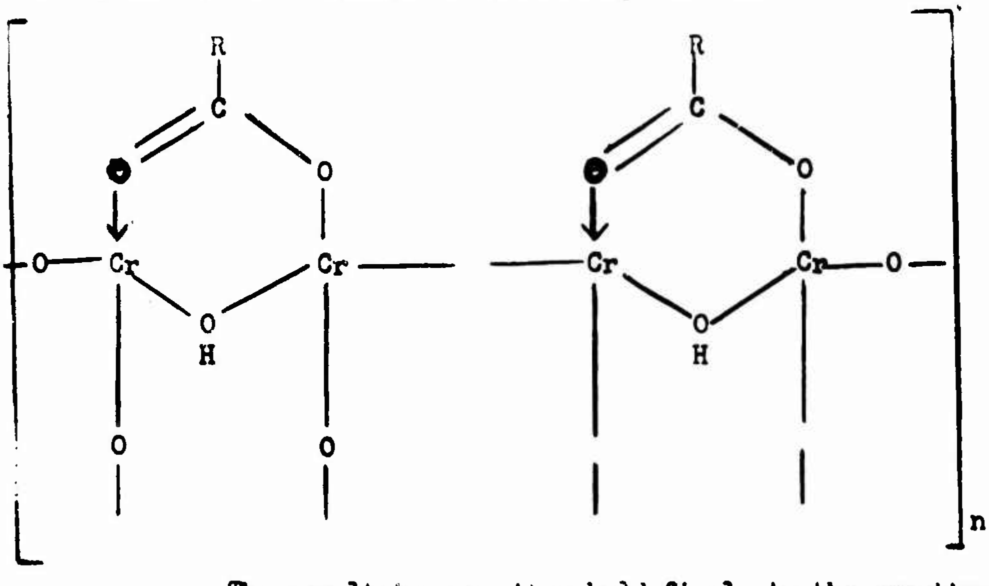
Since waterfowl feathers are naturally water-repellent and retain their filling power after laundering, it was thought that a water-repellent treatment for chicken feathers would have the same effect. Several commercial water-repellents used on textile fabrics were tried on chicken feathers but were unsatisfactory, as they left the feathers matted and with a very low filling power.

At the suggestion of Dr. Schubert, the application of Werner-type chrome complexes to chicken feathers to make them water repellent was investigated. These complexes are compounds of a trivalent chromium salt and a carboxylic acid formed in accordance with the valence theory of Professor Alfred Werner(16). According to the Werner theory, atoms may exert auxiliary valences as well as the principal valences that occur in simple compounds. These auxiliary valences serve to hold various groups to the atom exerting them, which then may become the nuclear atom of a complex compound or a complex ion. Although the structure of these compounds has not been proved, a typical Werner-type chromium complex has been graphically represented by the following formula(16)(17):



The R-C-O group is a functional acido group derived from various organic acids, such as stearic acid, gluconic acid, myristic acid, or tannic acid. These acido groups are coordinated with a nuclear chromium atom in accordance with Werner's valence theory and, following accepted terminology, are designated by the name of the corresponding acids with the addition of the suffix "ato." While the ratio between chromium atoms and acido groups is 2 to 1 in the illustrated graphical formula, this ratio may vary within wide limits, e.g., from 1 to 10 chromium atoms per acido group. The term "X" in the above graphical formula may be a monovalent negative ionic group, such as chloro, bromo, or fluoro. Under the proper conditions of application, surfaces which contain negatively charged groups form strong bonds with the complex. The long-chain hydrocarbon end of the complex is oriented away from the treated surface and, due to its hydrophobic properties, forms an insoluble water-repellent finish on the surface being treated.

The chrome complex used in the work described in this report is, unless otherwise stated, the myristato Werner-type chrome complex. It is commercially available as a 30 percent solution in isopropanol[17][18]. The above formula probably represents the molecule itself. Due to the presence of small quantities of water in the isopropanol solution of the chrome complex, chloride ions and hydrated cationic chromium are also present. Upon dilution, by raising the pH or by mild heating, partial hydrolysis takes place with the formation of a complex. With further heating, partial dehydration takes place with the formation of Cr-O-Cr linkages. Unless this polymerization is allowed to proceed too far, the product will remain water soluble. Heat-curing during the drying process carries the hydrolysis and condensation to the point where the polymer is no longer water soluble but is condensed, through dehydration and Cr-O-Cr linkages, to form an insoluble coating that is firmly attached to the negatively charged surface of the material being treated, as shown in the following formula:[17]



The result is a coating held firmly to the negatively charged surface by covalent chemical bonds between the Cr-O-Cr linkages in the complex and the polar groups on the surface. Bonding by this mechanism causes the hydrophobic portion of the molecule to be oriented away from the surface, thereby imparting water-repellent properties. Among the negatively charged surfaces that combine most readily with these compounds are those containing -OH, -COOH, and $-CONH_2$, all of which are present in feathers. In the Tan-O-Quil-QM treatment, the action of the chrome complex is combined with the basic chrome sulfate.

B. Application

To assure the partial hydrolysis of the chrome complex, upon which the success of the treatment depends, it is necessary that either the solution of the chrome complex immediately prior to its use or the wet treated feathers, be heated briefly to 200°F. or higher. Since it is inadvisable to bring feathers to this temperature, the chrome complex solution is boiled for five minutes immediately prior to use.

To obtain the best results, the feathers must be thoroughly cleaned prior to treatment. One index of cleanliness is the clarity of the water from the last rinse of the washing process prior to treatment. Experience has shown that the feathers must be rinsed until the water is clear or the feathers are not suitable for treatment.

The recommended procedure for treating 100 pounds of feathers by the Tan-O-Quil-QM process, in commercial equipment of the type described in the Appendix, is given below.

1. Add from 300 to 400 gallons of water at 100 pounds (dry basis) of feathers.

2. Add 20 pounds of common salt and sufficient sulfuric acid (usually about 3 pints) to bring the bath to a pH of between 3.4 and 3.6.

3. Add 10 pounds of the commercial basic chrome sulfate, previously dissolved in hot water, and from 3 to 5 pounds* of freshly prepared** 30 percent commercial chrome complex isopropanol solution

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* Three pounds for waterfowl feathers and five pounds for chicken feathers.

** The chrome complex solution is prepared not more than 30 minutes before its addition to the treatment bath, as follows:

a. Heat approximately 25 gallons of water to the boiling point. Maintaining the temperature above 200°F., add the chrome complex under the surface of the water using a funnel with attached tubing or piping.

b. Boil for at least 5 minutes after the addition of the chrome complex has been completed. During this preparation, isopropyl alcohol will be volatilized; therefore, appropriate precautions should be taken so that the vapors will not come in contact with an open flame or spark. Explosion-proof motors are required for agitators used in this phase of the process and adequate ventilation should be provided.

previously dissolved in water. Each solution should be added separately and gradually through the top opening of the washer so as to distribute it across the bath.

4. Hold the mixture at this temperature, with intermittent agitation, until the turbidity in the bath has cleared. This usually takes about one hour and is considered to have been reached when newsprint can be read through a clear glass container, about 3 inches high, containing a sample of the bath and placed directly on the print.

5. Rinse, drain, and centrifuge.

6. Dry the feathers at temperatures of about 130°F (160°F max.). Precautions should be taken not to overdry them. This should not entail any difficulty since waterfowl feathers are usually dried within this temperature range. The feathers should be cooled after drying and before packing them in bags, otherwise they will lose their curl. When cool, the feathers can be handled in the usual manner.

In carrying out the Tan-O-Quil-QM treatment, it is desirable that agitation be kept at a low rate to minimize damage to the feathers. A paddle speed of about 35 rpm was found to be satisfactory. If higher paddle speeds are used, agitation should be intermittent but sufficient to keep the chrome complex and chrome sulfate solutions well-mixed in the bath. To obtain proper agitation, the water level should be just below the center shaft.

While the treatment bath is not highly acidic (pH 3.5), it is corrosive. Therefore, it is necessary that all exposed parts of the washer be protected with an acid-resistant coating. All drain pipes should also be acid resistant. Some plants are using stainless steel washers. The usual precautions in handling concentrated sulfuric acid should be observed: e.g., the use of protective gloves and eyeshields and the dilution of the acid by slowly pouring the concentration acid into cold water. The solutions of chrome sulfate and chrome complex can be prepared in open-end, 55-gallon drums protected on the inside with an acid-resistant coating. For continued use, open-end, 55-gallon, stainless steel drums obtainable from the larger barrel manufacturers are recommended.

C. Equipment

1. Laboratory

Small quantities of material (up to 2 oz.) were treated in a tumbler identical to that used in determining the oxygen number of feathers and down. A detailed description of the apparatus is given in Federal Specification* CCC-T-191, Textile Test Methods, Method 5500, "Water Resistance of Cloth, Dynamic Absorption Method." Essentially it consists of a 6-liter jar, with cover, mounted in a vertical position and capable of being rotated about the horizontal axis at 55 rpm. Larger quantities of feathers or down (up to 16 oz.) were treated in a similar but larger tumbler.

2. Pilot Plant

Pilot plant equipment similar to commercial equipment, except for size, was used for washing and treating up to 6 pounds of feathers or down. This included a stainless steel treatment tank, a centrifugal hydro-extractor, a tumbler-drier, and a fractionator. The treatment tank with auxiliary equipment, shown in Figures 2 and 3, was 42 inches long and 30 inches in diameter, and was mounted on a platform. Feathers to be treated, and chemicals were added through an opening in the top of the tank. Hot and cold water were added through two rubber hose connections above this opening. The tank was drained through a valve connected to a pan cut into the bottom of the tank. A stainless steel screen, above this pan and flush with the inside surface of the tank, held back the feathers while the tank was drained. A pump mounted below the tank was connected to the bottom of the pan. This pump had a flexible neoprene impeller that could be run in either direction, thus allowing it to be used for either suction or pressure. The piping arrangement allowed the liquor to be pumped out of the tank to a barrel or drain or to be recirculated. The temperature of the bath, indicated on a dial thermometer mounted on the side of the tank, was increased by adding direct steam through a perforated pipe in the drain pan. Agitation within the tank was accomplished by paddles, rotating at 12 rpm, mounted on a shaft along the tank axis.

*Obtainable from the General Services Administration Business Service Center, Washington, D. C. 20407.

Figure 2. Pilot Plant-Washer and Treatment Tank Showing Pump

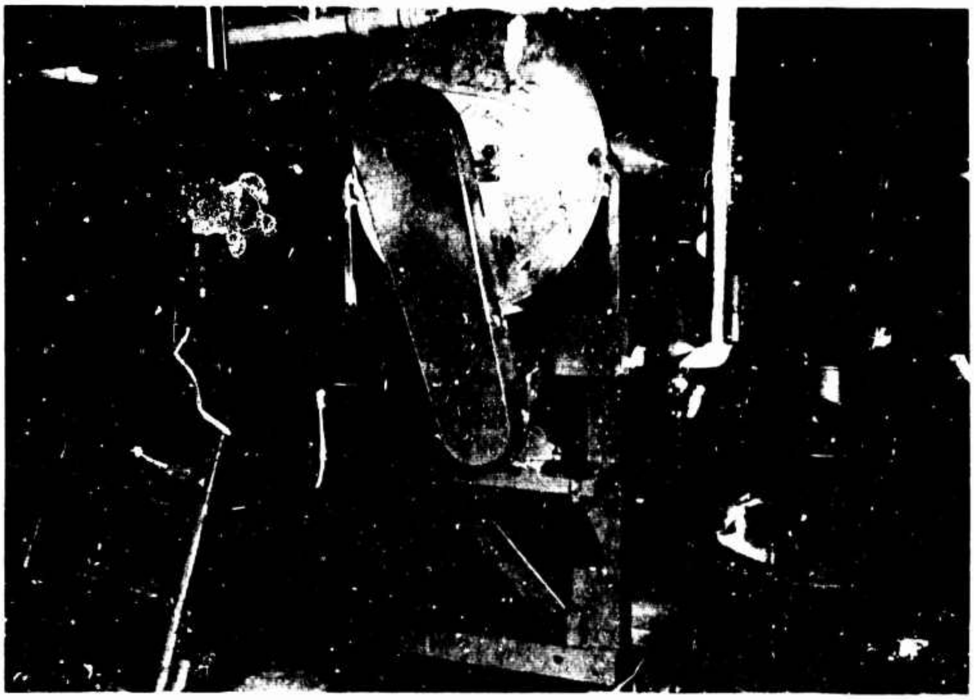

Figure 3. Pilot Plant-Washer and Treatment Tank Showing Drive

The washed or treated feathers were extracted in a stainless steel basket centrifuge of the type commonly used in commercial laundries. (It can be seen in the background of Figure 3 to the right of the platform.) The extracted feathers were dried in the drier, shown in Figure 4, which consisted of a cylindrically shaped wooden frame covered with bronze screening, rotating at 3 rpm within a plywood housing. Heat was supplied by two banks of strip infrared heaters mounted inside the housing below and concentric with the drier. Compressed air from a perforated pipe underneath the drier fluffed the feathers during the drying operation and also cooled them after the drying was completed. The cylindrical drier had a quarter section that was hinged so that it could be opened to admit the wet feathers or to permit the dry feathers to be removed. A series of wooden baffles, placed lengthwise inside the drier, caused the feathers to tumble as it rotated. The drying temperature was controlled by a regulator.

When necessary, the feathers were fractionated in the apparatus shown in Figures 5 and 6. This machine was about 9 feet high, with a base 3 feet square that tapered to a circular pipe 14 inches in doameter, which, in turn, tapered to a pipe 9 inches in diameter. The smaller pipe was in the shape of an inverted U, with an open end which discharged into a cloth bag. The operation was observed through a transparent plastic window built into the 14-inch pipe. In operation, the feathers to be fractionated were placed in a screened semicircular tray inside the base and agitated with a stirrer while compressed air was blown up through them. The lighter feathers were blown up through the duct and into the cloth bag, while the heavier feathers fell back into the tray. The operation was controlled by regulating the air pressure.

3. Commercial

Larger quantities of feathers were treated at various processing plants in the type of equipment described in the Appendix.

III. Test Methods for Evaluating Feathers

Current specifications* pertaining to Tan-O-Quil-QM treated feathers and down are as follows:

MIL-F-43097 for Feathers and Down, Waterfowl, Chemically Modified
MIL-F-43099 for Feathers, Landfowl (Whole), Chemically Modified
MIL-F-43100 for Feathers, Landfowl (Crushed), Chemically Modified

* Requests for these specifications should be addressed to the Commanding Officer, U.S. Naval Supply Depot, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120

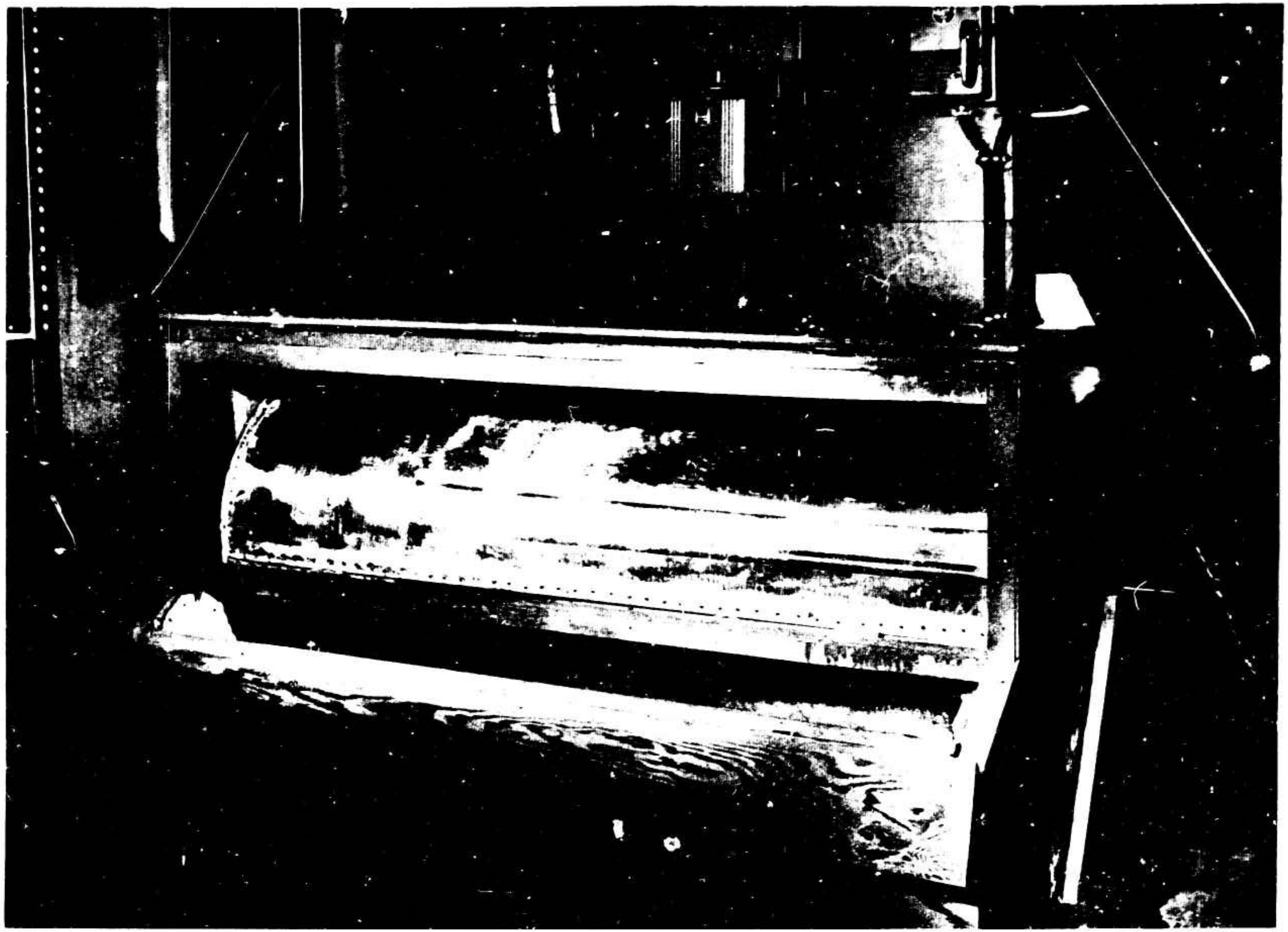

Figure 4. Pilot Plant Drier

The detailed test methods used to evaluate feather filling materials are contained in Federal Standard No. 148a - Classification Identification and Testing of Feather Filling Material.** A brief description of some of these methods and other methods used for evaluating feather filling materials discussed in this report is given below.

A. Filling Power

Filling power, as the term is used in this report, may be defined as the height of centimeters of a given weight (0.8 oz.) of the material being evaluated, when it is confined in a cylinder of fixed diameter (12.75 inches) and is subjected to a fixed load (.002 psi). The material being tested is placed in a cylindrical container, fluffed uniformly with compressed air, and its height determined after compression under a lightweight flat disc which applies a load of .002 psi.

B. Effect of Laundering

Launderability was determined by measuring the filling power of the material after subjecting it to the washing and drying procedure of method 13 in Federal Standard 148a. During laundering, the feathers were held in a cloth bag filled to a density of 1 ounce per 100 square inches (the density used in military sleeping bags). The decrease in filling power after laundering was used as the index of launderability.

C. Effect of Dry Cleaning

The effect of dry cleaning was determined by placing the feathers in a cloth bag, as in the launderability test, and having them dry-cleaned commercially, using perchlorethylene as the solvent. Again, the decrease in filling power was used as the index.

D. Oxygen Number

The oxygen number determination is a test used by State and Federal agencies to determine the cleanliness of feather filling materials. A water extract of the material is titrated with 0.1 normal potassium permanganate. The oxygen number is the milliliters of permanganate used, multiplied by 80. The smaller the oxygen number, the cleaner the material.

E. Effect of Compressed Storage

The effect of compressed storage was determined by the reduction in filling power after the material had been held under compression, as follows: The material was placed in a cylinder about 4 inches in diameter and 5 inches high. A plate placed on top was pressed down to the desired point and held in place by a metal rod. The containers and the plate

**Copies may be purchased from the General Services Administration, Business Service Center, Washington, D. C. 20407 were perforated so that air could circulate around the material being tested.

F. Turbidity

Turbidity was determined, with a Jackson Turbidimeter, on the water extract obtained from the oxygen number determination. The method is similar to that used by the American Public Health Association to determine the turbidity of water[19]. It consists essentially of the height in centimeters of a column of the water extract through which the light of a candle can be seen.

G. Odor

Odor was determined by immersing 10 grams of feathers or down in 100 ml of distilled water in a sealed quart jar, and holding it at 105°F. for 24 hours. The sample was considered to have failed this test if an odor of putrefaction developed.

H. Durability

During the early phases of this work, durability of treated feathers and down was determined by placing them in seat cushions and pillows. The decrease in filling power after use was taken as an index of durability. The results, however, were quite variable, apparently due to differences in the degree of use. It was then found that the decrease in filling power after laundering twice was about the same as the decrease in filling power after use and laundering. This is shown in Table III, which contains data from field trials of sleeping bags filled with various combinations of filling materials. With the exception of item 2, the filling powers after use and laundering did not differ appreciably from the filling power after laundering alone, indicating that the latter could be taken as an index of durability.

I. User Tests

User tests consisting of actual use of pillows or sleeping bags were made with items containing treated feathers and/or down. Wherever possible, controls containing untreated materials were also used for comparison.

NOTE: In the remainder of this report, details and results of various trials are given in which landfowl (chicken) feathers, waterfowl feathers and down were treated by the Tan-O-Quil-QM process. These trials, a portion of the large number conducted, were selected as being of the greatest interest and furnishing the most information. Since this process was developed, millions of pounds of Tan-O-Quil-QM crushed chicken feathers and whole waterfowl feathers have been produced both for Government and civilian use. As a result considerable data have been accumulated by this Laboratory. Space prohibits their inclusion in a publication of this type. It is recommended that those readers who are not familiar with commercial methods of processing feather filling materials read the brief review in the appendix before proceeding with the balance of this report.

Figure 5. Pilct Plant Fractionator (door closed)

Figure 6. Pilot Plant Fractionator (door open)

TABLE III

FILLING POWER OF MIXTURES OF FEATHERS AND DOWN AFTER USE AND LAUNDERING

Item No.	Filling Power (cm)			
	Initial	After Laundering Twice	After Use in Sleeping Bags	After Use and Laundering Twice
1	6.5	5.6	3.7	5.5
2	6.4	6.0	3.9	4.9
3	7.2	6.1	3.7	6.0
4	6.2	5.5	3.6	5.1
5	6.4	5.6	3.8	5.7
6	7.0	5.3	3.6	5.0
7	7.0	5.9	3.7	5.6
8	6.5	5.2	4.1	5.0*
9	6.6	5.4		

*Laundered once

IV. Treatment of Chicken Feathers

A. Whole Feathers

Since chicken feathers appeared to offer the most promise as a potential substitute for waterfowl feathers, a great deal of work was carried out in the early phases of this project to determine if they could be used either wholly or partially as a substitute for waterfowl feathers. This earlier work indicated that Tan-O-Quil-QM-treated whole chicken feathers could be produced which were equal in filling power to untreated duck feathers with a filling power of 3.8 cms after laundering. This work was done with feathers from 12 to 14-week old broiler chickens. Large-scale procurement of whole Tan-O-Quil-QM-treated feathers from broiler chickens have since been made and it was found that the filling power requirement of 3.8 cms after laundering could not be met. This is believed to be due to the presence of large amounts of immature feathers, since broilers are now sent to market at six to eight weeks of age.

Data obtained from these procurements indicate that filling powers above 3.2 cms cannot be obtained consistently. Since the Tan-O-Quil-QM process markedly increases the filling power of waterfowl feathers, thereby permitting a reduction in the amount of down required in blends for the sleeping bags, there is no advantage in using treated whole chicken feathers with their much lower filling power for this use.

The data obtained from this work with whole chicken feathers has a bearing on later work; some of this earlier work is presented at this point even though it is not applicable to chicken feathers available today.

1. Broiler Chicken Feathers

Three thousand pounds of chicken feathers from 12-week-old broilers raised in Arkansas were treated commercially by the Tan-O-Quil-QM process using 5 percent of the chrome complex and 10 percent of the basic chromic sulfate. The feathers were fractionated prior to treatment to remove the quill feathers. The treatment was carried out in cylindrical steel washers with rotating paddles of the type described for chicken feathers using 150 pounds of feathers per load. The filling powers of the untreated and treated chicken feathers, before and after laundering, are given in Table IV. The filling power of untreated duck feathers is included for comparison.

TABLE IV

FILLING POWER OF UNTREATED AND TREATED FEATHERS

	Filling Power (Centimeters)			
		After Laundering		
	Initially	Once	Twice	Three Times
Untreated Duck Feathers	4.3	4.0	3.8	3.8
Untreated Chicken Feathers	2.8	2.6	2.6	2.6
Treated Chicken Feathers	4.4	4.4	4.1	4.0

The marked improvement in filling power of the treated chicken feathers, as compared to untreated chicken feathers, was maintained after laundering.

The treated chicken feathers were blended with an untreated 40 percent down, 60 percent waterfowl feather mixture. The filling powers of the blends are given in Table V. (The filling power of the untreated 40/60 waterfowl down and feather blend is included for comparison).

TABLE V

FILLING POWER OF FEATHER AND DOWN MIXTURES

	Filling Power (Centimeters)		
		After Laundering	
	Initial	Once	Twice
100% Untreated 40/60 Waterfowl mixture	7.0	5.8	5.9
40% Treated chicken feathers 60% 40/60 mixture	6.6	5.8	5.6
50% Treated chicken feathers 50% 40/60 mixture	6.5	6.1	6.0

The filling powers of the mixtures containing treated chicken feathers were slightly less than that of the 40/60 mixture, both before and after laundering. Sleeping bags containing some of these mixtures were evaluated by actual use in the field. The results are given in Table XXXI of Section VI.

Three thousand pounds of fractionated broiler chicken feathers from upper New York State were also treated commercially by the Tan-O-Quil-QM process, with 5 percent chrome complex and 10 percent basic chrome sulfate. The treatment was carried out in washers with paddles of the flat type previously described for washing waterfowl feathers, using 125 pounds of feathers per load. An analysis of these feathers, before and after treatment, is given in Table VI.

The lower pH of the treated feathers shown in Table VI is expected since the Tan-O-Quil-QM process is carried out at a pH of about 3.5. The fact that there was little change in the solvent soluble content indicates that the carbon tetrachloride solvent used in this test does not remove the chrome complex. This is to be expected since the chrome complex, when properly applied and cured, appears to be insoluble in solvents. The extreme cleanliness indicated by the oxygen number of zero is typical of feathers treated by the Tan-O-Quil-QM process. In addition to having a low oxygen number, feathers properly treated by this process are always free of dust. The lack of odor, under the severe conditions by which this test is carried out, again is typical of Tan-O-Quil-QM-treated feathers. Under these test conditions, untreated feathers develop a nauseating odor and eventually disintegrate into a mass of fibers. There was a marked improvement in filling power after treatment, much of which was retained after laundering.

TABLE VI

ANALYSIS OF TREATED AND UNTREATED CHI...N FEATHERS

	Before Treatment	After Treatment
Acidity (pH)	6.5	3.6
Solvent soluble material	1.1%	1.3%
Oxygen number	4.0	0.0
Filling power (cm)		
Initially	3.5	4.4
After 2 launderings	2.5	4.0
Chromic oxide	0.0%	0.58%
Brittleness	Satisfactory	Satisfactory
Odor	Present	None
Composition		
Whole feathers (length)		
2 inches or less	26	22
2 to 3 1/2-inches	49	50
Larger than 3 1/2-inches	8	5
Quill feathers	0	0
Damaged feathers	16	22
Residual matter	1.3	0.6

2. Feathers from Various Geographical Locations

The breed of chickens usually varies with the geographical location. To determine if there are variations in the response of various types of chicken feathers to treatment, commercial lots from various geographical areas in the U.S. were obtained and fractionated on commercial equipment to remove the fiber and quill feathers. The fractions obtained are given in Table VII.

Additional feathers were obtained from Canada and New England and fractionated in the pilot plant fractionator. Feathers from each of the seven geographical areas were treated in the pilot plant by the Tan-O-Quil-QM process, using 5 percent chrome complex and 10 percent of the basic chromic sulfate. The filling powers obtained, along with that of a representative lot of untreated waterfowl feathers, are given in Table VIII.

TABLE VII

VARIATIONS AMONG FEATHERS IN FIBER AND QUILL CONTENT

Source	Composition (percent by Weight)		
	Feathers	Fiber	Quill Feathers
Delaware	84.0	3.0	13.0
California	78.5	3.0	18.5
Texas	83.0	3.7	13.3
Arkansas	88.9	0.9	10.2
Missouri	78.6	3.0	18.4

TABLE VIII

FILLING POWER OF TREATED CHICKEN FEATHERS FROM VARIOUS SOURCES

Source	Filling Power (cm)			
	Initial	After Laundering		
		Once	Twice	Three Times
Delaware	5.3	5.0	4.1	4.1
California	4.4	4.3	3.2	3.1
Texas	6.0	5.1	4.4	4.4
Arkansas	5.9	5.0	4.3	4.2
Missouri	5.6	5.1	4.2	4.4
Canada	4.2	4.0	3.6	3.6
New England	6.0	5.1	4.3	4.1
Untreated Waterfowl Feathers	4.3	4.0	3.8	3.8

After two launderings, the treated chicken feathers had lost some of their improved filling power. The feathers from California had large quantities of immature feathers, which probably accounted for their much lower filling power.

3. Fowl Feathers

While most of the chickens sent to market are immature birds known as broilers, there are quantities of older hens (known as fowl) which are up to two years old. Feathers from fowl do not contain the large quantities of immature pin feathers found on broilers, which are not amenable to treatment. Fowl feathers, on the other hand, are much larger and stiffer than broiler feathers and are difficult to treat since they do not curl easily. Fowl feathers from two different states, Delaware and New York, were treated commercially by the Tan-O-Quil-QM process. The feathers were fractionated prior to treatment to remove the wing and tail feathers. Table IX gives the analysis of the treated feathers.

TABLE IX

ANALYSIS OF TREATED FEATHERS FROM OLDER CHICKENS

Composition Analysis	Supply Area Delaware	 New York
Whole feathers 2 to 3 1/2-inches in length	65%	81%
Whole feathers less than 2 inches in length	19%	10%
Damaged feathers	15%	6%
Remainder	1%	3%
Filling Power (cms)(after 2 launderings)	2.8	3.5
Chromic Oxide (%)	0.73	0.83
Oxygen Number	0.0	0.0

A comparison of the composition of these feathers and the broiler feathers in Table VI shows a greater percentage of the longer feathers (2 to 3 1/2-inches in length) and a smaller percentage of the shorter feathers (less than 2 inches in length). Nevertheless, the filling power after laundering was less. It appears significant, however, that the Delaware feathers, which had a smaller amount of the larger feathers and a greater amount of damaged feathers, had a much lower filling power than the New York feathers.

4. Blends

Blends of Tan-O-Quil-QM-treated chicken feathers and untreated waterfowl feathers and down were made and the filling power determined before and after laundering. These blends were also evaluated by actual use in sleeping bags. The results given in Table XXX and XXXI show that a blend of 40 percent Tan-O-Quil-QM-treated chicken feathers with 60 percent of an untreated 40/60 waterfowl feather and down mixture had a lower filling power than the untreated 40/60 waterfowl mixture. Additional tests in pillows (Table XXXII, items A, B, and D) indicated that this blend was equal to the untreated 40/60 waterfowl mixture.

5. Cleanliness

Mr. Howard Winslow, Assistant Chief of The Bureau of Furniture and Bedding Inspection, State of California, and also a member of the NRC Committee, determined the coliform bacteria count on water extracts of untreated and Tan-O-Quil-QM-treated chicken feathers. This count is used as an index to the extent of microbial decontamination. The freedom from contamination of the treated feathers is shown in Table X.

TABLE X

COLIFORM COUNT ON CHICKEN FEATHERS

	Coliform Count per 100 mls. Extract
Untreated	7000
Treated commercially	23
As above after crushing	13
Treated in pilot plant	0
As above after crushing	6

6. Equilibrium Moisture Content, Water Repellency and Buoyancy

Tan-O-Quil-QM-treated feathers have a lower equilibrium moisture content than untreated feathers. The moisture content of untreated and treated feathers after allowing them to come to equilibrium at 65 percent relative humidity and 70°F is given in Table XI.

TABLE XI

EQUILIBRIUM MOISTURE IN TREATED AND UNTREATED CHICKEN FEATHERS

	Moisture Content*
Untreated chicken feathers	10.6%
Treated chicken feathers	7.2%

*Based on their bone-dry weight.

Tan-O-Quil-QM-treated feathers have a higher degree of water repellency than untreated feathers. Two methods were used to determine the water repellency of treated feathers. One method is a modification of the well-known absorption test used for determining the water repellency of fabrics*. It consists of tumbling the feathers in a cloth bag in water until they are thoroughly wet-out, squeezing them between two pieces of blotting paper at a fixed pressure, and then determining their moisture content. Some of the results obtained are given in Table XII.

TABLE XII

MOISTURE ABSORPTION OF TREATED CHICKEN AND UNTREATED WATERFOWL FEATHERS

	Moisture Content (%)
Untreated chicken feathers	33
Treated chicken feathers	12
Untreated waterfowl feathers	19

Another method used is a modification of a test used by the State of California** to determine the buoyancy of kapok. This test consists of placing the feathers in a weighted mesh bag, immersing them in water,

*American Association of Textile Chemists and Colorists - Test Method 21-1964. Federal Specification CCC-T-191 Test Method 5500
**Laboratory of the Bureau of Furniture and Bedding Inspection

and determining the loss in weight after they had come to equilibrium. The water repellency is assumed to be directly proportional to the loss in weight. Some of the results obtained by this method are shown in Table XIII.

TABLE XIII

BUOYANCY OF TREATED CHICKEN AND UNTREATED WATERFOWL FEATHERS

	Loss in Weight (gms)
Untreated chicken feathers	21
Treated chicken feathers	57
Untreated waterfowl feathers	68

The results by either method indicate that the water repellency of the treated chicken feathers is much superior to that of untreated chicken feathers and slightly lower than untreated waterfowl feathers.

7. Resistance to Dry Cleaning

The effect of dry cleaning on the filling power of untreated and treated chicken feathers, alone or blended with untreated waterfowl feathers and down, as compared to laundering, is shown in Table XIV. The solvent used was trichlorethylene.

TABLE XIV

FILLING POWER OF TREATED AND UNTREATED FEATHERS AFTER DRY CLEANING OR LAUNDERING

	Filling Power (cm)		
	Initial	Dry cleaning	Laundering
Untreated chicken feathers	2.8	3.2	3.0
Treated chicken feathers	5.4	4.5	4.2
Untreated 40/60 mixture	6.5	6.4	6.1
40% Untreated chicken feathers 60% Untreated 40/60 mixture	6.0	5.1	5.8
40% Treated chicken feathers 60% Untreated 40/60 mixture	6.4	5.6	6.3

The results indicate that the loss in filling power of the treated chicken feathers after dry cleaning is slightly less than the loss after laundering. The increase in filling power of the treated feathers, by themselves or in the mixtures, as compared to the untreated feathers, was maintained after dry cleaning or laundering.

8. Resistance to Compressed Storage

Federal and military specifications require that feathers and down be packed in bags which are then compressed into bales. The effect of compressed storage on treated feathers was, therefore, determined by using the plastic cylinders previously described. (See Test Methods for Evaluating Feathers). The feathers were stored for 18 weeks at standard conditions (65 percent relative humidity and 70°F) under compression equivalent to that in a bale. The effect on filling power, compared to an untreated 40/60 down and waterfowl feather mixture stored under the same conditions, is given in Table XV.

TABLE XV

FILLING POWER OF FEATHERS AFTER STORAGE

	Filling Power (cm)	
	Initial	After Compressed Storage
Treated chicken feathers	4.4	4.6
Untreated 40/60 mixture	7.0	6.8

The compressed storage did not reduce the filling power. Similar results were obtained with feathers stored in a simulated tropical climate.

9. Odor

Quite often, feathers or down have a characteristic odor which is considered objectionable by many people. The fact that Tan-O-Quil-QM-treated feathers or down do not have an odor is considered by many processors to be one of the main advantages of this process. A number of manufacturers and retailers have commented favorably on this lack of odor. In addition, untreated feathers, when held in a damp or wet state, develop an obnoxious odor and in time are degraded to such an extent that they become a mass of loose fibers. When held under the same conditions, Tan-O-Quil-QM feathers neither develop an odor nor do they become degraded.

B. Crushed Feathers

Large quantities of crushed or curled chicken feathers are used as an inexpensive filling material for pillows. Because of the low price of these pillows, the chicken feathers generally are not washed as thoroughly as the more expensive waterfowl feathers or down, nor are they dusted and fractionated to remove quill feathers, loose dirt, and other extraneous matter. As a result, they are usually not as clean or as free from foreign matter[20] as the higher quality waterfowl feather and down materials.

It has been found from user tests[21] that crushed Tan-O-Quil-QM chicken feathers are superior to untreated crushed chicken feathers as a filling material for pillows (Figures 14 and 15). In addition to increased bulk, the treated feathers are extremely clean and free from dust and have no odor. The improvement in bulk of the treated feathers over the untreated has been maintained after as much as two years use. Pillows containing crushed Tan-O-Quil-QM-treated chicken feathers have received the seal of approval from the American Institute of Laundering.

Because of their freedom from dust and their unusual cleanliness, it seems probable that Tan-O-Quil-QM-treated feathers will not cause the allergy reactions frequently attributed to the use of feathers in pillows. While no formal tests have been run, subjects who are allergic to feathers have reported an absence of symptoms when sleeping on pillows containing Tan-O-Quil-QM-treated feathers.

V. Treatment of Waterfowl Feathers

A. Laboratory Treatment

To determine the effect of the Tan-O-Quil-QM treatment on waterfowl feathers, a series of laboratory treatments were carried out on duck feathers in which the amounts of chrome complex and basic chrome sulfate were varied. The procedure was the same as previously described for chicken feathers. The filling powers obtained are given in Table XVI.

TABLE XVI

FILLING POWER OF TREATED DUCK FEATHERS

Sample No.	Treatment	Filling Power (Centimeters) Initial	After Laundering Once	Twice	Three
1	Wet out and fluff dried	5.4	5.2	4.6	4.5
2	Acid (pH 3.5)	5.5	5.5	5.0	4.6
3	10% Basic Chrome Sulfate	7.3	5.4	4.6	4.5
4	1% Chrome Complex, 10% Chrome Sulfate	6.6	5.7	5.7	5.3
5	3% Chrome Complex, 10% Chrome Sulfate	6.6	5.6	5.7	5.4
6	5% Chrome Complex, 10% Chrome Sulfate	6.9	5.6	5.6	5.4

Sample 1 was wet-out and dried only. Sample 2 was tumbled in water previously adjusted to a pH of 3.5 with sulfuric acid. Samples 3 through 6 were treated according to the standard Tan-O-Quil-QM procedure, using the amounts of chrome sulfate and chrome complex indicated. All percentages are on the weight of the dry feathers. The time of treatment was the same for all of the samples. All of these feathers were dried under the same conditions.

It is evident that the Tan-O-Quil-QM treatment improved the filling power of the duck feathers both before and after laundering. The treated feathers, in addition to having improved filling power, had all the other advantages of the Tan-O-Quil-QM process: lack of odor, increased cleanliness, increased water repellency, resistance to deterioration when wet, freedom from dust, etc. The feathers treated with 3 percent chrome complex were judged to be the best on the basis of resilience and overall appearance. Those treated only with 10 percent basic chrome sulfate had the highest initial filling power, but after laundering they had the same filling power as the untreated feathers. A visual comparison of the feathers treated with 3 percent chrome complex (No. 5) and the untreated feathers (No. 1) is shown in Figure 7.

B. Commercial Treatment

Mr. Benjamin Ludin, a member of the National Research Council, carried out a series of treatments on Long Island duckling feathers in cylindrical washers of the type previously described. Two classes of feathers known as types XL2 and XL234 were treated. The numbers designate the fractions obtained from the blowing or fractionating process. Type XL2 consists entirely of fraction 2; Type XL234 is a mixture of fractions 2, 3 and 4. The various fractions obtained were as follows:

Fraction No.	
5	Quill feathers
4	Down
3	Smallest feathers
2	Next largest feathers
1	Largest feathers

Figure 7. Filling Power of Waterfowl Feathers

One hundred pounds of raw (unwashed) feathers were used in each trial. One lot each of XL2 and XL234 were washed and fluff-dried without treatment. These were used as controls. One lot of XL2 was washed and treated for 2 hours with 3 percent chrome complex and 10 percent basic chrome sulfate. A second lot of XL2 was washed and treated with 2 percent chrome complex and 10 percent basic chrome sulfate for 1 hour. One lot of XL234 was washed and treated with 3 percent chrome complex and 10 percent basic chrome sulfate for 1 hour.

The feathers were dried in a conventional drier of the type previously described, at a temperature which varied from about 120°F at the beginning of the drying cycle to about 160°F at the end of the cycle. The feathers were removed from the dryer as sonn as they were dry. The filling powers of the feathers are shown in Table XVII.

TABLE XVII

FILLING POWER OF TREATED XL DUCKLING FEATHERS

		Filling Power (cm)				
		Initial	After Laundering			
			One	Two	Three	Four
XL2	None (control)	5.1	4.7	4.6	4.6	4.5
XL2	3% Chrome complex	7.6	5.9	5.9	5.8	5.9
XL2	2% Chrome complex	7.7	5.9	5.9	5.9	5.8
XL234	None (control)	6.5	4.2	4.1	4.1	4.1
XL234	3% Chrome complex	8.5	6.1	5.8	5.9	5.9

These results indicate the filling power of the treated feathers to be superior to that of the untreated feathers, both before and after laundering. The marked improvement in filling power of the treated feathers was maintained even after four launderings. Although the filling power of the XL2 feathers treated with 2 percent chrome complex was equal to that of the feathers treated with 3 percent chrome complex, the latter were judged to be superior from the standpoint of resilience, hand, and general appearance Mr. Ludin further evaluated the feathers by visual examination and by their use in pillows and found the treated feathers to be definitely superior to the untreated feathers (Table XXXII).

Samples of these feathers were evaluated at the laboratory of Mr. Winslow. He determined the oxygen number, turbidity, and filling power by methods used by the State of California, which differ from the test methods described earlier in this report. These results, therefore, while comparable to themselves, should not be compared with those given earlier in this report. Table XVIII gives the results of Mr. Winslow's analysis.

TABLE XVIII

ANALYSIS OF (XL) DUCKLING FEATHERS

	TYPE				
	XL2	XL2	XL2	XL234	XL234
Chrome complex applied	None	3.0%	2.0%	None	3.0%
Oxygen number	4.[illegible]	5.6	4.8	4.8	4.8
Acidity (pH) of extract	6.4	3.8	3.8	6.6	3.8
Solvent solubles (%)	0.8	0.6	0.7	1.3	1.2
Centrifugal suspended particles	10	0	1	13	0
Turbidity	17	1	1	13	0
Filling power	2.32	3.15	2.85	2.92	3.13
Moisture content (%)	8.7	7.6	7.6	8.6	7.5

All of the feathers, both untreated and treated, were exceptionally clean, as shown by their low oxygen numbers. The values for suspended particles and the turbidity, which were obtained on a water extract of the feathers, are an index of cleanliness and showed the treated feathers to be superior to the untreated feathers in these respects. The lower acidity (pH) of the treated feathers is to be expected since the treatment is carried out in an acidic bath. The low percentage of solvent soluble material in the treated feathers confirms previous findings that the chrome complex, when properly applied, is insoluble in solvents. The higher filling power and lower equilibrium moisture content also confirm previous results. Table XIX gives Mr. Winslow's composition analysis of the feathers.

TABLE XIX

COMPOSITION ANALYSIS OF (XL) DUCKLING FEATHERS

Type	XL2			XL234	
Chrome complex applied	None	3.0%	2.0%	None	3.0%
	Percent by Weight				
Duck feathers	81.0	89.3	89.3	58.3	64.1
Damaged feathers	5.0	3.1	3.7	2.1	3.0
Feather fiber	3.0	1.7	1.7	3.2	3.2
Down fiber	1.5	1.2	0.9	5.9	5.0
Down	6.1	4.5	3.8	25.5	23.8
Residue	3.4	0.2	0.4	5.0	0.8

The decreased percentage of feather fiber and damaged feathers in the XL2 lots indicates that the Tan-O-Quil-QM treatment did not damage these feathers. The almost complete lack of residual material in the treated feathers again indicates their extreme cleanliness. The non-allergenic properties claimed for Tan-O-Quil-QM-treated feathers is attributed to this almost complete lack of dust and loose dirt.

Feathers from these lots were used in pillows. After six weeks of continuous use and one laundering, there was no indication of matting or breakdown of the treated feathers. The increase in bulk of the treated feathers, as compared to the untreated, was still evident after use. Each pillow contained the same weight of feathers. The pillows are shown in Figures 8 and 9.

C. Waterfowl Feathers from Various World Geographical Areas

A series of commercial treatments were carried out by Mr. Ludin on waterfowl feathers from various geographical areas. Altogether, 36 lots of feathers of European, Asiatic or domestic origin were studied, each lot consisting of 150 pounds. To simplify the study, the lots were divided into 12 groups of three, each group totalling 450 pounds. The three lots comprising a group were so selected as to be of similar type and quality from the same general geographical area. The three lots comprising a group were carefully blended to form a uniform mixture and then fractionated to remove the flat wing and tail feathers (commonly known as quill feathers) and much of the loose dust, dirt, and other debris. The feathers were then washed and treated by the same procedure as has been previously described. For the majority of groups, as shown in Table XX, 10 percent of the basic chrome sulfate and 2 percent of the chrome complex were used. Table XX gives the percentages used and identifies the type and origin of the feathers comprising each group.

TABLE XX

PERCENTAGES* OF CHEMICALS USED IN TREATING FEATHERS

Type of Feather	Group No.	Basic Chrome Sulfate(%)	Chrome Complex(%)
European goose	1	10	3
	2	10	2
	3	10	2
Asiatic goose	4	10	2
Asiatic duck	5	10	2
	6	10	2
	7	10	2
	8	10	2
	9	10	2
	10	5	2
	11	10	2
Domestic duck	12	10	2

* Of the weight of the dry feathers

Table XXI gives the filling power of each group of feathers before and after treatment by the Tan-O-Quil-QM process. The results showed that the Tan-O-Quil-QM treatment improved the filling power of each group of feathers.

TABLE XXI

FILLING POWER OF FEATHERS

Type of Feather	Group No.	Filling Power (cm)	
		Before Treatment	After Treatment
European goose*	1**	5.7	6.6
"	2*	6.0	6.8
"	3*	5.6	6.4
Asiatic goose	4*	5.1	5.6
Asiatic duck	5*	4.3	5.4
"	6*	4.5	5.0
"	7*	4.3	5.0
"	8*	5.2	5.6
"	9*	4.4	5.4
"	10***	4.7	5.9
"	11***	4.5	5.8
Domestic duck	12*	5.3	5.7

* Treated with 2 percent chrome complex and 10 percent chrome sulfate unless otherwise noted.
** Treated with 3 percent chrome complex and 10 percent chrome sulfate.
*** Treated with 2 percent chrome complex and 5 percent chrome sulfate.

The quality of the feathers was determined by two experts who rated them on a descending scale from A to D, in which A was "equal to or better than what would be considered a good commercial grade". Among the factors taken into consideration were feel, size, contour and discoloration of the feathers, the amount of loose fibers, the amount and type of damage, and the resilience and overall appearance. The results, given in Table XXII, indicate that the Tan-O-Quil-QM treatment generally does not lower the quality of the feathers.

TABLE XXII

QUALITY RATINGS OF GOOSE AND DUCK FEATHERS

Type of Feather	Group No.	Ratings	
		After Washing	After Chemical Modification
European goose	1	A+	A
"	2	A	B+
"	3	B+	A
Asiatic goose	4	B+	B
Asiatic duck	5	B	B+
"	6	B+	B+
"	7	B	B+
"	8	B	B
"	9	B-	B
"	10	B	B
"	11	B	B
Domestic duck	12	B+	B

The oxygen number and turbidity of each lot of treated feathers were determined as 0 and 75, respectively, which indicates their extreme cleanliness.

The moisture content of each lot of feathers, before and after treatment, was also determined (Table XXIII). The results again confirmed previous findings that the moisture content of Tan-O-Quil-QM-treated feathers is less than that of untreated feathers.

TABLE XXIII

Type of Feather	Group No.	Moisture Content (%) Before Treatment	Moisture Content (%) After Treatment
European goose	1	10.4	8.3
"	2	10.6	7.2
"	3	10.8	8.3
Asiatic goose	4	9.2	7.7
Asiatic duck	5	9.8	8.3
"	6	10.0	8.0
"	7	10.5	7.8
"	8	10.2	9.2
"	9	11.2	8.4
"	10	10.3	8.7
"	11	10.1	8.7
Domestic duck	12	10.9	7.5
Average		10.3	8.2

A composition analysis of each lot of feathers, made before and after treatment, gave results which, while quite variable, indicated that the Tan-O-Quil-QM treatment does not damage the feathers as, on the average, the percentage of whole feathers or down did not decrease after treatment nor did the damaged feather content increase.

VI. Treatment of Down

A. Laboratory Treatment

It was found that down treated by the Tan-O-Quil-QM process, using 3 percent of the chrome complex and 10 percent basic chrome sulfate, is unsatisfactory. The down is matted, pilly, waxy and lacks resilience and, when rolled between the palms of the hands, forms tight balls which cannot be opened. Another series of treatments was made in which the basic chrome sulfate was used by itself in varying amounts and with smaller amounts of the chrome complex. Table XXIV gives the filling powers obtained.

TABLE XXIV

FILLING POWER OF TREATED DUCK DOWN

Treatment	Initial	Filling Power (cm) After Laundering			
		One	Two	Three	Four
Wet out and fluff dried	7.8	7.0	7.0	7.0	7.0
2% Chrome sulfate	10.0	9.4	7.5	7.2	7.2
7.5% Chrome sulfate	9.9	9.5	7.6	7.1	7.1
10% Chrome sulfate	10.0	9.5	7.5	7.2	7.2
0.5% Chrome complex, 10% Chrome sulfate	9.9	9.6	7.2	7.2	7.1
1.0% Chrome complex, 10% Chrome sulfate	10.0	9.7	7.3	7.4	7.4

The results indicate that the basic chrome sulfate with smaller amounts of chrome complex considerably increases the filling power of the down initially, but only slightly after laundering. Another series of treatments was made on goose down. These results are given in Table XXV.

TABLE XXV

FILLING POWER OF TREATED GOOSE DOWN

Treatment	Filling Power (cm)		
	Initial	After Laundering	
		Once	Twice
Wet out and fluff dried	12.0	6.2	6.2
Acid (pH 3.5)	12.0	6.3	6.3
10% Basic chrome sulfate	12.0	7.3	7.1
1% Chrome complex, 10% chrome sulfate	11.2	7.6	7.4

In this case, the results indicate that the use of basic chrome sulfate alone or with the chrome complex improves the filling power of down after laundering. The combination of the basic chrome sulfate and chrome complex gives slightly higher filling powers after laundering than the basic chrome sulfate used alone.

B. Down from Various World Geographical Sources

A series of commercial treatments were also carried out by Mr. Ludin on waterfowl down from various geographical sources, using commercial equipment of the type described in the Appendix. A total of 39 lots of down were studied, each lot consisting of 100 pounds of European or Asiatic origin. To simplify the study, the lots were divided into 13 groups, each consisting of three lots totalling 300 pounds. The three lots of down were selected to form a group of similar type and quality from the same general geographical area. The three lots comprising a group were carefully blended into a uniform mixture. They were then washed and treated by the Tan-O-Quil-QM process, using the procedure previously described. The types of down, the amounts of basic chrome sulfate and chrome complex used to treat them, and their filling powers are shown in Table XXVI.

Table XXVII gives the overall average of the filling powers as well as the average by type and source. The results show that there was a slight improvement in the filling power of the down after its chemical modification. There do not appear to be any differences that can be attributed to the amounts of basic chrome sulfate or chrome complex used.

TABLE XXVI

FILLING POWER OF DOWN

Type of Down	Group No.	Chrome* Sulfate(%)	Chrome* Complex(%)	Filling Power (cms) Before Treatment	Filling Power (cms) After Treatment
European goose	1	5	0.75	7.5	9.4
	2	5	0.75	7.0	3.0
	3	5	0.75	8.7	8.4
	4	5	0.75	9.1	8.4
	5	10	0.75	7.7	7.9
Asiatic goose	6	5	0.75	7.6	7.7
	7	5	0.75	6.8	6.7
	8	5	0.75	7.9	6.9
Asiatic duck	9	5	0.75	6.8	7.4
	10	10	1.0	7.1	7.6
	11	5	1.0	6.8	6.8
	12	5	0.5	7.1	8.2
	13	10	0.5	6.8	8.1

*On the weight of dry down.

TABLE XXVII

AVERAGE FILLING POWER OF DOWN

Type of Down	No. of Groups	After Washing	After Chemical Modification
European goose	5	8.0	8.4
Asiatic goose	3	7.2	7.0
Asiatic duck	5	7.0	7.6
Overall average		7.4	7.7

The quality of the down was determined subjectively by the same two experts who had evaluated the waterfowl feathers. Among the factors taken into account were the feel, size of the down cluster, amount of loose fiber, discoloration, type and amount of damage, resilience, and overall appearance. The down was graded, again on a scale of A to D, with A designated as "equal to or better than a good commercial grade." The results of their evaluation (Table XXVIII) show that the Tan-O-Quil-QM treatment did not lower the quality of the down, as six lots were upgraded after the treatment, while seven remained unchanged

TABLE XXVIII

QUALITY RATINGS OF DOWN

Type of Down	Group No.	Ratings	
		After Washing	After Treatment
European Goose	1	B+	A
	2	B+	A
	3	A+	A+
	4	A	A
	5	A-	A-
Asiatic Goose	6	B	B+
	7	B+	B+
	8	B+	B+
Asiatic Duck	9	B	B+
	10	B+	A+
	11	B	B+
	12	B+	B+
	13	B	B

The oxygen number and turbidity of the treated down were 0 and 75, respectively, which indicates its extreme cleanliness. The moisture content of the down, before and after treatment, is given in Table XXIX. The moisture content of the treated down was less than the untreated down, which confirmed previous findings on feathers, namely, that Tan-O-Quil-QM-treated materials have less moisture than untreated materials.

TABLE XXIX

MOISTURE CONTENT OF DOWN

Type of Down	Group No.	Moisture (%) Before Treatment	Moisture (%) After Treatment
European goose	1		7.4
	2		8.8
	3	9.7	7.7
	4	9.5	8.4
	5		8.8
Asiatic goose	6		8.4
	7	9.5	8.0
	8	10.0	8.5
Asiatic duck	9	9.6	7.2
	10		8.9
	11		8.4
	12		7.3
	13	9.5	8.0
Average		9.7	8.1

A composition analysis of each group of down, before and after treatment, was also made. The results indicated that the Tan-O-Quil-QM treatment does not damage down, as shown by the fact that, on the average, the fiber content did not increase nor did the down content decrease.

VII. User Test Results

A. Sleeping Bags

In one test, sleeping bags for field evaluation were filled with the following three blends of filling material:

1. 100 percent 40/60 untreated waterfowl down and feather mixture.

2. 40 percent Tan-O-Quil-QM-treated chicken feathers and 60 percent untreated 40/60 waterfowl down and feather mixture.

3. 40 percent untreated chicken feathers and 60 percent untreated 40/60 waterfowl down and feather mixture.

The filling powers of these blends are given in Table XXX.

TABLE XXX

FILLING POWER OF FEATHER AND DOWN MIXTURES

Description	Filling Power (Centimeters)		
	Initial	After Laundering	
		Once	Twice
100% 40/60 waterfowl Down and feather mixture	7.0	5.8	5.9
40% Tan-O-Quil-QM chicken feathers 60% 40/60 Waterfowl mixture	6.6	5.8	5.6
40% Untreated chicken feathers 60% 40/60 Waterfowl mixture	6.2	5.7	5.5

The sleeping bags filled with these mixtures were used in the field for 41 nights, after which they were laundered. The changes in filling power are given in Table XXXI.

TABLE XXXI

FILLING POWERS OF MIXTURES USED IN SLEEPING BAGS

Description	Filling Power (cm)		
	Initial	After Use	After Use and Laundering Once
100% Standard Untreated 40/60 Waterfowl down and feather mixture	7.0	3.7	5.6
40% Tan-O-Quil-QM chicken feathers 60% 40/60 Waterfowl mixture	6.6	3.8	5.7
40% Untreated chicken feathers 60% 40/60 Waterfowl mixture	6.2	3.6	5.1

The filling power of the mixture containing Tan-O-Quil-QM-treated chicken feathers was slightly lower initially than the untreated 40/60 down and feather mixture. However, after use, and after both use and laundering, the filling powers of both were about the same. The filling power of the mixture containing treated chicken feathers was greater than the mixture containing untreated chicken feathers, indicating its superiority in this respect.

During the user test, comments on the comfort and warmth of the sleeping bags were requested. Although this type of bag was not designed to give adequate warmth below 10°F. and above zero, it was used during the test at temperatures which, on occasions, ranged below zero. There were no complaints of inadequate warmth from those using sleeping bags containing treated chicken feathers.

The void areas, which are a measure of the migration of the filling material, were also determined after use. The sleeping bags containing Tan-O-Quil-QM-treated chicken feathers averaged less void areas after use than the standard mixture.

At the conclusion of this test, the sleeping bags were evaluated as to general appearance, resilience, and softness. The bags containing 100 percent of the standard untreated 40/60 waterfowl mixture, and those containing 40 percent of treated chicken feathers, were rated as equal but were far superior to those containing only untreated chicken feathers.

In another test, sleeping bags filled with a blend of 40 percent Tan-O-Quil-QM-treated chicken feathers and 60 percent of the standard untreated 40/60 waterfowl down and feather mixture were again compared to sleeping bags filled with 100 percent of the standard untreated 40/60 waterfowl down and feather mixture. The sleeping bags were used for 54 nights in untreated shelters, snow shelters, and improvised lean-tos at temperatures which ranged as low as minus 20°F, with an overall average of about plus 20°F. During this test, the participants were interviewed each morning to ascertain the degree of comfort and protection from cold afforded by the sleeping bags. The bags were also inspected daily for evidence of filler material lumping or matting, penetration through the fabric casing, and void areas. The bags were laundered after 18 nights of use and at the conclusion of the test. Thickness tests were made on each bag before and after laundering.

The results indicated that the majority of the test subjects kept warm and comfortable with at least 6 hours of restful sleep in either sleeping bag. There were no significant differences between the two types of filling materials with respect to warmth, comfort, lumping, or matting.

B. Pillows

1. Waterfowl Feathers

A series of pillows filled with equal weights of untreated and Tan-O-Quil-QM-treated duckling feathers were evaluated by actual use. The pillow filled with Tan-O-Quil-QM-treated feathers was noticeably bulkier (Figure 8). After six weeks of use and two launderings, the pillow filled with treated feathers showed no indication of lumping or matting (Figure 9). The increased bulk of the Tan-O-Quil-QM-treated feathers was still evident.

2. Waterfowl Feathers, Down and Whole Chicken Feathers

Another series of pillows filled with mixtures of Tan-O-Quil-QM-treated chicken feathers and the standard untreated 40/60 waterfowl mixture were evaluated by Mr. Ludin on a comparative scale. The results of his evaluation are given in Table XXXII.

Mr. Ludin found that a blend of 40 percent Tan-O-Quil-QM duck feathers with 60 percent of standard untreated 40/60 waterfowl mixture was superior to 100 percent of standard untreated 40/60 waterfowl mixture. He also found that a blend of 40 percent of commercially treated Tan-O-Quil-QM chicken feathers with 60 percent standard untreated 40/60 waterfowl mixture was equal to 100 percent of the standard untreated 40/60 waterfowl mixture. These results are considered particularly significant

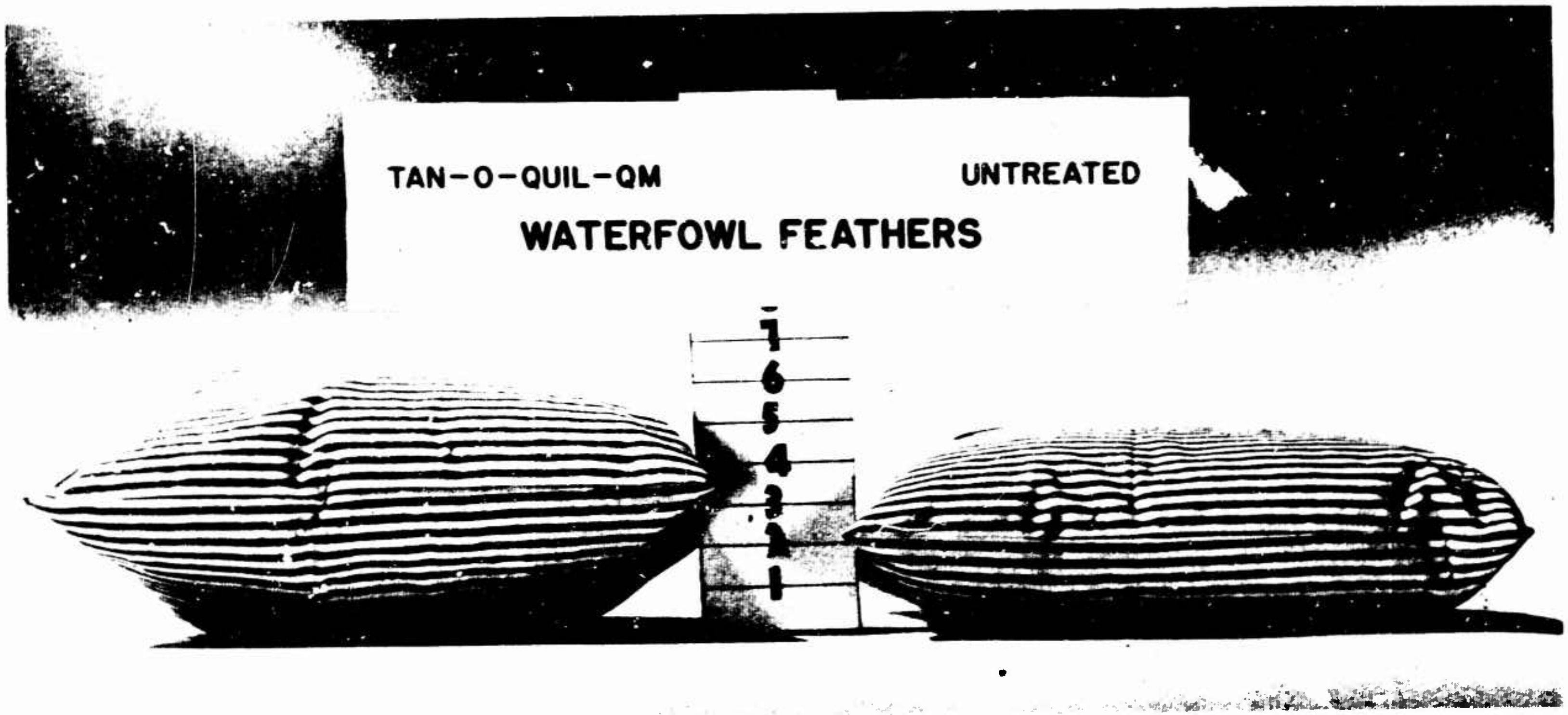

Figure 8. Comparison of Pillows Filled with Untreated and Treated Waterfowl Feathers

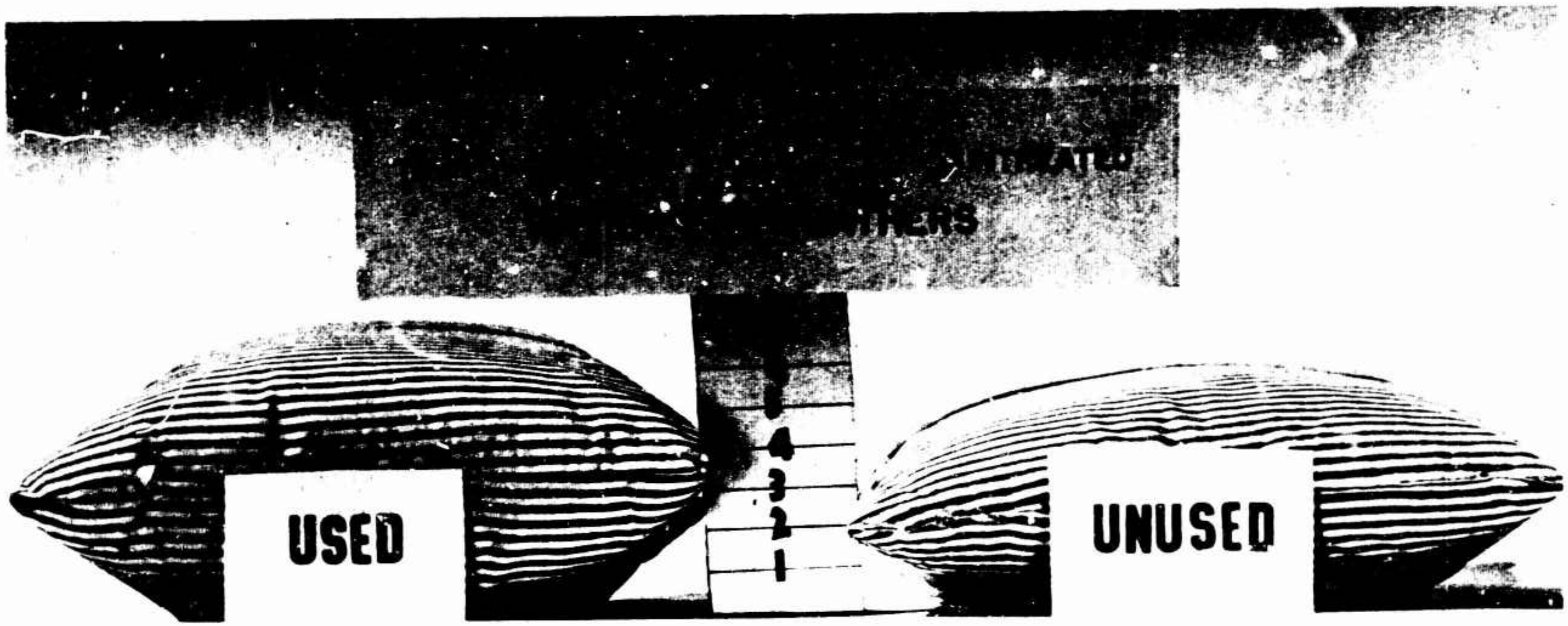

Figure 9. Retention of Bulk of Treated Waterfowl Feathers After Use

since the blends containing treated feathers only contain 24 percent down. Mr. Ludin found that similar blends containing untreated chicken feathers were unsatisfactory.

TABLE XXXII

COMPARATIVE EVALUATION OF PILLOWS FILLED WITH DOWN AND FEATHER MIXTURES

Filling Material	Comparative Value
A. 100% Standard untreated 40/60 waterfowl down and feather mixture	116%
B. 40% Tan-O-Quil-QM duck feathers 60% Standard untreated 40/60 waterfowl mixture	125%
C. 40% Tan-O-Quil-QM chicken feathers (1) 60% Standard untreated waterfowl mixture	115%
D. 40% Tan-O-Quil-QM chicken feathers (2) 60% Standard untreated 40/60 waterfowl mixture	80%
E. 40% Untreated chicken feathers (3) 60% Standard untreated 40/60 waterfowl mixture	Poor
F. 40% Untreated chicken feathers (4) 60% Standard untreated 40/60 waterfowl mixture	Poor

(1) Prepared and treated commercially
(2) Treated in pilot plant
(3) Same chicken feathers as in B except untreated
(4) Same chicken feathers as in D except untreated

After six months of use, pillows filled with a mixture of 60 percent Tan-O-Quil-QM chicken feathers and 40 percent Tan-O-Quil-QM duck feathers retained their bulk. These pillows and one containing 100 percent untreated duck feathers are shown in Figure 10.

3. Waterfowl Feathers and Crushing Chicken Feathers

A pillow filled with a mixture of 60 percent Tan-O-Quil-QM crushed chicken feathers and 40 percent Tan-O-Quil-QM duck feathers,

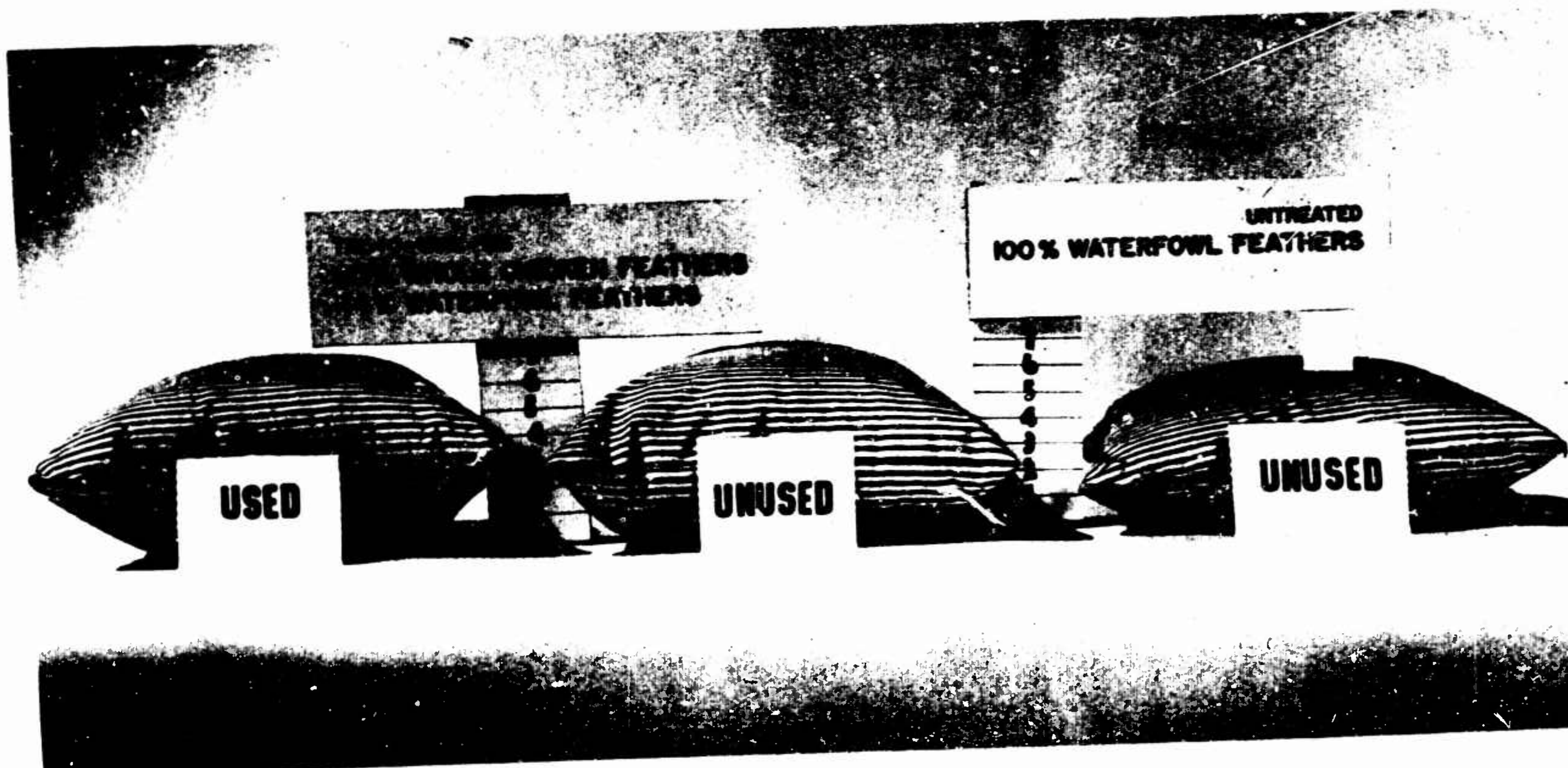

Figure 10. Comparison of Blends of Treated Waterfowl and Chicken Feathers with Untreated Waterfowl

along with a pillow filled with untreated duck feathers, are shown in Figure 11. The same pillows after two months use are shown in Figure 12. Both pillows had the same bulk initially and after use. Table XXXIII shows the filling power of the feathers initially and after use.

TABLE XXXIII

FILLING POWER OF FEATHERS IN PILLOWS

Material	Filling Power (cms) Initial	After Use
Crushed Tan-O-Quil-QM chicken feathers	2.8	
Tan-O-Quil-QM duck feathers	5.6	
60% Crushed Tan-O-Quil-QM chicken feathers 40% Tan-O-Quil-QM duck feathers	4.0	3.2
Untreated duck feathers	4.0	3.2

4. Crushed Chicken Feathers

A series of pillows containing equal weights of untreated or Tan-O-Quil-QM-treated, crushed chicken feathers were evaluated by actual use. The pillows are shown in Fugure 13 before use and in Figure 14 after two years of use. The increased bulk of the pillow containing Tan-O-Quil-QM feathers is still evident after two years of use.

Two other tests were conducted in which pillows containing crushed Tan-O-Quil-QM-treated chicken feathers were compared with similar pillows filled with untreated crushed chicken feathers. The pillows containing crushed Tan-O-Quil-QM-treated feathers were filled with 10 percent less feathers than those containing untreated feathers. During one test, which was conducted in a temperate climate, the pillows were used continuously for 64 weeks. For the first 48 weeks, they were laundered every eight weeks. During the other test, which was conducted in a tropical climate. the pillows were used continuously for 72 weeks. Again, these were laundered every eight weeks during the first 48 weeks of test. Despite the fact that the pillows filled with treated feathers had less filling material, both pillows were found to be satisfactory and equal in durability. The pillows, before and after use in a temperate climate, are shown in Figures 15 and 16.

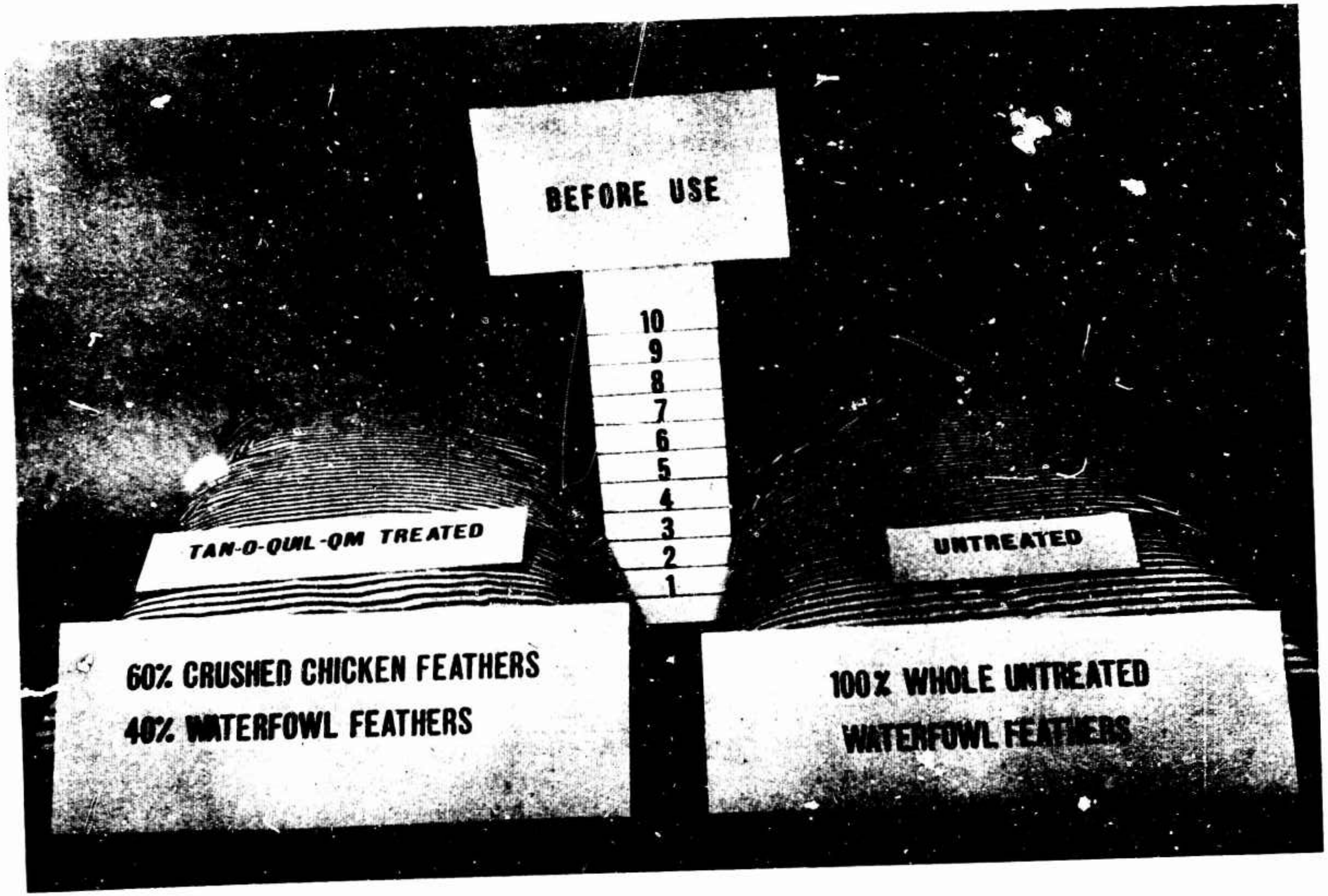

Figure 11. Pillows with Crushed Chicken and Whole Waterfowl Feathers - Before Use

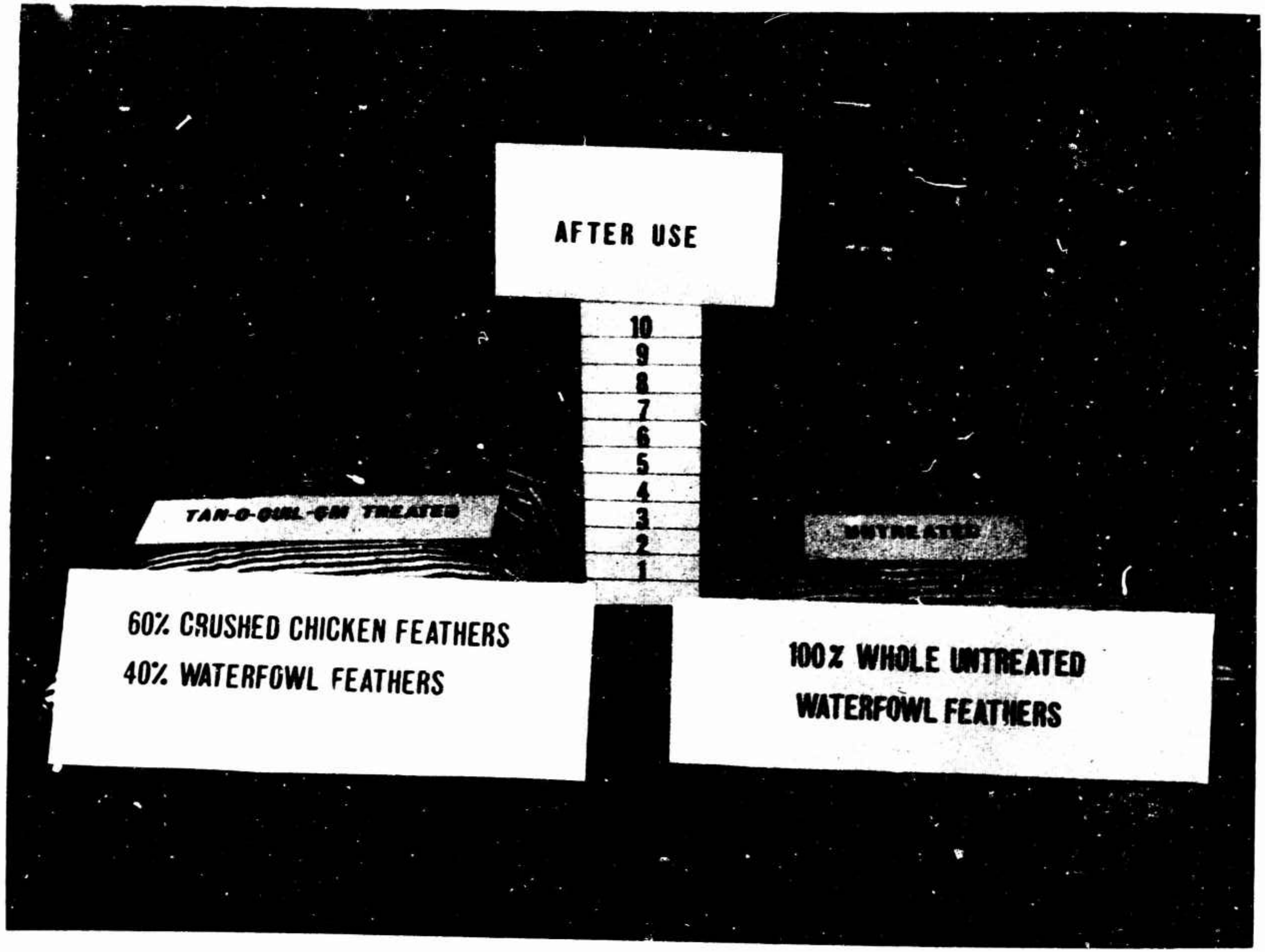

Figure 12. Pillows with Crushed Chicken and Whole Waterfowl Feathers - After Use

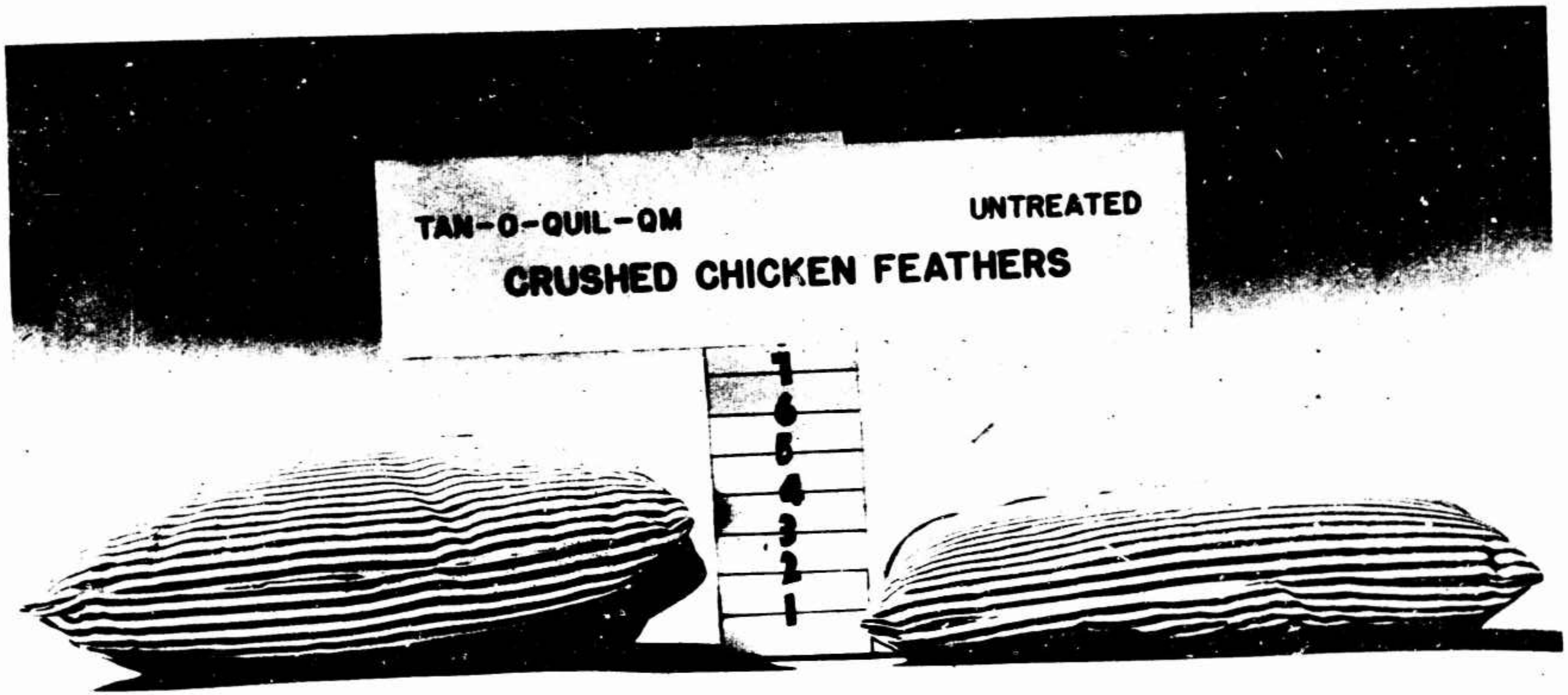

Figure 13. Pillows with Crushed Chicken Feathers - Before Use

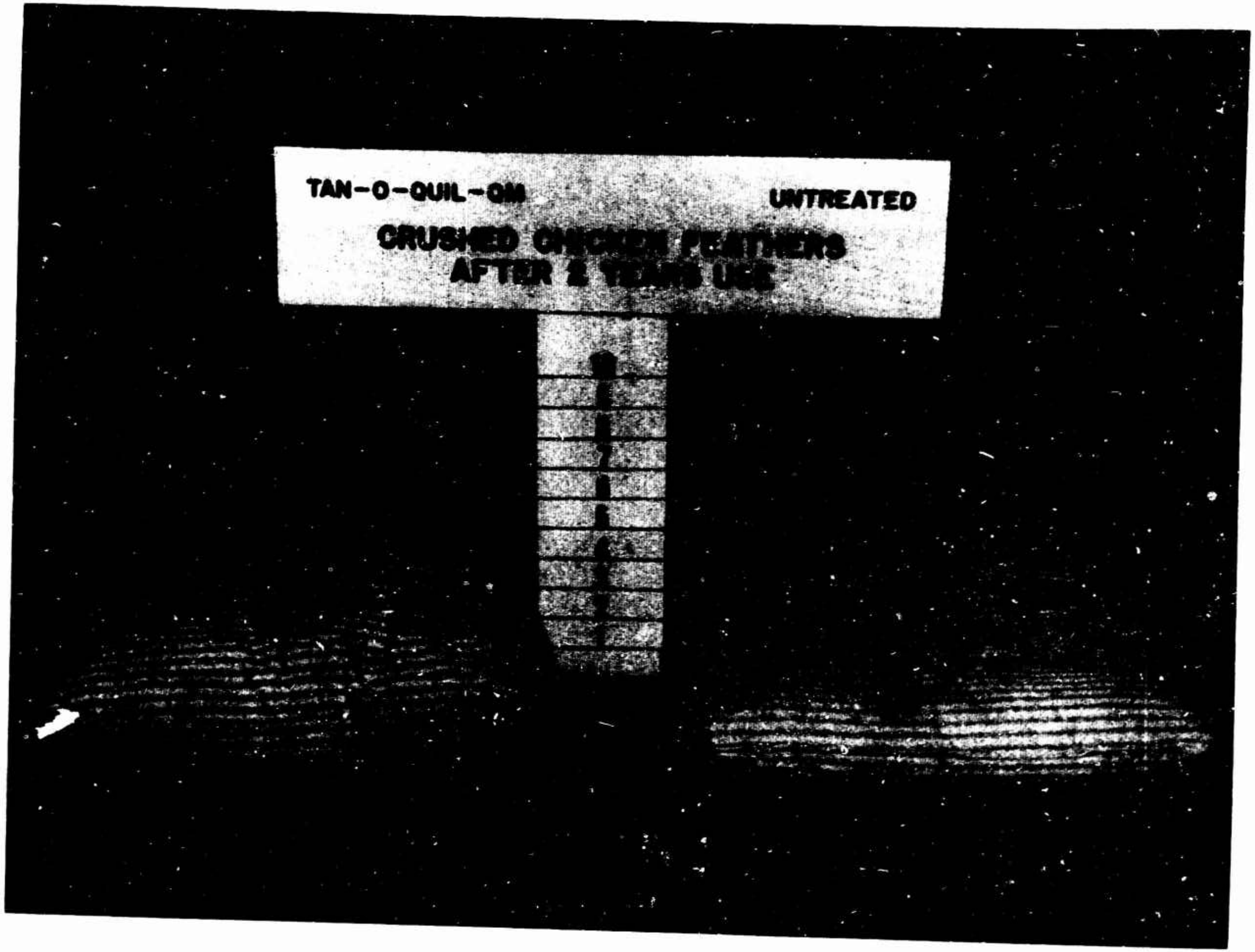

Figure 14. Pillows with Crushed Chicken Feathers - After Use

Extensive tests made at Mt. Sinai Hospital in New York City showed that pillows filled with Tan-O-Quil-QM-treated, crushed chicken feathers do not lose their resiliency after repeated use and laundering[21]. It was also found that considerable monetary savings can be accomplished by the use of such pillows in hospitals.

5. Waterfowl Feathers and Down

Blends of equal parts by weight of Tan-O-Quil-QM-treated duck feathers with untreated or Tan-O-Quil-QM-treated down were prepared and evaluated by use in seat cushions as well as in pillows. The seat cushions were filled to the same density as military sleeping bags. After two months of use they showed no indication of matting. Their filling power, before and after use, is shown in Table XXXIV.

TABLE XXXIV

FILLING POWER OF DOWN AND FEATHER BLENDS USED IN SEAT CUSHIONS

	Filling Power (cm)	
	Initial	After Use
50% Tan-O-Quil-QM-treated duck feathers* 50% Tan-O-Quil-QM-treated down**	6.3	5.7
50% Tan-O-Quil-QM-treated duck feathers* 50% Untreated down	5.0	4.7

* Treated with 10 percent basic chrome sulfate and 3 percent chrome complex.
** Treated with 10 percent basic chrome sulfate and 1 percent chrome complex.

6. Blends of Waterfowl Feathers and Down

The existing military requirement for the Tan-O-Quil-QM-treated waterfowl feather and down blend used in sleeping bags is that it have a filling power of 6.0 plus or minus 0.2 cms. after two launderings. The down and feather content will vary depending on the filling power of these two ingredients. Theoretically, the filling powers and weights of the feathers and down used in a blend are additive[1]. Actually, it has been found that the quality of material must be taken into account. The following formulas

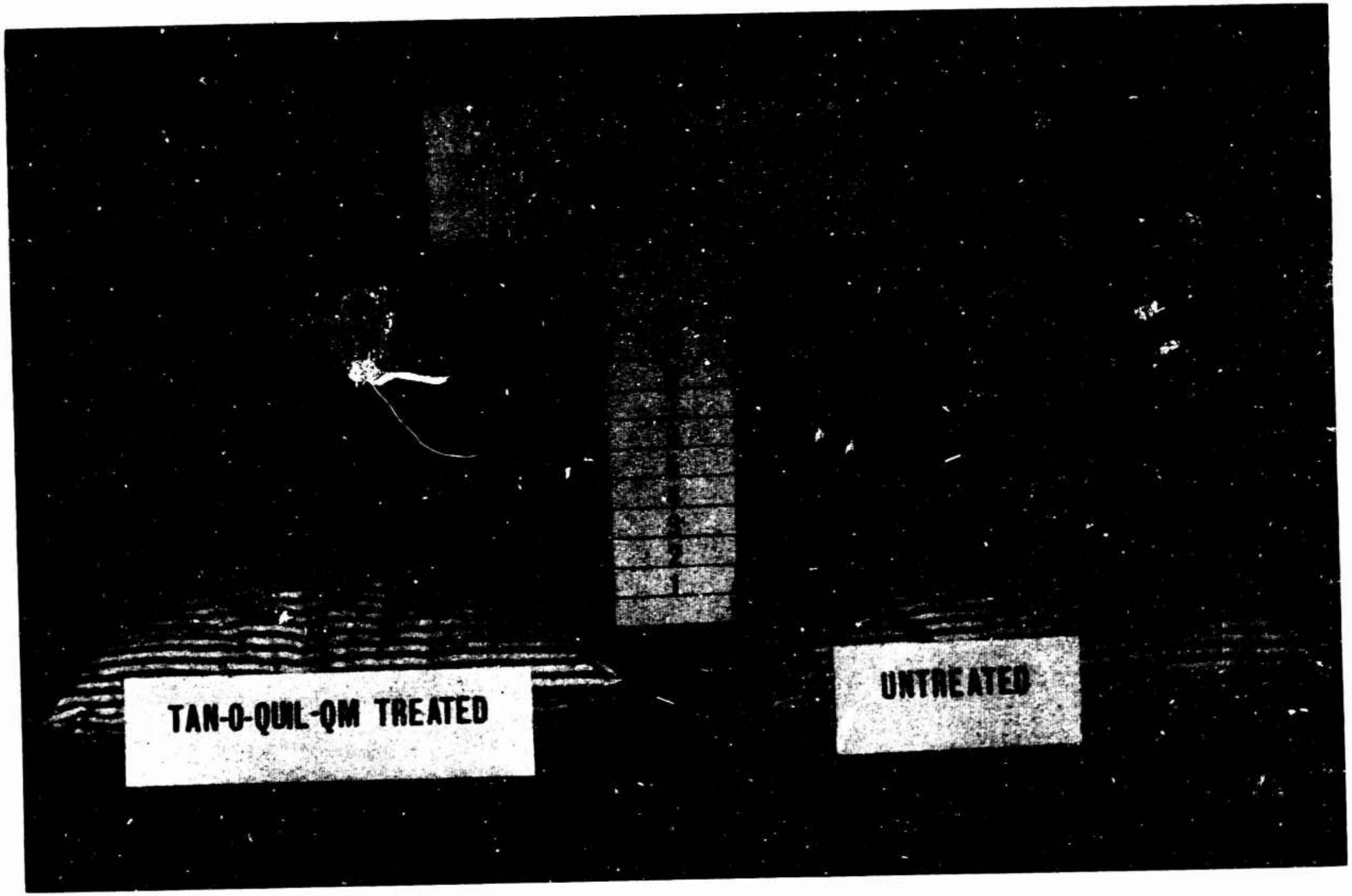

Figure 15. Pillows with Decreased Amount of Crushed Chicken Feathers - Before Use

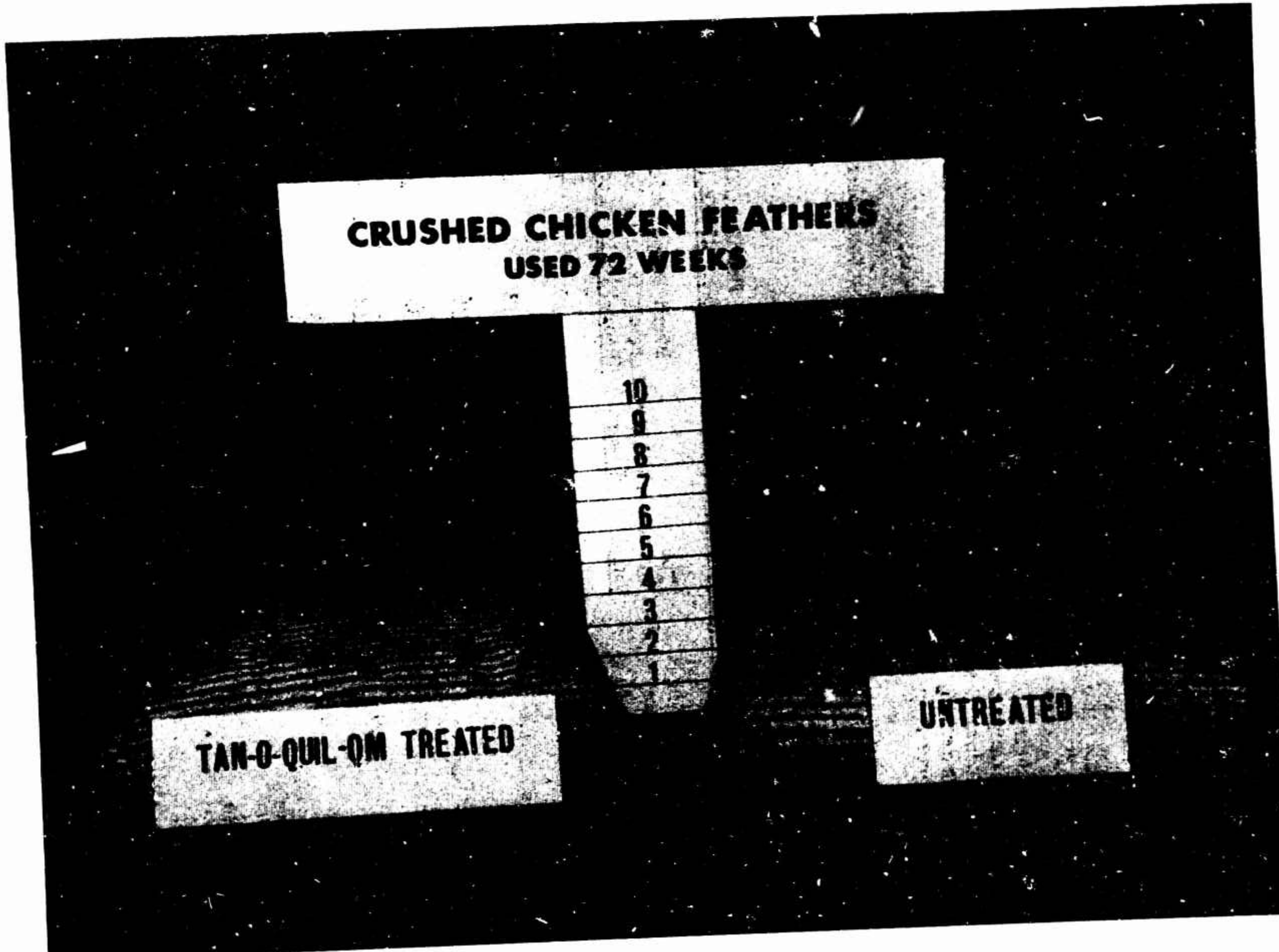

Figure 16. Pillows with Decreased Amount of Crushed Chicken Feathers - After Use

have been found to be of some assistance in preparing blends of this type to a desired filling power. The algebraic expressions are based on the assumption that the filling powers of the feathers and down in the blend are additive.

$$F = \frac{B-C}{B-A} \times 100 \qquad D = \frac{C-A}{B-A} \times 100$$

A is the filling power of the feathers in centimeters after laundering.
B is the filling power of the down in centimeters after laundering.
C is the filling power of the blend in centimeters after laundering.
D is the percent by weight of the down in the blend.
F is the percent by weight of the feathers in the blend.

Table XXXV gives some typical results obtained on actual blends prepared by contractors on a large scale.

TABLE XXXV

COMPOSITION AND FILLING POWER OF BLENDS OF TREATED WATERFOWL FEATHERS AND DOWN WITH A FILLING POWER OF 6.0 CMS. AFTER LAUNDERING

Type of Feathers	Filling Power (cms)	Type of Down	Filling Power	Blend Composition Percent Down by Weight	
				Theoretical*	Actual
China Goose	5.6	Asiatic Duck	7.8	18	16
European Goose	5.6	Asiatic Duck	7.8	18	15
China Duck	4.9	Asiatic Duck	8.0	36	33
Domestic Duck	4.9	Asiatic Duck	8.3	32	26
European Duck	4.9	European Goose	8.3	32	30
Domestic Duck	4.6	European Goose	8.5	38	27
European Goose	5.6	European Duck	7.7	19	18
European Goose	5.4	European Duck	7.7	26	25
Domestic Duck	5.0	European Goose	7.9	34	32

*Calculated by formula

VIII. Conclusions:

Feathers and down treated by the Tan-O-Quil-QM process are free from dust, exceptionally clean, and will not develop an odor even when wet. Treated feathers have an increased filling power even after laundering and a higher degree of water repellency. The treatment is durable to dry cleaning. The equilibrium moisture content of treated feathers is lower than that of untreated feathers. While no formal tests have been carried out, persons allergic to feathers have reported no discomfort when using pillows with treated feathers. Crushed treated chicken feathers are bulkier than untreated crushed chicken feathers and retain their added bulk after use. Due to the fact that chickens are now sent to market at six to eight weeks of age, chicken feathers now available have large quantities of immature feathers which are not amenable to treatment. Consequently, the use of treated whole chicken feathers is not recommended in sleeping bags. The great improvement in filling power of waterfowl feathers treated by this process, has made it possible to reduce the overall requirement for down in the sleeping bag mixture.

IX. Acknowledgments

While this report summarizes work carried out since 1956, it represents the culmination of a program conducted since World War II by many individuals. Since it is impossible to list all who have contributed to this program, and at the risk of repetition and with regrets for leaving out many others who also contributed, special acknowledgment is made to the following:

Dr. Adolf Schubert, Consultant, who had the original idea for the Tan-O-Quil-QM process and under whose guidance this process was developed.

Dr. Stephen J. Kennedy, Director, Clothing and Organic Materials Laboratory, U. S. Army Natick Laboratories, under whose direction this program was carried out.

Dr. Robert M. Lollar and Mr. Robert M. Delcamp who carried out the initial work with basic chrome sulfate and hydrophobic chrome complexes at the Tanner's Council Research Laboratory.

The members of the National Research Council Advisory Board on Quartermaster Research and Development, Committee on the Development of Substitutes for Waterfowl Feathers and Down who, under the chairmanship of Dr. Schubert, gave assistance and guidance in this entire program.

Mrs. Josephine M. Stephens, technologist at NLABS, who carried out most of the laboratory evaluations.

Mrs. Hubertina Hogan, chemist at NLABS, who developed the analytical method for determining the chrome content of feathers and down and gave assistance in many other phases of this program.

Mr. Benjamin Ludin who, as a member of the NRC Committee and from a lifetime of experience in the feather processing industry, not only offered guidance and advice but carried out plant runs and studies and evaluated many of the treated samples.

Mr. Samuel Lerman, also a member of the NRC Committee, who suggested the use of crushed Tan-O-Quil-QM-treated chicken feathers in pillows and carried out the first plant runs with chicken feathers.

Mr. Howard C. Winslow, Assistant Chief of the Bureau of Furniture and Bedding Inspection, State of California, and a member of the NRC Committee, who carried out analysis of some of the feathers and down and gave invaluable advice in evaluating this process.

Mr. Louis Buchman, a member of the Industry Advisory Committee, who gave us the benefit of his wealth of experience in the feather processing industry and who, with Messrs. Ludin and Lerman, was among the first to adopt and use the Tan-O-Quil-QM process.

I. References

1. Weiner, L.I., Physical Properties of Feathers and Down: "The Utilization of Chicken Feathers as Filling Materials", National Research Council, Washington, D.C., March 1956, pp 60-75

2. Vanderbie, J.H., and D. F. Rene, Development of Field Sleeping Gear, Headquarters, Quartermaster Research and Engineering Command, Natick, Mass., Tentage and Equipage Series Report 13, August 1956, p 7

3. Loconti, J.D., The Morphology of Feathers and Down. In NRC publication (Ref. 1), p 60

4. Roberts, N.E., and N.B. Edelman, Quartermaster Research on Down and Feathers and Other Filling Materials for Sleeping Bags, Textile Series Report 43, Headquarters, Quartermaster Research and Engineering Command, Natick, Mass., Reprinted Oct 1957, pp 1-2

5. Licht, E.H., Private Communication, 12 May 1955

6. See Reference 4, p 63

7. Koontz, C.H., The Availability of Chicken Feathers as a Raw Material in Commercial Utilization, In NRC publication (Ref. 1), pp 168-172

8. Stahl, W.H., Amino Acid Composition of Feathers and Down. In NRC publication (Ref. 1), pp 6-19

9. Low, B., Possible Polypeptide Chain Configurations in the Keratin Group of Fibrous Proteins. In NRC publication (Ref. 1), pp 19-26

10. Krim, S., The Structure of Feather Keratin. In NRC publication (Ref. 1), pp 26-34

11. Florio, P.A., Modification of Chicken Feathers Using the Acid Alum Process. In NRC publication (Ref. 1), pp 102-120

12. Frederick, E.B., Modification of Chicken Feathers by the Glyoxol Method. In NRC publication (Ref. 1), pp 120-150

13. Schubert, A., G. Cohen, R.M. Delcamp, and R.M. Lollar, Treatment of Feathers with Werner-Type Chromium Complexes. U. S. Patent 2,975,018, 14 March 1961

14. Pasternak, J.Z., and R.M. Delcamp, Investigation and Development of Tanning Treatments for Chemical Modifying the Physical Properties of Chicken Feathers, Textile Engineering Lab. Report #209, Headquarters, Quartermaster Research and Engineering Command, Natick, Mass., December 1957

15. Diamond Alkali Co., Tanolin for Chrome Tanning, Product Information Bulletin 1956, Allied Chemical-Solvay Process Division, Koreon B, One-Bath Chrome Tan for Leather, Product Information Bulletin 1964, Monsanto Co., Santotan KR, Product Specification Sheet 1967

16. Stone, F.G.A., W.A.G. Graham, Inorganic Polymers, Academic Press, p 849

17. E. I. duPont deNemours and Co., Quilon Chrome Complex, Product Information Bulletin, Industrial and Biochemicals Division

18. Metro-Atlantic Co.-Atcovex, J-Private Communication, Nov. 14, 1966

19. Standards Methods for the Examination of Water, Sewage, and Industrial Wastes, 10th ed., Am. Public Health Assoc., New York, pp 207-221

20. Lind, H.E., A paper presented at a meeting of the American Public Health Assoc. in San Francisco, Nov. 1960, and summarized in Time Magazine, 14 Nov. 1960

21. Field, F., Inexpensive Washable Pillows Can Benefit Institutional Laundry Operations, National Assoc. of Institutional Laundry Managers Bulletin, Jan. 1964

APPENDIX

Review of Commercial Processing Procedures for Feathers and Down

It has long been recognized by the feather processing industry, particularly in regard to waterfowl feathers and down, that the type and source of the material, the conditions under which it is plucked and stored prior to processing, the washing procedure, and subsequent processing all have an effect on the final product. Waterfowl feathers and down are carefully processed to preserve the original structure and, in the case of the feathers, to increase the curl. On the other hand, practically all chicken feathers used in pillows are crushed in a machine that breaks the shaft of the feather. Since the preliminary processing methods can affect the results of any chemical treatment, the methods are briefly reviewed, along with the commercial washing and drying practices.

A. Plucking Methods

Generally, in processing plants, chickens and waterfowl are plucked mechanically by processes which remove the feathers in a wet state. Since the feathers are mixed with blood and dirt, they will deteriorate rapidly unless they are washed and dried quickly or held in a preservative. In most cases, the feathers are washed the same day that they are plucked. Imported waterfowl feathers often are wet plucked by hand after the newly killed birds have been scalded at the farm, small shop, or restaurant where they are slaughtered. The feathers are then dried and packed into bags. Feathers of this type are commonly referred to by industry as "raw" feathers.

B. Washing

It is evident from this brief description of the plucking process that feather filling materials, prior to processing, contain foreign material such as blood, soil, vegetable and fecal matter. Fortunately, this material is easily removed by a relatively simple procedure of washing with a detergent and an alkaline builder, followed by several rinses and a laundry sour. The alkali, in addition to acting as a builder for the detergent, serves as a blood solubilizer. The sour, which acts as a preservative, is applied by soaking the washed feathers or down in a bath containing a laundry sour such as sodium silicofluoride or sodium acid fluoride.

1. Equipment

The washers commonly used in the feather processing industry are similar, except for size, to that used in the pilot plant (Figures 12 and 13). They usually consist of a large cast iron or stainless steel horizontal cylinder, 4 to 5 feet in diameter and 8 to 12 feet long, with rotating paddles mounted on a shaft along its axis. Wet feathers and down pack tightly and prevent the flow of water. To promote free drainage, the bottom half of the cylindrical washer consists of a perforated metal screen above an annular space that is built into the washer. This annular space slopes toward a drain valve at the midpoint bottom of the washer. On washers used for waterfowl feathers and down, the paddle blades are rectangular metal bars mounted with the widest face toward the direction of rotation. The rotating paddles hit the feathers with a great deal of force, moving them under the surface of the water and causing them to wet-out quickly. The paddles on some washers built specially for chicken feathers are mounted at an angle so that they hit the feathers with less force, since chicken feathers lack the natural water repellency of waterfowl feathers and down and wet-out much more easily. This type of blade causes less damage to the feathers.

The feathers or down are removed from the washer through a large, quick-opening, flapper-type valve mounted at the bottom of one end of the washer above the metal screen. This valve opens into a chute which, in turn, leads to a large basket type of centrifugal extractor. To empty the washer, it is first filled with water. The flapper valve is then opened and the rush of water carries the feathers or down into the extractor basket which is rotating slowly to insure uniform loading. The water drains out through perforations in the extractor basket. The extractor, after it is fully loaded, is rotated at high speed to extract water from the feathers.

2. <u>Washing Procedure</u>

A typical commercial washing procedure for waterfowl feathers is as follows:

a. Place 125 pounds of feathers into a washer containing about 500 gallons of water at 100°F (the level of the water should be just below the center shaft). Add about 3 pounds of trisodium phosphate and about 10 pounds of a detergent.

b. Run 10 minutes, drain, and rinse at about 90°F until the wash water is clear.

c. Hold 10 minutes at room temperature in a bath containing about 4 pounds of sodium silicofluoride, then drain and extract the water from the feathers.

Down is washed in the same manner except that the quantity may be reduced due to its extra bulk.

To remove as much dirt as possible, chicken feathers are usually given a preliminary rinse in cool water with the temperature kept low so as not to coagulate the blood and make it difficult to remove in subsequent operations. This is usually followed by an alkaline bath to remove the blood. The subsequent steps are the same as outlined for waterfowl feathers.

C. Drying and Cooling

The driers most commonly used consist of large horizontal insulated metal cylinders heated by low pressure steam in jackets built around the cylinder, or by hot air blown into the drier. The wet feathers or down from the centrifugal extractor are loaded in one end of the drier through a small sliding door as a series of paddles, rotating at high speed, keep the feathers or down in intimate contact with the hot air inside. This air is exhausted through a screen and a duct at the top of the drier. As the material begins to dry, it becomes airborne due to the turbulence created by the rotating paddles. The progress of the drying is observed on samples removed through the sliding door. The dry material is removed by suction through a duct. The total drying time is usually between 10 and 20 minutes. The drying temperature varies from about 120°F on the wet material to about 160°F on the dry material. Since over-drying impairs the filling properties, the material should be removed as soon as it is dry. As previously mentioned, it is extremely important that feathers be cooled after drying and before being packed in bags, or they will lose their curl.

D. Fractionating or Blowing

This is an air flotation process used to separate waterfowl feathers from down, to remove the undesirable wing and tail feathers, and to separate the feathers according to size. While it can be carried out either before or after the washing process, it is usually applied on the "raw", unwashed feathers, since the buildup of static electricity, which interferes with the process, is less before washing. Also, it enables the down to be handled separately from the feathers in the subsequent processing.

The fractionator or blowing machine consists of a large, completely enclosed, rectangular chamber divided into compartments by partitions extending from the floor almost to the ceiling, leaving an open space extending across the entire top of the machine below the ceiling. The front end of the machine consists of a narrow rectangular tunnel extending up full width along its entire front end and opening, at the top, into the open space described above. The front end of the machine, which is also the front wall of the above tunnel, is made of glass so that the feathers or down passing up the tunnel can be observed by the operator. A totally enclosed "U"-shaped trough with rotating paddles is mounted at the bottom of this tunnel. A fan, which either sucks or blows air through the machine, is mounted at one end of the fractionator. These machine vary in size but usually are about 10 to 12 feet high, 8 to 10 feet wide, and 14 to 20 feet long.

In operation, a quantity of the feather and down mixture to be separated is placed in the trough. The rapidly rotating paddles turn the mixture over, throwing the material up, and air, blown or sucked through the mixture by the fan, causes the lighter material to become airborne. The operator regulates the air flow by using dampers. The lighter material is carried to the top of the tunnel through the opening at the top, and over the partitions into the furthest compartment. Heavier materials are deposited in the nearest compartments. The undesirable wing and tail feathers, due to their weight and shape, remain in the trough. The size of the material being separated is determined by the air flow, which is regulated by the operator who observes the operation through the glass window. This process requires a great deal of skill and judgment on the part of the operator. Most of these machines have only one large compartment and therefore can separate only one fraction at a time.

E. Crushing or Curling

Crushing or curling is a process that increases the filling power of chicken feathers. The apparatus used is a double-disc attrition mill such as is commonly used to grind fibrous materials. The mill contains two large, slightly tapered, steel plates that rotate at high speeds in opposite directions. The plates are set closely together but the distance between them can be adjusted. As the feathers are fed between the plates, a series of sharpened teeth on the inner surface of the plates bends or breaks the shaft of the feathers without detaching the feather fiber. Practically all the untreated chicken feathers that are used in pillows are processed in this manner.

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13. ABSTRACT

The development of the Tan-O-Quil-QM process for the treatment of feathers and down is described. The process, involving the use of a tanning agent and a water repellent, is applicable to both landfowl and waterfowl feather filling materials. Feathers treated by this process, in addition to having an increased filling power that is durable to laundering, are free from dust, are exceptionally clean and will not develop an odor even when wet. Chicken feathers so treated may be used as a partial replacement for waterfowl feathers and down in pillows. Crushed Tan-O-Quil-QM treated chicken feathers in pillows have been found to be an improvement over untreated crushed feathers and have retained their increased bulk even after more than two years of continuous use.

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Tan-O-Quil-QM treatment	10		8			
Sleeping bags	4		4			
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